The Future of X-Ray Optics

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Looking to the Future.

- Progress in X-ray optics, with emphasis on the angular resolution, is central to the paradigm-shifting discoveries and the contributions of X-ray astronomy to multiwavelength astrophysics over the past 51 years.
  - Rocket, Uhuru, Einstein, Rosat, Chandra
Learn from the Chandra experience.

- Clear scientific goals drove the design of the mission.
- Approaching our next X-ray mission in this way is more important than ever.
  - Why? The lesson of history is that this next mission will certainly not launch until after 2020 or, more likely, after 2030.
Take advantage of the hiatus.

• Use the time for developing technologies and manufacturing approaches that will satisfy our scientific needs for the next 51 years.
  • Seek fresh ideas from a broad community for the challenge that I will describe.
What should the next (notional) major X-ray mission be?

- Conservative (i.e., reasonable) requirements:
  - Sub-arcsecond on-axis angular resolution
  - Capability for wide-field deep surveys
  - Effective area sufficient to detect the first galaxies in an integration time $\approx$ Msec
  - Wide energy band to enable spectroscopy.

- To (inexpensively) realize such specifications will require a technology program of the type I shall describe.
Learn from Chandra - develop the optics before we have a mission!

• Follow multiple, competitive, physics-based (not programmatic-based) approaches.
  • Currently several ideas but no proven answers.
    • Adjustable X-ray optics
    • Differential deposition
    • New materials
  • Even then, prove both technical readiness and manufacturing readiness.

• Defining and costing the mission before the technology is in hand hurts us.
  • Outrageous and self-fulfilling cost estimates.
Learn from Chandra - develop the optics first!

Demonstrate technology

Demonstrate manufacturing

Build flight optics
Do not drive the optics design to:

- satisfy an arbitrary mass limit.
  - Scientific performance takes precedence.
- address thermal and vibration issues.
  - Assume that external hardware will provide adequate thermal stability and vibration isolation.
- accommodate horizontal 1-g operations.
  - Assume & impose *vertical* alignment, assembly, metrology, and X-ray testing of the mirror assembly.
What will these optics look like?

- Grazing incidence technology.
- Full-shell or segmented — unclear.
- Total weight — unclear.
- Number of telescopes to achieve the required area — unclear.
Conclusions.

• The most important next step is the development of X-ray optics comparable to (or better than) Chandra in angular resolution that far exceed Chandra’s effective area.

• Use the long delay to establish an adequately funded, competitive technology program along the lines I have recommended.

• Don’t be diverted from this objective, except for Explorer-class missions.