The Potential of Future X-ray Missions

Gravity and Extreme Magnetism SMEX

Randall Smith
Smithsonian Astrophysical Observatory

…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?

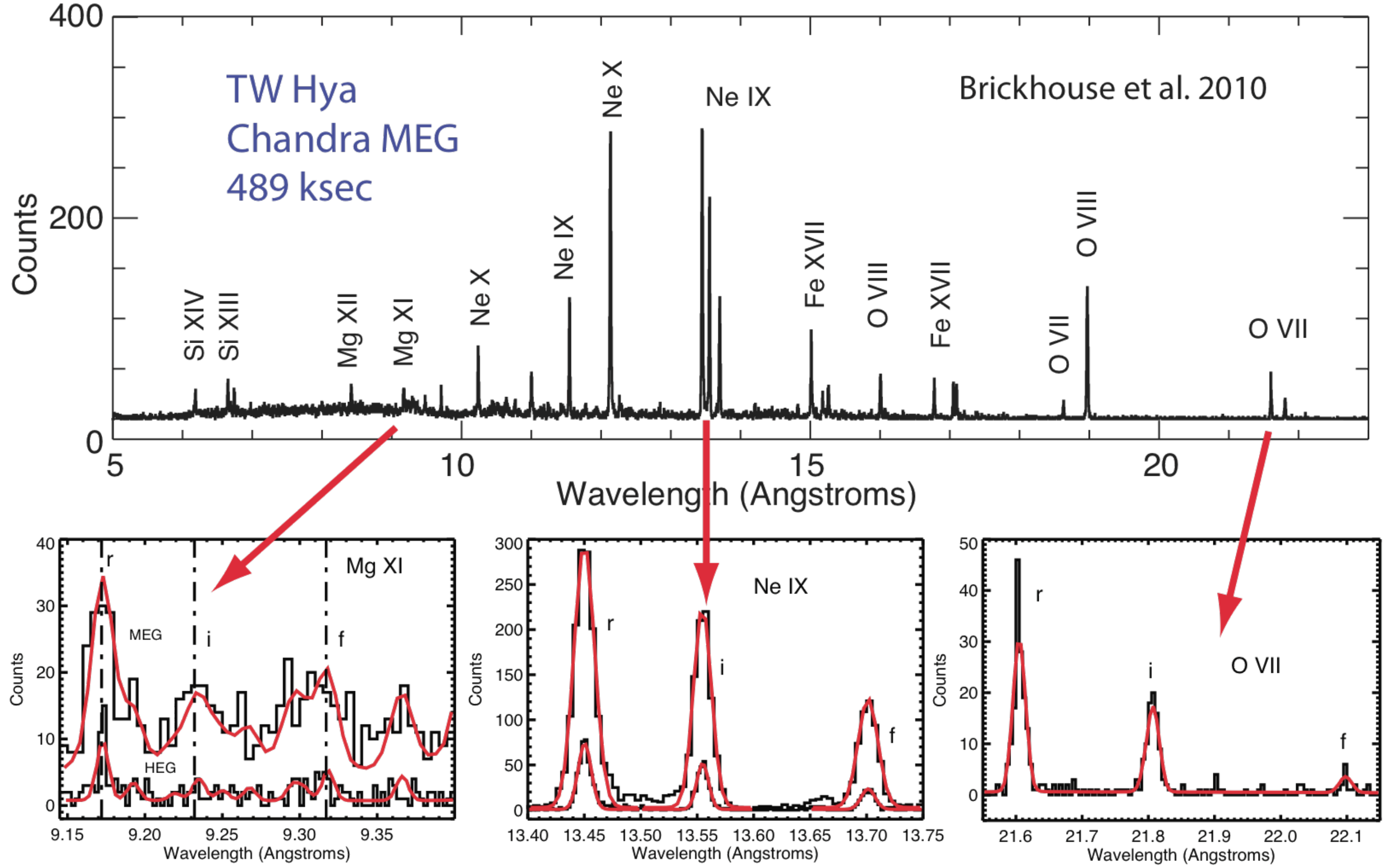
– Mostly from the "Fundamental Accretion and Ejection Astrophysics" Astro2010 White Paper, Miller et al.

