Future Directions in Ultraviolet Spectroscopy

A conference inspired by the accomplishments of the Far Ultraviolet Spectroscopic Explorer Mission

The Future Directions in Ultraviolet Spectroscopy conference is sponsored by the Astrophysics Division of the National Aeronautics and Space Administration's Science Mission Directorate, (NASA HQ) and the Canadian Space Agency (CSA). Additional support has been provided by the French Space Agency, Centre National d'Etudes Spatiales (CNES).

Future Directions in Ultraviolet Spectroscopy

A Conference Inspired by the Accomplishments of the
Far Ultraviolet Spectroscopic Explorer Mission

Future Directions in Ultraviolet Spectroscopy

October 20-22, 2008
Annapolis, Maryland

Final Program
October 15, 2008

Sunday, October 19, 2008

17:00 – 19:00 Registration and Opening Reception

Monday, October 20, 2008

Session I, Chair and Provocateur: B. Savage

9:00	C. Danforth	(I)	Finding "Missing" Baryons in the Local Universe?
9:30	T. Tripp	(I)	New Results on O VI Absorbers, Warm-Hot Intergalactic Gas, and Feedback
10:00	A. Narayanan	(C)	Probing the WHIM Gas Through Ne VIII Absorption
10:15	Discussion		

10:30 – 11:00 Coffee Break and Poster Viewing

Session II, Chair and Provocateur: C. Howk

11:00	R. Lallement	(I)	Local Interstellar Medium: New Perspectives
11:30	D. Bowen	(I)	The Distribution of Hot Gas in the Disk of the Milky Way
12:00	V. Dixon	(C)	FUSE Observations of O VI Emission from the Milky Way and Beyond
12:15	Discussion		

12:30 – 13:30 Lunch and Poster Viewing

Session III, Chair and Provocateur: T. Heckman

13:30	A. Aloisi	(I)	A UV Perspective of Starburst Galaxies
14:00	G. Kriss	(I)	FUSE Observations of Active Galactic Nuclei and Prospects for the Future
14:30	N. Lehner	(C)	The Magellanic System - Accretion, Feedback
14:45	Discussion		

15:00 – 15:30 Coffee Break and Poster Viewing

Session IV, Chair and Provocateur: A. Fullerton

15:30	R. Prinja	(I)	Mass Loss from Hot Stars
16:00	K. Werner	(I)	Abundances in Hot Evolved Stars
16:30	N. Walborn	(C)	Systematics of Magellanic Cloud OB Spectra from FUSE
16:45	Discussion		

Invited talks (I) – 30 minutes, including discussion
Contributed talks (C) – 15 minutes, including discussion

A Conference Inspired by the Accomplishments of the
Far Ultraviolet Spectroscopic Explorer Mission

Tuesday, October 21, 2008

Session V, Chair and Provocateur: C. Froning

9:00	K. Long	(C)	Disks, Winds, and White Dwarfs in Cataclysmic Variables
9:15	S. Engle	(C)	The Secret FUV/X-ray Lives of Cepheids
9:30	K. France	(C)	Far-UV Studies of H2 Emission from Photodissociation Regions
9:45	V. Lebouteiller	(C)	Metal enrichment in the neutral gas of blue compact dwarfs
10:00	S. Mathur	(C)	Super-solar metallicity in AGNs measured with FUSE
10:15	Discussion		

10:40 – 11:15 Coffee Break and Poster Viewing

Session VI, Chair and Provocateur: J. Linsky

11:15	C. Oliveira	(I)	D/H Observations: Present Understanding and Future Perspectives
11:45	G. Steigman	(I)	Tracking The Post-BBN Evolution Of Deuterium
12:15	Discussion		

12:30 – 13:30 Lunch and Poster Viewing

Session VII, Chair and Provocateur: C. Grady

13:30	E. Guinan	(I)	The Sun in Time: Effects of the Young Sun's Radiation
14:00	A. Brown	(I)	The Ultraviolet Environment of Protoplanetary Systems
14:30	A. Gomex de Castro	(C)	The formation of planetary disks and winds

14:45 – 15:15 Coffee Break and Poster Viewing

15:15	A. Vidal-Madjar	(I)	Ultraviolet Studies of Extra-Solar Planets
15:45	A. Roberge	(I)	Gas in Protoplanetary and Debris Disks
16:15	C. Martin-Zaidi	(C)	H_2 in the circumstellar environments of Herbig Ae/Be stars
16:30	Discussion		

18:00 - 20:00 Conference Dinner (included with registration)

W. Oegerle (I) After Dinner Remarks
Director Astrophysics Division NASA GSFC

Wednesday, October 22, 2008

Session VIII, Chair and Provocateur: J. Morse

9:00	M. Shull	(I)	The Cosmic Origins Spectrograph and the Future of UV Astronomy
9:30	C. Martin	(I)	The Galaxy Evolution Explorer: Results and Future Implications
10:00	S. McCandliss	(C)	Essential observations of the Lyman continuum

10:15 – 10:45 Coffee Break and Poster Viewing

10:45	K. Werner	(C)	WSO/UV - Ultraviolet mission for the next decade
11:00	J. Green	(I)	Future Ultraviolet Observatories
11:30	M. Postman	(I)	Future of UV Astronomy
12:00	Discussion		

12:30 Lunch

14:00 End of Conference

Oral Presentations & Discussions

Monday, October 20, 2008

Provocateur

10/20/2008 9:00:00 AM

Session I, The Nearby Inter-Galactic Medium

Dr. Blair D Savage University Wisconsin, Madison
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Invited Talk

10/20/2008 9:00:00 AM

Finding "Missing" Baryons in the Local Universe?

Dr. Charles W Danforth University of Colorado
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Simulations predict that shocks from large scale structure formation and galactic winds have reduced fraction of baryons in the warm, photoionized phase (the Lya Forest) from nearly 100% in the early universe to less than 50% today. Some of the remaining baryons are predicted to lie in the warm-hot ionized medium (WHIM) phase at T=105-107 K, but the quantity remains a highly tunable parameter of the models. Modern UV spectrographs we have allowed us unprecedented access to both the Lya Forest and potential WHIM tracers in the local universe. Several independant groups have constructed large catalogs far-UV absorbers along multiple AGN sight lines. There is general agreement between the surveys that the warm, photoionized phase makes up 30% of the baryon budget at z~0. Another 10% can be accounted for in collapsed structures. However, interpretation of the ~100 high-ion (OVI, etc) absorbers at z<0.4 is more controversial. These species are readily created in the shocks expected to exist in the IGM but they can also be created via photoionization and thus not represent WHIM material.

I review here the results from several large IGM surveys and discuss the evidence for photoionized vs. WHIM OVI. Given the observational evidence and theoretical expectations, I argue that most of the observed OVI absorbers represent shocked gas at T~105.5 rather than photoionized gas and are thus valid tracers of the WHIM phase. Given this assumption, enriched gas at T=105-6 can account for ~10% of the baryon budget at z=0. The remaining 50% of the "missing" baryons may reside in gas T>106 or in metal-poor regions. Finally, I discuss ways in which COS data can expand the legacy of FUSE and STIS to solve the photo/shock OVI debate and account for additional WHIM baryons.

Invited Talk
10/20/2008 9:30:00 AM

A High-Resolution Survey of Low-Redshift QSO Absorption Lines: New Results on O VI Absorbers, Warm-Hot Intergalactic Gas, and Feedback

Dr. Todd M Tripp University of Massachusetts
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Currently, two broad questions are driving observational and theoretical studies of the low-redshift intergalactic medium: (1) Are the missing baryons located in the "warm-hot" intergalactic medium (WHIM) at the present epoch? Hydrodynamic cosmological simulations predict that as the universe evolves and large-scale structures grow, intergalactic gas accretes into increasingly deeper potential wells, and a substantial amount of intergalactic material is shock heated. By z = 0, the simulations predict that 20 - 50% of the baryons are shock heated to temperatures of 1e5 - 1e7 K, the so-called WHIM. This is purported to be a robust prediction from these popular simulations, but is there any observational evidence of the WHIM? (2) How do galaxies affect their surroundings, and how do surroundings affect their galaxies? Processes grouped under the rubric of "feedback" (e.g., supernova- or AGN-driven outflows) are often invoked to solve problems in galaxy evolution, but observational constraints on feedback are still quite limited. Conversely, theorists have suggested that gas accretion is more complex than previously thought and occurs in "cold" and "hot" flavors.

To provide observational constraints relevant to these topics, we have been conducting a high-resolution spectroscopic study of the low-redshift IGM using QSO absorption lines. This talk will summarize several new results from this survey, with a focus on QSO absorption systems detected in the O VI doublet. The O VI doublet is frequently detected in low-z QSO spectra, but it will be shown that the absorbers have some surprising properties, e.g., the gas is often cooler than expected (T << 1.0e5 K), sometimes quite enriched with metals (in some cases approaching solar metallicity), and rather far from luminous galaxies.

Contributed Talk
10/20/2008 10:00:00 AM

Probing the WHIM Gas Through Ne VIII Absorption

Dr. Anand Narayanan University of Wisconsin
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We report the detection of Ne VIII in the intergalactic medium at z=0.32566 in the FUSE spectrum of the z=0.6460 quasar 3C263. The Ne VIII 770 feature is detected at a significance of 2.9 sigma. This is a conservative limit since the measurement also takes into account the continuum placement and fixed pattern noise errors. Additionally, O III, O IV and N IV are detected at the same velocity as Ne VIII. The rest-frame equivalent width of the Ne VIII 770 feature is Wr=50.7+/-17.5 mA, with an apparent column density of log N(Ne VIII)=14.02(-0.18 +0.13) and b(Ne) = 67.3+/-4.1 km/s. The Ne VIII 780 line is heavily contaminated by Ly-gamma at z =0.089. The rest-frame equivalent widths of the other lines are Wr(O III 832)=96.5 ± 14.1 mA, Wr(O IV 788)=79.8+/-12.9 mA and Wr(N IV 765)=87.9+/-18.8 mA. The low ionization O II 834 line is not detected, with a 3 sigma upper limit of 21 mA.

Using photoionization models, we show that the Ne VIII traces gas of a different density and temperature compared to the moderately ionized species. A single phase model of photoionized gas within a column density range of log N(HI)=14.6-16.2 cm-2, log n~-3.83 cm-3, and a metallicity range of [Z/H]=0.09 to -1.78, can explain the observed O II, O III, O IV and N IV. However, for this range of metallicity, the models require a log n~-6 cm-3 in order to reproduce the observed N(Ne VIII). Alternatively, collisional ionization in a hot gas can also generate the observed N(NeVIII). This would require temperatures in excess of 105 K, making this system an interesting probe of the shock-heated warm-hot intergalactic medium (WHIM). COS observations will provide better constrains on the physical nature of this multiphase system through coverage of associated O VI and H I lines.

Provocateur

10/20/2008 11:00:00 AM

Session II, The Interstellar Medium

Dr. Chris Howk Univesity of Notre Dame
jhowk@nd.edu

Invited Talk

10/20/2008 11:00:00 AM

Local Interstellar Medium: New Perspectives

Dr. Rosine Lallement Service d'Aéronomie /IPSL/UVSQ
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I will discuss some recent results on the local interstellar gas distribution : -titanium absorption measurements and updated correlations between deuterium and metals. -dense gas distribution inferred from optical absorption data. -recent modeling of X-ray emission following charge exchange between solar wind high ions and interstellar neutrals, induced contamination of the soft-X ray background and consequences for the Local Cavity hot gas. -comparison of X-ray data with high ions from FUSE (Welsh et al): both suggest a lack of hot gas at small distance of the galactic plane in the local cavity. I will discuss the need for new high resolution soft X-ray, UV and optical data.

