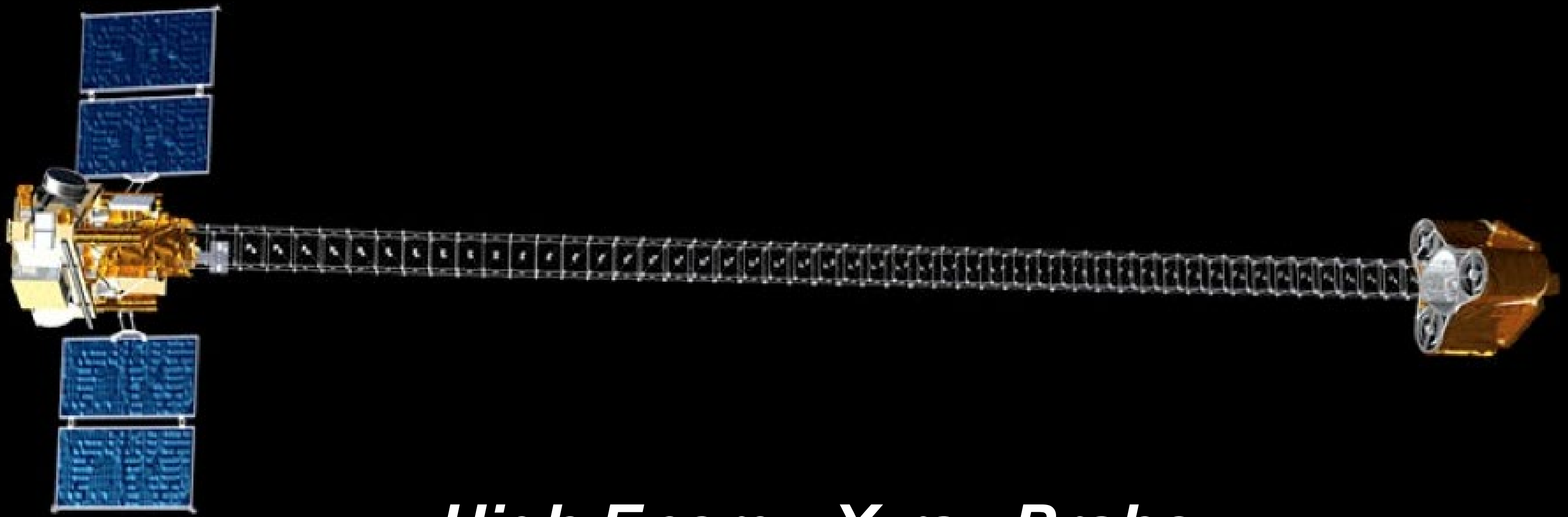


# *High Energy X-ray Probe*


Fiona Harrison

Caltech

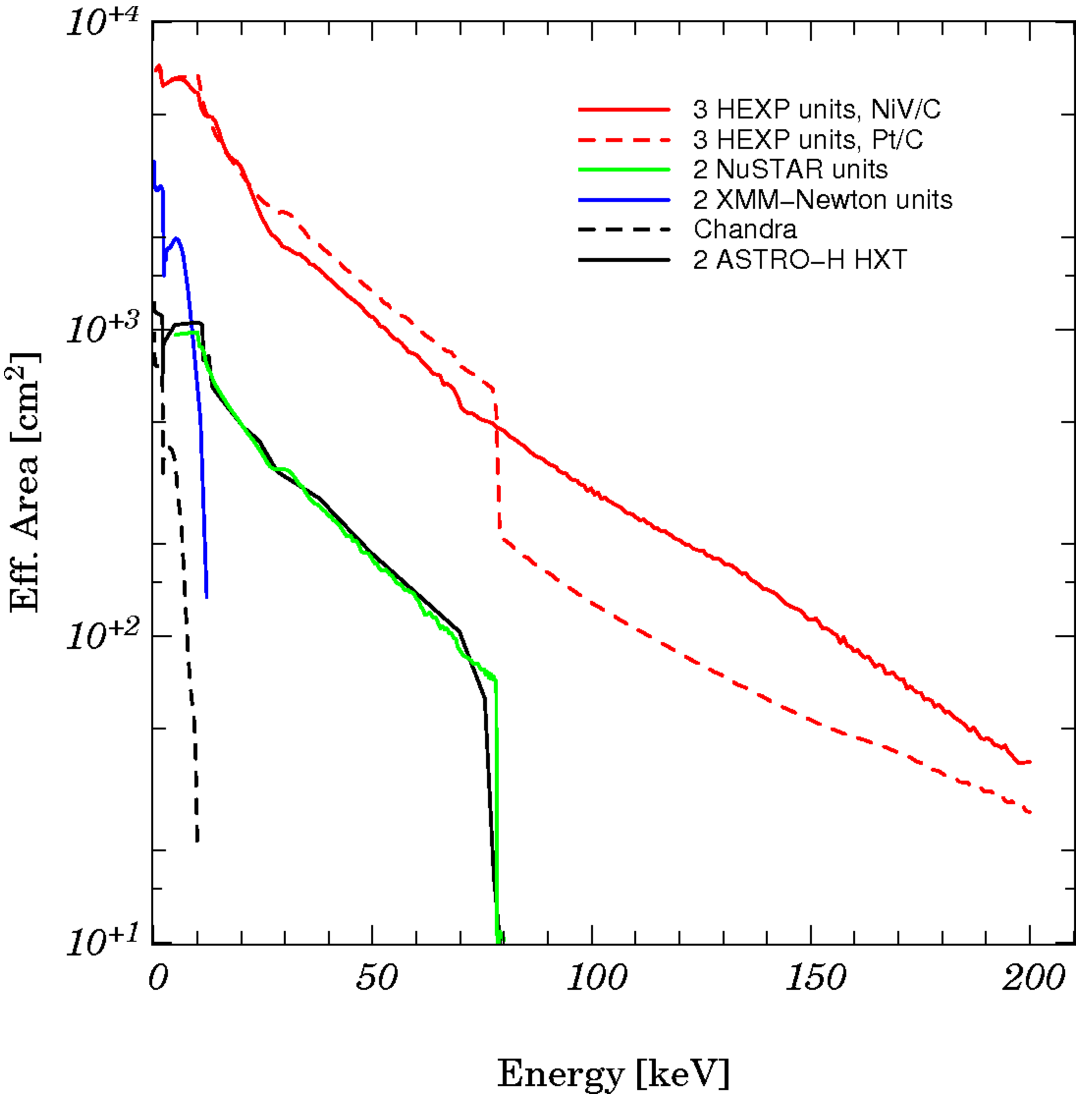
# *Context for the HEX-P White Paper*

- Primary IXO capability was large-area high-resolution spectroscopy 0.3 – 10 keV
- Other key IXO capabilities
  - Hard X-ray coverage
  - High time resolution
  - Polarimetry
- Athena recovers the calorimeter science
- The U.S. should consider several options that retain flexibility and are robust to Athena selection, continued JWST cost issues
  - U.S.-only spectroscopy mission
  - Participation in Athena
  - Develop complementary mission(s) with international appeal
- Replacing HXI+WFI (broadband + timing) is obvious choice
