HEAD 2017
Sun Valley, Idaho
21 August 2017

AXIS

Advanced X-ray Imaging Satellite

Erin Kara and Eric Miller

on behalf of PI Richard Mushotzky and the AXIS Team

The AXIS Team

PI: Richard Mushotzky

Our first team meeting at the University of Maryland, College Park. June 14-15, 2017.

List of Attendees (left to right): Mike Lowenstein, Andy Ptak, Randall Smith, Lynne Valencic, George Chartas, Will Zhang, Maxim Markevitch, Richard Mushotzky, Brian Morsony, Francesco Tombesi, Rob Petre, Eric Miller, Helen Russell, Chris Reynolds and Erin Kara.

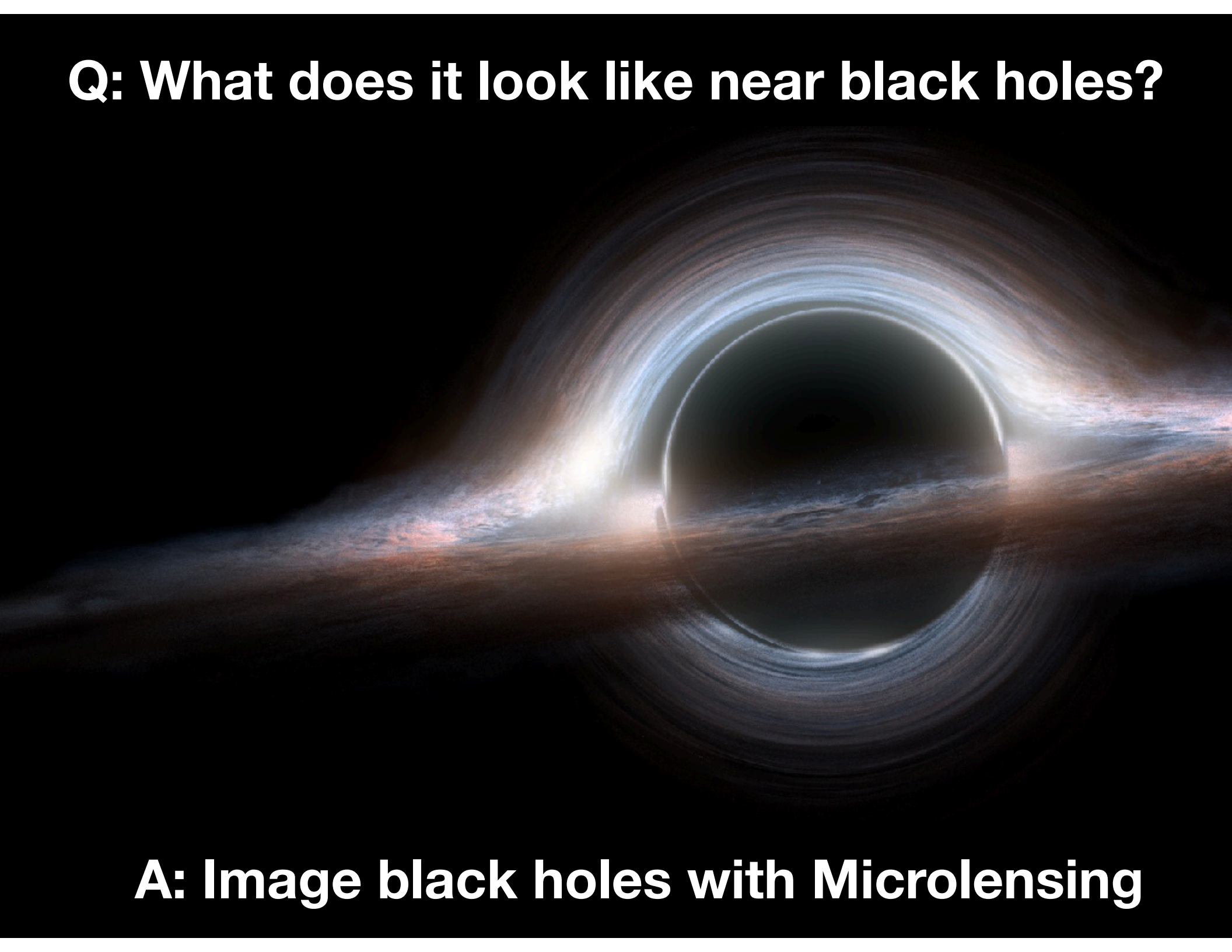
Not Pictured: Amy Barger, David Burrows, Andy Fabian, Catherine Grant, Edmund Hodges-Kluck, Mike Koss, Jon Miller, John Mulchaey and Hiroya Yamaguchi.

AXIS Basics

Area	Value
Angular Resolution	~ 0.3 arcsec
Bandpass	0.1-12 keV
Effective Area	4000 cm2 @ 1 keV; 1000 cm2 @ 6 keV
Energy Resolution	150 eV @ 6 keV (CCD resolution)
Total count rate / source	10x Chandra's at launch value
Detector Background	5 x less than Chandra

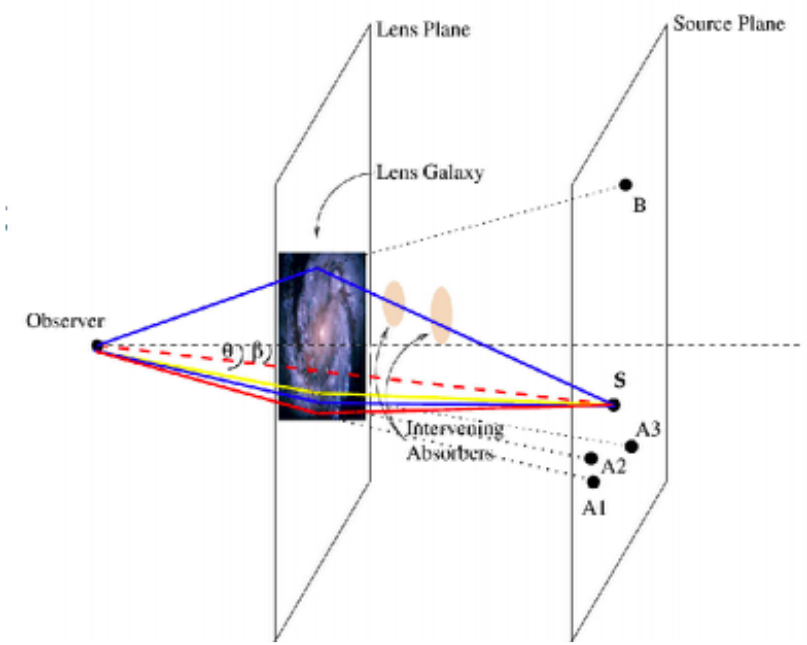
The range of AXIS science…

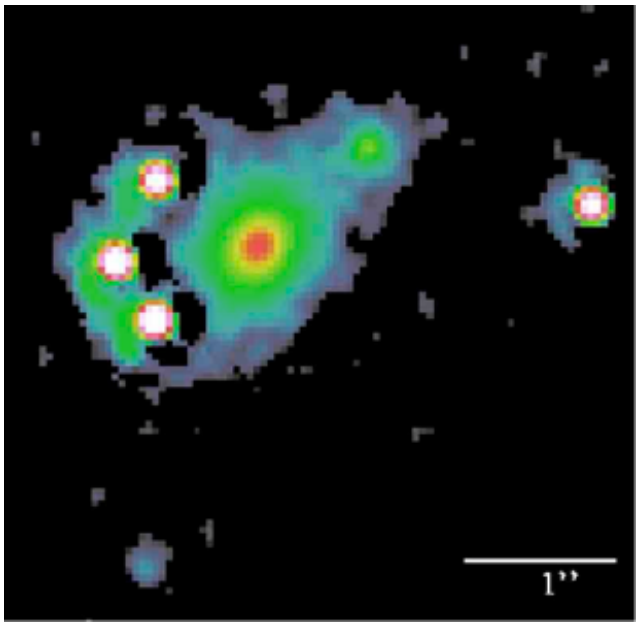
Q: What does it look like near black holes?