Invited Talk
10/20/2008 11:30:00 AM

The Distribution of Hot Gas in the Disk of the Milky Way

Dr. David V Bowen Princeton University
E. B. Jenkins, T. M. Tripp, K. R. Sembach, B. D. Savage, H. W. Moos
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We review the results of a FUSE-team program designed to characterize the distribution of hot gas in the disk of the Milky Way. By observing OVI absorption lines towards 148 early-type stars at distances of more than 1 kpc, combining our new results with earlier surveys of OVI, and eliminating stars that show conspicuous localized X-ray emission, we find an average OVI mid-plane density of 1.3e-8 cm-3. The density decreases away from the plane of the Galaxy in a way that is consistent with an exponential scale height of 3.2 kpc at negative latitudes or 4.6 kpc at positive latitudes. Average volume densities of OVI along different sight lines exhibit a dispersion of about 0.26 dex, irrespective of the distances to the target stars. This indicates that OVI does not arise in randomly situated clouds of a fixed size and density, but instead is distributed in regions that have a very broad range of column densities, with the more strongly absorbing clouds having a lower space density. Line widths and centroid velocities are much larger than those expected from differential Galactic rotation, but they are nevertheless correlated with distance and OVI column density, which reinforces our picture of a diverse population of hot plasma regions that are ubiquitous over the entire Galactic disk. The velocity extremes of the OVI profiles show a loose correlation with those of very strong lines of less ionized species, supporting a picture of a turbulent, multiphase medium churned by shock-heated gas from multiple supernova explosions.

Contributed Talk
10/20/2008 12:00:00 PM

FUSE Observations of O VI Emission from the Milky Way and Beyond

Dr. W. Van Dyke Dixon Johns Hopkins University
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Observers using the Far Ultraviolet Spectroscopic Explorer (FUSE) have detected emission in the 1032 and 1038 A resonance lines of the lithium-like O VI ion from a variety of sources in the Milky Way and Magellanic Clouds, including planetary nebulae, supernova remnants, superbubbles, and the diffuse interstellar medium. Observed line intensities span three orders of magnitude, from a few thousand line units (photons/s/cm2/sr) for the faintest interstellar sight lines (a limit set by the detection threshold of FUSE) to a few million line units for the brightest supernova remnants. In this talk, we review these results, highlighting some unexpected discoveries -- such as the detection of collisionally-excited O VI in several planetary nebulae and of photoionized O VI around a hot white dwarf -- and pointing out some general conclusions about O VI emission that run contrary to our initial expectations. We discuss the scientific questions that could be addressed by a next-generation survey of O VI emission.
This work is supported by NASA grant NAS5-32985 to the Johns Hopkins University.

Provocateur
10/20/2008 1:30:00 PM

Session III, Galaxies and Active Galactic Nuclei

Dr. Tim Heckman Johns Hopkins University
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Invited Talk
10/20/2008 1:30:00 PM

A UV Perspective of Starburst Galaxies

Dr. Alessandra Aloisi Space Telescope Science Institute
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Starbursts are an important component of both the low- and high-redshift Universe. Thanks to their proximity, local starbursts constitute a perfect laboratory where to test our ideas about star formation, evolution of massive stars, physics and chemical evolution of the ISM. This type of studies is also fundamental in order to better understand star-formation phenomena in more distant galaxies, the connection between the low- and high-z universe and the processes involved in the origin and evolution of galaxies, including mergin, accretion and feedback. The rest-frame UV spectral range provides unique insights into the starburst phenomenon by offering unique diagnostic tools for investigating the properties of the hot massive stars and the different ISM phases. I will review several key results from past UV observations of nearby starburst galaxies, including FUSE observations, and I will give an overview of the open issues that can only be addressed by the next generation of UV observatories.

Invited Talk
10/20/2008 2:00:00 PM

FUSE Observations of Active Galactic Nuclei and Prospects for the Future

Dr. Gerard Kriss Space Telescope Science Institute
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Over its 8-year lifetime, the Far Ultraviolet Spectroscopic Explorer observed over 200 hundred active galactic nuclei (AGN). Many of these observations were campaigns dedicated to AGN science, including coordinated observations with other observatories such as Chandra, XMM-Newton, and the Hubble Space Telescope. However, most observations were part of large samples of nearby AGN that served as background probes of gas in the interstellar medium, the Galactic halo and the local intergalactic medium. These large samples and the dedicated campaigns have broadly advanced our understanding of the far-ultraviolet continuum of AGN and the ubiquitous outflows of photoionized gas from their active nuclei. The bright, nearby, lower-luminosity AGN

observed with FUSE generally have bluer continua than their higher luminosity counterparts observed with HST, and the spectral shapes are broadly consistent with accretion disk models. More than half of the Type 1 AGN observed with FUSE show blueshifted intrinsic absorption by the O VI doublet, indicative of highly ionized outflows from the central nuclear regions. I will give an overview of these observations, and interpret them in the context of winds from accretion disks and thermally driven winds originating from the obscuring torus, with an eye toward what observational capabilities are needed in the future to understand the role of outflows in the structure and evolution of AGN, and their impact on their environments.

Contributed Talk
10/20/2008 2:30:00 PM

The Magellanic System - Accretion, Feedback: What have we learnt from FUSE?

Prof. Nicolas Lehner University of Notre Dame
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Characterizing the infall and outflow of gas and metals in galaxies is crucial for understanding the evolution of galaxies and the intergalactic medium. The study of these phenomena in local galaxies provides the most robust diagnostic tests for models of tidal interaction, galactic winds, and accretion of primordial material onto galaxies, which are important for piecing together the history of matter and metals in the Universe. The Magellanic System with its high-velocity complexes connected to the Magellanic Clouds provides a laboratory where the techniques of gas-phase absorption line spectroscopy can be used to study the gas toward many individual stars and QSOs. Many of the FUV spectra show significant blueshifted and redshifted interstellar absorption relative to the systemic velocities of the SMC and LMC, signatures of outflow and infall in these galaxies. FUSE provides the largest and highest quality LMC/SMC database in the FUV and has truly open the door to new sciences and discoveries in these galaxies. I discuss how present (and future) observations in the UV bandwith have changed our view of these nearby galaxies and what can we learn from it for the higher redshift Universe.

Provocateur

10/20/2008 3:30:00 PM

Session IV, Hot Massive Stars

Dr. Alex W. Fullerton Space Telescope Science Institute
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Invited Talk

10/20/2008 3:30:00 PM

Mass Loss from Hot Stars

Prof. Raman K Prinja University College London
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This review deals with some of the key areas where FUSE spectroscopy advanced our understanding of hot star winds. The power of the far-UV spectral line diagnostics observed by FUSE is discussed in the context of both time-averaged and temporally varying winds. The results encompass diverse, but related settings, including the winds of luminous OB stars, disk-driven outflows from cataclysmic variable binaries, and the fast winds of PN central stars.

The current serious discordance of different mass-loss estimates for O-type stars is described, and the pivotal role played by analyses of FUSE observations of the PV resonance line doublet is highlighted. Because this discordance has wide ranging implications, its confirmation and resolution are extremely important. Currently, the origin of the problem is thought to be clumping (or, more generally structure) in winds, which is not well characterized by the current theories used to interpret the observations. However, before progress can be made, the nature of the clumping must be constrained. I discuss how additional FUSE diagnostics, together with a multi-wavelength strategy may provide the needed information.

FUSE time-series data have also provided unique insights into the structured and variable outflows in other hot star systems. Successes include the first detections of migrating DAC-like features in the fast winds of PN central stars, and new perspectives on global modulation, often strictly periodic, in the collimated outflows from the inner accretion disks of cataclysmic variable binary stars.

Invited Talk
10/20/2008 4:00:00 PM

Abundances in Hot Evolved Stars

Klaus Werner University of Tuebingen, Germany
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We present results of abundance analyses in hot (pre-) white dwarfs and central stars of planetary nebulae. We concentrate on hydrogen-deficient objects, for which the results allow to conclude on interior nucleosynthesis and mixing processes in the progenitor AGB stars. The analyses are almost entirely based on ultraviolet spectroscopy performed with HST and primarily with FUSE. We identify observational and modeling requirements that are necessary to achieve further progress in this field.

Contributed Talk
10/20/2008 4:30:00 PM

Systematics of Magellanic Cloud OB Spectra from FUSE

Dr. Nolan R Walborn Space Telescope Science Institute
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The FUSE data for 287 OB stars in the Magellanic Clouds are an unprecedented resource to investigate the behavior of the stellar winds as a function of spectral type, luminosity class, and metallicity. The smaller extinction and interstellar absorption relative to Galactic counterparts render the MC sample more powerful, especially below 1100 A. IUE provided a comparable Galactic sample at longer UV wavelengths, but HST has yet to do the same in the MCs. An initial FUSE atlas of 47 objects published in 2002 charted several basic trends, including the luminosity (or wind-density) sensitivity of the S IV, P V, and C III profiles, analogous to the previously unique Si IV behavior at longer UV wavelengths; this effect is due to the relatively low ionization of these species except for P V, for which the much lower abundance prevents saturation at lower luminosities. Now we are augmenting our sample by about 150 more objects, to provide better coverage of the parameters and redundancy at some spectral types, as well as to investigate categories of peculiar objects. Some outstanding early results are increased representation of the earliest spectral types (O2-O4), and the extension of the CNO dichotomy between O2 and ON2 spectra to the superionized O VI profiles. This work and subsequent quantitative modeling will improve our understanding of stellar winds, massive stellar evolution, and the integrated spectra of distant starbursts.

Oral Presentations & Discussions

Tuesday, October 21, 2008

Provocateur

10/21/2008 9:00:00 AM

Session V, Scientific Breadth of UV Spectroscopy

Dr. Cynthia S. Froning CASA, University of Colorado
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Contributed Talk

10/21/2008 9:00:00 AM

Far Ultraviolet Observations of Disks, Winds, and White Dwarfs in Cataclysmic Variables

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Cataclysmic variables are the nearest and most easily studied laboratories for understanding accretion onto compact objects. FUSE has provided the first significant sample of high resolution, high S/N spectra of such objects in the wavelength range 900-1183 A. As expected, the FUSE spectra of most nova-like variables and dwarf novae in outburst show broad features associated with emission from the inner accretion disk. Detailed modeling has proven difficult, however, because the flux near the Lyman limit is higher than expected, indicating that the vertical structure of the disk differs significantly from that of normal stellar atmospheres of similar temperature and gravity. Wind features, due to OVI and CIII, are also evident in many systems, and in most cases are accompanied by fairly narrow lower ionization-state lines that are blue shifted by no more than a few 100 km/s. These narrower features and the small number of systems with P-Cygni-like profiles suggest that most of the wind features observed with FUSE arise in material fairly near the disk surface, a picture quite different from that inferred from analyses of longer wavelength HST data. Dwarf nova systems in optical quiescence show FUV emission from the WD, which is heated by and cools after outbursts, and from the disk, and, surprisingly, at least in some cases, the hot spot. Here I will briefly illustrate the observational contributions FUSE has made to our understanding of cataclysmic variables, describe the quantitative state of the modeling, and suggest where we might go from here.

Contributed Talk
10/21/2008 9:15:00 AM

The Secret XUV Lives of Cepheids: FUV/X-ray observations of Polaris and beta Dor

Scott G Engle Villanova University
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We report on the surprising recent discovery of strong FUV emissions in two bright, nearby Classical Cepheids from analyses of FUSE archival observations (combined with one of our own approved observations just prior to the failure of the satellite). Polaris and beta Dor are currently the only two Cepheids to have been observed with FUSE, and beta Dor is the only one to have multiple spectra. Both Cepheids show strong C III (977Å, 1176Å) and O VI (1032Å, 1038Å) emissions, indicative of 50,000 - 500,000 K plasma, well above the photospheric temperatures of the stars. Also, more remarkably, beta Dor displays variability in the FUV emission strengths which appears to be correlated to its 9.84-d pulsation period. This phenomenon has never before been observed in Cepheids. The FUV studies are presented along with our recent Chandra/XMM X-ray observations of Polaris and beta Dor, in which X-ray detections were found for both stars. Further X-ray observations have been proposed to unambiguously determine the origin and nature of the observed high energy emissions from the targets, possibly arising from warm winds, shocks, or pulsationally induced magnetic activity. The initial results of this study are discussed, along with their impact on understanding the structure, heating, dynamics and possible magnetic activity of Cepheid (and related Hybrid Star) atmospheres. We gratefully acknowledge support for this project from NASA grants: Chandra-GO6-7011A, XMM-Newton grant NNX08AX37G, FUSE grant 06-FUSE8-0088 and NSF grant AST05-07542.