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

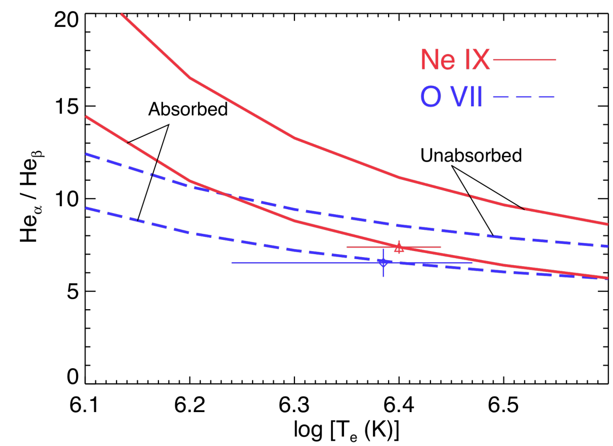
Spectra are the Key

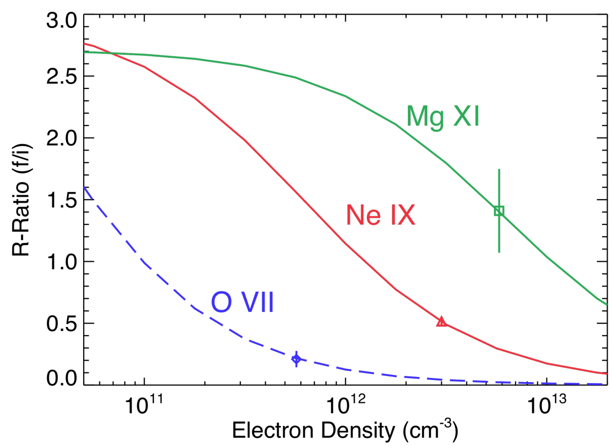


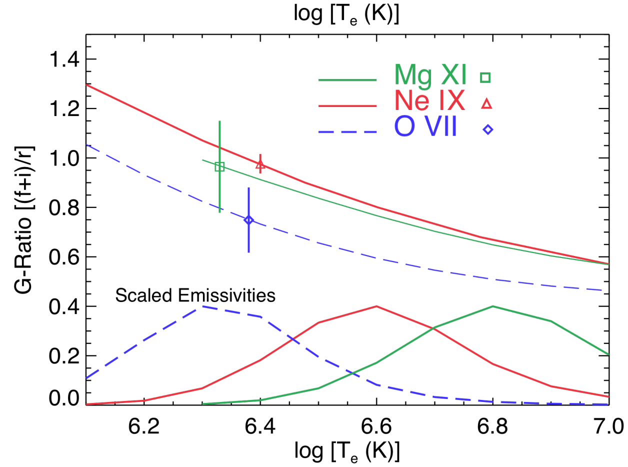
CTTS

Spectra are the Key

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



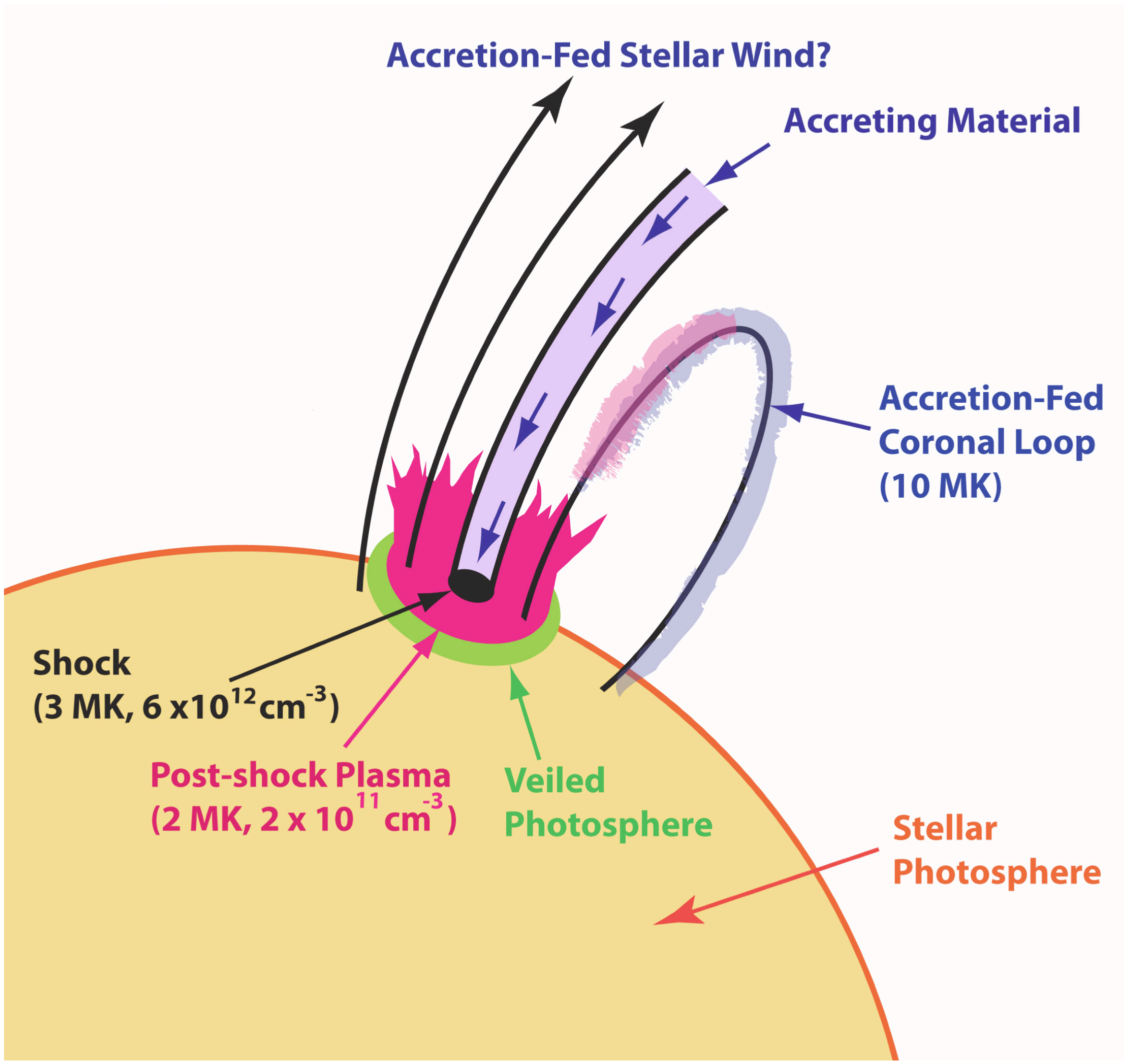




Brickhouse et al. 2010

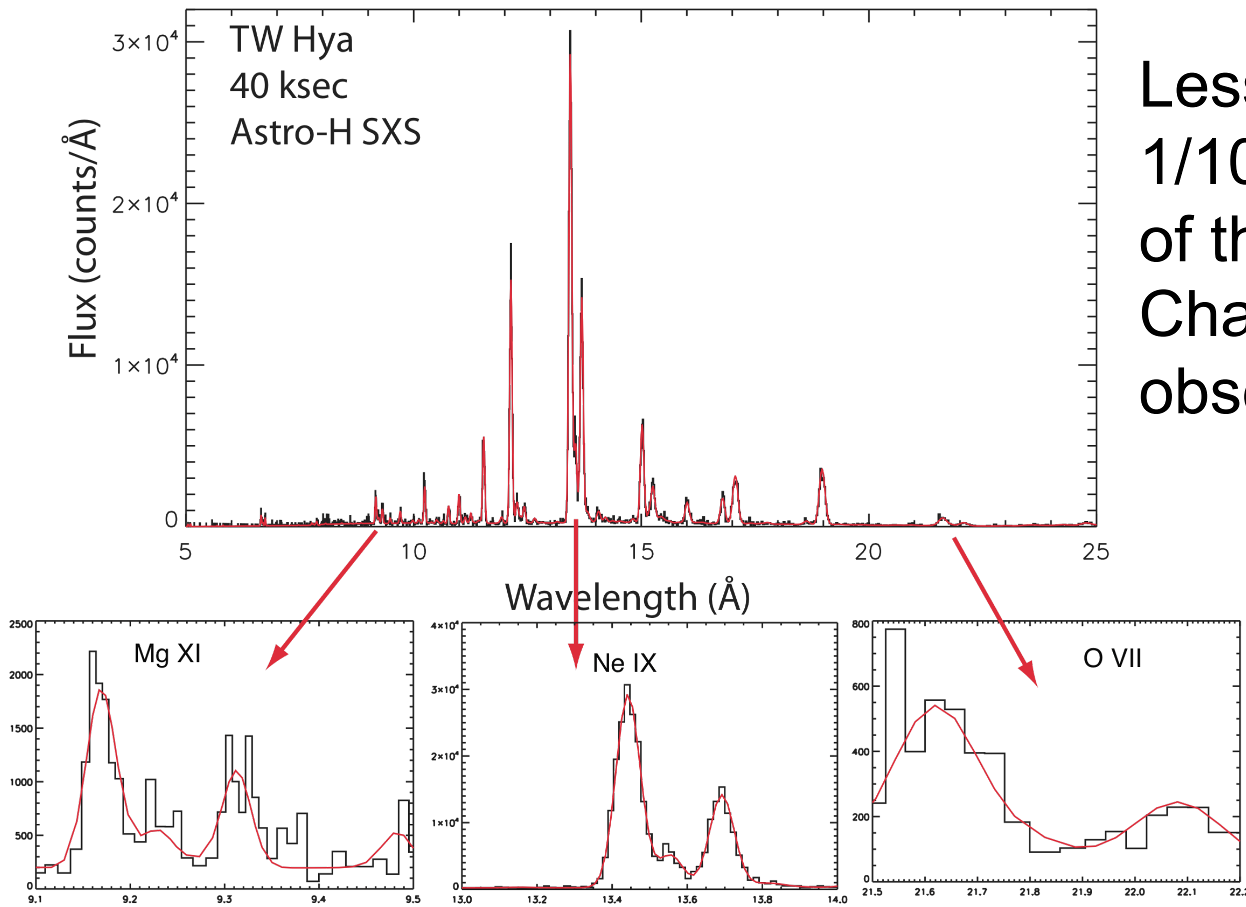
CTTS

New Picture of Accretion



CTTS

TW Hya with Astro-H



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

Note improved Mg XI spectrum…

The Accretion Continuum

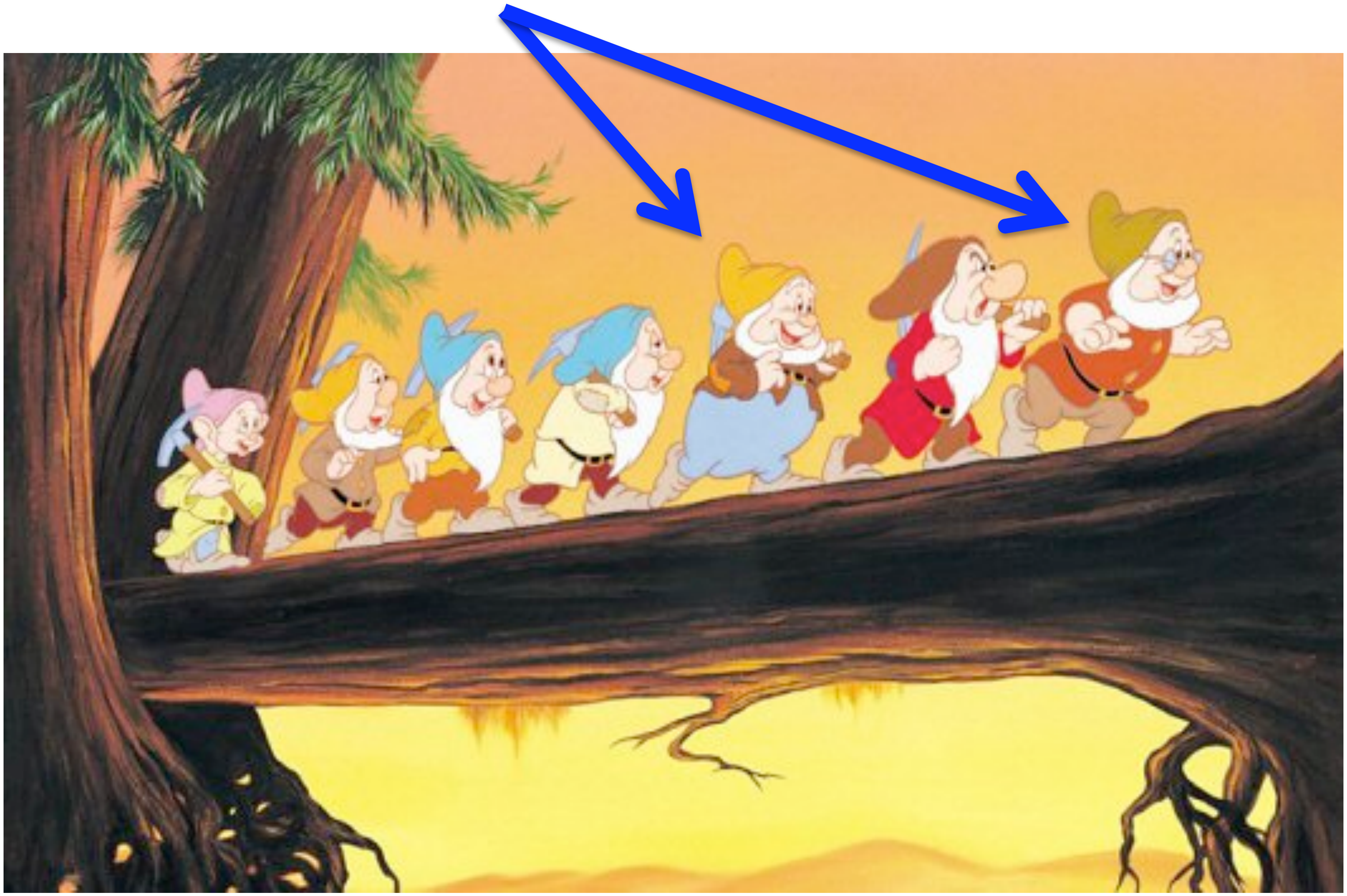
1. Protostars (CTTS)
2. White Dwarfs
3. X-ray Binaries (w/ Neutron Stars)
4. Black Hole Candidates
5. Active Galactic Nuclei

