SMART-X

team at SAO, PSU, MIT, GSFC, MSFC, JHU, Stanford, U.Waterloo, Rutgers, NIST, Dartmouth

Aim at a mission more compelling than IXO:

- with significant cost savings
- ***and*** big science gains via achieving *Chandra*-like angular resolution.

Configuration

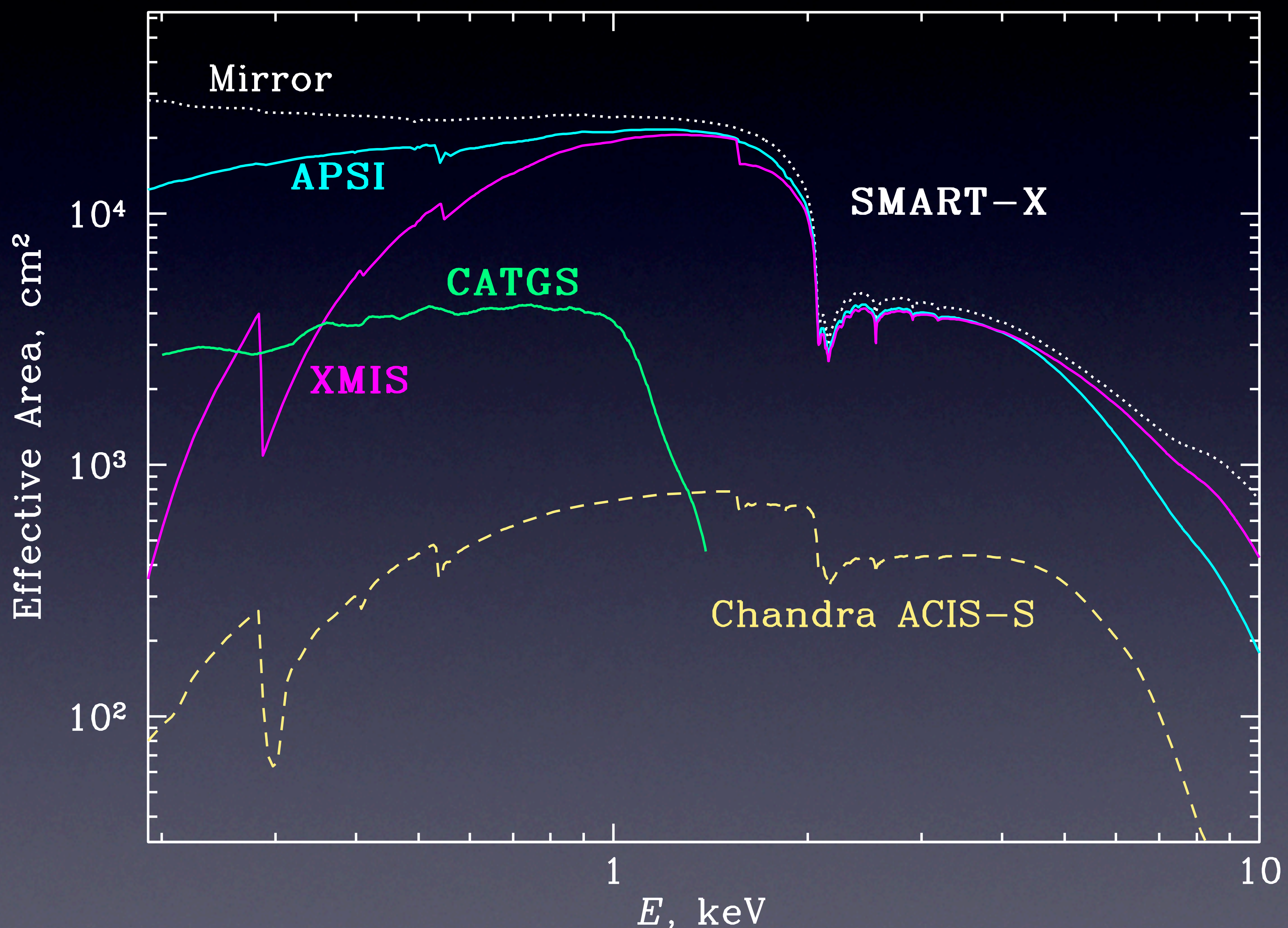
- No extendable optical bench
- $M_{tot} < 4{,}000$ kg (including 30% growth contingency)
- ATLAS V–541 launch to L2; throw weight > 5,000 kg, 28% margin for *SMART-X*
- Parameters very similar to *Chandra* and AXSIO

Configuration

- 5×5′ microcalorimeter with 1″ pixels (XMIS)
- 22×22′ CMOS imager with 0.33″ pixels (APSI)
- insertable CAT gratings with $R = 5000$ (CATGS)

- **$f = 10\,\mathrm{m}$, $\varnothing = 3\,\mathrm{m}$ mirrors with 0.5″ HPD resolution and $A_{\mathrm{eff}} = 2.3\,\mathrm{m}^2$ at 1 keV**

Performance



IXO Science

✓ *What Happens Close to a Black Hole?*

time-resolved Fe-K line spectra for 5–10 AGNs

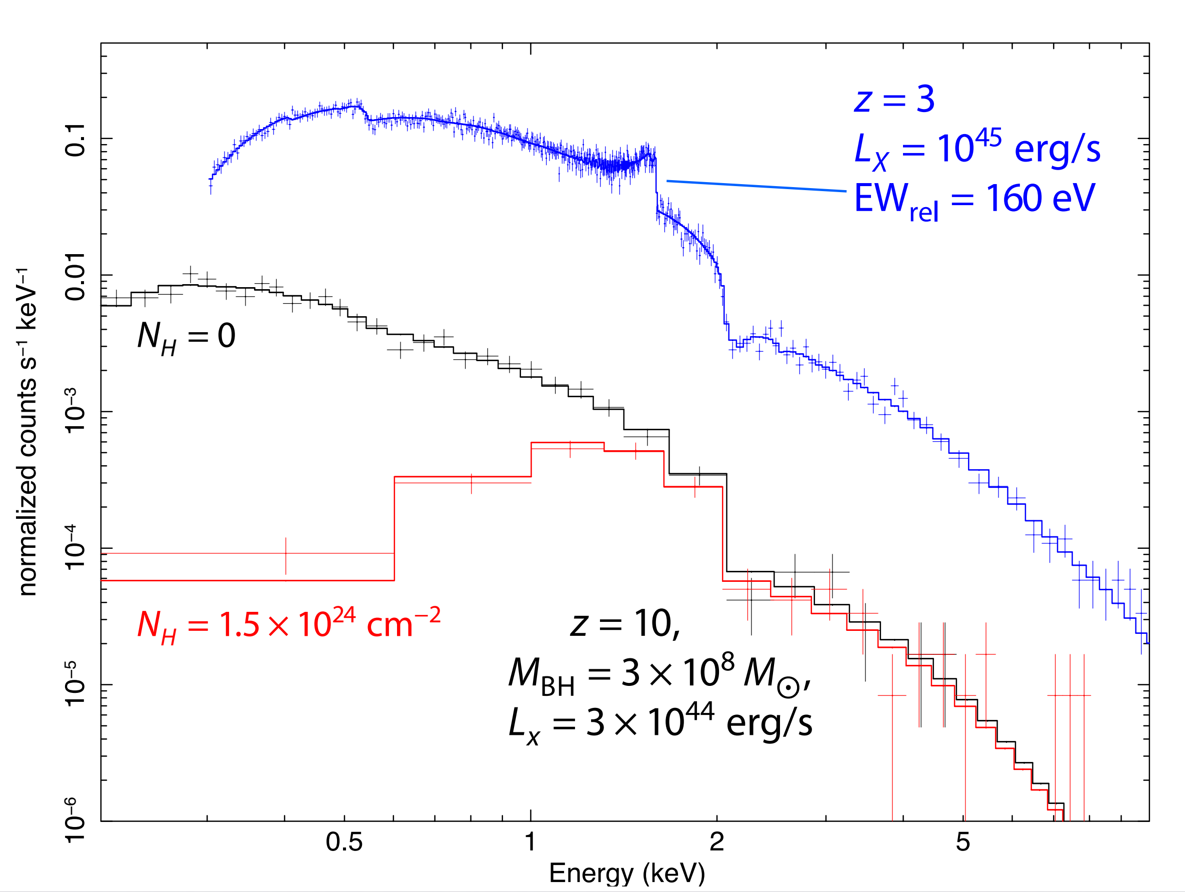
✓ *How does matter behave at high ρ?*

- ✓ high-res spectroscopy
- - no timing for 10^6 cnt/s sources

✓ *When and How Did SMBHs Grow?*

- ✓ BH spins in ~40 low-z AGNs
- - (little area at $E > 10$ keV)
- ✓ BH spins for brightest z=3 AGNs
- ✓ Observations of BHs to z=10 found in other wavebands or in *SMART-X* surveys