Contributed Talk
10/21/2008 9:30:00 AM

Far-UV Studies of H2 Emission from Photodissociation Regions

Dr. Kevin France University of Colorado
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Photodissiocation regions (PDRs) lie at the interface between a strong ultraviolet radiation field and a dense molecular cloud, often the cloud associated with the formation of a hot star. PDRs cover the transition from HII region (traced by ionized gas) to molecular cloud (traced by molecular emission from species like CO). A thin boundary layer exists between these phases, where the ultraviolet spectrum of PDRs is dominated by fluorescent H2 emission and dust scattered stellar continuum. These regions are difficult to isolate because they require clouds in close proximity to an OB star and a favorable geometry with respect to earth. We present a mini-survey of five local PDRs carried out with FUSE. We use these data to characterize the far-UV spectra of PDRs for the first time and to refine models of the H2 fluorescent emission process. We find that our models can adequately reproduce the observed emission spectra of three of these regions (IC 63, M42, and IC 405). The remaining two (NGC 2023 and NGC 7023) do not show clear emission from H2 in the FUSE band, despite the well defined and characteristic double-peaked emission features at 1575 and 1608 A observed in these

object, as well as the clear fluorescent signatures in the well studied near-IR rovibrational emission lines, thus suggesting a more complex radiative transfer scenario in these environments.

Contributed Talk
10/21/2008 9:45:00 AM

Metal enrichment in the neutral gas of blue compact dwarfs: the compelling case of Pox 36

Dr. Vianney Lebouteiller Cornell University
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The presence of extremely metal-poor dwarf galaxies in the Local Universe is a challenge for models of galaxy chemical evolution. Within the chemical downsizing scenario, it is expected that dwarf galaxies can remain quiescent for times longer than the Hubble time. Such galaxies are thus ideal targets to seek for pristine gas in the present day Universe. Chemical abundances in the ionized gas of HII regions within star-forming dwarf galaxies such as IZw18 lead to the conclusion that there could be a minimum metallicity due to a single starburst episode. This naturally explains the difficulty to find metal-poor objects while emphasizing the need for observing other gaseous phases. The search for pristine gas has since pursued with the study of the neutral envelope around galaxies. Such gas could have remained partly unprocessed since the galaxy formation, except via mixing of material ejected at high-galactic latitude by supernovae (SNe) events. We will present results obtained with the FUSE telescope indicating that the neutral gas of the blue compact dwarf galaxy Pox 36 has already been enriched with heavy elements. Furthermore, the ionized gas of the HII regions is found to be ~10 times more metal-rich. We argue this can be explained by successive localized star-formation episodes, with 99% of the SNe products mixing in the HI phase (increasing only slightly its metallicity) and only 1% mixing locally. Pox 36 and other galaxies are compared to draw a general picture in which the neutral gas of BCDs systematically harbor a metallicity deficiency.

Contributed Talk
10/21/2008 10:00:00 AM

Super-solar metallicity in AGNs measured with FUSE

Prof. Smita Mathur The Ohio State University
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Measuring metallicity in the nuclear regions of AGNs is difficult because only a few lines are observed and ionization correction becomes a major problem. Nitrogen to carbon ratio has been widely used as an indicator for metallicity, but precise metallicity measurements have been lacking. We made such measurements for the first time using a wide baseline of ionization states with observations from FUSE, HST and Chandra. OVI observations with FUSE were crucial in this effort. We measured super-solar metallicities in two AGNs and found that N/C does not scale with metallicity. This suggests that chemical enrichment scenario in nuclear regions of AGNs may be different from traditional models of galactic metal enrichment, at least in the high metallicity regime.

Provocateur

10/21/2008 11:15:00 AM

Session VI, Deuterium

Prof Jeffrey L Linsky JILA/University of Colorado and NIST
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Invited Talk

10/21/2008 11:15:00 AM

D/H: Present Understanding and Future Perpectives, An Observers Point of View

Dr. Cristina M Oliveira The Johns Hopkins University
H. Warren Moos
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Determining the abundance of deuterium in the Galaxy was one of the primary goals of the FUSE mission. FUSE-based D/H and D/O measurements have been published for about thirty new lines of sight, probing column densities and distances that had not been previously accessible. The measurements confirmed that the deuterium abundance is variable on relatively small spatial scales. This had been observed before by Copernicus and IMAPS, albeit for a small number of sightlines. Together with previous D/H measurements, the FUSE observations led to a model that explains the D/H variations in terms of variable depletion of deuterium onto dust grains. Although not perfect and probably not the complete final answer this model is a big step forward in trying to understand the abundance of deuterium in the Milky Way. Such a model would not have been possible without the backdrop of the many FUSE measurements.
In this talk we review all the Galactic measurements of D/H and discuss the causes of uncertainty in these measurements and how they can be affected by systematic errors. We consider the possible causes of the D/H variability and explore future scientific directions that will allow us to better understand the behavior of D/H in the Galaxy.

Invited Talk

10/21/2008 11:45:00 AM

Tracking The Post-BBN Evolution Of Deuterium

Dr. Gary Steigman Ohio State University
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The primordial abundance of deuterium produced during Big Bang Nucleosynthesis (BBN) depends sensitively on the universal abundance of baryons (the baryon to photon ratio). Observations of deuterium in high-redshift, low-metallicity QSO Absorption Line Systems (QSOALS) provide a key baryometer, determining the baryon abundance at the time of BBN to a precision of ~5%. In the post-BBN universe, as gas is cycled through stars, deuterium is only destroyed so that the abundance measured anytime, anywhere,

bounds the primordial abundance from below. A comparison of the deuterium abundances inferred from observations of enriched, processed material in the Galaxy with the primordial abundance offers a constraint on models of Galactic chemical evolution. In this talk the BBN-predicted deuterium abundance will be compared with the primordial value inferred from QSOALS, testing the standard cosmological model. The relic abundance is further compared with the FUSE-inferred deuterium abundances in the local ISM constraining models of post-BBN Galactic chemical evolution.

Provocateur

10/21/2008 1:30:00 PM

Session VII, Protoplanetary Systems

Dr. Carol A Grady Eureka Scientific and GSFC
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Invited Talk

10/21/2008 1:30:00 PM

The Sun in Time: Effects of the Young Sun's Strong X-ray-FUV Radiation on Terrestrial Planets & Life

Prof. Edward F Guinan Villanova University
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Multi-wavelength studies of solar analogs (G0-G5 V stars) with ages from ~50 Myr to 9 Gyr have been carried out as part of our "Sun in Time" program. These studies infer that the young Sun was rotating over 10x faster than today and as a consequence, these young solar-type stars, and the young Sun, had vigorous magnetic dynamos and correspondingly strong coronal X-ray and transition region/chromospheric FUV-UV emissions up to several hundred times stronger than the present Sun. The chief science goals are (1) to study the solar magnetic dynamo (with rotation as the only variable) and (2) to determine the radiative and magnetic properties of the young Sun with the purpose of constructing spectral irradiances that are being used to study paleo-planetary atmospheres. The strong radiation and particle fluxes inferred for the young Sun have major implications and impacts on the photochemistry and photo-ionization of paleo-planetary atmospheres (in particular for the terrestrial planets) and also play important roles in the possible atmospheric erosion of the planets as well as studying their suitability for life. Recent results of the effects of the young, active Sun's enhanced X-ray/FUV emissions and wind fluxes on the early Earth (as well as on Venus and Mars) will be discussed. The importance of planetary magnetic fields in protecting the young planets' atmospheres from the erosive effects of young Sun's strong X-UV and plasma fluxes also will be briefly discussed. The important role played by FUSE FUV spectrophotometry of solar-

type stars will be emphasized. We are grateful for the support from grants from NASA (FUSE, XMM, Chandra and HST)and from NSF/RUI grants. We also express our thanks to the FUSE team for their heroic efforts in extending the FUSE mission

Invited Talk
10/21/2008 2:00:00 PM

The Ultraviolet Environment of Protoplanetary Systems

Dr. Alexander Brown CASA, University of Colorado
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Young stars undergoing the conversion of pre-main-sequence circumstellar disks into protoplanetary systems are strong sources of high energy (FUV/EUV/X-ray) radiation that controls the physical and chemical processes in their circumstellar environment out to hundreds of AU from the star. The high energy emission, both as radiation and particles, resulting from magnetic activity on the central star controls the thermal structure of disks, the formation process of planetesimals, and the photoexcitation, photoionization, and photodissociation of atoms and molecules forming protoplanets and in young planetary atmospheres. Modeling of the dust and gas evolution requires an accurate understanding of the local radiation field throughout the UV and X-ray spectral regions, even those parts of the spectrum that are impossible to observe from Earth. Most young stars are well over 100 pc from the Sun and are consequently hard to observe in the UV at even moderate spectral resolution. Fortunately, members of the ``Local Association'' [offshots from the ongoing Sco-Cen star-formation complex], whose ages range from 7 Myr to a few hundred Myr, surround the Sun at distances of 50 pc or less and permit the detailed study of the early evolution of stellar activity. I shall review the current knowledge of the level and range of UV and X-ray stellar activity within the various Moving Groups of the Local Association, describe a few well-studied examples in detail, and discuss how future observations could improve our understanding of the role of the stellar radiation in shaping the protoplanetary environment.

Contributed Talk
10/21/2008 2:30:00 PM

The formation of planetary disks and winds: an UV view

Prof. Ana I Gomez de Castro Universidad Complutense de Madrid
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Planetary systems are angular momentum reservoirs generated during star formation. This accretion process produces very powerful engines able to drive the optical jets and the molecular outflows. A fraction of the engine energy is released into heating thus the temperature of the engine ranges from the 3000K of the inner disk material to the 10MK in the areas where magnetic reconnection occurs. There are important unsolved problems concerning the nature of the engine, its evolution and the impact of the engine in the chemical evolution of the inner disk. Of special relevance is the understanding of the shear layer between the stellar photosphere and the disk; this layer controls a significant fraction of the magnetic field building up and the subsequent dissipative processes ought to be studied in the UV.

This contribution focus on describing the connections between 1 Myr old suns and the Sun and the requirements for new UV instrumentation to address their evolution during this period. Two types of observations are shown to be needed: monitoring programs and high resolution imaging down to, at least, milliarsecond scales.

Invited Talk
10/21/2008 3:15:00 PM

Ultraviolet Studies of Extra-Solar Planets

Dr. Alfred Vidal-Madjar IAP-CNRS-UPMC
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Transmission spectroscopy is a powerful tool for probing atmospheres of extra-solar planets when transiting their parent star. The first detection of an atmospheric species was NaI in HD209458b (Osiris), thanks to the Hubble Space Telescope (HST) sensitivity reaching ~10-4 in relative absorption depth. Still with HST, HI, OI and CII were discovered in the far UV, and more recently in the UV, H_2 via Rayleigh scattering. This underlines once more the potentialities of the UV-farUV spectral domain where a large number of diagnostic lines are available.
The next steps will be the detection and characterization of additional species toward further extra-solar planets, hopefully down to Earth-like worlds which will require sensitivities in the ~10-6 range. Fortunately, wide absorption bands of particular interest do exist in this spectral domain. Key parameters for their detection are the parent star spectral type, the density of the planet and the thickness of the atmosphere. From model simulations one can estimate the number of potential targets for a future UV space mission as a function of its collecting area.

Invited Talk
10/21/2008 3:45:00 PM

Gas in Protoplanetary and Debris Disks: Insights from UV Spectroscopy

Dr. Aki Roberge NASA Goddard Space Flight Center
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Over the last two decades, observations of protoplanetary and debris disks have played an important role in the new field of extrasolar planetary studies. Many are familiar with the extensive work on the cold circumstellar dust present in these disks done using infrared and sub-millimeter photometry and spectroscopy. However, UV spectroscopy has made some unique contributions by probing the elusive but vital gas component in protoplanetary and debris disks. In this talk, I will outline our picture of the evolution of protoplanetary disks and discuss the importance of the gas component. New insights obtained from UV spectroscopy will highlighted, as well as some new puzzles. Finally, I will touch on upcoming studies of gas in protoplanetary and debris disks, some at UV wavelengths, some at far-IR and sub-mm wavelengths.

