Synergies with the Chandra X-ray Observatory

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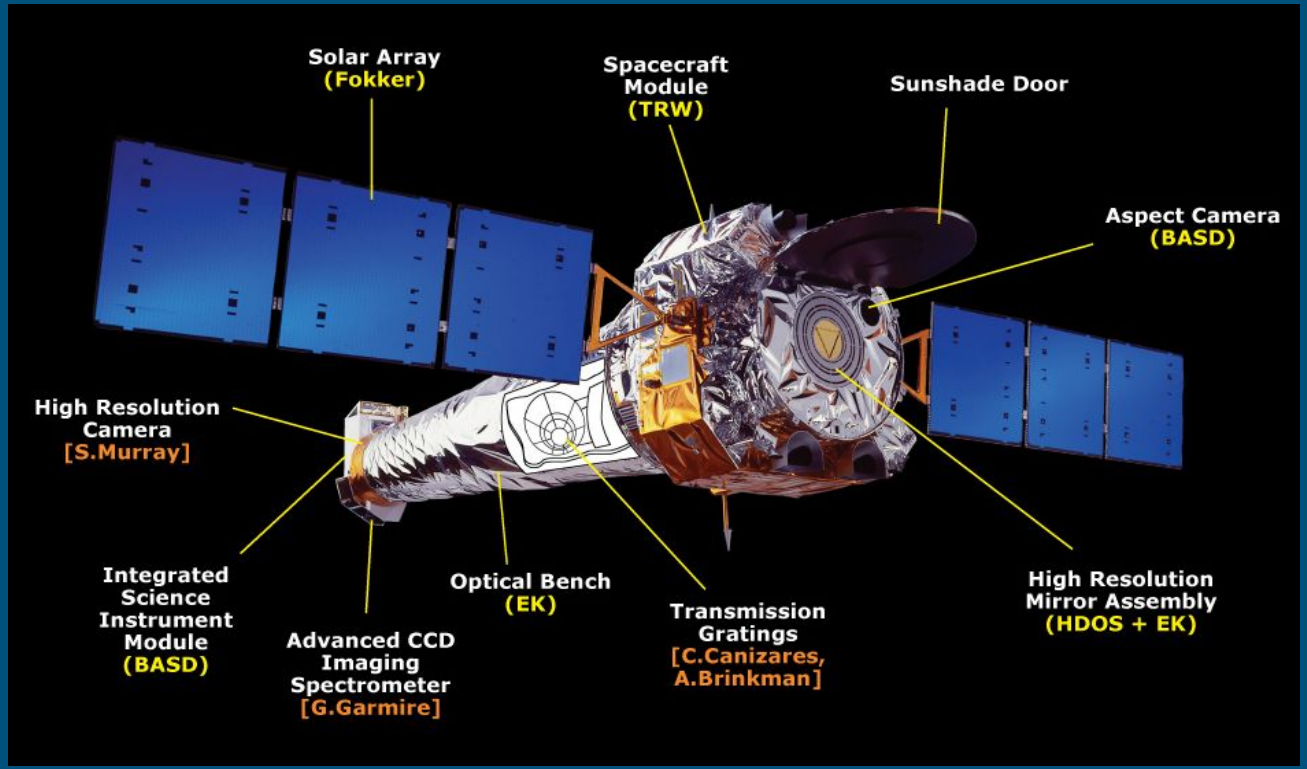
Outline

