

Probing the Hot and Energetic Universe:

X-rays and Astrophysics

Mark Bautz

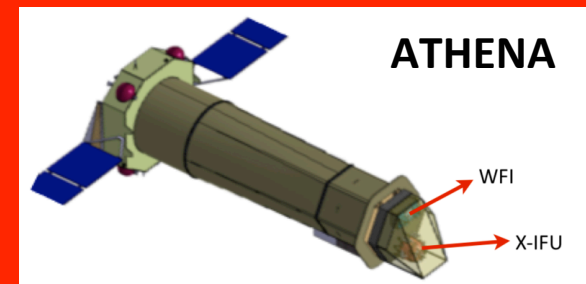
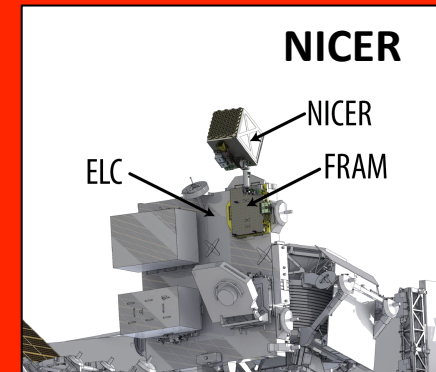
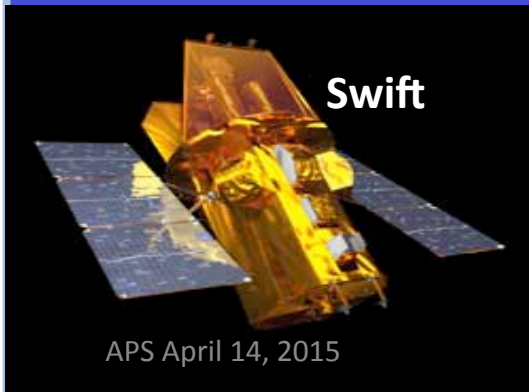
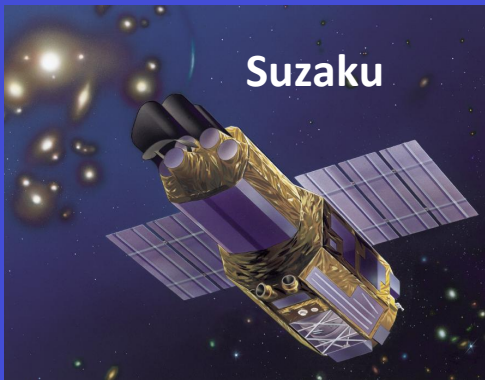
Co-Chair, X-Ray Science Interest Group (XRSIG)

MIT Kavli Institute for Astrophysics & Space Research

High Energy Missions

TODAY

THE FUTURE



Probing Dark Matter

The “Bullet Cluster”



Two galaxy clusters colliding in the plane of the sky.

The total mass shown in blue from gravitational lensing measurements combined with X-ray emission in red shows visually that the X-ray emitting plasma (containing most of the baryons) interacts differently than the bulk of the mass in this collision.

Cosmic Collider “Experiments”

Red: X-ray-emitting plasma (*Chandra*); Blue: Lensing mass (*Hubble*)