Contributed Talk

10/21/2008 4:15:00 PM

Molecular hydrogen in the circumstellar environments of Herbig Ae/Be stars probed by FUSE

Dr. Claire Martin-Zaidi Laboratoire d'Astrophysique de Grenoble
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H2 gas is the most abundant molecule in the circumstellar (CS) environments of young stars. It is a key element in our understanding of the evolution of pre-main sequence stars and their environments towards the main sequence. At the present time, little is known about the gas as compared to the dust in the environments of young stars. We thus observed H2 around a sample of pre-main sequence stars in order to better characterize their CS environments. We analyzed the FUSE spectra of ~20 Herbig Ae/Be stars (HAeBes) covering a broad spectral range. To better diagnose the origin of the detected H2 and its excitation conditions, we used a model photodissociation region (PDR). Our analysis demonstrates that the excitation of H2 is clearly different around most of the HAeBes compared to the interstellar medium. Moreover, the characteristics of H2 around these stars give evidence for different excitation mechanisms. For the most massive Be stars, the excitation diagrams are reproduced well by a PDR model. Our results favor an interpretation in terms of large CS envelopes, remnants of the molecular clouds in which the stars were formed. On the other hand, the group of Ae stars known to possess disks is more inhomogeneous. In most cases, when CS H2 is detected, the lines of sight do not pass through the disks. The excitation conditions of H2 around Ae stars cannot be reproduced by PDR models and correspond to warm and/or hot excited media very close to the stars. Our results suggest structural differences between Herbig Ae and Be star environments. Herbig Be stars do evolve faster than Ae stars, and consequently, most Herbig Be stars are younger than Ae ones at the time we observe them. It is thus more likely to find remnants of their parent cloud around them.

Oral Presentations & Discussions

Wednesday, October 22, 2008

Provocateur

10/22/2008 9:00:00 AM

Session VIII, The Future of UV Astronomy

Dr. Jon A Morse NASA
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Invited Talk

10/22/2008 9:00:00 AM

The Cosmic Origins Spectrograph and the Future of UV Astronomy

Dr. Michael Shull University of Colorado
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After the fall 2008 servicing mission, the Hubble Space Telescope should again provide exciting discoveries, through UV spectroscopic studies of quasars, galaxies, clusters, hot stars, white dwarfs, planetary objects, and the large reservoirs of gas between the stars, in galactic halos, and throughout the intergalactic medium. The next 5-10 years should be promising for UV science on Hubble, with the new COS and restored STIS spectrographs on a 2.4-meter telescope. However, both UV and X-ray astronomy are falling behind, compared to the advances made at other wavebands, both in aperture and through investments in new instrumentation. During the upcoming NRC Decadal Study, the US space-astronomy community should consider whether it can afford to abandon high-energy (UV/X) windows on many astrophysical objects and phenomena in the universe. Will we be able to support (and afford) future transformative missions with large aperture and high throughput, such as ATLAST (UV/O) and IXO (X-ray)? Or is the future likely to be with moderate-size missions?

Invited Talk
10/22/2008 9:30:00 AM

The Galaxy Evolution Explorer: Results and Future Implications

Prof. Christopher Martin California Institute of Technology
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The Galaxy Evolution Explorer (GALEX) continues to map the ultraviolet sky. GALEX surveys have supported the following galaxy evolution investigations: calibrating UV as a star formation rate tracer, using wide and deep surveys to measure star formation history, studying the evolution of dust extinction and metallicity, selecting and analyzing galaxies in transitory states, finding local analogs to Lyman Break Galaxies, probing and time-dating star formation in a wide variety of physical regimes, and probing star formation properties in low mass, low density settings. Our continuing mission is focussed on relating star formation history and galaxy evolution paths to the properties of dark matter halos and their assembly history, and on beginning to relate the evolution of galaxies to that of black holes and the intergalactic medium. Over and above GALEX's study of galaxy evolution the surveys are: finding all UV bright QSOs at low and high redshift, discovering tidal capture flares from inactive black holes, discovering shock breakout flashes from distant supernovae, selecting a sample of galaxies for Baryon Acoustic Oscillation surveys, and in our own Milky Way, discovering and diagnosing spectacular new stellar wind nebulae from aging, mass-losing stars. In this talk I will review some of these results and surprising discoveries, and describe how UV missions in the future (small to large), motivated in part by, and expanding upon the results of GALEX, could play a key role in the next decades.

Contributed Talk
10/22/2008 10:00:00 AM

Essential observations of the Lyman continuum

Dr. Stephan R McCandliss Johns Hopkins University
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Concurrent observations of Lyman continuum (LyC) and Lyman alpha (LyA) emission escaping from star-forming systems at low redshift are essential to understanding the physics of reionization at high redshift ($z >\sim 6$). Some have suggested reionization is dominated by numerous small galaxies with LyC escape fractions $f_e \sim 10\%$, while others suggest quasars with higher f_e might also play a role. At $z > 3$, direct observation of LyC leakage becomes progressively more improbable due to the increase of intervening Ly limit systems, leaving LyA as the primary diagnostic available to the James Webb Space Telescope for exploring the epoch of reionization. If a quantitative relationship between escaping LyC and LyA emission can be established at low z, then the diagnostic power of LyA as a LyC proxy at high z can be fully realized. Here I review past and ongoing efforts to detect the elusive LyC and present detection requirements for future efforts as a function of redshift and escape fraction. At redshifts $0.02 < z <\sim 1.3$ modest aperture instruments (~ 1 m) with large grasp can determine whether low mass galaxies have higher f_e than high mass galaxies, as has been suggested to be the case at high redshift. Such an instrument can also provide concurrent LyA information and perhaps even begin to trace the seeds of the cosmic web. At 1.3 <

z < 2.9, observations of LyC become zodiacal background limited and consequently will require much larger spacebased telescopes. Such a large telescope should be capable of revealing the cosmic web of LyA in its full glory.

Contributed Talk

10/22/2008 10:45:00 AM

WSO/UV - Ultraviolet mission for the next decade

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The World Space Observatory UltraViolet (WSO/UV) is an international space mission led by Russia and devoted to UV spectroscopy and imaging. The observatory includes a 170cm aperture telescope capable of UV spectroscopy and deep UV and optical imaging. The project is included in the Federal Space Program of Russia for the period 2006-2015. Launch is planned for the mid of the next decade.
The instrument suite consists of i) a high-resolution (R=55,000) double echelle spectrograph for the wavelength range 102-320nm, ii) a low-resolution (R=2000) long-slit spectrograph covering the same wavelength range, and iii) a number of UV/optical imaging cameras having different resolution and field-of-view.

Invited Talk

10/22/2008 11:00:00 AM

Future Ultraviolet Observatories

Dr. James C Green University of Colorado
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I will review the fundamental science drivers for future optical/ultraviolet observatories, as well as the future infrastructure capabilities to support them. I will also discuss some conceptual mission concepts for observatory class as well as medium and small class observatories and discuss the strengths and weaknesses of the various approaches.

Invited Talk
10/22/2008 11:30:00 AM

The Future of UV Astronomy

Dr. Marc Postman Space Telescope Science Institute
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Major astrophysics facilities in the 2020 decade and beyond will be addressing scientific problems that cannot be addressed by the capabilities of ANY of today's current or planned missions. Identifying the fundamental questions that will NOT be answerable in the coming decade is the challenge facing those who are beginning to envision the observational capabilities that will be required of large space-based missions of the future. I will, with great humility, attempt to frame some of the key scientific, technological, and programmatic leaps astronomers will need to make if we are to have a vibrant space-based program in the next 20 years.

Contributed Posters

Monday, Tuesday, and Wednesday,
October 20, 21, 22, 2008

Contributed Poster 1

Transient Processes in the Atmosphere of Alpha Tau

Dr. Vladimir Airapetian George Mason University at NASA/GSFC
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The Far Ultraviolet Spectrograph Explorer (FUSE) spectra of UV emission lines observed in Alpha Tau (K5 III) at two epochs separated by four months show dramatic differences in emission line fluxes and line shifts. This presents the first evidence of dynamic plasma heating in the active region of this cool giant star. We discuss these observations in terms of Alfven wave heating in magnetic loops.

Contributed Poster 2

The Impact of Accurate Distances on UV Spectroscopy of White Dwarfs and Cataclysmic Variables

Paul Barrett US Naval Observatory
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J-MAPS and GAIA are two astrometry missions to be launched in 2011. The positions and parallaxes of stars brighter than 15 magnitude will be measured to an accuracy of 1000 and 25 microarcseconds, giving distances to better than 1 parsec. Accurate distances allow us to constrain the luminosity and hence temperature, radius and mass of isolated white dwarfs. With a sufficiently large sample, evolutionary models can be tested. For white dwarfs in binaries where the mass is known, the atmospheric structure can be extrapolated to zero temperature to test the mass-radius relation. For cataclysmic variables, evolutionary models can also be tested, particularly for dwarf novae in quiescence where the white dwarf is detected. By measuring the temperature of the white dwarf, the long term accretion rate of the binary can be estimated and compared with the expected accretion rate of magnetic braking for CVs above the period gap (>3 hr) and gravitational braking for those below the gap (< hr). For nova-like systems, whose luminosity is dominated by the accretion disk and affected by interstellar extinction and reddening, accurate distances can help constrain the temperature profile of the disk. With a sufficient sample, standard disk models can be tested.

Contributed Poster 3

The fundamental parameters of massive stars

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We analyzed far-UV (FUSE), UV (HST, IUE) and optical spectra of hot massive stars in the Milky Way with non-LTE, line-blanketed models with expanding winds. We were able to reconcile previously discrepant diagnostics from H alpha to the highly ionized far-UV lines (e.g. OVI, NV) with a revised treatment of X-rays from shocks and clumping in the stellar wind. These effects could be fully constrained thanks to the lines in the FUSE range. A revised (downwards) Teff scale has resulted, and previous discrepancies in the estimate of mass loss rate from optical and UV lines have been reconciled.

Contributed Poster 4

The UV sky surveys: a road-map for future UV missions

Dr. Luciana Bianchi Johns Hopkins University
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Unprecedented UV surveys of the sky in two UV bands, FUV and NUV, and catalogs of UV sources, are provided by the Galaxy Evolution Explorer (GALEX). We describe the major surveys, which have different depth and coverage, and we characterize the nature of the UV sources. The UV surveys, linked to a multi-wavelength archive, offer great sensitivity to detect and characterize several classes of astrophysical objects, including low-redshift QSOs, white dwarfs in the Milky Way, and star-forming galaxies.

Contributed Poster 5

FUSE Observations of O VI Absorption in the Large Magellanic Cloud

Dr. William P Blair Johns Hopkins University
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We have embarked on a project to characterize the global properties of O VI absorption toward stars in the Large Magellanic Cloud observed with FUSE. Earlier studies with a smaller sample of stars established that O VI absorption is ubiquitous and spatially variable. However, at least one study has claimed that localized enhancements in O VI column density may be associated with nebular sub-structures such as superbubbles (SBs). It is the aim of our program to perform a broader analysis of O VI absorption characteristics using all of the data available.
O VI ISM absorption in LMC stellar spectra shows a wide range of appearances, depending on the stellar spectral type and luminosity class as well as the presence or absence of galactic or intermediate velocity absorption. Hence, we have performed a spectral morphology classification of the sight lines. We have also identified sight lines with little or no LMC ISM O VI. Without including such sight lines, the dispersion of

LMC O VI absorption (attributed to the halo of the LMC) has been underestimated, and the average value has been overestimated. We are using these data to assess whether excess O VI absorption can be attributed to nebular sub-structures within the LMC such as superbubbles (SBs) or supershells. We will discuss this and other aspects of the project and report our preliminary findings.
This project has been funded through a NASA FUSE Cycle 5 Legacy grant NNG05GE03G to The Johns Hopkins University.