- Constraints
  - Probe class (~600M$) mission
  - Development on timescale that allows overlap with Athena

# *HEX-P Performance Requirements*

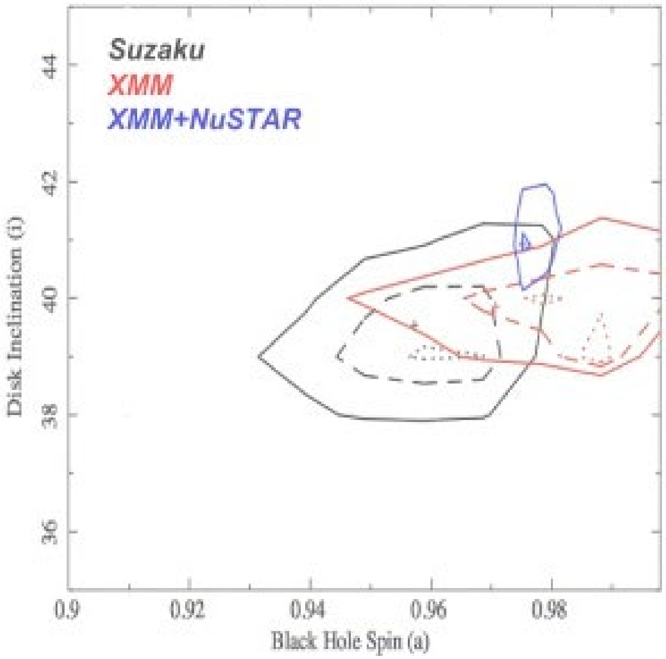
| Parameter | HEX-P | IXO (HXI+WFI) |
|---|---|---|
| Bandpass | 0.15 – 200 keV | 0.1 – 40 keV |
| Angular resolution | 10 – 15” (HPD)<br>7 – 9” (FWHM) | 5” (3 – 7 keV)<br>30” (7 – 40 keV) |
| Time resolution (msec) | <1  0.2 – 10 keV<br>0.01 (>10 keV) | 1.3 msec |
| Spectral resolution | 150 eV @ 6 keV<br>1 keV @ 60 keV | 150 eV @ 6 keV<br>1 keV @ 60 keV |
| Field of View | 13’ x 13’ | 18’ x 18’ |
| Collecting area | 8000 $cm^2$ @ 6 keV<br>1500 $cm^2$ @ 50 keV | 0.65$m^2$ @ 6 keV<br>150 $cm^2$ @ 30 keV |

