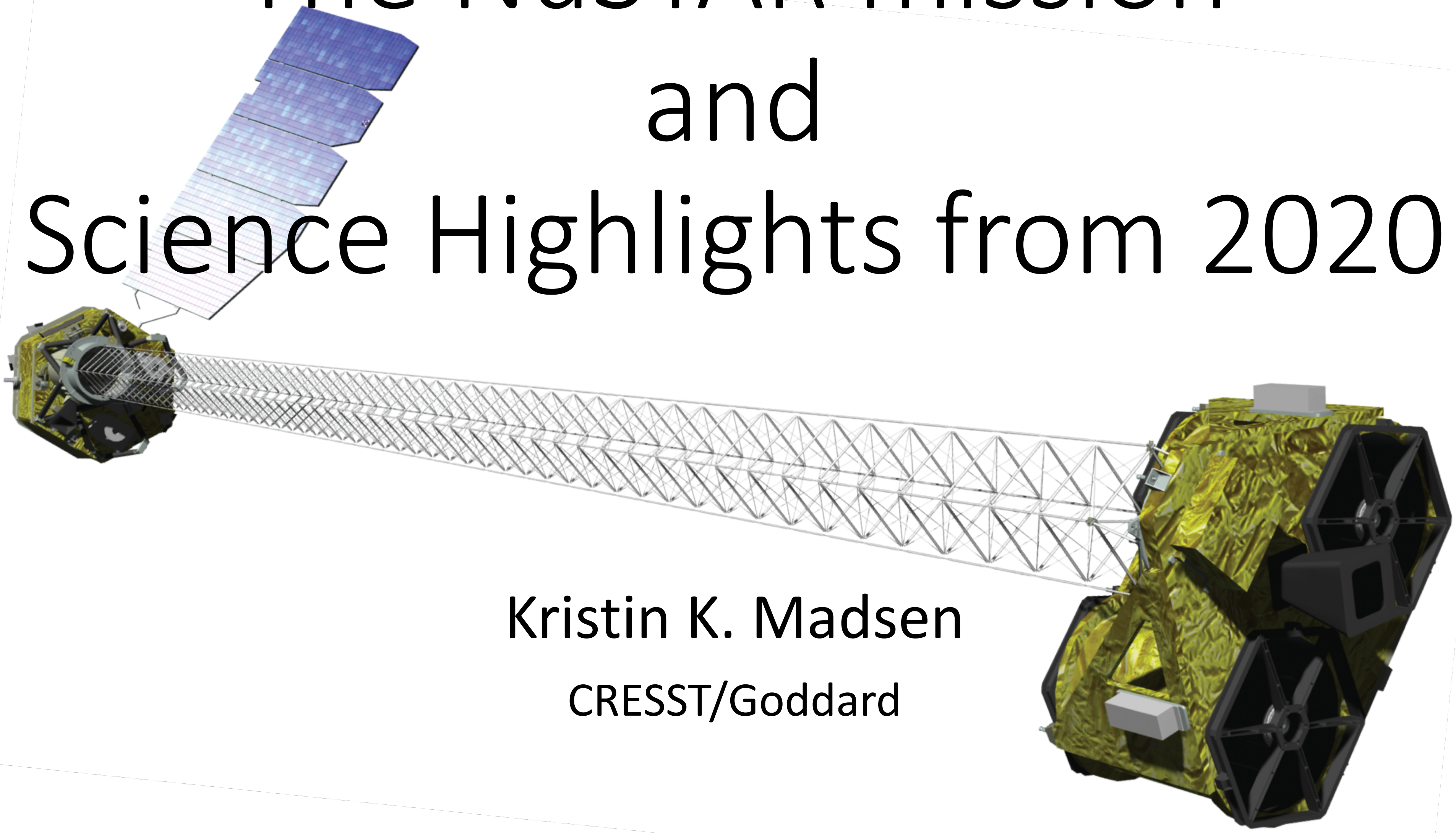
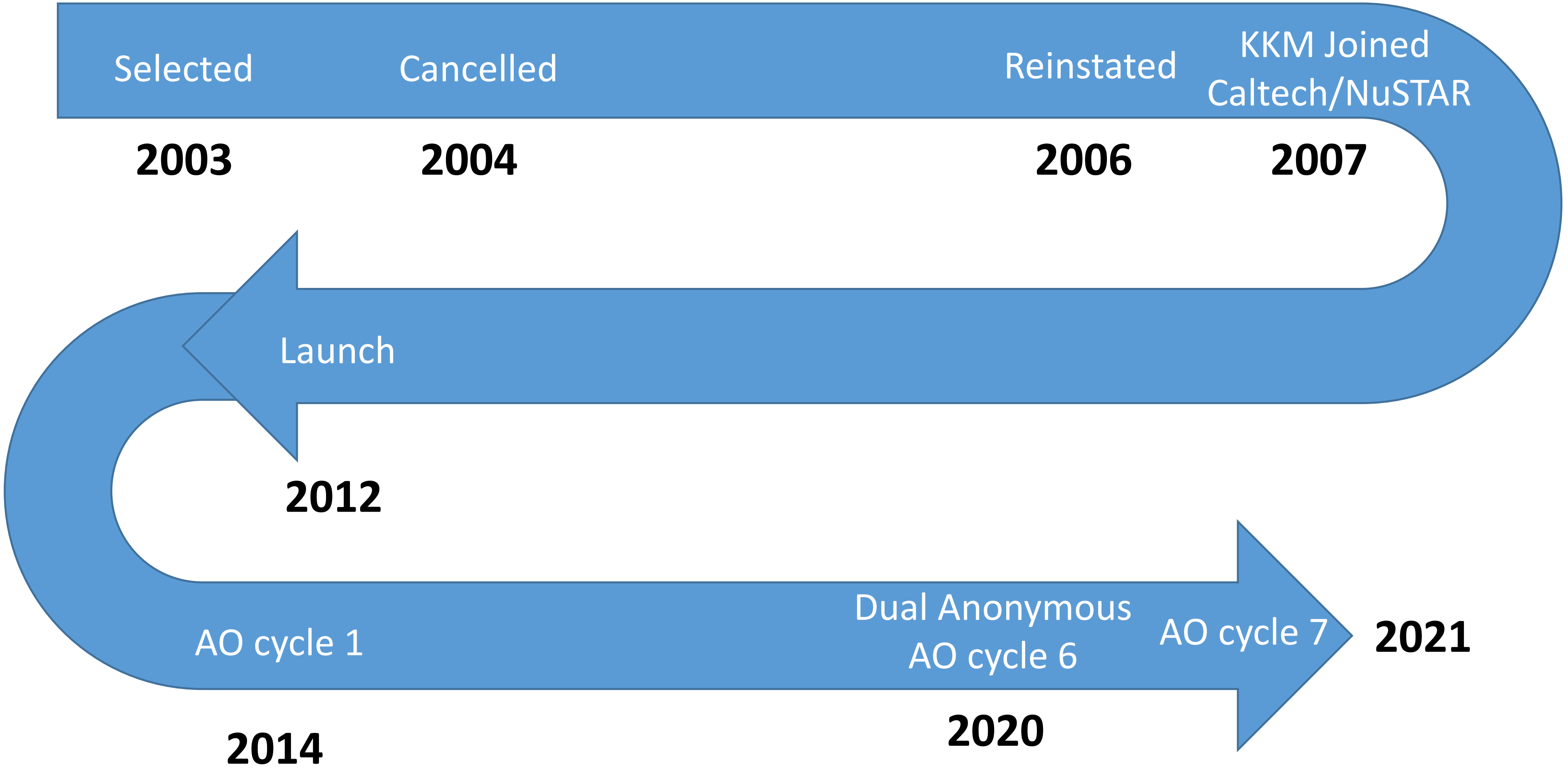
The NuSTAR mission and Science Highlights from 2020