SMART-X projections for high-z AGNs



IXO Science

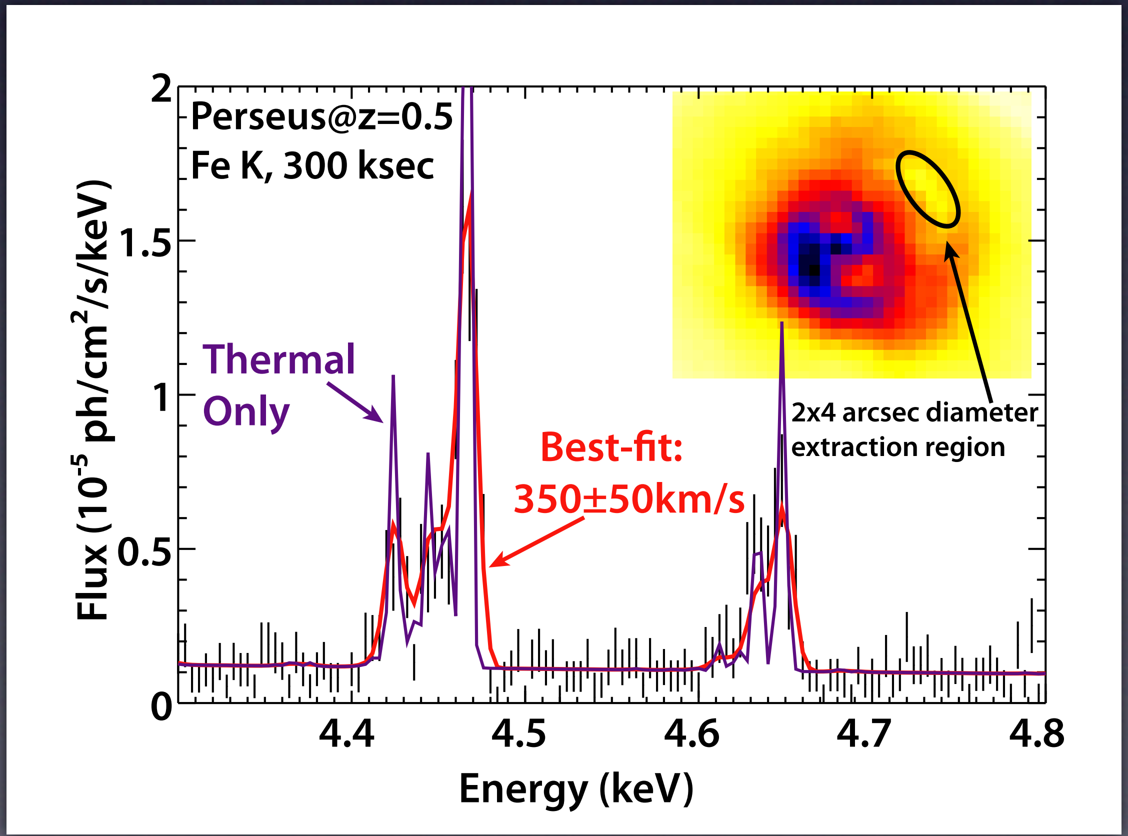
✓ *How does Large Scale Structure Evolve?*

- ✓ Precision Cosmology using ~1000 eRosita/ WFXT clusters: $\Delta\gamma = \pm 0.02$, $\Delta w \simeq \pm 0.02$
- ✓ Detection of WHIM in absorption (2× IXO efficiency)

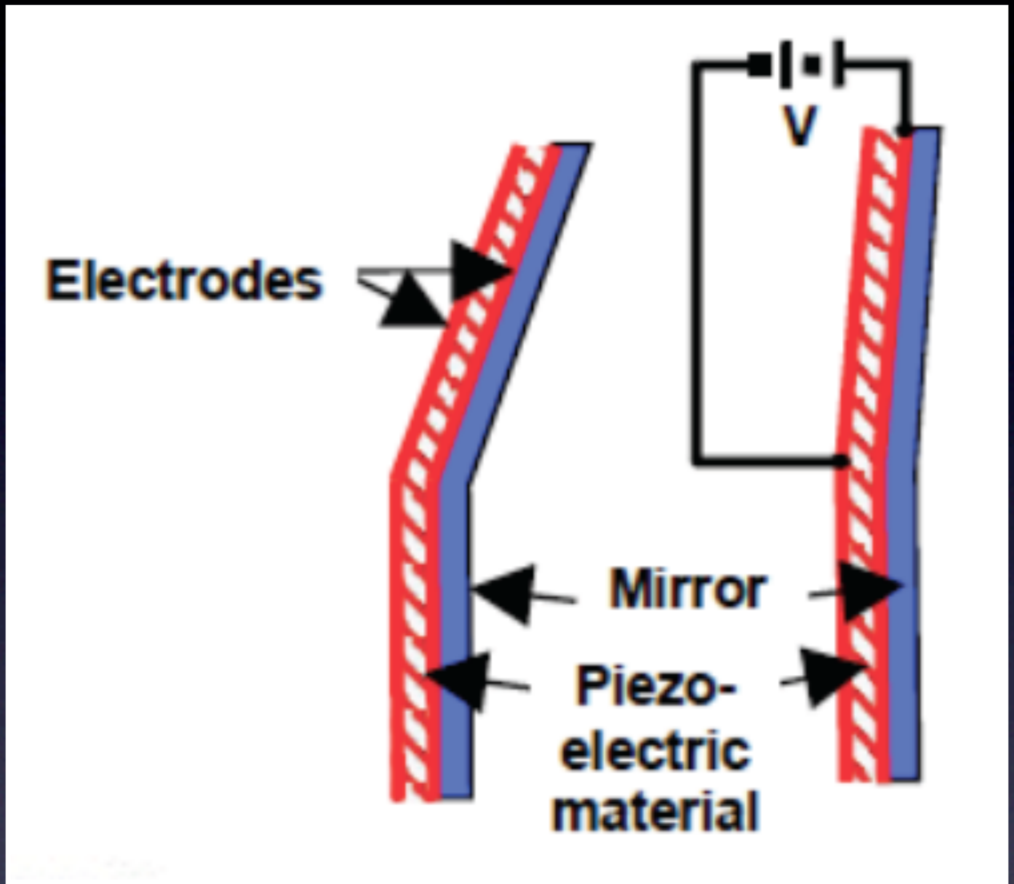
✓ *Connection between SMBH and LSS*

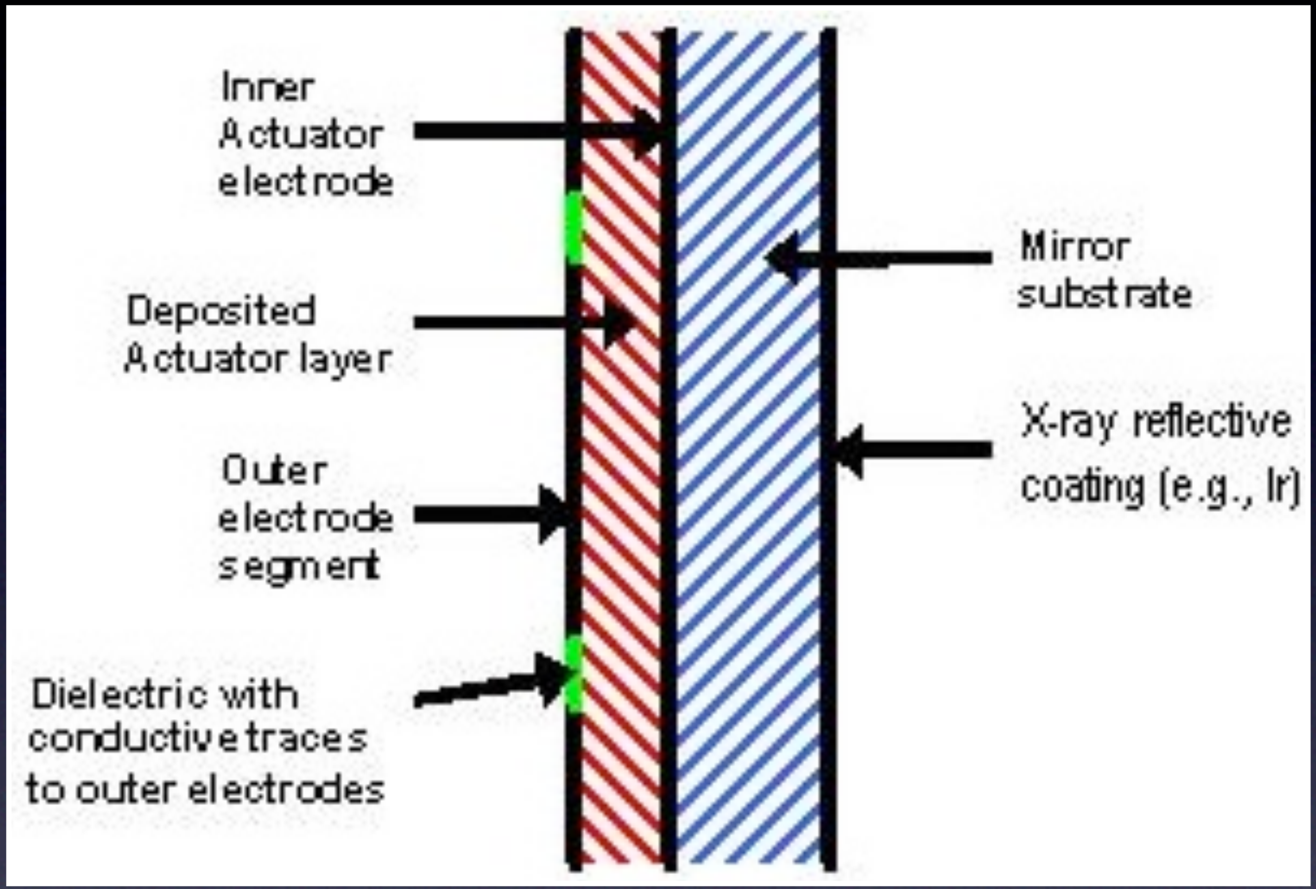
- ✓ Exquisite data on groups and clusters to high-z
- ✓ Spatially-resolved turbulence measurements
- ✓ High-res spectroscopy of AGN outflows, galaxy winds

