X-rays and star formation
The future…

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Unsolved important questions

- How stars form
  - Angular momentum
  - Magnetic fields
- How planetary systems form
- Chemistry of clouds, stars, planets
- Global questions (cosmological relevance), local answers

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Why X-rays?

- X-ray observations are a tool!
- Don't make them into an end…
- Should be used to answer physics questions of broad importance!

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Before *Einstein* …

- Star forming regions were a cool place
- Slow, regular processes
- Near-equilibrium chemistry
- B fields (nearly) irrelevant
- All pretty boring ☺
- IR king of observing tools

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After…

- SFRs are pretty hot places!
  - Rife with violence!
  - Smoking hot (almost 10^9 K plasma in YSOs!)
- X-rays are a great probe of young stars
- X-rays influence the star formation process itself
- X-rays likely to have dramatic influence on early planetary environment

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X-ray offer unique diagnostics

- High-contrast YSO identification and census
  - IMF's become child's play ☺
  - Class III were discovered in X-rays!
  - Bridge between SFRs and ZAMS
- Size and structure of magnetospheres

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X-rays modify the SFR environment!

- Ionize medium
  - Disk ionization -> B field coupling
    - Dominate over cosmic rays by 8 orders of mag
    - Accretion, angular momentum loss
    - Planetary formation?
- Nuclear reactions
  - Isotopes
- Photochemistry

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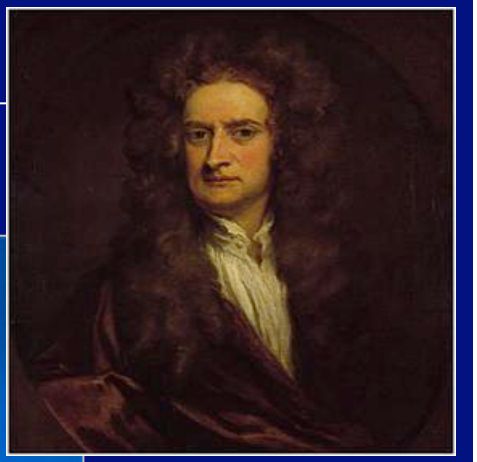
XMM-Newton



launched 1999

XMM-Newton

- X-ray observatory
- ESA-only mission
- Ca. 0.5 m^2, 10 arcsec resolution
- Open to worldwide scientific community
- Most productive ESA astronomy mission
  - Ca. 1 refereed paper per day

XMM-Newton

- Start of ops 2000
- Planned lifetime: 10 yr
- Ca. 1 B€ from ESA, plus ca. 0.4 B€ from European member states

Chandra

Chandra

- X-ray observatory
- NASA only mission
- Ca. 0.05 m^2, 1 arcsec resolution
- Open to worldwide scientific community
- Starts of ops 1999
- Planned lifetime: 10 yr
- Ca. 4-5 B$ NASA cost

