The Virtual Observatory at the *Chandra* X-Ray Center: past, current and future

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CENTER FOR **ASTROPHYSICS**

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in collaboration with J. Evans, M. Tibbetts, A. Rots, P. Fabbiano

Why did *Chandra* embrace the VO?

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Why a new *Chandra* should embrace the VO?

⊙ Leveraging existing, community-developed & tested tools instead of developing *ad hoc* solutions for shared problems

⊙ Efficient use of effort: concentrating on implementation and operation of services instead of design

⊙ Interoperability with (non-*Chandra*) data, services, interfaces

The *Chandra* VO portfolio

- CXC personnel has contributed to a diverse range of IVOA-related projects
  - **Standards**: STC, Coordinates, Measurements, Transforms, early involvement in DMs, VODML
  - **VO tools**: Iris (Spectral Energy Distribution builder and analysis tool), Seleste (general TAP client)
  - **Infrastructure**: *Chandra* data access, Registry of Registries
  - **Organization**: leadership roles in various WGs/IGs, Exec, TCG

- Continuous involvement of both scientific & software, senior & junior staff

- Varying level of commitment over time: from 3 dedicated FTEs (during VAO project) to best effort within CXC contract mandate

A long history of personal participation to IVOA

⊙ Early membership (IVOA establishment, NVO in the US)

Pepi Fabbiano
Jonathan McDowell
Arnold Rots

⊙ Intermediate period (IVOA consolidation, VAO in the US)

Mark Cresitello-Dittmar
Ian Evans
Janet Evans
Omar Laurino
Yulie Zografou

⊙ The IVOA maturity (2016 to present)

Jamie Budynkiewicz
Francesca Civano
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Jonathan McDowell	DM-WG chair
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Mark Cresitello-Dittmar	**TD-IG vice-chair**, DM-WG chair
Ian Evans	
Janet Evans	**TCG chair**, **CSP member**, TCG vice-chair, Exec secretary
Omar Laurino	DM-WG vice-chair
Yulie Zografou	

⊙ The IVOA maturity (2016 to present)

Jamie Budynkiewicz	
Francesca Civano	**Exec secretary**, **CSP vice-chair**
Raffaele D'Abrusco	**KD-IG chair**, **CSP member**, Applications WG vice-chair

