2016-08-18 - STDT Meeting #10 (Face-to-Face #2) Day 1

Thursday, August 18, 2016 8:46 AM

Introductions:
- Welcome from Brad & Debra
- By end of calendar year, want notional idea of aperture size and instrument payload

Julie Crooke: Study Plan & Schedule
- Review of success criteria
- August F2F: focus on instruments:
    - Prioritization, definition, assign science leads (PIs)

John O'Meara: COR with LUVOIR
- Cosmology, Large Scale Structure, and Dark Matter
- Galaxies and Galaxy Evolution
    - Use coronagraph for AGN: does this require different capability than what's needed for exoplanets?
- Stars, Stellar Evolution, and the Local Universe
- Do the impossible: make 10,000-hour science programs routine
    - Incremental increase in aperture enables new science, but at the expense of time, so still not going to do them
- Need to be flexible AND powerful: adapt to future science
- Must reach out to the full community, give them the tools to think big
- Instrument themes:
    - As wide a FOV as possible
    - R=100-5000 MOS or IFU
    - R>25,000 UV point source spectrograph
    - FUV spectroscopic capability (to Lyman image)
- Also worth considering:
    - Polarimetry
    - Laser combs
    - Ultra-precise astrometry
    - Fast-timing
    - Energy-resolving detectors
- What could we do if...?
- Leonidas: how do we work on the balance between science that will drive capabilities that we want vs. be open to what could be done?
- Brad: Some capabilities will be so expensive that they will drive the design. So we need to be sensitive to this and institute ***some*** boundaries to help maintain cost (i.e. going cold vs. staying warm, etc.)

Scott Gaudi: HabEx Overview
- Two architectures:
    - 4-m monolith off-axis with SS & C
    - 6.5-m segmented off-axis with SS
- Two instruments:
    - Imager 10 sq. arcmin
    - R 30,000 spectrograph
- Notional wavelength range:
    - 250 nm to 1um
    - 90 nm to 2 um - stretch

Mark Marley: EXO with LUVOIR

- HZ Discovery: Finding our own
  - Radial Velocity (SNR > 700, R~300K, need to resolve stellar velocity field)
    - What bandpass, time requirement, RV reference?
    - Provides mass with direct imaging
  - Astrometry (8x8 arcmin imaging, 10^-6 pixel calibration floor, onboard metrology)
    - What is total observing time, need to validate assumptions
    - Provides mass
  - Blind Imaging Survey (10^-10 raw contrast - C. Stark assumptions)
    - Does not provide mass by itself
- HZ Characterization
  - Transiting beyond JWST (200-1800 nm)
  - Coronagraph spectroscopy
    - Optical R > 70; 100 or 200 is preferable
    - 200 nm to 1.8 um will allow measurement of greenhouse gases
    - FUV CO_2 detection may be an option (need UV coronagraph?)
    - Another CO_2 band at 4.5 um
    - 0.94 um band needs to be good detection: high SNR
    - Need overall SNRs of 15-20
  - Second order characterization
    - Light curves (annual, daily)
    - Glint
    - Polarization
- Other Science Cases:
  - Warm jupiters
    - Motivation to go as blue as possible (<400 nm)
  - Lots of science cases for non-habitable planets from ExoPAG SAG15 (final report Dec. 2016)
  - Stellar UV characterization
- ⭐ Summary:
  - R~200,000 spectrograph
  - Coronagraph(s): 100 nm to [1.8 um, 2.3 um, 5 um]
  - Need more specific search capabilities, search method comparisons and optimization, transit science requirements (cadence, data storage, etc.)
- Olivier: ambiguity of UV drop-off. Vikki: going into the UV is going to be very difficult; choice between UV and NIR, choose NIR every time
- Walt: Target identification...by having to find targets and then characterize them ends up requiring a significant portion of the mission. What are prospects of doing search elsewhere? Aki: blind search with LUVOIR is actually likely the most efficient way

Walt Harris: SS with LUVOIR

- The Magnificent 7:
  a. Icy Frontiers (TNOs, Centaurs, Dwarf Planets)
  b. Asteroids (NEOs to Trojans)
  c. Comets
  d. Sun-Planet Connection
  e. Surfaces (Terrestrial planets to icy satellites)
  f. Atmospheric Structure
  g. Solar Companions (Planet 9)
- (a) & (b): surface spectroscopy, size distributions, ring systems, etc.
- Technical Drivers:
  - ⭐ Solar exclusion angle: want 45-47 degrees for Venus, 28 degrees for Mercury
  - ⭐ Moving target tracking: 100x faster than 1 arcsec/24 secondss
  - Large dynamic range in target brightness