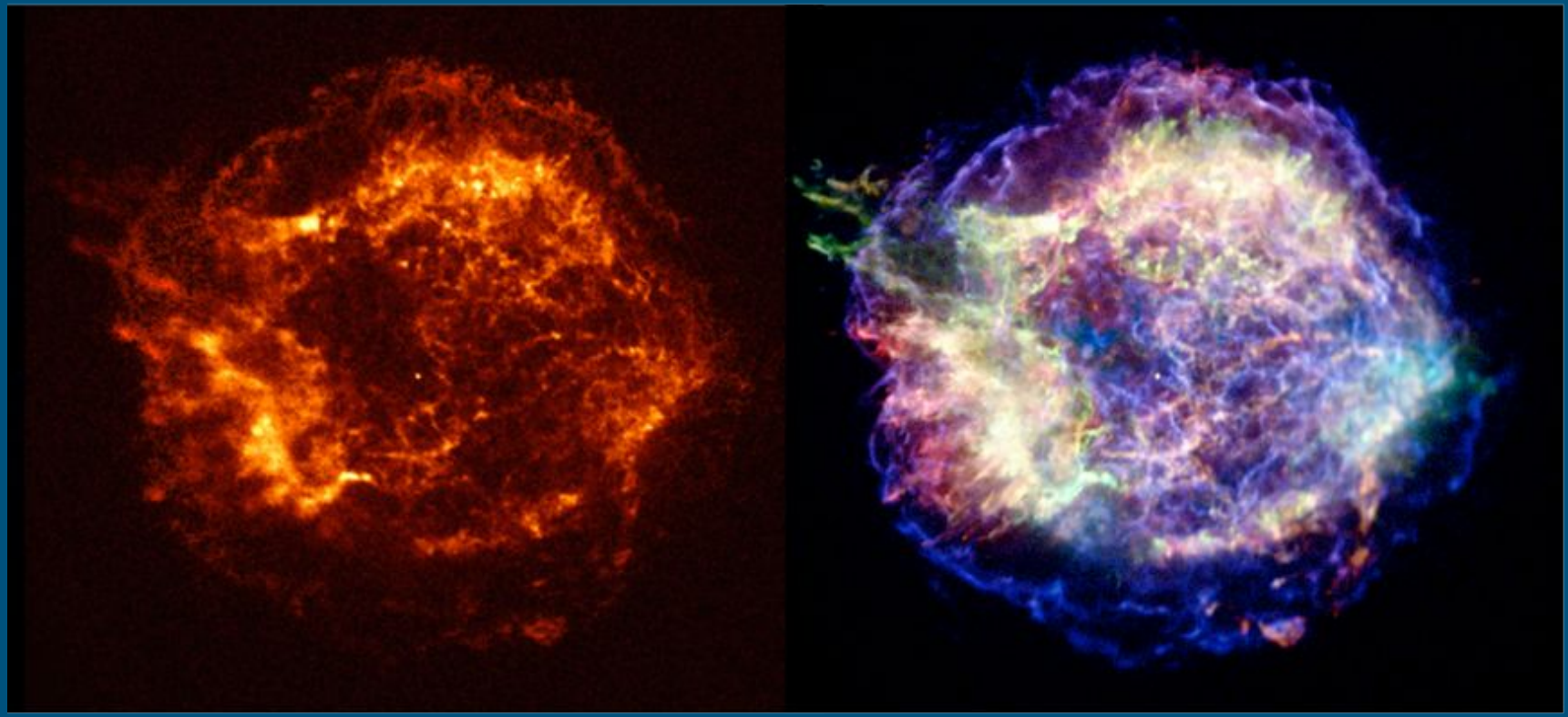
- Chandra Basics
  - Observatory
  - Science Examples
- TOOs and DDTs with Chandra
- Visibility and Thermal Constraints
- Coordinated Time
- Joint Programs
- Questions & Opportunities

Chandra Spacecraft



- Highest X-ray spatial resolution ever
- Broad energy range from 0.3-8 keV
- Event lists including time and energy for each photon
- Three day orbit, not serviceable