SMART-X/XMIS simulation of Perseus-like clusters at z = 0.5



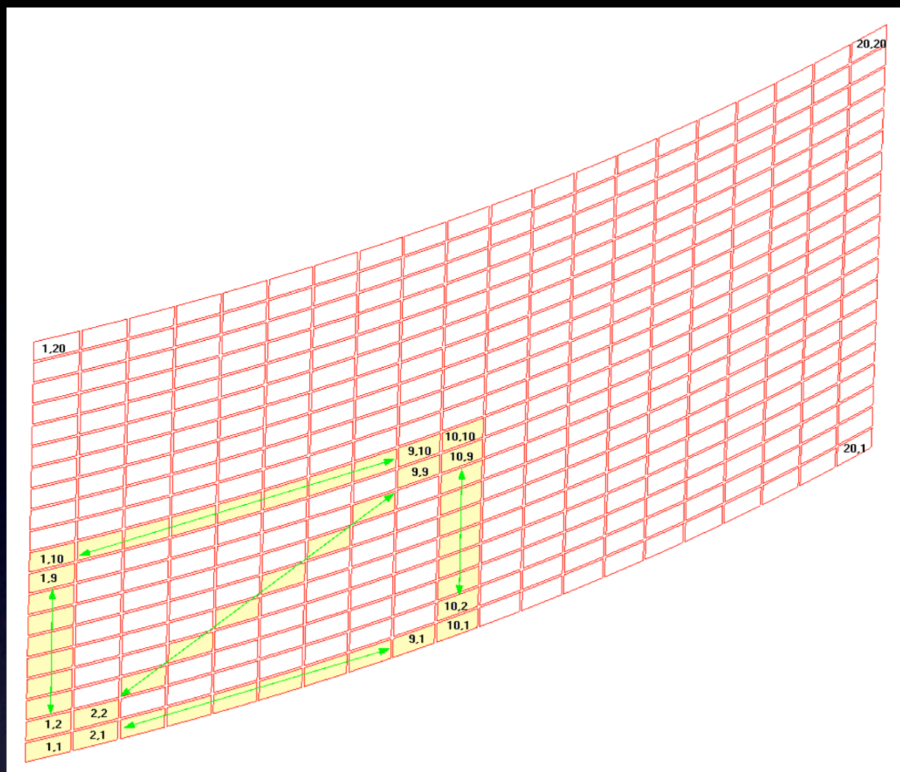
Adjustable mirrors





- make segments for ~7″ mirror quality (AXSIO-like), deposit PZT & electrodes
- mount, calibrate and determine required piezo voltages on the ground, using available optical interferometry
- apply voltage to correct the figure when in orbit (low power)

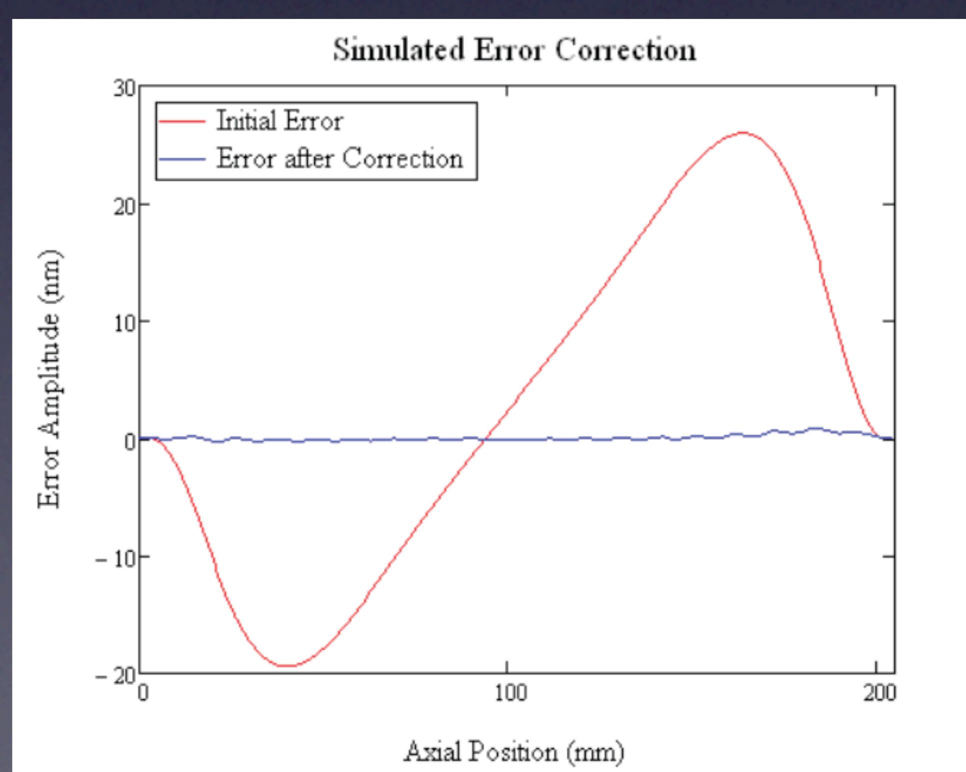
Adjustable mirrors: analytic modeling

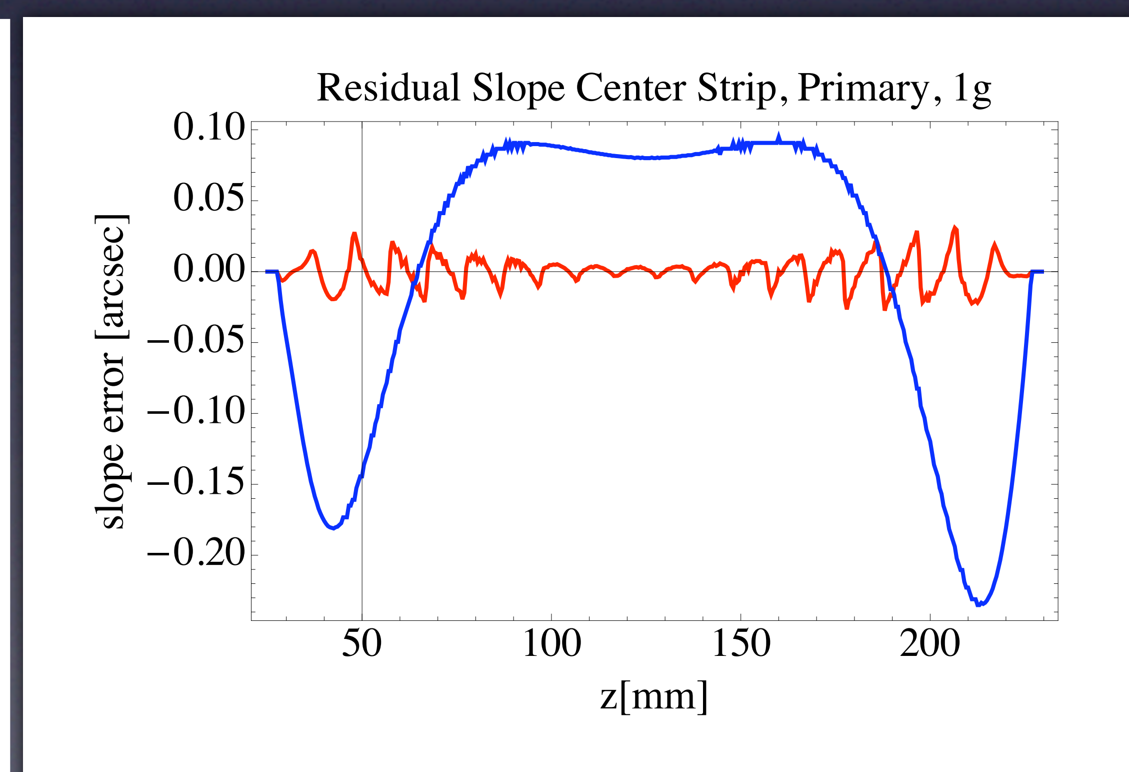


Finite element analysis of 410×205mm conical elements with 20×20 piezo adjusters, 10+2 point mount:

