Capabilities and Science Drivers for the X-ray Surveyor mission concept

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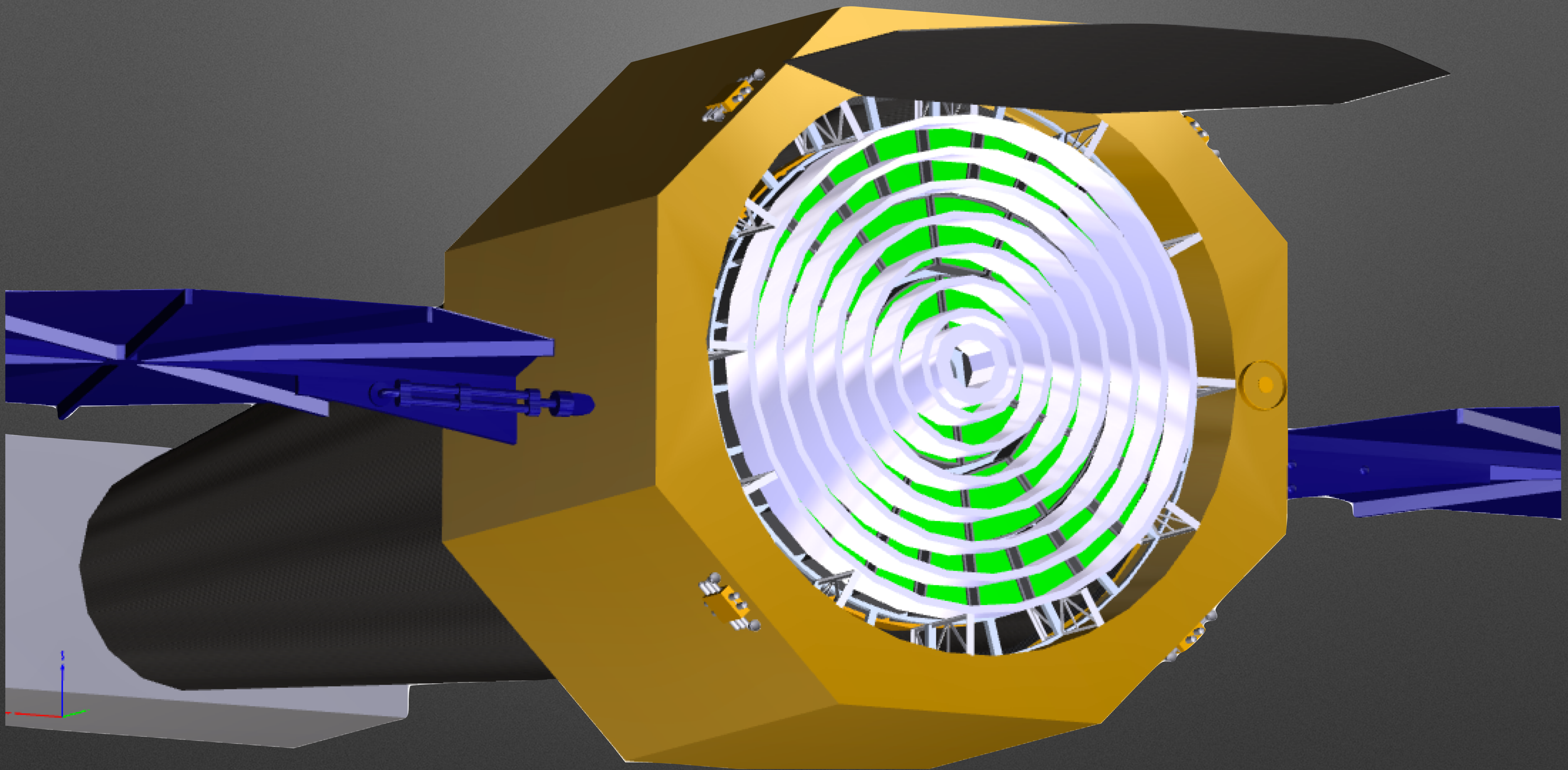
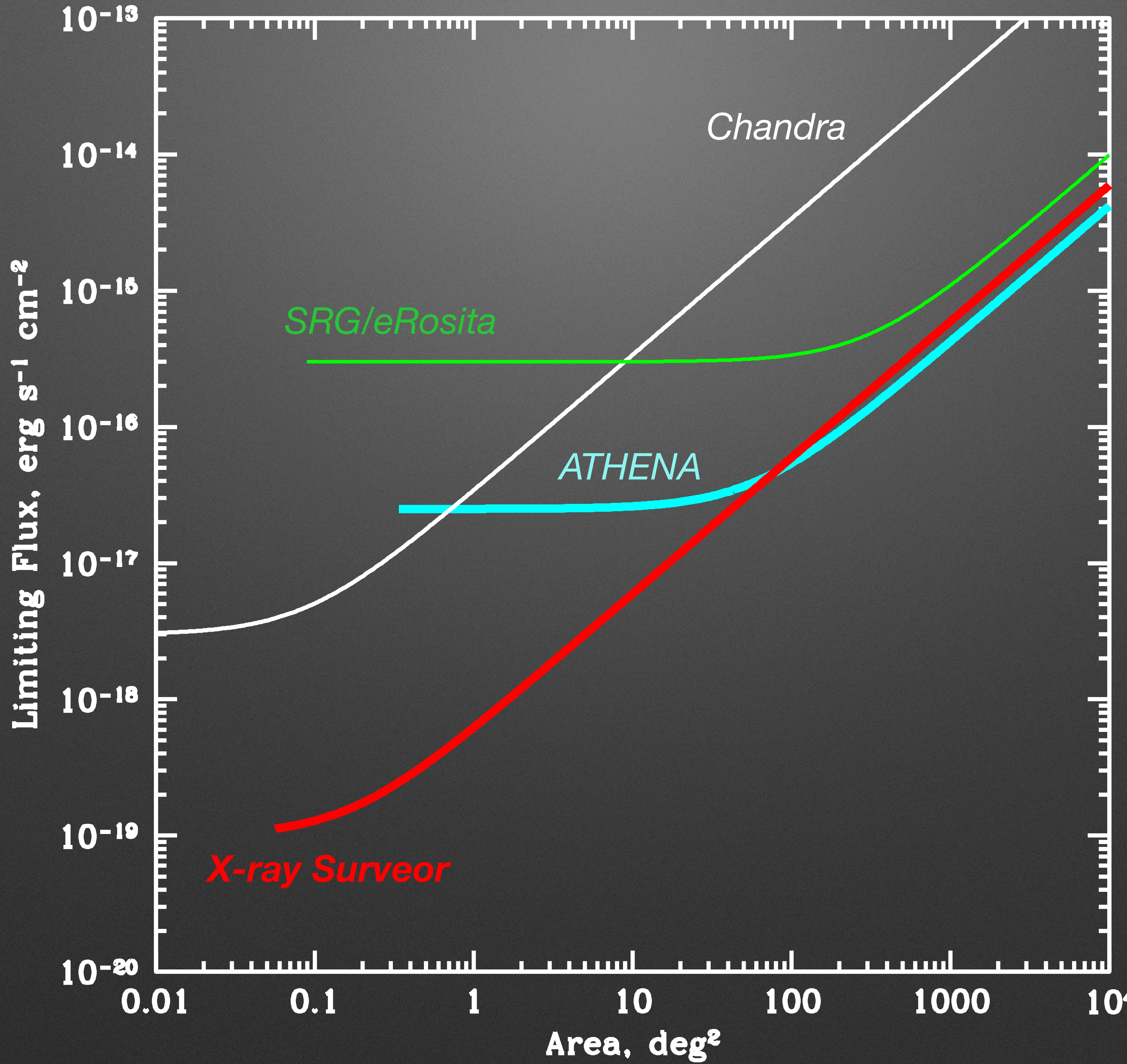
on behalf of the X-ray Surveyor community