Cassiopeia A

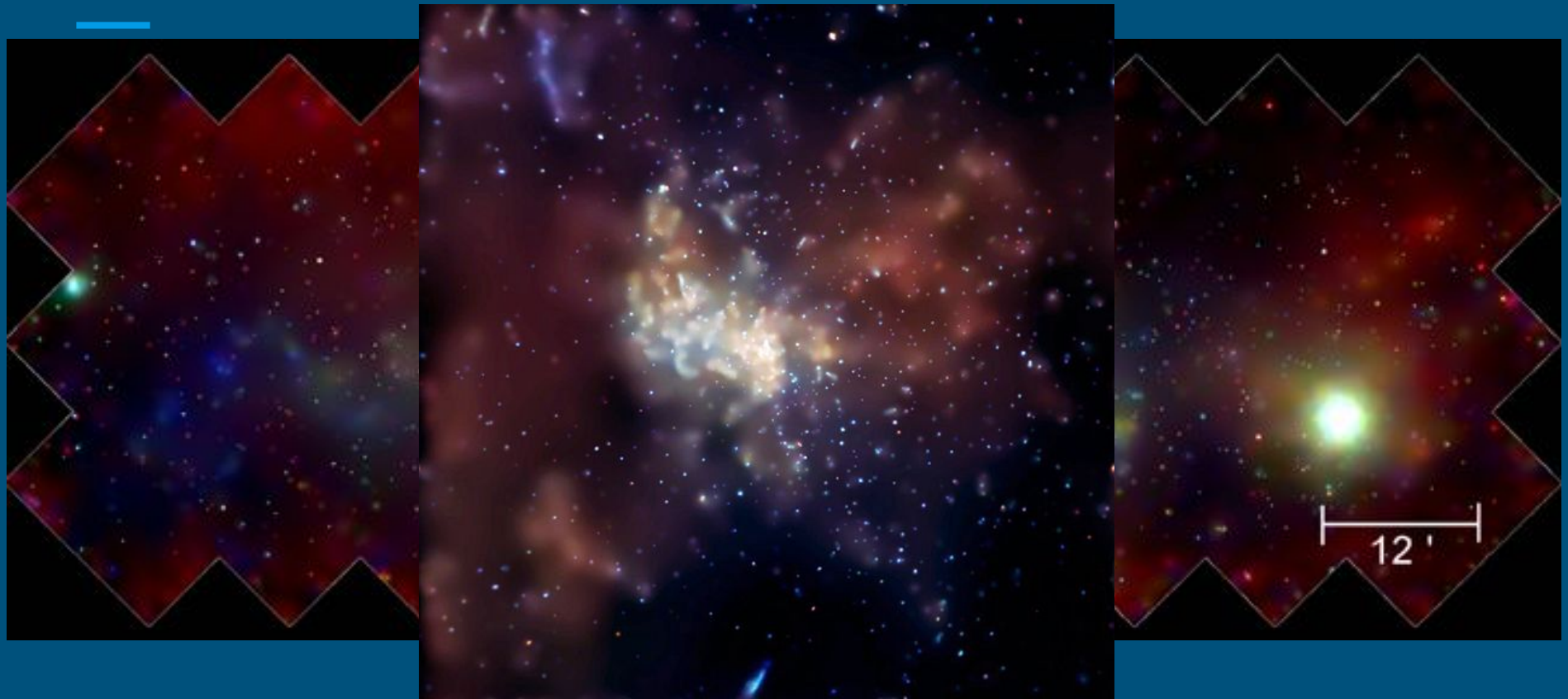


First Light

1 Ms

Galactic Center Mosaic

Galactic Center Mosaic: Zoom



Targets of Opportunity

- Broad Classes of TOO:
  - Known objects being monitored.
  - Localize/characterize new discoveries expected e.g., from surveys.
  - Mix of both (alternate targets)

- TOO Stats:
  - Approved: ~30 ToO proposals, about 80 targets per cycle
  - Oversubscription ~2 by proposal
  - TOO exposure time approved (completed): ~4.6Ms (~1Ms) per cycle

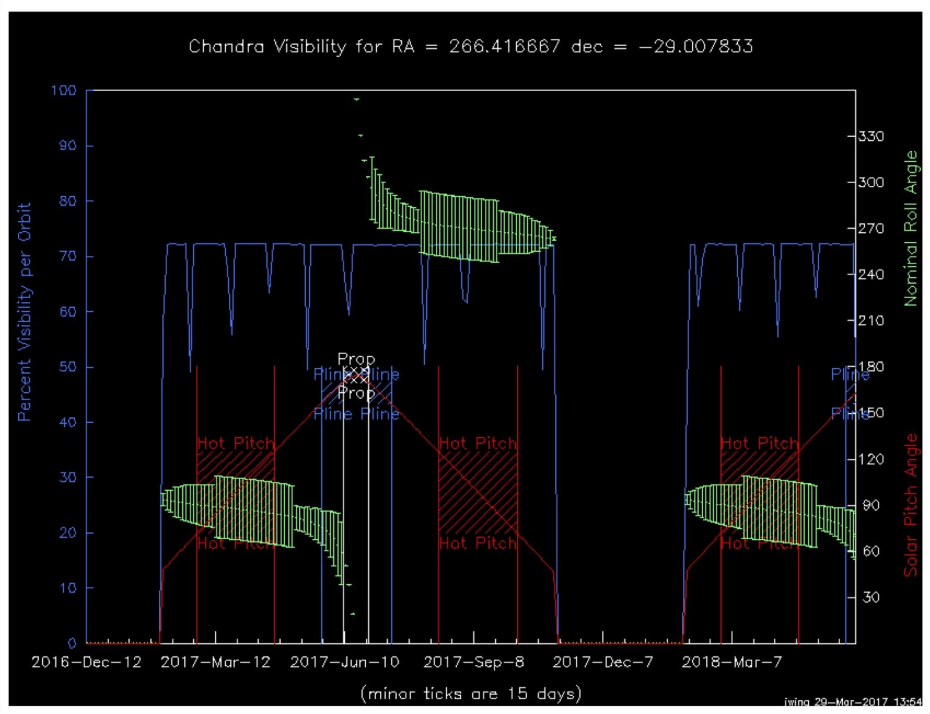
- These are peer-review-approved programs with set trigger criteria