The FUSE/MAST Magellanic Clouds Legacy Project

Dr. William P Blair Johns Hopkins University
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We present a new online resource through the High Level Science Products program at the Multi-Mission Archive at Space Telescope (MAST) involving reprocessed data for all FUSE stellar sight lines in the Magellanic Clouds. We have reprocessed the entire FUSE sight line database of stars observed in both Magellanic Clouds (187 in the LMC, 100 in the SMC) using the final version of the FUSE calibration pipeline, CalFUSE 3.2. Where multiple data sets were available, they have been combined to improve data quality. We provide subsets of these data in several formats, along with 20 arcmin FOV optical and infrared context images for each sight line. The data formats include a set of spectral postage stamps of interstellar absorption lines aligned in heliocentric velocity, an enlargement of the spectral region near the important O VI doublet lines, and an overview spectrum of the entire FUSE spectral range for each object. The imagery includes MCELS optical H alpha, [S II], and [O III] emission line images and infrared 3.6, 8, and 24 micron data from Spitzer. These context images are available as three color composites in each band and as individual images in black and white. The availability of these diverse data sets in a convenient online interface provides a significant quick look capability that will allow researchers to effectively utilize this rich archival FUSE data set for a wide variety of science investigations. The web site for the FUSE/MAST Magellanic Clouds Legacy Project is http://archive.stsci.edu/prepds/fuse_mc/ This project has been funded through a NASA FUSE Cycle 5 Legacy grant NNG05GE03G to The Johns Hopkins University.

Contributed Poster 7

A multiwavelength study of the close environment of HD34078

Dr. Patrick Boissé Institut d'Astrophysique de Paris
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To clarify the origin of highly excited H2 detected with FUSE toward HD34078 (Boissé et al. 2005), we mapped the CO(2-1) emission at 12-arcsec resolution in the field. The data show a pronounced maximum near HD34078's position, indicating that the star and diffuse cloud are closely associated. The comparison of one MDRS and seven LWRS FUSE spectra of HD34078 shows that LWRS spectra are significantly contaminated by diffuse emission. No variations of N(H2, J=0) are detected among the LWRS spectra, over four years. The analysis of the high S/N MDRS spectrum allows the detection of H2 absorption up to the v=3, J=1 level and yields improved estimates for all N(H2,v,J) values. A series of new visible CH and CH+ absorption lines have been obtained between 2003 and 2008. Our measurements confirm the reality of rapid, large amplitude and correlated variations of N(CH) and N(CH+) previously detected by Rollinde et al. (2003). Temporal variations in CH and CH+ line profiles are also clearly seen. The available observations suggest a picture in which HD34078's wind swept up ambient molecular gas to form a dense shell of gas and dust, coincident with the bow shock seen by France et al. (2007). The amount of highly excited H2 is well consistent with the shell-star distance. Further, the large CH and CH+ abundances and time variations can be understood as a result of a high CH+ production rate due to a shock and/or the presence of an inhomogeneous turbulent mixing layer at the cloud/wind interface. To the contrary, gas located well beyond the interface should be little affected by the presence of the star and the lack of significant N(H2, J=0) variations indicates the absence of marked density structure in the ambient cloud over scales of about 10 - 100 AU.

Contributed Poster 8

Abundance Patterns in Hot Subdwarf B Stars: The Case of Carbon

Dr. Pierre Chayer STScI
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Hot subdwarf B stars (sdB) are helium core burning stars without a hydrogen burning layer. They have effective temperatures ranging from 22,000 K to 40,000 K and gravities ranging from log g = 5.0 to 6.2. After the helium core exhaustion, sdB stars evolve to low mass white dwarfs without reaching the asymptotic giant branch. One of the most puzzling phenomena observed at the surface of sdB stars is their abundance anomaly. For instance, high-resolution optical spectroscopy shows that the carbon abundance is lower than the solar abundance by about a factor of ten on average. A few stars, however, show a solar abundance or an abundance higher than solar. Although optical spectroscopy allows the measurement of relatively high carbon abundance, it fails to measure stringent upper limits when no carbon lines are detected. The Far Ultraviolet Spectroscopic Explorer (FUSE) comes to the rescue when no carbon lines are detected in the optical,

because it is 1,000 times more sensitive than the VLT for the purpose of measuring very small amounts of carbon in the atmospheres of sdB stars. We measure the carbon abundance in the FUSE spectra of 31 stars. We confirm the carbon abundance trend reported in previous studies, but report the disappearance of carbon in five stars. The upper limits that we measure for these stars are about four orders of magnitude lower than the solar abundance. The observation of very low carbon abundance suggests that the normal equilibrium between gravitation and radiative levitation has been disrupted, perhaps by a weak stellar wind.

Gas Content in the Debris Disks of Nearby A-type Stars

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Since the IRAS discovery of Vega's large thermal infrared excess over the expected photospheric flux, dust disks have been found around a large fraction of main-sequence A-type stars. While dust in debris disks has been studied extensively with Spitzer, relatively little is known about their gas content. We have carried out detailed studies of the circumstellar environments of all nearby A-type stars. We have studied both thermal emission from their circumstellar dust and absorption from circumstellar gas. With high-resolution and high signal-to-noise visible spectra, we identified about a dozen main-sequence A-type stars with circumstellar gas through a volume-limited survey. Although these spectra confirm the existence of the circumstellar gas and serve as a probe of the gas dynamics, they do not allow us to determine the gas density and temperature. Fortunately, there are many absorption lines in the UV and FUV range that are sensitive to the gas density and temperature. Through our FUSE, IUE, HST, and ground-based observations, we found five of these stars with variable, infalling circumstellar gas similar to that seen in spectra of Beta Pic. This unique set of stars allows us to study the evolution of both gas and dust in the circumstellar disks of A-type stars at the same time. We will describe what we have been able to learn from the subset of these stars observed with before the termination of the FUSE mission. Our FUSE results regarding the evolution of gas in debris disks raise further questions that can only be answered with future high-resolution UV spectroscopy missions.

Contributed Poster 10

Far-UV Constraints on Mass Outflows in Active Galactic Nuclei

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Mass outflows from Active Galactic Nuclei (AGN) are revealed through high-ionization absorption lines in the UV that are blue shifted with respect to their host galaxies. The mass outflow rates are comparable to the accretion rates needed to power the active supermassive black holes, indicating the importance of outflows in determining the overall structure and energetics of AGN. Using high-resolution UV spectroscopy from FUSE and HST, including multiple-epoch observations of the variable absorption lines, we have derived detailed constraints on the physical conditions, transverse velocities, and locations of the outflowing absorbers. We have also recently isolated a component of the emission lines that likely arises in the outflowing absorbers, which allows us to place tight constraints on the locations, geometry, and dynamics of the outflows. In the best-studied Seyfert galaxies to date, NGC 4151, the available evidence favors magnetocentrifugal winds over radiation driving or thermal expansion as the dominant acceleration mechanism for the outflows.

Contributed Poster 11

Intergalactic HI and Metal Absorbers at z<0.4

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We present results from a large survey of the low-redshift IGM using STIS and FUSE observations toward 28 AGN. Our survey includes 640 HI absorption systems (Lyman lines) at z<0.4 and corresponding absorbers in seven metal ions (OVI, CIII, CIV, SiIII, SiIV, NV, and FeIII). In a redshift path length of 5.27, we detect the largest sample of metal absorbers to date in the low-z IGM: 83 OVI systems, 39 CIII, 53 SiIII, 24 CIV, 24 NV, etc. We determine completeness-corrected column density distributions, statistical metallicities, and more accurate estimates of the IGM baryon content for all species. In the low-z IGM, we have accounted for ~40% of the baryons: 30% in the photoionized Lya forest and up to 10% in the 105-106 K warm-hot intergalactic medium (WHIM) as traced by OVI. Improved statistics for weak OVI absorbers allows us to estimate Omega_WHIM/Omega_b=8.6+-0.8% down to log(N_OVI)=13.0. The NV absorption follows a similar pattern to OVI, with both ions providing reliable tracers of the portion of the WHIM at T=105-106 K. However, CIV is not as clearly a WHIM tracer, and it may be present in both collisional and photoionized phases. The ions CIII, SiIII, and SiIV are well correlated with HI and show patterns typical of photoionization. Adjacent ion stages of the same element (CIII/IV and SiIII/IV) provide useful constraints on the photoionization parameter, log(U)=-1.5+-0.2. Observed OVI and NV detections require an ionization field ~10 times stronger, supporting our hypothesis that these ions trace the WHIM phase. Comparison of SiIV and CIV with high-z surveys shows a modest increase in line density, consistent with increasing IGM metallicity at recent epochs. Even at z<0.4, there is some evidence for evolution among IGM absorbers.

Contributed Poster 12

CalFUSE and the Final FUSE Archive

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In support of the final data archive of the Far Ultraviolet Spectroscopic Explorer, we have reprocessed the entire FUSE data set using CalFUSE v3.2, the latest version of the FUSE data-reduction software. Recent improvements to CalFUSE include effective-area and background files for the final two years of the mission; software modifications to increase the signal-to-noise ratio of observation-level spectral files for histogram data; software modifications to extract spectra from airglow exposures and to produce quick-look spectral plots for the airglow exposures associated with each observation; and database changes to standardize the assignment of object classes for observations of the background sky and bright Earth. Future CalFUSE users will benefit from modifications that allow the pipeline to be compiled on additional fortran compilers (f77, f90, g77, gfortran) and operating systems (Solaris 10, Linux, Mac OS X), including machines with 64-bit architectures. Finally, we have conducted an assessment of the archival data quality, including analyses of the remaining systematic uncertainties in the effective-area and wavelength calibrations.
This work is supported by NASA contract NAS5-32985 to the Johns Hopkins University.

Contributed Poster 13

Intrinsic Ultraviolet Absorbers in Active Galactic Nuclei

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We present Far Ultraviolet Spectroscopic Explorer (FUSE) measurements and photoionization analysis of UV absorption in the 3 observations of the low-z Seyfert 1 object IRAS F22456-5125. These 5 distinct, narrow (FWHM > 200 km/s) absorbers span a significant range in velocity (~ 0 to -700 km/s) and ionization (Lyman series, C III, N III, and O VI). We find that the object shows little evidence for corresponding X-ray absorption, and shows variability in the continuum flux of the object (by a factor of 6) and variability within one of the 5 components in the timescale covered by the FUSE observations, component 4. This provides us with an upper limit on the distance of 602 pc for component 4.
In the coming HST cycle we will observe this object and 5 other low-z quasars and Seyfert galaxies with the Cosmic Origins Spectrograph (COS) as part of a systematic effort to determine the chemical abundances of AGN. Three of these objects show strong C III absorption, which leads us to believe that these targets are good candidates to search for C III* 1173 A. This will provide us with both the density and the distance to the absorbers for several objects, which therefore yield the kinetic luminosity for the outflows. These measurements will be instrumental in determining the relationship between absorbers in Seyfert galaxies and higher luminosity quasars where we are currently finding distances and densities for several objects in the latter category.

Contributed Poster 14

Far Ultraviolet Spectroscopy of Hot DA White Dwarfs: a retrospective and looking forward

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With its unprecedented sensitivity and spectral resolution, FUSE has been sources of important data that have helped further our knowledge and understanding of white dwarf stars. We will summarize the results based on our search for heavy elements in white dwarf atmospheres since the last FUSE conference and present an interpretation of the observed abundance patterns and their implications on diffusion theory. In the spirit of this conference, we will discuss the current limitations to our understanding of abundance patterns in white dwarfs, and address the scientific requirements for a future far ultraviolet spectroscopic mission specific to the study of degenerate stars.

Contributed Poster 15

Symbiotic binaries: testbeds for mass-loss, accretion physics, and atomic data

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Symbiotic binaries are the widest separation interacting systems, consisting of a red giant primary and (generally) a white dwarf secondary. The strong spectral distinction between cool and hot star - and also their interaction region - gives rise to a range of separable emission and absorption features from both collisional and photoionised material.
For those symbiotic systems which undergo eclipses, we can obtain further (unique) information on stellar mass loss by observing the spectrum of the white dwarf as it passes behind the extended atmosphere of the giant primary. In this instance, time-resolved spectra enable us to derive tomographic information to directly determine the physics of mass-loss (e.g., abundances, temperature, ionisation), at least in the plane of the system. The main goal of our work in the UV and far-UV has been to utilise these systems to derive self-consistent models for mass loss – including the velocity field – from the giant surface out to the circumbinary material.
A portion of the wind from the giant flows towards the secondary, and this material can sometimes be diagnosed in absorption. We have found evidence for partial coverage of the white dwarf with clumpy material, with short (orbit-to-orbit) variations in appearance from inflow to outflow. For systems that outburst due to material accreted onto the white dwarf, the far-UV allows insight into the progress of the eruption and processed material properties. We have observed the ejection of a narrow shell of material from one such system, that subsequently dissipates, as the spectrum of the system recovers towards its pre-outburst state.
I shall also comment on the use of symbiotic binary spectra as testbeds for atomic data.

