NASA PCOS X-RAY CONCEPTS STUDY STATUS

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X-ray Concepts Study Scientist

Outline

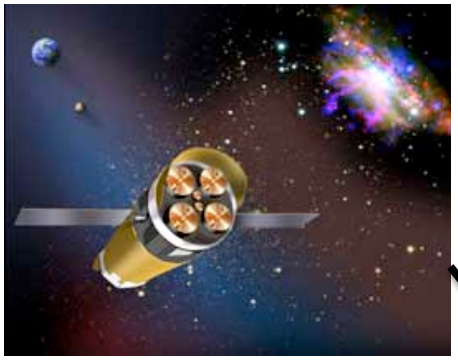
Background

- Motivation for Study

- **X- ray Study**
  - Objectives, Process, Participants, Schedule
  - Workshop
  - NASA Design Lab runs
  - Next Steps

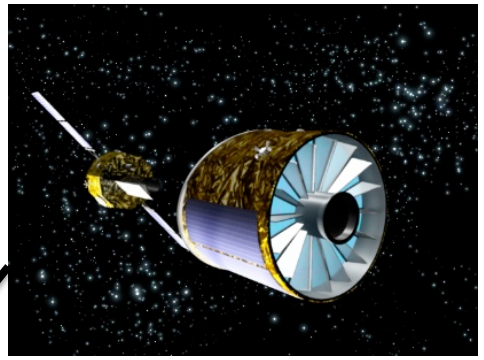
- **Questions/Discussion**

The road to the next strategic X-ray observatory



Constellation-X
(1996-2008)

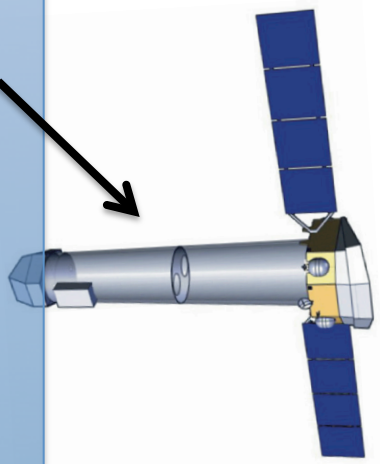
IXO
(2008-2011)



XEUS
(2000-2008)

- **Tech. development plan (2011-2012)**
- **Mission architecture assessment, with and without US contribution to Athena (2011-2012)**
- **Mission concept(s) definition (>2012)***

*** Purview of the CAA and NASA HQ**



Athena
(2011-??)

NASA ***ESA***

Background behind concepts study

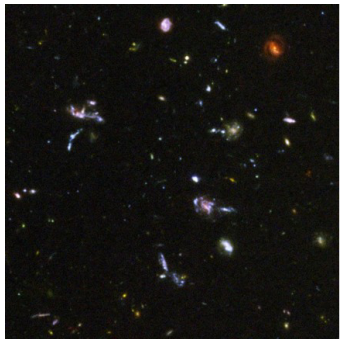
- **IXO study activities in US were terminated in fall 2011**
  - Prior to termination:
    - Produced mirror development plan consistent with NWNH recommendation
    - Developed AXSIO concept (a descope of IXO)
- **X-ray study activities and technology development moved under the Physics of the Cosmos (PCOS) Program Office**
  - SAT plus directed support for technology in 2012 and beyond (depending on available budget)
- **In September 2011, NASA initiated a concept study to identify more cost effective ways to perform IXO and LISA science**

X-ray Concepts Study

- **Objectives**
  - Determine the range of science objectives of IXO achievable at lower cost points
  - Explore new mission architectures and technical solutions
  - Fully engage the community and ensure that all voices are heard, all perspectives considered
  - Create data for a report to the CAA that describes options for science return at multiple cost points for X-ray astronomy
- **Deliver final report to NASA HQ that:**
  - Describes and analyzes trade space of science return vs. mission cost
  - Summarizes the mission concepts developed during the study and how they relate to the trade space and other mission concepts that were not developed in a design lab
  - Summarizes the RFI responses and the workshop and describes how they were folded into the whole study

