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US X-Ray Flagship Astronomy

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United States: A long history in breakthrough X-ray space technology

X-ray astronomy is a relatively new field, made possible by advances in space technology

The US has been building and deploying X-ray flagships for five decades

The US plays a leadership role in X-ray astronomy

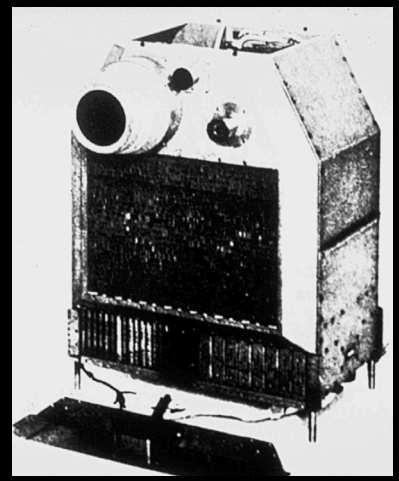
Are we at risk of losing our expertise and leadership?

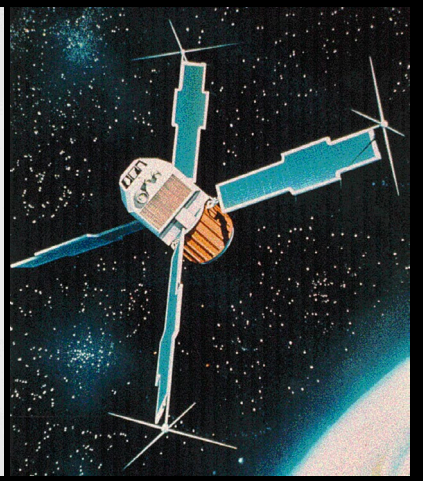
Uhuru

Uhuru Satellite launched in 1970

- first comprehensive survey of the X-ray sky (Giacconi+71)
- extended X-ray emission from galaxy clusters (Forman+72)
- binary star systems (Forman+72)
- active galactic nuclei (Gursky+71).

X-ray detector on Uhuru





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HEAO 1

HEAO 1 Satellite launched in 1977 – operated until 1979

- monitoring of hard X-ray and gamma-ray sources (Doxey+79)
- Large area X-ray survey (Friedman+79)
- Active galactic nuclei (Remillard+93)
- Soft X-ray background (Martin-Mirones+91,Garmire+92)
- Fast X-ray transients (Ambruster+86)
- Diffuse cosmic hard X-rays (Gruber+99)

HEAO 1
In the lab

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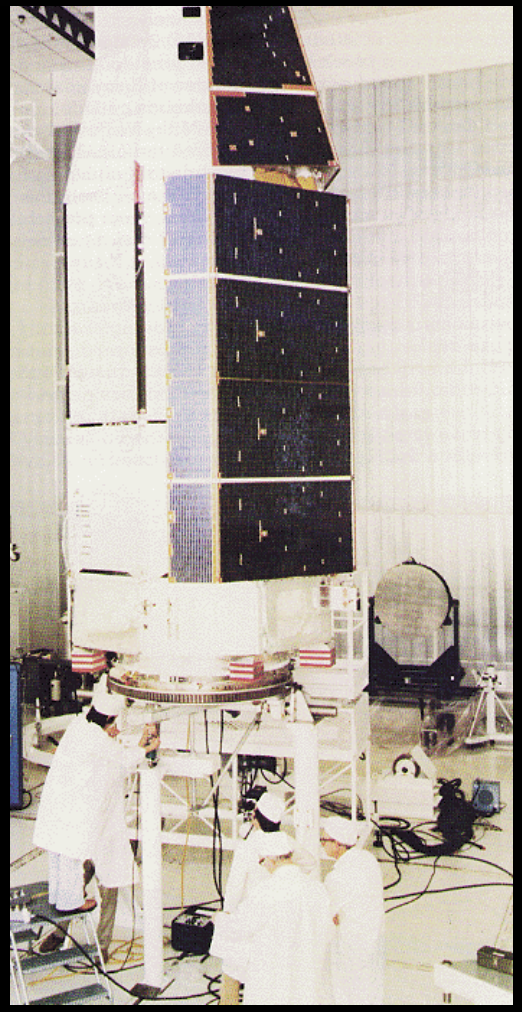
HEAO 2 - Einstein

HEAO 2 Satellite (Einstein) launched in 1978 – operated until 1981

Significant increase in sensitivity in the soft X-rays

- soft X-ray background (Giacconi+79)
- stars (Ku+97,Seward+79,Helfand+80,Ayres+81)
- globular clusters (Leahy+83,Hertz+83)
- supernova remnants (Long+79,Murray+79)
- quasars (Tananbaum+79)
- Galaxies (Fabricant+80,Kriss+80,Elvis+81,Fabbiano+82,84,Forman+85)
- Galaxy clusters (Jones+79,Canizares+79,Jones+84)
- our Milky Way center (Watson+81)
- center of our neighbor galaxy M87 (Schreier+82)



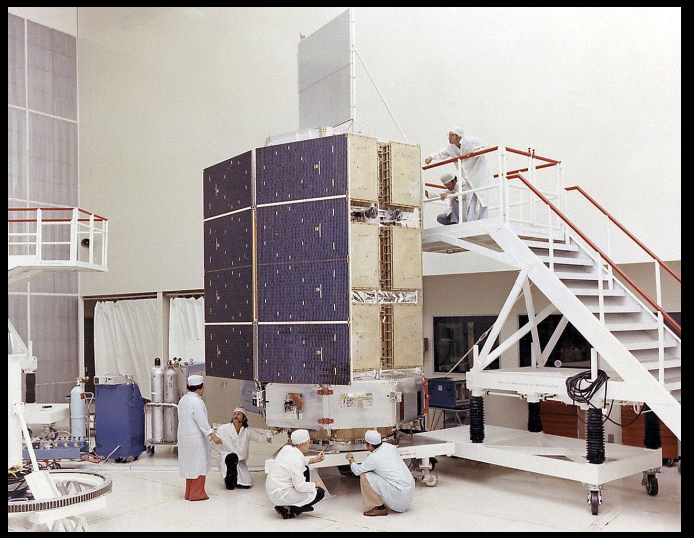
Einstein
In the lab

HEAO 3

HEAO 3 Satellite launched in 1979 – operated until 1981

hard X-ray, gamma-rays, cosmic-rays.