    - Rapid temporal measurements
    - Ultra-wide field imaging, not necessarily diffraction-limited (nice to have)
    - Heterodyning (nice to have)
    - Spectro-polarimetry (nice to have, could possibly use coronagraph, take as far into UV as possible)

Aki: Summary of Desired LUVOIR Observation Capabilities
- Science matrix (on Google Drive)
- Candidate instruments:
    - UV imager & spectrograph
        - High-resolution
        - MOS spectroscopy
    - Optical / NIR high contrast instrument
        - Imaging
        - Low resolution, spatially resolved spectroscopy
    - Wide-field optical / NIR imager
    - Multi-resolution optical / NIR spectrograph
        - High R for RV / template matching
        - Med R for transit spectroscopy, solar system
- Brad: What science do we lose if we're warm? Aki: all of this science assumes we're warm.

Cirasuolo: E-ELT:
- MAORY: multi-conjugate AO system; 6 Laser Guide Stars, 3 Natural Guide Stars
    - 2 DMs conjugated to 4 km and 27 km

Skidmore: TMT:
- Issue with building in Hawaii; looking to finalize the site

McCarthy: GMT:

2016-08-18 - STDT Meeting #10 (Face-to-Face #2) Day 2

Friday, August 19, 2016 8:19 AM

Group Discussion to Create 1st Draft of High-Level Instrument List

- UV Imager & Spectrograph
    - High-resolution point spectroscopy (R=1000-200,000)
    - MOS spectroscopy (look into IFU)
    - Imaging (1 arcmin FOV min.)
    - Key Science:
        - Characterization of host star
        - Lyman Continuum luminosity function over 11 Gyrs
        - Imaging the circumgalactic medium
        - Exoplanet formation
        - High-energy physics in SS
        - Intergalactic medium in absorption
        - Dust everywhere
        - Characterizing sources of re-ionization
- Optical / NIR Coronagraph
    - Imaging w/polarimetry
    - Low-resolution, spatially resolve spectroscopy (R~200)
    - As big a bandpass as we can
    - Key Science:
        - Biosignatures for exoEarths around sunlike stars
        - Habitable exoplanet discovery and characterization
        - AGN & their hosts
        - Exoplanetology
        - Terrestrial & giant planet formation
        - Exoplanet evolution
        - Substellar objects
        - Exomoons / rings
        - Biosignatures for exoEarths around some low-mass stars (check this)
        - Extreme mass-ratio binaries
- Wide-field Optical / NIR Imager
    - Sub-microarcsec astrometry
    - Colors, maybe grism
    - 4-6 arcmin FOV
    - What exact bandpass? How blue?
    - Key Science:
        - Transcendent deep fields (aka galaxy evolution)
        - KBO discovery
        - Exoplanet masses
        - Dark matter
        - Comet atmospheres
        - Lensing
        - Gravity wave source localization (look into this one)
        - Galactic structure
        - Characterizing sources of reionization
        - NEOs
        - Stellar populations / IMF
        - Fast solar system targets
        - Supernovae and SN progenitors
        - Low surface brightness diffuse streams (needs great flat fielding)

- Multi-resolution optical / NIR spectrograph
    - R~100,000 for template matching, solar system
    - R~2000 for transit spectroscopy, solar system
    - High-precision ~1cm/s RV capability R > 100,000 (needs study)
    - Point detector (consider IFU for med. R; needs to be an additional mode)
    - Broad-wavelength coverage in a single shot, as red as we can go
    - Key Science:
        - Exoplanet transit spectroscopy
        - Low metallicity stars
        - Planet masses
        - Planet formation chemistry
        - Biosignatures at low and high resolution w/ template matching
        - High-redshift galaxies
        - Deep molecular probes
        - Kinematics, winds, dynamics of planetary atmospheres
        - Dynamics of giant exoplanets
        - Characterization stars in the local group
- Optical / NIR Multi-object Spectrograph
    - Does it hold up against ELTs?
    - 2-6 arcmin FOV
    - Key Science:
        - Characterizing star clusters everywhere
        - Stellar populations
        - Star formation in galaxy at 100 parsec scales
        - Galactic outflows and feedback
        - Emergence of large-scale structure
        - Extra-galactic supernovae & planetary nebula
        - Fine structure constant
        - IMF
        - Fundamental constants
- Second generation instruments
    - Follow-on starshade
        - Have an eye to keeping the facility "starshade ready"
        - Key science:
            - Really good NUV/NIR high contrast exoplanet spectroscopy
    - Upgraded coronagraph instrument / spectrograph
    - Black-box that gets planet masses one way or another, if necessary
    - Kilohertz-speed UV / optical photometer
        - What is it for? Astroseismology
        - David Redding & Marc Postman to write the science cases for this capability
    - Super-high resolution NIR spectrograph
        - Heterodyne?
        - Like R > 1,000,000
    - Super-resolution imager
        - Interfering fibers / non-redundant masks, etc.
        - Imaging the surfaces of stars, AGNs, etc.