WDs

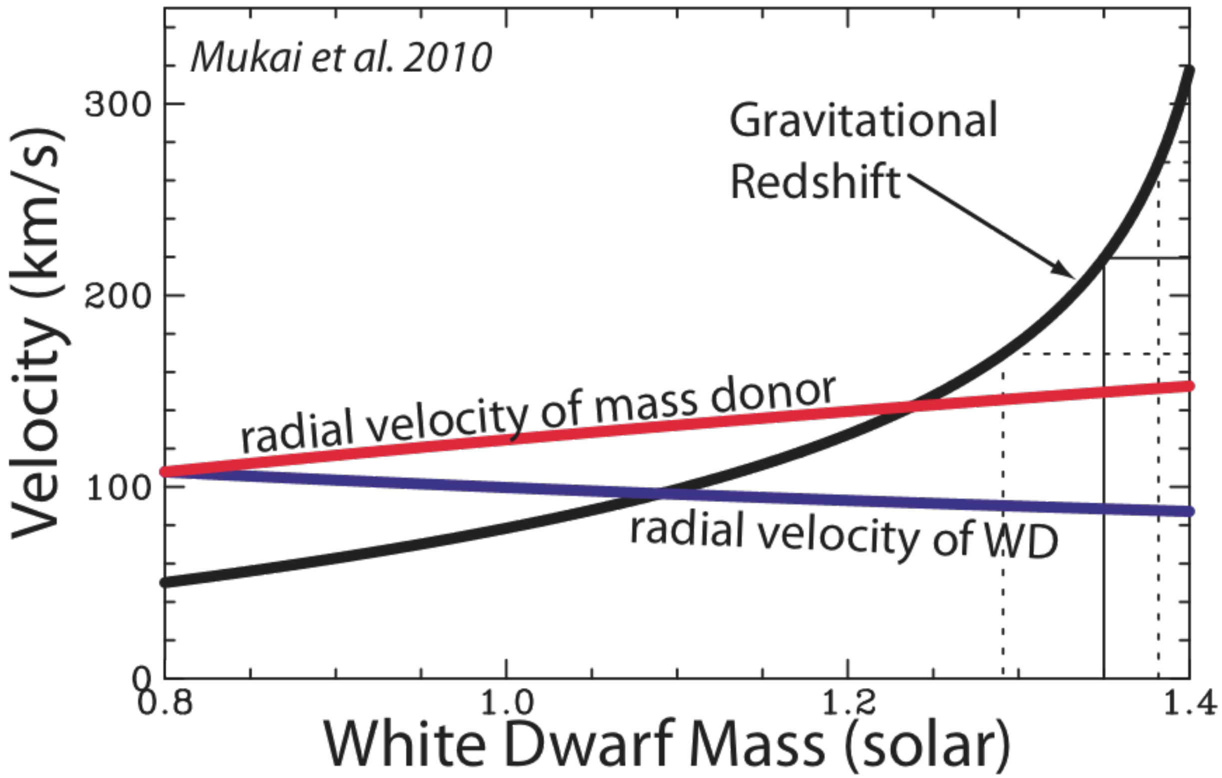
Type Ia Progenitors

- "*A clearer understanding SNIa progenitors can help address the significant (±0.6 mag in V) scatter in the raw peak absolute magnitudes of SNIa. …future use of SNIa for precision cosmology…requires that we further reduce any systematic effects.*" (Mukai et al. 2010)
- **Must find Massive White Dwarf binary systems.**