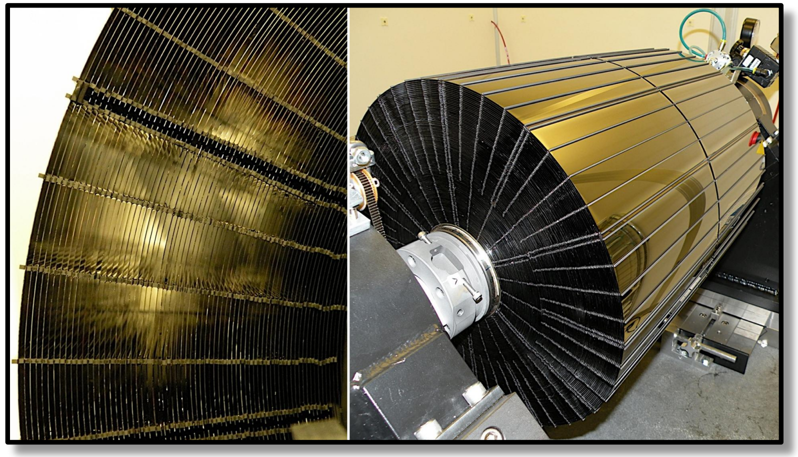
Kristin K. Madsen
CRESST/Goddard

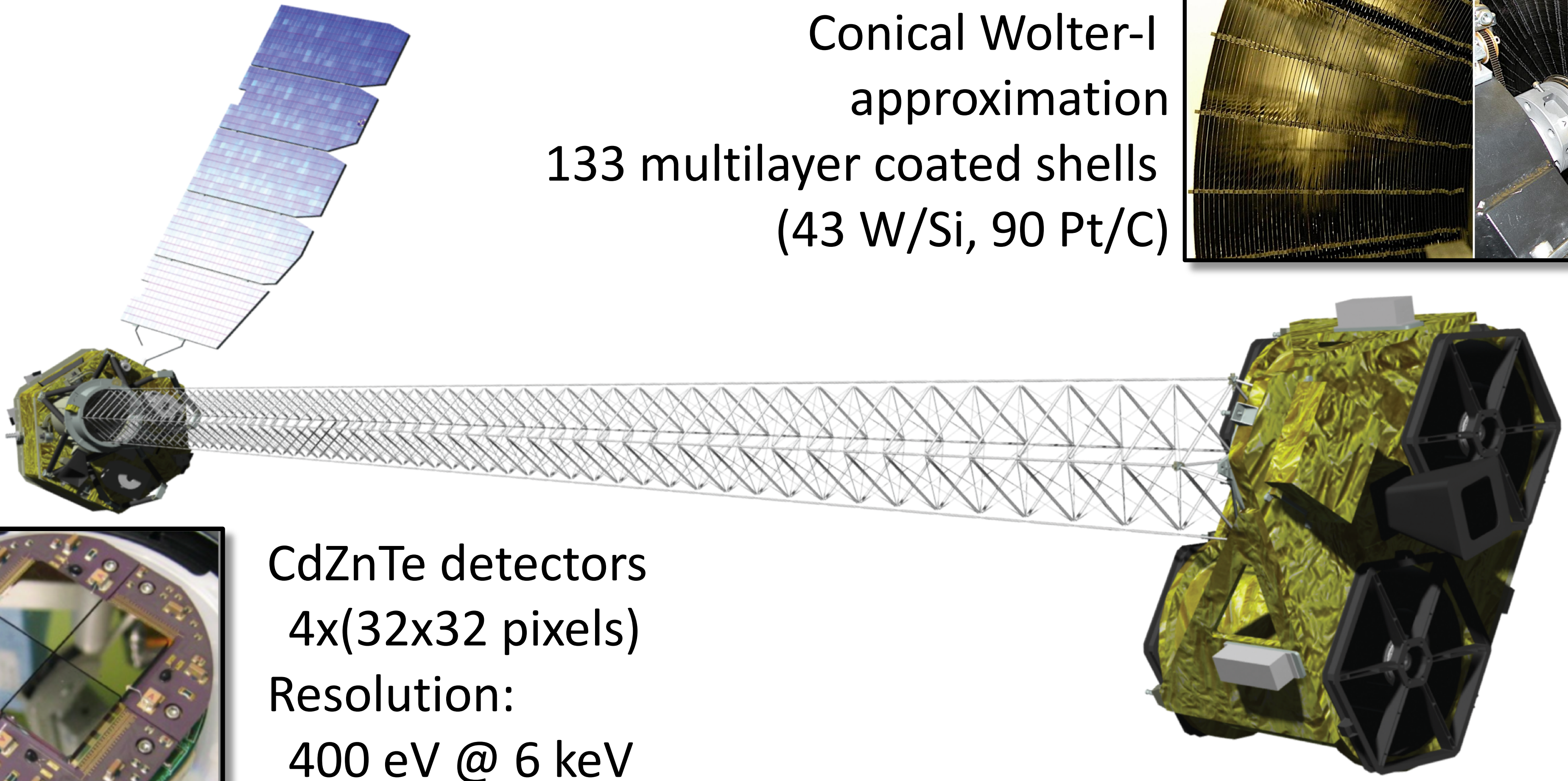
NuSTAR: NASA Small Mission Explorer