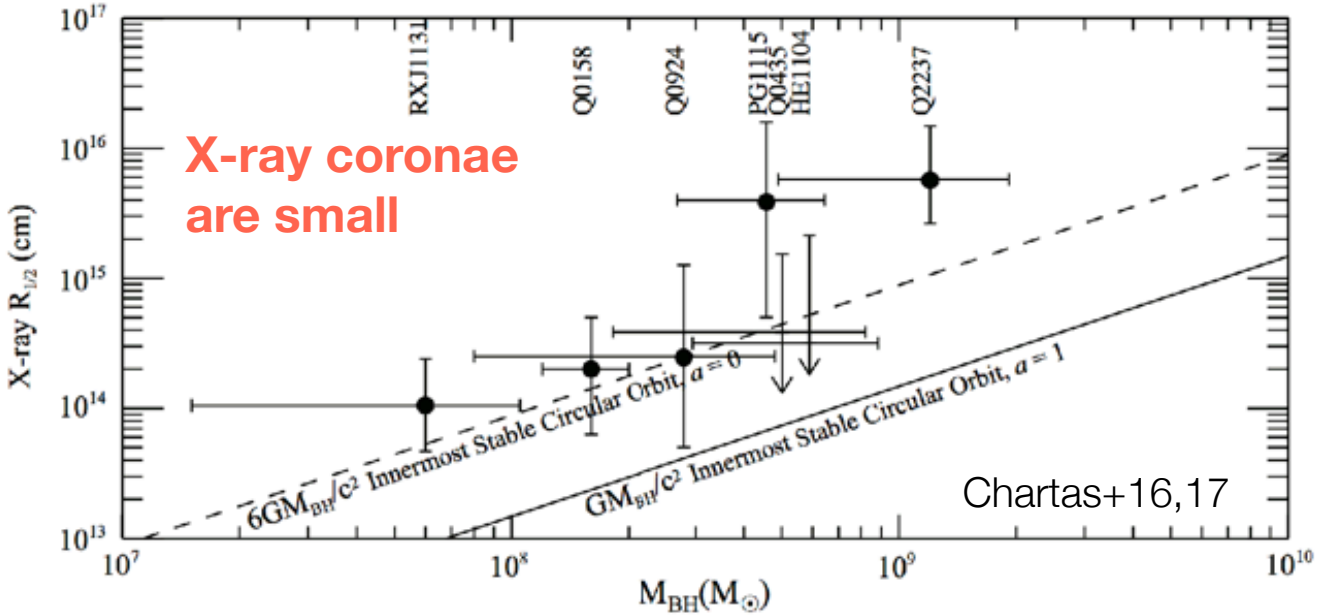


A: Image black holes with Microlensing

Quasar Microlensing

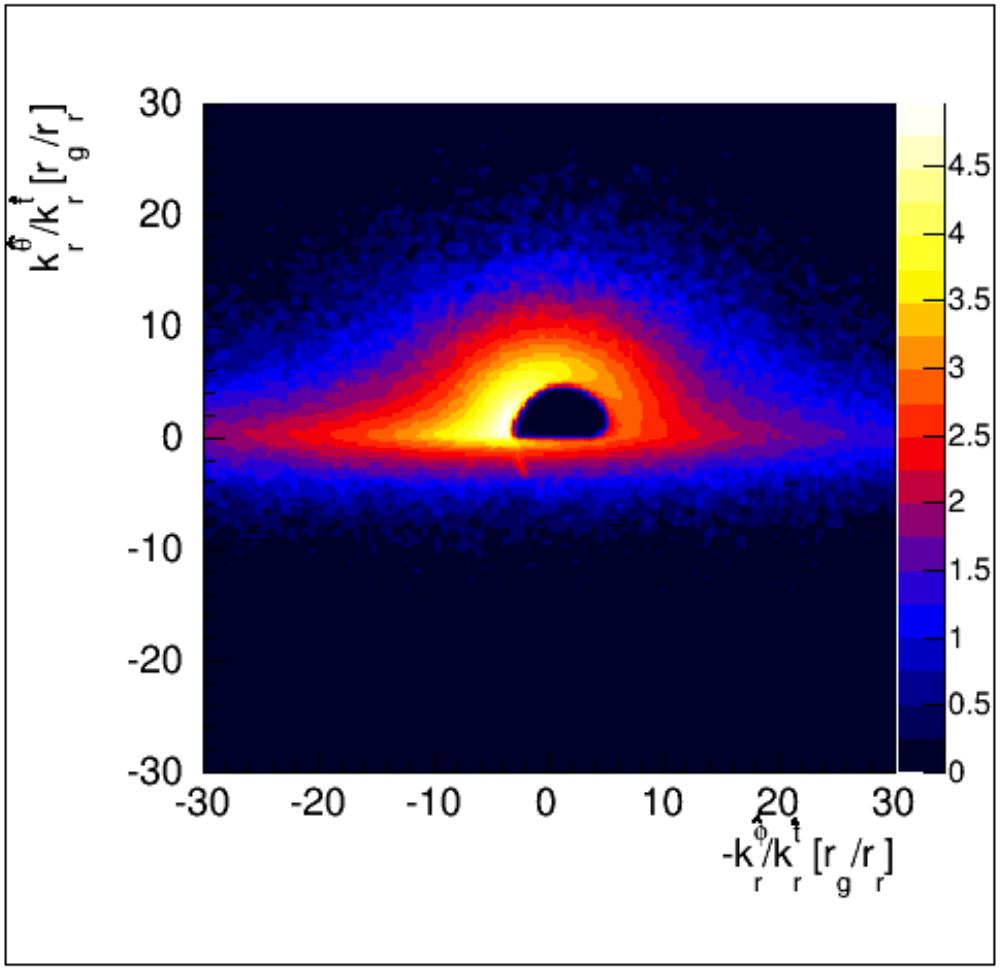




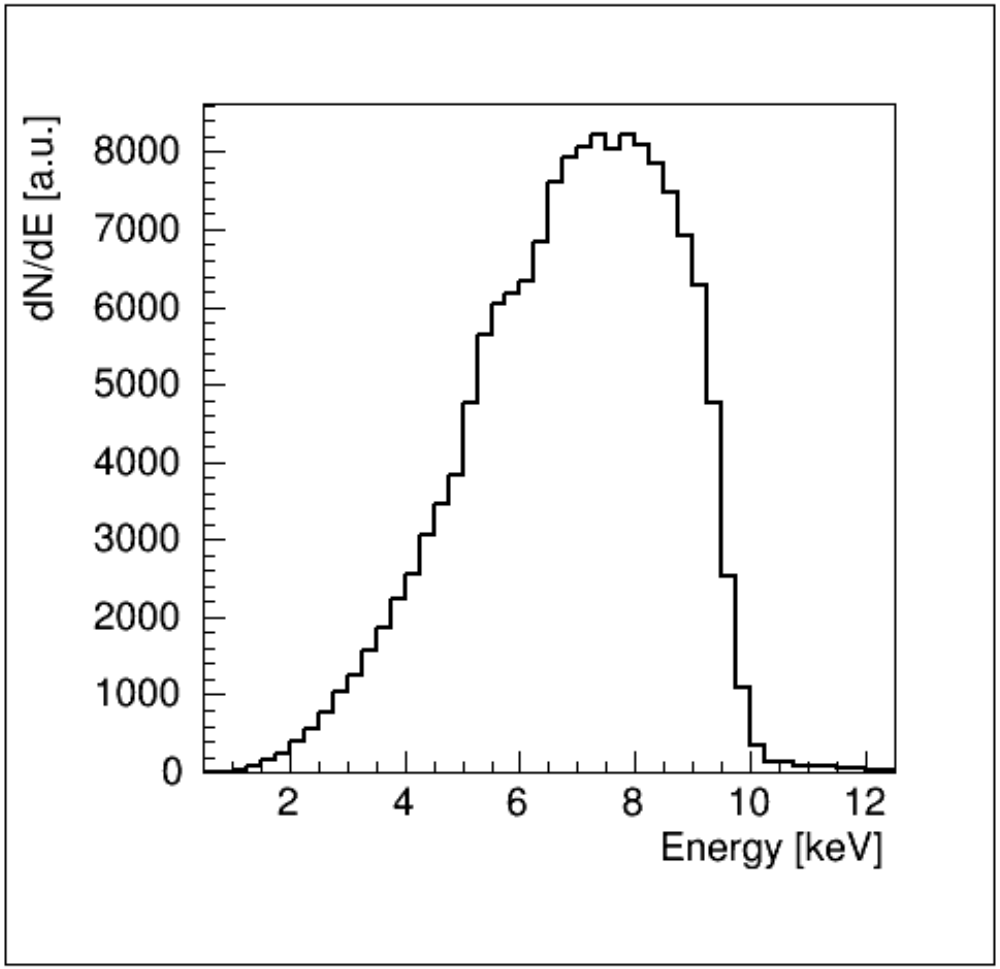


AXIS Science Lead: George Chartas

Imaging SMBHs in Quasars



Iron K emission map from disc at i=82° around black hole with a=0.3

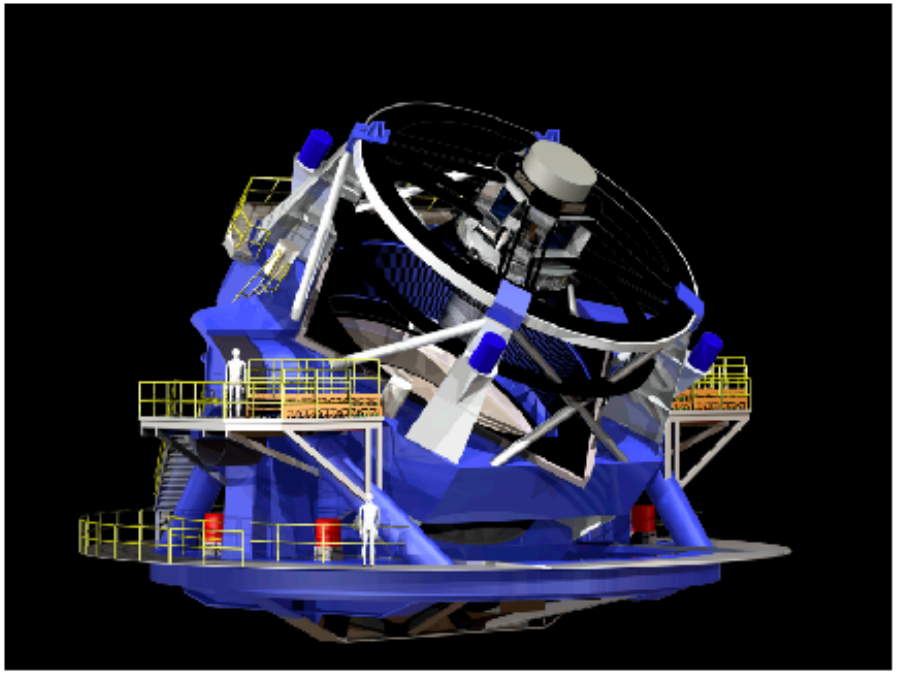


Resulting iron K emission line spectrum (look at y-axis change!)

AXIS Science Lead: George Chartas

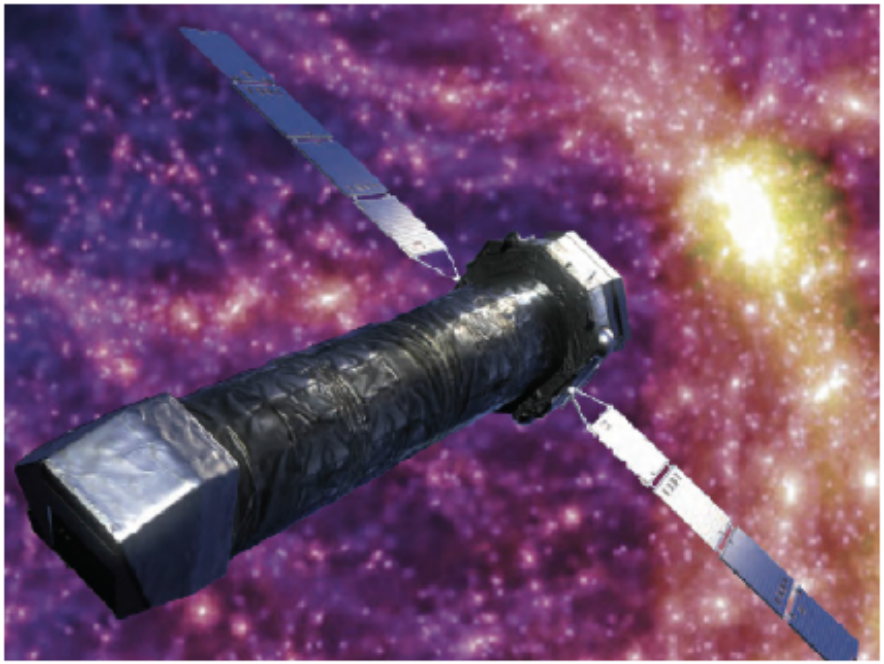
AXIS comes at the perfect time!

LSST (2023-2033)