- correction works for generic low-*f* distortions (e.g., gravity release)
- up to 5% errors on correction coefficients can be tolerated

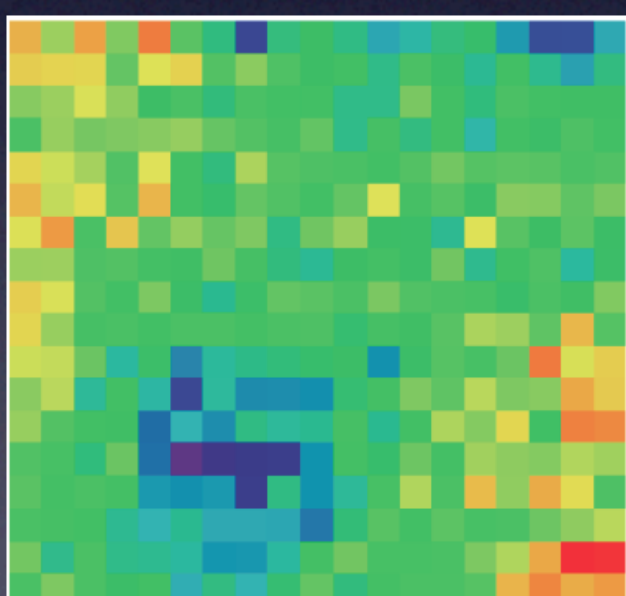
Simulations of 1-g gravity release correction — an order of magnitude reduction in slope error





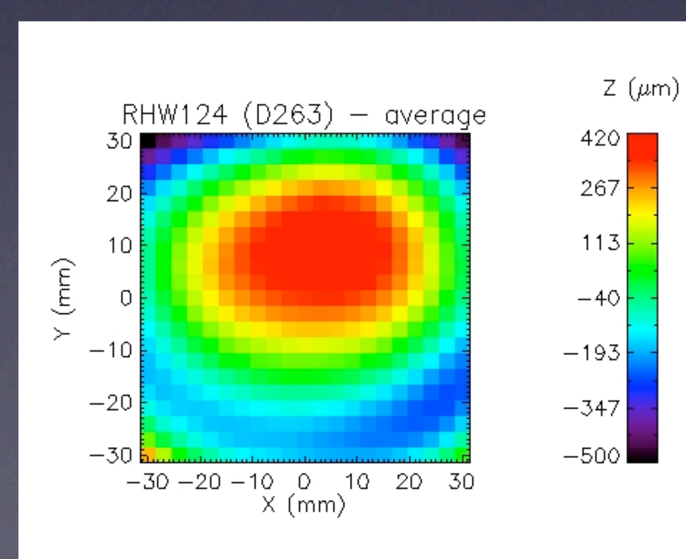
Adjustable mirrors: current state

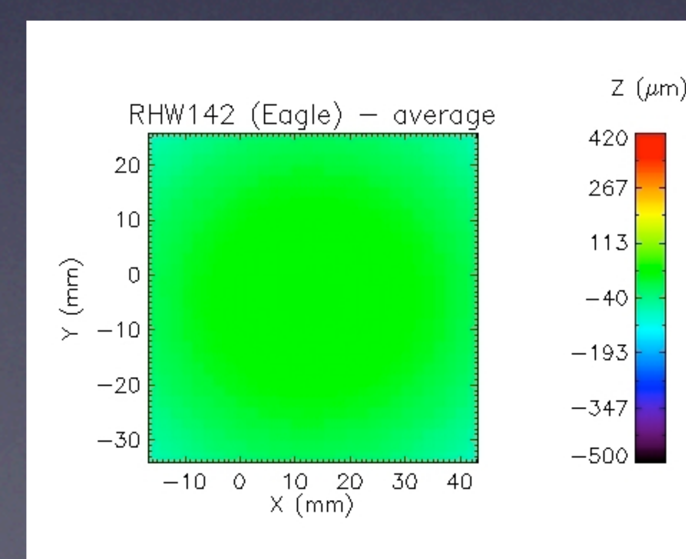
- PZT film successfully deposited and energized.
  ~500 ppm strain required, 700–900 ppm obtained;
- Deposition on Corning Eagle glass
- PZT lifetime, stability, repeatability studies on-going



"first move" measurement:
60×60mm,
~2μm displacement

PZT deposition on D263 vs Corning Eagle





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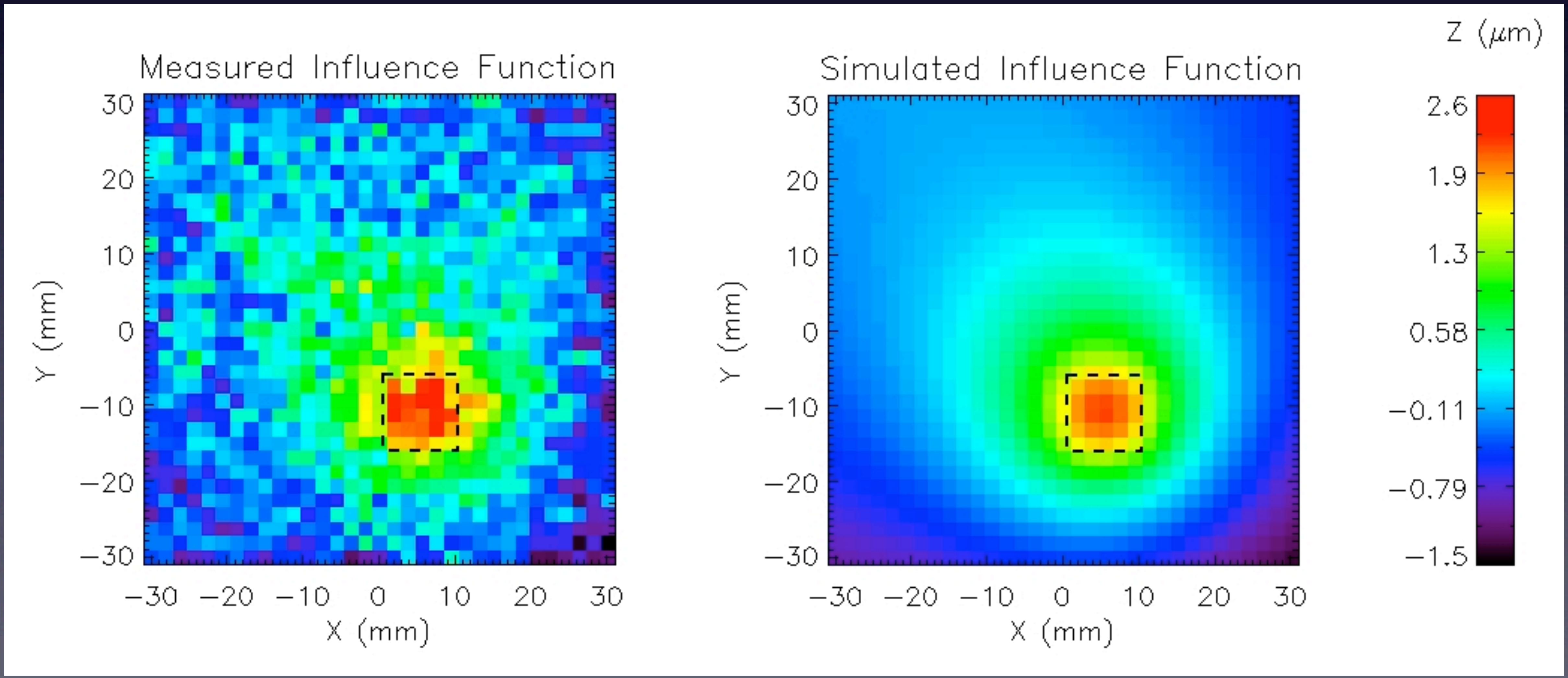
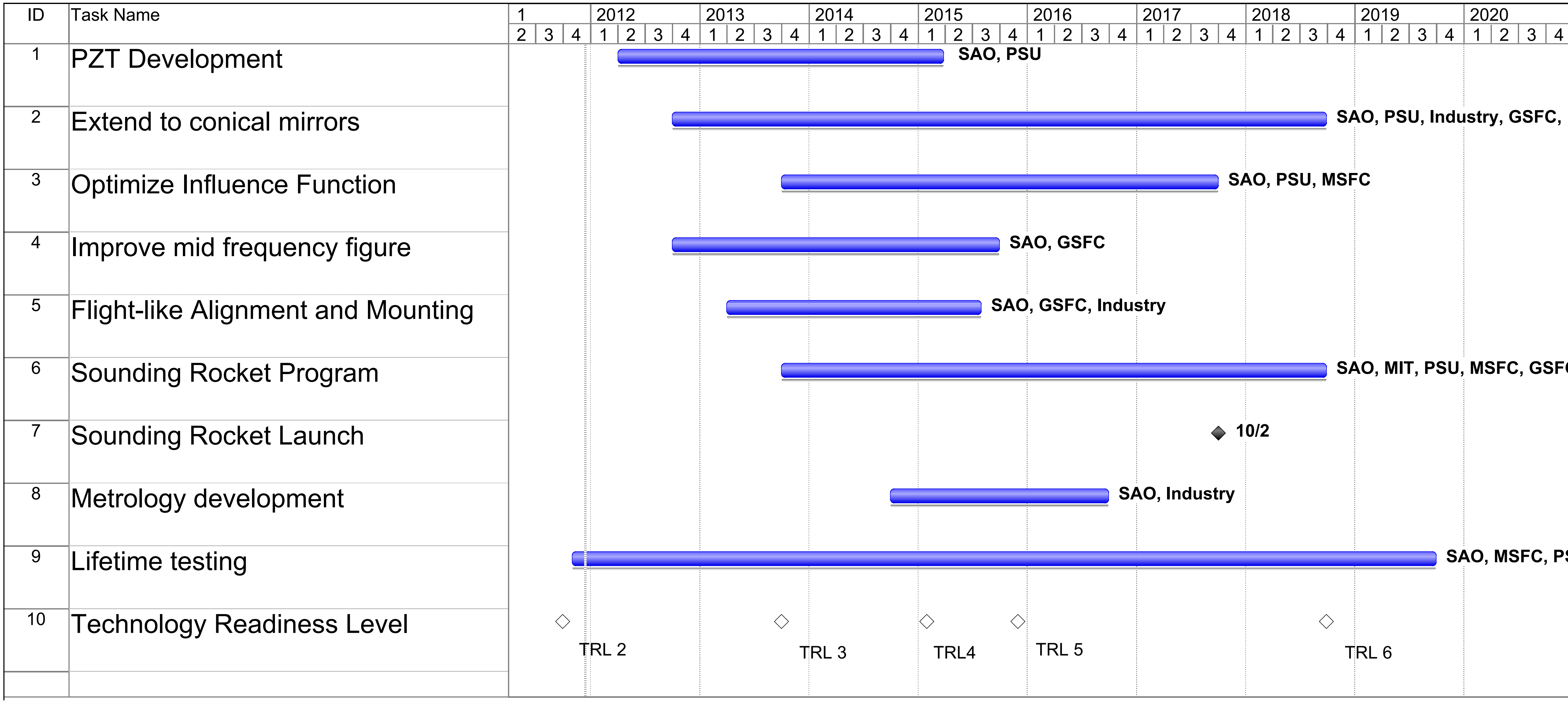