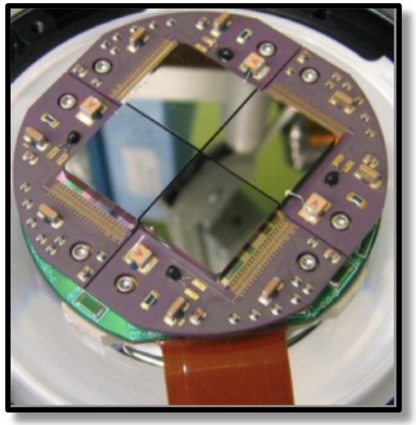


NuSTAR Observatory [3-80 keV]

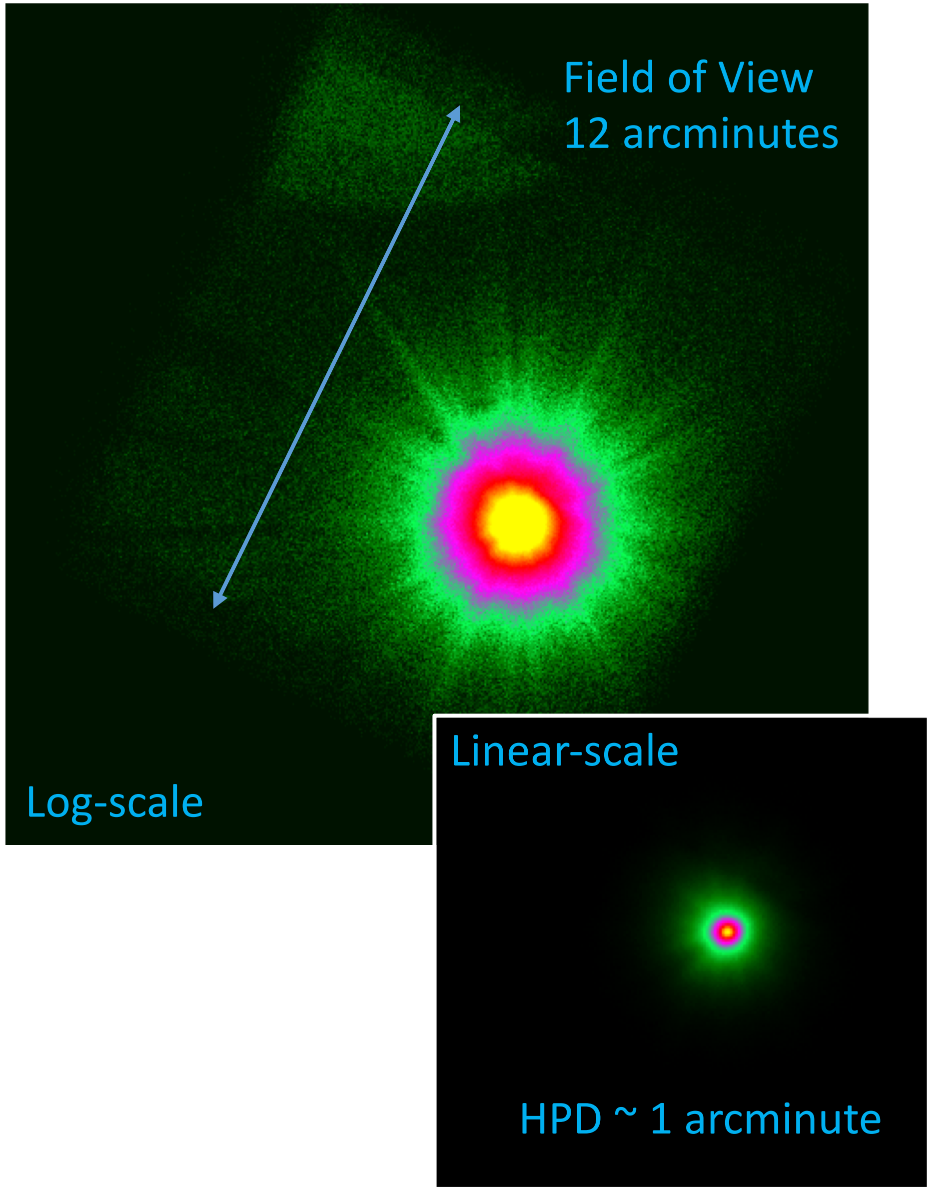
Conical Wolter-I approximation
133 multilayer coated shells
(43 W/Si, 90 Pt/C)