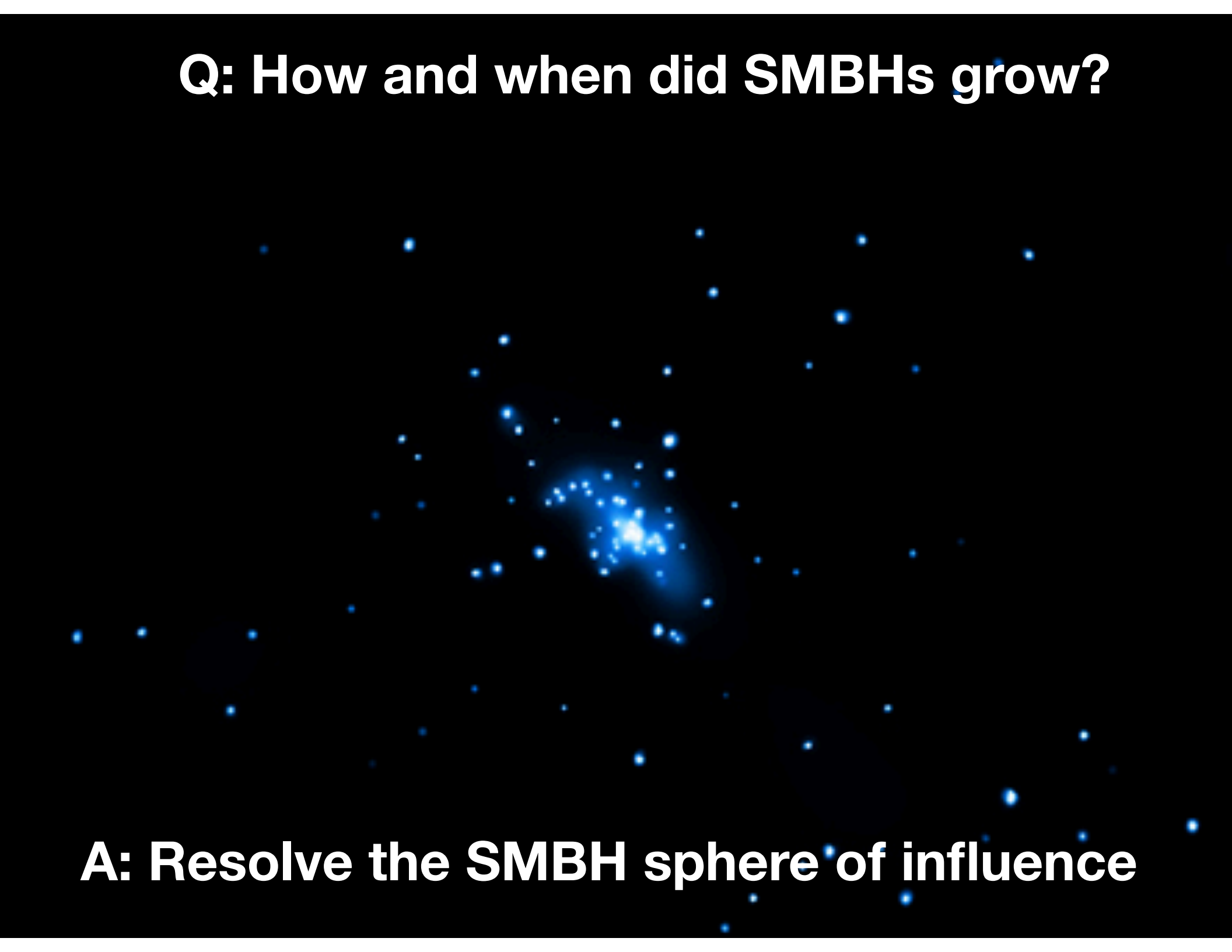
- **LSST will find 4000 new lensed quasars**
- **Daily monitoring will determine which sources have active caustic crossings**

Athena (2028 - 2033)



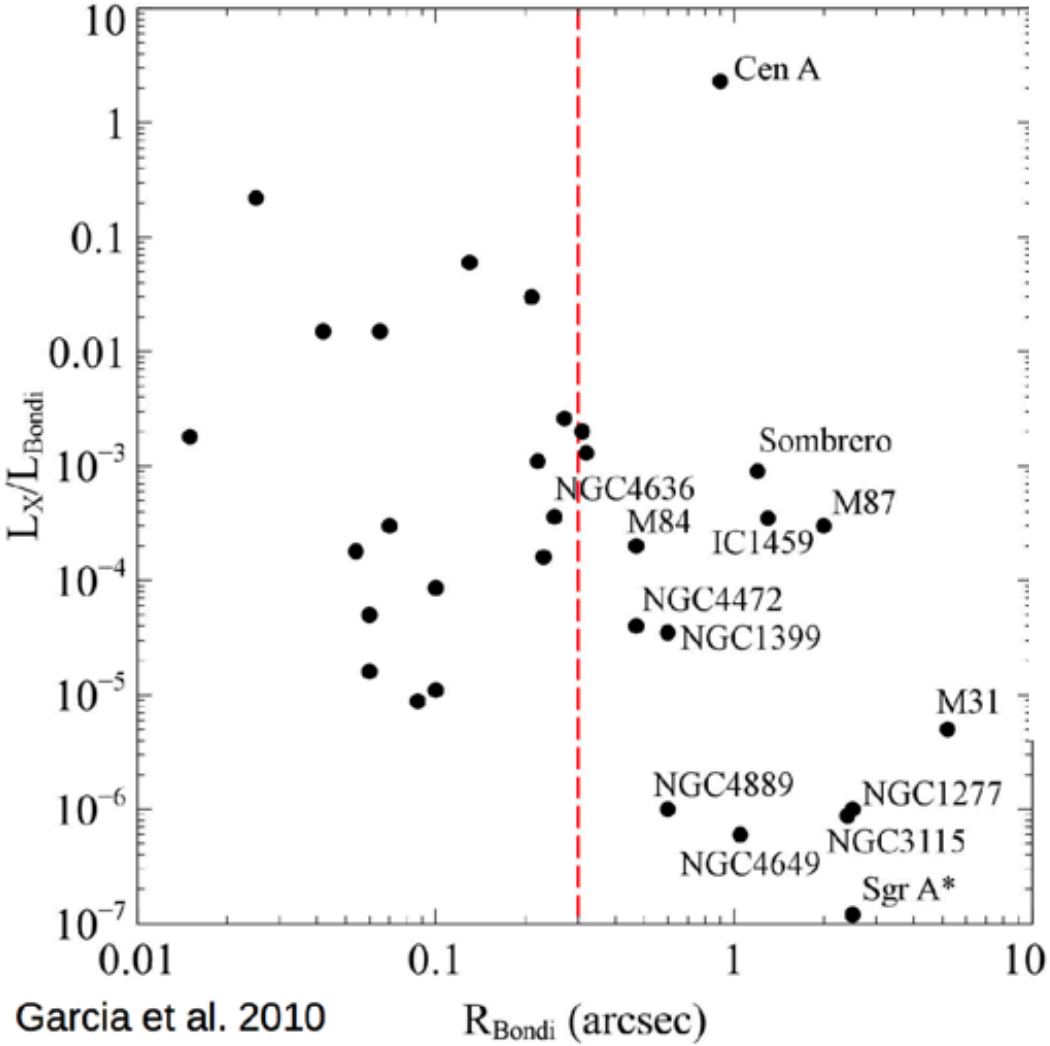
- **Prime science of Athena is to measure black hole spin in distant quasars**

Q: How and when did SMBHs grow?