Director’s Discretionary Time

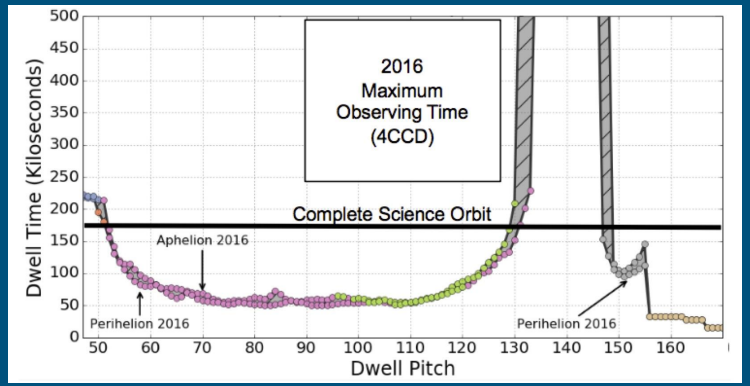
- DDTs
  - Unforeseen celestial events
  - New campaign opportunities e.g., JUNO on Jupiter, EHT on SgrA*

- DDT Stats:
  - Historically 700ks available per cycle, 500ks typically used
  - Oversubscription ~2 by proposal
  - Just raised to 1Ms/cycle to include high priority, non-transient science, similar motivation to Gemini and HST mid-cycle proposals

Visibility and Thermal Constraints



Chandra PRoVis tool - calculate a target's Pitch, Roll, and Visibility
http://cxc.cfa.harvard.edu/cgi-bin/provis/provis_load.cgi



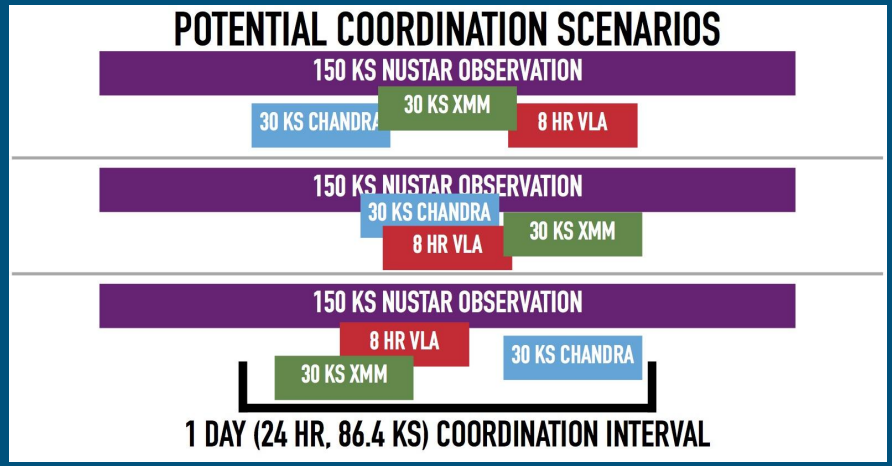
- **Target visibility by date depends on the location of the target on the sky**
- **Maximum dwell time is limited over a range of pitch angles**
  - **Longer observations need to be split if observed at a hot pitch angle**
  - **Need to observe at a cooling pitch angle for sufficient time before another observation at a hot pitch angle**