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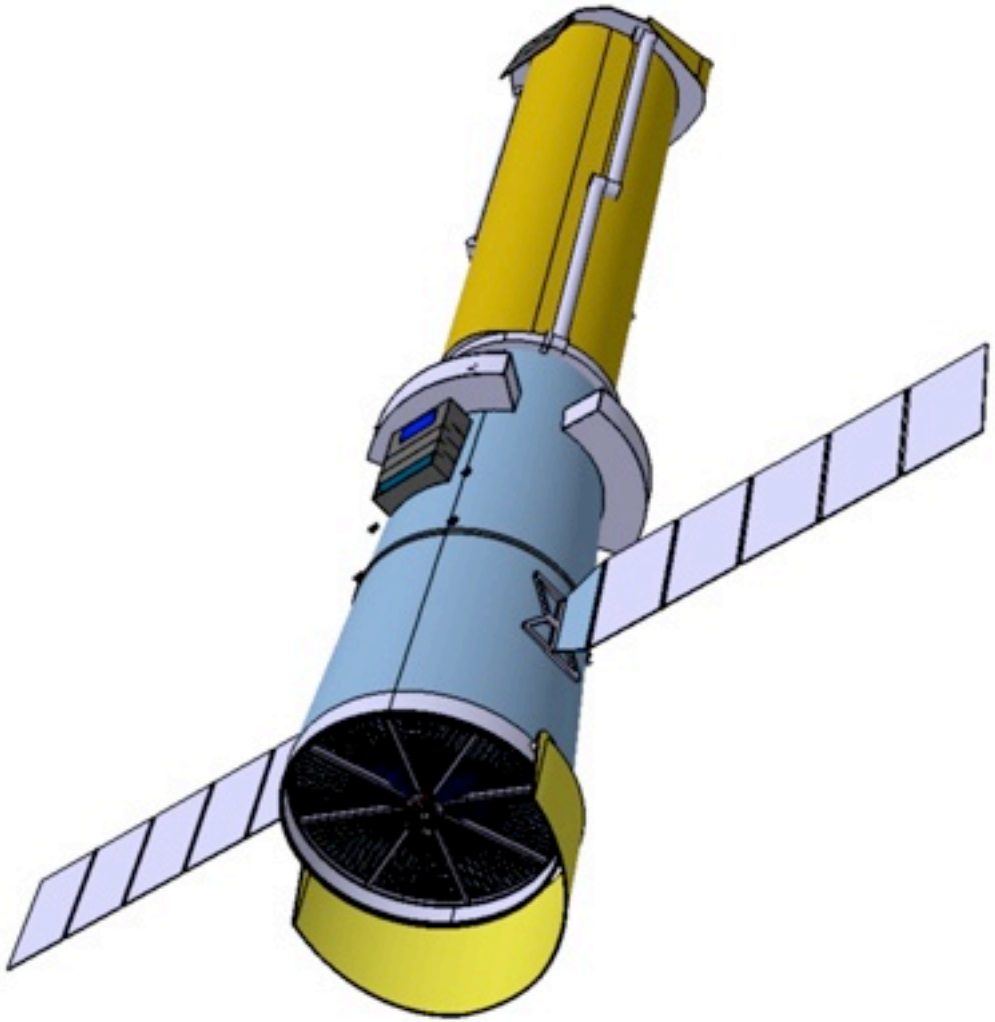
The next generation

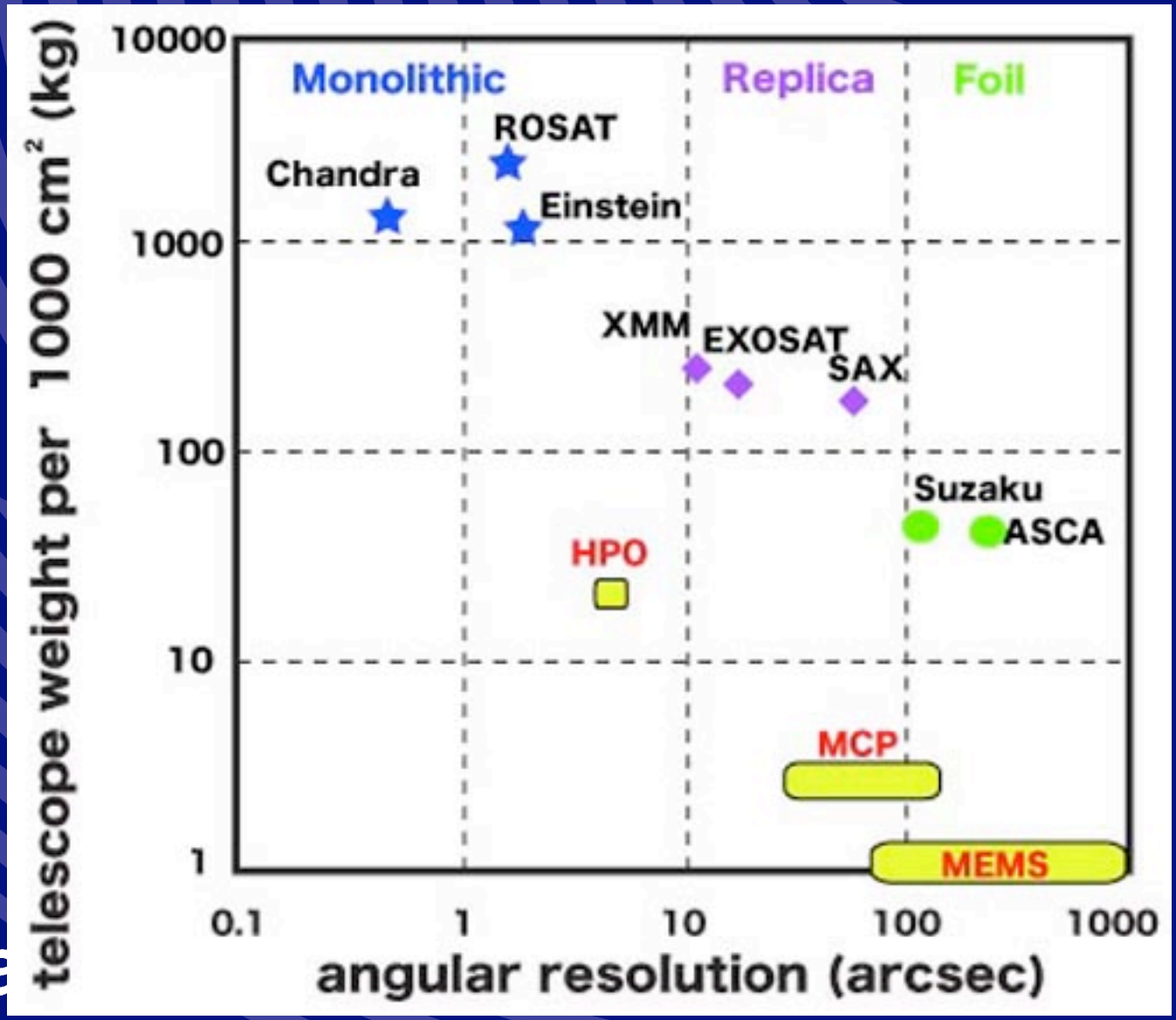
- Long history of "planning the future"
- Successors to XMM-Newton and Chandra
- Bigger and better!
- XEUS in Europe
- Constellation-X in the US
- … merged into IXO