Contributed Poster 16

Connections between low-z and high-z O VI observations

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Of all the absorption lines in the far-UV, none has gained as much attention from FUSE as the OVI doublet. In this talk I will present observations of OVI absorption at z>2 using high-resolution ground-based spectroscopy, in various classes of absorption-line system, including the IGM and gamma-ray-burst host galaxies. Comparisons will be made between the properties of the high-redshift and low-redshift O VI populations. The goal will be to demonstrate how space-based UV studies of O VI and other high ions at low redshift provide valuable context for understanding the high-redshift Universe, and are crucial to understand the evolution of cosmic structure from high-redshift to the present day.

Contributed Poster 17

Far-UV Studies of H2 Emission from Photodissociation Regions

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Moved to Session V, Scientific Breadth of UV Spectroscopy as a Contributed Talk
10/21/2008 9:30:00 AM

Contributed Poster 18

A Survey of Milky Way Dust Extinction in the FUSE Far-Ultraviolet

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New results on the Milky Way interstellar extinction in the far-ultraviolet will be presented. Far-ultraviolet (912-1150 A) extinction curves for 80+ sightlines have been constructed using targeted and archival FUSE spectra. The important effects of H_2 absorption are modeled and removed prior to constructing the extinction curves. The extinction curves were constructed using the standard pair method. The standard stars used were carefully dereddened using comparisons to the existing dereddened IUE standard stars and requiring a smooth progression in spectra with spectral type. All the sightlines probed have existing mid-ultraviolet (from IUE or STIS) extinction curves allowing for a direct comparison of the mid- and far-ultraviolet extinctions. This large set of FUSE extinction curves provides a detailed probe the extinction due to small dust grains. Comparisons to CCM curves and FM fits will be presented as well as limits on residual extinction structures.

Contributed Poster 19

The Nearest Herbig Ae Star Transitional Disks

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As a result of more than 20 years of infrared astronomy from space, circumstellardisks can be most easily identified from excess light over that expected to be produced by the photosphere of the star. The shape of this IR spectral energy distribution (SED) has been used to infer the accretion rate onto the star and the degree of dust grain growth and settling in protoplanetary disks. More recently, it has been used to identify disks with warm dust deficits, the "transitional" disks. Flared disks are expected to be gas-rich, and concentrated among the younger systems lacking evidence of grain growth and settling, and in those with higher current accretion rates. However, transitional disks with dust deficits in the inner disk have similar SEDS to flared disks. By combining FUSE FUV excess light measurements, the SED data, disk outer radius measures, and the radial surface brightness of the disk in scattered light, we test the hypothesis that the majority of Herbig Ae star disks detected in scattered light have flared disks. Instead, we find that the majority of these disks are flatter structures. Low current accretion rates sampled by FUSE FUV spectra further suggest that these disks are the nearest intermediate-mass transitional disks. We next use the presence or absence of accretion onto the star to identify those transitional disks which are likely to harbor planetary mass companions.

Contributed Poster 20

Living with a Red Dwarf: FUV & X-ray emissions of dM stars and effects on hosted Planets

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Red Dwarf (dM) stars are overwhelmingly the most numerous stars in our Galaxy. These cool, faint and low mass stars make up > 80% of all stars. Also dM stars have extremely long life times >50-100 Gyr. Determining the number of red dwarfs with planets and assessing planetary habitability (a planet's potential to develop and sustain life) is critically important because such studies would indicate how common life is in the universe. Our program - "Living with a Red Dwarf"- addresses these questions by investigating the long-term nuclear evolution and the magnetic-dynamo coronal and chromospheric X-ray & FUV/UV properties of red dwarf stars with widely different ages (~50 Myr - 12 Gyr). One major focus of the program is to study the magnetic-dynamo generated coronal and chromospheric X-ray-FUV/UV emissions and flare properties of a sample of dM0-5 stars. Observations carried out by FUSE of a number of young to old dM stars provide important data for understanding Transition-Region heating in these stars with deep convective zones as well as providing measures of FUV irradiances. Also studied are the effects of X-ray-FUV emissions on possible hosted planets and impacts of this radiation on their habitability. Using these data we are constructing irradiance tables (X-FUV/UV irradiances) that can be used to model the effects of XUV radiation on planetary atmospheres and possible life on planetary surfaces. Here we discuss the initial results of this program.

This research is supported by grants from NASA/FUSE (NNX06AD38G), and NSF (AST-0507542 & AST-0507536) which we gratefully acknowledge.

Contributed Poster 21

Is there a future in space-based visible/UV spectroscopy?

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The past three decades have provided many advances in space-based spectroscopy in both the visible and ultraviolet spectral regions. Many diverse studies have been enabled by multipurpose spectrographs in spacecraft such as Copernicus, International Ultraviolet Explorer, Far Ultraviolet Spectrographic Explorer and Hubble Space Telescope. The latter utilized increasingly improved spectrographs from the Faint Object Spectrograph and the Goddard High Resolution Spectrograph to the Space Telescope Imaging Spectrograph and soon the Cosmic Origins Spectrograph. These instruments have provided increasing capabilities through detector and optical technology advances. Space-based spectroscopy offers many advantages: access to the ultraviolet, no limitations by atmospheric extinction, absorption or emission and near-diffraction-limited angular resolution. Yet no space-based, general purpose visible/ultraviolet observatory is planned for the near term.

As new observatories are considered for the ultraviolet longward of 912A, designs should include near-diffraction imaging spectroscopy extended through the visible portion of the spectrum. Tradeoffs of large, monolithic primary mirrors versus segmented telescopes must consider stability of point spread functions, especially in the studies of complex, extended sources.
Examples from the HST/STIS studies will be presented, especially of the massive binary winds of Eta Carinae.

Contributed Poster 22

Far-UV diagnostic wind lines of hot CSPN

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As they transition toward the white dwarf cooling sequence, the fading winds of Central Stars of Planetary Nebulae (CSPN) are characterized by very high temperatures (Teff > 100kK). Determination of wind parameters of these stars is challenging because their tenuous winds offer few if any optical spectral diagnostics. Fortunately, the FUSE wavelength range has revealed new useful wind diagnostics such as high-ionization Iron and Neon lines. We show examples of results from our ongoing analysis of hot Galactic CSPN stars.

Contributed Poster 23

Connecting Absorbers and Galaxies: FUV Observations of Strong OVI Absorber and a Lyman Limit System

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With a column density log N(OVI) = 14.95 ± 0.05, the OVI absorber at z=0.2028 detected in the spectrum of the QSO PKS0312-77 is the strongest discovered so far in the low redshift Universe. The OVI absorber is observed near a Lyman limit system (LLS). We present an analysis of these absorbers and their connection to galaxies based on a combination of FUV and NUV spectra of PKS0312-77 obtained from FUSE and HST/STIS E140M/E230M and optical imaging and spectroscopy of galaxies in the field. Based on OI/HI and a photoionization model, we find a metallicity of 0.25 solar for the LLS, too enriched to be pristine IGM gas. We find that the gas resulting from the merger of a 0.7 L* galaxy (impact parameter of 38 kpc) is the likely origin for the LLS. At -180 km/s from the LLS, another absorber is found with a supersolar metallicity. Outflow from this galaxy is likely responsible for this supersolar, fully ionized absorber. The metallicity variation is a possible evidence for poor mixing of metals on galactic structure as observed in the Milky Way halo. The origin of the strong OVI remains more enigmatic with plausible origins including an intragroup medium or a galactic corona.

Contributed Poster 24

Far-ultraviolet Spectroscopy of Massive Binaries in the Galaxy and in the Magellanic clouds

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We report on phase-resolved FUSE observations of three massive colliding wind binaries in the Galaxy: HD149404 HD93205, and HD93403. The systems have different masses, eccentricities, and evolutionary states. The massive O-type binary HD93205 is a double-line spectroscopic system consisting of an O3.5V and an O8V star in a 6.08-day orbit. HD93403 consists of an O5.5I and an O7V star in a 15.093 day orbit. Both are located in the Carina OB1 Association. In HD93403, the winds are comparable in strength, while for HD93205 the wind of the O3.5 star dominates. HD149404 consists of type O7.5 I(f) and an ON9.7 I star.
We compare these observations with FUSE observations of three HMXRBs, 4U1700-37, SMC X-1 and V801 Cen, and three O-type double-lined spectroscopic binaries in the Magellanic clouds, LH54-425, J053441-693139 in the LMC and Hodge 53-47 in the SMC. Improved orbit parameters, including revised masses, for LH 54-425 are derived from new CTIO spectroscopy.
Phase-locked wind variability and wind-wind collision effects in the binaries are studied as traced by changes in terminal velocity and optical depth of the large number of wind diagnostics in the FUSE spectral range (O VI, S VI, C III, N III, S III, IV, & VI, P V, Si IV) S IV, S VI, Si IV and P V lines are important and unique probes of O star winds because they are strong but not saturated. We determined the Mdot v_infinity ratio in each system. The spectra provide quantitative and systematic studies of phase-dependent stellar properties, wind collision effect and FUV spectrophotometric changes as a function of orbital phase.

Contributed Poster 25

Multiwavelength Approaches to Understanding Interstellar Dust

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Perhaps more than almost any other subject of astrophysical study, the interstellar medium can be studied at any wavelength---from gamma rays to the radio---with each waveband providing unique and significant information. However, there are substantial limitations on the available data. One important limitation is that very few lines of sight have been adequately observed in both wavebands of a potentially enlightening combination, such as the UV and the IR. This in turn restricts our understanding of topics as fundamental as interstellar abundances and dust composition. In this poster, I will review the reasons that such data limitations exist, what waveband combinations would be useful, what scientific insight would be gained from those combinations, and what the prospects are for the future. I will also specifically describe two accepted observing programs that will, in the near future, utilize a multiwavelength approach in studying dust. The first is a Chandra/HST program that will provide unique insight into dust

composition by disentangling the gas-phase and dust-phase abundances of oxygen and iron. The second is a Spitzer/HST program that will examine the extinction curves of possible "translucent clouds" at wavelengths from the UV to the IR.

Contributed Poster 26

Implications of SWCX 1/4 keV emission on the LB hot gas in the galactic disk: Model-Data comparison

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We present calculations of the heliospheric solar wind charge exchange (SWCX) emission spectra below 0.3 keV and the resulting contributions of this diffuse background in the ROSAT 1/4 keV bands. We compare our results with the soft X-ray diffuse background (SXRB) emission detected in front of identified shadowing regions during the ROSAT All-Sky Survey (Snowden et al. 2000). This foreground component is principally attributed to the hot gas of the so-called Local Bubble (LB), an irregularly shaped cavity of ~ 50-150 pc around the Sun, which is supposed to contain ~10^6 K plasma. Our results suggest that the SWCX emission from the heliosphere is bright enough to account for most, if not all the foreground emission at low galactic latitudes, where the LB is the least extended. However, the SWCX R2/R1 band ratio (1.39) differs from the data (1.04-1.25), especially in the galactic anti-centre direction where the observed ratio is the smallest. Assuming that both SWCX and hot gas emission are present and restricting our modelling to the low latitudes, we have tested a series of thermal plasma spectra for different temperatures ranging from 10^5 to 10^6.5 K and searched for a combination of SWCX spectra and thermal emission matching the observed intensities and band ratios, while simultaneously being compatible with FUSE OVI emission measurements. In the frame of collisional equilibrium models, the range we derive for hot gas temperature and emission measure cannot reproduce the Wisconsin B/C band ratios. Moreover, it is incompatible with upper limits based on the CHIPS data, and marginally compatible with EUVE measurements.