Corning Eagle glass, single cell energized, 690ppm strain

Adjustable mirrors: development plan

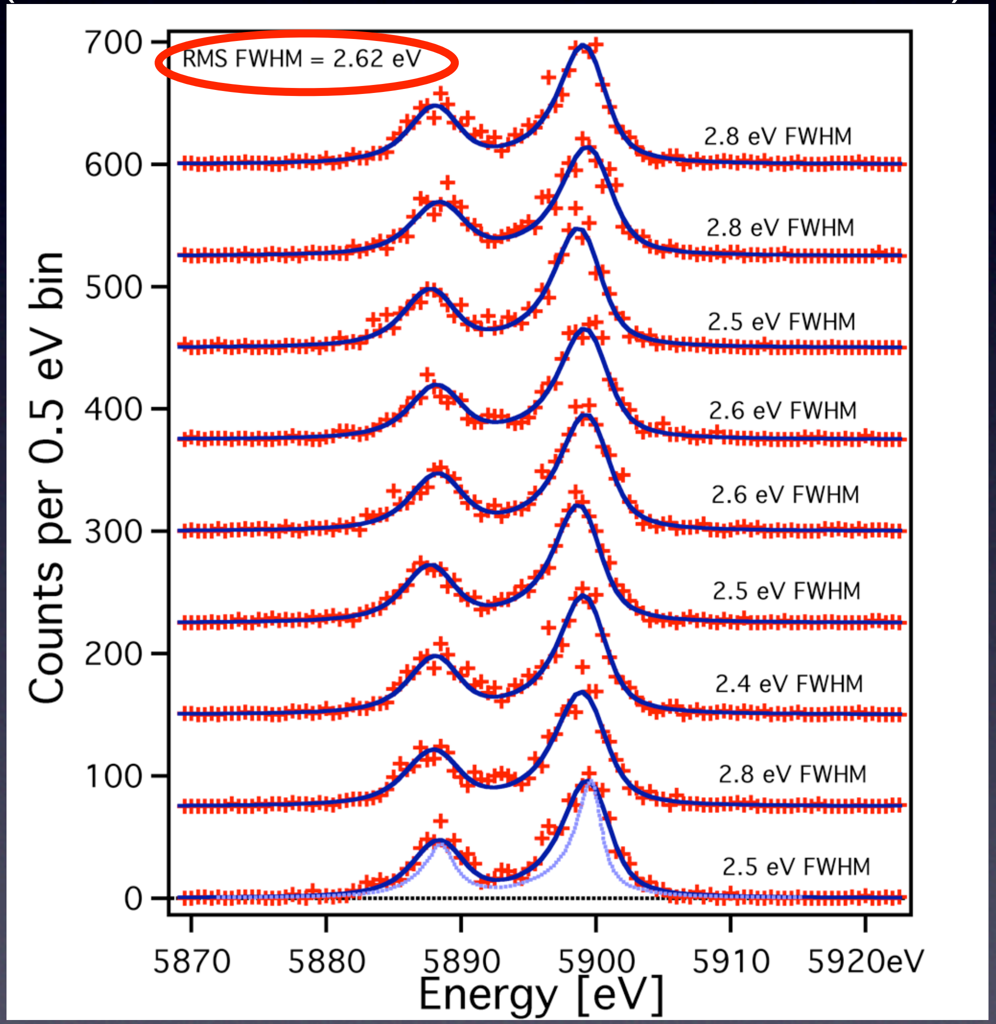


- $45M, 7-yr development program (SAO, GSFC, PSU, MSFC, Industry)
- TRL6 by 2019 through a rocket flight

Science instruments status

- CATGS — see Bautz et al.,Heilmann et al.
- XMIS — some areas of development are specific to *SMART-X* (4×4 or 5×5 Hydras, more pixels, energy vs. spatial resolution trade-off)
- APSI — straightforward development, but funding needed (see D. Burrows talk):
  - small pixel size + large depth
  - thin filter without hydrocarbon
  - fast readout + large arrays

Results for 3×3 Hydra
(65 μm absorbers vs. 46μm for *SMART-X*)



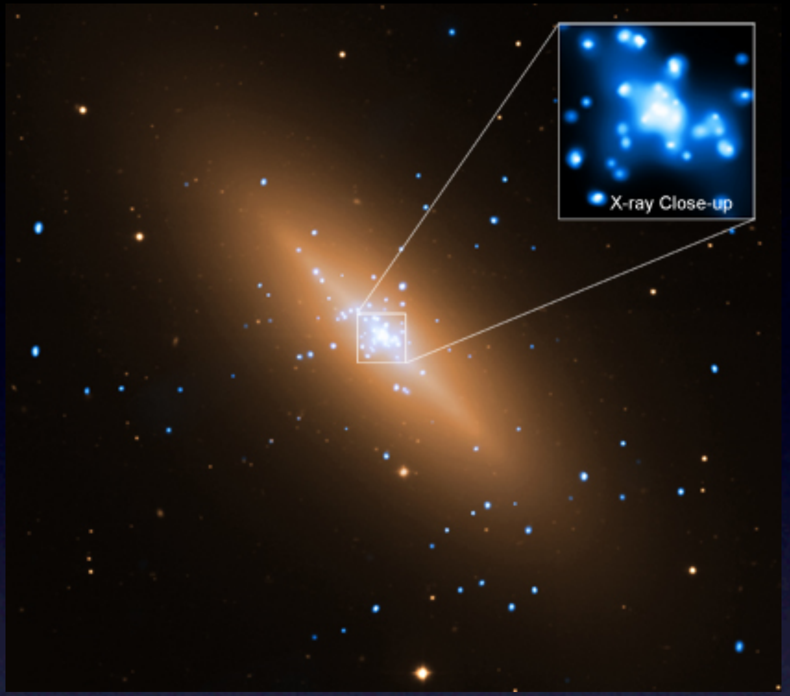
Cost

- Use AXSIO as a basis
- Add knowns and unknowns (conservatively)
  (e.g., 2× cost of module facilities, 50% instead of 30% reserves for mirror production)
- Δ from AXSIO = $430M
  $170M (mirrors) + $188M (instruments & spacecraft systems) + $52M (integration & test) + $20M (Atlas V-541)
- End-to-end cost = $2,328M