- Centaurus A (NGC 5128) at 2 keV-2.3 MeV (Baity+81)
- Transient observations (incl. pulsars; Mahoney+84)



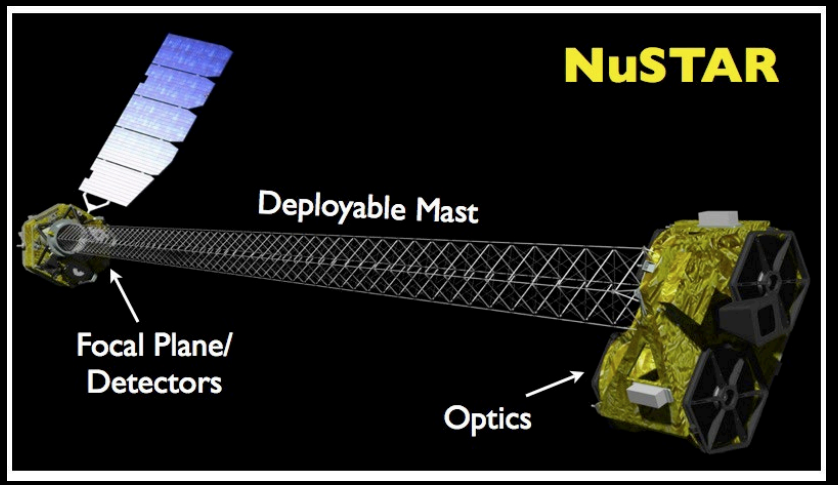
HEAO 3
In the lab

NUSTAR

NUSTAR Satellite launched in 2012: hard X-rays

Initially deployed as a 2 year mission, still collecting data (Harrison+13)

- Hard X-ray monitoring of transients (Paterson+24,Bozzo+24)
- X-ray binaries (Parker+15)
- GRBs (Kouveliotou+13)
- Gravitational wave observations (Evans+17)
- AGN (Balokovic+14,Fabian+15,Marinucci+15,Ricci+16)
- Jets (Miller+13)
- Quasars (Stern+14)



25th Anniversary: Launching & Deploying Chandra

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Chandra

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Chandra launched in 1999: soft and hard X-rays

Unprecedented spatial resolution – really enables multi-wavelength astronomy

- Multi-messenger observations of a binary neutron star merger (Abbott+17)
- Co-evolution of galaxies and SMBH (see Kormendy & Ho 2013 for review)
- Direct physical proof of dark matter – X-ray hot gas in a merging cluster (Clowe+06)
- Relationship between SMBH and the X-ray background (Marconi+04)
- Feedback (e.g., Fabian+12,di Matteo+05,Veilleux+05)
- Black hole binaries (Remillard+06 for a review)
- High energy atomic physics (Smith+01)
- GRB physics (Ho+20)
- Dark matter halos (Vikhlinin+06)
- Neutron star physics (Ozel+16)
- Supernova remnants (Bamba+03,Vink+03)

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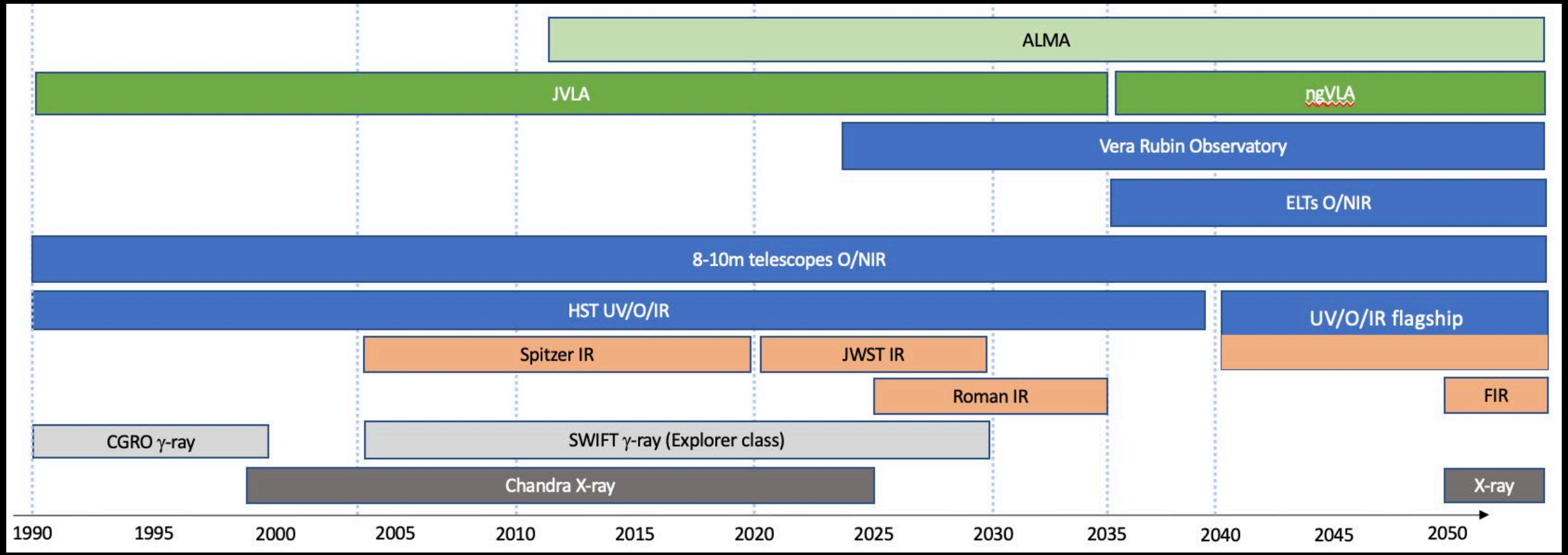
Flagship Facility Recommendations



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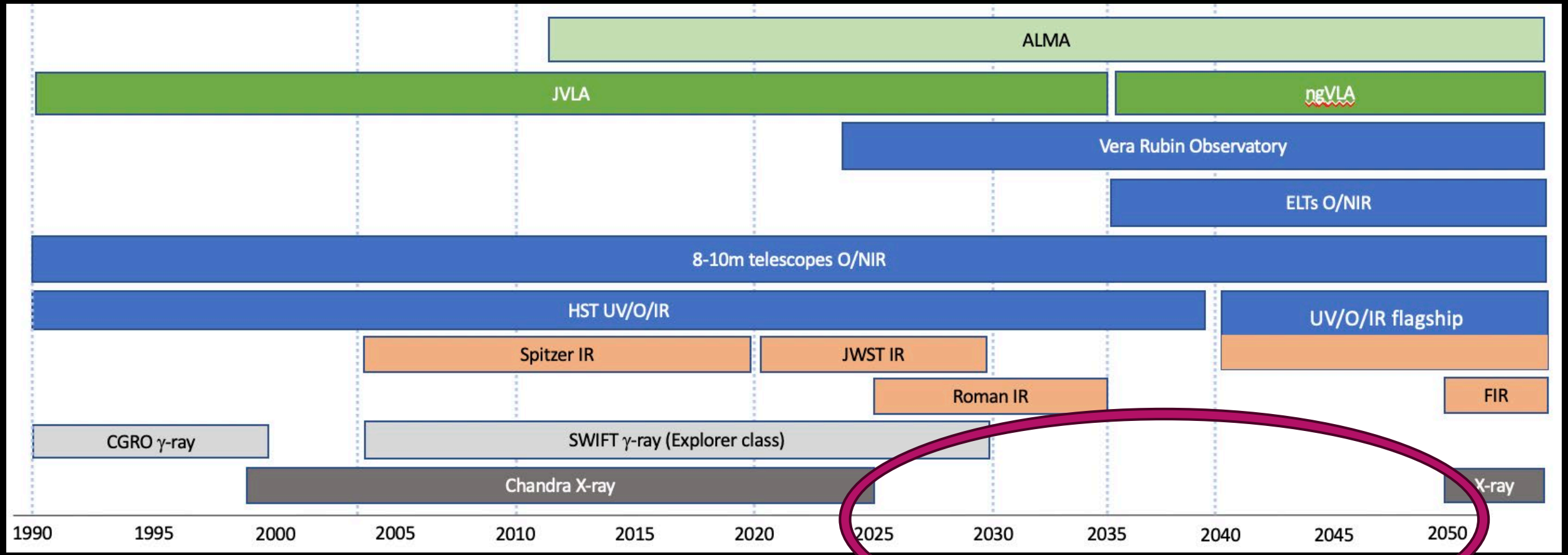
Flagship Facility Recommendations