2010 Decadal Science Plan (for X-rays)

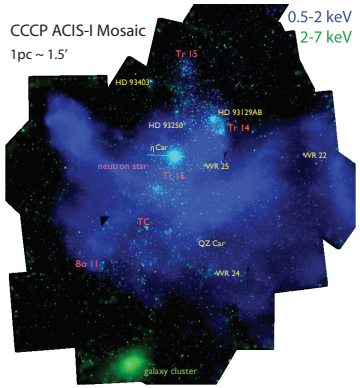
Cosmic Dawn



- Gas exchange between the galaxies and the surrounding inter-galactic medium.
- Formation and growth of black holes in the nuclei of young galaxies

(p.192)

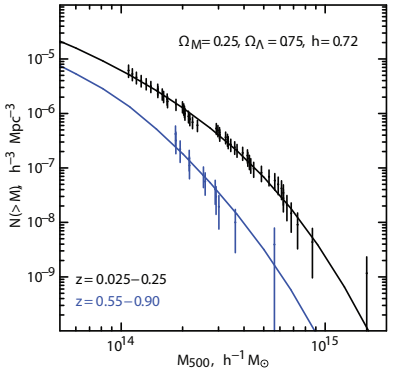
New Worlds



- Assess habitability by using IXO to characterize the frequency and intensity of flares on host stars.

(p.196)

Physics of the Universe



- **Find and study distant clusters of galaxies to measure the rate of growth of structure in the universe**
- **Observe x-rays from gas orbiting close to the event horizon of black holes**

(p.200)

Study Phases

- ✓ **Request for Information (RFI)**: ideas for missions and enabling technology. **29 responses received.**
- ✓ **Community Science Team (CST)**: 10 members of the community selected by NASA HQ
- ✓ **Workshop**: provide the community a forum to comment on concepts and technology and identify concepts for further study.
- ✓ **Notional Mission Selection**: Three mission concepts at different cost points.
- – **Design Labs**: Study team develops concepts through mission design lab runs. Focus is on identifying the technical and cost drivers of each concept.
- – **Final Report:** Summarizes study activities and results for HQ and CAA. **Due to NASA HQ on June 7, 2012**

Study Boundary Conditions

- The basis for discussion and selection of concepts for further study is the degree of compliance with IXO science objectives, as endorsed by NWNH.
- We are **NOT** revisiting decadal survey decisions regarding science questions or mission priorities.
- We are studying *representative, notional* missions for the various cost classes. The goal is to assess the fraction of IXO science that can be performed vs. mission cost. There are no winning or losing concepts.
- No recommendation for a specific mission or a preferred cost class will be given in the final report. This is the CAA's responsibility.
- External constraints (e.g., Athena) will need to be taken into consideration.

Study Team Membership

- **Study Manager –** Gerry Daelemans (GSFC)
- **Study Scientist** – Rob Petre (GSFC)
- **Community Science Team** – 10 members selected by NASA HQ (next slide)
- **Science Support Team** – Andy Ptak (GSFC), Jay Bookbinder, Randall Smith, Mike Garcia (SAO)
- **Engineering Support Team** – Tony Nicoletti, Gabe Karpati (GSFC), Mark Freeman, Paul Reid (SAO), discipline engineers
- **Support & oversight from:**
  - NASA HQ
    - Rita Sambruna (PCOS Program Scientist), Richard Griffiths, Wilt Sanders
    - Jaya Bajpayee (PCOS Program Executive)
  - PCOS Program Office (GSFC)
    - Ann Hornschemeier (Chief Scientist)
    - Jackie Townsend (PCOS/COR Program Office)

Community Science Team Members

- Joel Bregman (Michigan) - chair
- Mark Bautz (MIT)
- David Burrows (Penn State)
- Webster Cash (Colorado)
- Christine Jones-Forman (CfA)
- Steve Murray (Johns Hopkins)
- Paul Plucinsky (CfA)
- Brian Ramsey (NASA / MSFC)
- Ron Remillard (MIT)
- Colleen Wilson-Hodge (NASA / MSFC)

RFI responses

- **29 received: 16 mission concepts, 13 enabling technology**
  - In the aggregate, the notional missions should probe various points of the science return vs. mission cost trade space.
  - Variety of concepts in nominal "cost bins" (for those with sufficient information for a cost estimate):
    - 1 ≤ $0.6B (small)
    - 8 ~ $1.0B (medium)
    - 4 ≥ $2B (large)
  - Small missions generally addressed one IXO goal well; medium, large mission concepts addressed more than one IXO topic directly
- **Technology responses addressed wide range of technology: optics, gratings, calorimeters and other detectors, structures**
- **All responses posted on PCOS website (http://pcos.gsfc.nasa.gov)**