IXO

- The challenge
  - Same rocket
  - ≤ budget
  - Order of magnitude improvement in performance
    - Mirror area!
- Similar step as JWST from HST

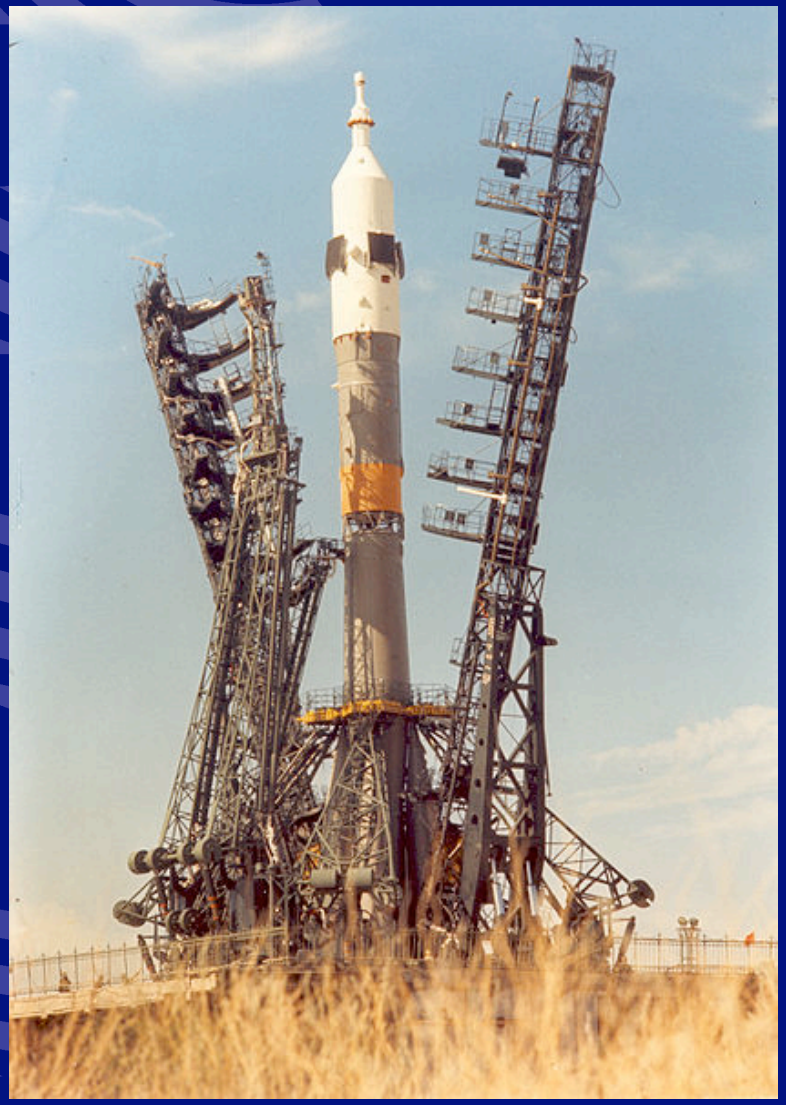


Optical technology challenge



Rocket technology…

Progress in rocket technology…



Space Astrophysics budgets

- NASA: ca. 1.2 B$/yr
- ESA: ca. 0.2 B€/yr
- European member states: comparable to ESA
- Available for new missions: between $\frac{1}{2}$ and $\frac{3}{4}$ of above budget figures
- Chandra or Newton: ca. 6-7 yr of available resources

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Space astronomers as parasites ☺

