Plan B

What does X-ray Astronomy do now?

Martin Elvis
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50 Years of X-ray Astronomy:
1 billion times more sensitive
“naked eye” to “Hubble Deep Field”

Sco X-1

1/10,000

good enough for my thesis

NGC3783

1962 1978 2010

We dreamed of IXO continuing this rapid progress
“Until the early 1990s, particle physics was the flagship of the physical sciences. Facilities continued to grow, and it seemed that there was no limit. But Congress’ cancellation of the Superconducting Supercollider (SSC) after massive cost overruns, crippled morale in the field. Now, experimental particle physics is in steep decline in the US. Could a similar flame-out happen to astronomy?

After the SSC debacle, many particle physicists re-tooled themselves as astronomers, others have gone to work for Wall Street. Would we re-discover the excitement of less expensive projects overlooked in the rush to justify huge investments? There is more opportunity for that in astronomy. But once a discipline has suffered a major setback, the tendency is to leave the disappointment behind, and do something totally different. It is hard to tell exactly where the Funding Wall for astronomy is... Peter V. Foukal”
Pyramids, Cathedrals & Accelerators

- Over time, ventures grow to the limit of what their societies can afford (c/o Shri Kulkarni)
- Pyramids,
- Cathedrals,
- Accelerators.
  - SSC abandoned after $2B
  - Cost rose from $5B to $12B.
Room for 1 Big Mission

Budget Guidance for Decadal Survey – Notional scenario

New Missions: $2.3B to 2020

Development

JWST

Chandra, HST, Fermi...

HST de-orbit

We are here

• Assumed operating missions beyond 2016 include JWST, SOFIA, plus HST, Chandra, Fermi, etc. (e.g., Astro-H)
• HST De-orbit mission development ramps up ~2020
• “Future Missions” wedge is for strategic missions recommended by the Astro2010 decadal survey
• The amount of “Future Missions” funding available between 2013–2020 in such a scenario would be ~$2.3B

The Great Observatories

From X-ray discovery to IR follow-up now 1 year

1990-2015?

1999-2015?

2003-2013

The Era of the Great Observatories is about to end
JWST Follow-up will take a decade

James Webb Space Telescope: Launch 2014
5-10 year lifetime

IXO Launch NET 2025*?
>= 10 years
* Unless LISA trips

Or more: No UV/near-opt capability after HST

Has happened before: 10 years from HST to Chandra. But JWST not serviceable
Astronomical Objects don’t know about our technologies
Astro2010 Space Recommendations

- Wide Field IR Survey Telescope
- Enhanced Explorer Program
- LISA
- IXO
- The new Flagship scale:
  “...allowing any major mission to exceed $2 billion in total cost to NASA would unacceptably imbalance NASA’s astrophysics program.” [p.7-22]
The Great Observatories

NOW. 2010

- Fermi
- Chandra
- HST
- Spitzer
- ALMA
- EVLA/VLBA
- SOFIA
- Radio
- Heat lamp
- Microwave radar
- Heat lamp
- TV/AM/FM

Pre- and Post-Decadal Landscape

C.2020

- GeV
- MeV
- Hard X
- Soft X
- EUV
- UV
- Visible
- Near infrared
- Shortwave infrared
- Middle infrared
- Thermal infrared
- Radio
- LISA
- #4 IXO
- New Worlds
- B-mode CMB
(+4m UV)

In development for 2020-2030 launch:
- LISA
- #4 IXO
- New Worlds
- B-mode CMB (+4m UV)

No major new facilities

source: Christopherson (2000) Geosystems
Pre-Decadal Situation

IXO: the International X-ray Observatory

• Wonderful
  – A powerful Observatory
  – Spectra, timing, polarimetry, imaging
  – 5” HPD
  – Launch NET 2021
  – $2B or so to launch
  – NASA/ESA/JAXA collaboration
  – IXO should be the One Big Mission

But what if...
What if IXO isn’t #1?