High-resolution spectroscopy

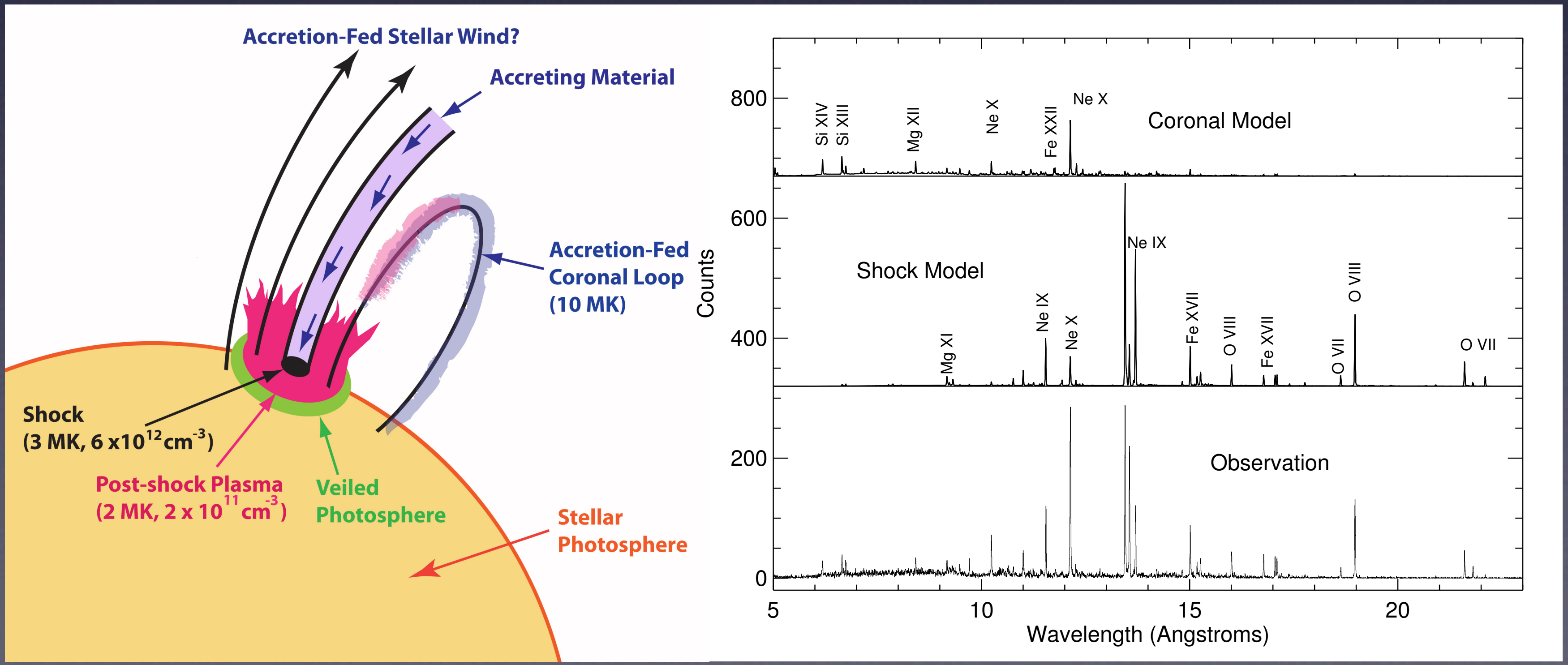
- Gas outflows in AGNs and starbursts
- Spectroscopy / tomography of slightly extended sources
- Active stars

Bondi radius in NGC3115

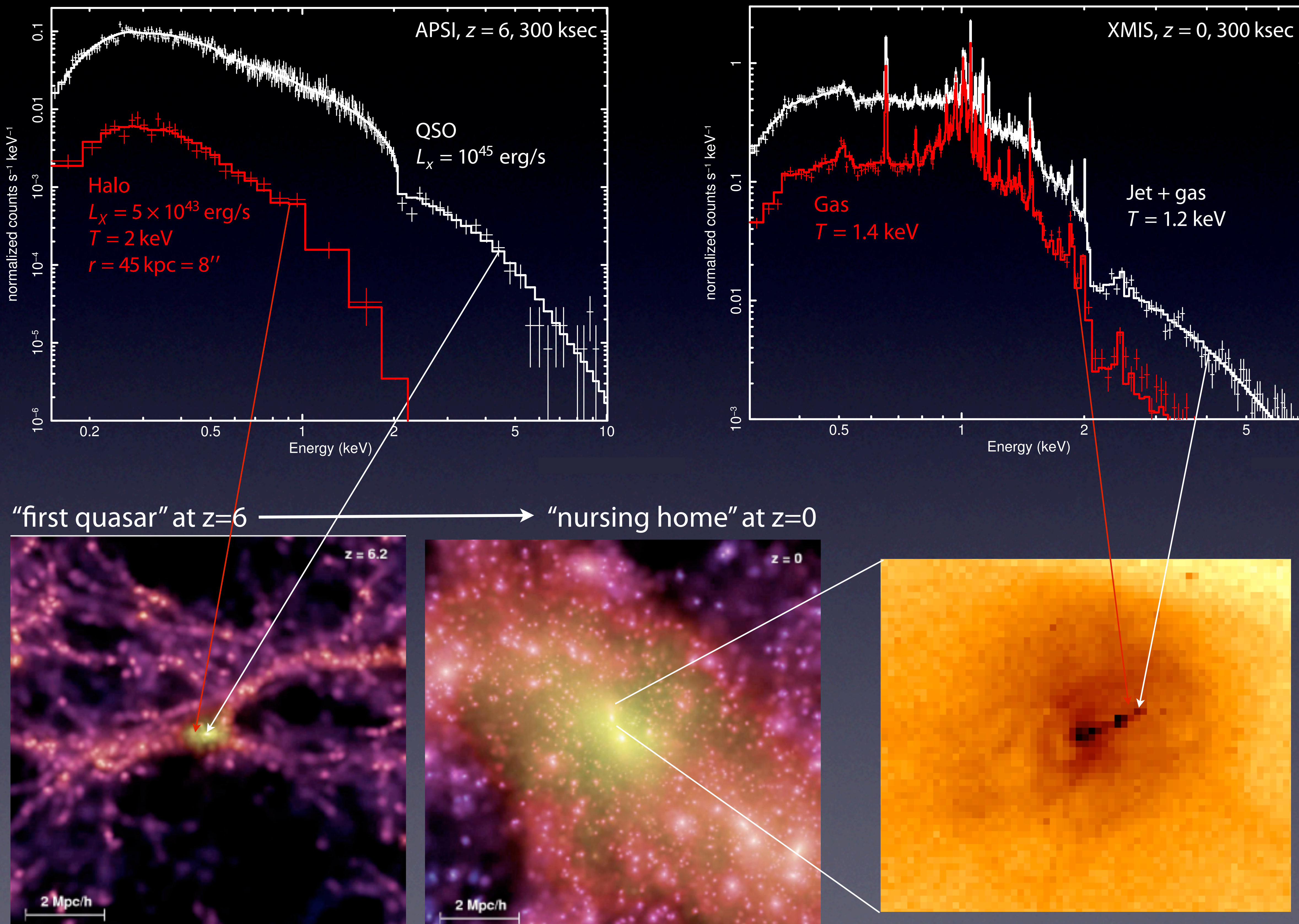


Trumpler 14, *Chandra*

X-ray spectral diagnostic of TW Hydrae with *Chandra* (Brickhouse et al '10)