- Rockets
- Spacecraft
- Optical technology
- CCDs
- IR detectors
- … more

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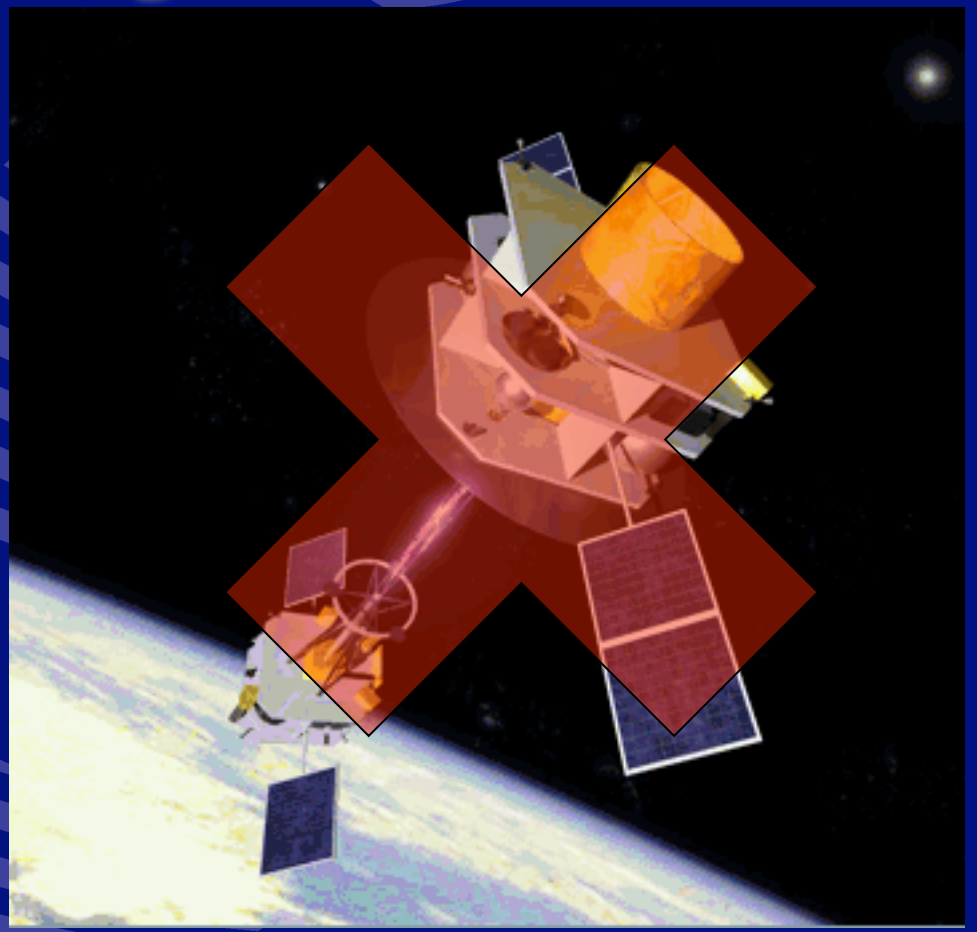
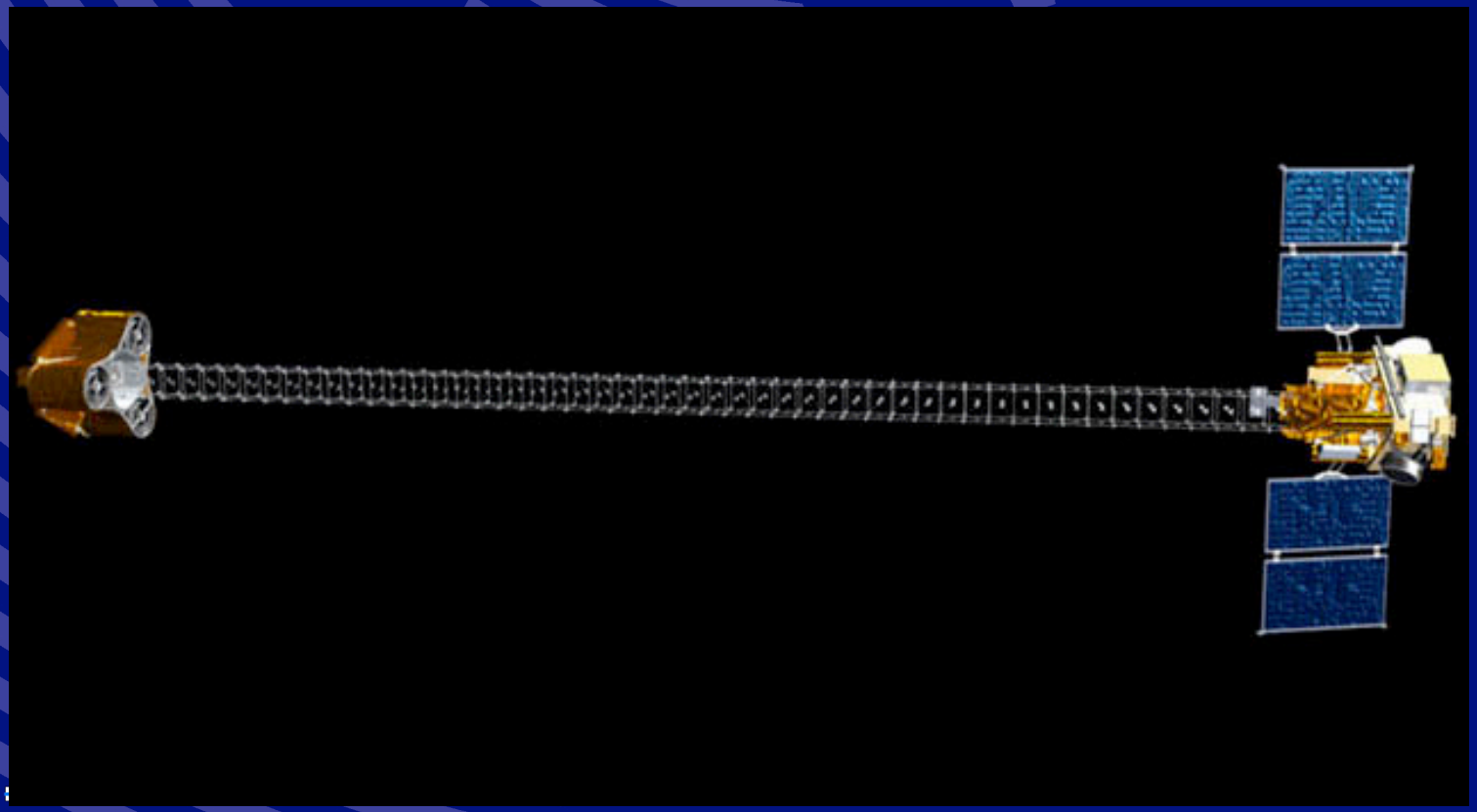
Other X-ray observatories in the making