The CXC VO offerings

Data access
- ⊙ ConeSearch
- ⊙ SIAP
- ⊙ TAP
- ⊙ ObsCore

Visualization
- ⊙ HiPS
- ⊙ MOC

Mission Operations
- ⊙ ObsLocSAP
- ⊙ ObsVisTAP

The growth of the *Chandra* archive
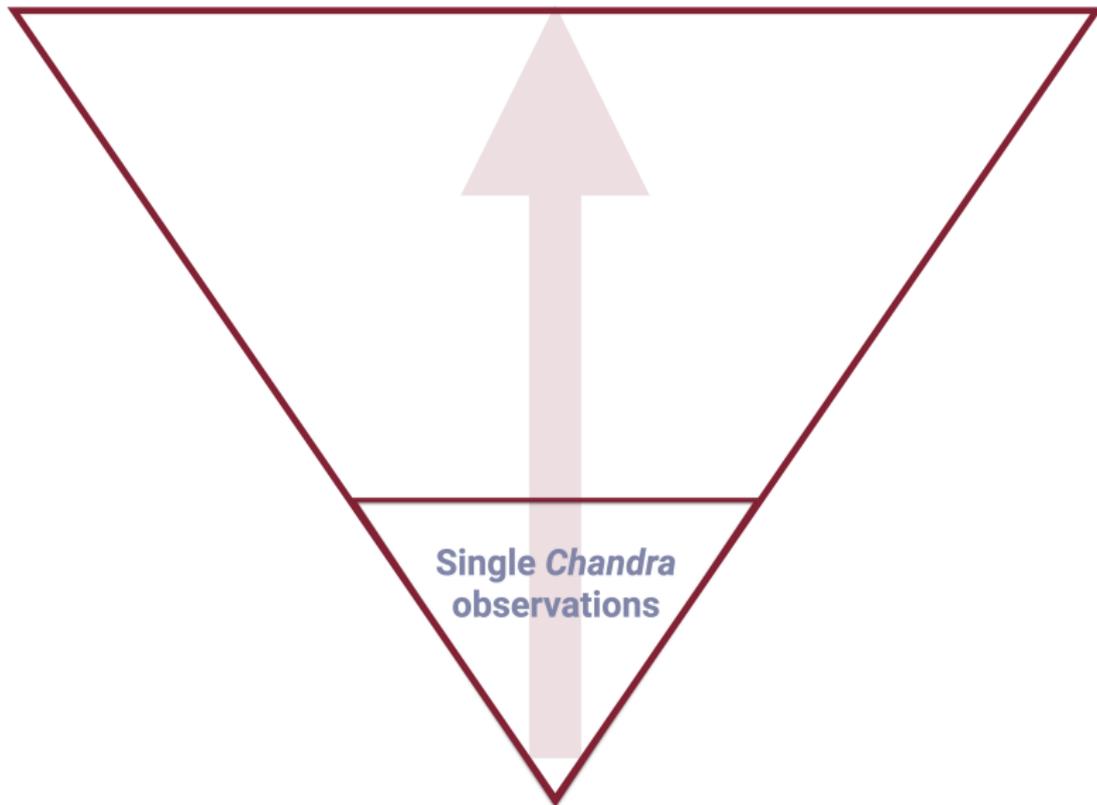
Single *Chandra* observations