Black holes and LSS from z=6 to the present

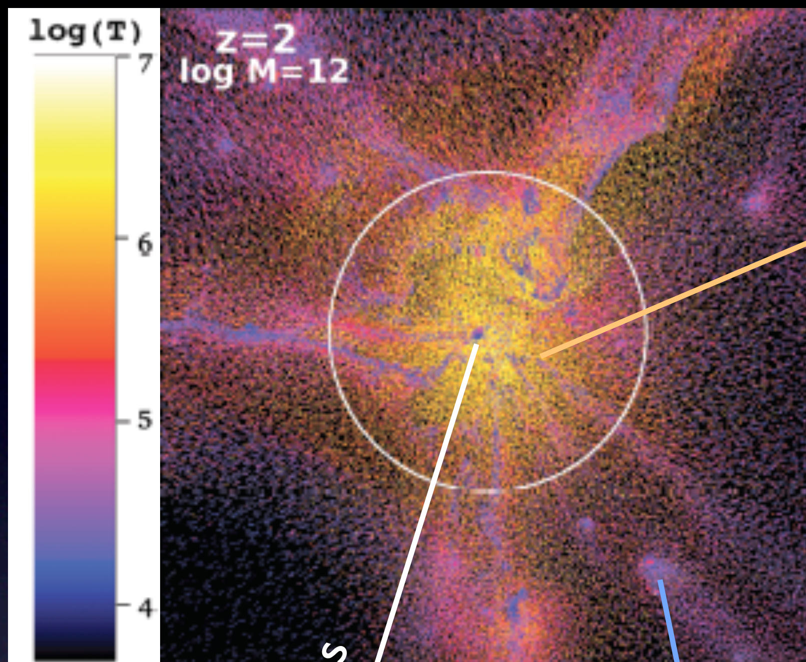


Springel et al. 2005 simulations — dark matter density

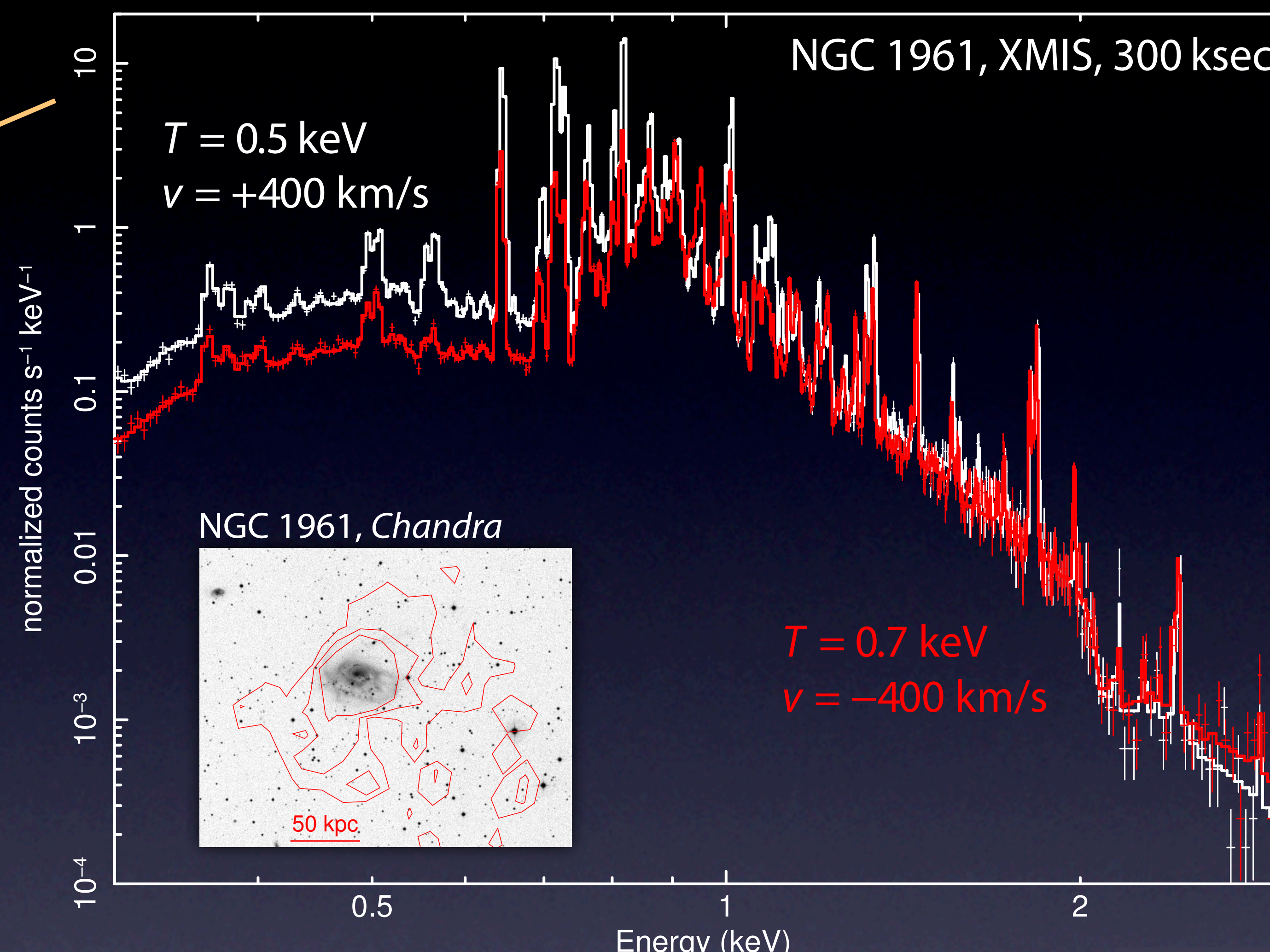
M87, *Chandra*, 1″ pixels

Galaxy and star formation

Keres et al. simulations



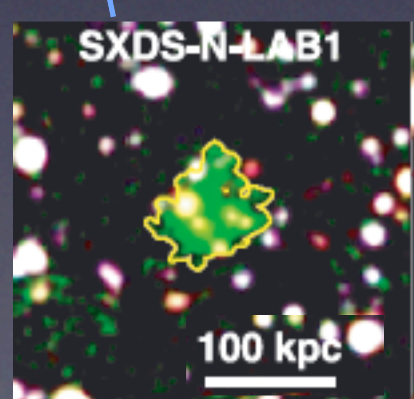
Hot halos
SMART-X



Stars, dust,molecular gas
optical, IR, ALMA, eVLA

Cold accretion
Ly-α

HST+ALMA, z=0



Subaru, z=3

- Observations of hot halos around SFR≳30 $M_\odot$/yr galaxies at $z\sim2.5$
- Detailed study of hot phase at $z=0$
- Star-forming regions in the MW

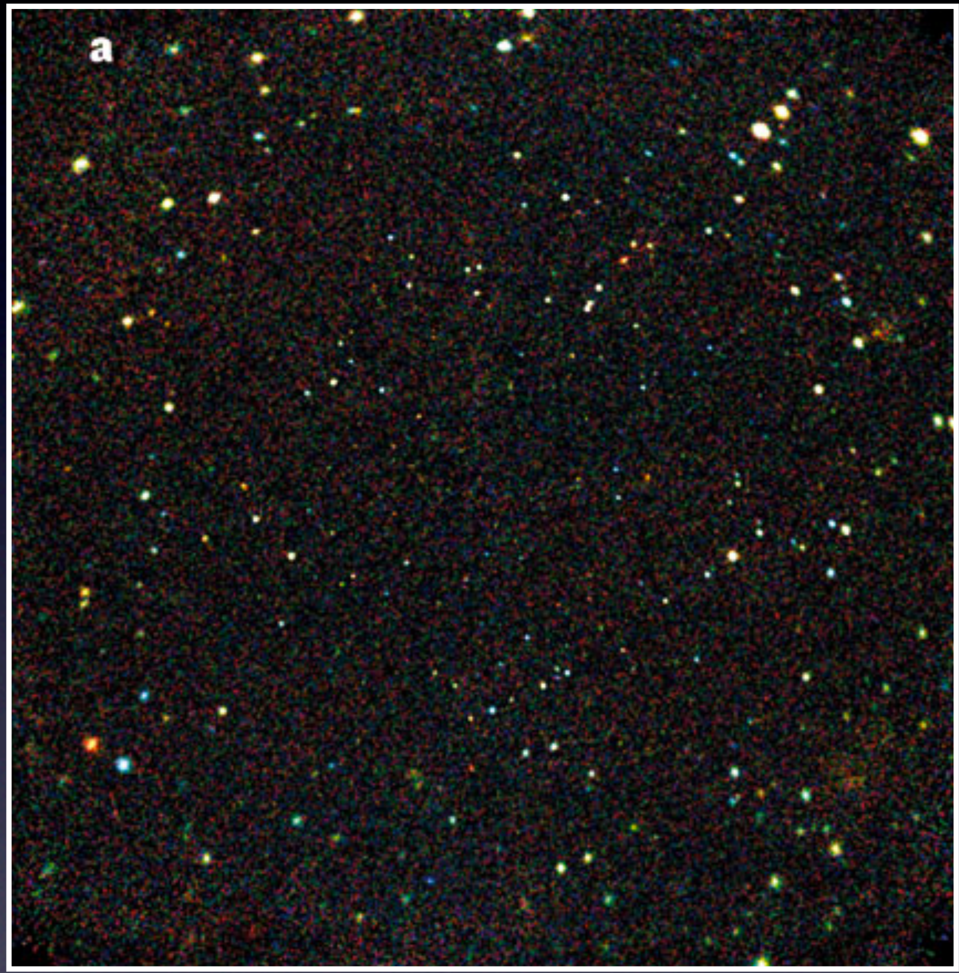
Surveys

- Vs. *Chandra*:
  50× soft-band throughput,
  98× grasp,
  more uniform PSF (4″ HPD at 10′),
  same particle background