Voting / Outstanding questions about instrument details / Instrument Leads:

- 32 votes: Optical / NIR Coronagraph
    - What bandpass? (Simultaneous vs. total)
    - Spectral resolution?
    - IWA, OWA?
    - Contrast floor & contrast

    - Define polarization capabilities
- 28 votes: UV Imager & Spectrograph
    - FOV for imager
    - Exact bandpass for imager and spectrograph
    - Exact simultaneous bandpasses
    - Spectral resolution range, how many Rs? 3?
    - Define multi-object capability. How many at once, FOV? Something about angular resolution?
    - Look at adding IFS
- 27 votes: Wide-field Optical / NIR Imager
    - Exact FOV
    - What exact total bandpass? How blue?
    - Exact simultaneous bandpasses (filters)
    - Diffraction-limited at 0.5 micron?
    - Scheme for astrometry calibration
- 15 votes: Multi-resolution optical / NIR spectrograph
    - Broad wavelength coverage in single observation, as red as we can go
    - Exact resolutions
    - Scheme for high-precision RV measurement;
    - Shall we have an IFS? Can we do better than the ground?
    - How compelling and feasible is the RV case? Better done in second-generation case?
    - More detailed science case for template matching. Feasibility? Need coronagraph?
- 3 votes: Optical / NIR Multi-object Spectrograph

More questions:
- Flag observation concepts that drive telescope operations (e.g. time-resolved observations)
- Prepare for architecture decisions in November
    - Driving science cases
    - Feasibility considerations
    - Other things?

Tumlinson: Simulations
- Sensitivity simulation
- Observation simulation
- Catalog simulation
- Yield simulation
- Want to integrate engineering knowledge: actual instrument curves
- Instrument teams basic instrument parameters for inputs to simulation

Wrap up & Homework:

Live Notes for F2F LUVOIR Meeting August 18, 2016
COR Breakout Discussion

Trades:

900 vs 1000 vs 1100 Angstroms

UV coatings must be elevated. Can we baseline Mag Fluoride (1015 Angstroms)

Use MgFl (on HST now) 1150 Angstroms. Can still work down a little lower

Lithium Fluoride gets you down to 1000 Angstroms. Degrades very quickly. A lot of work thin film AILD overcoat to protect it to help make LiFl workable

Aluminum degrades very very quickly
Aluminum trifluoride is the underlayer (Kevin France)

912 Angstroms is a stretch goal

One spectrograph with multiple gratings on a single grating wheel

Dynamic Range – what do we do about it?

Micro-channel plates have limited dynamic range and plate sag

MOS vs IFU: Considering throughput: A MOS is a piece of metal with holes in it. IFUs have much smaller throughput

Need to nail down what wavelengths we're talking about
Micro-mirror arrays then could be attractive

To get real IFU

Need to look at individual science cases that best match which instrument capabilities.

Broadband imaging in the optical
5 milli-arcsecond pixels

wavelength range: shortest (1000-1100 (with stretch goal of 912 Angstroms) to longer UV wavelength into U-Band at atmospheric limit (continuous coverage between 1000 Angstroms to 1 micron).

No case for COR past 1.8 microns. Want to stay a warm telescope
Polarimetry: UV polarimetry. Coatings an issue for polarimetry? No, not really.

Synthesis:

Broad capabilities and drivers

- Focused on what are extremes, FOV, spectroscopic resolution, wavelength range
- UC spectroscopy is key for broad range of science cases
- Wavelength range our interest is – practical terms down to Lyman limit, but minimum 1000 Angstroms and 912 Angstroms as a stretch goal
- High wavelength range – atmospheric cutoff U-Band (above 300 nm)
- Continuous coverage, efficiency and throughput
- Multiplexing – tension of going for MOS compared to IF spectroscopy Conclusion: there are certain science cases where are smaller FOV are preferred. The MOS wins out. How big does the IFS have to be (unchartered territory). So, leaning toward MOS. Need to do a deeper science trade-off here. The science case were IFS for NearUV whereas MOS was FarUV
- Question of spectroscopic resolution capabilities. Can we synthesize those desires into one instrument that has different modes. Drew a cartoon.
- Paired with that what do spectroscopic resolutions need to be? science drivers. R of 100,000 is target.. That's the maximum you need for COR science. 1000-3000 Angstroms
- UV Imaging capability: range of science drivers for that: connect to mapping ionizing photons and that environment.
- Pushes to 1 arc minute FOV; Diffraction limited imaging at 500 nm; similar decay and performance as HST

Also driver for spectro-polarimetric capability. What is required FOV for this? There are similar FOV needs. Need to discuss requirements more. Mapping of interstellar dust sounds interesting.