WDs Finding Massive White Dwarfs



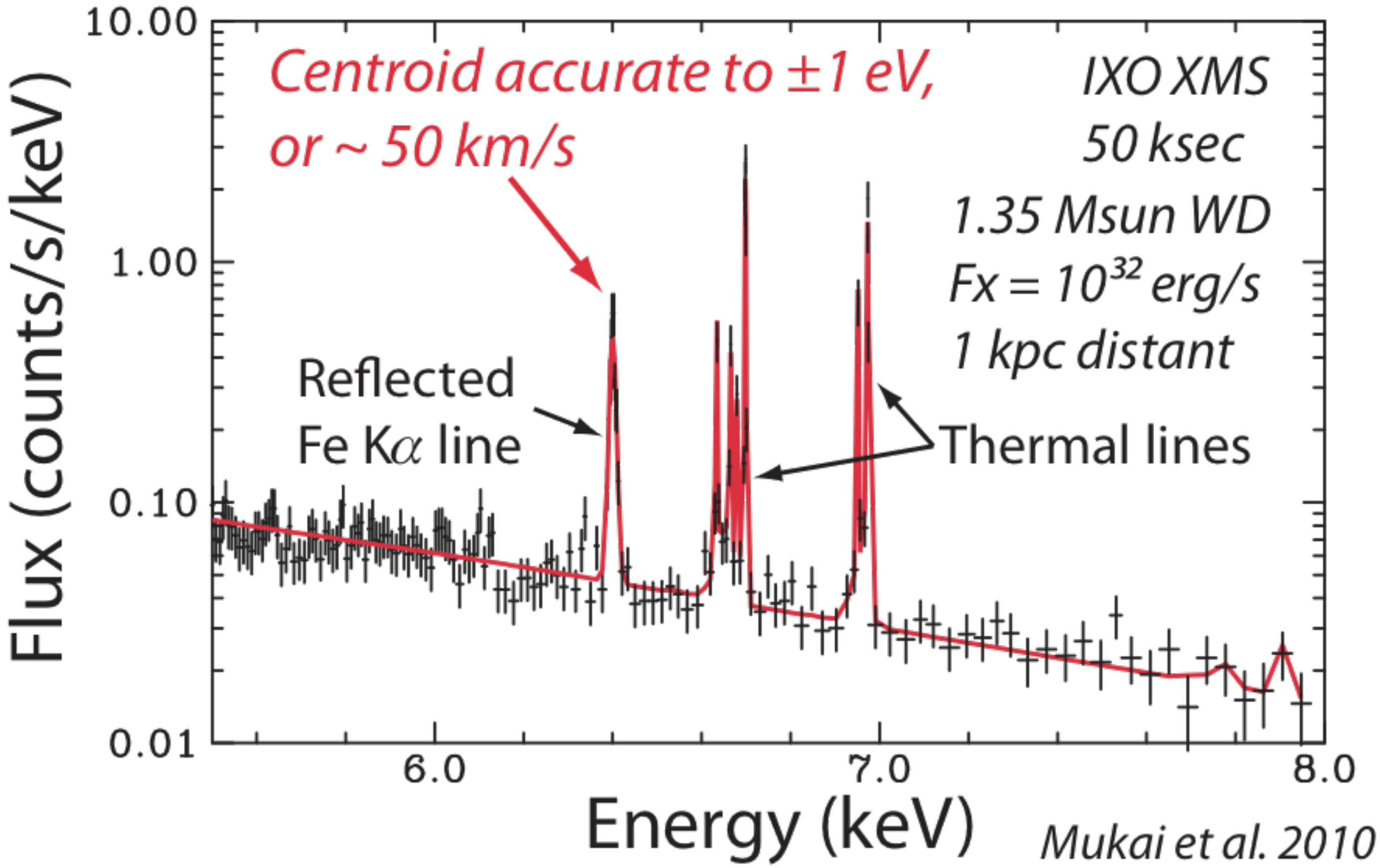
WDs
Finding Massive White Dwarfs



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

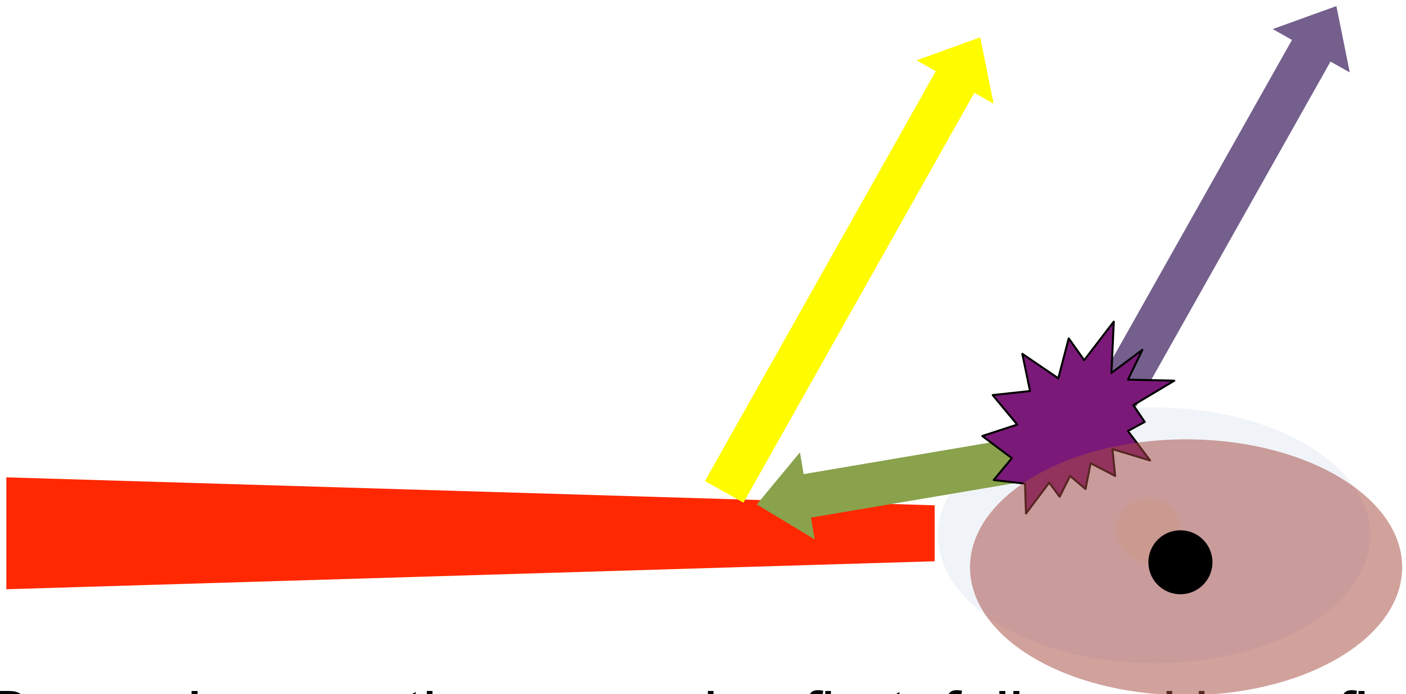
The Accretion Continuum

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

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

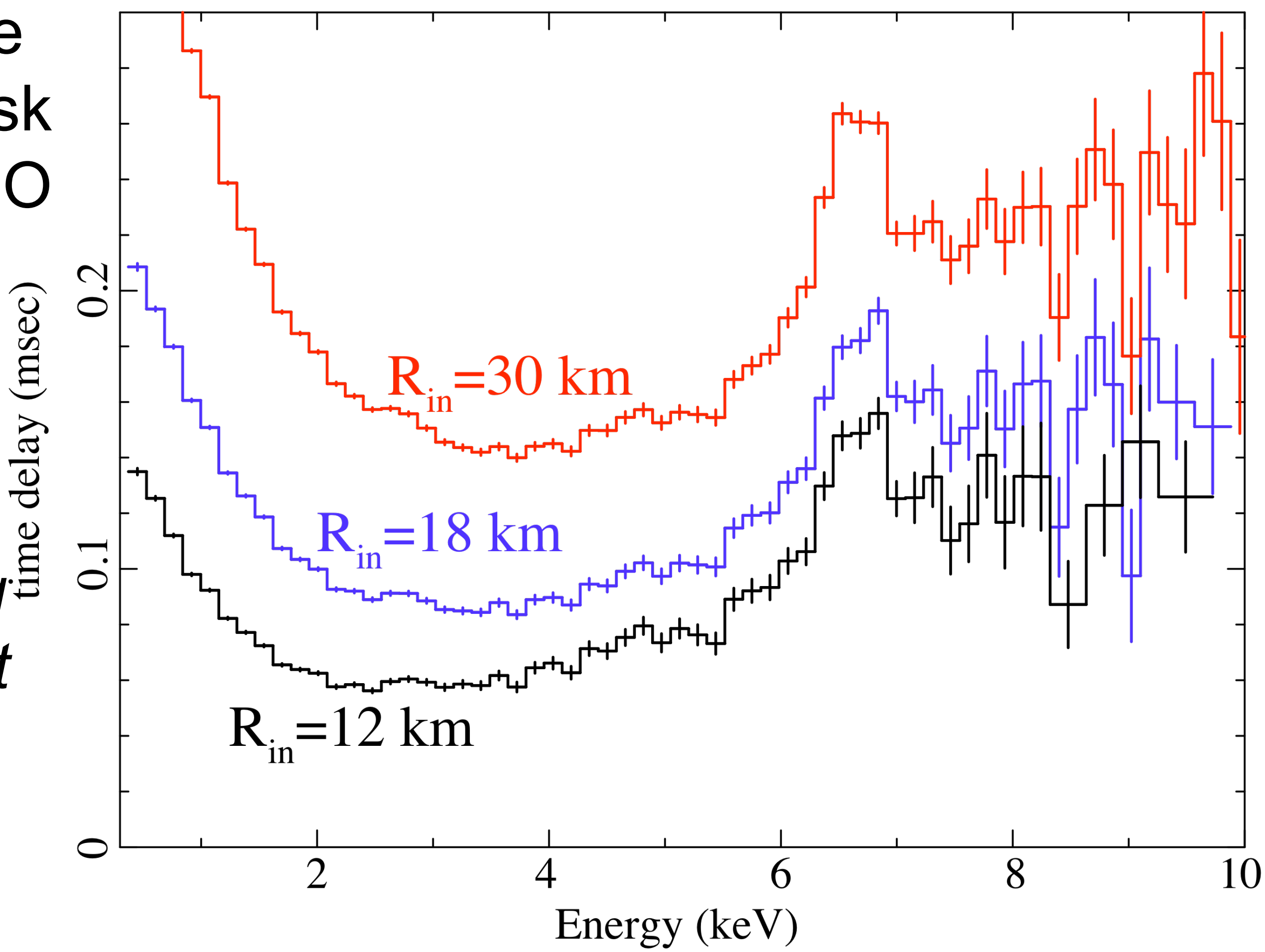
Path-length difference defines *intrinsic lag.* Observed lag is the intrinsic lag diluted by the ratio of continuum to reverberating emission

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.