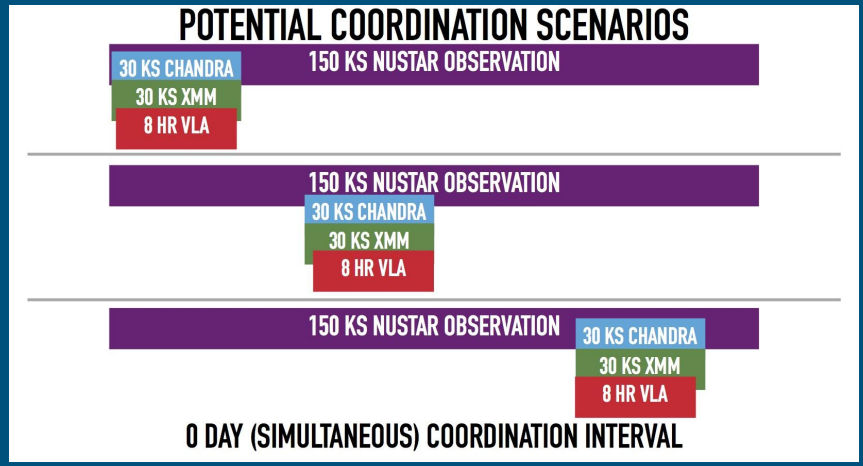
Coordinated Time

- Identify programs requesting coordinated observations
- Communicate with planners at other observatories
- Place observation in the Chandra Long Term Schedule
- Come to an agreement with other observatory concerning final observing schedule ~5 days before start of observing week

- TOOs and DDTs can be coordinated

Coordinated Time





- The coordination interval specifies the maximum duration encompassing all observations
- Coordination interval longer than the longest observation implies no need for simultaneous observations
- A coordination interval of 0 or an interval shorter than the longest observation implies simultaneous observations

TOO/DDT Science Examples

- X-ray NS and BH binary outbursts
- GRBs
- Magnetar Outbursts
- Fast radio bursts
- WHIM toward Mkn 421
- ASAS-SN TDEs
- SNe of all types
- LIGO-Virgo GW sources
- Precise Localization of ...
  - ULXs, transient LMXBs, obscured NuSTAR sources in the Galactic Plane
- Neutron star quakes
- Extreme accretion flares on young stars
- AGN

Why Have Joint Programs?

- When science demands
  - multiwavelength data (sometimes contemporaneous)
  - time coverage, given observatory visibility windows
  - TOO-triggered transient followup
- Quite difficult to survive multiple peer reviews (“double jeopardy”).
- Out-of-phase reviews *especially* difficult when contemporaneous observations are required.
- Agreements with Joint Partner Observatories (*JPOs*) allow one proposal to justify observations on multiple facilities.
- JPOs must pre-approve the technical feasibility.