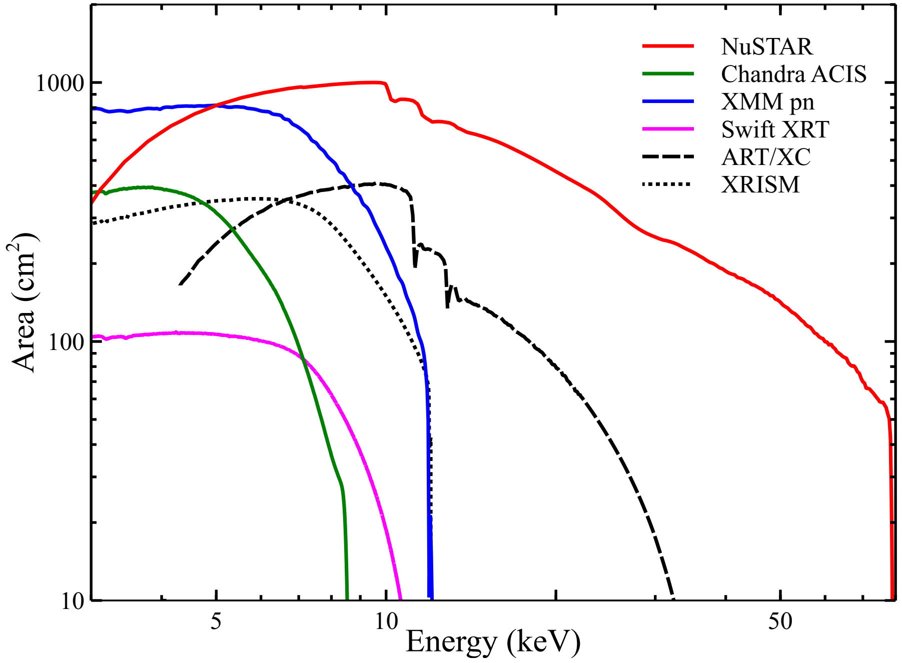


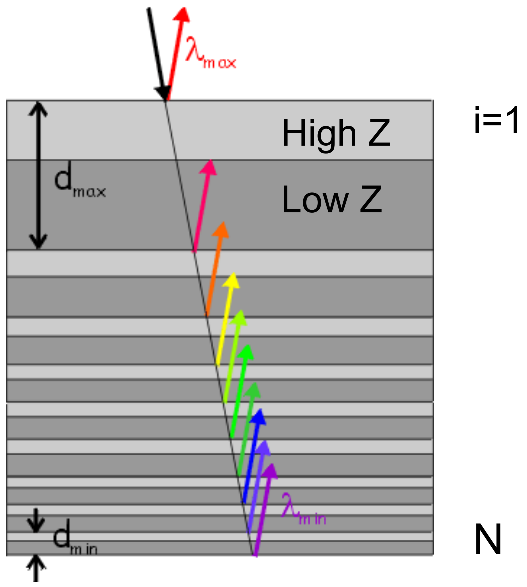




CdZnTe detectors
4x(32x32 pixels)
Resolution:
400 eV @ 6 keV
900 eV @ 60 keV


Field of View
12 arcminutes
Log-scale
Linear-scale
HPD ~ 1 arcminute


NuSTAR
Chandra ACIS
XMM pn
Swift XRT
ART/XC
XRISM
1000
100
10
Area (cm^2)
5
10
50
Energy (keV)


λ_{max}
High Z
Low Z
d_{max}
i=1
λ_{min}
d_{min}
N

NuSTAR Primary Mission Objective Anno 2012

Locate **massive black holes** in other galaxies at high energy X-ray energies (6 – 79 keV) that are dim at X-ray energies below 10 keV, measure their density on the sky, as well as the distribution of their high-energy X-ray apparent brightness, and correlate these properties with those found at other wavelengths.

Measure the intensity and distribution of material in **the remnants of stars that have exploded within the last ~ 500 years** by using the radioactive tracer ^{44}Ti, which has key diagnostic decay lines at X-ray energies of 68 and 78 keV.

Locate the **remnants of collapsed stars**—black holes, neutron stars, and white dwarfs—in our Galaxy that radiate high-energy X-rays, measure their spatial distribution, and correlate their properties with those found at low-energy X-ray, radio, and infrared wavelengths.

Observe a sample of **Very High Energy (VHE) gamma-ray sources** and measure their high energy X-ray temporal, spatial and spectral properties in order to constrain the mechanisms responsible for the high energy emission.

Observe any **core collapse supernovae** in the Local Group and/or any **Type Ia supernovae** identified by optical telescopes that are in or closer than the Virgo cluster that occur during the mission life. Although such an event is not guaranteed to happen within the mission lifetime, the scientific implications would be profound, and observations of such events are therefore included in the primary objectives.

NuSTAR PMO Anno 2016

Probing Strong Gravity and Extreme Conditions

NuSTAR has fundamentally changed the landscape for studying strong gravity and extreme conditions, confirming our ability to study the innermost regions of accretion flows. This PMO is extremely popular, with the vast majority of guest investigator programs focusing on active galaxies and Galactic compact objects. *NuSTAR* will further advance models of the regions close to black holes and neutron stars, build statistics of black hole spin measurements, and improve our understanding of the activity of the nearest supermassive black hole, Sgr A*. During the 2016–2018 period, this will be carried out through a combination of GO, ToO, and Legacy observations.

Measuring Black Hole Growth over Cosmic Time

NuSTAR has made tremendous progress by resolving 35% of the cosmic X-ray background in the 8–24 keV bandpass through its extragalactic Legacy surveys. These surveys have measured the sky density of active galaxies over a range of fluxes never before explored and have probed the evolution of the hard X-ray luminosity function over cosmic time. There is strong motivation to improve the statistics by extending these community-driven Legacy surveys to both wider area and greater depth. In addition, *NuSTAR* will continue its study of heavily obscured black holes, where most black hole growth occurs.

Studying Populations of Compact Objects in the Milky Way and Nearby Galaxies

Building on observations performed as part of previous Legacy survey programs, we will expand *NuSTAR's* studies of populations of compact objects in the Milky Way, M31, and other nearby galaxies where these populations can be resolved and studied for the first time. These observations will be accomplished through community-driven Legacy surveys.