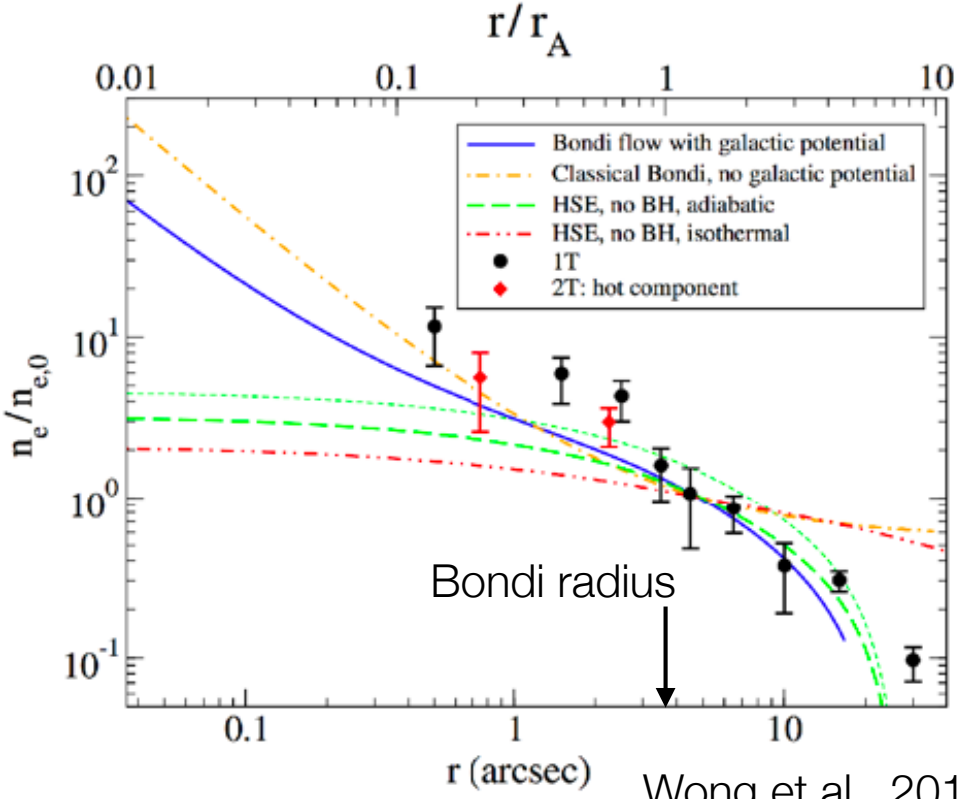


A: Resolve the SMBH sphere of influence

Imaging the gravitational sphere of influence in SMBHs



Garcia et al. 2010

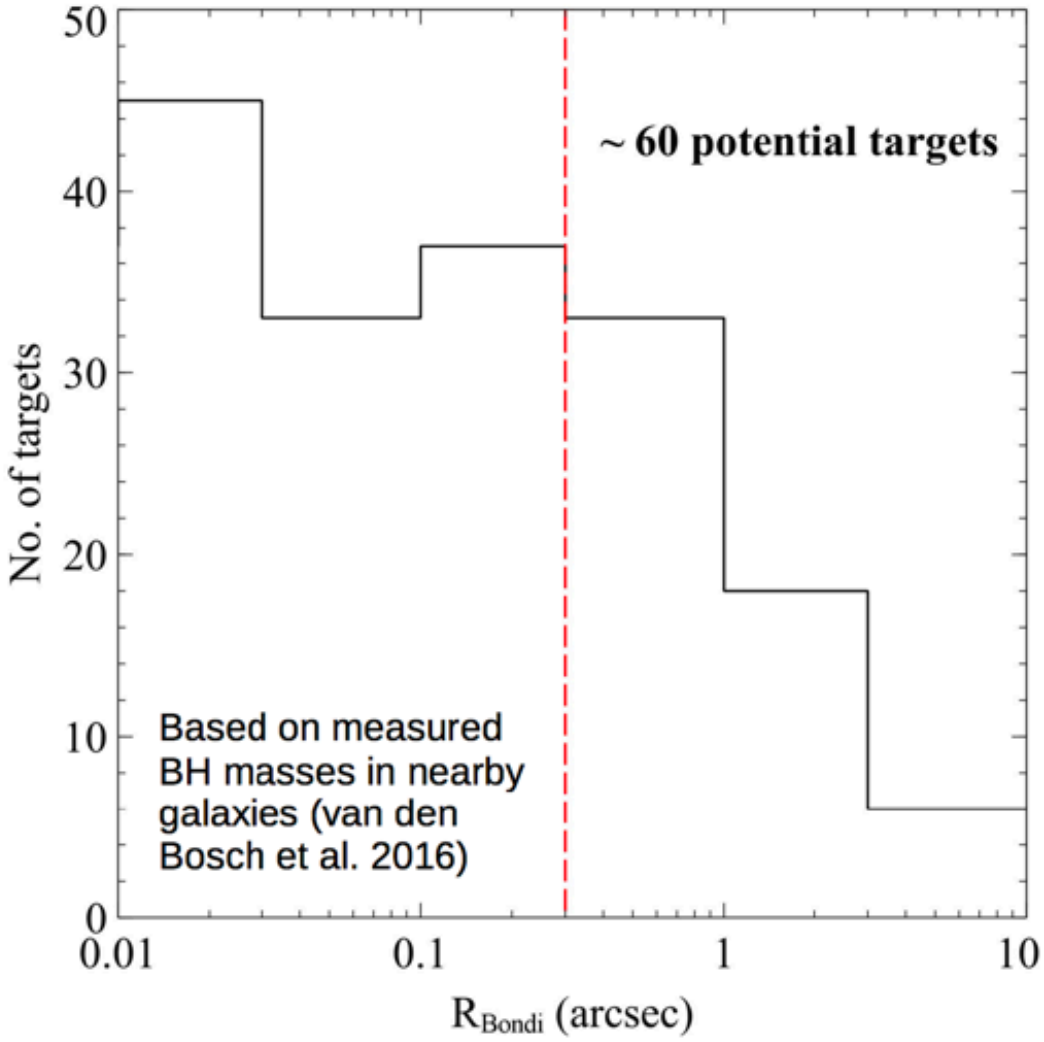


Wong et al., 2014

Chandra can only measure Bondi radius in a handful of elliptical galaxies…

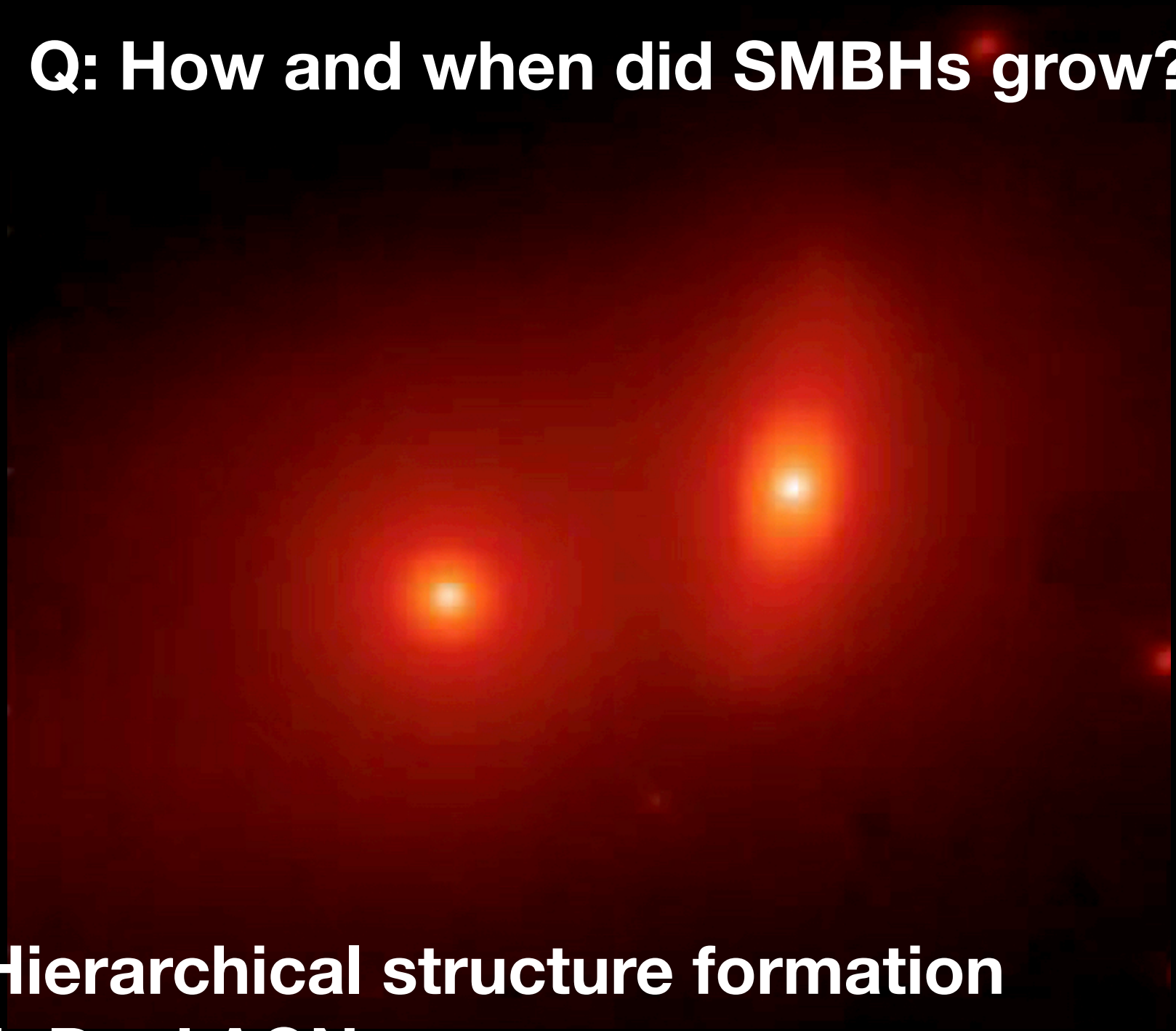
AXIS Science Lead: Helen Russell

Imaging the gravitational sphere of influence in SMBHs



AXIS will measure Bondi radius in ~60 AGN!

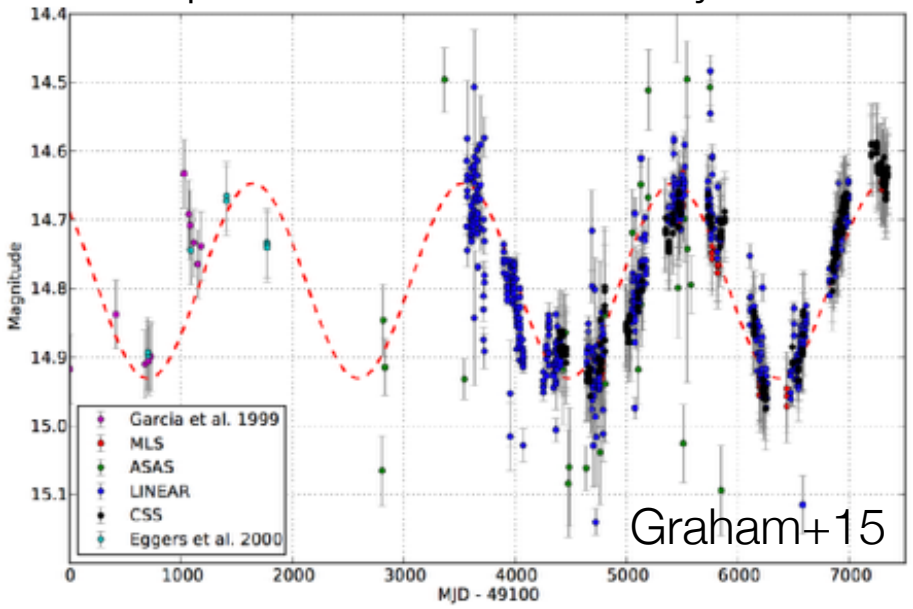
Q: How and when did SMBHs grow?

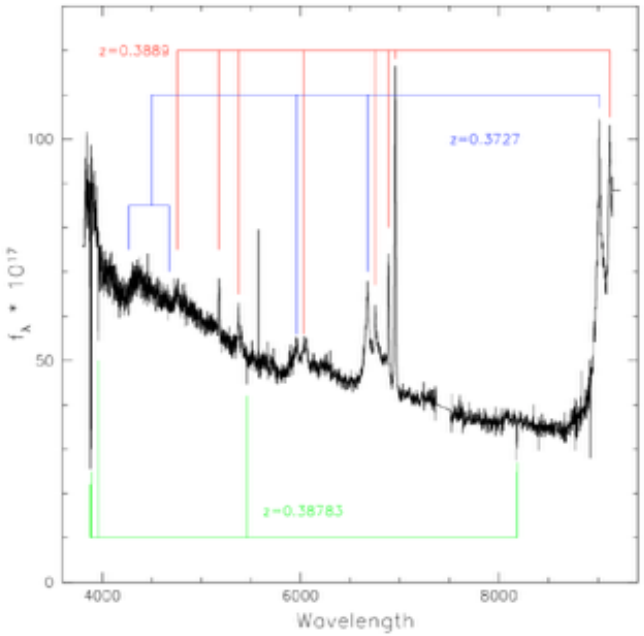


A: Hierarchical structure formation with Dual AGN

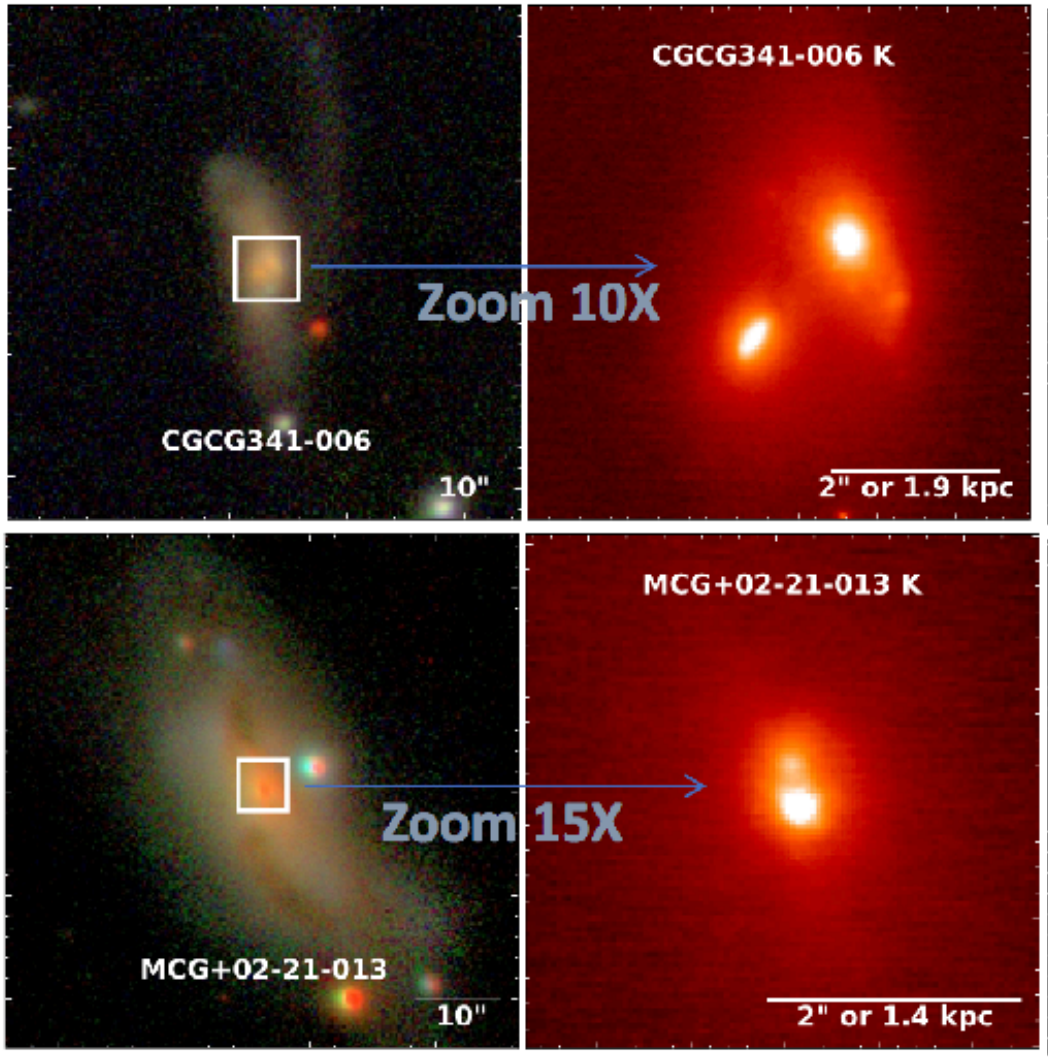
Dual AGN

Optical searches for binary AGN





X-rays are a great way to find dual AGN



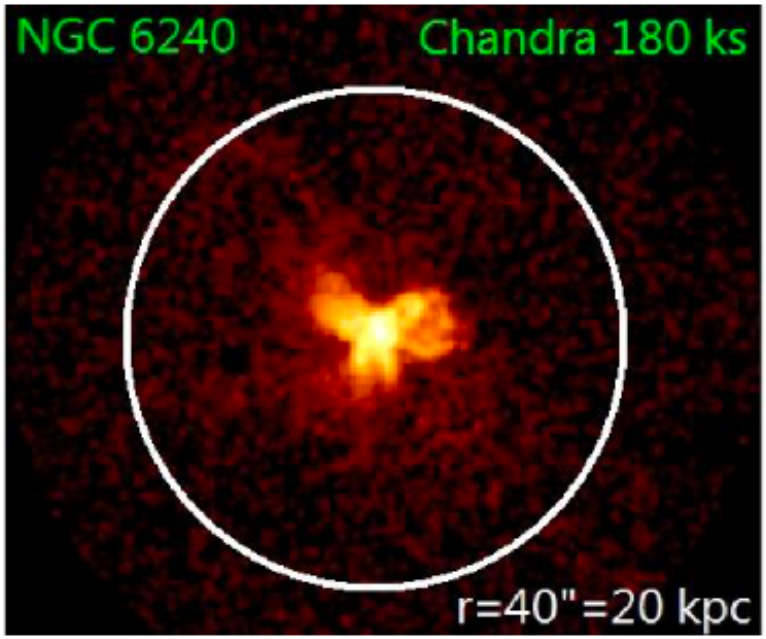
Koss + submitted, using Swift BAT selected luminous absorbed AGN