• Must get
  #1 rank in US Decadal Survey
  *AND*
  #1 rank in ESA “Cosmic Vision 2015-2025”

  1st of 3 ‘L class’: IXO, LISA, Laplace (Jupiter) for L1 launch ~2020.

• Not quite as tough as betting on “22” twice in *Casablanca*

• Worst case: 2nd place. *Waiting and waiting and waiting…*

  • The young Bulgarian refugee, Jan Brandel, has to bet on 22, twice, and win, to save his wife from Inspector Renault. Rick Blaine helps. Are we so lucky?

  We need a “Plan B”, just in case
Factoid: DoE Particle Physics = $800M/year [6-1]; ~$80M/year Astro-particle
Option: Step back a factor 2-4 in Cost

- Expected a High Energy ‘Consolation Prize’
- Unaffordable at ~$1B
- Much to be said about cost estimates, other choices...
  irrelevant now
- Hard to scale down to Explorers
  ~1/5 scale
- ESA M3?
Astro2010 Recommendations

- What can we do with what is recommended?
  - Augmented Explorers
  - $200M in IXO development
- Other Opportunities
- No Magic Bullet
Enhanced Astrophysics Explorer Program

• #2 Priority in Decadal [p.7-19] (space, large)
  – Now 1 astrophysics launch/3 yr,
    • ~$40 M/yr
  – Increase in 2010-2020 to
    • $100M/yr for astrophysics
      – 2 MIDEX
      – 2 SMEX
      – 4 Missions of Opportunity

• Parallel Small Program enhancements
  – R&A +$2M → +$15M [p. 7-26]
    • TRL3 → TRL5
  – Sub-orbital +25% launches [p.7-27]
  – Lowered costs, requirements?
  – Enhanced ADA/LTSA for Explorer exploitation?

• CXC offer Data Center services
  – heritage, cost → science
Interoperable Archives becoming a requirement: CXC/VO experience is an asset

RECOMMENDATION:
Proposals for new major ground-based facilities and instruments with significant federal funding should be required as a matter of agency policy to include a plan and, if necessary, a budget for ensuring appropriate data acquisition, processing, archiving, and public access to a suitable proprietary period.

Effective Oct 1, 2010, NSF will require that all grant proposals include a data management plan in the form of a two-page supplementary document.
Looking good through ~2015
Post-2015 X-ray Explorer-Class Concepts

• **LOBSTER:** George Fraser 0.5-2keV ASM, survey
  Microchannel plate optics (Leicester/Photonis)

• **Fresnel Zone Plates.** sub-milli arcsec. 1/2m dia., 1000 km focal length Paul Gorenstein

• **Telephoto X-ray Interferometer.** 1mas, 20m physical length (40km f.l.) Dick Willingale

• **Extreme Physics Explorer.** 0.5-15keV Calorimeter spectra/fast timing. “Sq.meters” microchannel plate optics

• **Pharos.** 0.1-2keV R~3000 spectroscopy: WHIM, Physics, Hot Jupiters.

*By optimizing for specialized missions Explorers can rival IXO in sub-areas: Do One Thing Right*
**Extreme Physics Explorer**

**Science**

- **QCD effects:** Magnetar polarization, Hydrogen Lyman series @ ~1 keV
- **Strong Force:** neutron star equation of state: M/R, R from bursts
- **General Relativity:** map metric around black holes: Fe-K, polarization
  
  "You don’t have to be a genius to see there’s a potential Nobel Prize in here."