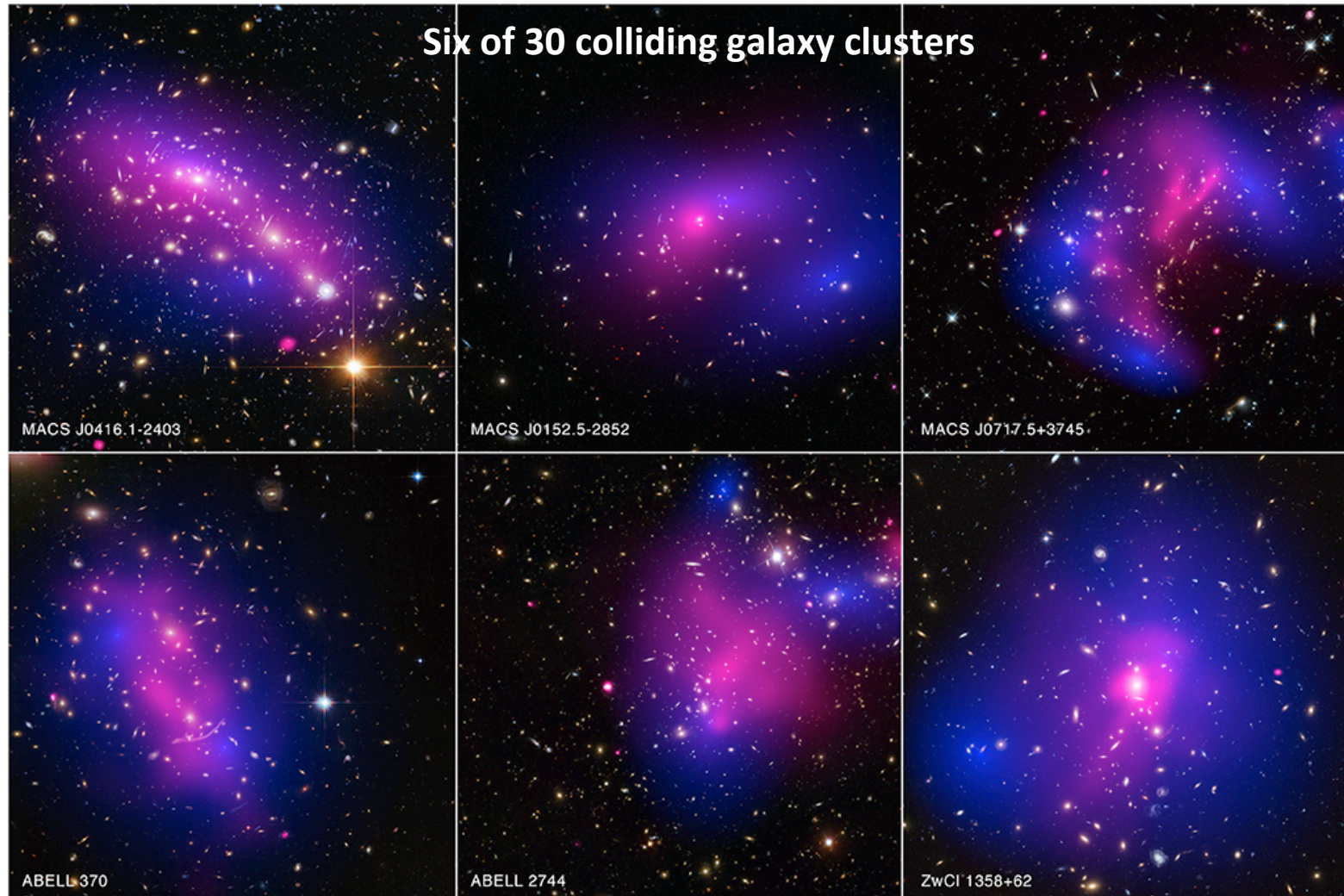


Image: CXC/NASA/ESA/Ecole Poly Lausanne/Durham/Harvey/Massey
APS April 14, 2015

X-ray SIG/M. Bautz

Harvey+, 2015 *Science*

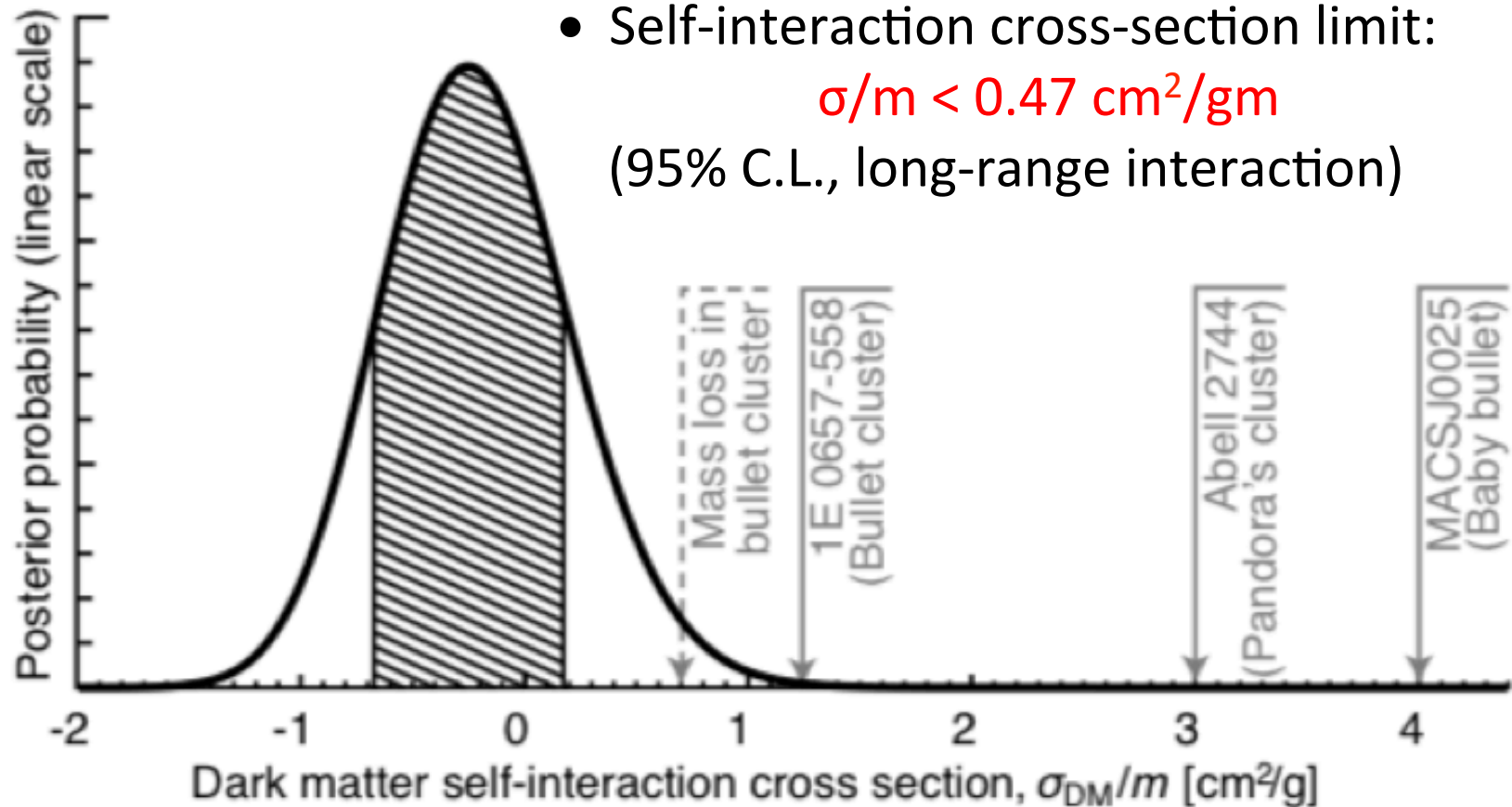
Cosmic Collider “Experiments”

Harvey+, 2015 *Science*

- 72 Collisions in 30 Clusters
- Detection of dark matter at 7.6σ
- Self-interaction cross-section limit:

$$\sigma/m < 0.47 \text{ cm}^2/\text{gm}$$

(95% C.L., long-range interaction)