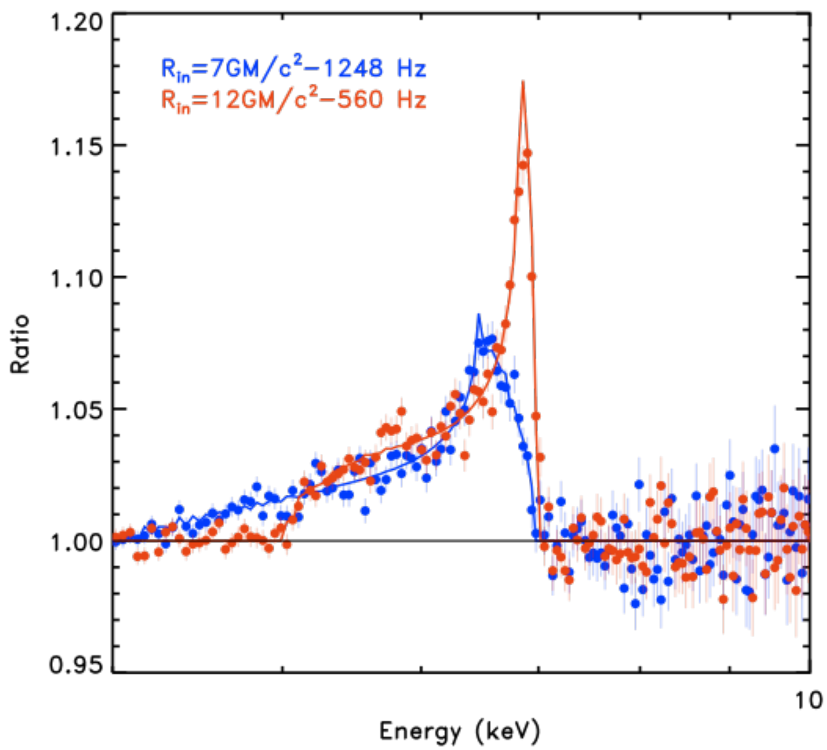


Courtesy P. Uttley

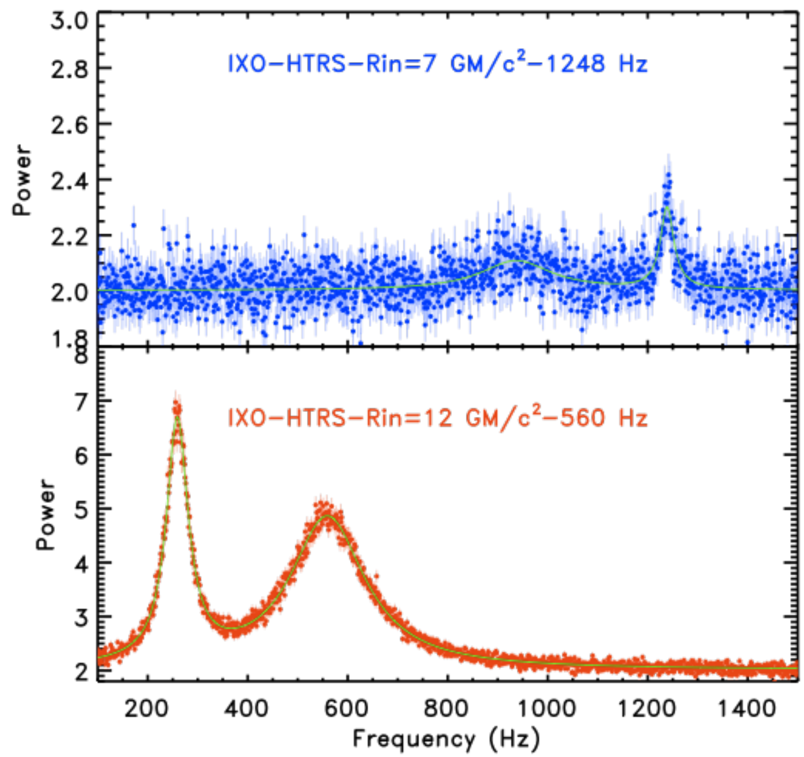
Linking QPOs and lines

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

Lines resolved by the HTRS



Power spectra



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

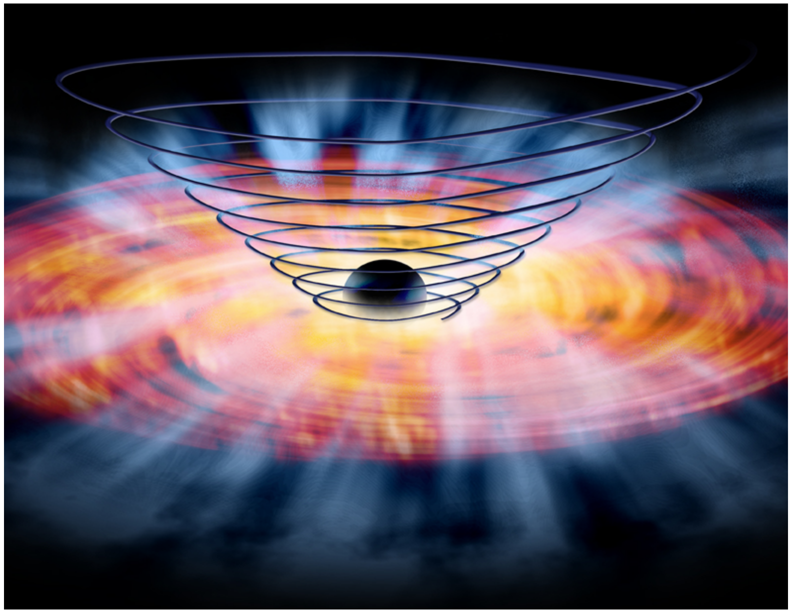
The Accretion Continuum

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

BHCs

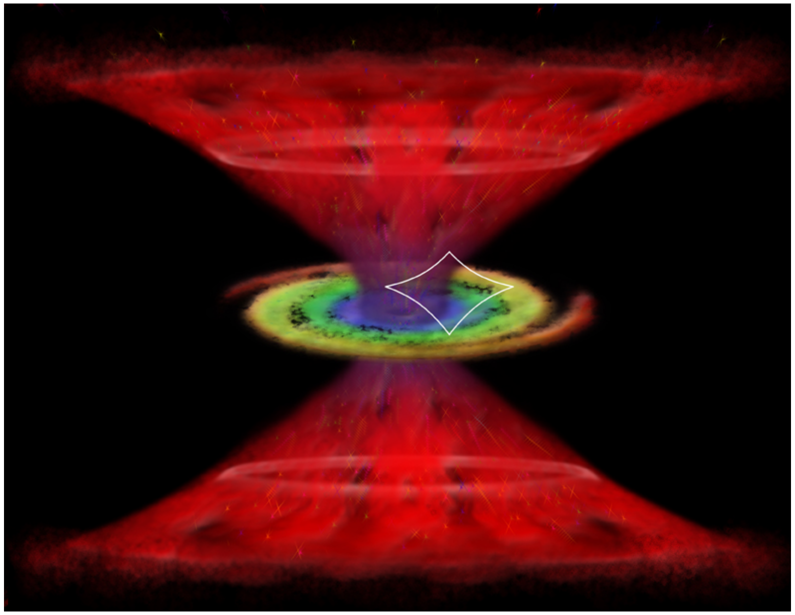
Accelerating Winds

Magnetically-driven



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

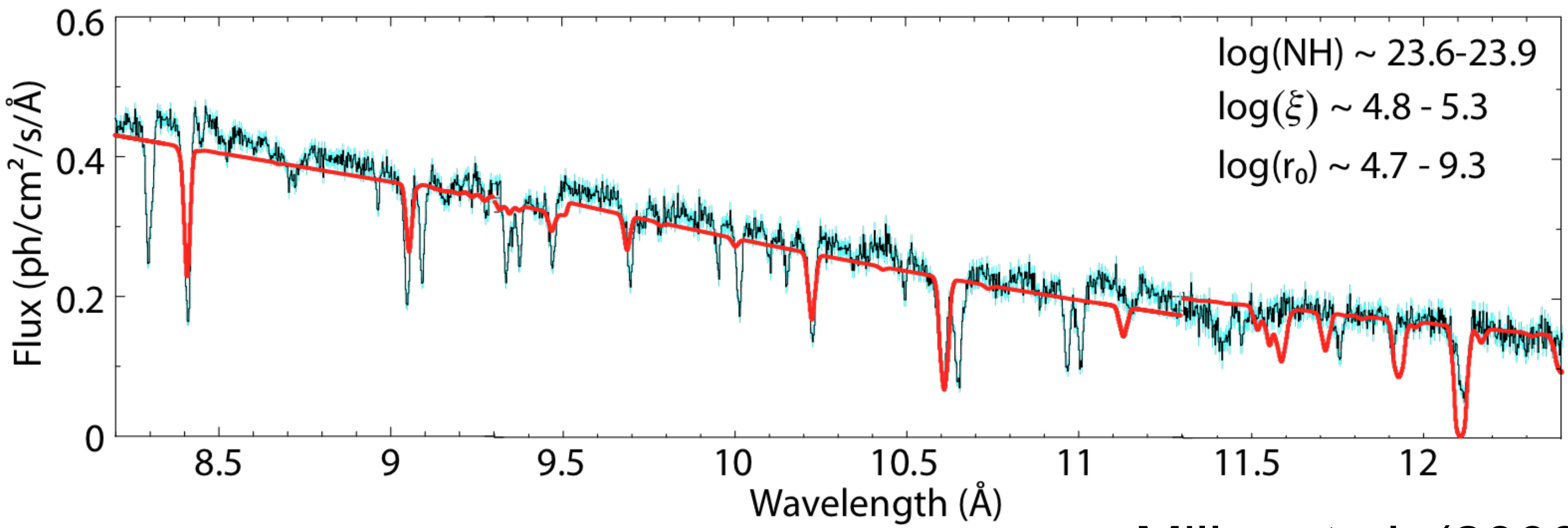
Radiative-driven



Smooth less dense winds that primarily show outflow velocity.