Chandra Joint Programs

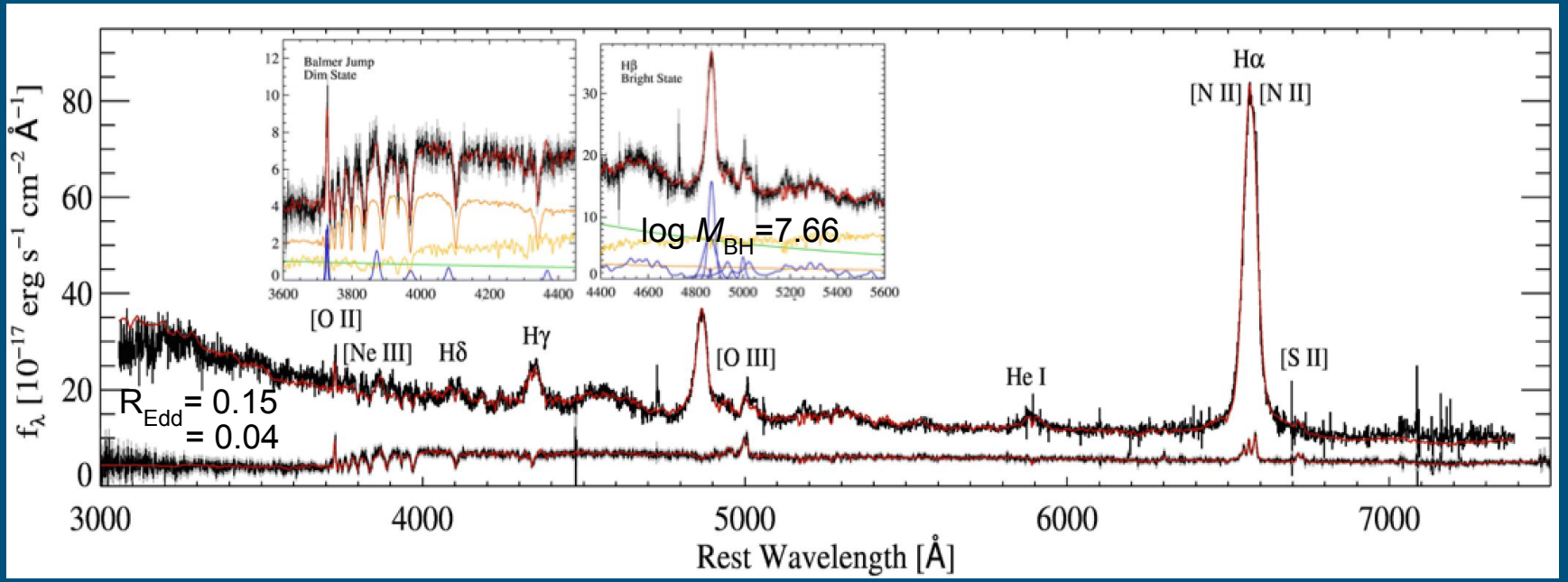
Maximum Allocations						
	CXO TAC			*JPO TAC*		
JPO	*GO*		*V/LP*	*GO*	*V/LP*	*Note*
HST	100	orbits	250	400	600	
XMM	400	ks	600	400	600	
NuSTAR	500		500			
Swift	500					
NRAO	3%			120		incl GBO/LBO
NOAO	5%					
~~RXTE~~	500ks					
~~Suzaku~~	500ks					
~~Spitzer~~	60hours			200ks		

Joint Time Requirements

- Joint time must be scientifically *justified*.
- No joint time without *Chandra time*.
  Exception for *Archive* proposals requiring NOAO nights.
- *Multi-cycle* joint time if scientifically required:
  up to 10% (5%) of the available joint time in Cycle *N+1 (N+2)*
- Can be *coordinated* if required, but time constraints are limited.

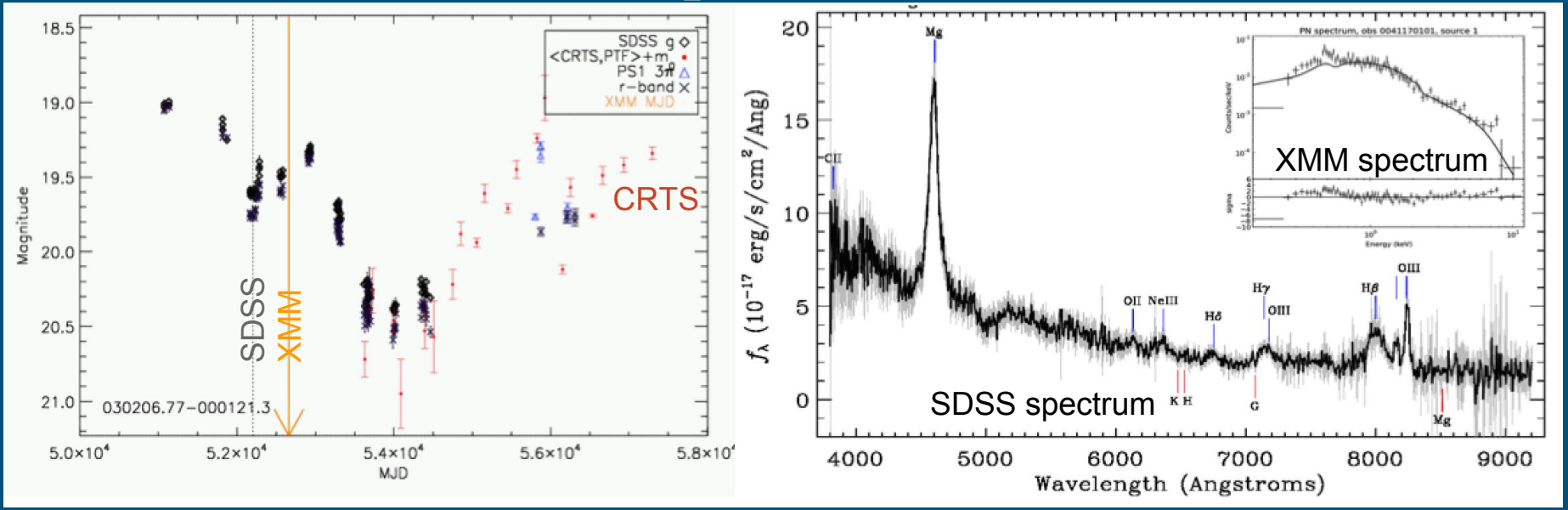
Example of Chandra TOO/Joint Program Science