Contributed Poster 27

Internal consistency of the FUSE flux calibration: implications for future missions

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The FUSE flux calibration is defined by synthetic spectra of six hot DA white dwarfs. The six stars include the four DAs used as primary standards for HST: GD71, GD153, HZ43, and G191-B2B, plus GD659 and GD246. These stars were chosen to provide a wide range of effective temperature, 32800K to 61200K, to minimizepotential systematic errors in the calibration arising from uncertainties in the model parameters for individual stars and from uncertainties in the theoretical models. The internal consistency of the

HST spectrograph calibrations is impressive, typically 1-2%, but inherent uncertainties in the FUSE waveband are greater. We will discuss the internal consistency of the FUSE flux calibration and present lessons learned from the FUSE experience.

Contributed Poster 28

The FUSE Mission Archival Web Site Moves to MAST

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With the close-out of FUSE operations, the long time FUSE web presence at JHU will soon be closed down. To ensure key project support information remains available in the long term, FUSE project personnel are working closely with Multimission Archive at Space Telescope (MAST) staff to build an improved FUSE archival web site, to be hosted at MAST. We have been working to identify all meta-data, documentation, website content and associated products that should be permanently archived. FUSE staff are rewriting the Data and Instrument handbooks for future archive users. We are making significant new support information generally available to users for the first time. These data include Mission Planning Schedule Timeline Plots (showing each observation as scheduled in the context of orbital events), Guide Star plots (showing the anticipated guide stars, field context, and FUSE aperture locations on the sky), and Science Data Assessment Forms (SDAFs), which contain information relevant to how the observation actually executed. These data are being linked into observation Preview pages for easy reference by archival users. Finally, the entire FUSE science data set, some nearly 6000 observations, have been reprocessed and re-archived with the final version of the CalFUSE pipeline, version 3.2. Thus, while some observations may still benefit from personalized processing, the best overall automatically-generated data products for all FUSE data will be available for use in previews and NVO data sets. At this writing, the transition is in progress, and is expected to be complete by the end of calendar 2008.

Contributed Poster 29

Additional evidence for deuterium depletion

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In our study of D/H in the Galaxy (ApJ 647, 1106 (2006)), we argued that the wide range in gas-phase D/H values outside of the Local Bubble could be explained by deuterium depletion onto dust grains in some lines of sight. We presented two arguments for this conclusion: a theoretical argument based on the larger carbon-deuterium binding energy compared with the carbon-hydrogen bond, and an empirical correlation of low values of gas-phase D/H with large depletions of such refractory elements as iron and silicon. One problem with the second argument is that the depletions were measured relative to neutral

hydrogen, but an unknown amount of hydrogen can be ionized. To avoid this problem we have compared gas-phase D/H values with column densities of Fe II/P II. Singly-ionized phosphorus is a useful replacement for the total hydrogen column density, because (1) P II is the dominant ionization stage over a wide range of temperatures, (2) phosphorus has a small depletion in the ISM, and (3) P II is measured in many of the same FUSE spectra used for measurements of D/H. This work provides additional support for the deuterium depletion hypothesis. Thus the best test of the amount of deuterium astration and infall of near primordial gas into the Galactic disk is the difference between the highest gas-phase D/H measurements and estimates of primordial D/H.

Contributed Poster 30

Modeling H2 Fluorescence in Planetary Atmospheres with Partial Frequency Redistribution

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We present the modeling of partial frequency redistribution (PRD) effects in the fluorescent emission lines of molecular hydrogen, the general computational approximations and the application to planetary atmospheres. We show that this process produces significant modifications to the line shape for large optical depths, and estimate its importance for line radiative transfer and detectability in astrophysical environments. Our model can be applied to FUSE observations of Jupiter and Saturn, allowing an independent confirmation of the H2 abundance and atmospheric structure. The (6-v") progression pumped by Ly-beta through the (6-0) P(1) transition is a good candidate for a fluorescence model with PRD due to the strong variation of the excitation source over the line profile, translating into the observed asymmetry of the emission lines.

Contributed Poster 31

The Effects of Clumping on UV Wind Line Diagnostics

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By comparing mass loss rates determined from radio, H alpha, and UV resonance lines, it has become reasonably certain that clumping in OB star winds affects empirical determinations of their mass loss rates. We examine three additional UV spectral diagnostics that are sensitive to clumping and, ultimately, may help constrain its nature. They are:

1) Doublet ratios of resonance lines.
2) Deep cusps near terminal velocity in stars with weak winds.
3) Ratio of the resonance and radiatively excited state lines of Si IV in certain O9-B0 supergiants.

We present examples of each diagnostic and explain why they respond to clumping.

Contributed Poster 32

Broad O VI Emission Wings From Active Stars

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The chromospheric and transition region emission lines of the most active stars have routinely been shown to consist of very broad wings superimposed on the narrower, rotationally-broadened emission core. If these wings are attributed to a single emission mechanism in the stellar atmosphere, the implied thermal broadening often strains credibility. If they are due to active regions or loops rotating into and out of view, they should be present only for a small range of rotational phase. They have also been attributed to continuous flaring and to circumstellar material (loops, disks, etc.). We have been analyzing spectra of very active stars in the FUSE continuous viewing zone, allowing them to be observed continuously over one or more complete rotations. This helps to distinguish between spatial (repeatable, phase-dependent) and temporal variations and provides further insight into the mechanism(s) responsible for the broad wing emission. For example, in observations spanning 3 rotational cycles of AB Dor in December 2003, we observe a phase-dependent velocity shift between the narrow and broad emission components of the O VI lines. We will discuss the contributions FUSE spectra have made to resolving the origin of the broad emission components.

Contributed Poster 33

Eta Car: The good, the bad and the ugly of nebular and stellar confusion

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Observations in the far UV provide a unique opportunity to investigate the massive star Eta Car and its hot binary companion. Eta Car was observed with FUSE over a large portion of the 5.54 year spectroscopic period before and after the 2003.5 minimum. The observed spectrum is defined by strong stellar wind signatures, primarily from Eta Car A, complicated by the strong absorptions of the ejecta surrounding Eta Car plus interstellar absorption. The Homunculus and Little Homunculus are massive bipolar ejecta historically associable with LBV outbursts in the 1840s and the 1890s and are linked to absorptions at -513 and -146 km/s, respectively. The FUSE spectra are confused by the extended nebulosity and thermal drifting of the FUSE co-pointed instruments. Interpretation is further complicated by two B stars sufficiently close to Eta Car to be included most of the time in the large FUSE aperture. Follow up observations partially succeeded in obtaining spectra of at least one of these B stars through the smaller apertures, allowing potential separation of the B star contribution and Eta Car. A complete analysis of all available spectra is currently underway. Our ultimate goals are to directly detect the hot secondary star, if possible, with FUSE and to identify the absorption contributions to the overall spectrum.

Contributed Poster 34

Spectral Analysis of the sdOB Primary of the Post-Common-Envelope Binary LB 3459 (AA Dor)

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LB 3459 is an eclipsing, close, post common-envelope binary consisting of a sdOB primary star and an unseen secondary with an extraordinary small mass - formally a brown dwarf. A recent NLTE spectral analysis shows a discrepancy to the surface gravity which is derived from analyses of radial-velocity and light curves. One probable reason for this ``gravity problem'' might be a too-low surface gravity previously determined from optical and near UV observations of LB 3459.We present results of a detailed spectral analysis of the FUSE observation of LB 3459 by means of state-of-the-art NLTE model-atmosphere techniques.

Contributed Poster 35

The Evolution of O(He) Stars

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Spectral analyses of H-deficient post-AGB stars have shown that a small group of four extremely hot objects exists which have almost pure He absorption-line spectra in the optical. These are classified as O(He) stars. For their evolution there are two scenarios: They could be the long-sought hot successors of RCrB stars, which have not been identified up to now. If this turns out to be true, then a third post-AGB evolutionary sequence is revealed, which is probably the result of a double-degenerate merging process. An alternative explanation might be that O(He) stars are post early-AGB stars. These depart from the AGB just before they experience their first thermal pulse (TP) which will then occur as a late thermal pulse (LTP). This would be a link to the low-mass He-enriched sdO stars and low-mass, particularly He-rich PG 1159 stars. We present results of a spectral analysis of FUSE observations of the O(He) stars by means of NLTE model-atmosphere techniques and summarize our present picture of their evolutionary scenario.

Contributed Poster 36

The Impact of FUSE on our Understanding of Stellar Post-AGB Evolution

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State-of-the-art non-LTE spectral analysis requires high-resolution and high-S/N observations of strategic metal lines in order to achieve reliable photospheric parameters like, e.g., effective temperature, surface gravity, and element abundances. Hot stars with effective temperatures higher than about 40000 K exhibit their metal-line spectrum arising from highly ionized species predominantly in the (far) ultraviolet wavelength range. FUSE observations of hot, compact stars provided the necessary data. With these, it has been, e.g., possible to identify fluorine for the first time in observations of post-AGB stars. The evaluation of ionization equilibria of highly ionized neon, phosphorus, sulfur, and argon provides a new sensitive tool to determine effective temperatures of the hottest stars precisely. Moreover, abundance determinations have put constraints on stellar evolutionary models which, in turn, have improved greatly our picture of stellar post-AGB evolution. We present highlights of our spectral analyses in the recent years which are based on FUSE observations.

Contributed Poster 37

Far Ultraviolet Spectroscopic Explorer Observations of OB Stars in the Magellanic Clouds

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The Far Ultraviolet Spectroscopic Explorer has provided an extensive sample of Magellanic Cloud OB spectra in the 900-1200 A range. The shorter wavelengths are more accessible in the Clouds than in the Galaxy, because of the lower interstellar extinction and absorption. Many additional objects have been observed since the initial compilation by Walborn et al. (ApJS 141, 443, 2002). These new data have been reduced and organized into spectral-type sequences, some of which are presented here, including several objects of special interest.

Contributed Poster 38

The Extension of the Transition Temperature Interstellar Plasma into the Lower Galactic Halo

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Column densities for H I, Al III, Si IV, C IV, and O VI toward 109 stars and 30 extragalactic objects have been assembled in order to study the relative extensions of these species away from the Galactic plane into the Galactic halo. H I and Al III trace the warm neutral and warm ionized medium, respectively, while Si IV, C IV and O VI trace a combination of warm photoionized and collisionally ionized transition temperature plasma. The large object sample allows us to consider and correct for the effects of the sample bias that has affected the results of earlier but smaller surveys of the gas distributions. We find Si IV and C IV have similar exponential scale heights of ~3.2 to 3.6 kpc. The scale height of O VI is marginally smaller with h~ 2.6 kpc. The transition temperature gas is ~6 times more extended than the warm ionized medium traced by Al III with h ~ 0.65 kpc and ~14 times more extended than the warm neutral medium traced by H I with h ~ 0.21 kpc. There is a factor of 2 decrease in the dispersion of the ionic column density ratios for transition temperature gas for lines of sight in the Galactic disk compared to extragalactic lines of sight through the entire halo. The logarithmic dispersions for N(C IV)/N(O VI) and N(Si IV)/N(O VI) are approximately twice that found for N(Si IV)/N(C IV). The observations are compared to the predictions of the various models for the production of the transition temperature gas in the halo.

Contributed Poster 39

Preparation of a Far-UV Spectral and Line Atlas for B III=III Stars

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B type stars are major contributors to the total far-UV flux (950-1125 Å) produced in the Milky Way and external galaxies. The final processing of the Far Ultraviolet Spectroscopic Explorer (FUSE) dataset, together with the the existing archives of the International Ultraviolet Explorer (IUE) high dispersion spectra and the Copernicus Atlas of tau Sco, permit the construction of an atlas of 10 sharp-lined main sequence (class III-V) B stars. We are building an atlas denoting the H I and molecular H2 features separately from photospheric lines and listing essentially all noticeable absorption features with known oscillator strengths. This atlas will allow investigators to identify anomalous features in other B-type spectra as well as to select lines that can serve as proxies for the determination of Teff, anomalous abundance patterns, and possible departures of the star's atmospheric T(tau) from nonstandard gradients. We discuss the input constituents for this atlas. We also show three examples of the atlas panels, showing photospheric line identifications for types B0V, B2V, and B8V. The ~3600 lines we have identified comprise over 11% of the list used in our line library. We have been unable to identify only ≈5% of the visible features for the tau Sco spectrum, and fewer still for the B8 spectrum. A comparable number of lines is found to be overpredicted.