# Collecting Area



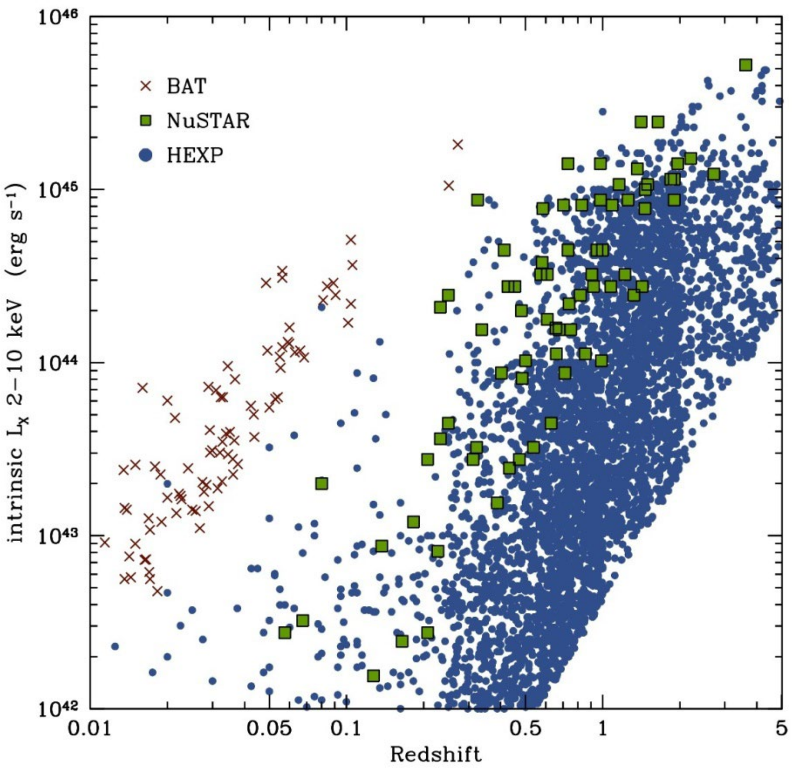
# IXO Science Goal

- What happens close to a black hole?
  - Spectral distortions due to strong gravity
    - Measurements of distortion of Fe-K line with high energy continuum modeling to remove ambiguities
  - High energy continuum measurements to understand accretion physics
    - Measurement of Compton reflection
    - Measure high energy cutoff
  - Probe inner regions of accretion disk in Galactic BHs through high energy QPO measurements



# IXO Science Goal

- When and how did supermassive black holes grow?
  - Determine distribution of ~300 BH spins to distinguish merger vs. accretion history
  - Wide field survey of AGN to determine accretion history of obscured AGN



# *IXO Science Goal*

- How does large scale structure evolve?
  - Map non-thermal components in clusters
    - Halos in merging clusters – measure CR density, B fields
    - Merger shocks in relics – measure particle densities, B fields
    - Accretion shocks – result in shell of hard X-ray emission
  - Combine with Astro E/Athena spectroscopy (gas kinematics), get structure of accretion shocks

# *IXO Science Goal*

- How does matter behave at high density?
  - Measure mass and radius in neutron stars to constrain EOS
    - Absorption edges in Type 1 X-ray bursts through time-resolved spectroscopy (eg $^{60}$Zn 12.2 keV, $^{59}$Co @ 9.9 keV, $^{32}$S from base of photosphere)
    - Probe inner regions of accretion disk and neutron stars in X-ray binaries by measuring QPOs
  - Broadband spectra of BHs and NSs in X-ray binaries

# *IXO Science Goals*

- IXO Science goals not addressed
  - What is the connection between supermassive black hole formation and evolution of large scale structure?
  - Characterize the hot component of WHIM
- These would be goals addressed by Athena or other similar mission

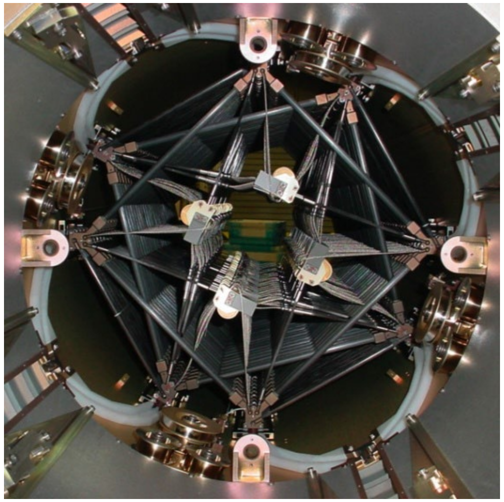
# *“Other” HEX-P Science*

- Nature of ultraluminous X-ray sources
- Binary populations in the local group
- Explosion dynamics in Supernova 1a’s
- Starburst galaxies – cosmic ray acceleration
- BH content of ULIRGs
- Supernova remnants – non-thermal components
- Nature of flares from Sgr A*
- Jet production and particle acceleration in blazars

# *Mission Overview*

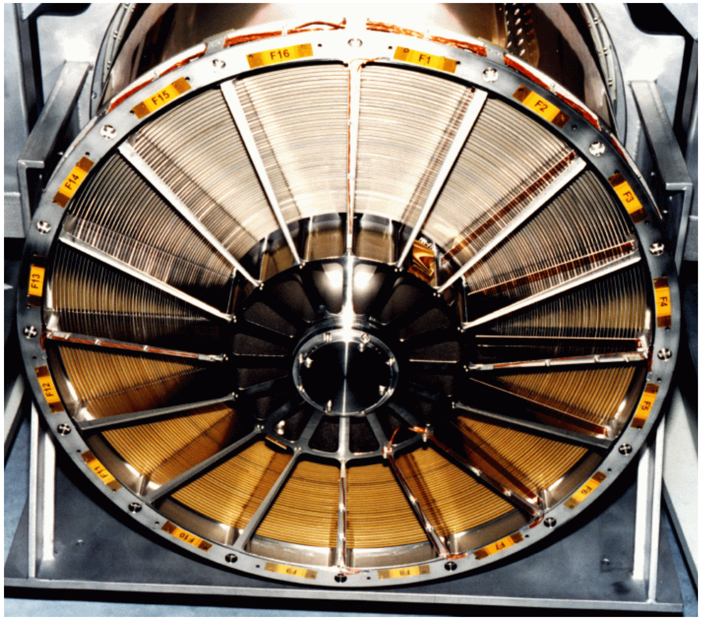
| Parameter | NuSTAR | HEX-P | Comment |
|---|---|---|---|
| Focal length | 10 m | 20 m | 30% larger diameter provides similar performance |
| mass | 380 kg | 1061 kg | Driven by optics and ACS |
| volume | 1 m diam x 1 m height | 2.2 m diameter x 1.6 m height | Driven by optics modules |
| power | 550 W BOL | 900 W BOL | Driven by thermal and ACS |
| orbit | 575 x 600 km<br>$5^o$ LEO | 650 x 950 km<br>2 – $7^o$ LEO | Lifetime vs. background trade |
| LV | Pegasus | Falcon 9 | CCAS or Kwajelein |
| lifetime | 2 years | 5 years | No consumables |
| optics | 2 modules<br>133 layers<br>Pt/C + W/Si | 3 modules<br>390 layers<br>NiV/C + W/Si | |
| Focal plane | CdZnTe | Si APS or CCD + CdTe | |
| metrology | 2 laser units | 3 laser units | Tracks mast motion |

# *Mast*



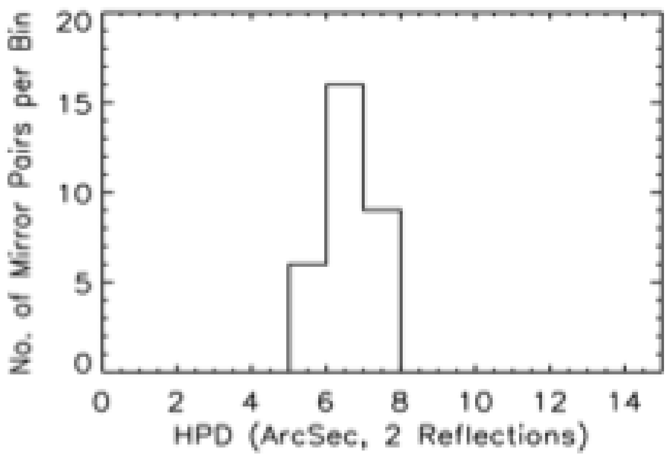
- Based on SRTM (60-m) and NuSTAR
- TRL 7
- No significant technical challenges or developments

# Optics



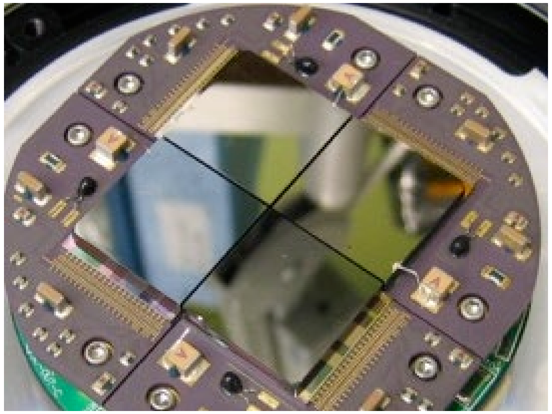
- Thermally formed glass
- NiV/C + W/Si multilayers
- NuSTAR mounting technique
- TRL 5-7

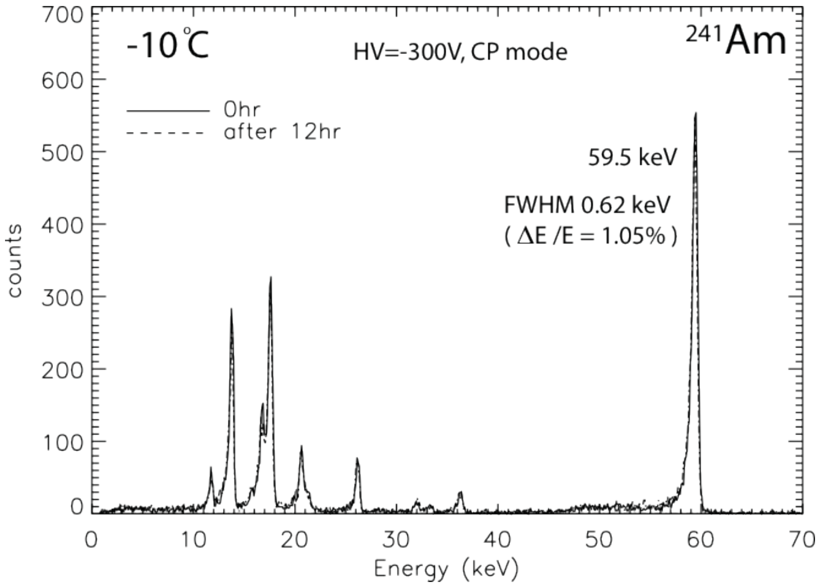
# *Optics – Required Development*




- Substrate quality has been demonstrated
- Required improvements relative to NuSTAR
  - H-P mandrels (much less deformation when mounting)
  - NiV/S multilayer demonstration
  - Backside coating
  - Improved mounting hardware (more uniform load)
  - Refinements in grinding process

# *Focal Plane*






- Si Detectors
  - CCD or active pixel sensor
  - Selection dependent on technology readiness
- CdTe detectors
  - Based on NuSTAR ASIC and Acrorad Al/CdTe/Pt
  - Required modifications
    - Decrease dead time – 80 micros/evt achievable without significant work
    - Reformat for larger focal plane
  - TRL 5-7

# Cost

Table 3. ROM cost estimate ($M, FY12).

| WBS | Dev | Ops | Total | Notes |
|---|---|---|---|---|
| PM/PSE/SMA | 23.4 | 8.6 | 32 | historical mission average wrap rates |
| Science | 4.7 | 33.0 | 37.7 | Dev based on *NuSTAR*; Ops based on *Spitzer* |
| Payload | 107.9 | | 107.9 | NICM + PRICE model |
| Spacecraft | 65.2 | | 65.2 | SSCM + PRICE model; includes ATLO |
| MOS/GDS | 7.8 | 90.0 | 97.9 | Dev based on *NuSTAR*; Ops based on *Spitzer* |
| Launch vehicle | 56.0 | | 56.0 | SpaceX published cost for Falcon 9 |
| E/PO | 2.1 | 1.3 | 3.4 | 1% of total, excluding Reserves and LV |
| Reserves | 63.3 | 19.9 | 83.2 | 30% Phases A-D, excluding LV; 15% Ph. E-F |
| **Total** | **330.3** | **152.9** | **483.2** | |

## *Summary*

- Together with Athena (or similar) mission HEX-P would recover original IXO science
- In addition HEX-P will have broad and compelling science program
- Is mature enough that could be launched on similar timescale as Athena
- Probe-class cost