Analysis of RFI responses (concepts only)

- **Analysis by science support team + CST**
  - Brief summary of each concept
  - Comparison of objectives to those of IXO
  - Set of questions created for each concept and sent to respondent
  - Responses to questions are being posted
- **Analysis by engineering support team**
  - Responses assessed for "completeness" (sufficient information for a Design Lab run?)
  - Cost assessed based on information provided (for binning purposes)

Workshop Objectives

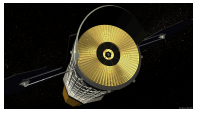
- **Provide the community an opportunity to comment on the study and shape the missions that will be developed in design labs.**
- **Provide a forum for discussion and exchanging information between the study team and the community.**

Workshop Outcome

- **Over 100 participants; more would have attended if timing had been better**
- **Every respondent to RFI was given an opportunity to present**
- **General support by community for the current limited study**
  - Unclear whether a real opportunity exists, but we need to be ready to take advantage
- **Recognition of small number of key technology areas**
  - Mirrors (7 concepts used segmented glass)
  - Microcalorimeters (and coolers) (6 concepts)
  - Grating spectrometers (3 concepts)
- **Genuine concern about longer term future of X-ray astronomy**
  - Competitive strategic mission for 2020 decadal survey
  - Technology funding is marginal at best (APRA, SAT)
    - Is ~$200M recommended in NWNH going to materialize?
  - Should follow this effort with broader study of future of field (1995 XAPWG)