Measuring the masses of magnetic white dwarfs: A NuSTAR Legacy Survey

Measuring the masses of magnetic white dwarfs: a *NuSTAR* legacy survey

A. W. Shaw et al, MNRAS, 2020

Survey of 19 magnetic cataclysmic variables

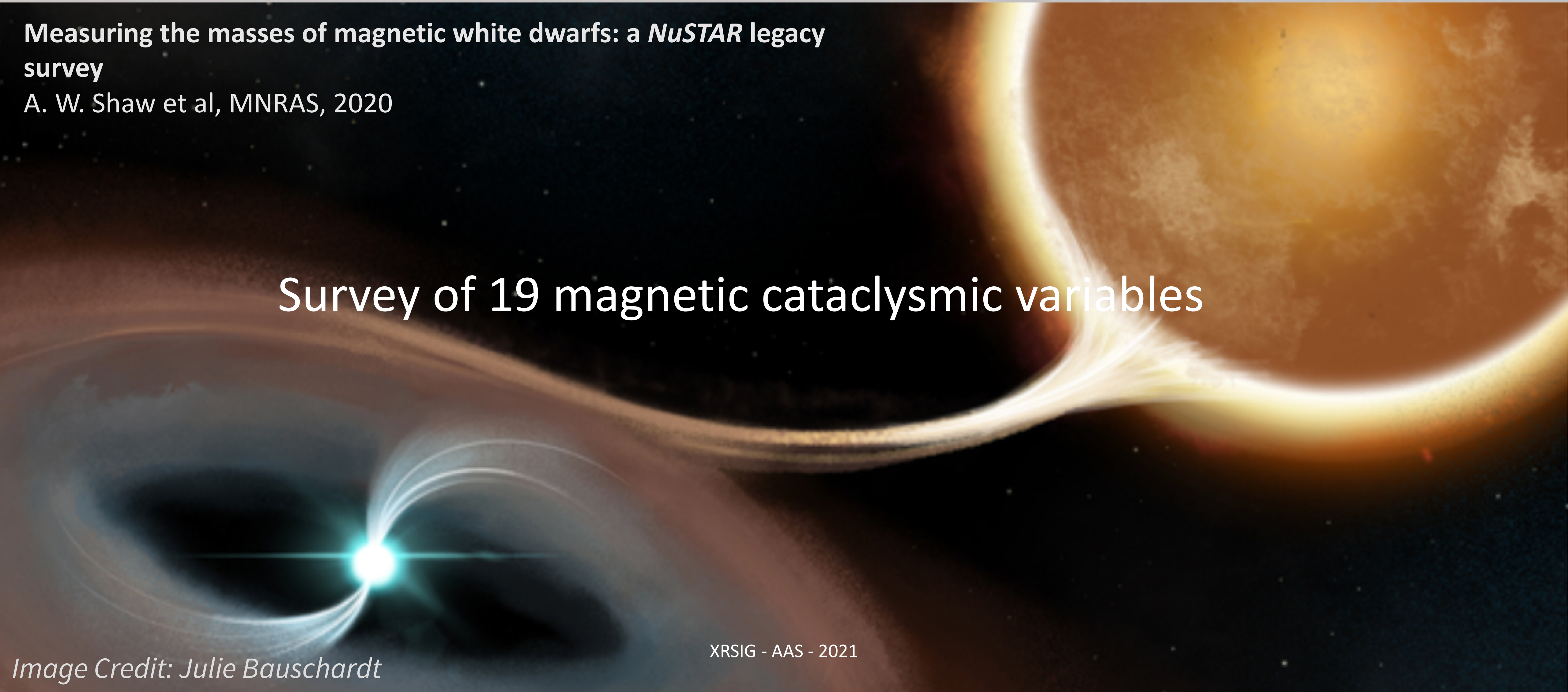
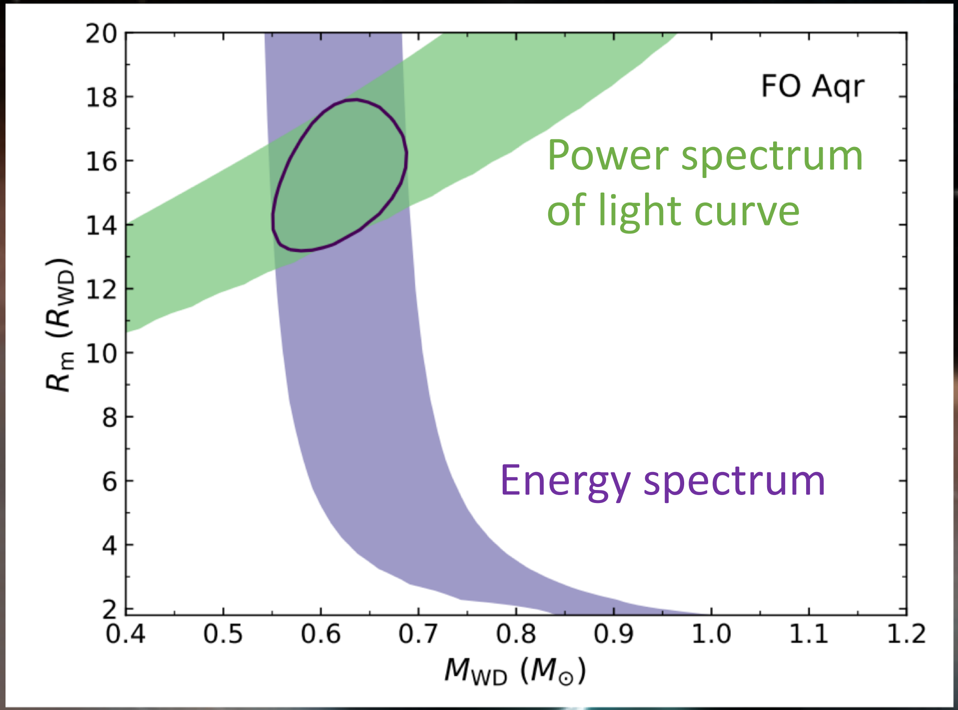