BHCs

GRO J1655-40



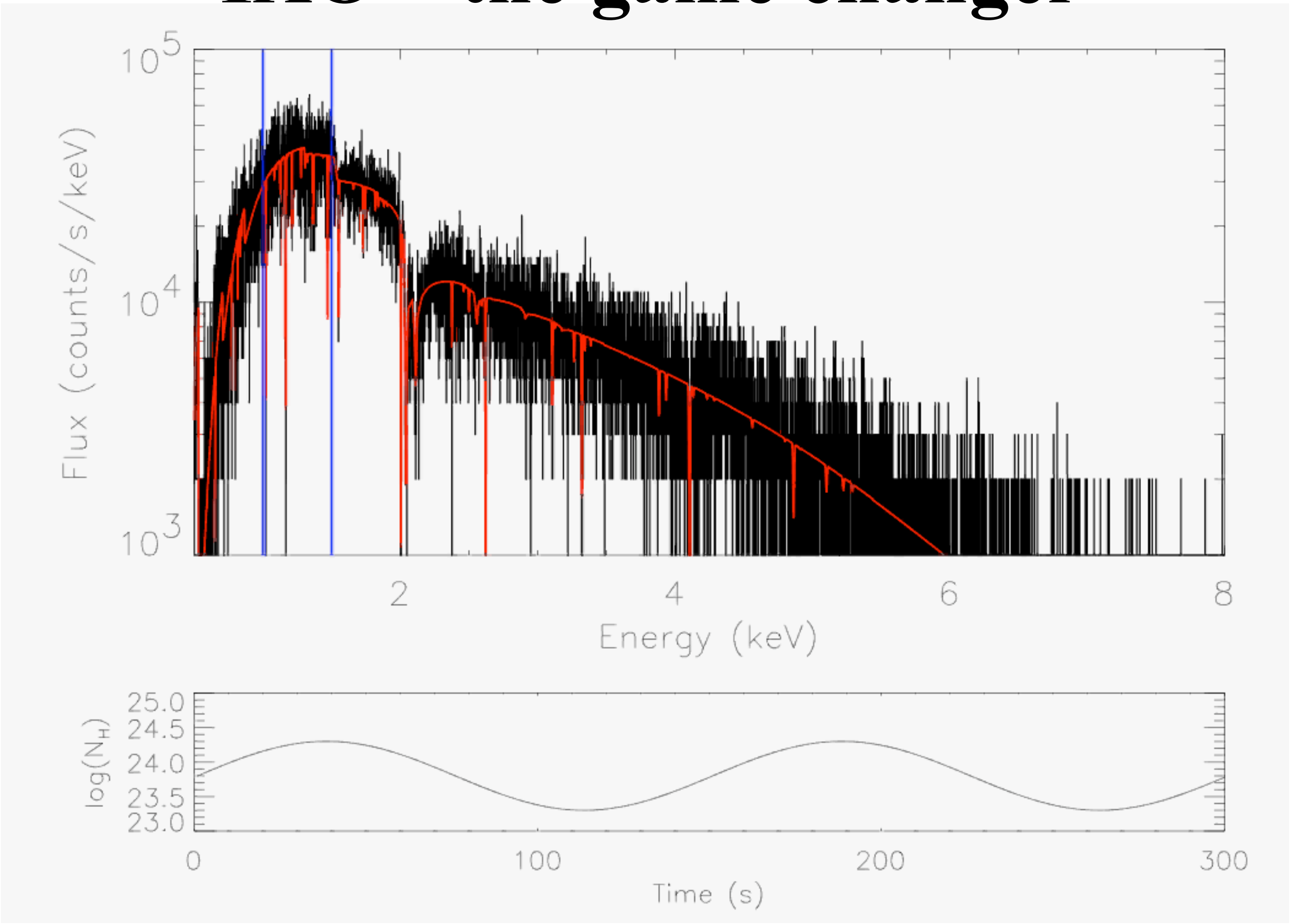
Miller et al. (2008)

Photoionization models require densities 10^3x and distances less than 1/10th of what radiative and thermal scenarios predict; magnetic models can fit the results, albeit not perfectly.

BHCs

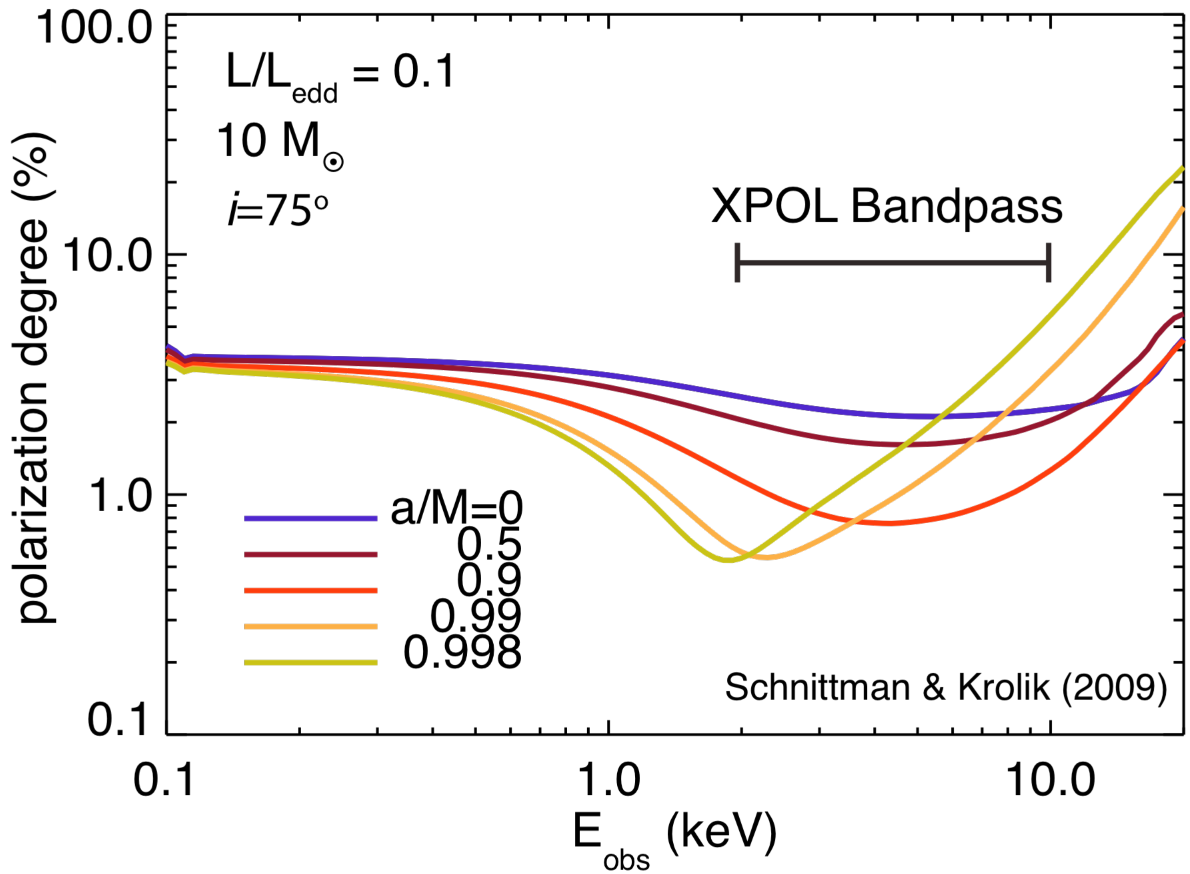
BHC - GROJ1655

IXO – the game changer



BHCs

Polarization



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 ~0.5% (3σ), easily separating these models.