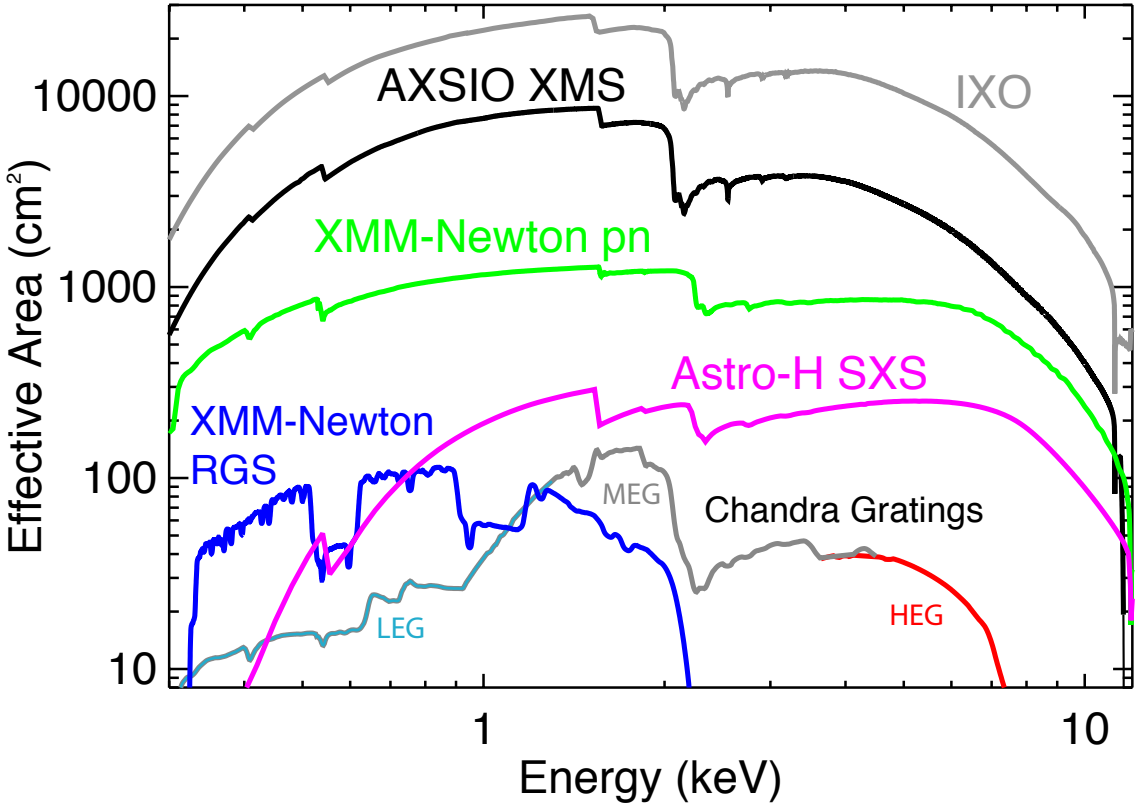
Notional Missions For Design Lab Runs

- Notion Mission 0: AXSIO
  - Cost goal: < $2B
  - Formulated and underwent mission design lab run before X-ray study commenced
- Notional Mission I: Gratings only
  - Cost goal: < $600M
  - Most inexpensive option
  - Concept of choice if Athena is selected
- Notional Mission II: Calorimeter only
  - Cost goal: < $1B
  - Most desirable scenario if Athena is not selected
    - of three notional concepts, achieves the most IXO science by far
- Notional Mission III: Wide Field only
  - Cost goal: < $1B
  - Alternative to calorimeter mission if acceptable calorimeter < $1B not formulated
- All three missions currently configured for an L2 orbit
  - Maximizes observing efficiency (~ 85% vs ~ 65%)
  - Simper spacecraft design
    - Better thermal environment (most relevant for calorimeter mission)



AXSIO: The Advanced X-ray Spectroscopic Imaging Observatory

Notional mission “0” designed to meet NWNH recommendations (<$2B)
Optics: 0.9m^2 at 1.25 keV; 0.2m^2 at 6 kev
10” resolution (5” goal)
Calorimeter 40X40 array with < 3 eV resolution
Grating $\lambda/\Delta\lambda$ >3000; ~1000 cm^2 (0.3-1.0 keV)

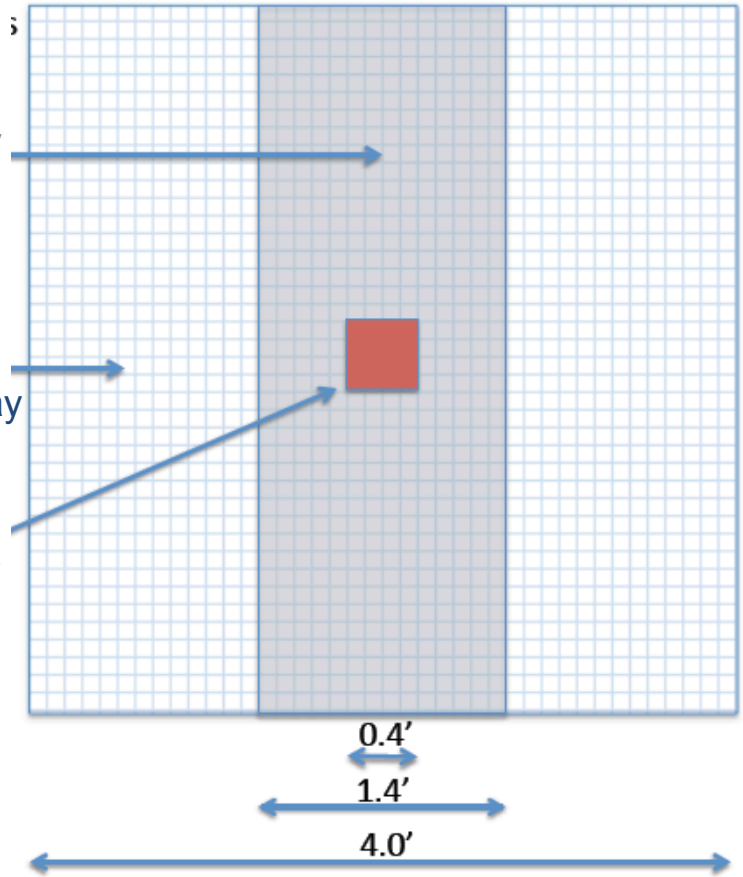


Notional Mission I: Gratings

- **Merging of off-plane (WHIMEx) and critical-angle transmission (Aegis) designs**
  - Takes advantage of segmented mirror design by only using part of aperture (azimuthally) to reduce mass
  - 7 m focal length
- **>500 cm^2 over 0.3-1.3 keV**
- **R > 3000**
- **Key science**
  - Large-Scale Structure: Warm-Hot Intergalactic Medium
  - Matter under Extreme Conditions
    - Active Galactic Nuclei outflows, absorbers
    - X-ray binary accretion physics
  - Life Cycles of Matter and Energy: Stars and Protostars