Contributed Poster 40

Far-UV Temperature Diagnostics for Hot Central Stars of Planetary Nebulae

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The effective temperatures of hot central stars of planetary nebulae are usually determined from the ratios of optical He II lines. However, far-ultraviolet spectra from the FUSE satellite of several hot (Teff > 70,000 K) hydrogen-rich central stars have stellar features that imply a significantly hotter effective temperature than that determined from He II. There are many stellar features in the long wavelength portion of the FUSE spectrum. These include O VI 1146-47, F VI 1039.5, Fe VII 1118.6, 1141.4, Fe VI 1120.9, 1131.5, and Ni VI 1124.2, 1148.2. The strong F VI 1139.5 line is of interest because of the large overabundance (over 100X solar) of F in some PG1159 stars reported by Werner et al. (2005). Modeling of these spectral feature provide an independent method for measuring the effective temperatures of these stars. An example of HD 200516, the central star of NGC 7009 (Teff = 82000 K from optical He II line ratios vs 95000 K from Far-UV metal lines) is presented. This difference in Teff implies a large increase in the EUV ionizing radiation field and is important for photoionization modeling of the planetary nebula.

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Search for O VI Emission from the Shocked Circumstellar Gas of SN 1987A

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The Far Ultraviolet Spectroscopic Explorer (FUSE) was used to search for broad O VI emission from the shock interaction zones produced by the collision of high-velocity supernova ejecta with the dense inner circumstellar ring of SN 1987A. Since the shock interaction with the inner ring began in 1997, broad (FWHM = 300 km/sec) emission from optical coronal lines (e.g. [Fe X], [Fe XI], and [Fe XIV]) has emerged and increased exponentially in strength. O VI 1032-1038 A emission is expected to track the coronal lines. O VI is also expected to be the primary cooling transition for the million-degree shocked gas. An accurate measurement of the O VI line strength would significantly improve current models of the shock interaction. FUSE observations of SN 1987A in 2000 and 2001 did not detect broad O VI due to spectral contamination from two early-type stars within a few arc seconds of the SN. However, O VI emission was detected with narrow line widths (FWHM less than 35 km/sec) and a heliocentric radial velocity of +280 km/sec. This places the emitting gas at rest relative to the supernova and is interpreted as emission from unshocked circumstellar gas. The last FUSE observation of SN 1987A was obtained in May 2007 and used a narrow slit (1.25x20 arcsec) to significantly reduce the spectral contamination from the two early-type stars. Yet the 2007 spectrum does not reveal and significant O VI emission. The implications of these results are discussed.

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Ultraviolet studies of Classical and Recurrent Novae in Outburst

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Studies of the Classical Nova Outburst in the ultraviolet have been ongoing since the advent of space based UV astronomy. While sporadic observations occurred before the International Ultraviolet Explorer Satellite (IUE), the data from this satellite resulted in huge advances in our understanding of the outburst. For example, we discovered two compositional classes of novae, those that occurred on a carbon-oxygen white dwarf and those that occurred on an oxygen-neon white dwarf. We were also able to use these data to determine ejecta masses and the energetics of the outburst to a far higher accuracy than before. One of the highlights of the IUE studies were the detailed observations of the outburst of RS Oph in 1985. These data confirmed that the outburst was caused by a thermonuclear runaway on the white dwarf and that the characteristics of the explosion were a result of the ejected material running into the outer layers of the giant companion. I will review these results and suggest necessary observations that could be done by a future UV spacecraft

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High-Stage Ions in the ISM from Supernova Remnants: Role of Anisotropic Thermal Conduction

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We use 2.5D numerical simulations to explore the production of hot gas and transitional gas from supernova remnants in the presence of flux-limited anisotropic thermal conduction and equilibrium cooling. We have followed the evolution of supernova remnants embedded in a variety of environments representative of the interstellar medium, over several millions of years. We track the volume, luminosity, line widths and dosages of the FUSE-sensitive ions O VI, O VII and O VIII over the entire time that this hot gas persists, using an equilibrium ionization model. We demonstrate that anisotropic thermal conduction can moderate the temperature of the hot gas and increase the luminosity of high-stage ions of oxygen that are deposited into the interstellar medium. We also show that the magnetic field can have a role in reheating the gas long after the initial supernova event.

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Testing binary population synthesis models with hot subdwarfs

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Models of binary star interactions have been successful in explaining the origin of field hot subdwarf (sdB) stars in short period systems. The hydrogen envelopes around these core He-burning stars are removed in a "common envelope" evolutionary phase. Reasonably clean samples of short-period sdB+WD or sdB+dM systems exist, that allow the common envelope ejection efficiency to be estimated for wider use in binary population synthesis (BPS) codes. About one-third of known sdB stars, however, are found in longer-period systems with a cool G or K star companion. These systems may have formed through Roche-lobe overflow (RLOF) mass transfer from the present sdB to its companion. They have received less attention, because the existing catalogues are believed to have severe selection biases against these systems, and because their long, slow orbits are difficult to measure. Are these known sdB+cool systems worth intense observational effort? That is, can they be used to make a valid and useful test of the RLOF process in BPS codes? We use the Binary Stellar Evolution (BSE) code of Hurley et al. (2002), mapping sets of initial binaries into present-day binaries that include sdBs, and distinguishing "observable" sdBs from "hidden" ones. We aim to find out whether (1) the existing catalogues of sdBs are sufficiently fair samples of the kinds of sdB binaries that theory predicts, to allow testing or refinement of RLOF models; or instead whether (2) large predicted hidden populations mandate the construction of new catalogues, perhaps using wide-field imaging surveys such as 2MASS, SDSS, and Galex. We also report on a pilot study to identify hidden subdwarfs, using 2MASS and GALEX data.
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The Soft X-ray Background - OVI Connection Solved!

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There has been much recent controversy regarding the physical state of the interstellar gas located within the Local Cavity. Observations of the Soft X-ray background emission and local OVI absorption have long implied that the Local Cavity is filled with a hot gas. However new data on local OVI absorption and the recent recognition of the importance of solar wind charge exchange processes with regard to the production of soft X-rays in the heliosphere pose serious problems with the aforementioned accepted picture of a hot Local Cavity. We present a new model of the Local Cavity which can explain (i) the observed distribution of soft X-ray background emission, (ii) the observed distribution of local OVI absorption, (iii) the solution to the Local Cavity "pressure" problem, (iv) the importance of the Local Chimney with regard to infalling hot gas from Loop I, and (iv) the importance of local magnetic fields.

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HIRDES - The High-Resolution Double-Echelle Spectrograph for WSO/UV

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The World Space Observatory Ultraviolet (WSO/UV) is a multi-national project grown out of the needs of the astronomical community to have future access to the UV range. WSO/UV consists of a single UV telescope with a primary mirror of 1.7m diameter feeding the UV spectrometer and UV imagers. The spectrometer comprises three different spectrographs, two high-resolution echelle spectrographs (the High-Resolution Double-Echelle Spectrograph, HIRDES) and a low-dispersion long-slit instrument. Within HIRDES the 102-310nm spectral band is split to feed two echelle spectrographs covering the UV range 174-310nm and the vacuum-UV range 102-176nm with high spectral resolution (R>50,000). The technical concept is based on the heritage of two previous ORFEUS SPAS missions. The phase-B1 development activities are described.

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Highly Ionized HVCs in the Inner Galaxy: Evidence for a Galactic Origin

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Highly-ionized high-velocity clouds have been studied for the last decade. Some lines of reasoning have suggested an extragalactic origin for these clouds, placing them near the outskirts of the Milky Way or Local Group, and some models have explored the possibility that they may be associated with dark matter minihalos. We have observed highly-ionized HVCs toward the inner Galaxy globular cluster Messier 5 that appear to have a Galactic origin. Here we present FUSE and STIS observations of the post-AGB star ZNG 1 in M 5 (l=3.9, b=47.7; d=7.5 kpc, z=+5.3 kpc). Absorption is seen in OVI, CIV, SiIV, and lower ionization species at LSR velocities near -140 and -110 km/s. Photoionization models and path length arguments rule out the possibility that this gas is circumstellar. The metallicity of these HVCs is [O/H] = +0.22+/-0.10, the highest of any known HVC. Given the metallicity and distance constraints, we conclude that these HVCs have a Galactic origin. We hypothesize that these HVCs are part of a large-scale circulation and may be related to a Galactic nuclear wind. This work has appeared in Zech et al. (2008, ApJ, 679, 460).

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Highly Ionized Envelopes of High Velocity Clouds

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We present recent results on highly ionized gas in Galactic High-Velocity Clouds (HVCs), originally surveyed in O VI (Sembach et al. 2003). In a new FUSE/HST survey of Si II/III/IV (Jones, Shull, et al. 2008) toward 37 AGN, we detected Si III (1206.500 A) absorption with a sky coverage fraction 78 ± 5% (61 HVCs along 29 of 37 high-latitude sight lines). The Si III (1206.500 A) line is typically 4-5 times stronger than O VI (1031.926 A). The mean HVC column density per sight line, log N(Si III) = 13.44 ± 0.21, corresponds to a column density of perhaps 1019 cm-2 of low-metallicity (10-20% solar) ionized gas in the low halo. Recent determinations of HVC distances allow us to estimate a total reservoir of 108 M_sun. Estimates of infall velocities indicate an infall rate of perhaps 1 M_sun yr-1, comparable to the replenishment rate for star formation in the disk. HVCs appear to be sheathed by intermediate-temperature gas (104.0 - 104.5 K) detectable in Si III, Si IV, as well as in O VI and other high ions. To prepare for HST observations of 10 HVC-selected sight lines with the Cosmic Origins Spectrograph (COS), we compile FUSE/STIS spectra of these ions, plus Fe III, C III, C IV, and S IV. Better constraints on the physical properties of HVC envelopes and a careful treatment of HVC kinematics and mass infall rates will come from high-quality (S/N = 30-40) COS data.

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Spatially Resolved Far-Ultraviolet Spectroscopy of the Nuclear Region of NGC 1068

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We carry out high-resolution FUSE spectroscopy of the nuclear region of NGC 1068. The first set of spectra was obtained with a 30" square aperture that collects all emission from the narrow-line region. The data reveal a strong broad O VI component of FWHM 3500 kms^{-1} and two narrow O VI 1031/1037 components of 350 kms^{-1}. The C III 977 and N III 991 emission lines in this spectrum can be fitted with a narrow component of FWHM 1000 kms^{-1} and a broad one of 2500 kms^{-1}. Another set of seven spatially resolved spectra were made using a long slit of 1."25×20", at steps of 1" along the axis of the emission-line cone. We find that (1) Major emission lines in the FUSE wavelength range consist of a broad and a narrow component; (2) There is a gradient in the velocity field for the narrow O VI component of 200 kms^{-1} from 2" southwest of the nucleus to 4" northeast. A similar pattern is also observed with the broad O VI component, with a gradient of 3000 kms^{-1}. These are consistent with the HST/STIS findings and suggest a biconical structure in which the velocity field is mainly radial; (3) A major portion of the C III and N III line flux is produced in the compact core. and (4) The best-fitted UV continuum suggests virtually no reddening, and the He II 1085/1640 ratio suggests a consistently low extinction factor across the cone.

The Roles of the Invited Speakers and the Provocateurs

The Invited Speakers have been asked to present a discussion of their subject based on measurements made by FUSE and other ultraviolet observatories, their connection with measurements made with other techniques and, where appropriate, the implications of the low-z measurements for high-z phenomena. We are seeking to not only celebrate the accomplishments of the FUSE mission and understand the status of this field, but to look forward and understand the major scientific drivers for the ultraviolet capabilities of the next generation of space observatories.

The leadership of the Provocateurs in the discussion will enhance the progress of the conference towards these goals. We will ask knowledgeable leaders in major topic areas to lead and stimulate significant discussions during each session, addressing such questions as: Where does this field stand at this time? What progress will be made in the coming years? Looking further ahead, what capabilities will be needed in a future ultraviolet observatory to make significant progress?

Toward that end, in addition to the usual question period at the end of each talk, we have incorporated an additional 15 minute period into each session for a Provocateur-led discussion.

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