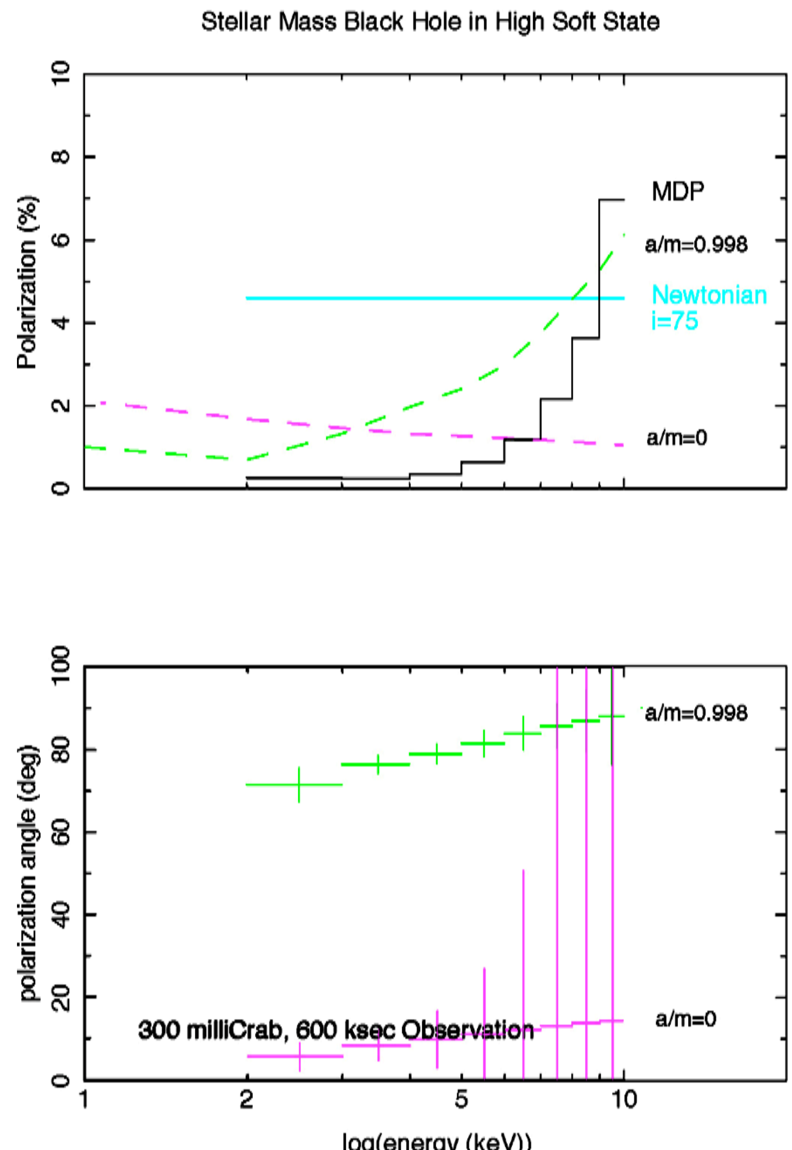
GEMS
Gravity and Extreme Magnetism SMEX

GEMS observations constrain black hole spin

- 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

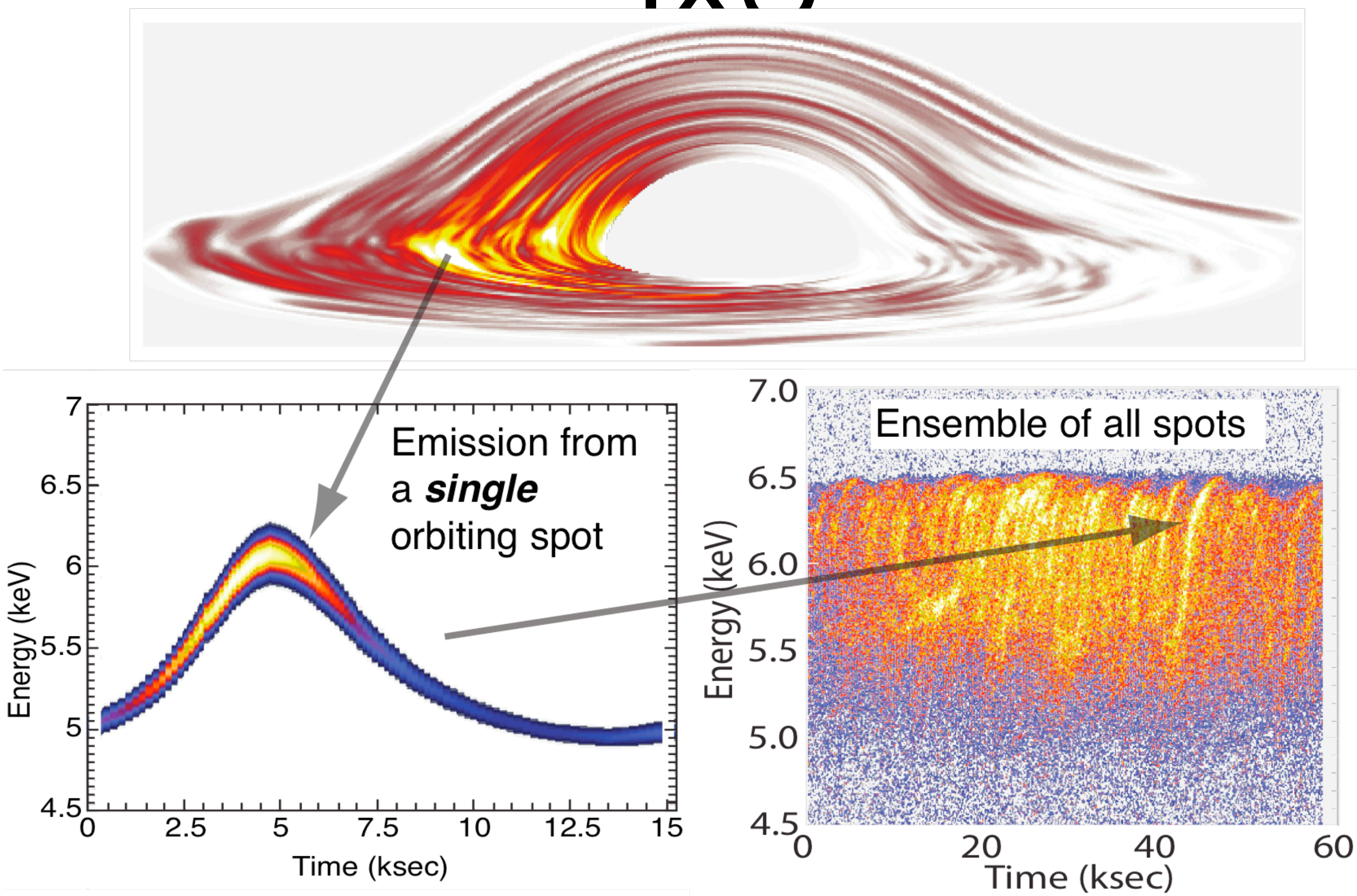
- In the case of hard state black holes, GEMS will be able to test for the combined effects of spin and coronal geometry



The Accretion Continuum

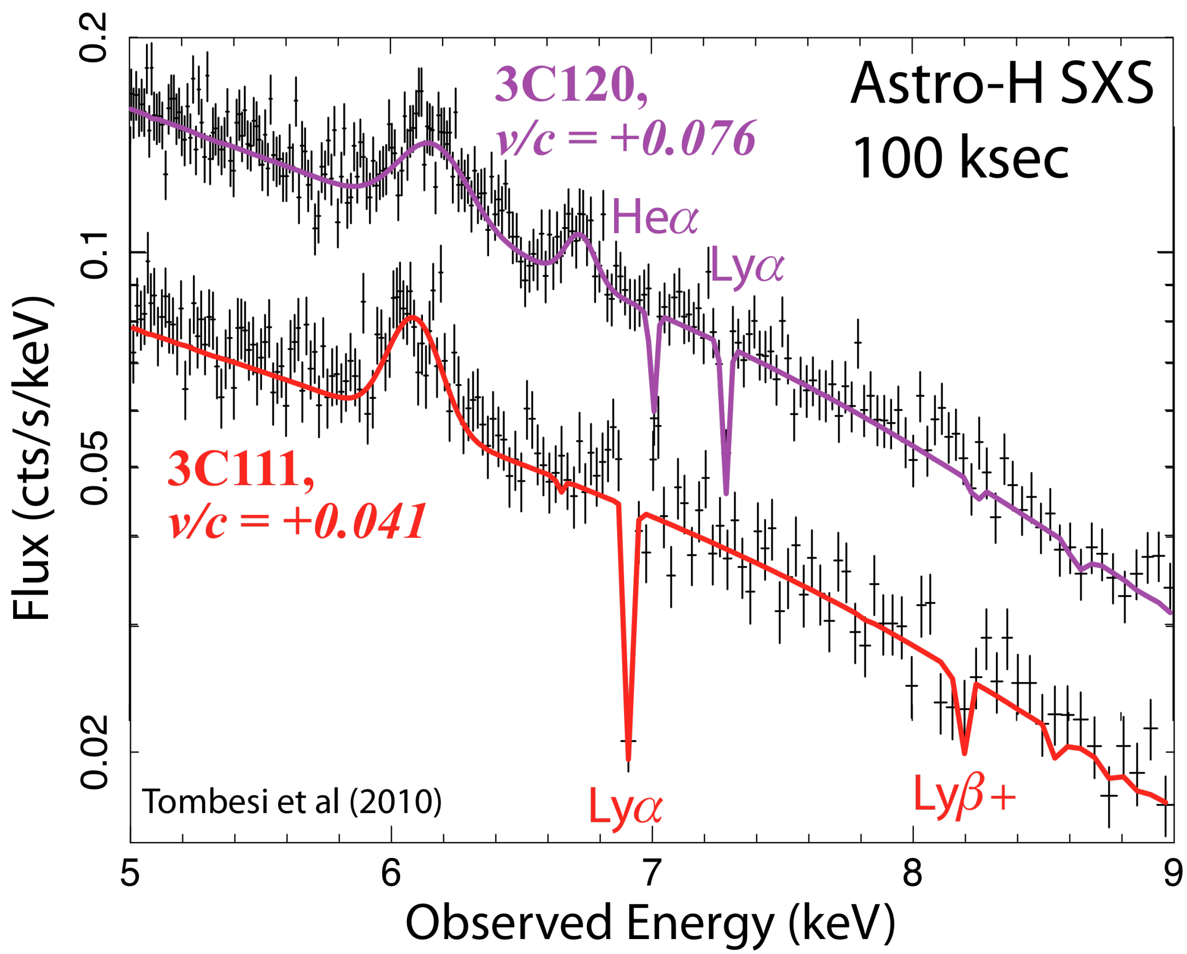
1. Protostars (CTTS)
2. White Dwarfs
3. X-ray Binaries (w/ Neutron Stars)
4. Black Hole Candidates
5. Active Galactic Nuclei