‘Changing Look’ Quasars



SDSS J101152.98+544206.4 from Runnoe et al. (2016)

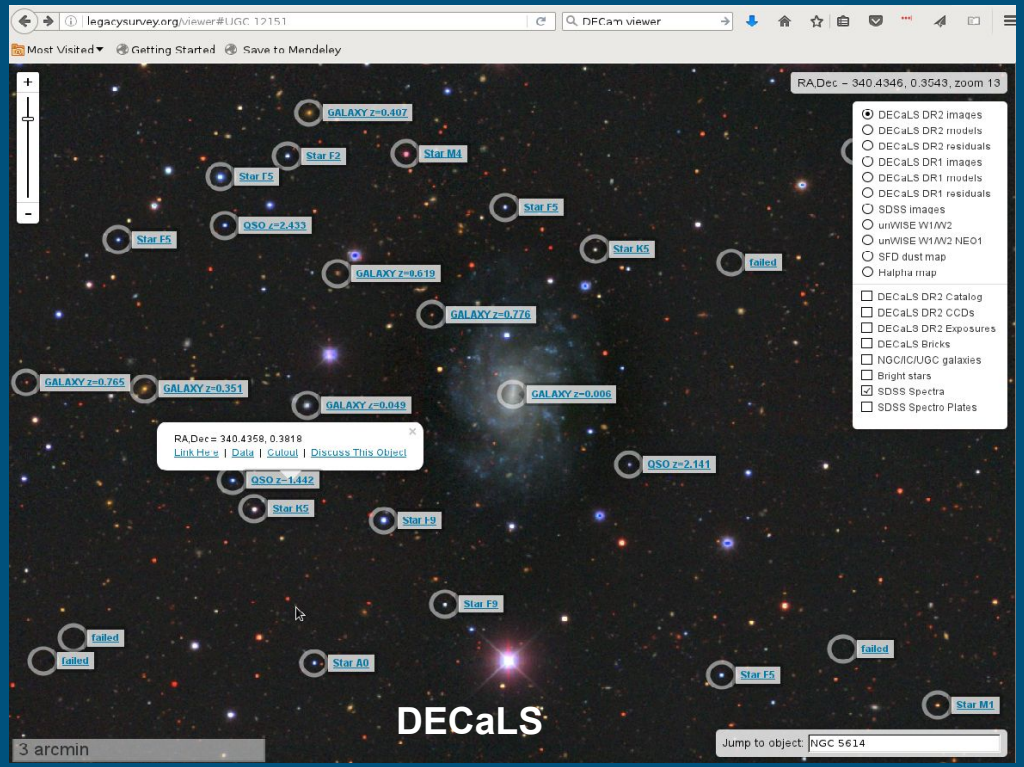
TOO to be Triggered by Joint Gemini Spectrum