Nuclear Spectroscopy for Supernova Forensics

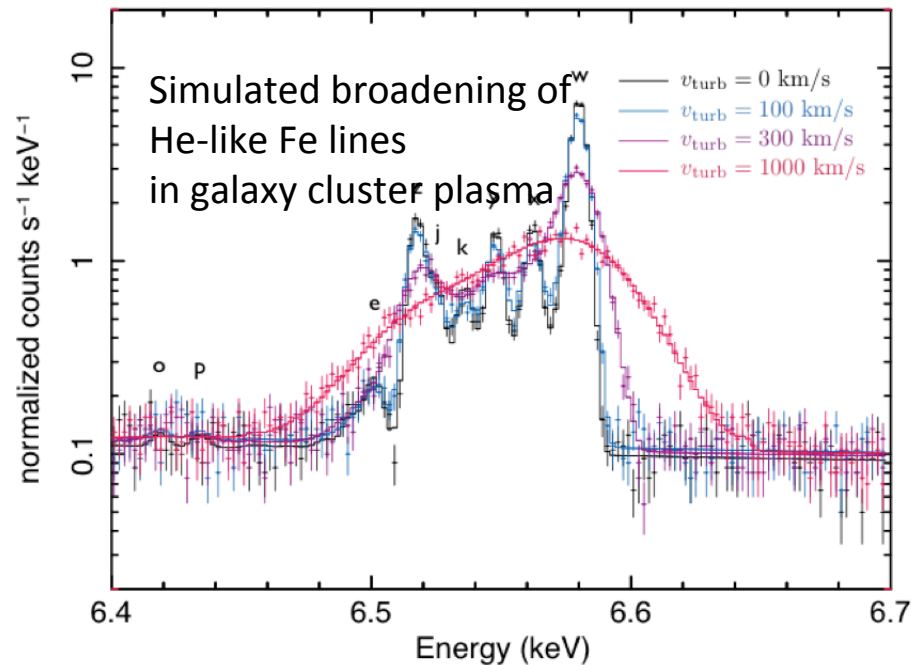
Cassiopeia A Supernova Remnant



- Massive stars die in core-collapse supernova explosions, ejecting products of stellar nucleosynthesis
- Shock-heated ejecta emit characteristic lines in the soft X-ray (0.1- 10 keV) band (O thru Fe)
- **NuSTAR** provides 1st imaging spectroscopy to 80 keV → access to nuclear transitions
- Ti and Fe are produced together in core of progenitor star
- 1st map of radioactive ^{44}Ti in Cas A (68 & 78 keV lines) shows **little correlation between Ti and Fe**, ruling out both spherical and rotational explosion models

ASTRO-H: High-resolution X-ray Spectroscopy

Testing Astro-H in Tsukuba, Japan

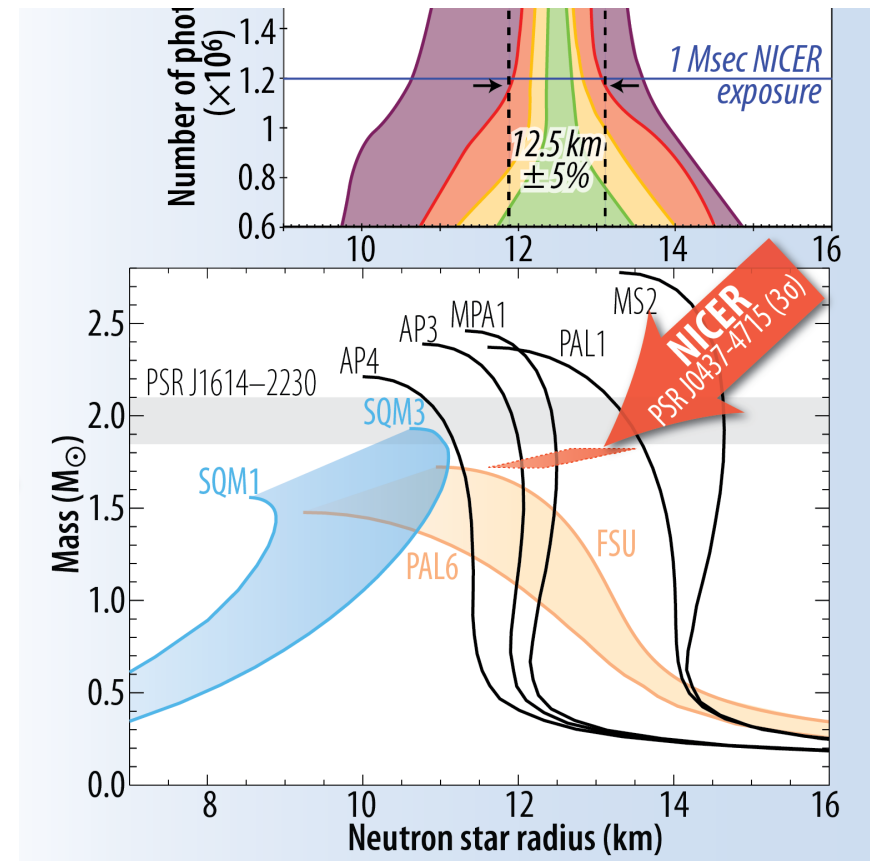


- 1st X-ray Microcalorimeter will provide spatially-resolved spectroscopy with $E/\Delta E \sim 1000$ @ 6.7 keV
- New windows on:
 - Turbulence in galaxy cluster plasma
 - Black hole spin
 - Cosmic ray acceleration
 - Stellar magnetospheres
 - Search for dark matter...
- Launch planned within a year



NICER: Neutron Star Interiors from the International Space Station

- **NICER will determine precise (5%) radii of msec pulsars from spectrally-resolved X-ray pulse profiles (4 objects)**
- **Radii + (known) masses yield powerful constraints on EOS of ultra-dense matter in neutron star interiors**
- **NICER launch to International Space Station expected in 2016**