- Photon Hungry apps.
  - 10^3 cts in 10^3 spec. bins/time bin
  - Most IXO point source calorimeter science covered

**Technology**

- **Big Bad Mirror:**
  - Microchannel Plate Optics
  - ~1 arcmin, ~1cm spot
  - ~5 sq. meters @ 1keV
  - Light: 3.7 kg/m^2

- **Calorimeter array**
  - **Rapid timing** 100 µs
  - **High count rate** 1000Hz/pixel, 32x32 ~10^6 ct/s
  - **High Res. Spectra** 2eV. R~500 @ 1keV

- **Polarimeter**

- **ASM?** for state/transient alert

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Not ready for 2010 Explorer: Do spadework for later round
Pharos

Science

• #1: Missing Baryons: the Warm-Hot Intergalactic Medium.
• #2 Physics: QED - Lyman series @ ~1 keV in magnetars; NS EOS
• New: Exoplanet-Star interactions
• Soft X-rays (<2keV)
• High Resolving power (~3000)

Technology

• Short Focal Length mirror
  • High area/mass ratio
  • XMM-class Ni Replica shells
  • 10” HPD -> ~2” in dispersion
• CAT blazed gratings (IXO)
  • ~50% dispersed power
• CCD readout; 0-order
• ~40% of IXO grating area
• 100% of observing time
• ½ SM for GRBs, blazars
• fast slew

Fits 2010 Explorer cost, weight envelope. High TRL. We will propose it.
Pharos & 2010 Explorer AO

• AO ‘early Fall’, +90 days due Jan/Feb; Launch <2018
• $200M cap
  – Incl. 25% reserves
  – NASA adds launch
• LEO ~1000 kg (Taurus)
• 2 years (2-3 year extension)
• Pharos fits easily into Explorer envelope
• Team now forming rapidly:
  – Contact me right away if interested.
  – Lots of work!
  – Prospect of great science reward
Other Opportunities, 1: Micro-satellites
(c/o Shri Kulkarni)

- Microsatellites: $10M, <100kg
- Canadian MOST
  - “Microvariability and Oscillations of Stars”
  - 15cm optical telescope + CCD
  - 60kg
  - 65x65x30cm “suitcase sized”
- Cheap enough for small countries, rich institutions (Allen, Keck, Harvard...)
- Culturally hard for big agencies?
- Lobby to include in MoO?
- X-ray astronomy apps?

[Image: Diagram of satellite and table with Falcon 1 details]

Fig. 2.— Above: The phase diagram of the w/o X-ray photometry of HD 189733, and the transit model, folded at the orbital period of the planet. The data have been averaged in 5 min bins. Below: Residuals from the model.
Other Opportunities, 2: Human Program

- Core expertise: X-ray/Space Technology
- Asteroids: Humans to visit ~2025
- Need to characterize destinations
- X-rays give regolith composition
- Current asteroid X-ray tech. is collimated gas counters

Regolith X-ray Imaging Spectrometer: proposed Student experiment for OSIRIS-REX
IXO development funding

- $200M over 10 years (recommended)
  ~$5M/year for first few years
  Then ~$30M/year for ~5 years
to accommodate SPICA funding?

- Implies mainly mirror development to high TRL

- Options:
  a. Continue as before. Tripwires on LISA may trigger
     - 2011 downselect by ESA: may eliminate LISA, or IXO
     - 2012 LISA Pathfinder launch, ~2014 results
       → IXO takes LISA’s place for ~2020-2021 launch. All is well.
  c. Move to develop radically better optics.

“Given the multidecade timescales required for development of major facilities from concept to construction to operation, it should not be surprising that many of these projects have evolved in technical and/or scientific scope since AANM [2000 Decadal]...” [7-2]
IXO Development: A Problem

• Is re-proposing IXO in 2020 going to get #1 ranking?
• That sinking feeling: E.g. Stein Sigurdson, “Dynamics of Cats” blog post, 11 Aug 2010:
  • “That is ONE of the large scale projects, only, for the next decade. Maybe one or two medium/small projects to keep a community alive. I’m biased: I think JDEM screwed up, first by bumping in line demanding a new priority review, and then not being ready to go; I have had some involvement in LISA for over a decade, though only platonic for now, due to total absence of funding - I really like LISA as a concept, and there is the pesky matter of the agreement with ESA to do LISA; IXO is solid, has a huge constituency of good hard working x-ray observers, but is incremental. Unfortunately I don’t see the TPFs as ready to go phase-A, though something like a New World Observer concept could fly early with some success and have strong secondary science.”