Notional Mission II: Calorimeter

- **Descope of AXSIO mirror**
  - smaller size and mass
  - 9.5 m focal length
- **Central "Point Source Array" (red square) to enable high-count rate science (X-ray binaries)**
- **Spectral resolution of < 3 eV (inner arrays), < 6 eV (outer array)**
- **Key science:**
  - Matter under Extreme Conditions
    - AGN accretion, outflows
    - X-ray binaries
  - Large-Scale Structure
    - Clusters of galaxies
    - WHIM
  - Life Cycles of Matter
    - Starburst galaxies, Supernova remnants, Stars
  - In other words, *most of IXO science*



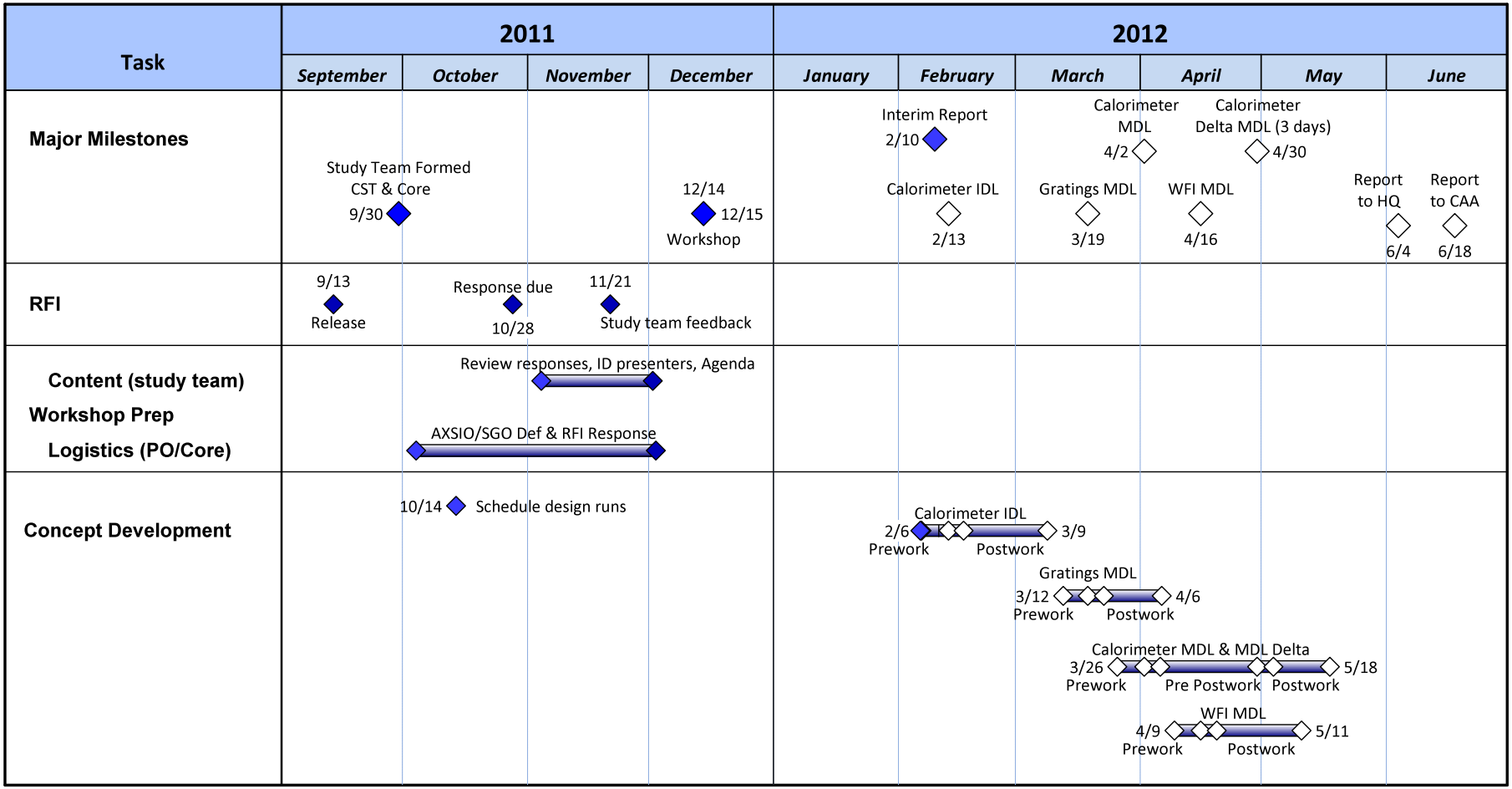
Notional Mission III: Wide-field Imager

- **Focal-plane with CCD-like detectors**
  - > 24’ FOV with ~ 7” spatial resolution constant
  - CCD resolution removes high spectral resolution science goals
- **Two possible mirror designs**
  - 3 identical mirrors (with three focal planes)
  - Single AXSIO-like mirror
- **Rationale**
  - Alternative if calorimeter mission cannot be brought under $1B without giving up too much essential science *and* can itself be under $1B
- **Key science (done statistically)**
  - Black hole evolution, high-redshift obscured AGN
  - Large-scale structure, clusters of galaxies

Design Lab Runs

- **One Instrument Design Lab (IDL) run for calorimeter**
  - Completed Feb. 12-17, final report in ~ 3 weeks
  - Resulted in significant reduction in mass and simplification of focal plane
- **Three Traditional Mission Design Lab (MDL) runs**
  - Grating mission 3/19-23
  - Calorimeter mission 4/2-6
  - WFI mission 4/16-20
- **"Delta"s to each notional mission assessed by MDL personnel**
  - Date: 4/30-5/6
  - Plan is to try alternatives to reduce cost
    - Calorimeter: major reduction in mirror, simpler cooling system
    - Grating: LEO instead of L2
    - WFI: Reduce number of telescopes or smaller single telescope design
    - Not all of these deltas can be tried within current time frame
  - May also need MDL time to assess cost to add instruments to single-instrument designs

Schedule


Task
2011
2012
September
October
November
December
January