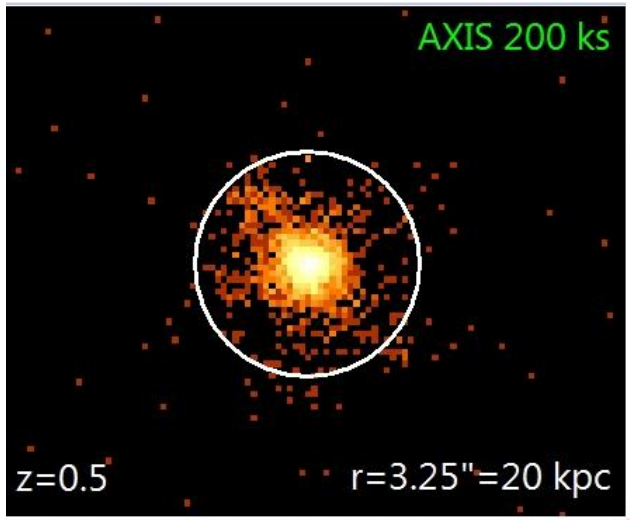
AXIS Science Lead: Mike Koss

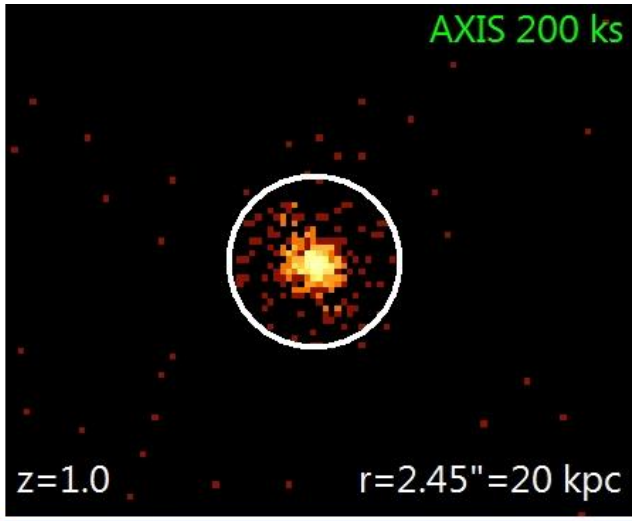
Q: How does gas get into and out of galaxies?

