The Potential of Future X-ray Missions

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…with huge assistance from the IXO, Astro-H and GEMS teams…
The Big Questions

• How do disks transfer angular momentum to deliver gas onto compact objects?
• How do accretion disks launch winds and jets?

– From the “Fundamental Accretion and Ejection Astrophysics” Astro2010 White Paper, Miller et al.
The Big Questions

• How do disks transfer angular momentum to deliver gas onto compact objects?
• How do accretion disks launch winds and jets?
• What recommendations will the Astro2010 panel make?

– Mostly from the “Fundamental Accretion and Ejection Astrophysics” Astro2010 White Paper, Miller et al.
The Accretion Continuum

1. Protostars (CTTS)
2. White Dwarfs
3. X-ray Binaries (w/ Neutron Stars)
4. Black Hole Candidates
5. Active Galactic Nuclei
CTTS

Spectra are the Key

TW Hya
Chandra MEG
489 ksec

Brickhouse et al. 2010
CTTS

Spectra are the Key

From these lines, we can measure ionic temperatures (right) and densities (below)
CTTS

New Picture of Accretion

Accretion-Fed Stellar Wind?

Accreting Material

Accretion-Fed Coronal Loop (10 MK)

Shock
(3 MK, $6 \times 10^{12} \text{ cm}^{-3}$)

Post-shock Plasma
(2 MK, $2 \times 10^{11} \text{ cm}^{-3}$)

Veiled Photosphere

Stellar Photosphere
CTTS

TW Hya with Astro-H

Less than 1/10th the time of the Chandra observation!

Note improved Mg XI spectrum…
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Type Ia Progenitors

- “A clearer understanding SN Ia progenitors can help address the significant (±0.6 mag in V) scatter in the raw peak absolute magnitudes of SN Ia. … future use of SN Ia for precision cosmology … requires that we further reduce any systematic effects.” (Mukai et al. 2010)

- Must find Massive White Dwarf binary systems.
$W_D$s Finding Massive White Dwarfs
**WDs**

Finding Massive White Dwarfs

Hard X-ray bright non-magnetic white dwarfs may be the key – easy to find with hard X-ray surveys, and the redshift is…
**WDs**

**Finding Massive White Dwarfs**

Detectable with IXO – Measurement of 1.35 (+0.03, -0.06) Msun

*Centroid accurate to ±1 eV, or ~ 50 km/s*

*Reflected Fe Kα line*

*Thermal lines*

*IXO XMS*

*50 ksec*

*1.35 Msun WD*

*Fx = 10^{32} erg/s*

*1 kpc distant*

*Mukai et al. 2010*
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It’s Hard to be Bright

• XRB exhibit a **wide** range of luminosities
• A limitation has been the difficulty of doing both timing and spectral studies simultaneously, due to lack of instrumental range.
  – Reverberation Mapping
  – QPOs matched to iron lines
Reverberations

Power-law continuum varies first, followed by reflection thermally-reprocessed emission

Path-length difference defines *intrinsic lag*. Observed lag is the intrinsic lag diluted by the ratio of continuum to reverberating emission

Courtesy P. Uttley
Reverberations

The delayed response of the reprocessed disk line relative to the QPO variations sets the characteristic ‘size’ of the system.

Shown here is the lag vs energy for different inner disc radii for a neutron star KHz QPO observed with IXO.

Courtesy P. Uttley
Linking QPOs and lines

Measuring the Keplerian frequency and radius yields $M_{NS}$ and constrains $R_{NS}$.

$$M_{NS} = \frac{32.2}{(\nu_K/1000 \text{ Hz})} \left( \frac{R_{in}}{R_g} \right)^{-3/2} M_{\odot}$$

Power spectra

Lines resolved by the HTRS
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**BHCs**

**Accelerating Winds**

**Magnetically-driven**

Dense, clumpy winds, with significant rotation as they originate near the BH

**Radiative-driven**

Smooth less dense winds that primarily show outflow velocity.
Photoionization models require densities $10^3 x$ and distances less than $1/10^{th}$ of what radiative and thermal scenarios predict; magnetic models can fit the results, albeit not perfectly.
BHCs

BHC - GROJ1655

IXO – the game changer

![Graph showing flux vs. energy and log(N) vs. time.](image)
Polarization observations can accurately determine the spin/mass \((a/M)\) ratio for a typical Galactic BH binary. A 100 ksec XPOL observation will make energy-resolved measurements each sensitive to \(\sim 0.5\% \ (3\sigma)\), easily separating these models.
A GEMS observation of a stellar mass black hole in the thermal state can measure expected dependences on angular momentum.

Short observations (30 ksec) will be capable of detecting 1% polarization in 2-4 keV and 4-8 keV bands.

In the case of hard state black holes, GEMS will be able to test for the combined effects of spin and coronal geometry.
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Strong Gravity Seen in Disks with IXO

Emission from a *single* orbiting spot

Ensemble of all spots
High velocity outflows

3C120, $v/c = +0.076$

3C111, $v/c = +0.041$

He$\alpha$, Ly$\alpha$, Ly$\beta+$

Tombesi et al (2010)
Conclusions

• The approved missions Astro-H and GEMS will open up the high-resolution Fe K and X-ray polarization studies, respectively.

• IXO will entirely revolutionize the field
  – Sources we study today with grating spectra will have *time-resolved* grating spectra
  – Will have 3 ORDERS OF MAGNITUDE more “area x resolution” product than currently available.
AGN

Time-variable AGN

Source

SXS

CCD

Energy (keV)

250 500 750

Time (ksec)
X-ray and Planetary Disks

How do X-rays influence planet formation in protoplanetary disks?

YLW 16A: protostar in Oph

Chandra YLW 16A superflare, 1.2 days
Imanishi et al. 2001

Imanishi et al. 2001