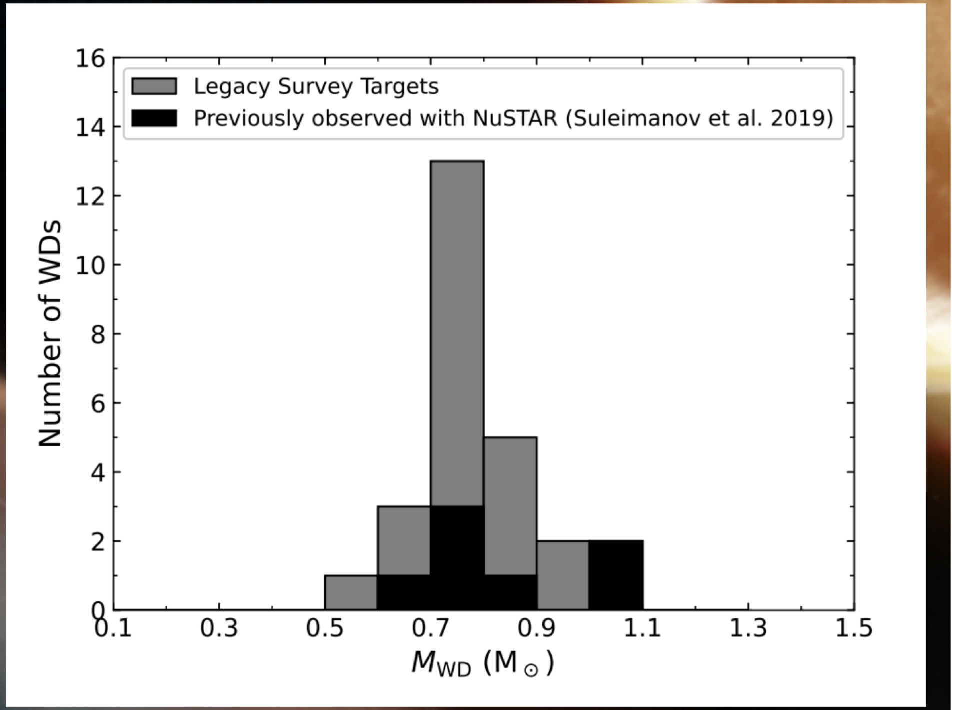
Image Credit: Julie Bauschardt

Measuring the masses of magnetic white dwarfs: A NuSTAR Legacy Survey

Measuring the masses of magnetic white dwarfs: a *NuSTAR* legacy survey

A. W. Shaw et al, MNRAS, 2020





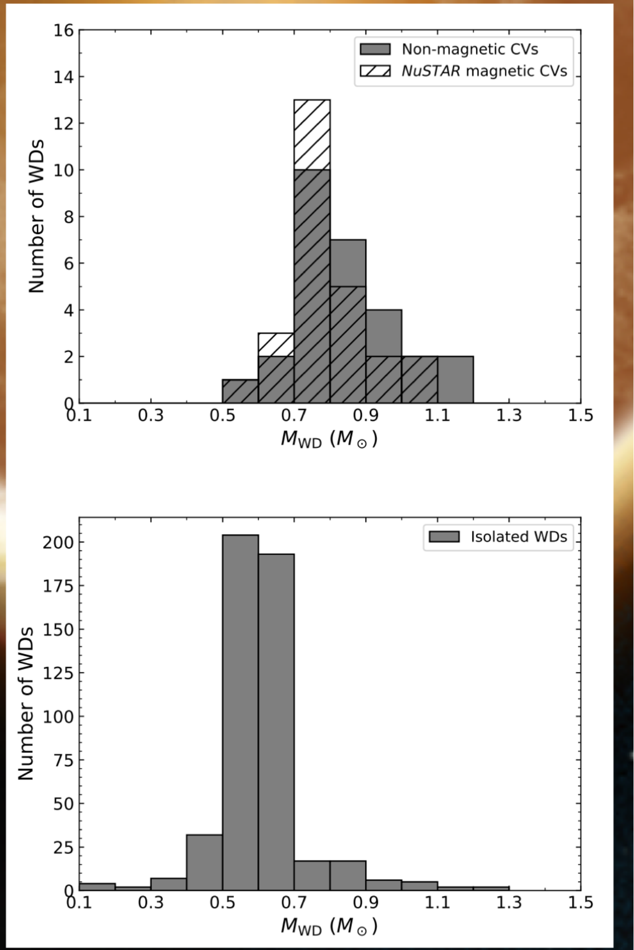
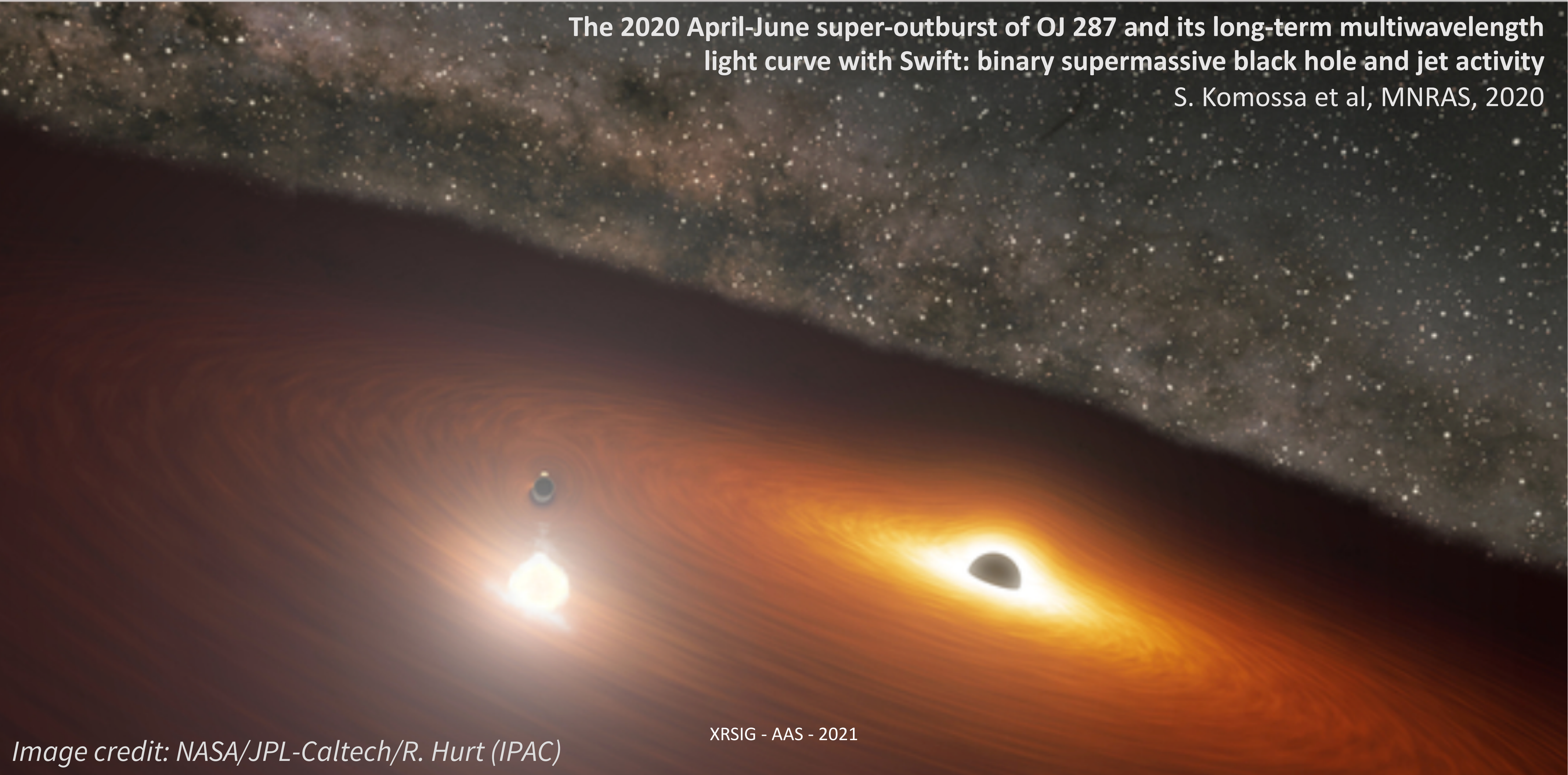