Leap in sensitivity: High throughput with sub-arcsec resolution

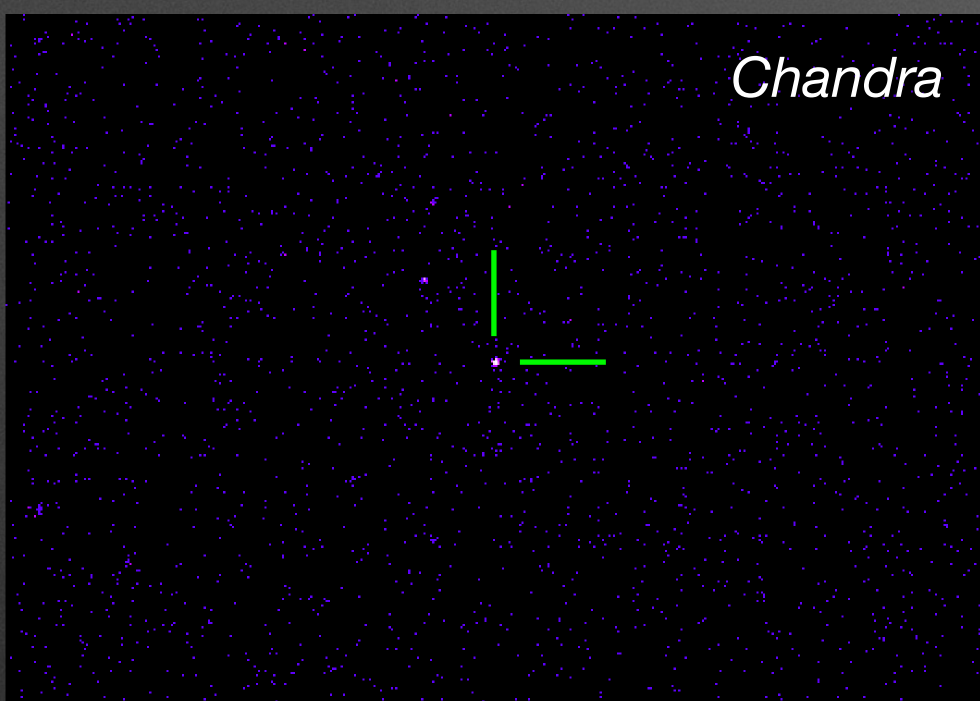


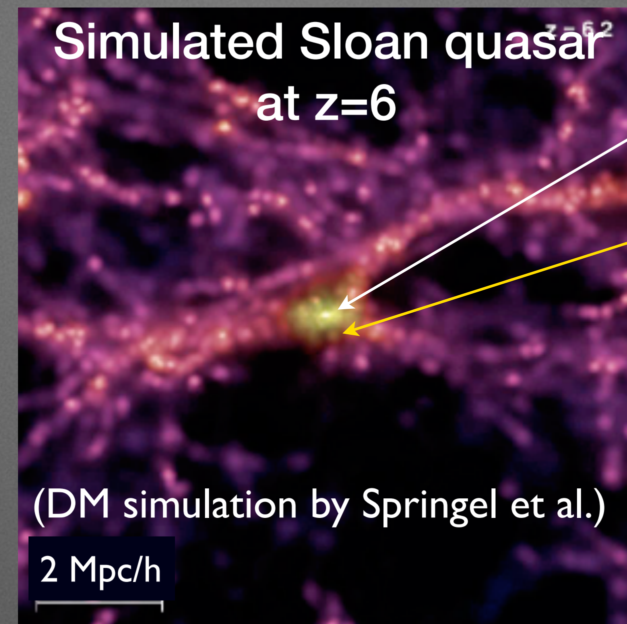
- ×50 more effective area than *Chandra.* 4 Msec *Chandra* Deep Field done in 80 ksec. Threshold for blind detections in a 4Msec survey is ~ 3×10^{-19} erg/s/cm^2 (0.5–2 keV band)
- ×16 larger solid angle for sub-arcsec imaging — out to 10 arcmin radius
- **×800 higher survey speed at the *Chandra* Deep Field limit**

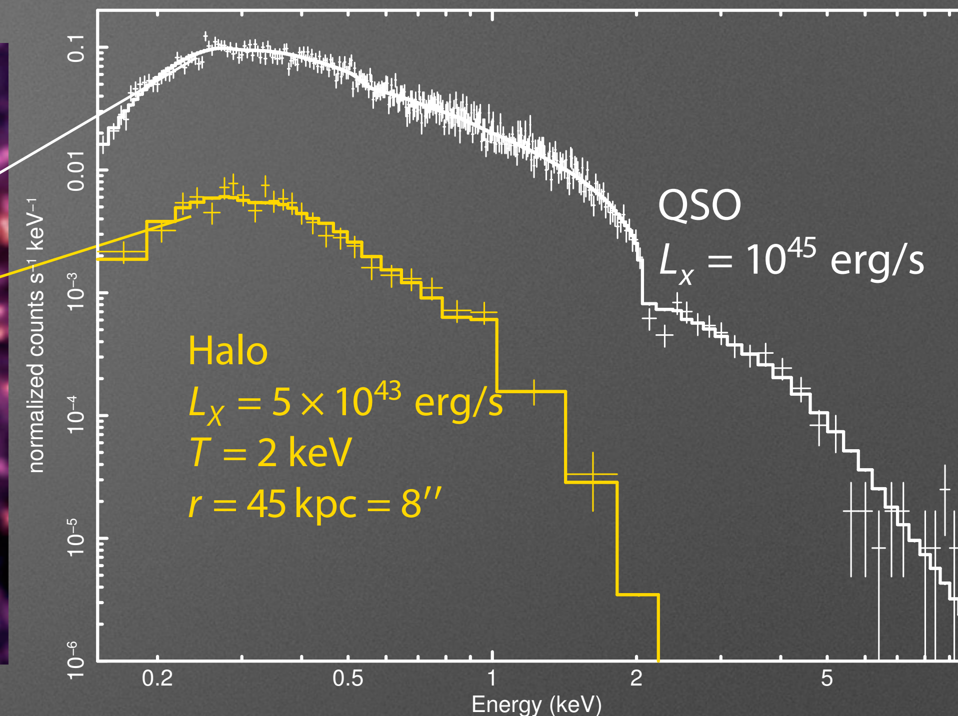
Comparison of survey capabilities: Flux limit vs. area for a 15 Msec program

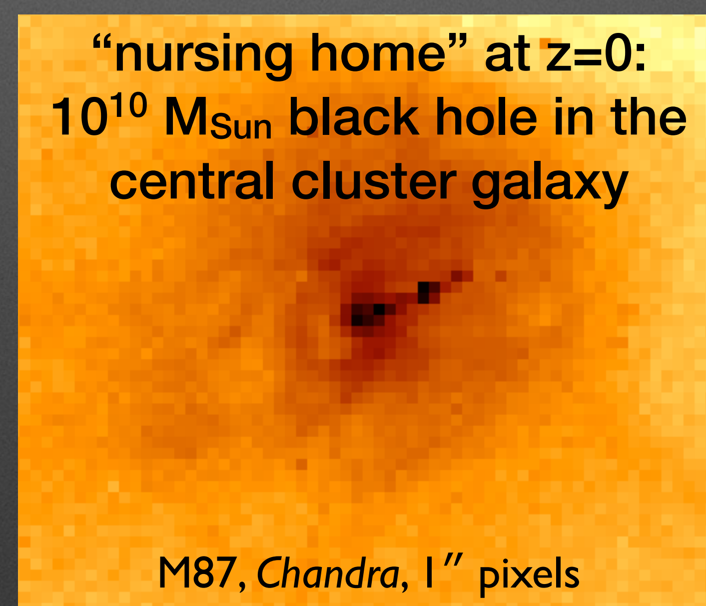


Black holes: from birth to today's monsters









Also:

- Electromagnetic signatures of black hole mergers
- Using X-ray binary population as tracers of star formation, their role in cosmic reionization
- Jets

What is their origin?

How do they co-evolve with galaxies and affect environment?

Nature of black hole seeds —
First accretion light in the Universe

Simulated 2x2 arcmin deep fields observed with JWST, X-ray Surveyor, and ATHENA

- JWST will detect ~2×10^{6} gal/deg^{2} at its sensitivity limit (Windhorst et al.). This corresponds to 0.03 galaxies per 0.5″ X-ray Surveyor beam (not confused), and 3 galaxies per ATHENA 5″ beam (confused).
- Each X-ray Surveyor source will be associated with a unique JWST-detected galaxy. Limiting sensitivity, ~1×10^{-19} erg/s/cm^{2}, corresponds to L_X ~ 1×10^{41} erg/s or M_{BH} ~ 10,000 M_{Sun} at *z=10* — well within the plausible seed mass range.
- X-ray confusion limit for ATHENA is 2.5×10^{-17} erg/s/cm^{2} (5× worse than the current depth of *Chandra* Deep Field). This corresponds to M_{BH} ~ 3×10^{6} M_{Sun} at *z*=10 — above seed mass range. Confusion in O&IR id's further increases the limit (M_{BH}~10^{7} M_{Sun} at *z*=8 is quoted by ATHENA team).

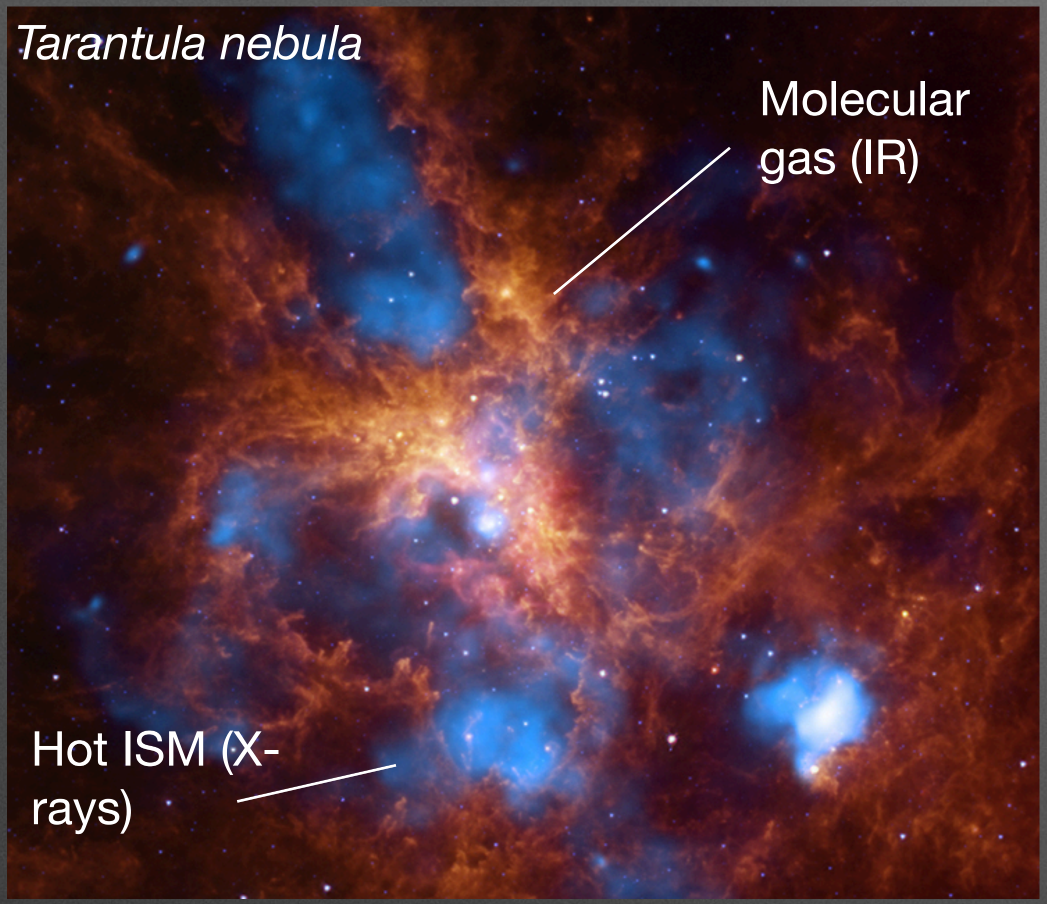
High-contrast imaging of faint extended objects

- Limiting factors: a) contrast relative to the background, and b) ability to separate out point sources

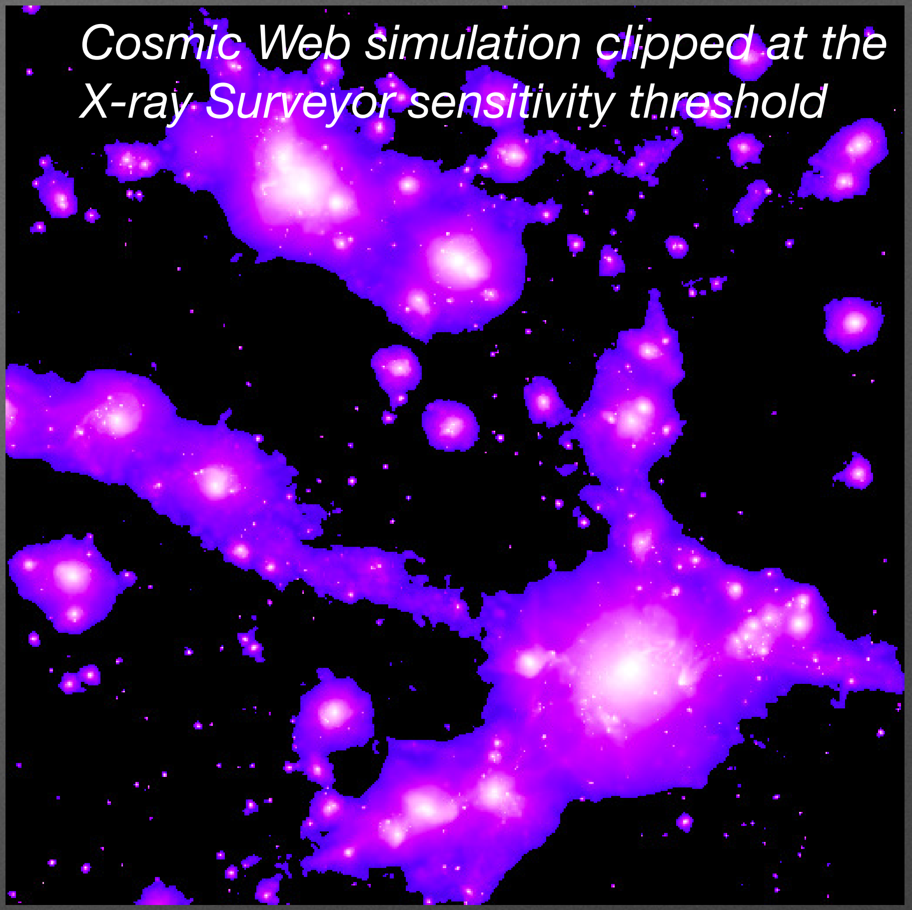
- X-ray Surveyor expected to maintain Chandra-like particle background, while amplifying source brightness by factors 30—100
- Cosmic X-ray Background is resolved into discreet sources and not amplified
- 1/4 keV particle background reduced by a factor of ~10 through analysis of cloud shapes on ~50mu scale (same for Chandra ACIS-S3)
- For microcalorimeter observations, the soft diffuse Galactic foreground is resolved into emission lines and removed.

Reachable surface brightness levels are ~ 1/30 of Chandra limits

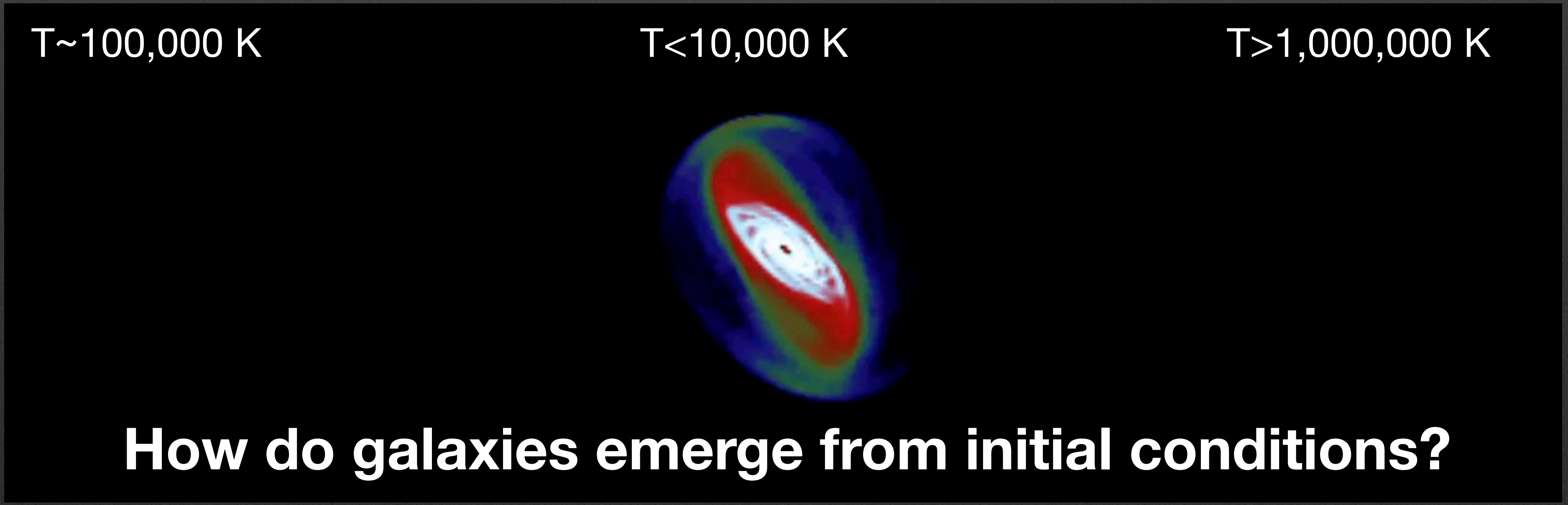
Cycles of baryons in and out of galaxies



Generation of hot ISM in young star-forming regions. How does hot ISM push molecular gas away and quench star formation?

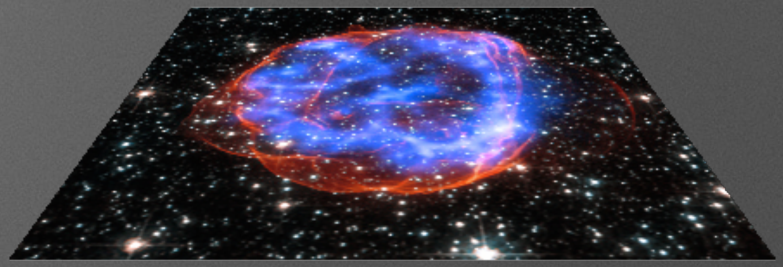


Structure of the Cosmic Web through observations of hot IGM *in emission*

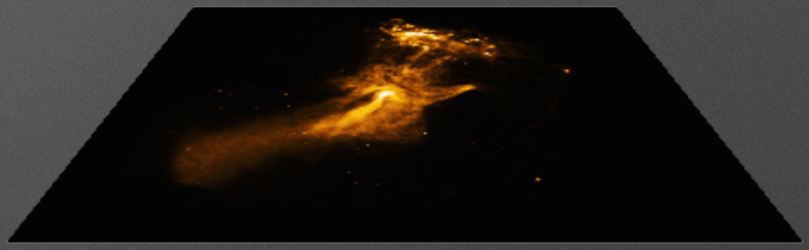


What physics is behind the structure of astronomical objects?

Plasma physics, gas dynamics, relativistic flows in astronomical objects:



- Supernova remnants
- Particle acceleration in pulsar wind nebulae

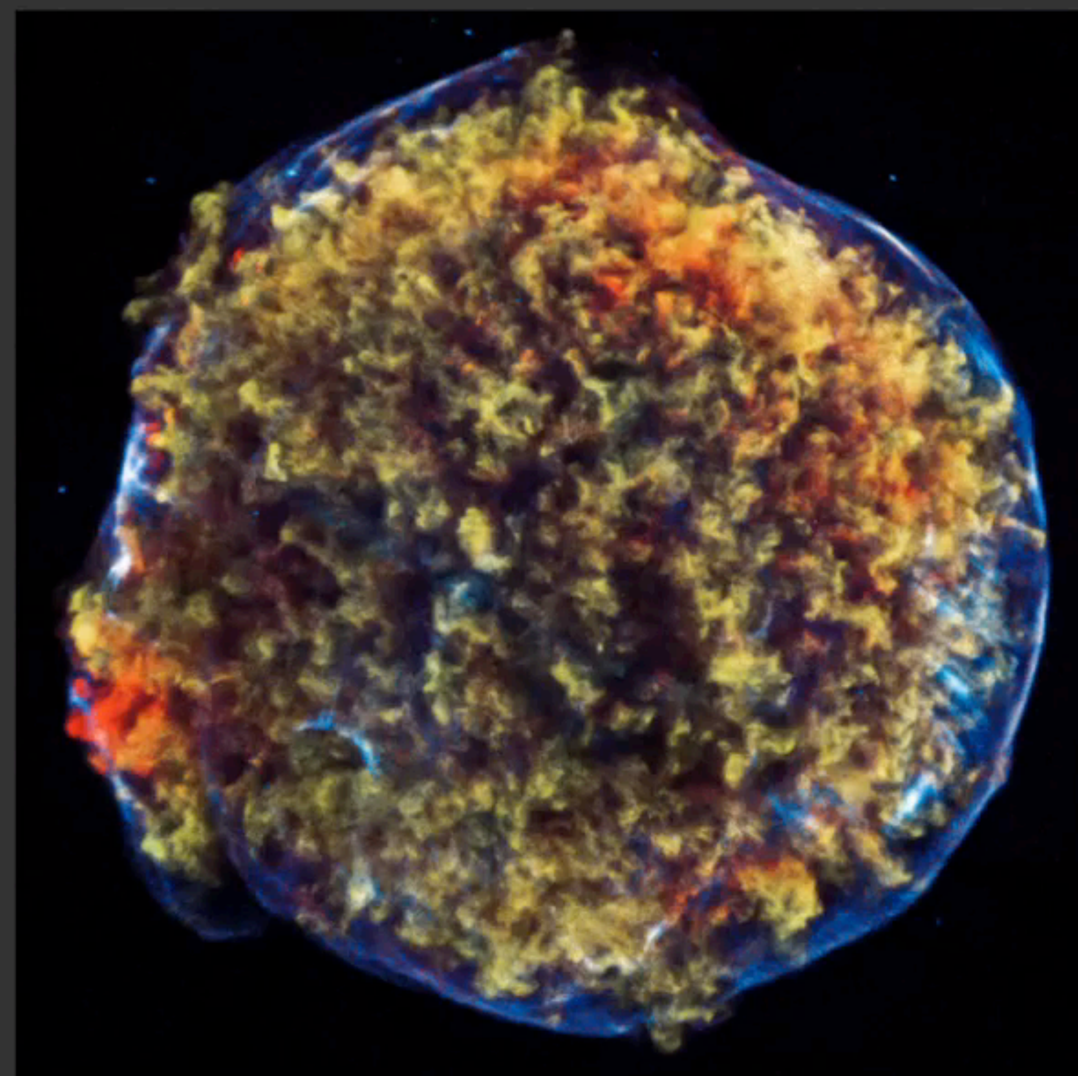


- Jet-IGM interactions
- Hot-cold gas interfaces in galaxy clusters and Galactic ISM
- Plasma flows in the Solar system, stellar winds & ISM via charge exchange emission

- Off-setting radiative cooling in clusters, groups & galaxies
- …

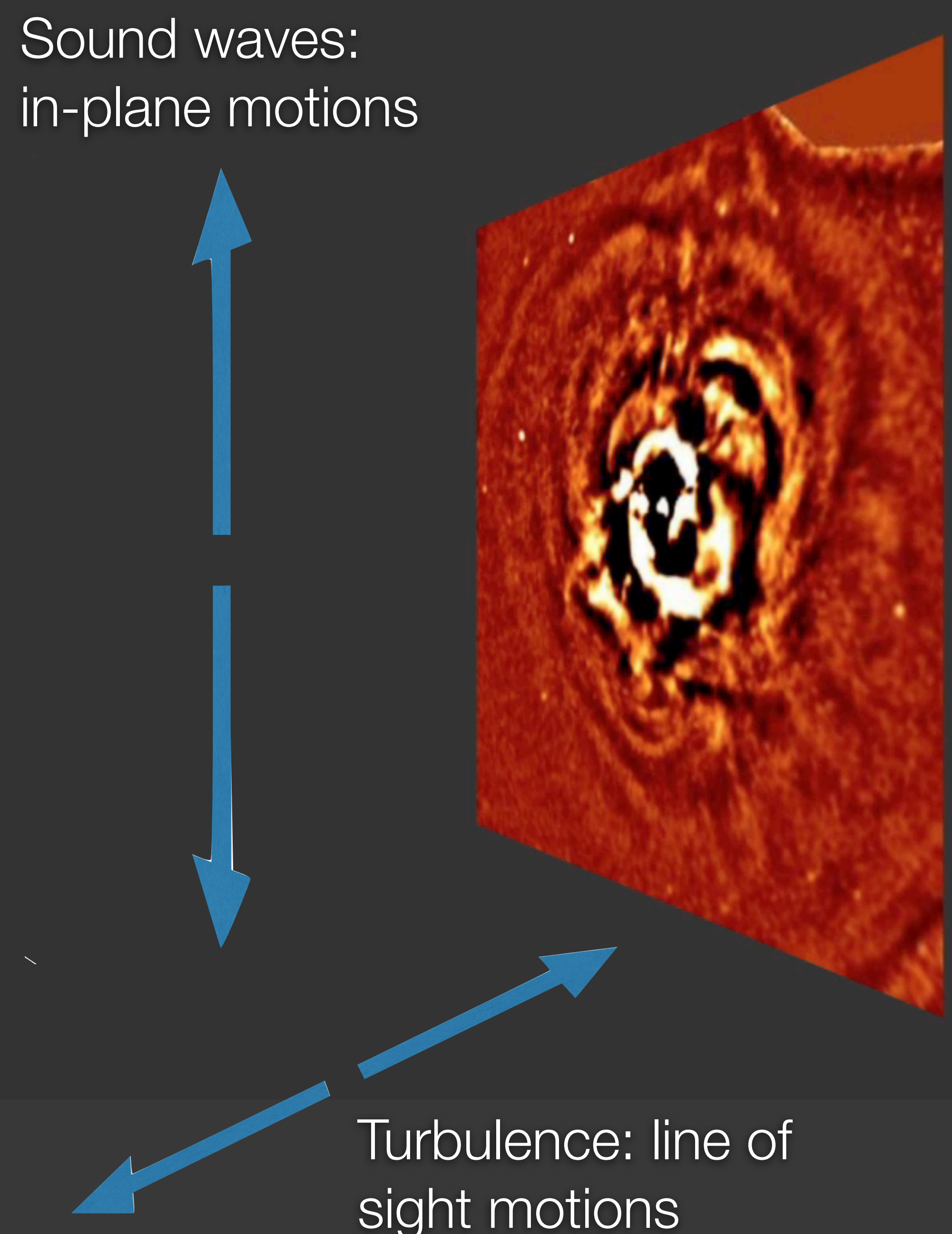
Required capability: high-resolution spectroscopy ***and*** resolving relevant physical scales

New capability:
Add 3rd dimension to the data



X-ray microcalorimeter will provide high-resolution, high throughput spectroscopy with 1 arcsec pixels — detailed kinematics, chemistry & ionisation state of hot plasmas

Plasma physics in astronomical objects



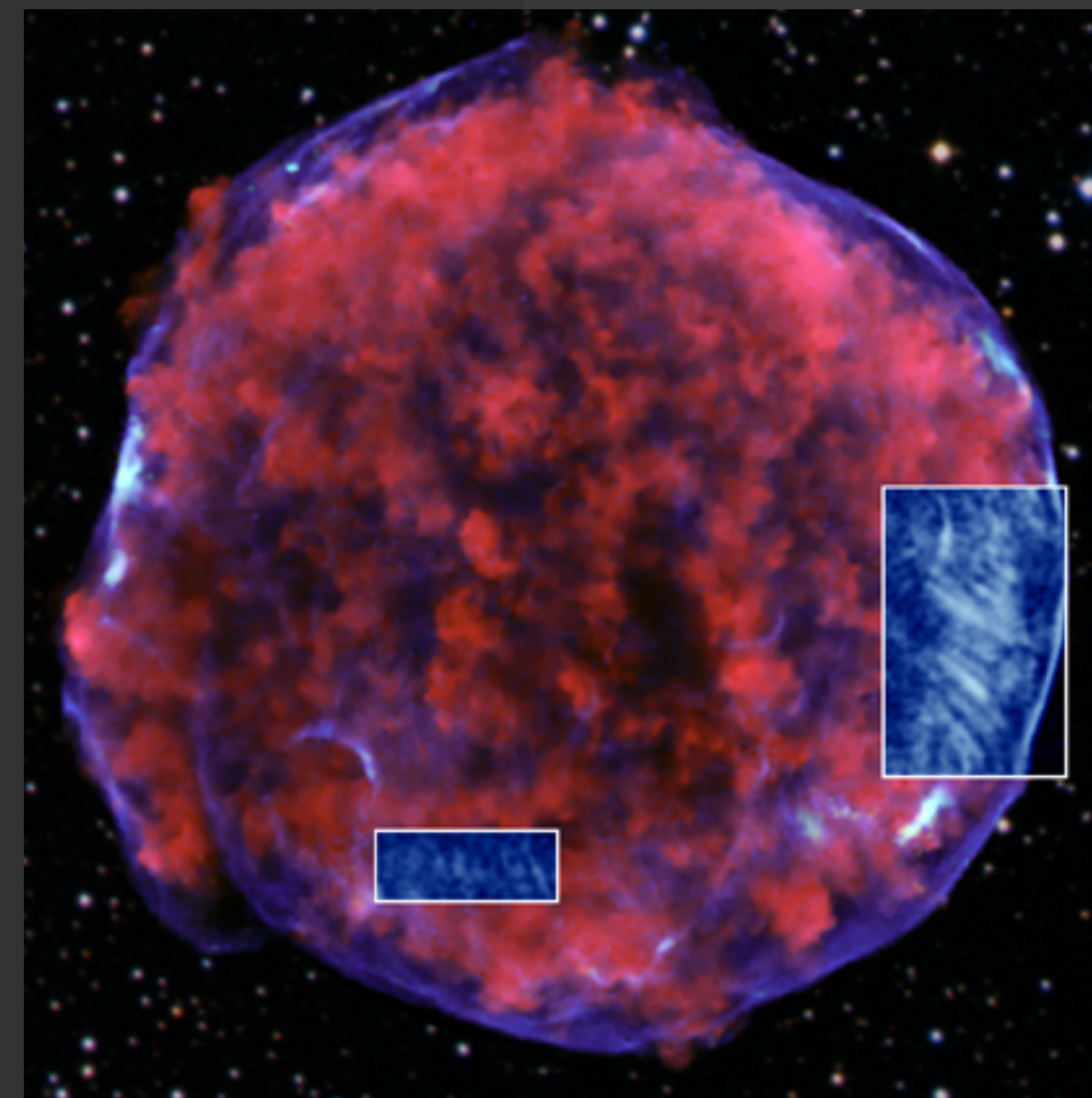
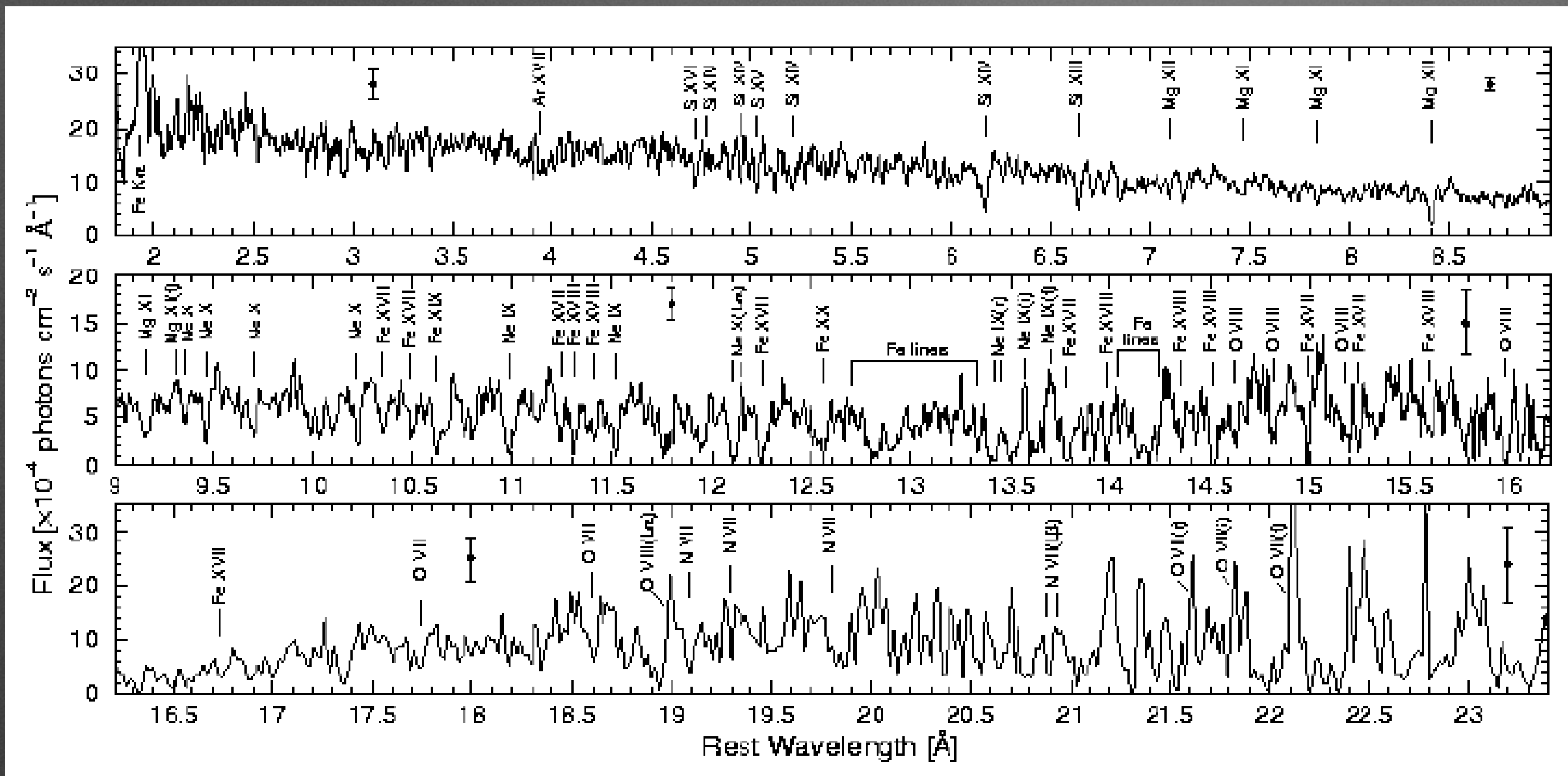


Image separation by chemistry and emission mechanism

Bulk gas motions with v=30 km/s can be measured with microcalorimeter (compare with c_s~1000 km/s).