- Deep Field South depth in 80 ksec,
  10 deg^2 to this depth = 8 Msec program

- 4 Msec ⇒ $f_{min} = 3\times10^{-19}$ erg s^{-1} cm^{-2},
  $L_{min} = 3.3\times10^{41}$ erg s^{-1} at $z = 10$

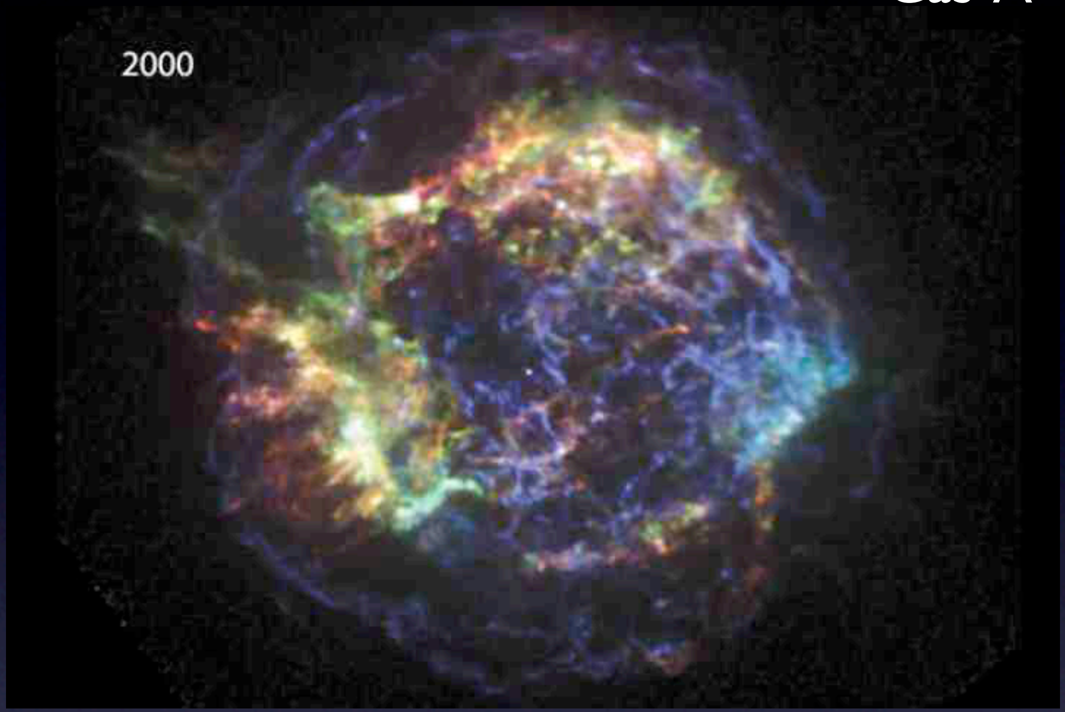
CDFS, *Chandra*, 4 Msec, 16′×16′

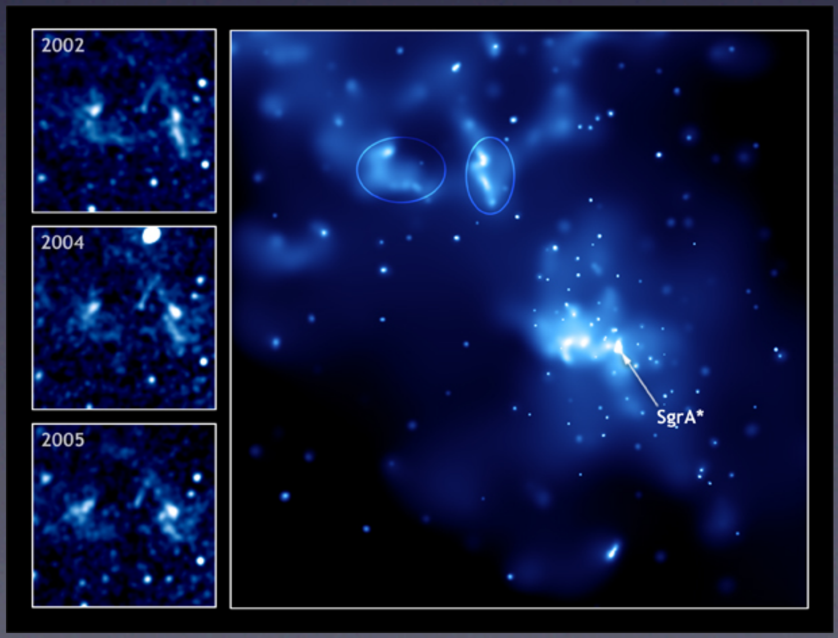


Imaging time-domain X-ray astronomy

- Evolution of SNRs (Cas-A)
- Cooling of neutron stars
- Light echos from Sgr A*
- Long-term evolution of jets (M87), repeated Deep Field observations
- SN 1987A

Cas-A

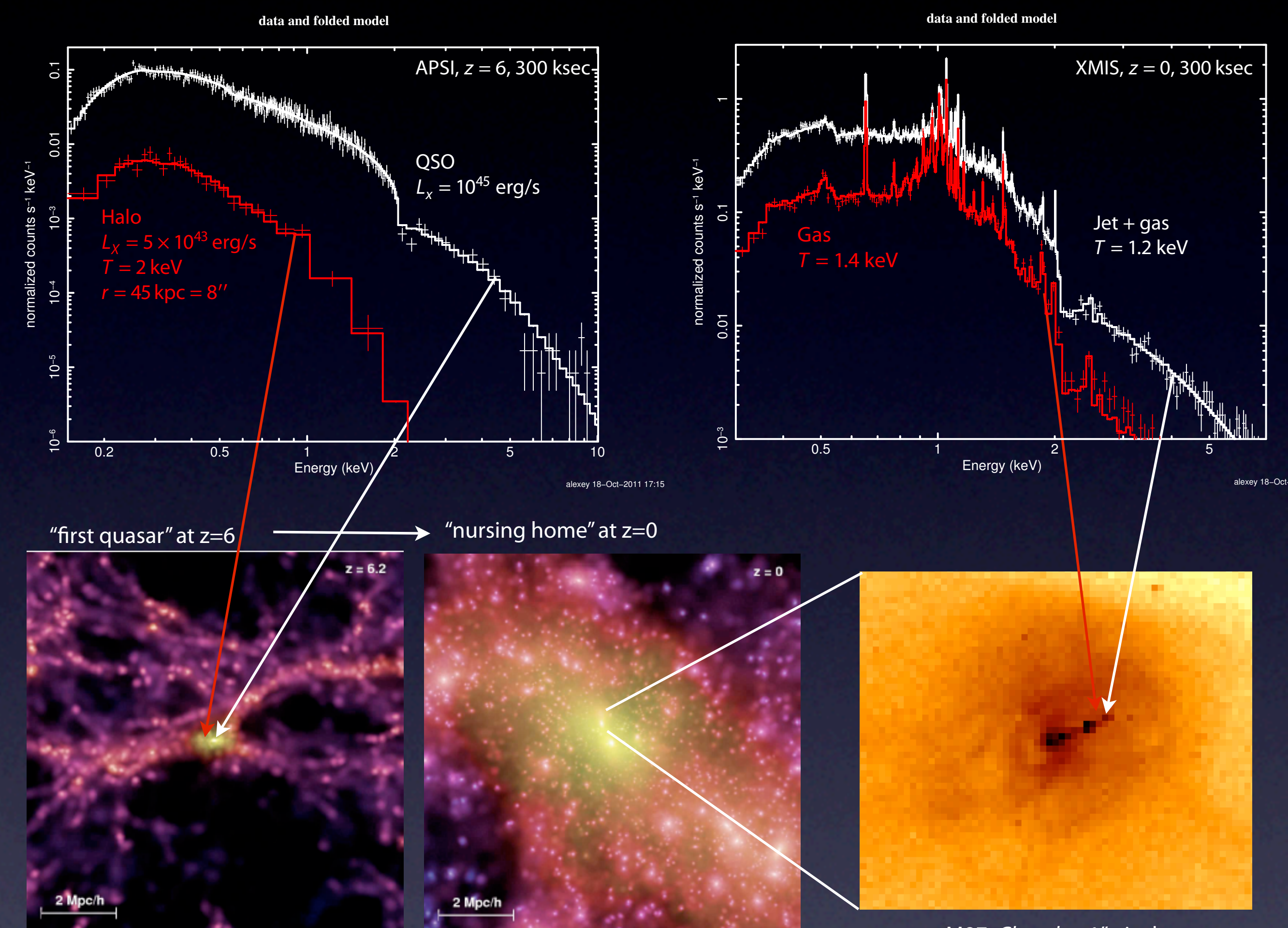




SMART-X

- *Chandra*'s angular resolution, 0.5″
- with 30× effective area
- and state-of-the-art science instruments
- for $2.3B

Needs funding for mirror technology program



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