Image Credit: Julie Bauschardt

After-Flare Detected from Black Hole Dance



The 2020 April-June super-outburst of OJ 287 and its long-term multiwavelength light curve with Swift: binary supermassive black hole and jet activity

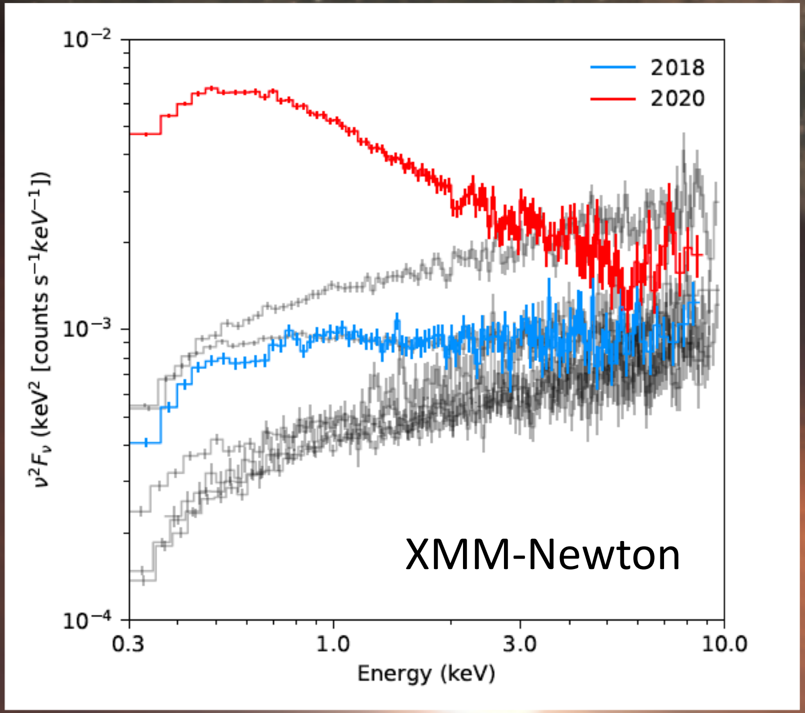
S. Komossa et al, MNRAS, 2020

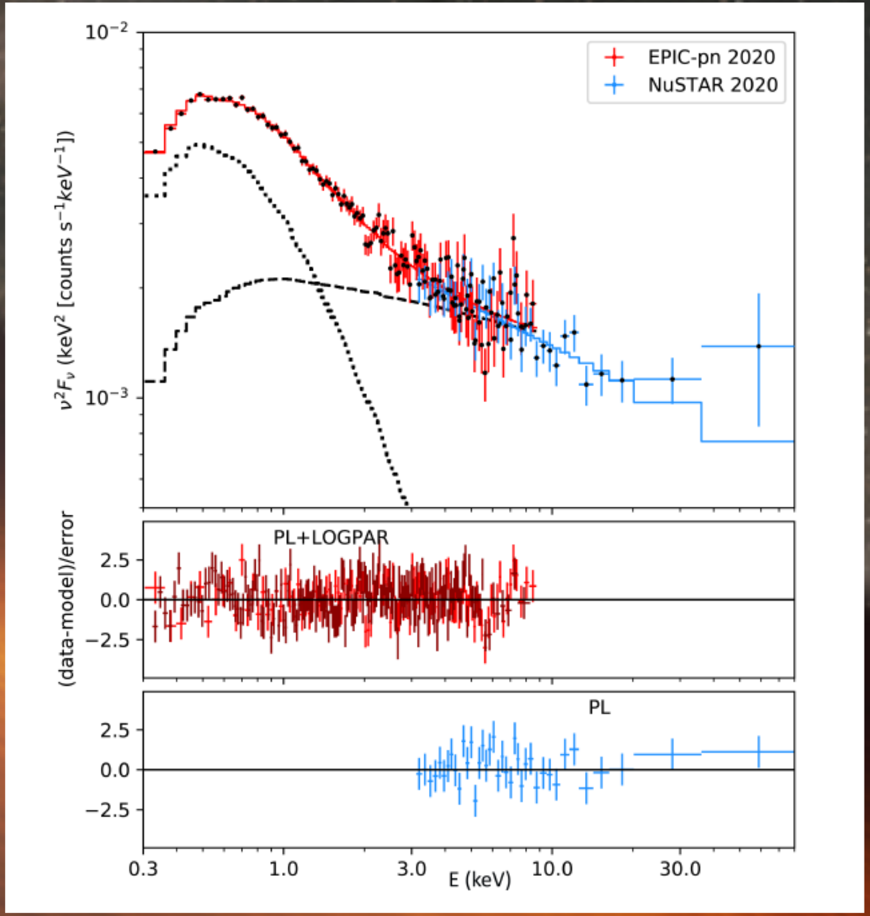
Image credit: NASA/JPL-Caltech/R. Hurt (IPAC)

After-Flare Detected from Black Hole Dance

The 2020 April-June super-outburst of OJ 287 and its long-term multiwavelength light curve with Swift: binary supermassive black hole and jet activity