Moving to Optical:

- What would be unique vs ground: Sensitivity as long as we capture a sufficient FOV to complement observing efficiency. Strong arguments for going for a large FOV like 5 arc minutes.
- This would be equivalent to an LSST FOV. The PSF sampling we want to have. Need to study more.
- Much smaller FOV we encroach on ground based future large telescopes.
- 4x4 arc minute FOV is target
- 6x6 arac minute FOV is stretch goal
- Lee Feinberg wants to have a minimum of 4x4 arc minute FOV and a stretch FOV to 6x6 arc minutes and dither
- 4 minus 1 plus 2 (range). With bigger is better.

Optical Spectroscopy
Exoplanets:

How to get masses: Precursor mission? (Don't want this)
2 ways: RV on a spectrometer or wide field on a spectrometer?

- Spectrometer –s that one instrument with R of 1000 to 100,000? Or is this two different instruments
- Coronagraph (350 nm, R of 200) and ? contrast, iWA? Etc.
- UV transit spectroscopy. R of 100,000 (want to see the molecules in the outflow)
- UV spectro of stars for photochemical modeling of the stars
- Near-IR spectrograph 10 to the fifth and maybe RV

Day 2:

Instrument Prioritization

1. Optical/NIR Coronagraph (32 Votes)
2. UV Imager and Spectrograph (28 Votes)
3. Wide-Field Optical-NIR Imager (27 Votes)
4. Multi-resolution Optical/NIR spectrograph (15 Votes)
5. Multi-object Optical/NIR spectrograph (3 Votes)

Questions for Coronagraph:
- Exact total bandpass
    - Distinguish simultaneous band pass vs total band pass
- Spectral resolution
- Inner (IWA)and outer working angles (OWA)
- Contrast floor and contrast
- Band pass is a capability and throughput is a requirement
- Define polarization capabilities
- End to end system polarization budget
- Polarization specification for telescope focal plane

Questions for UV Imager and Spectrograph
- FOV for UV Imager
    - Greater than an arc minute
- Exact Bandpass (separate for Imager and Spectrograph)
- Exact simultaneous bandpass
- FOV Range (> 1 arc minute)
- Resolution and how many (2000-100,000 with N gratings (3 modes?)
    - Spectral resolution range, how many values of R? 3?
- Define multi object capability. How many at once, FOV? Spatial (and/or angular) resolution of telescope -> spacing of sources
- As much wavelength range you can get at a time with a good number of sources
- Need a FOV of MOS (> 1 arc minute) real estate will matter
- Look at adding an IFS
- Angular resolution for imaging spectroscopy (diffraction limited by 1000 angstroms, but (50 milli arc seconds should be the target (Kevin France) for MOS (sizes and spacing of the windows (PSF) how close can I separate two objects?

Questions for Wide-Field Optical-NIR Imager:
- Exact FOV
- Define simultaneous color bands (filters) you want and how many
    - What exact bandpasses? How blue?
- Diffraction limited at .5 microns?
- Scheme for astrometry calibration (sub micro-arcsecond) Mix of stability requirements and calibration tools

Questions for Optical-NIR Spectrograph
- Broad wavelength coverage in single observation, as red as we can go
- Exact spectral resolutions?
- Shall we have an IFU/IFS? How hard is it and can we be better than the ground?
- Consider micro-shutter array
- How compelling and feasible is the RV case and sketching it out
    - Scheme for high precision RV calibration
    - How compelling is the RV case?
    - Better considered as a second generation instrument?
    - Go as red as we can go without costing a lot
    - More detailed science case for template matching
    - Feasibility?
      Need coronagraph?

More Questions:
- Flag observation concepts that drive telescope operations requirements (e.g. time resolved observations)
- Prepare for aperture/architecture decisions in November
    - Driving science cases
    - Feasibility considerations
    - Other things?

Jason Tumlinson:
Wall Clock Time
HST and JWST 3000-5000 observing times per year and all missions this is true
Time of measurement matters a lot.
- Sensitivity simulation
- Observation simulation
- Catalog simulation
- Yield simulation
- Want to integrate engineering knowledge: actual instrument curves
- Instrument teams basic instrument parameters for inputs to simulation

Wrap up & Homework: