Jessica A. Gaskin (Study Scientist, MSFC)

On Behalf of the X-Ray Surveyor Community

THE X-RAY SURVEYOR MISSION

X-ray Surveyor Goals

- ***Scientifically compelling:*** frontier science from Solar system to first accretion light in Universe; revolution in understanding physics of astronomical systems

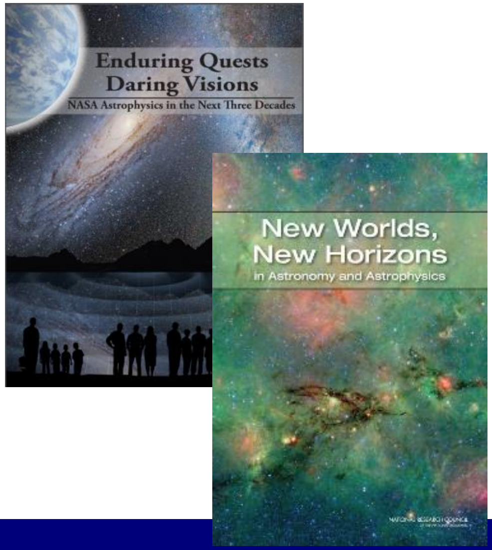
- ***Leaps in Capability:*** large area with high angular resolution for 1–2 orders of magnitude gains in sensitivity, large field of view with subarcsec imaging, high resolution spectroscopy for point-like and extended sources

- ***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

Consistent with:

NASA Astrophysics Roadmap: Enduring Quests, Daring Visions

2010 Astrophysics Decadal Survey: New Worlds, New Horizons



Scientifically Compelling

X-Ray Surveyor will allow us to explore all sources of high energy in the Universe and in doing so will address NASA Strategic Questions:

How does the Universe work?

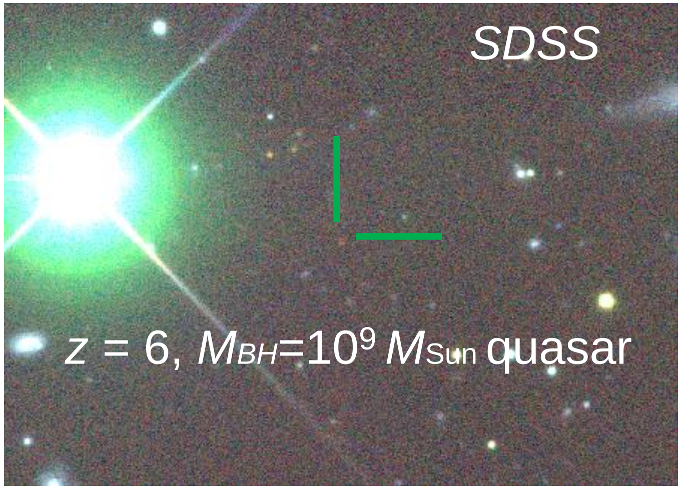
and

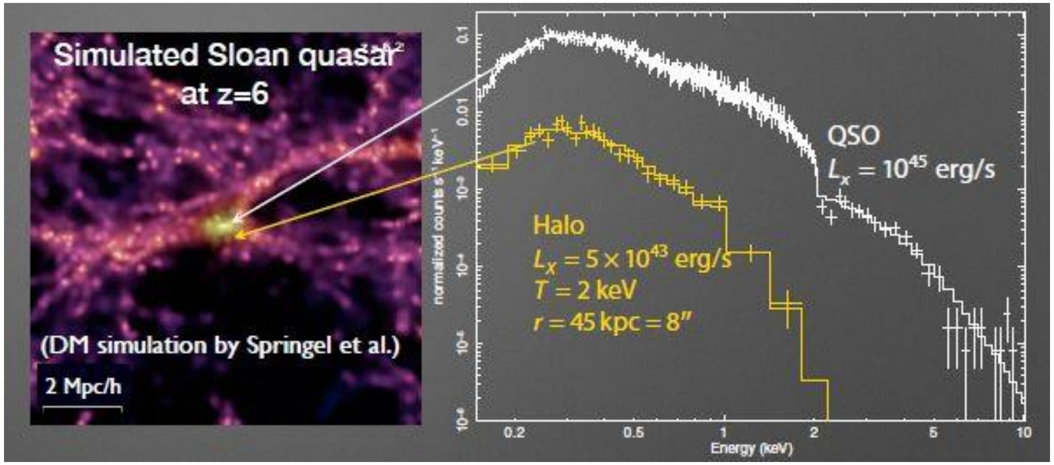
How did we get there?

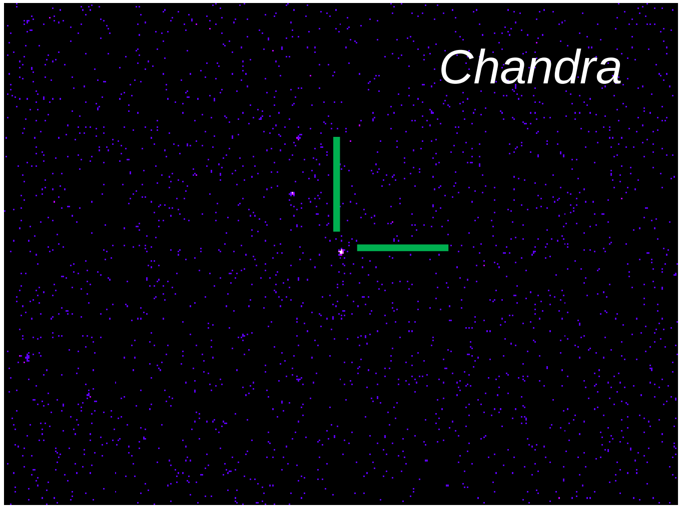
Key topics that will be addressed include:

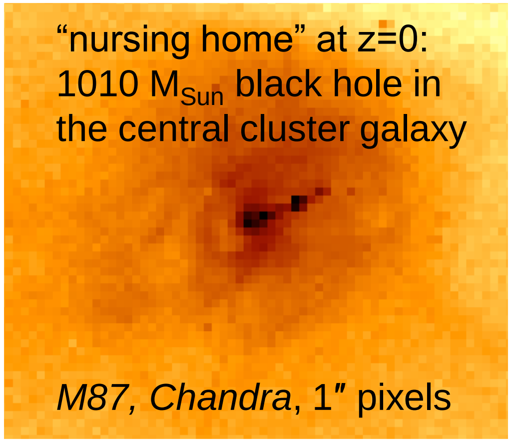
1) ***The Origin and Growth of the First Supermassive Black Holes***
2) ***The Physics of Feedback and Accretion in Galaxies and Clusters***
3) ***Galaxy Evolution and the Growth of Cosmic Structure***
4) ***The physics of matter in Extreme Environments***
5) ***The origin and evolution of the stars that make up our universe.***

Black Holes: From Birth to Today's Monsters







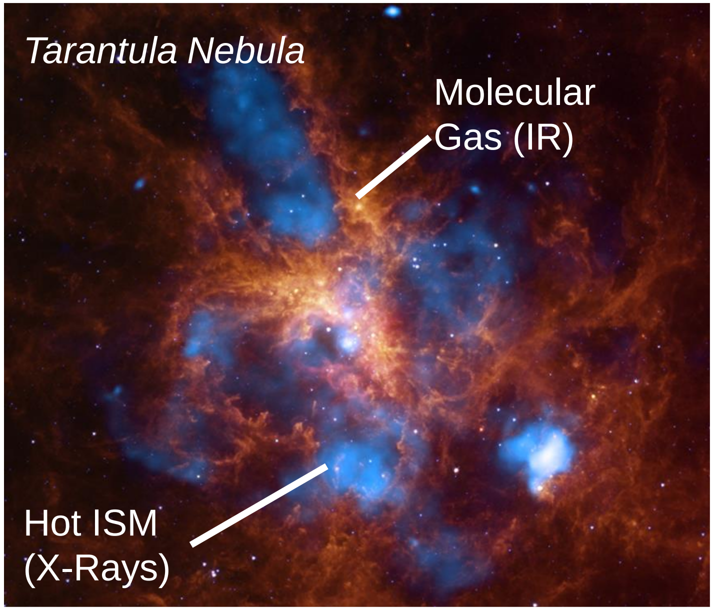


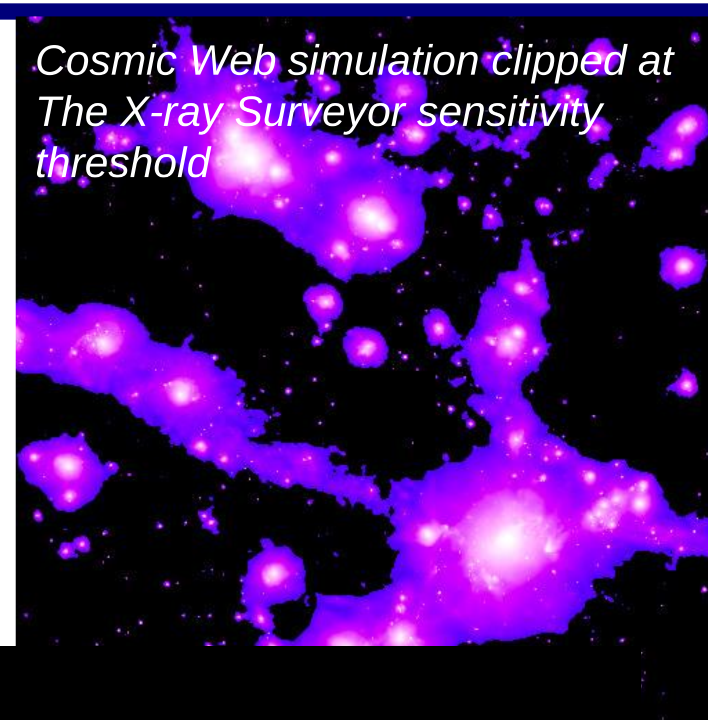
Also:
- Electromagnetic signatures of black hole mergers
- Using X-ray binary population as tracers of star formation, their role in cosmic reionization
- Jets

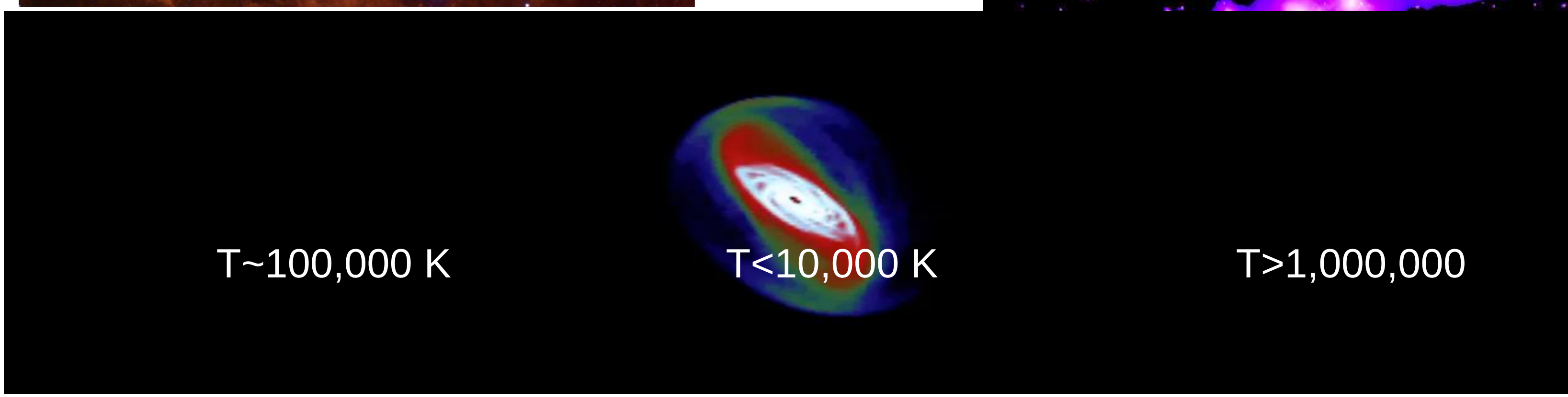
What is their origin?

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

Cycles of Baryons In and Out of Galaxies







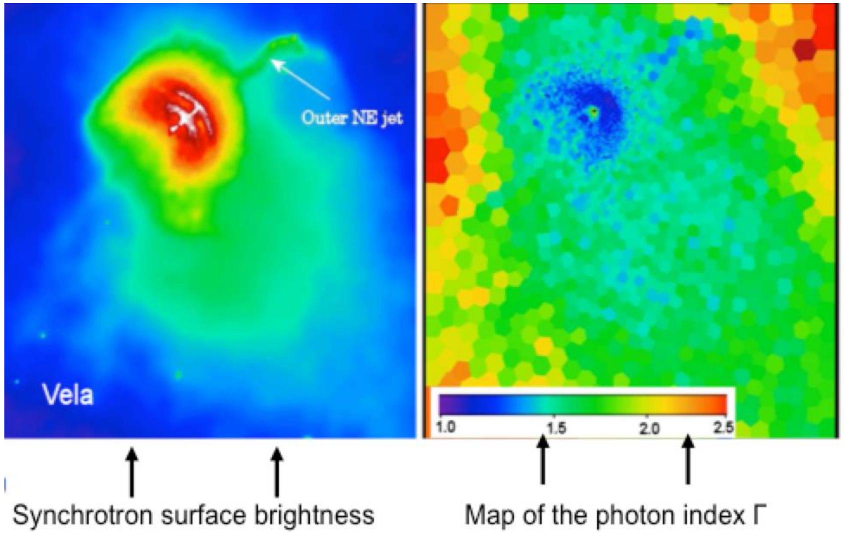
Generation of hot ISM in young star-forming regions. How does hot ISM push molecular gas away and quench star formation?

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

How do galaxies emerge from initial conditions?

What physics is behind the structure of astronomical objects?

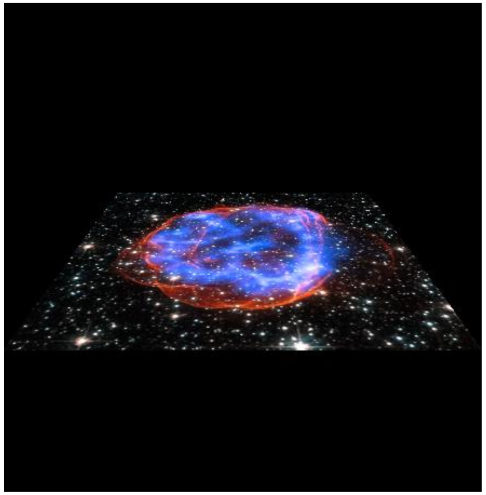
Plasma physics, gas dynamics, relativistic flows in astronomical objects:



- 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

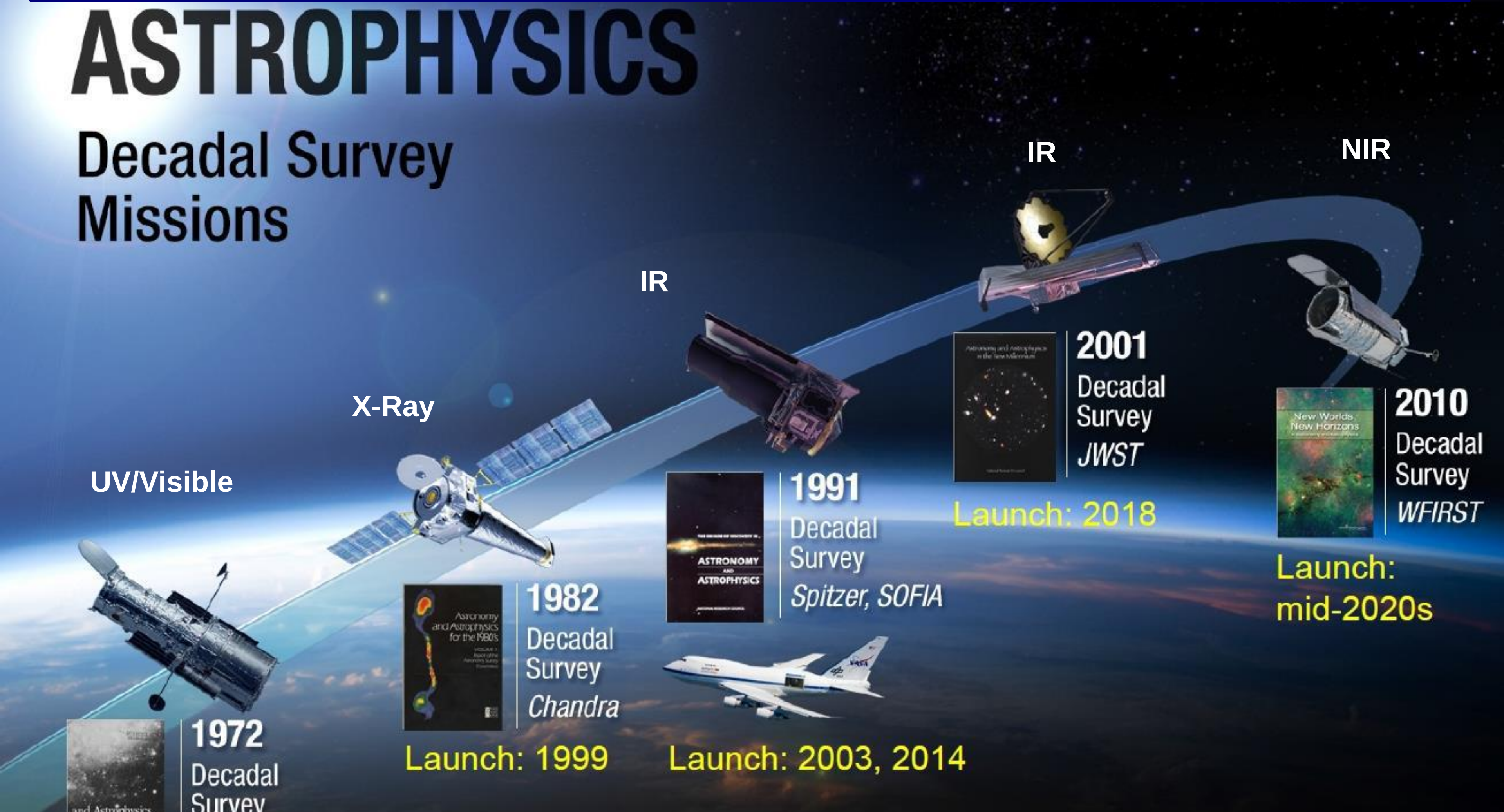
charge exchange emission

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



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

THE MISSING PIECE



-Thirty Meter Telescope will have 144 times the collecting area of Hubble and more than a factor of 10 better spatial resolution at near-infrared and longer wavelengths

-European Extremely Large Telescope (Visible, images 16x sharper than Hubble)

STDT Members

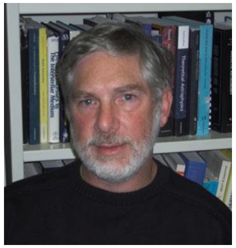
Alexey Vikhlinin, SAO (Chair)

Feryal Özel, Arizona (Chair)

Steve Allen, Stanford

Mark Bautz, MIT

Niel Brandt, Penn State



Joel Bregman, Michigan

Megan Donahue, MSU

Ryan Hickox, Dartmouth

Tesla Jeltema, UCSC

<u>Juna Kollmeier, OCIW</u>

Laura Lopez, Ohio State

<u>Piero Madau, UCSC</u>

Rachel Osten, STScI

Frits Paerels, Columbia

Mike Pivovaroff, LLNL

Dave Pooley, Trinity

Andy Ptak, GSFC

<u>Eliot Quataert, Berkeley</u>

Chris Reynolds, UMD

Daniel Stern, JPL

Ex-Officio Non-Voting Members Of The STDT

**Daniel Evans, NASA HQ
(Program Scientist)**

**Ann Hornschemeier,
PCOS Program
Office Chief Scientist**

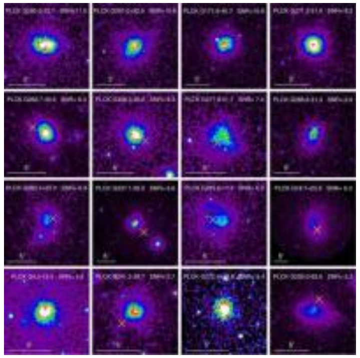
**Jessica Gaskin, MSFC
(Study Scientist, voting
member of STDT)**

**Rob Petre,
GSFC X-ray Lab
Branch Chief**

**Randall Smith,
Athena liaison**

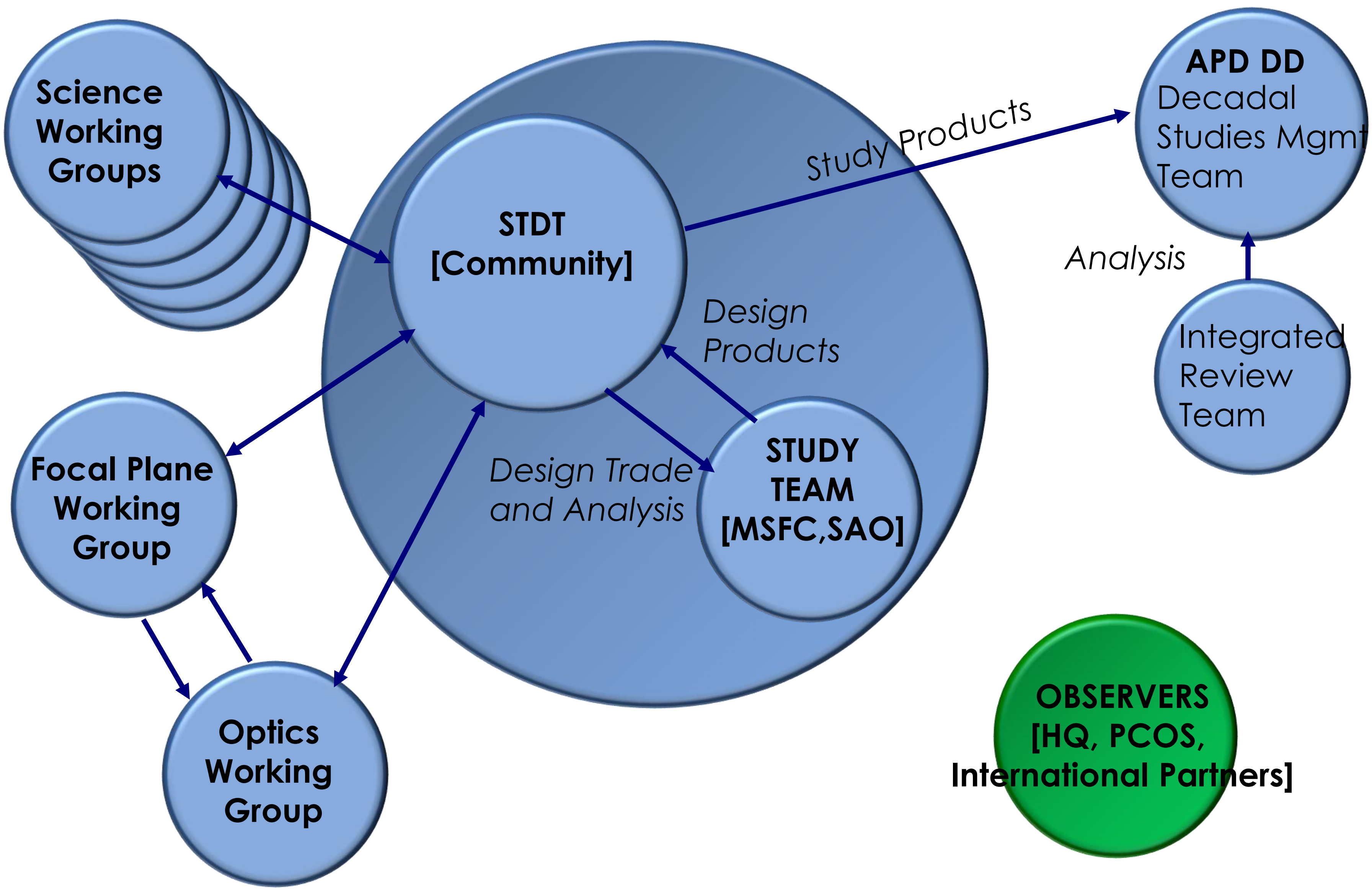
**Paul Nandra
DLR-Appointed
Observer**

**Brian McNamara
CSA-Appointed
Observer**



**Gabriel Pratt
CNES-Appointed
Observer**

STDT And Management Structure



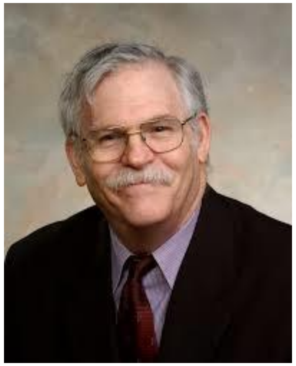
MSFC AND SAO STUDY TEAM LEADERSHIP

Alexey Vikhlinin,
SAO, STDT Chair

Jessica Gaskin,
MSFC, Study Scientist

Gregg Gelmis
MSFC Study Manager

Harvey Tananbaum
SAO Senior Scientist



Martin Weisskopf
MSFC Senior Scientist

Doug Swartz
USRA/MSFC
Deputy Study Scientist

STDT DELIVERABLES

Study output will provide the Decadal Survey Committee with:

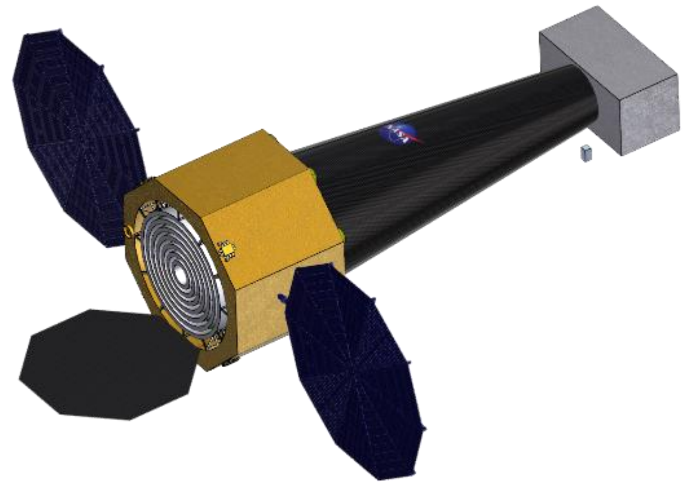
1. A **science case** for the mission
2. A **notional mission** and observatory, including a report on any tradeoff analyses
3. A **design reference mission**, including strawman payload trade studies.
4. A **technology assessment** including: current status, roadmap for maturation & resources
5. A **cost assessment** and listing of the top technical risks to delivering the science capabilities
6. A **top level schedule** including a notional launch date and top schedule risks.

Concept Maturity Level 4 should be achieved by the end of the study

X-ray Surveyor Mission Concept

Study Goal: Obtain a feasible cost estimate and provide the STDT with one possible configuration as a starting point. The STDT may choose to use all, some or none of the work resulting from this effort.

Notional Mission Concept: Spacecraft, instruments, optics, orbit, radiation environment, launch vehicle and costing



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/cm2 (0.5–2 keV band)

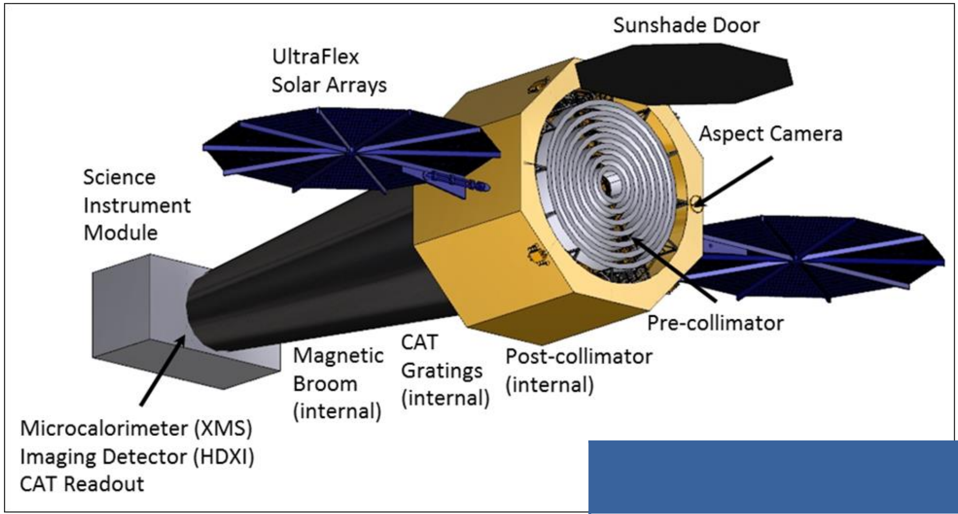
- × 16 larger solid angle for sub-arcsec imaging — out to 10 arcmin radius

- **× 800 higher survey speed at the *Chandra* Deep Field limit**

Informal Concept Definition Team:

J. A. Gaskin (MSFC), A. Vikhlinin (SAO), M. C. Weisskopf (MSFC), H. Tananbaum (SAO), S. Bandler (GSFC), M. Bautz (MIT), D. Burrows (PSU), A. Falcone (PSU), F. Harrison (Cal Tech), R. Heilmann (MIT), S. Heinz (Wisconsin), C.A. Kilbourne (GSFC), C. Kouveliotou (GWU), R. Kraft (SAO), A. Kravtsov (Chicago), R. McEntaffer (Iowa), P. Natarajan (Yale), S.L. O'Dell (MSFC), A. Ptak (GSFC), R. Petre (GSFC), B.D. Ramsey (MSFC), P. Reid (SAO), D. Schwartz (SAO), L. Townsley (PSU)

Notional Optics & Instruments



- High-resolution X-ray telescope
- Critical Angle Transmission XGS
- X-ray Microcalorimeter Imaging Spectrometer
- High Definition X-ray Imager

Concept Payload for:
- Feasibility (TRL 6)
- Mass
- Power
- Mechanical
- Costing (~**$3B**)

NOT THE FINAL CONFIGURATION!!!

	Chandra	X-Ray Surveyor
Relative effective area (0.5 – 2 keV)	1 (HRMA + ACIS)	50
Angular resolution (50% power diam.)	0.5”	0.5”
4 Ms point source sensitivity (erg/s/cm^2)	5×10^{-18}	3×10^{-19}
Field of View with < 1” HPD (arcmin^2)	20	315
Spectral resolving power, R, for point sources	1000 (1 keV) 160 (6 keV)	5000 (0.2-1.2 keV) 1200 (6 keV)
Spatial scale for R>1000 of extended sources	N/A	1”
Wide FOV Imaging	16’ x 16’ (ACIS) 30’ x 30’ (HRC)	22’ x 22’

X-Ray Surveyor Success

Scientifically compelling

- Gather broad (domestic and international) Science Community Support beyond the X-Ray Astronomy Community

- Maintain steadfast science requirements throughout the lifetime of the Program

Leaps in Capability

- Allow for multiple technology paths to achieve the requirements for the optics and Science Instruments.

- Formulate a strong plan for achieving these requirements

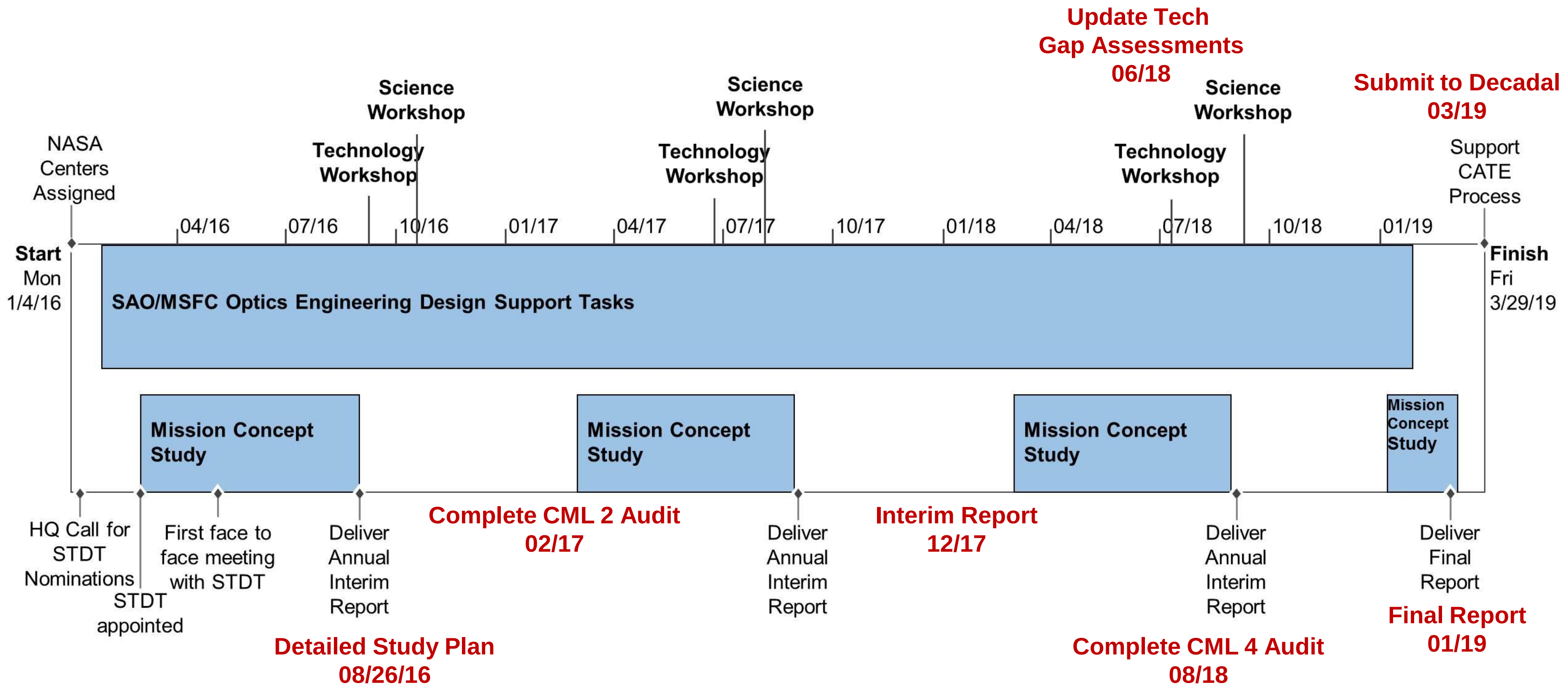
- Invest in technology development and proof-of-concept testing
  - Concept studies are great, but having working hardware is better

Feasibility

- Embrace Chandra Heritage and lessons learned

- Utilize multiple previous studies when possible (IXO, Con-X, AXSIO, etc…)

Schedule (TBC by STDT)

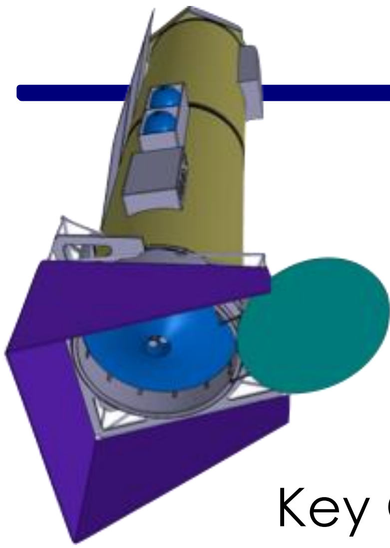


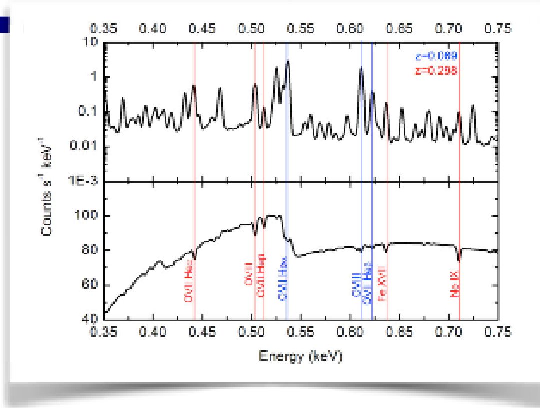
- **Mission Concept Studies can be adjusted in time and duration as needed**
- **Workshops can be adjusted as needed to fit deliverables and schedules**

CML = Concept Maturity Level

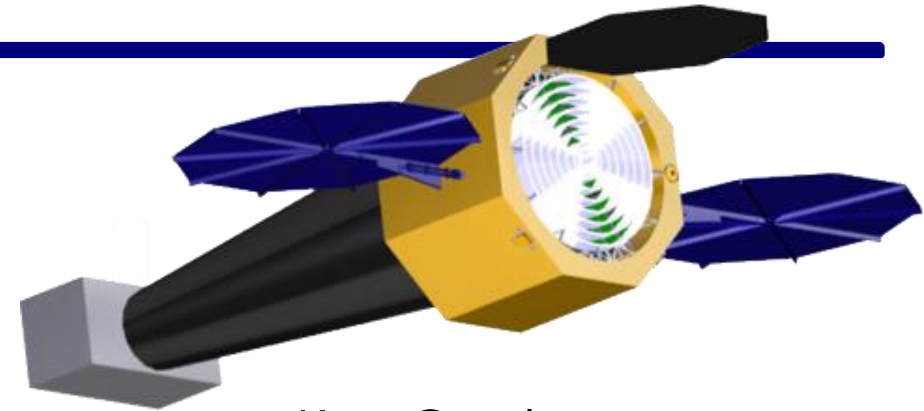
BACKUP SLIDES

Athena





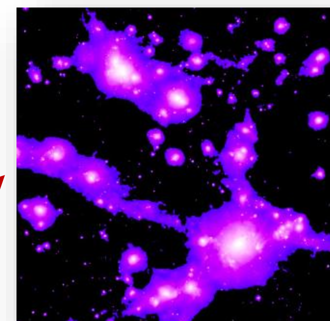
X-ray Surveyor



Key Goals:

- Microcalorimeter spectroscopy ($R \approx 1000$)
- Wide, medium-sensitivity surveys

Area is built up at the expense of angular resolution (10× worse) & sensitivity (5× worse than *Chandra*)

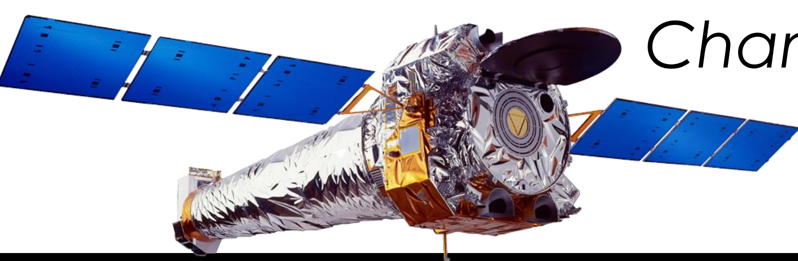


Key Goals:

- Sensitivity (50× better than *Chandra*)
- $R \approx 1000$ spectroscopy on 1″ scales, adding 3rd dimension to data
- $R \approx 5000$ spectroscopy for point sources

✓ Area is built up while preserving *Chandra* angular resolution (0.5″)

✓ 16× field of view with sub-arcsec imaging

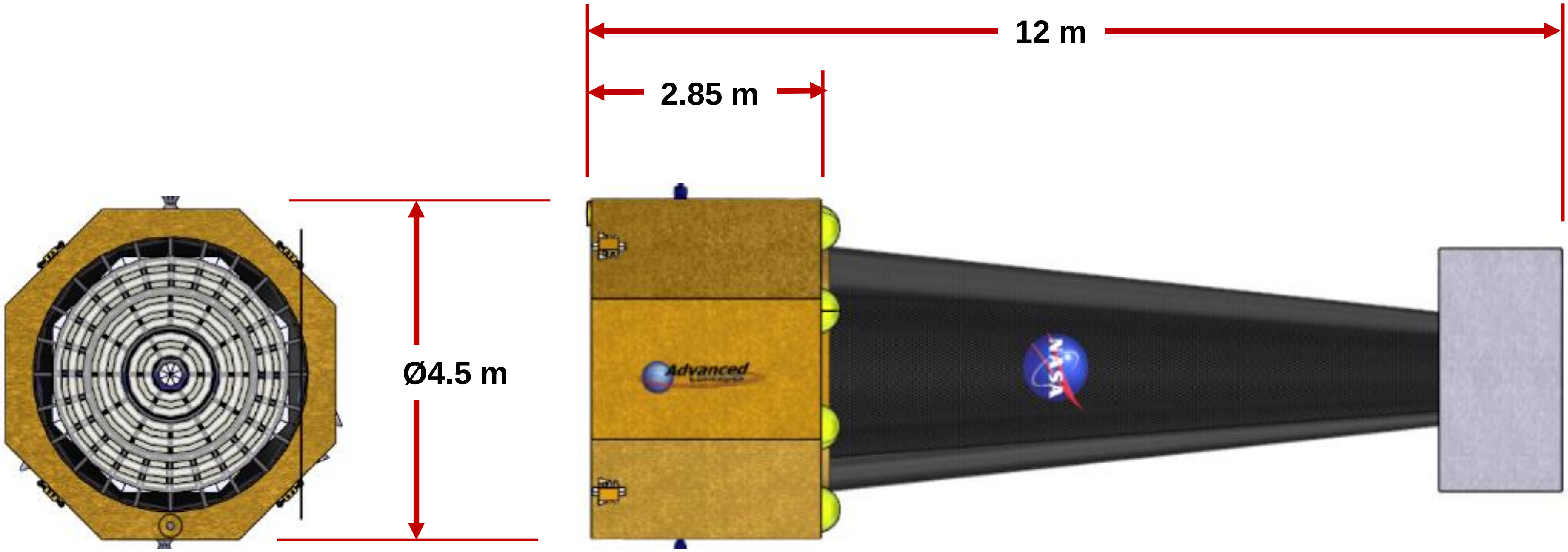


Chandra

A Successor to *Chandra*

- Angular resolution at least as good as *Chandra*
- Much higher photon throughput than *Chandra* (observations are photon-limited)

✓Incorporated relevant prior (Con-X, IXO, AXSIO) development and *Chandra* heritage → ✓ Limits most spacecraft requirements to *Chandra-like* → ✓ Achieves *Chandra-like* cost ($2.95B for Phase B through launch)



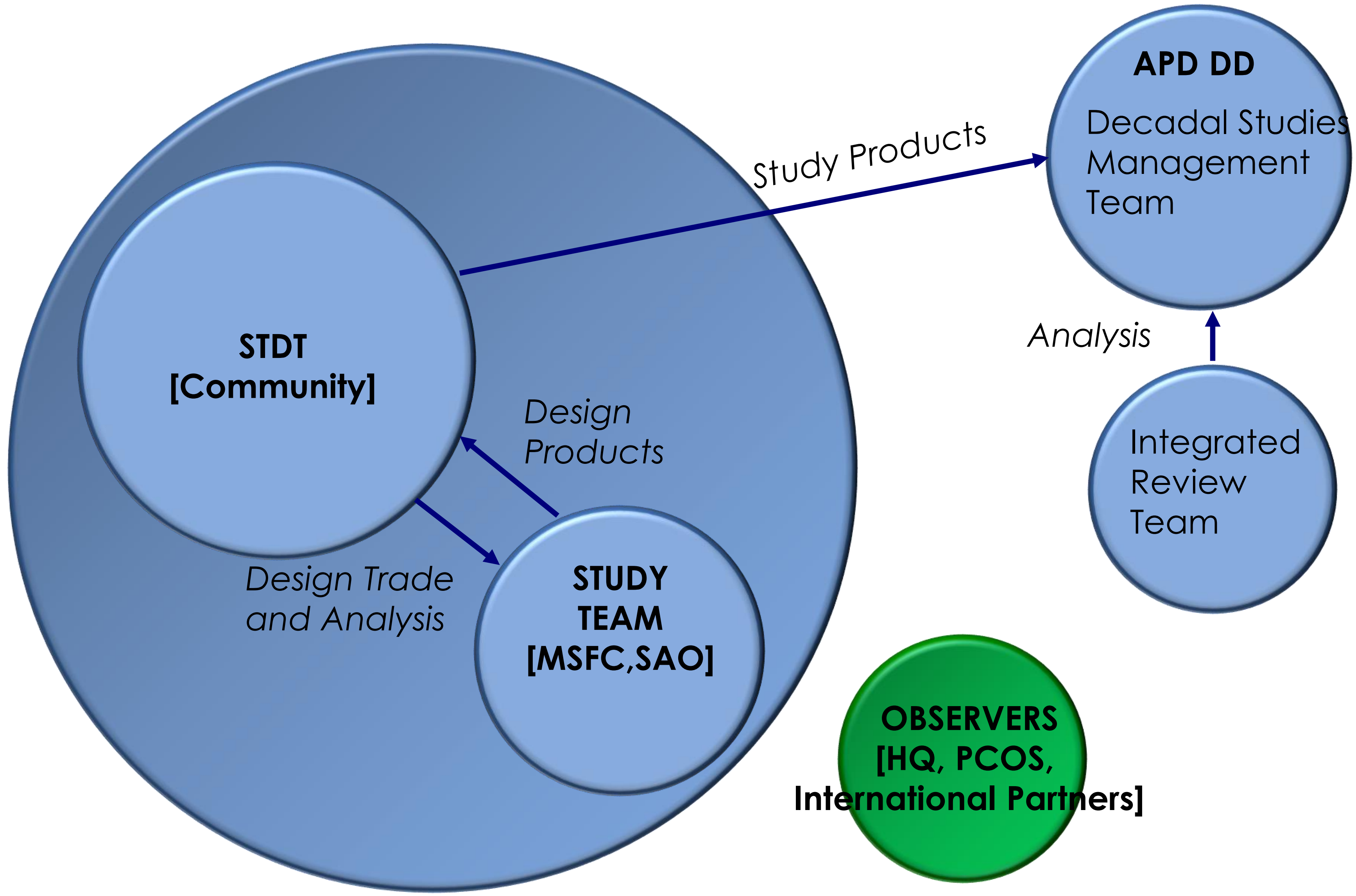
MSFC AND SAO SUPPORT

Support the STDT In Carrying Out Concept Development through the Advanced Concept Office at MSFC and Engineering/Science Design Studies for risk reduction

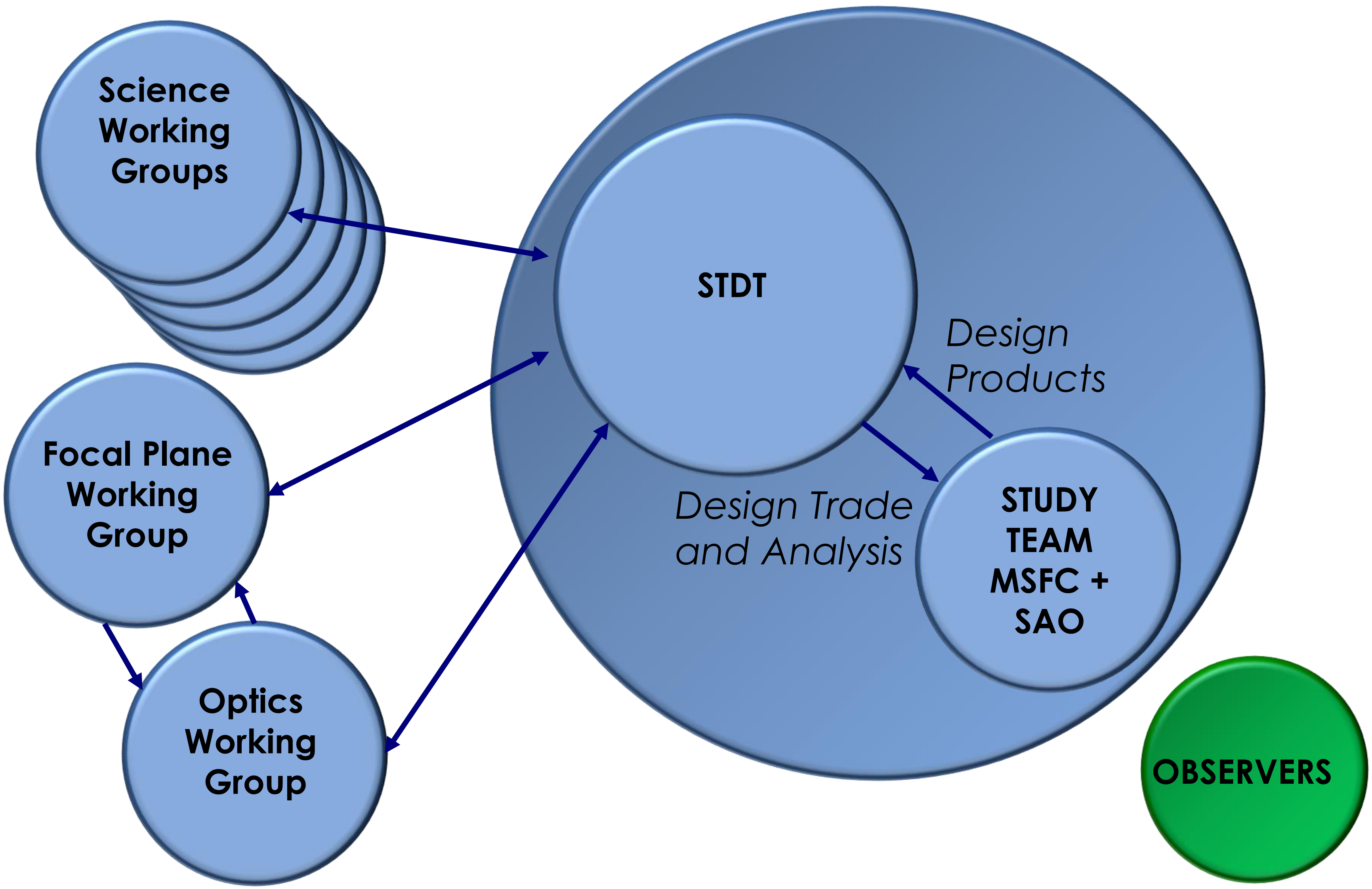
Example Engineering/Science Design Studies that can be carried out as requested by the STDT include:

- develop a detailed optical prescription
- consider trades between angular resolution, effective area, and vignetting in different energy bands
- conceptualize an approach to a module mount design
- conceptualize an approach to full module design
- develop a model incorporating mechanical design and the notional assembly and alignment process
- perform structural, thermal, and optical analyses and check consistency with expected launch load
- develop independent error budget to assess allocations for reflector figure quality, mounting, aligning
- evaluate the type of metrology required, its accuracy and its volume
- develop a set of calibration requirements and use these to formulate a calibration plan
- develop a preliminary workflow for the assembly and alignment

STDT And Management Structure



Example Working Groups -TBD by STDT



STDT Science & Technology Specializations

Last	First	Expertise	Mission Experience
Allen	Steve	Clusters, clusters as cosmological probes	Astro-H SWG, IXO, LSST DES collaboration, SPT
Bautz	Mark	Mission development, detectors, clusters, SZ	IXO, X-ray CST, ASTRO-H SWG, MSFC/SAO XRS concept team
Brandt	Niel	Deep surveys, high-z quasars, LSST	Athena SWG Chair, numerous previous X-ray mission teams, LSST Advisory Committee
Bregman	Joel	Missing baryons around galaxies, highly cognizant of instrumentation	Athena, Con-X, IXO US Science Chair
Donahue	Megan	Circumgalactic medium, diffuse gas, feedback	GMT Advisory Committee
Hickox	Ryan	AGN, surveys, large scale structure, X-ray background	WFXT mission concept, NuSTAR Sci Team
Jeltema	Tesla	Clusters, groups, supernovae, multi-wavelength, XRBs, DES, LSST	
Kollmeier	Juna	Hydrodynamical simulations, large scale structure, galaxy evolution, SMBH growth, IGM	
Lopez	Laura	Sne, SNR, PWN, high resolution spectroscopy	
Madau	Piero	High-z Universe, first generations of supermassive black holes, and epoch of reionization	E-ELT SWG
Osten	Rachel	Stellar atmospheres, stellar flares, high resolution spectroscopy	Con-X FST, IXO, XAP STDT, ALMA Advisory Commit
Ozel	Feryal	Neutron stars and black holes	NICER Co-I, LOFT Co-I
Paerels	Frits	High resolution spectroscopy	XMM RGS, STDTs for HTXS, Con-X, IXO, XEUS, ASTRO-H SWG
Pivovaroff	Mike	Design and manufacturing of X-ray optics	NuSTAR Science Team, Int Axion Observatory
Pooley	Dave	Lensed quasars, globular clusters, AGN mergers	
Ptak	Andy	Mission development, galaxies, LLAGN	WFXT, IXO, Athena, MSFC/SAO XRS Study
Quataert		Compact objects, plasma astrophysics, stellar physics, galaxy formation	
Reynolds	Chris	Accreting black holes	NuSTAR, ASTRO-H, Praxys, Con-X, IXO
Stern	Daniel	Heavily obscured AGN, mission operations and development	NuSTAR, WFIRST SDT, PolSTAR
Vikhlinin	Alexey	Clusters, mission development	Lead of MSFC/SAO XRS Study. Very familiar with X-ray optics and instrumentation