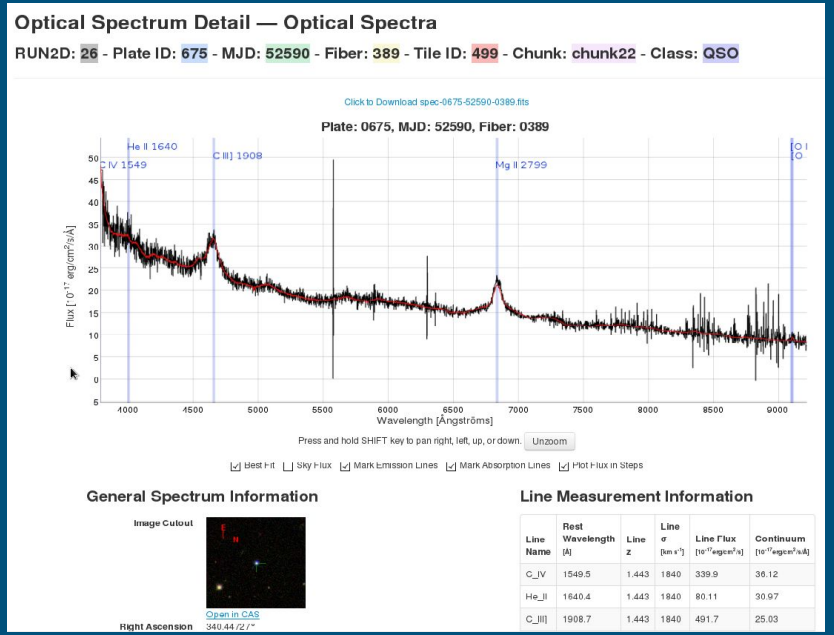


18700157: Green, MacLeod, Anderson, Eracleous, Ruan, Runnoe, Graham, & Civano.

Joint-triggered TOO also using archival X-ray data!

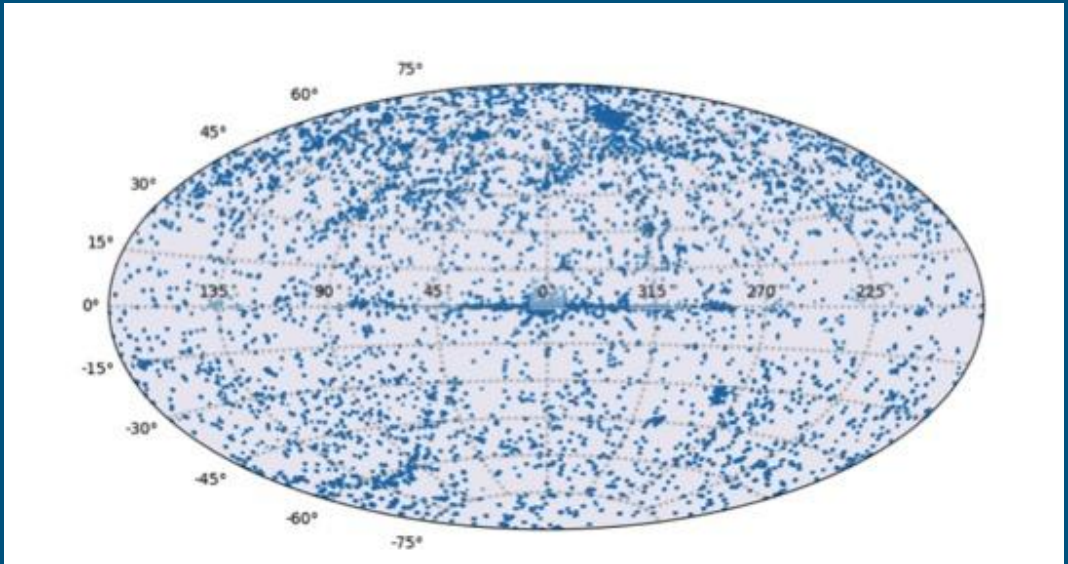
Opportunity: Expand Access to Survey Portals





SDSS

Chandra Source Catalog: V2.0



- **Preliminary detections, pd1: >362,000 sources, released 21 Mar, 2017**
- **Includes positions, likelihoods, extents, intensity (no matching)**
- **Complex fields are still being processed**
- **Website has been updated: http://cxc.harvard.edu/csc2/**

Questions & Ideas for Time Domain Synergies

- What will the dominant transient alert methods be in the LSST era?
  - Will the sky images be released at the same time? How long after the observation?
  - If there is overlap with ANY Chandra observation, it could be made accessible as part of the Chandra archive.
- How/can we make clearinghouse(s) for transient lists/images/properties easily accessible to *Chandra* community.

- Schedule sharing between facilities needs further planning and infrastructure (Multimission Synergies Workshop Pasadena)

- Automatic Chandra TOO triggering for certain target types?
  - Likely such programs must be approved via Chandra peer review
- Expand to include space *survey* facilities e.g., GAIA, Euclid, TESS, eROSITA. (Coordinate with coverage schedule?)

Questions & Ideas for Time Domain Synergies

- ***Your ideas welcome!***
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Thanks!