- Simbol-X
- Hard X-rays, imaging



Other X-ray observatories in the making

- NuSTAR
- NASA
- Hard X-rays, imaging
- 40 arcsec
- 0.1 m^2
- mid-2011

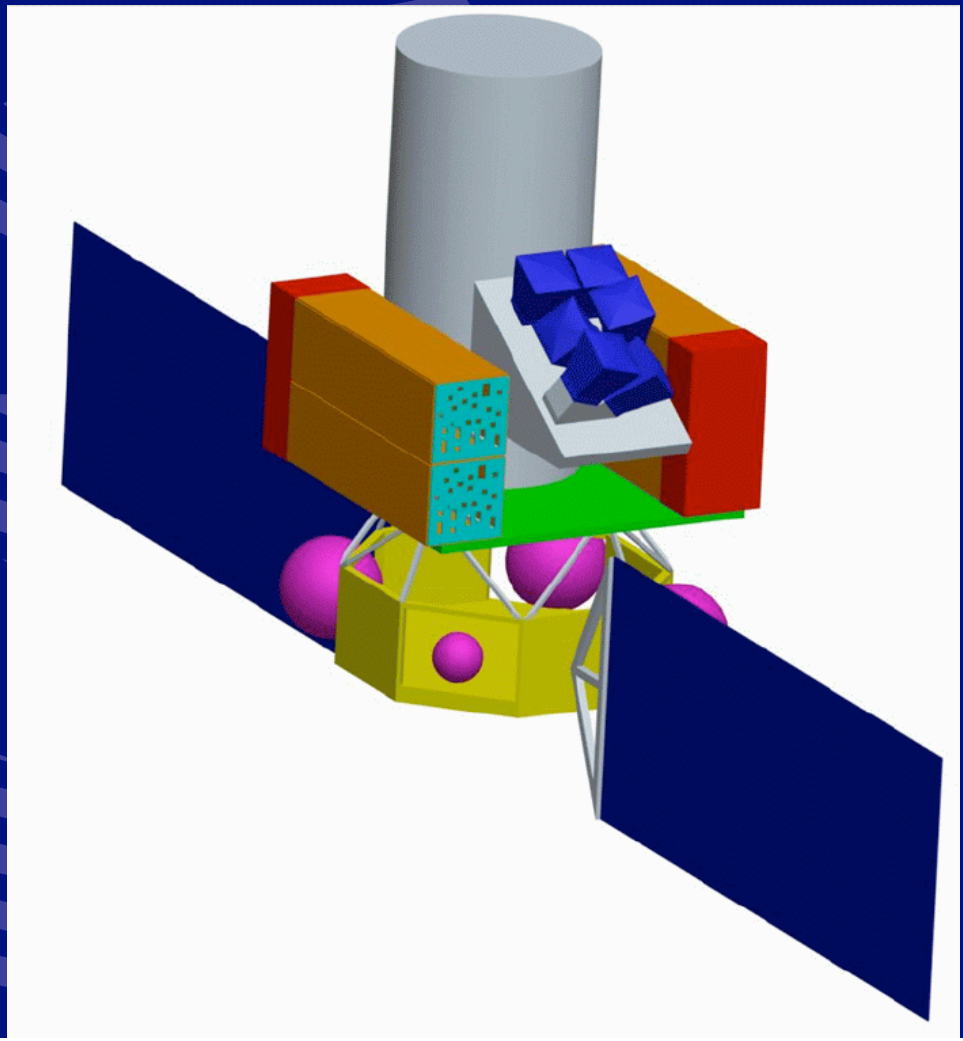


Other X-ray observatories in the making

- Astro-H
- Mainly JAXA
- Broad-band
  - 0.3-600 keV
- TBC arcsec
- TBC m^2
- mid-2013

Other X-ray observatories in the making

- SRG
  - eRosita
- Roskosmos, DLR, others
- All-sky survey to 10keV
- Launch?



The cost of your science

- Price of Chandra time: ca. 20$/s
- 100 ks Chandra observation = 2 M$

- Space Science funding in Europe (ESA)
  - 1 cup of coffee/European/year
- Space Science funding in USA
  - 2 Big Macs/American/year
- Space astronomy gets less than half

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Multiple challenges…
You have to convince…

- Taxpayers (and elected representatives)
  - Fund astronomy at large
- Astrophysics community
  - Compete for facilities
- Time allocation committees
  - Compete for time

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Timescale of future big facilities

- Newton & Chandra
  - Nominal lifetime over pretty soon
  - Living on borrowed time
  - 2015?
- Major facility (IXO)
  - Needs new technology
  - Needs prioritization
  - Needs money
  - > 2020

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Be creative!

- Best use of existing facilities
  - Exploit time domain
  - Complete ongoing work
  - Complete census of SFR, increase exposure
    - But don't turn it into butterfly collecting ☺
  - Organize massive optical & NIR follow-up
  - Spectroscopy (opt & NIR) -> ELT?
  - Extragalactice – would be nice, but very challenging!

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Be creative!

- Think about smaller, more focused new facilities
- Beware of going the particle physics way…
- But don't get discouraged!

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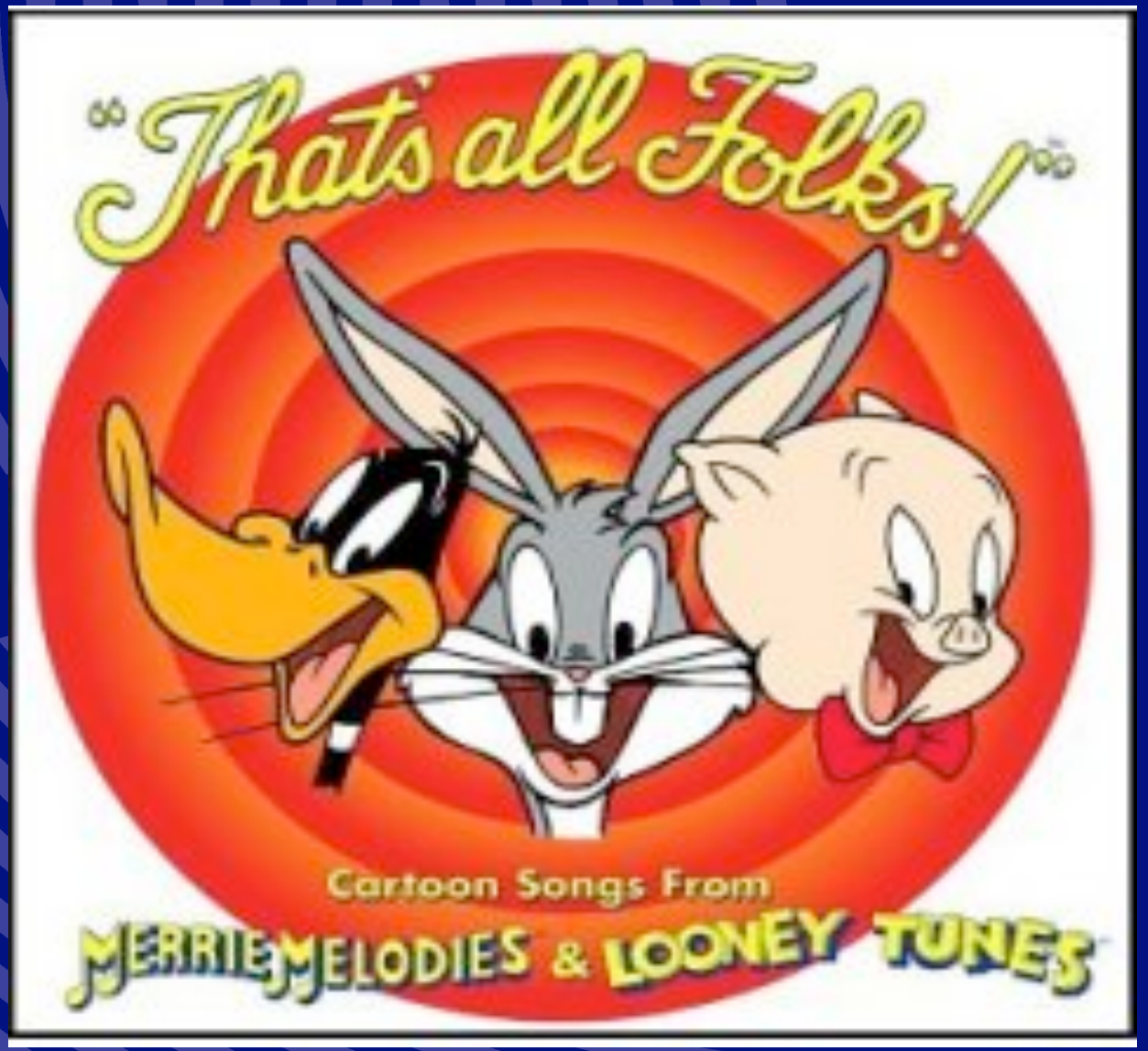
"That's all Folks!"
Cartoon Songs From
MERRIE MELODIES & LOONEY TUNES