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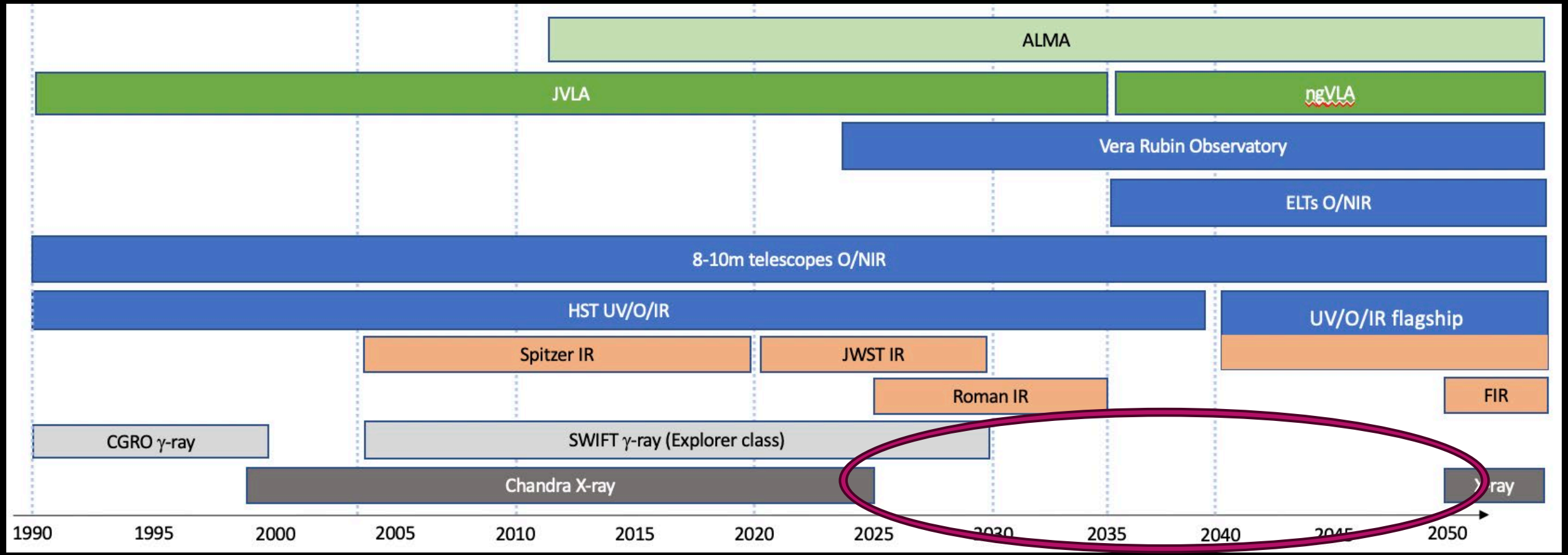
Flagship Facility Recommendations



It takes 10 years to build a probe-class mission, 20 years to build a flagship

ASTRO 2020 X-ray flagship recommendations

Potential Impacts

- Loss of science – all areas that require high resolution X-ray imaging, including (but not limited to):
  - BHs
  - galaxy formation & evolution
  - time domain astronomy
- Loss of scientific community supported through Chandra
- Potential loss of expertise and critical mass required to build and deliver scientifically on future X-ray flagships
- Loss of US leadership in X-ray astronomy

ASTRO 2020 X-ray flagship recommendations

Impacts

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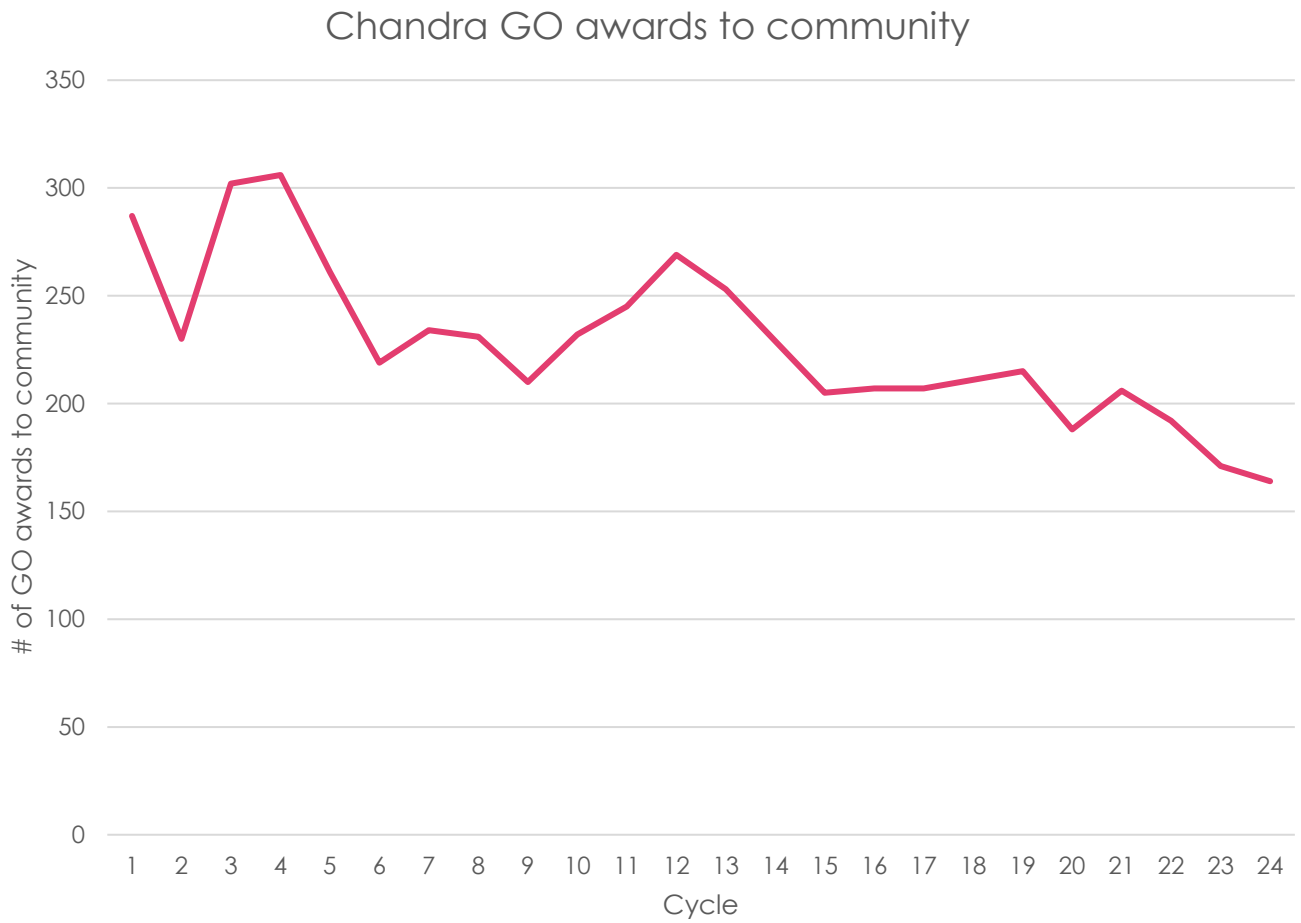
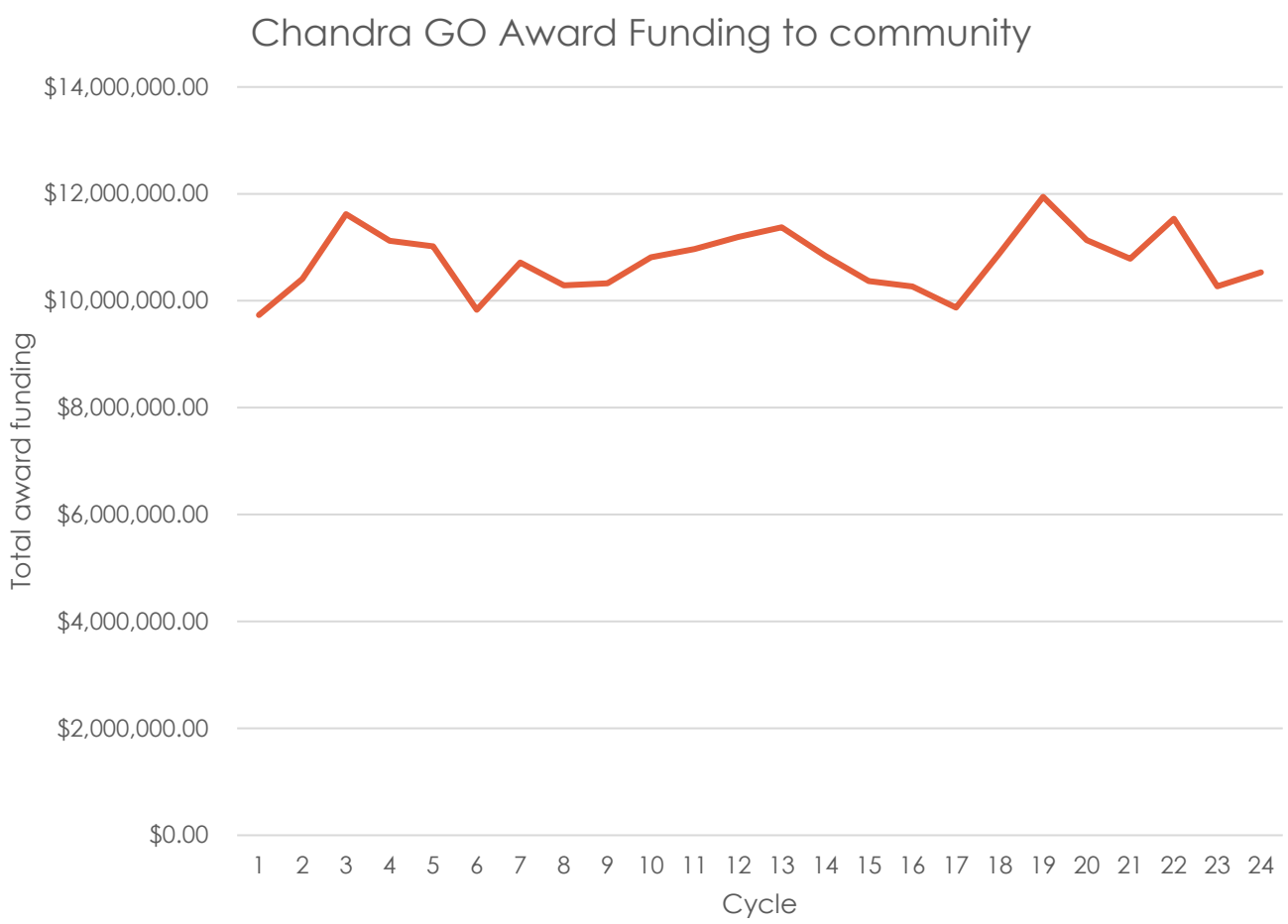
Chandra GO Awards





Chandra GO Awards

> 100 postdocs
+ students

ASTRO 2020 X-ray flagship recommendations

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What is the international landscape?

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Europe:
- ESA Athena – launch late 2030s

Japan:
- JAXA – XRISM – launched 2023

China:
- Insight-Hard X-ray Modulation Telescope (HXMT) - MIDEX-size – launched 2017
- Lobster Eye X-ray satellite (the size of a SMEX mission) – launched in July 2020
- Einstein Probe (EP) – transient detector – MIDEX size - launched Jan 2024
- Diffuse X-ray Explorer (DIXE) – launch 2027-2028
- enhanced X-ray Timing and Polarimetry (eXTP) – probe-class size - launch 2027-2028
- Hot Universe Baryon Surveyor (HUBS) -

ASTRO 2020 X-ray flagship recommendations - questions

Questions:

- What will the US X-ray community do without an X-ray flagship?
- Will there be a US brain drain to Europe, China, Japan?
- Will X-ray astronomers leave astronomy?
- What fraction of the community will leave?
- Of those that stay, will they stay in X-ray astronomy? With what data?

ASTRO 2020 X-ray flagship impact survey

We need your input!

Closes Friday 14 April

https://forms.gle/xtiCgFA7JxAwsH4o7

Results will be published in a White Paper titled *“The upcoming gap in US flagship X-ray astronomy: Impact on US and international astronomy."*

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Key Questions:

- What fraction of time do you use US X-ray flagship data?
- How critical is X-ray flagship data for your science?
- What would be the impact of a lack of a US flagship on your science and/or your job?
- If there is no US X-ray flagship for more than a decade, would you likely remain in US astronomy? Leave astronomy? Move to a different country for astronomy?
- (If remain in US astronomy) without a US X-ray flagship, would you conduct science using X-ray flagship archival data? X-ray Probe/MIDEX/SMEX data (if possible), theory, X-ray flagship data from other countries?

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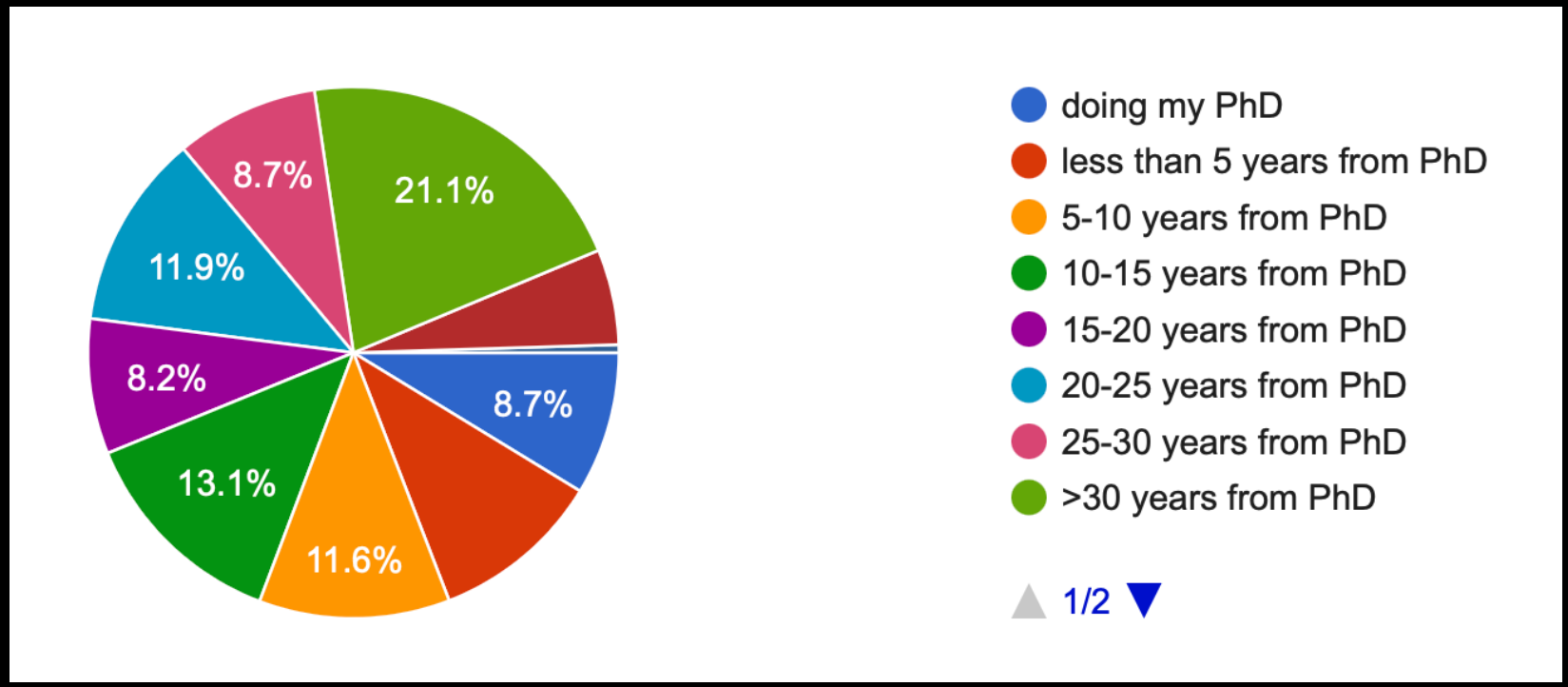
ASTRO 2020 X-ray flagship impact survey

Results sneak preview: 413 respondents so far



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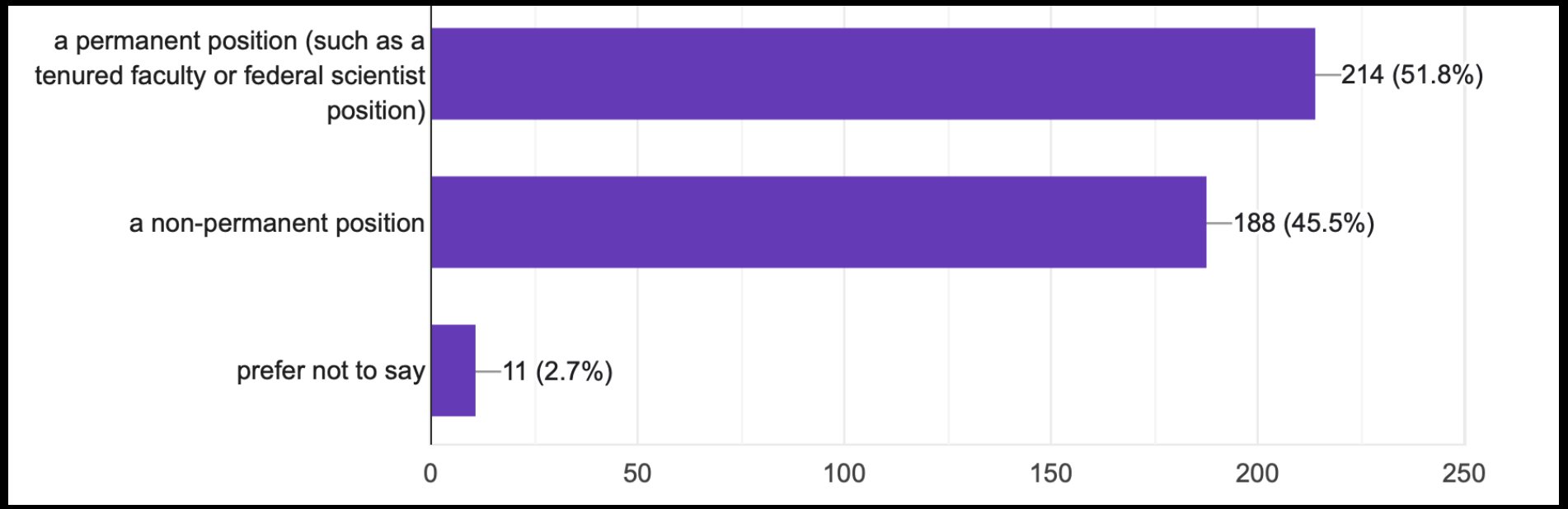

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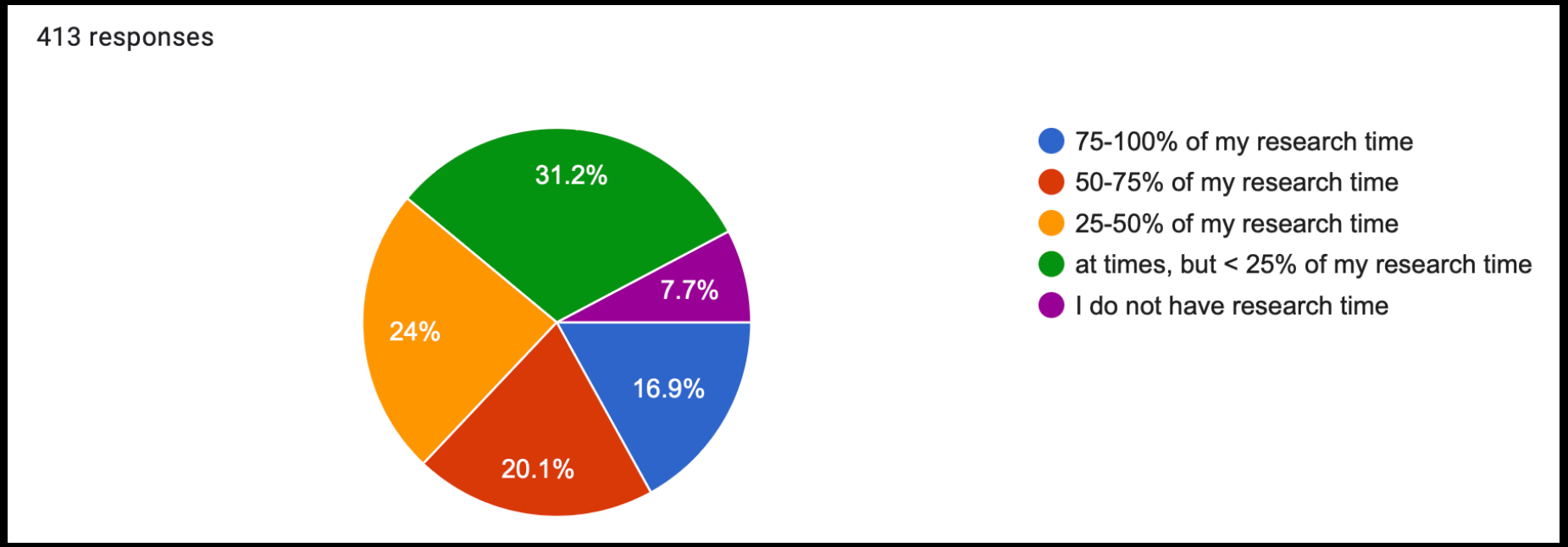

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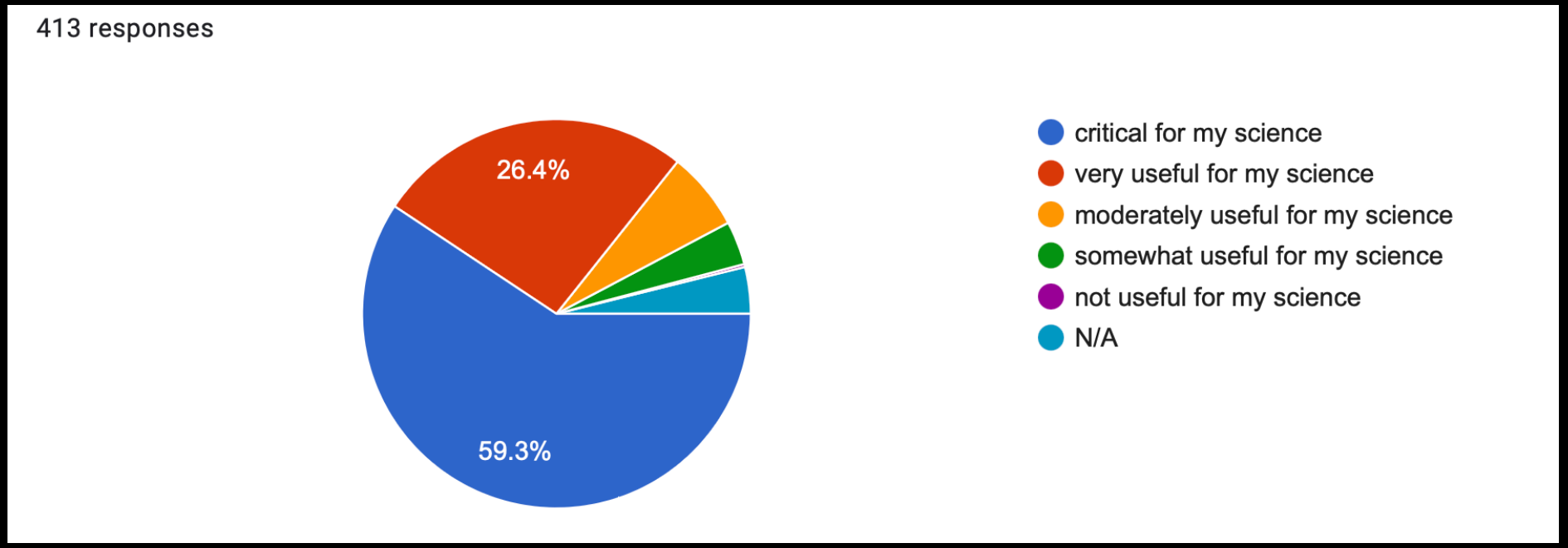

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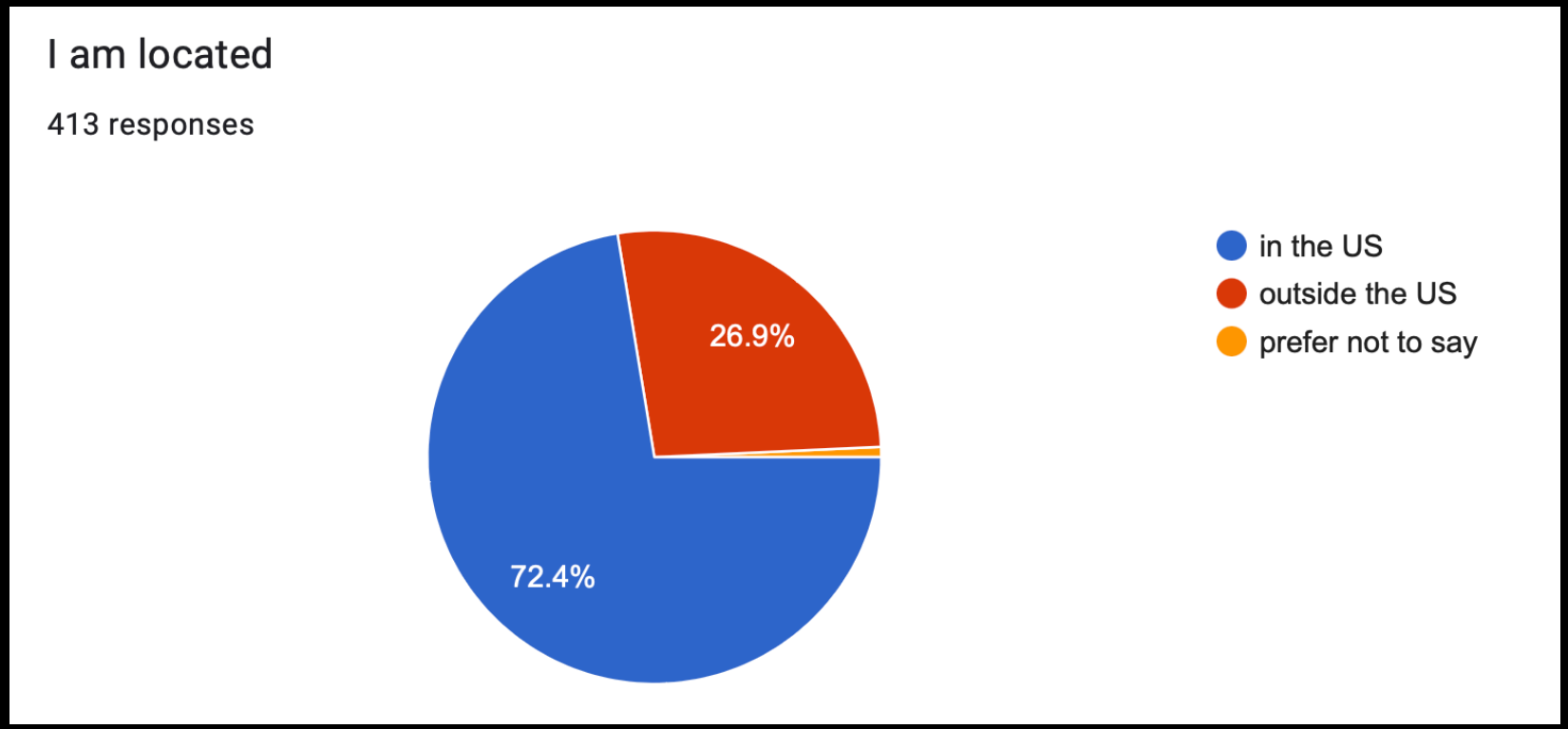

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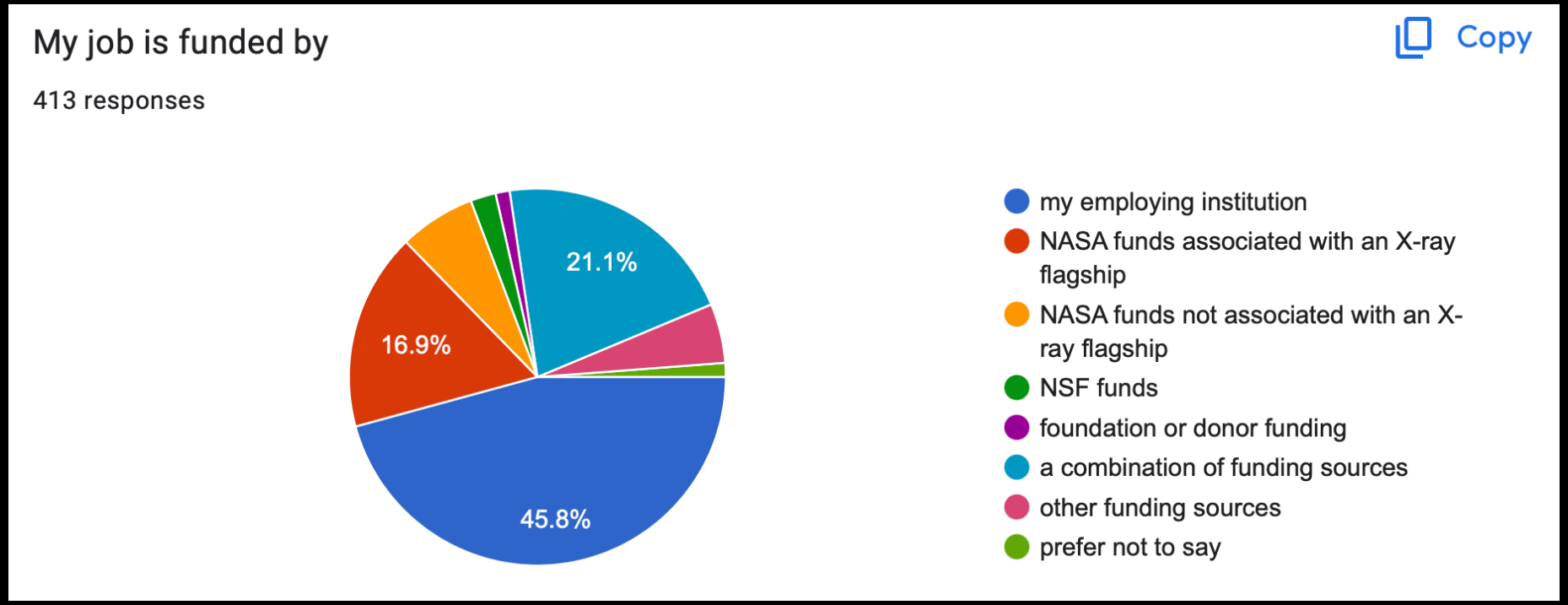

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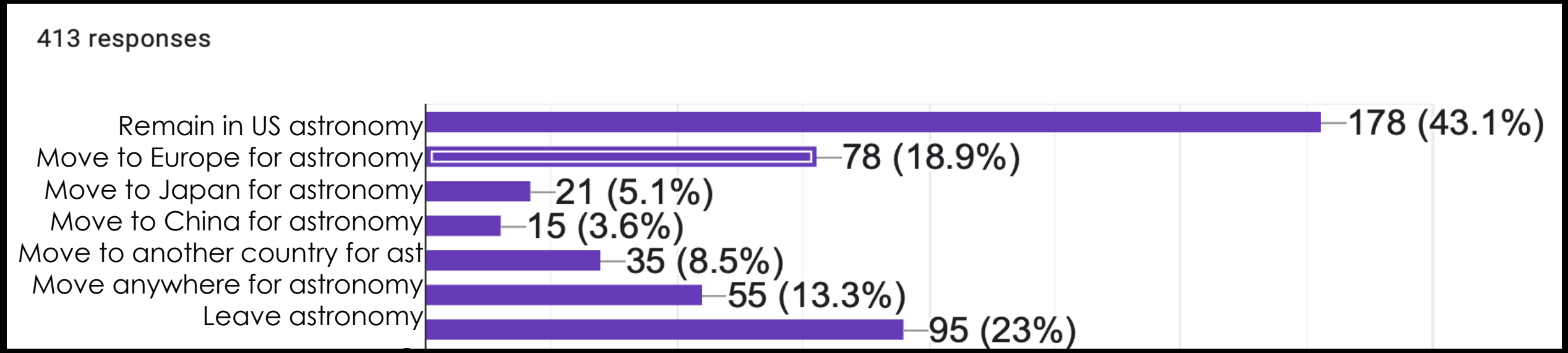

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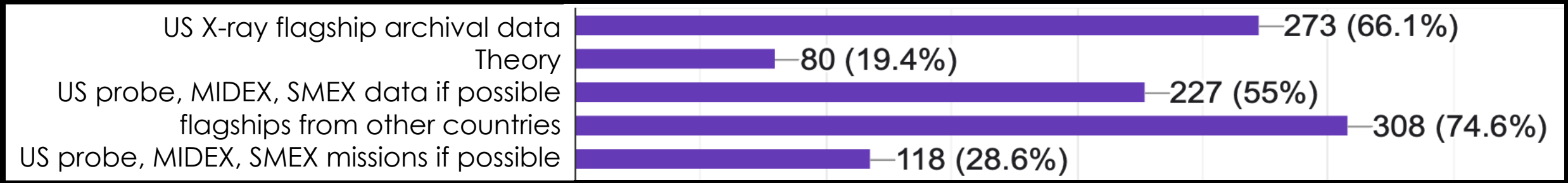
Results sneak preview:

Of those that remain in US astronomy, they would conduct science using



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ASTRO 2020 X-ray flagship recommendations - questions

Questions:

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- Will X-ray astronomers leave astronomy?
- What fraction of the community will leave?
- Of those that stay, will they stay in X-ray astronomy? With what data?