February
March
April
May
June
Major Milestones
Study Team Formed
CST & Core
9/30
12/14
12/15
Workshop
Interim Report
2/10
Calorimeter IDL
2/13
Calorimeter
MDL
4/2
Gratings MDL
3/19
Calorimeter
Delta MDL (3 days)
4/30
WFI MDL
4/16
Report
to HQ
6/4
Report
to CAA
6/18
RFI
9/13
Release
Response due
10/28
11/21
Study team feedback
Content (study team)
Workshop Prep
Logistics (PO/Core)
Review responses, ID presenters, Agenda
AXSIO/SGO Def & RFI Response
Concept Development
10/14
Schedule design runs
Calorimeter IDL
2/6
Prework
Postwork
3/9
Gratings MDL
3/12
Prework
Postwork
4/6
Calorimeter MDL & MDL Delta
3/26
Prework
Pre Postwork
Postwork
5/18
WFI MDL
4/9
Prework
Postwork
5/11

Enabling Technology

- **RFI solicited responses regarding enabling technology**
- **Technology responses will be used to:**
  - Inform discussion about notional missions
  - Provide input to NASA about key areas to be addressed through APRA and PCOS funding
  - Identify in study report critical and enhancing technology areas where support needed for short and long term needs

Next Steps

- **Interim Study Report (done)**
  - Summarize RFI responses and analysis
  - Summarize Workshop Outcome
  - Summarize concepts selected for further study
- **Design labs (ongoing)**
  - Study team is collecting data needed for design lab and defining trades
- **Results from design runs plus external trades incorporated into study report**
  - Outline completed, CST and study team members assigned writing and editing duties

Involvement of the broader community

- **Workshop**
- **Mostly through the PCOS web site**
  - RFI responses and study team summaries
  - Workshop presentations
  - Regular status reports
  - Community "bulletin board" for comments
  - Study report
- **Presentations to PhysPAG (Austin and beyond)**
- **Informal "town hall" at Austin AAS meeting (Tuesday evening)**
- **Regular progress reports distributed through PCOS, HEAD newsletters**
- **Final study report will be distributed to the community online and summarized at conferences.**

Backup Slides

Near Term X-ray Landscape – a "Golden Age"