Strong Gravity Seen in Disks with IXO



AGN

High velocity outflows

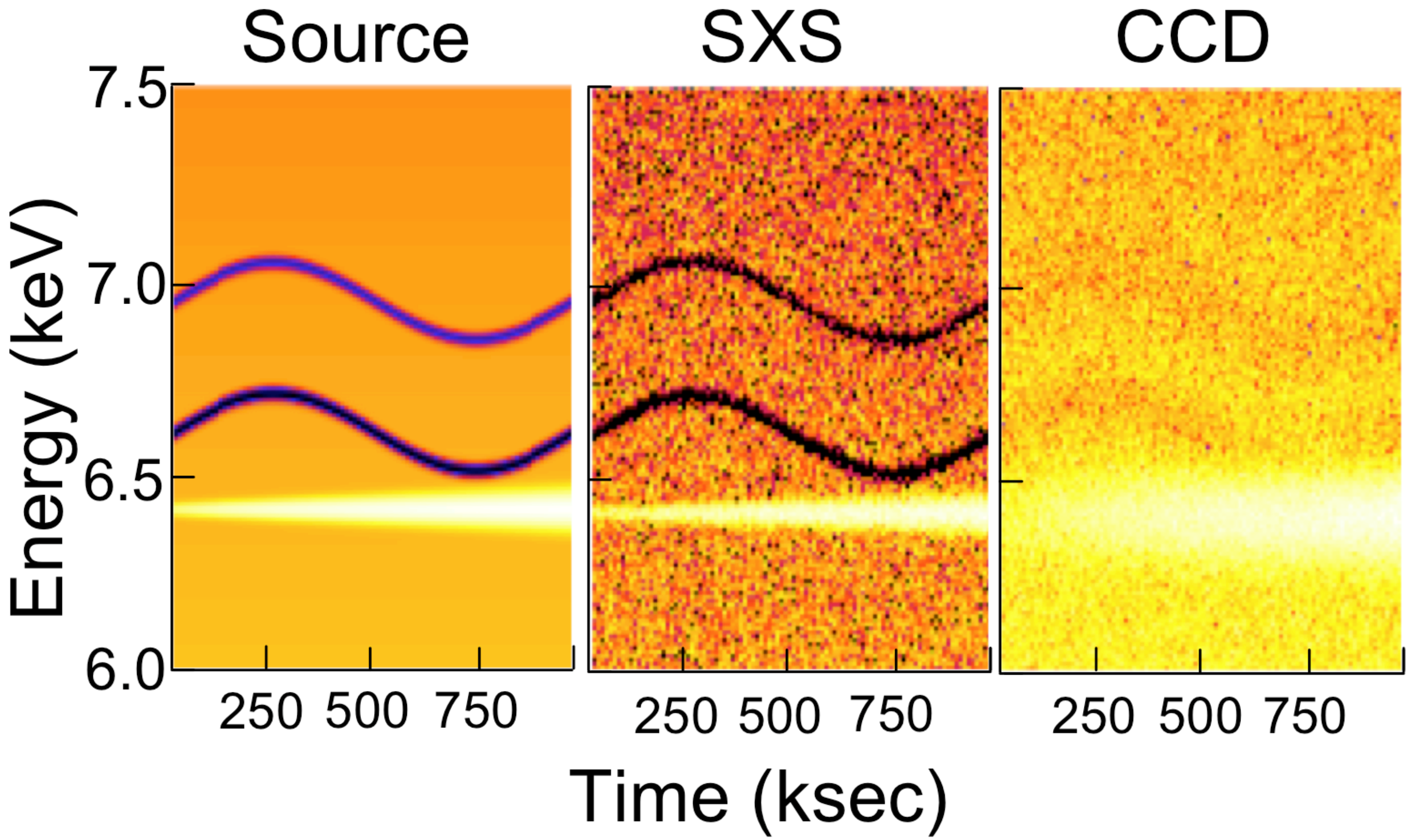


Conclusions

- 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

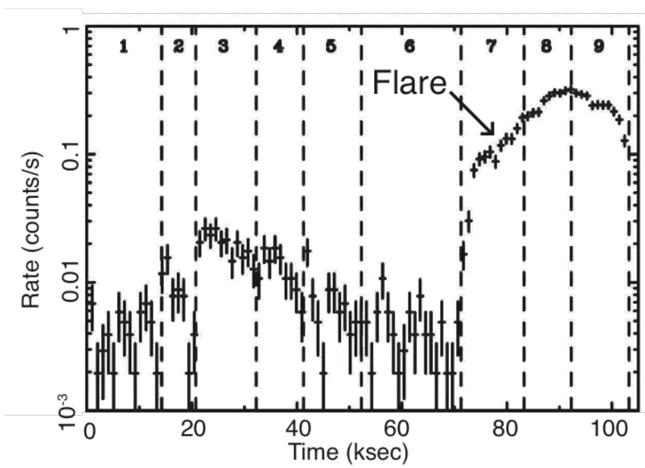
Time-variable AGN

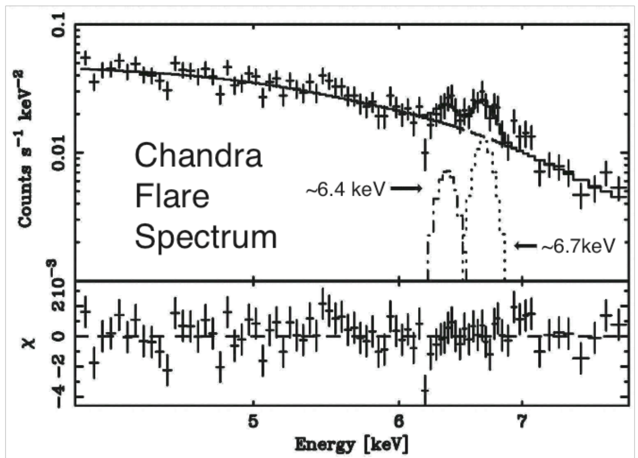


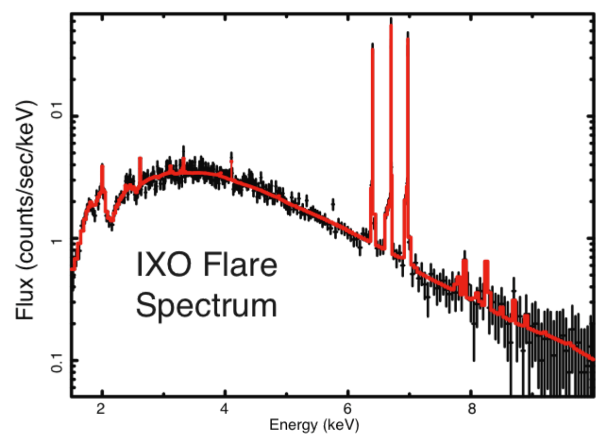
X-ray and Planetary Disks

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