ASTRO 2020 X-ray flagship impact

Note: survey results may change between now and deadline.

Questions:

- What will the US X-ray community do without an X-ray flagship?

  43% of respondents will remain in US astronomy

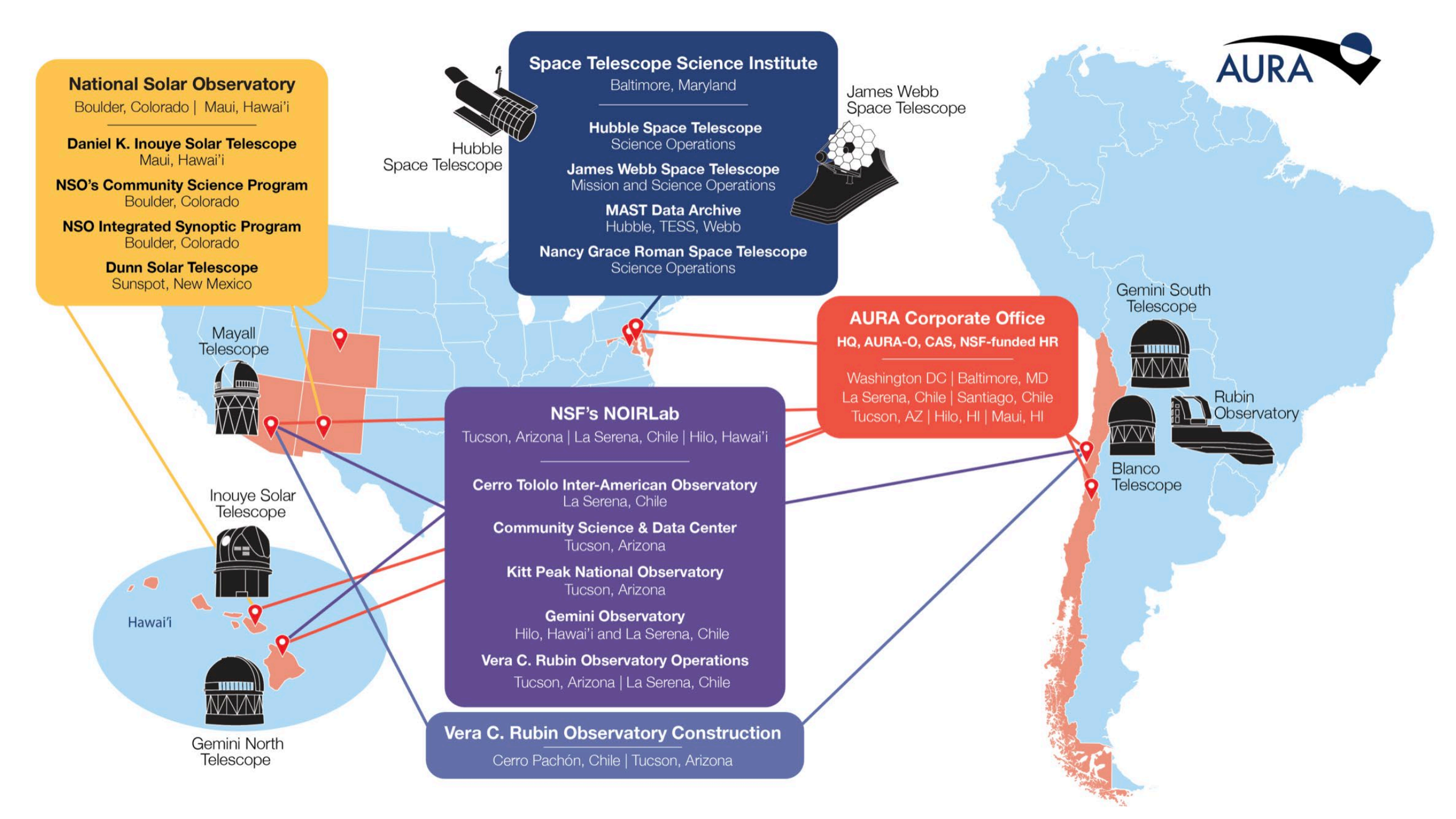
  (but this 43% may not still be around in 2050 for a new US X-ray flagship)
- Will there be a US brain drain to Europe, China, Japan? Yes. Over 100 astronomers.
- Will X-ray astronomers leave astronomy? Yes. Almost 100 astronomers
- What fraction of the community will leave? Roughly a quarter of the respondents
- Of those that stay, will they stay in X-ray astronomy? With what data? A range of things, but most respondents would use X-ray flagship archival data and flagship data from other countries

Results to be published in a white paper on ArXiv shortly

ASTRO 2020 X-ray flagship impact

New questions:

- How can we stem the flow of X-ray astronomers to other countries and to jobs outside astronomy?
- How can we ensure that the Decadal Mid-Term Review and future Decadal Surveys represent X-ray Flagship astronomy on an equal footing to optical/infrared astronomy?
- Related: How many X-ray astronomers are there in the National Academy of Sciences?
- How can we ensure that the impact of a large gap in X-ray flagship astronomy is considered in the mini-senior review by NASA?
- Is AURA for optical/infrared astronomy only? Do we need a high energy version of AURA? What are the functions of AURA we would need for HEAD?


AURA
National Solar Observatory
Boulder, Colorado | Maui, Hawai'i
Daniel K. Inouye Solar Telescope
Maui, Hawai'i
NSO's Community Science Program
Boulder, Colorado
NSO Integrated Synoptic Program
Boulder, Colorado
Dunn Solar Telescope
Sunspot, New Mexico
Space Telescope Science Institute
Baltimore, Maryland
Hubble Space Telescope
Science Operations
James Webb Space Telescope
Mission and Science Operations
MAST Data Archive
Hubble, TESS, Webb
Nancy Grace Roman Space Telescope
Science Operations
Hubble Space Telescope
James Webb Space Telescope
AURA Corporate Office
HQ, AURA-O, CAS, NSF-funded HR
Washington DC | Baltimore, MD
La Serena, Chile | Santiago, Chile
Tucson, AZ | Hilo, HI | Maui, HI
Gemini South Telescope
Rubin Observatory
Blanco Telescope
Mayall Telescope
NSF's NOIRLab
Tucson, Arizona | La Serena, Chile | Hilo, Hawai'i
Cerro Tololo Inter-American Observatory
La Serena, Chile
Community Science & Data Center
Tucson, Arizona
Kitt Peak National Observatory
Tucson, Arizona
Gemini Observatory
Hilo, Hawai'i and La Serena, Chile
Vera C. Rubin Observatory Operations
Tucson, Arizona | La Serena, Chile
Inouye Solar Telescope
Hawai'i
Gemini North Telescope
Vera C. Rubin Observatory Construction
Cerro Pachón, Chile | Tucson, Arizona

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