The growth of the *Chandra* archive

Chandra observations grouped by proximity or class of targets

Single *Chandra* observations

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Chandra Source Catalog

Chandra observations grouped by proximity or class of targets

Single *Chandra* observations
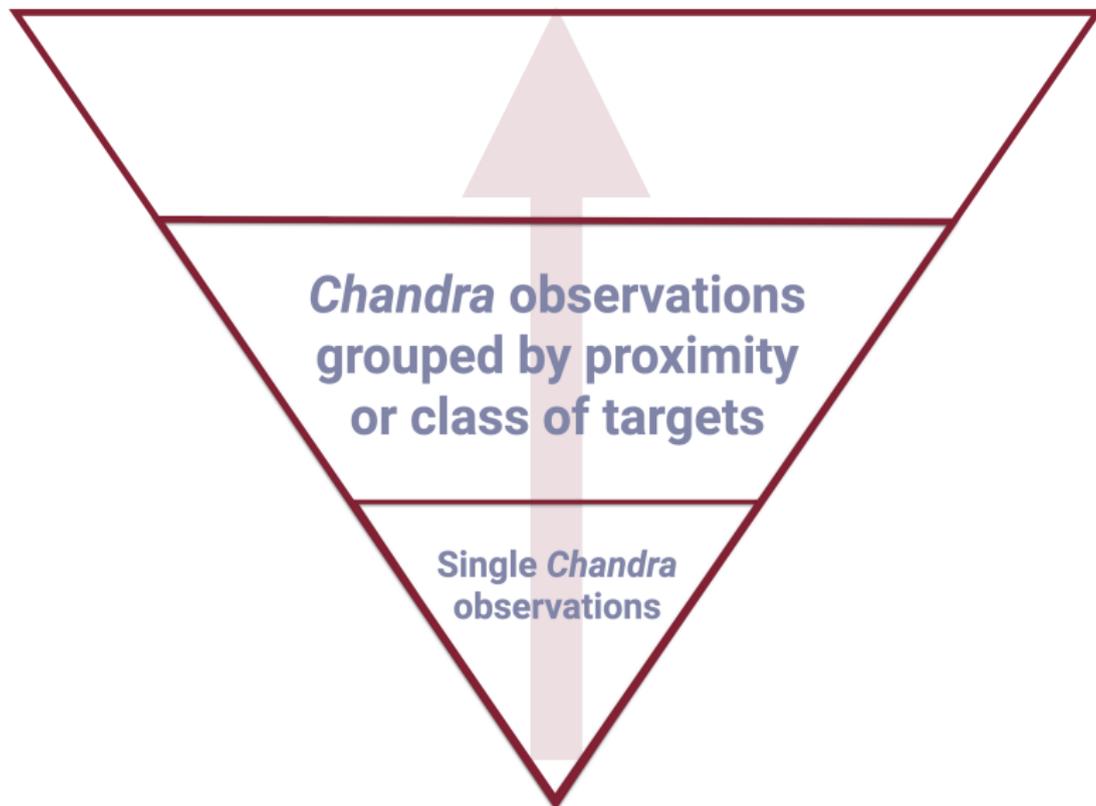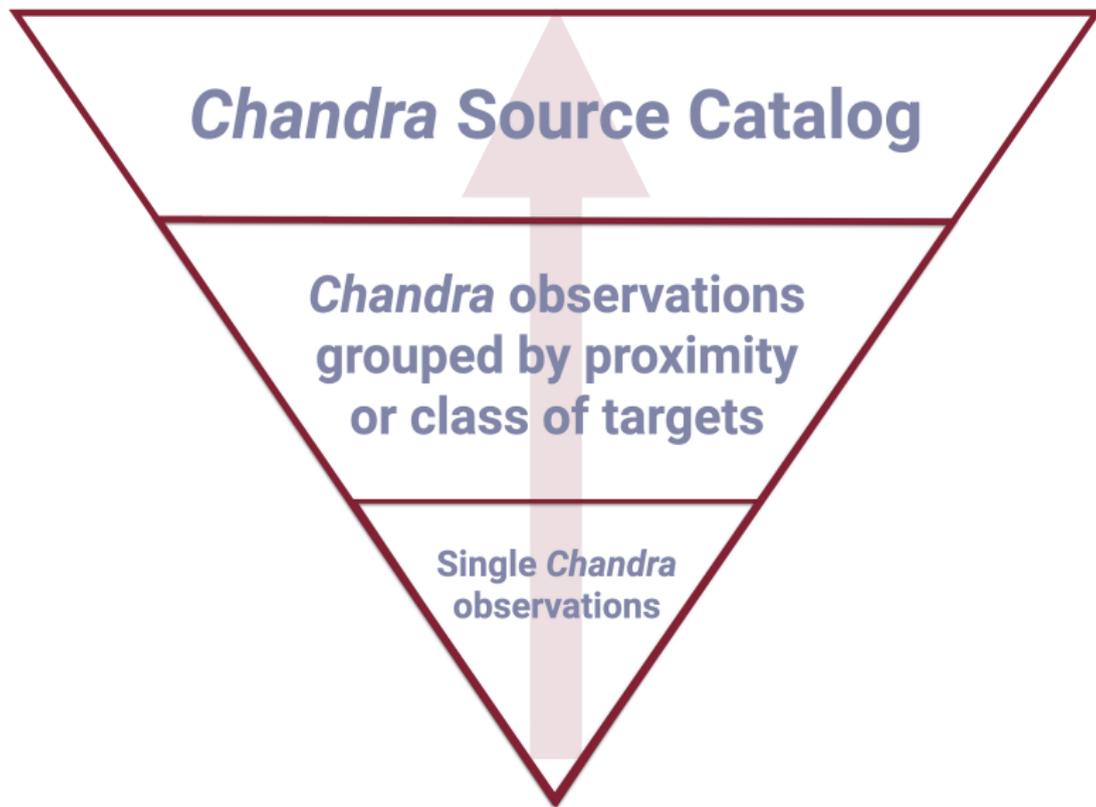
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Chandra Source Catalog
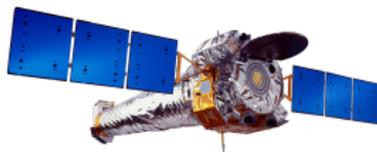
Chandra Archive

The *Chandra* VO offerings

Chandra Source Catalog (CSC)

- ⊙ ConeSearch
- ⊙ SIAP
- ⊙ TAP
- ⊙ ObsCore (ObsTAP)

Chandra Archive (CXC)

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- ⊙ SIAP
- ⊙ TAP
- ⊙ ObsCore (ObsTAP)
- ⊙ HiPS
- ⊙ MOC

Missions Operations

- ⊙ ObsLocTAP
- ⊙ ObjVisSAP

**Chandra Source
Catalog**

**Chandra
Archive**

The *Chandra* VO offerings

Chandra Source Catalog (CSC)
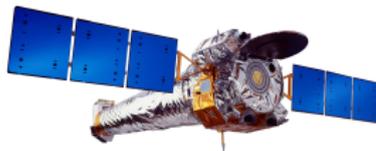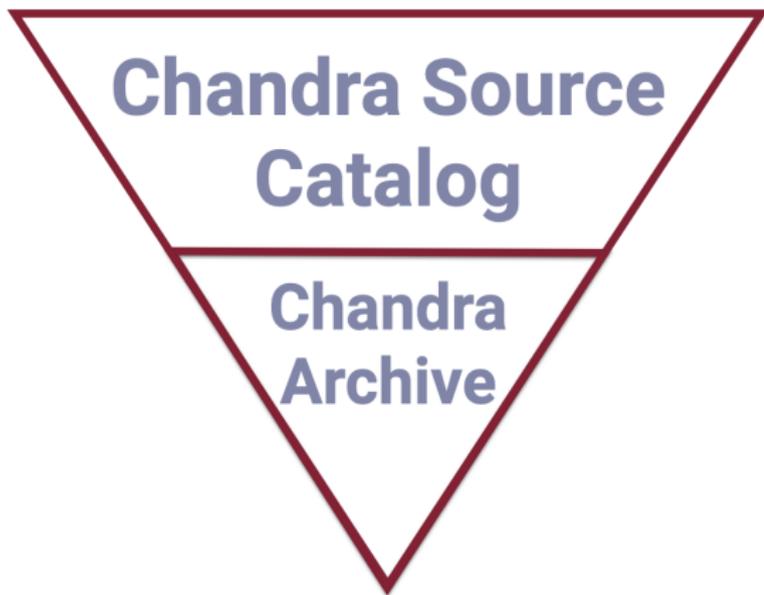
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Chandra Source Catalog CSC2.1 CSC1.1

Chandra Archive
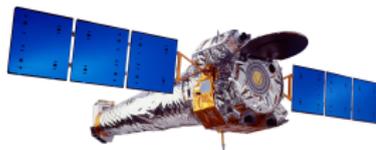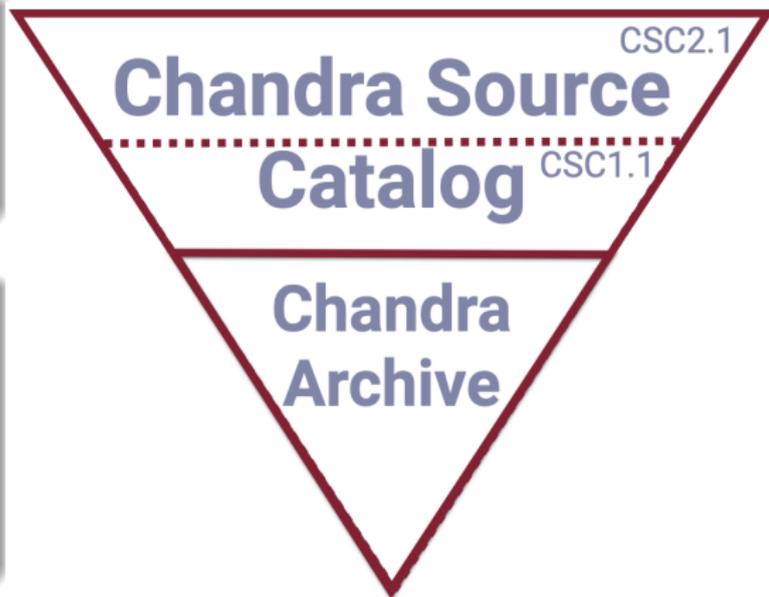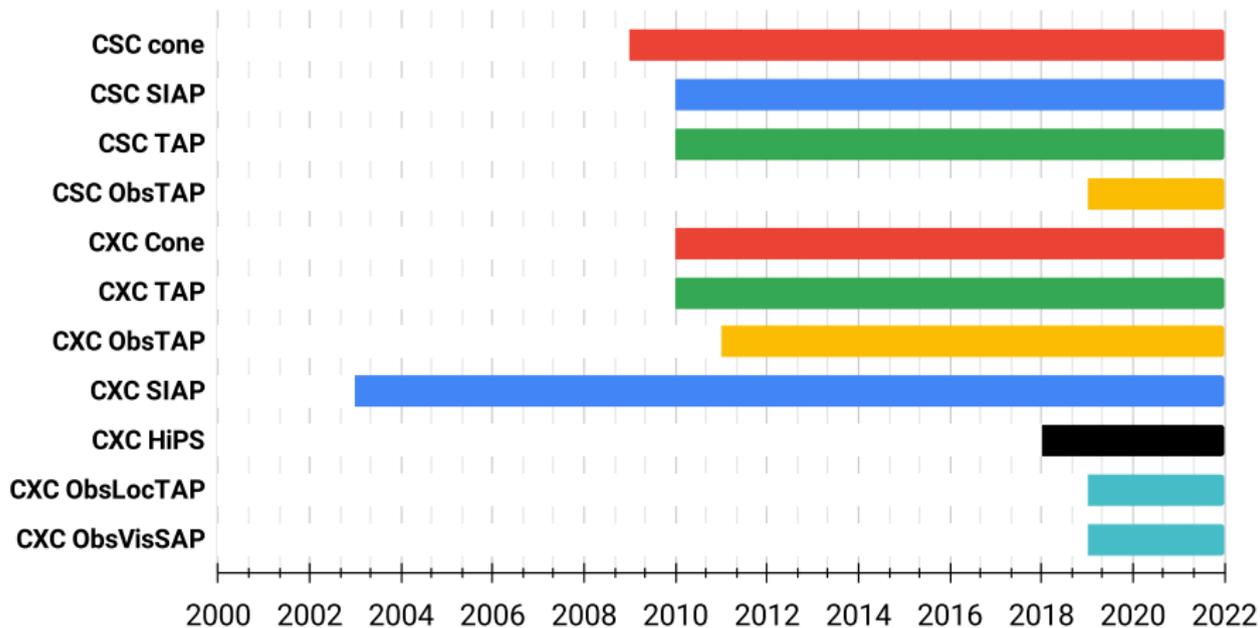
Timeline*

* Approximate date, ± 3 months;

Timeline[*],[**]
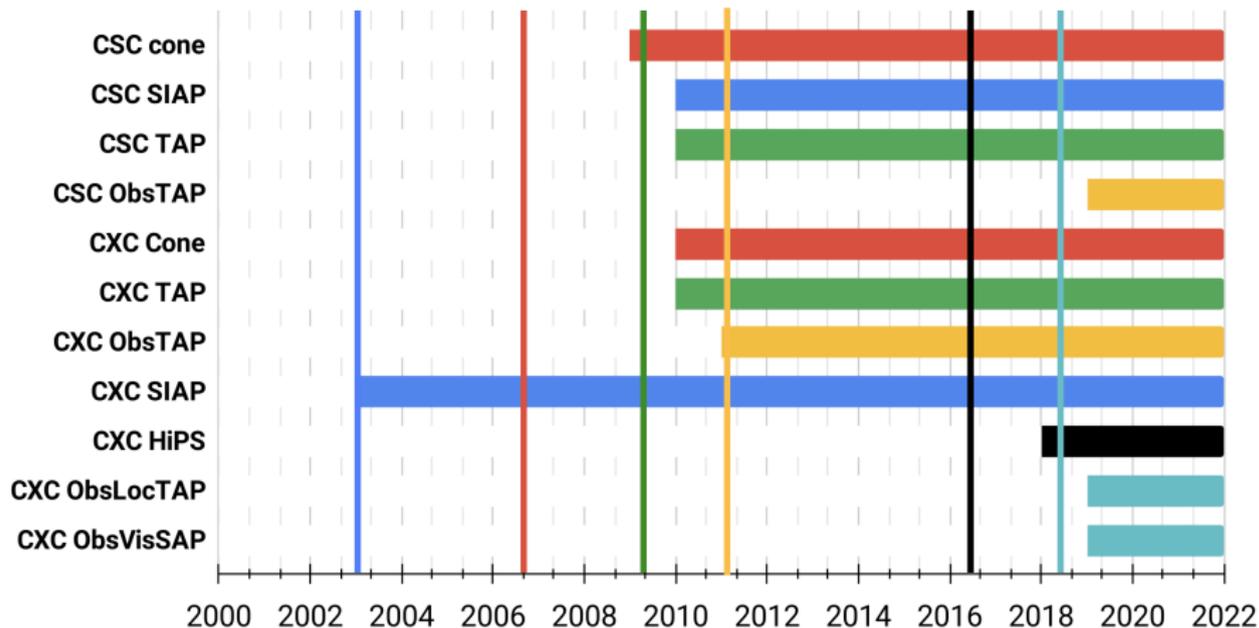
* Approximate date, $\pm$ 3 months; ** Date of first IVOA specification documents;

Usage report
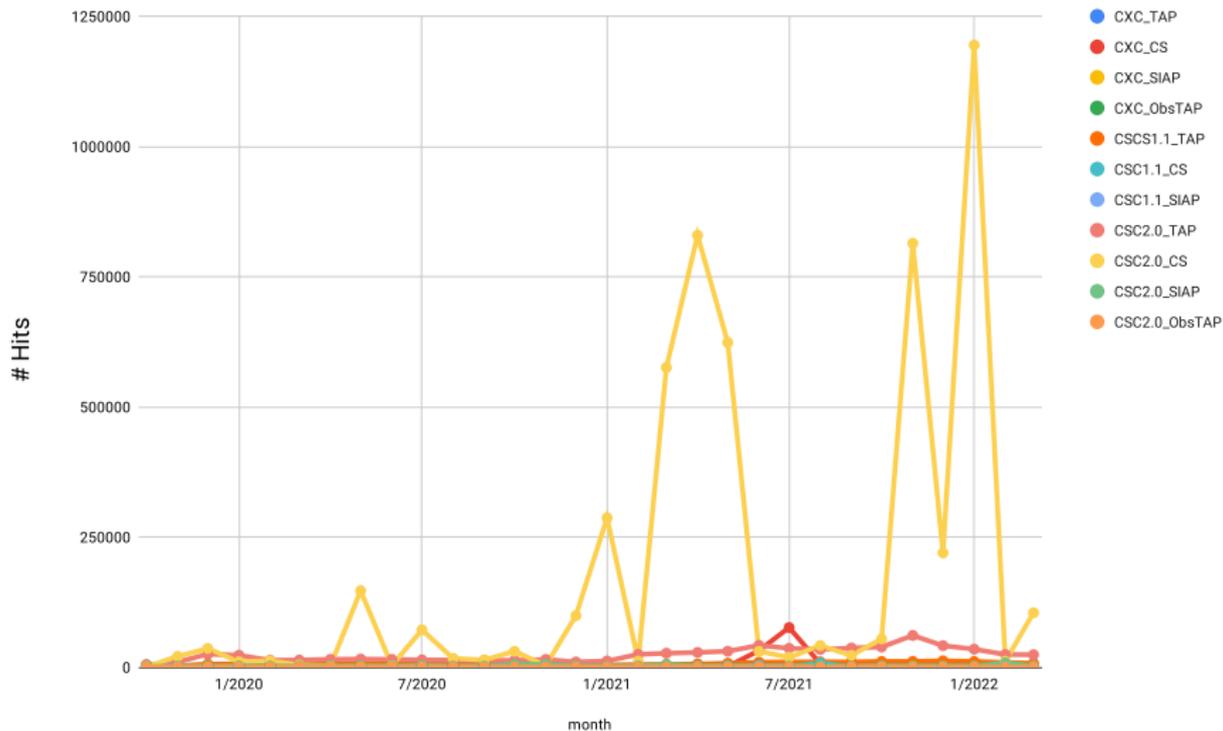
Usage report
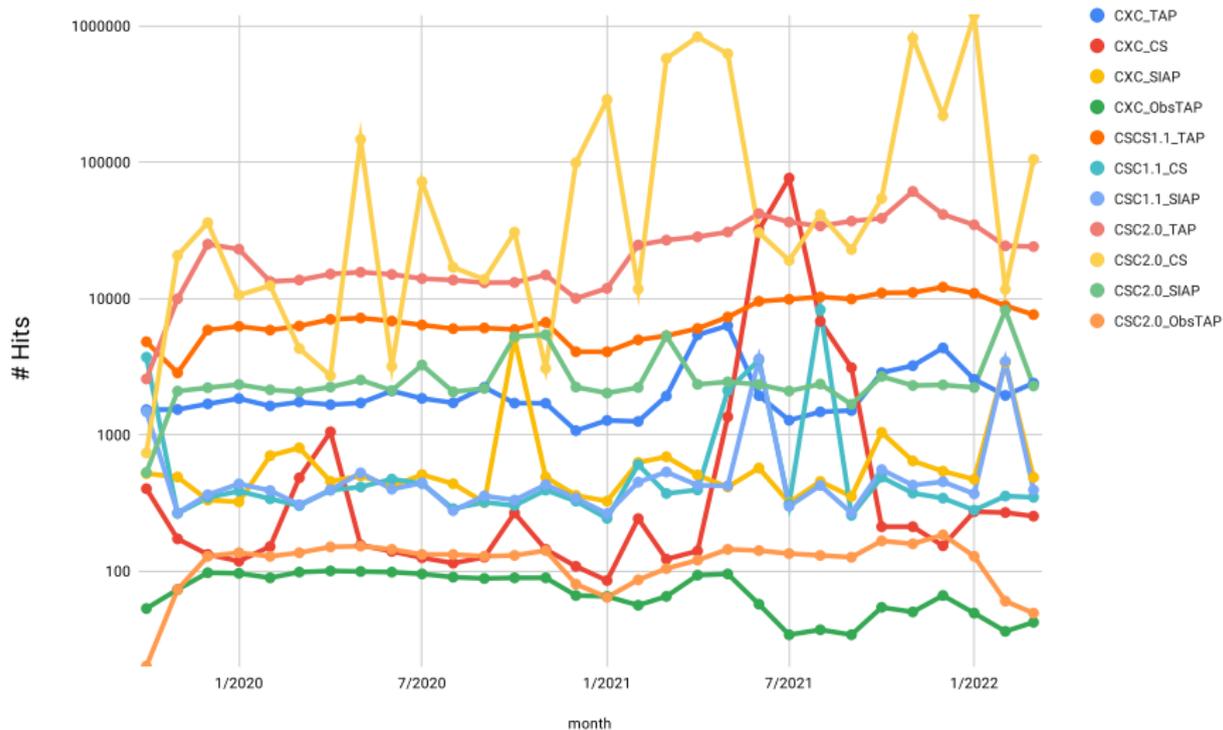
Trends and patterns

- ⊙ ConeSearches dominate; stable TAP & SIAP usage across different datasets
- ⊙ Large spikes in ConeSearches
  - ⊙ CXC: hints of proposal-related seasonality with additional random spikes
  - ⊙ CSC: stochastic, driven by super-requests by few users
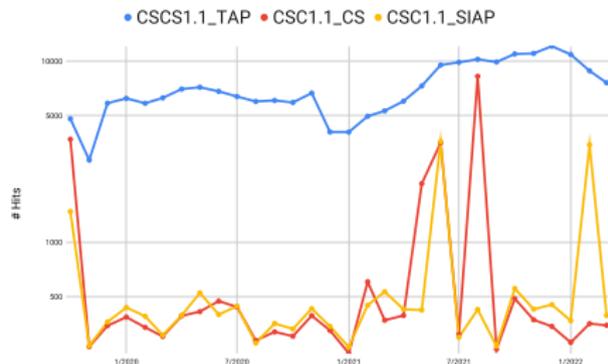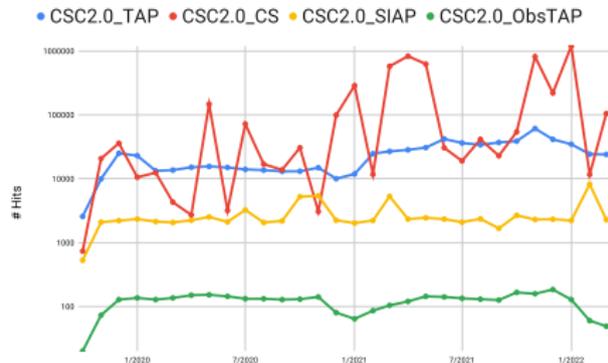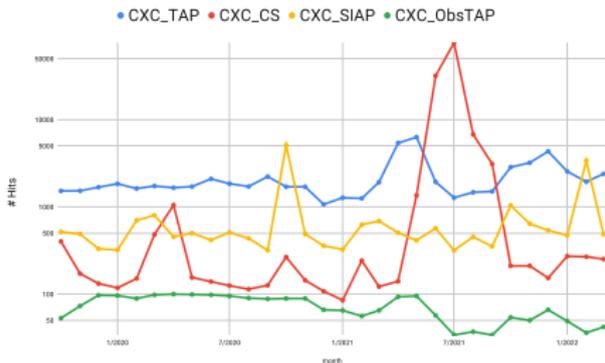
Lessons learned

⊙ Through the VO, we can **shift our focus from in-house interfaces to the support of external interfaces** to keep abreast with the changing needs of the community at large

⊙ Experience with how our scientific community interacts with *Chandra* VO interfaces has highlighted some potential areas of improvements
  ⊙ ObsCore: current specification does not allow to differentiate the "center of the observation" vs "target coordinate" (relevant for off-axis observations), class and cycle of observations, etc.

⊙ Building an **multi-generational IVOA presence** is key to maximize the benefits throughout the mission lifetime

Future

- **Expand** *Chandra* **VO services** to map the complexity of *Chandra* data:
  - CXC HiPS
    - New, regularly updated CXC color HiPS
    - Grayscale HiPS
  - CSC HiPS
    - CSC-based image HiPS
    - CSC-based limiting sensitivity HiPS
    - CSC catalog HiPS

- **Housekeeping**: keep up with new versions of standards, improve compliance of existing services

- Feed our experience with standards back to the IVOA, inform further **extention of standards** (ObsCore)

- Continue promoting **VO practices in our parent institution SAO** and provide expertise for new projects