• IXO first proposed ”BC”: before Chandra launch (c. 1997)
  – Will be a >20 year old concept for next Decadal
  – Competition will be:
    • Earth-like planets imager,
    • Inflation: B-modes in CMB
    • UV 4-meter class telescope
    • other new concepts

• Newer approaches?
  – No alternative paths in 1997. Landscape now changed.
  – Higher angular resolution: unmentioned in Astro2010
  – Fresnel Zone plates? X-ray Interferometry?
  – Super-Chandra
Need a Replacement for Chandra

1/2” is not enough

Hubble: ~0.1”

Chandra: ~0.5”

The Antennae Colliding Galaxies System
NEED A REPLACEMENT FOR CHANDRA

MEGASECOND CLASS OBSERVATIONS FOR THE BRIGHTEST, NEAREST EXAMPLE OF EACH CLASS

THE SUPERNova REMNANT CASSIOPEIA A
Chandra is a ¼" Telescope

- 0.5” ACIS pixels
- ¼” HPD
- Can be retrieved
  - Sub-pixel positioning (PSU)
  - ‘multi-drizzle’ from dither (Leon van Speybroeck)
  - Will be part of pipeline, calibration in ~1 year
  - Thanks to $1.5M from Senior Review
  - shows level of excitement
IXO is Dead. Long Live IXO!

• Pharos, Extreme Physics Explorer reduce pressure to do everything on IXO: 3-4 instruments done
• Concentrate on One Thing – High Spatial Resolution
• New Optics
  – Cheaper, lighter, High resolution
  – Active, Piezo-controlled figure
  – 0.1” HPD goal. Promising in lab (Reid)
  – Presently targeted at “Generation-X”
    • 50 sq.meters: 1000 x Chandra

  – *Decades away*
  – Re-orient to high resolution successor to Chandra?
• **A ‘Super-Chandra’**
  - 10 x area, 5 x resolution
  - Active Piezo-optics
  - Small pixel “CCDs”, Calorimeter array

• **Explorer Proposal to AO c.2015? (Reid, Schwartz)**
  - One imager
  - $E < 3\text{keV}$ (cf Einstein): >5x area of 20m f.l.

• **Need revolutionary science**
  - Equivalent to AXAF/Chandra driver:
    “resolve the X-ray background”
  - What would YOU do with ATHENA?
A Post-Decadal Plan for X-ray Astronomy

1. No single All-or-Nothing venture
2. Specialized Explorers: *Pharos 1st*
3. *Super-Chandra* – ATHENA
4. Privately funded micro-satellites
5. Human space program [NEOs]
6. Data Center Services, VO
Another IXO Approach: 4 ‘Explorers’

- In 2004 Con-X had 4 identical spacecraft
  - Co-pointing Gratings, Calorimeter, Hard-X-rays: *inefficient*
  - Would rarely co-point GALEX – blue/hot - and Spitzer – red/cold
  - Same $\Delta \log E$ as Con-X: 1 or 2 instruments mostly idle

- Separate spacecraft gives 70% gain in instrument utilization
- Each mission MIDEX class: $\Sigma$ is smaller
3 Explorer IXO Approximation

**NuSTAR:** 2012. SMEX
- Imaging 10-80keV
- Area: ~200 cm$^2$ @ 40keV

**ASTRO-H:** 2014
- Calorimeter, 210 cm$^2$

**Pharos:** Explorer 2017?
- R$\sim$3000 gratings @ E<1.2keV
- Area ~400 cm$^2$ (1.5m focal length)

10-40% Con-X
Tear Down that Funding Wall

• Can we ever beat the Funding Wall?
• Cheaper launches
  – No launchers designed with cost as a driver
  – SpaceX may be the first: factor 2-3 cheaper/kg, as of now
• Cheaper Space operations:
  – Needs a commercial driver
Plan C: Asteroid Mining

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Itokawa from Hayabusa