- **Current missions**
  - Chandra (1999-) Unprecedented imaging and (limited) high resolution spectroscopy
  - XMM-Newton (1999-) Wide field, good angular resolution, large area
  - Suzaku (2005-) Very broad-band, low surface brightness spectroscopy
  - Swift (2004-) Rapid response to transients, deep 10+ keV survey
  - ~~RXTE (1996-2012)~~
- **Upcoming missions**
  - NuSTAR (2012) Hard X-ray imaging (6-80 keV)
  - Astro-H (2014) Spatially resolved high res spectroscopy + broad band
  - GEMS (2014) Sensitive X-ray polarimetry
  - Astrosat (2012?) RXTE-like X-ray timing
  - SRG (eROSITA, ART) (2013) 0.3-15 keV all sky survey
  - NICER (NASA), LOFT (ESA) Timing missions in study phase
- **No guaranteed mission after 2017 – "golden age" will end abruptly**
- **What's missing is a strategic mission**

Background for concepts study (1 of 3)

- **Constellation-X was NASA's strategic X-ray mission concept (1996-2008)**
  - High resolution spectroscopy with large effective area
  - Four mirrors (~3m^2 @ 1 keV) with calorimeter and gratings, plus HXT
  - Ranked 2nd among large missions in 2000 decadal survey
  - Substantial technology development – mirrors, calorimeters, gratings
- **X-ray Evolving Universe Spectrometer mission (XEUS) was European counterpart (2000-2008)**
  - Very large collecting area with wide field imaging plus high resolution spectroscopy, high time resolution and polarimetry
  - One of three L-class mission candidates selected in 2006 for ESA's Cosmic Visions
- **In 2008, the missions were merged to form the International X-ray Observatory (IXO)**
  - Submitted to both US Decadal Survey and ESA Cosmic Visions

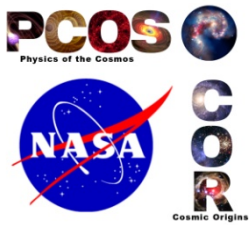
Background behind concepts study

- **In 2010 IXO was among the four large missions identified in *New Worlds New Horizons* to move forward this decade**
  - Science was very well received but projected cost thought to be too high ($3.3B-$4.8B)
  - Key IXO science is high resolution spectroscopy
  - IXO should cost no more than $2B; 10 arcsec resolution acceptable
  - Strong recommendation to develop optics and other enabling technology to higher readiness level (~$200M over decade)
- **In March 2011, ESA decided to redefine all three L candidates**
  - Due to JWST costs and budget realities, ESA was no longer confident that NASA could contribute its share, about half the cost of each mission
  - ESA component of mission to be less than ~€800M
  - US participation possible at ≤$150M level
  - Downselect decision postponed until February 2012 (now April at earliest)
- **ESA decision meant the termination of the formal IXO project (and LISA) by NASA**
- **ESA has subsequently developed Athena concept**
  - Two mirrors, focusing onto WFI and microcalorimeter

The Decadal View of IXO

- **"IXO is a versatile, large-area, high-spectral-resolution X-ray telescope that will make great advances on broad fronts ranging from the *characterization of black holes* to *elucidation of cosmology* and the *life cycles of matter and energy in the cosmos*. Central to many of the science questions identified by this survey, IXO will revolutionize high-energy astrophysics with more than an order-of-magnitude improvement in capabilities." (p19, emphasis. added)**

Broad Range of Mission Concepts submitted as RFI responses



- The Warm-Hot Intergalactic Medium Explorer
- The Advanced X-ray Timing Array
- The High Energy X-ray Probe
- The Black Hole Evolution and Space Time Observatory
- SuperMon & Black Hole Tracker
- An Astrophysics Experiment for Grating and Imaging Spectroscopy
- The Extreme Physics Explorer
- Spectral Analysis with High Angular Resolution Astronomy
- Orbiting Wide Field X-ray Imaging Spectrometer
- Wide Field X-ray Telescope Mission
- Epoch of Reionization Energetic X-ray Survey
- Xenia: A Probe of Cosmic Chemical Evolution
- The Advanced X-ray Spectroscopic Imaging Observatory
- Square-Meter Arcsecond Resolution X-ray Telescope

Calorimeter Mission Effective Areas