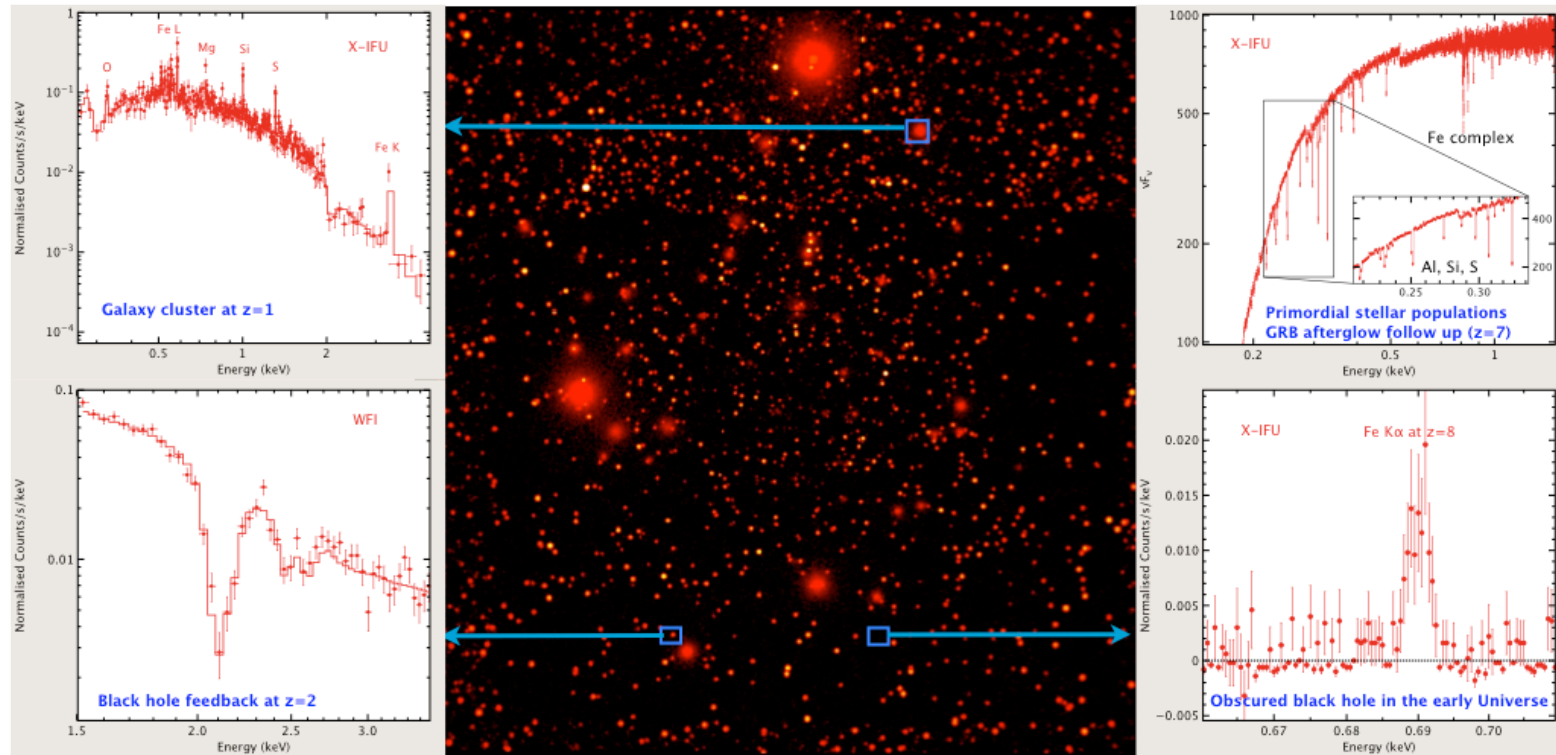
Simulations show the assumed radius is recovered to $\pm 5\%$ with $\sim 10^6$ photons

ATHENA: ESA's Large Mission for 2028

- Square-meter effective area @ 1 keV, 5 arcsec resolution
- High-resolution spectrometer, wide-field imager