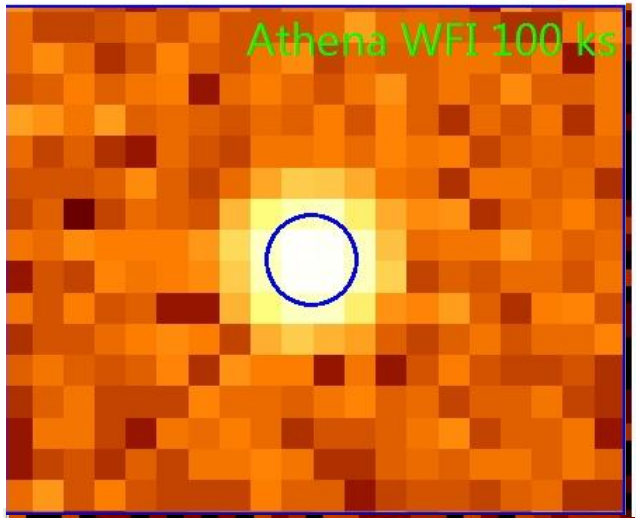
A: Probe galaxies over Cosmic Time

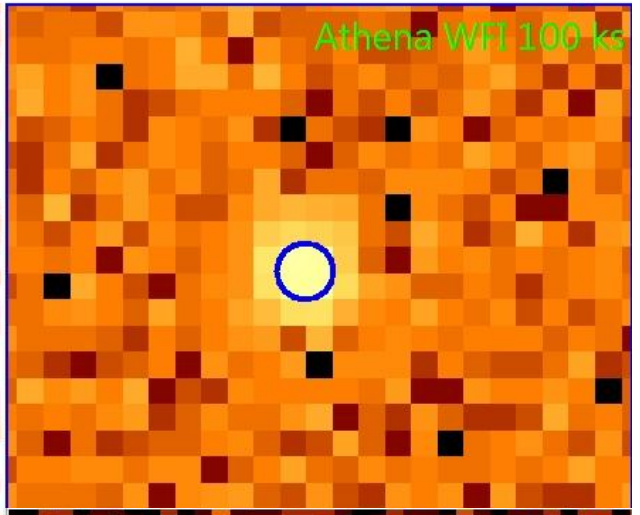
Imaging galaxies out to high redshift

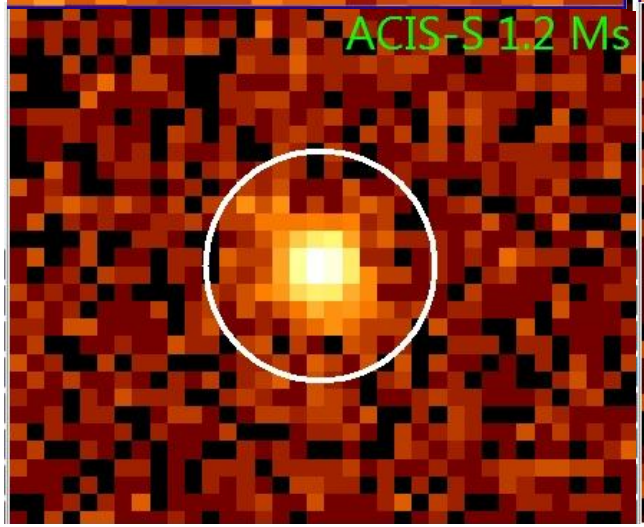


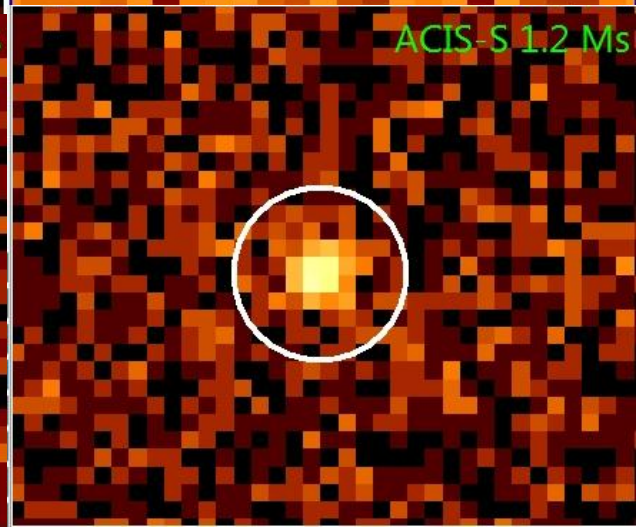










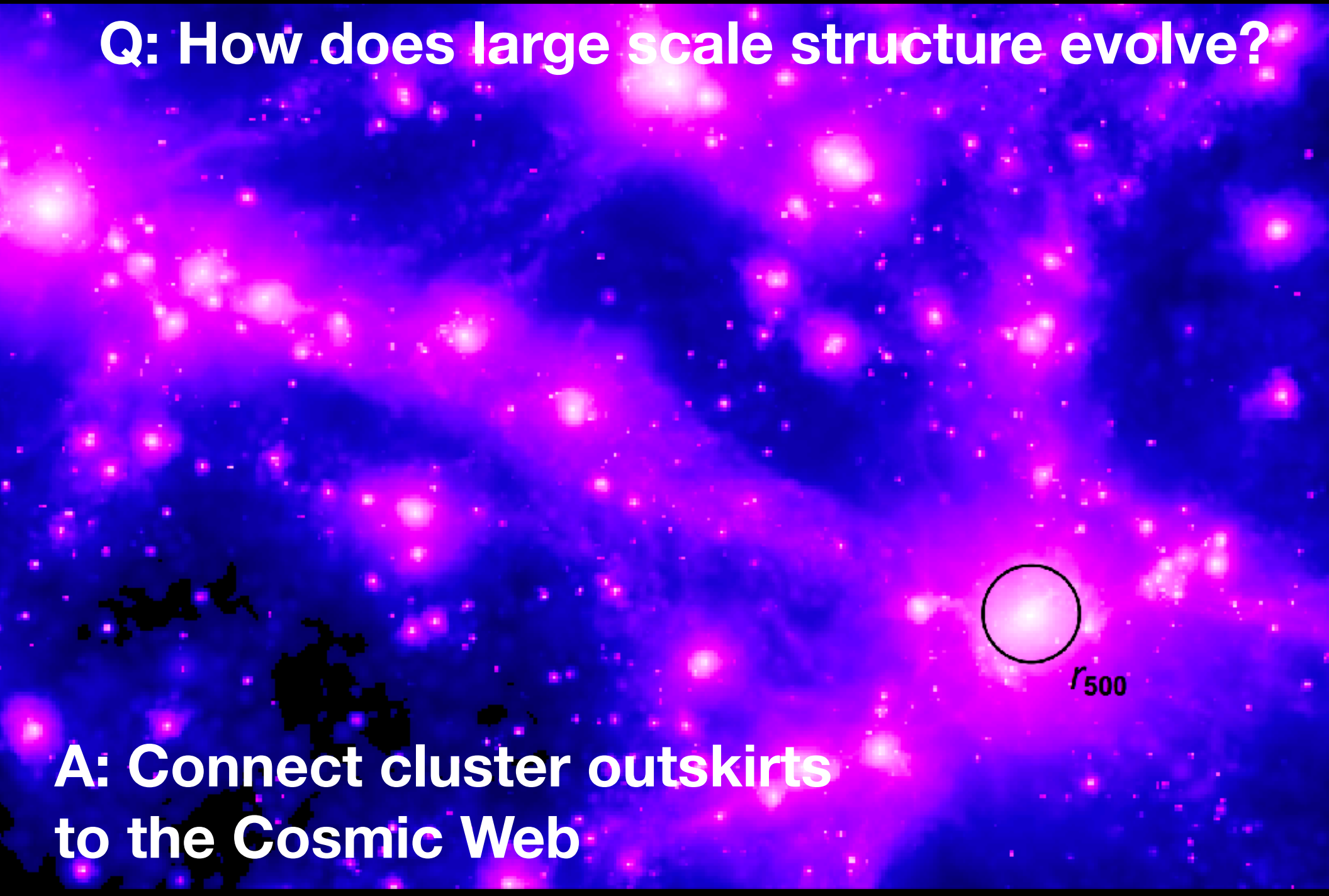


NGC 6240
ULIRG at z=0.02

local analog to galaxies common at z>0.5

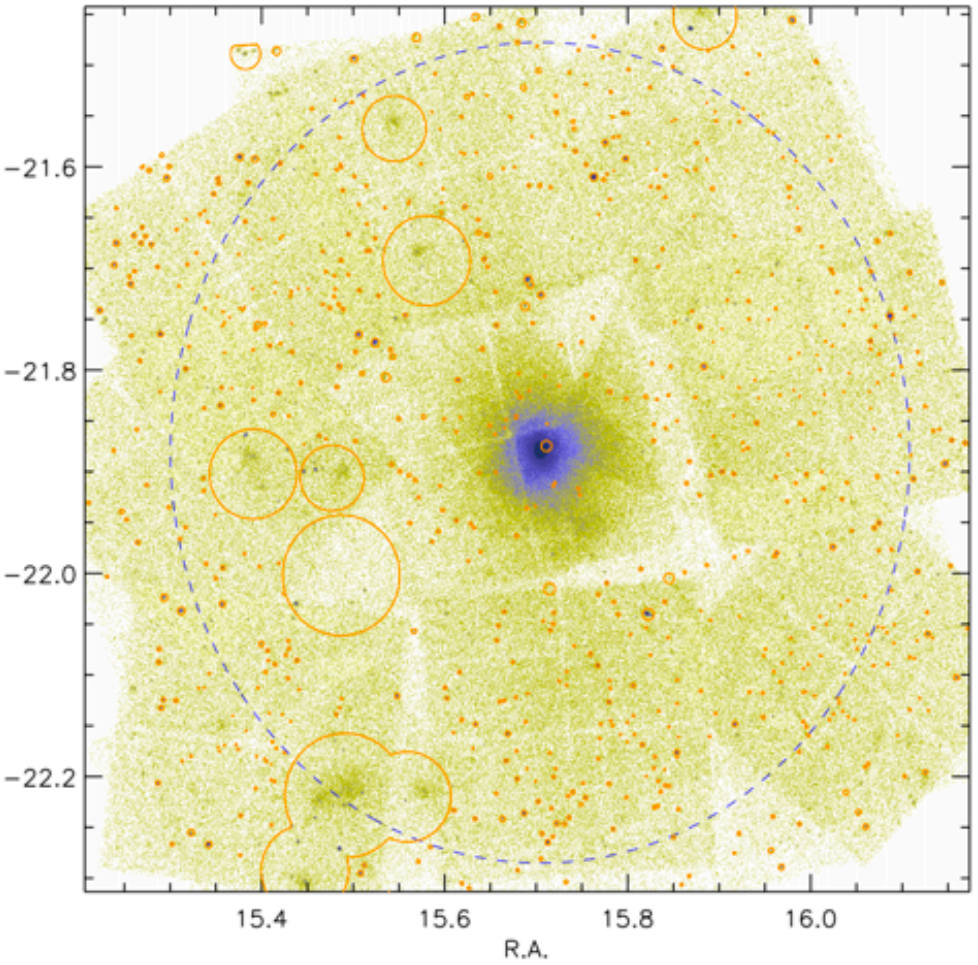
simx simulations by
Edmund Hodges-Kluck

Q: How does large scale structure evolve?

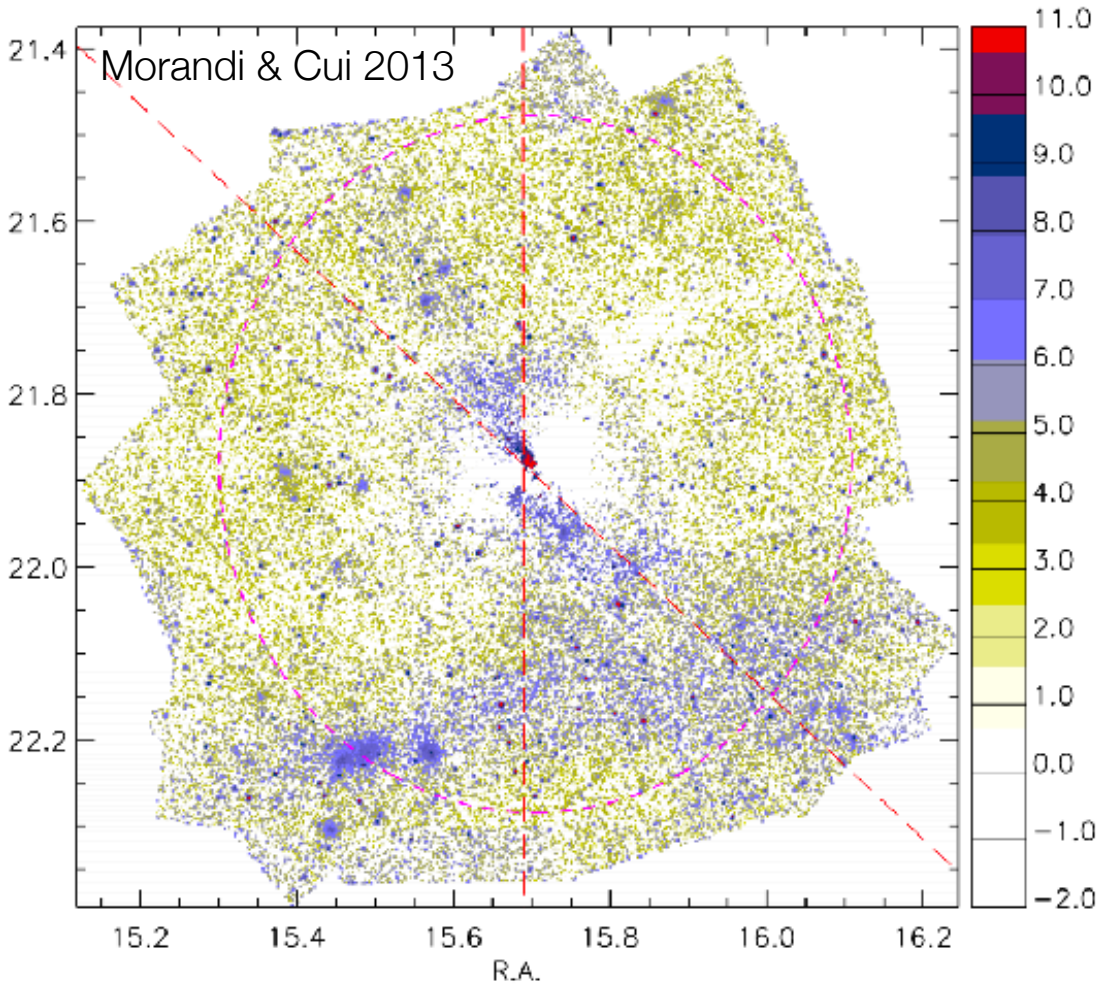


A: Connect cluster outskirts to the Cosmic Web

Connecting cluster outskirts to the Cosmic Web



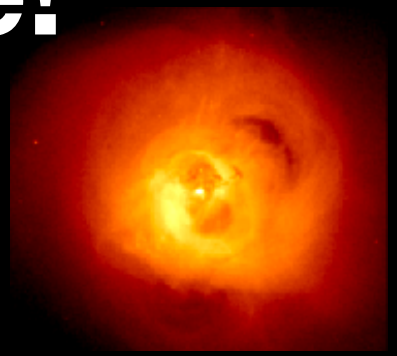
Chandra Mosaic of A133 with point sources identified



Unsharp mask image showing excess surface brightness

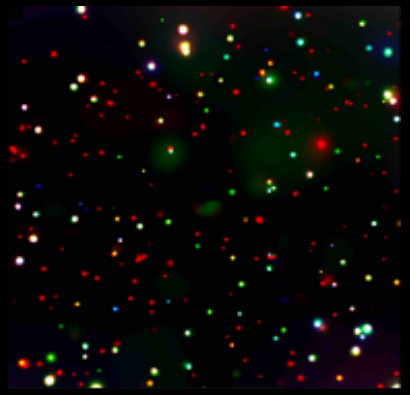
AXIS Science Lead: Maxim Markevitch

Lots of other cool science!
Do you have ideas?