Capability leap: high throughput X-ray gratings spectroscopy



Chandra HETG spectrum of NGC 3783. Note the wealth of emission and absorption lines with λ>~9Å (*E*<~1.3 keV)

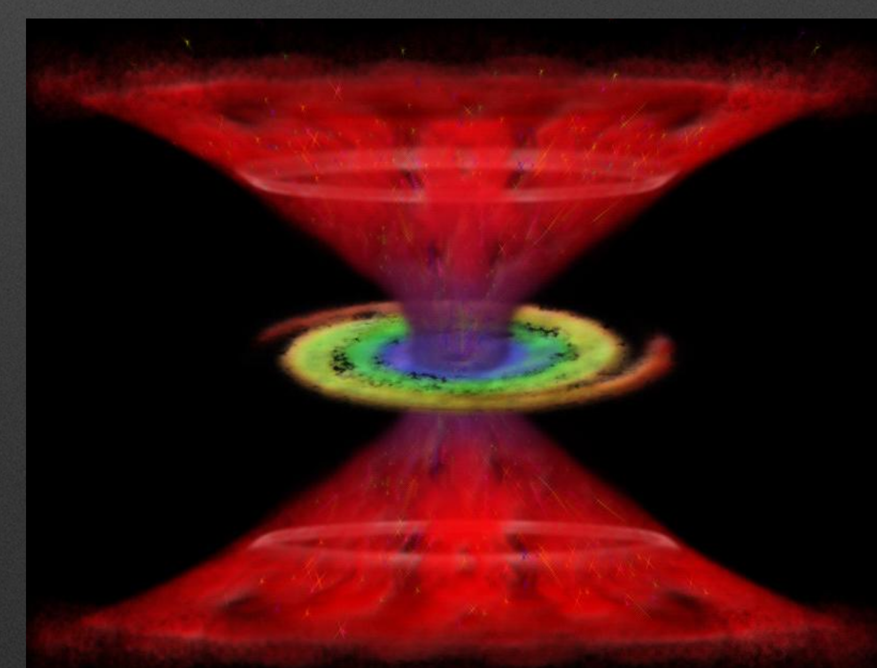
X-ray Surveyor gratings will provide R≈5000 and 4000 cm² effective area, adding 250× in throughput and 5× in resolving power compared to Chandra at E=0.6 keV (50× throughput and 20× resolving power compared to XMM Newton)

Physics of the "New Worlds", e.g.:

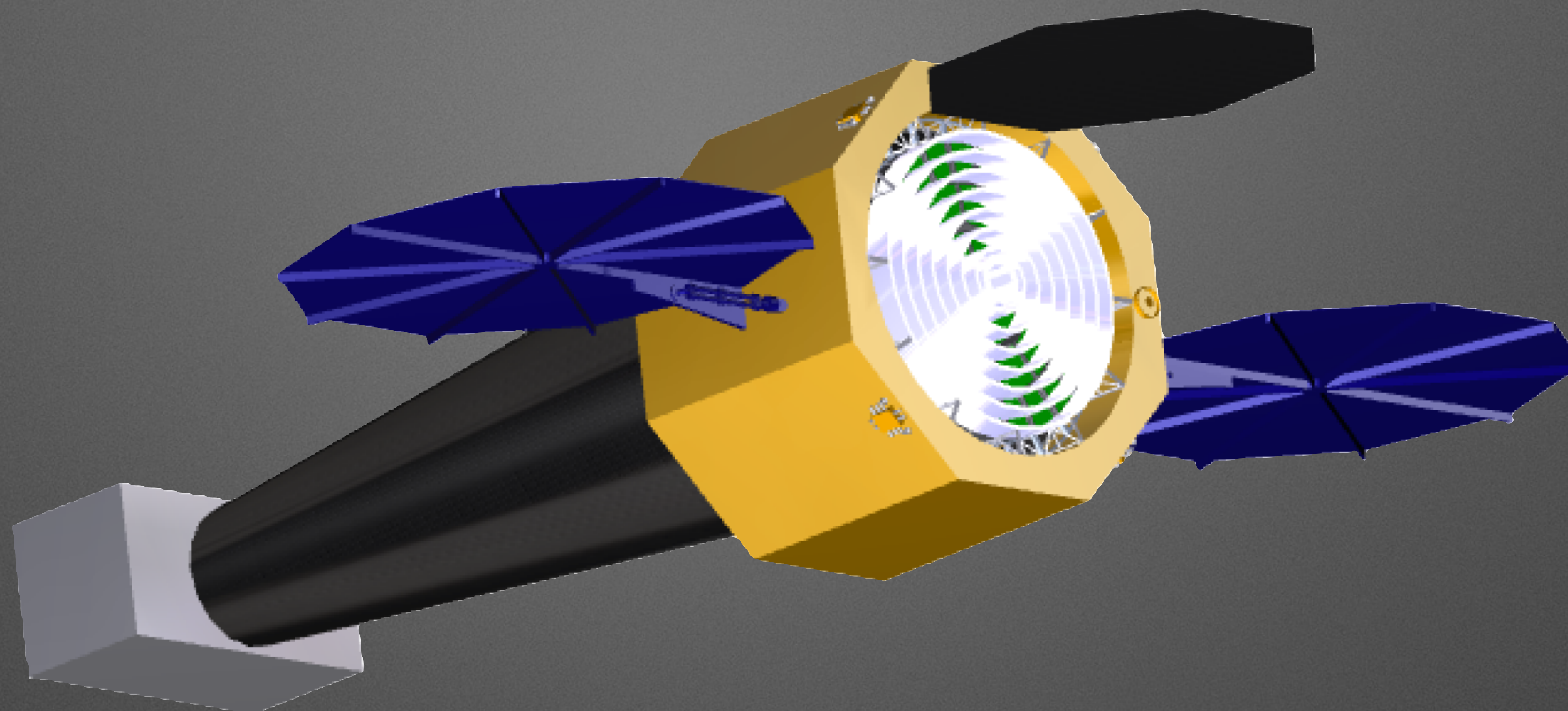
- Star-planet interactions & X-ray absorption in atmospheres of "hot Jupiters"
- Stellar coronae, dynamos in sub-stellar regime
- Stellar winds

Inner workings of the black hole central engine, e.g.

- spectroscopy of outflows
- tidal disruption events



X-ray Surveyor



- ***Leaps in Capability:*** large area with high angular resolution for 1–2 orders of magnitude gains in sensitivity, field of view with subarcsec imaging, high resolution spectroscopy for point-like and extended sources.
- ***Scientifically compelling:*** frontier science from Solar system to first accretion light in Universe; revolution in understanding physics of astronomical systems.
- ***Feasible:*** *Chandra*-like mission with regards to cost and complexity, with the new technology for optics and instruments already at TRL3 and proceeding to TRL6 before Phase B

Unique opportunity to explore new discovery space and expand our understanding of how the Universe works and how it came to look the way we see it