Cluster at $z=1$

GRB afterglow at $z=7$

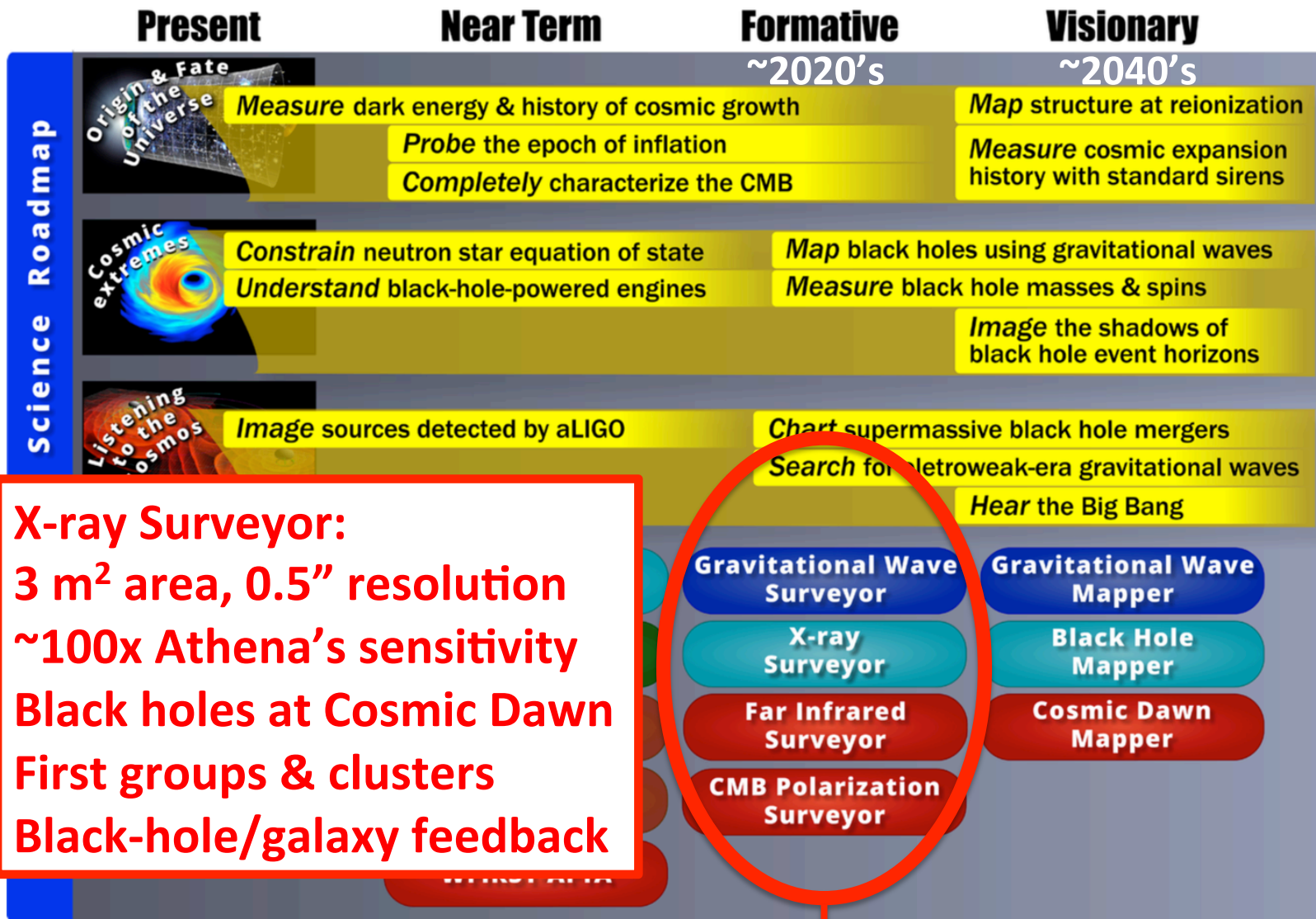


QSO feedback $z=2$

Early AGN at $z>6$

Envisioning the 2020's and Beyond

Daring Quests, Enduring Visions NASA, 2013
Graphic: F. Reddy/NASA GSFC



X-ray Surveyor:
3 m² area, 0.5" resolution
~100x Athena's sensitivity
Black holes at Cosmic Dawn
First groups & clusters
Black-hole/galaxy feedback

Some possible candidates for discussion by the 2020 Decadal Survey

Near-term X-Ray SIG Activities

- Regular telecons to support NASA Astrophysics Division's request for input (via PhysPAG) on planning for the 2020 Decadal Survey
- Full **XRSIG meeting at the special HEAD meeting** (Chicago, June 29 – July 1) on Large- and Medium-Sized Space Missions in the 2020's. See https://aas.org/meetings/high_energy_decadal
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