AGN Feedback
in Clusters

Ultraluminous
X-ray Sources

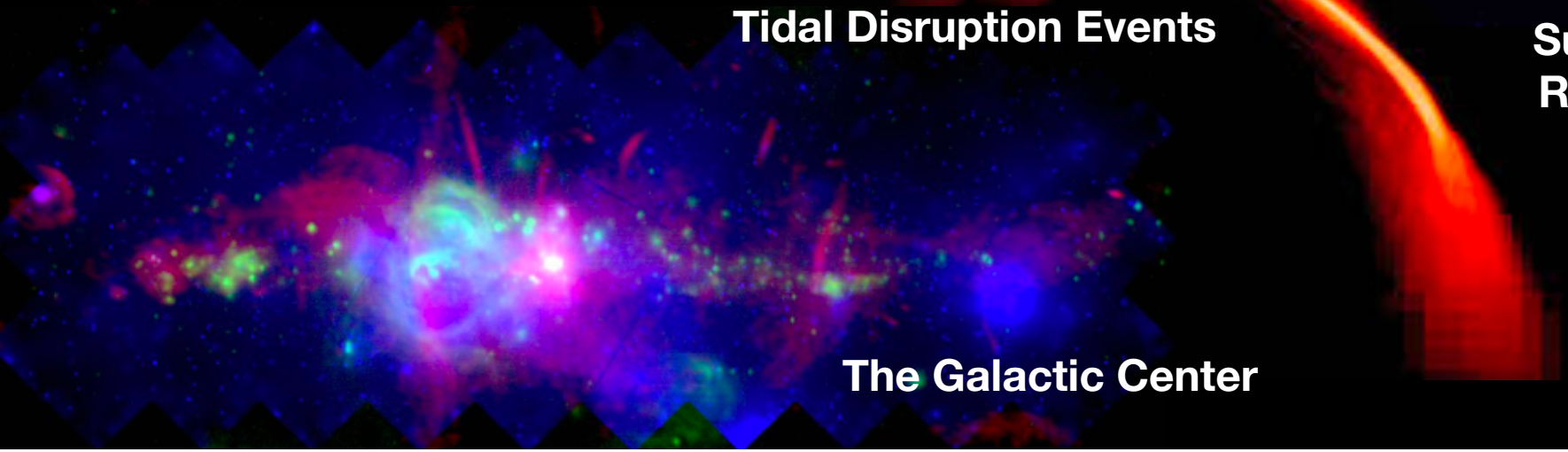


Deep fields

Relativistic Jets

Supernove
Remnants

Tidal Disruption Events



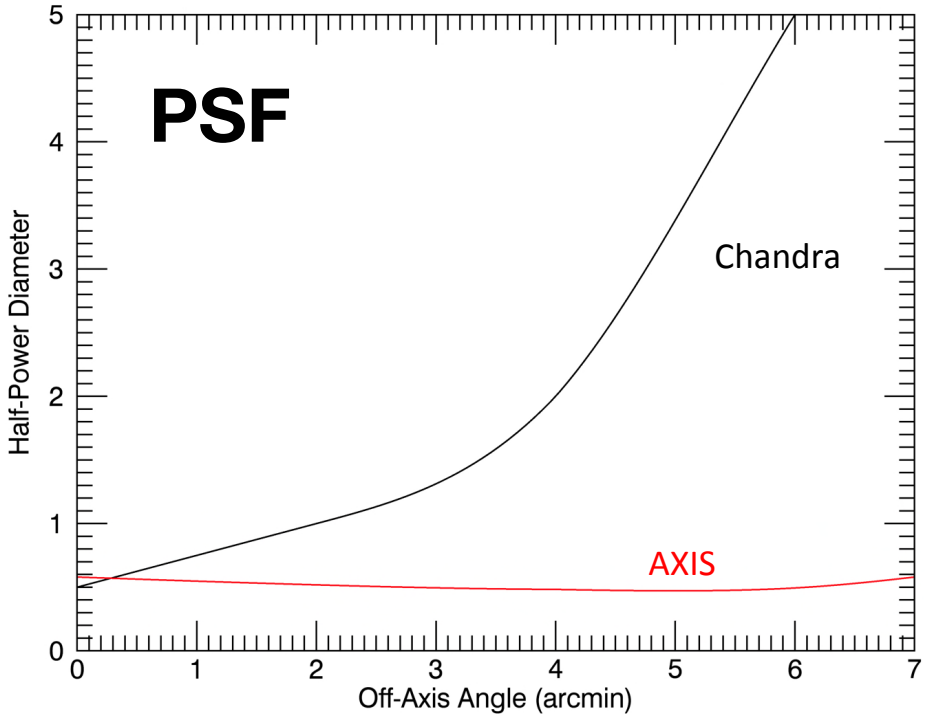
The Galactic Center

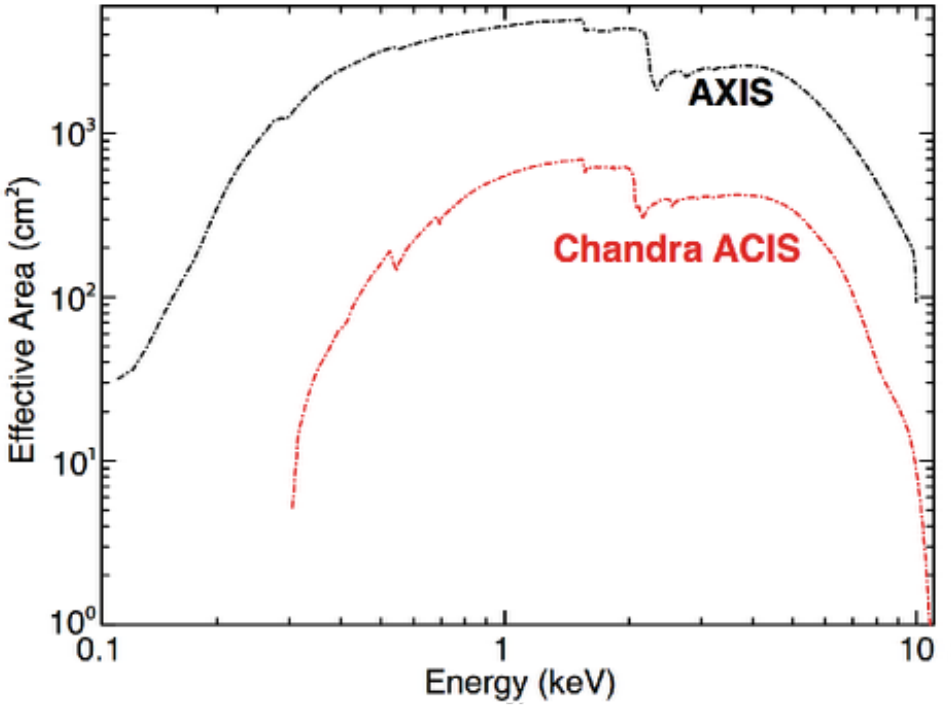
The new AXIS technology…

AXIS Optics

Requirements

Angular resolution	0.5″ HPD
Field of view	15′ diameter with best PSF
Effective area	10x Chandra





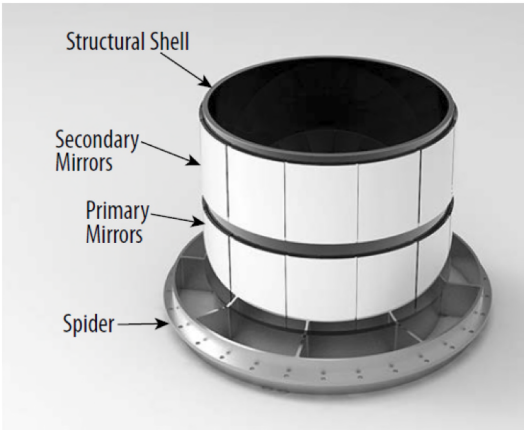
AXIS Optics Lead: Will Zhang

AXIS Optics

Mirror Configuration

Focal length	9.5m
Outer diameter	1.5m
Mirror thickness	0.5mm

- based on post-IXO mission concept study N-CAL
- monocrystalline silicon substrate
  - stress-free
  - lightweight
  - good thermal properties
  - understood and commercially available
  - many possible optical designs (Wolter-I, etc.)
- iridium or gold coating
- fabrication amenable to automation and mass production

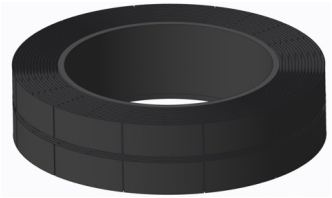


AXIS Optics Lead: Will Zhang

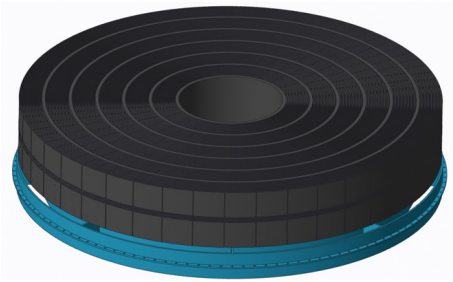
AXIS Optics

The Meta-Shell Paradigm

Mirror Segment



Meta-shell



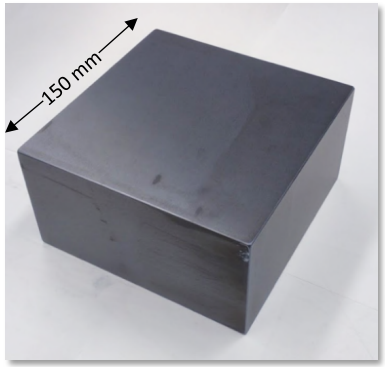
Mirror Assembly

- Each mirror segment is fabricated, qualified, and then aligned by and bonded to four spacers which kinematically constrain it.
- Several hundred mirror segments are aligned and bonded to form a meta-shell.
- A dozen or so meta-shells of different diameters form the final mirror assembly

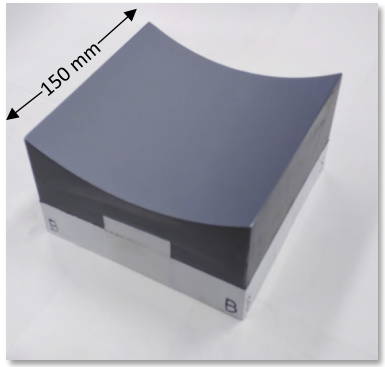
AXIS Optics Lead: Will Zhang

AXIS Optics

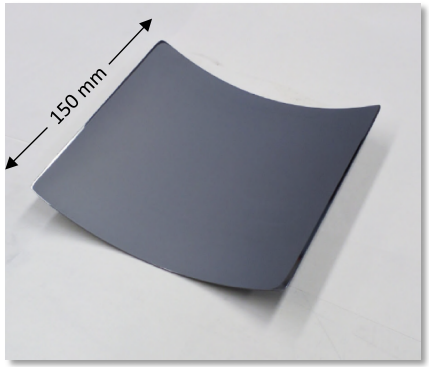
Fabrication Process



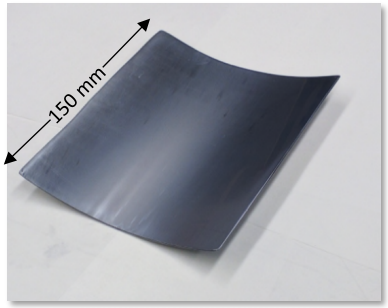
Monocrystalline silicon block



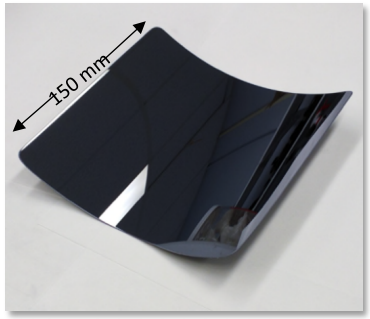
Conical form generated



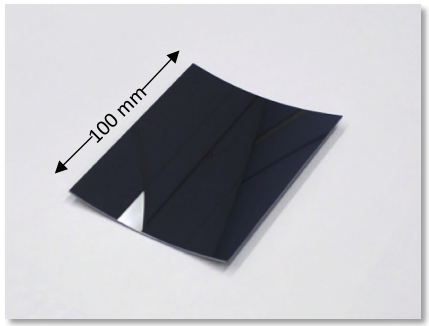
Light-weighted substrate



Etched substrate



Polished mirror substrate

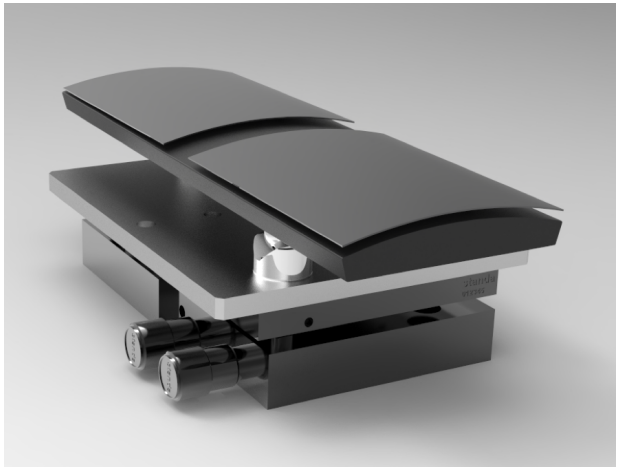


Trimmed mirror substrate

AXIS Optics Lead: Will Zhang

AXIS Optics

Fabrication Process



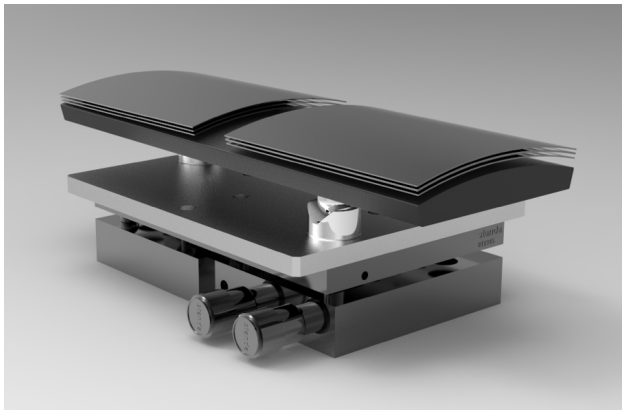
Accomplished as of August 2017

Individual mirror segment fabrication can produce 0.5″ HPD in pairs (optical metrology).

Single pair of mirrors aligned, bonded, and X-ray tested. Best X-ray result: 3.8″ HPD.

Expected by December 2017

Multiple pairs of mirrors aligned, bonded, and X-ray tested.



This work has been funded by NASA through ROSES/SAT and ROSES/APRA.

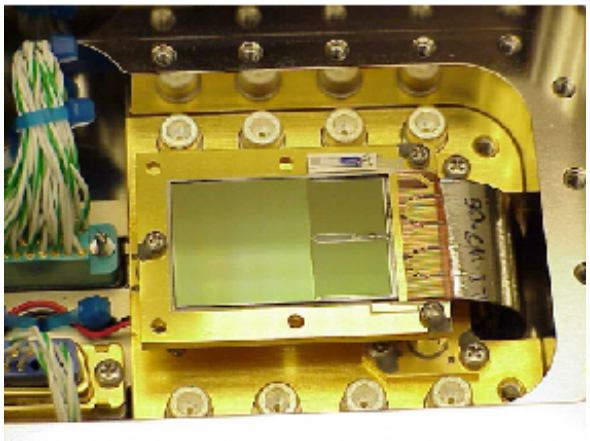
AXIS Optics Lead: Will Zhang

AXIS Detectors

Requirements

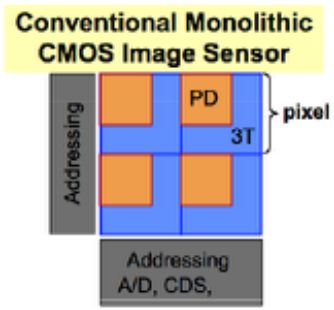
Angular resolution	small pixels (8–16 μm, 0.2-0.4″)
Field of view	large format (30 Mpix)
Effective area	fast readout, high QE at 0.2 keV

CCD

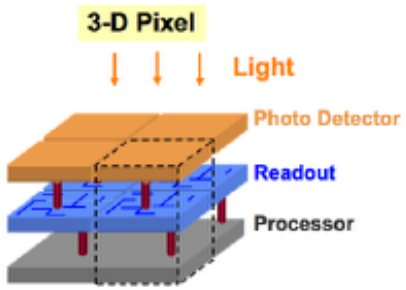


CMOS

Monolithic



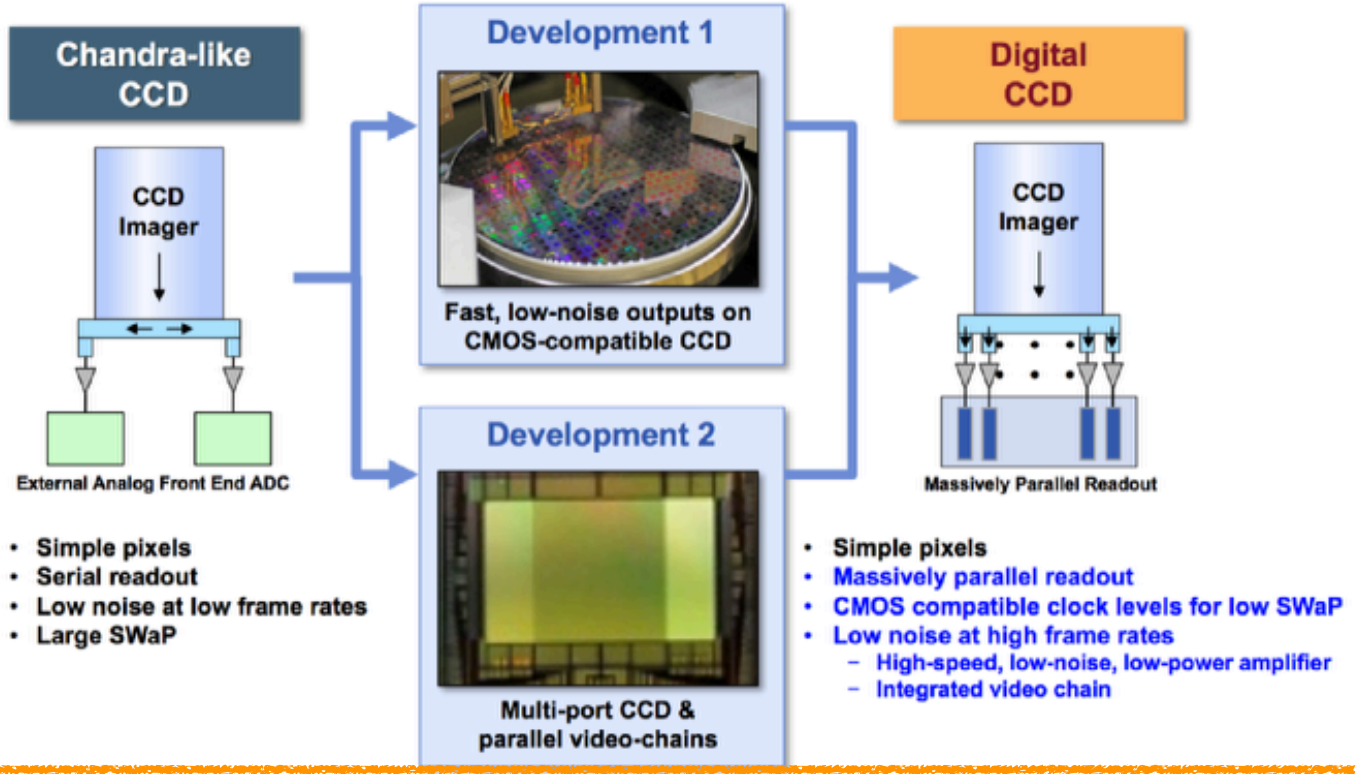
Hybrid



AXIS Detectors Lead: Eric Miller

AXIS Detectors

Digital CCDs



Poster 103.09 by Mark Bautz, et al.
Toward Fast, Low-noise, Low-power, Small Pixel Digital CCDs for X-ray Astronomy

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

MIT KAVLI INSTITUTE

AXIS Detectors Lead: Eric Miller

AXIS Detectors

Digital CCDs

2x2 BI DCCDs, 4.2 cm (15′) FOV
8 μm (0.17″) pixels
50–100 μm depletion (0.1–10 keV sensitivity)
128 outputs at 5 MHz
70 frames/sec (200x Chandra)

QE with filters:	25% at 0.2 keV
	75% at 0.5 keV
	90% at >1 keV
challenges:	charge splitting with small pixels
	huge data rate

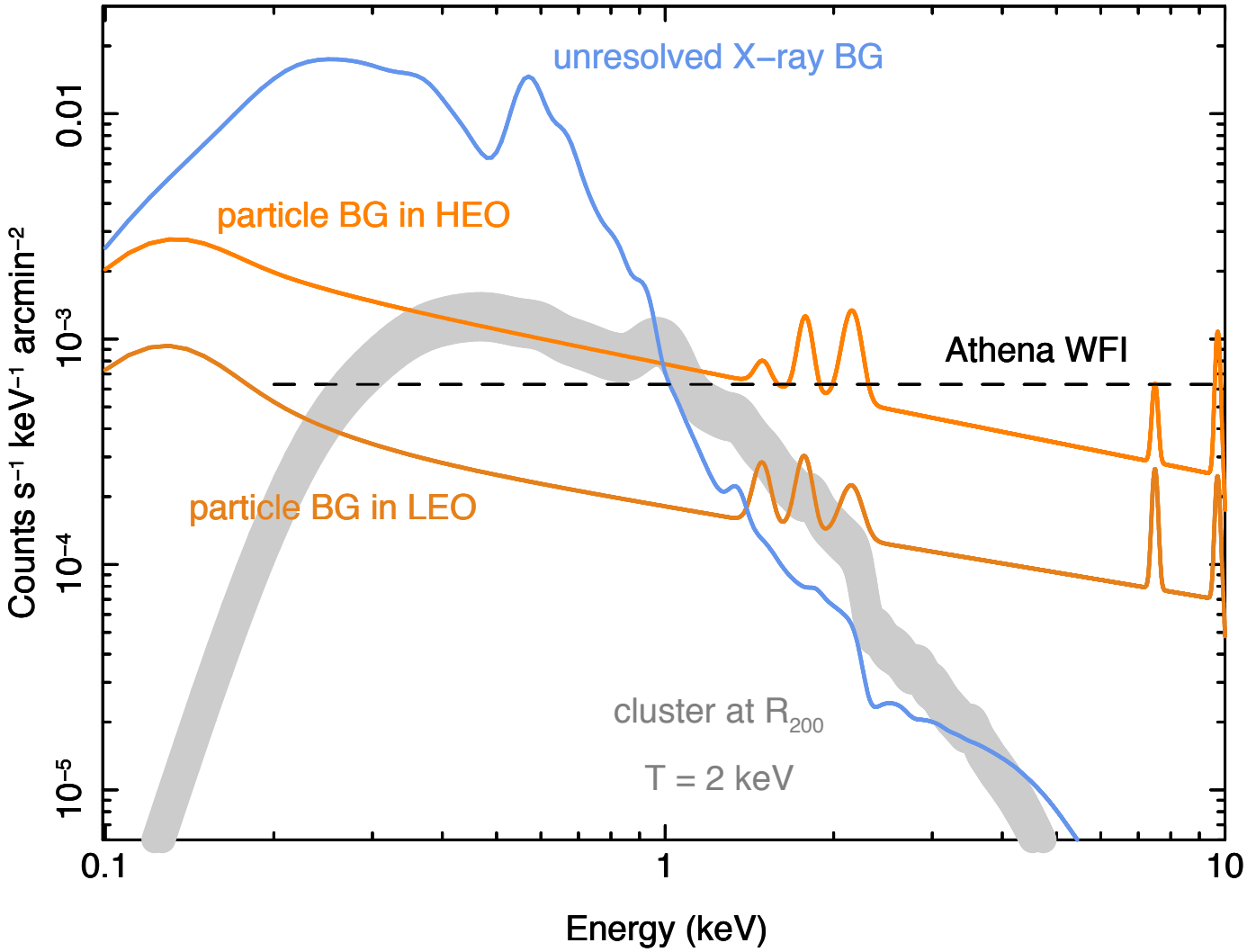
AXIS Detectors Lead: Eric Miller

AXIS Trades

Orbit	equatorial LEO vs. HEO background observing efficiency data rate
Optics	PSF over the field of view energy range
Detectors	CCDs vs. APS frame rate pixel size radiation tolerance QE, spectral resolution

AXIS Detectors

Background



Background: Maxim Markevitch

AXIS does not compete with Lynx

- AXIS could launch by 2028, Lynx not before 2036
- AXIS will overlap with Athena, LSST, other next-gen instruments
- AXIS will (likely) be in low-Earth orbit with very low background
- AXIS lacks high spectral resolution instruments
- AXIS will have lower effective area
- AXIS can be a pathfinder for Lynx technology
- AXIS will be a seamless link in high spatial resolution X-ray imaging between Chandra and Lynx

AXIS

Advanced X-ray Imaging Satellite

AXIS Cheat Sheet

1. 10x area of Chandra ACIS
2. 5x lower background
3. New CCD technology
4. Rapid response capability

What do YOU want?

1) 3″ over entire 40′ FOV
2) 0.5″ over entire 14′ FOV
3) 0.1″ in central 6′; 15′ total FOV

Thank you!

axis.astro.umd.edu