S. Komossa et al, MNRAS, 2020

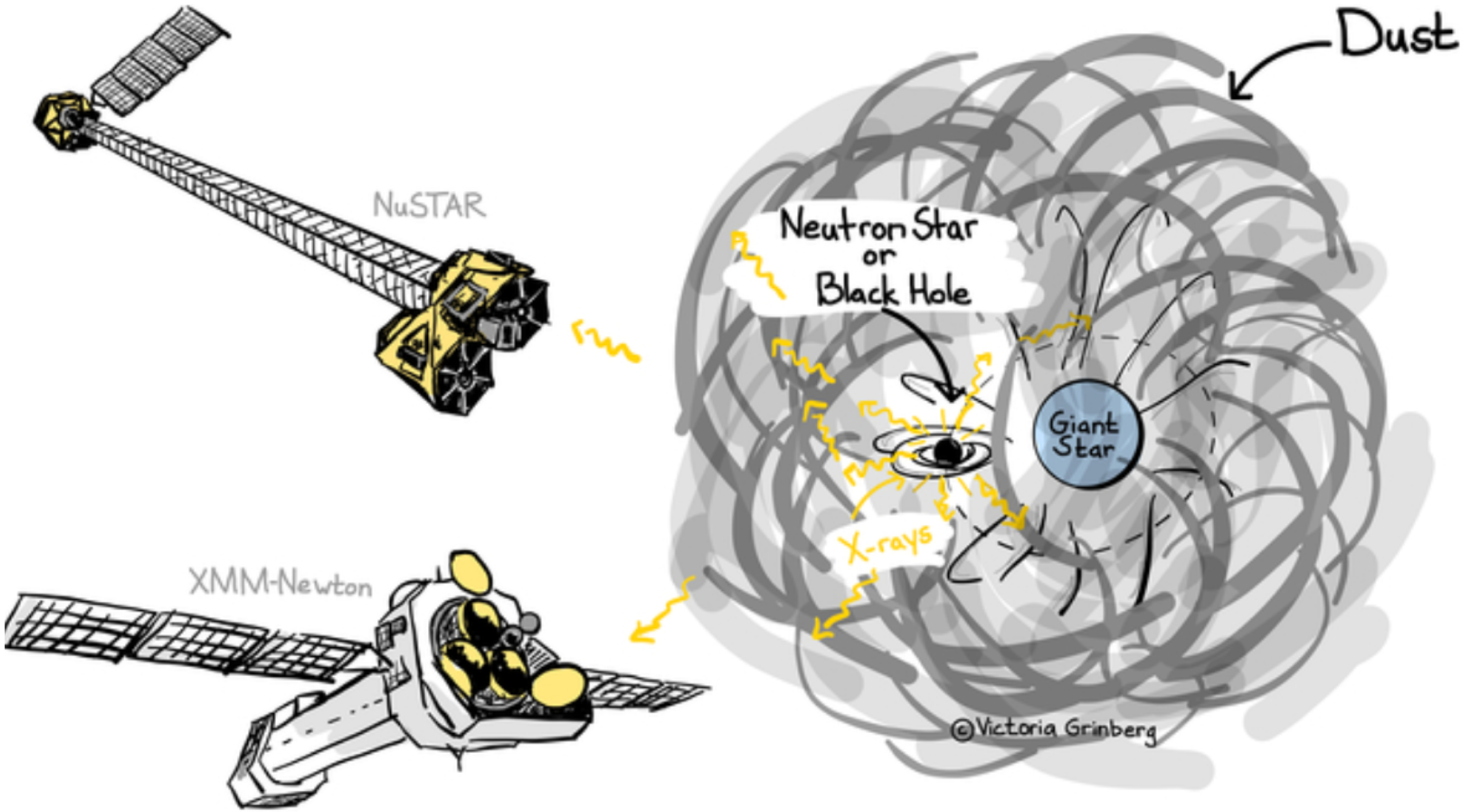




XRSIG - AAS - 2021

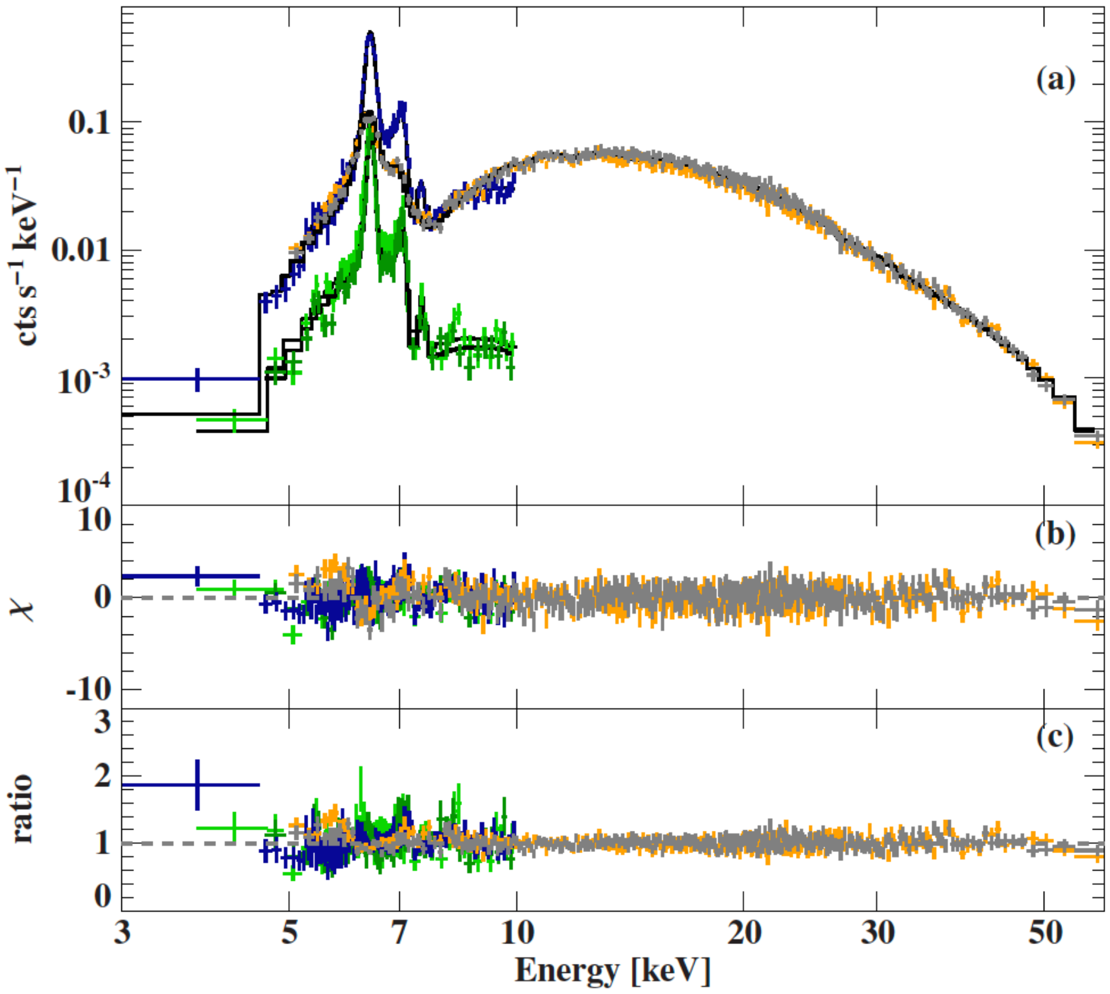
Image credit: NASA/JPL-Caltech/R. Hurt (IPAC)

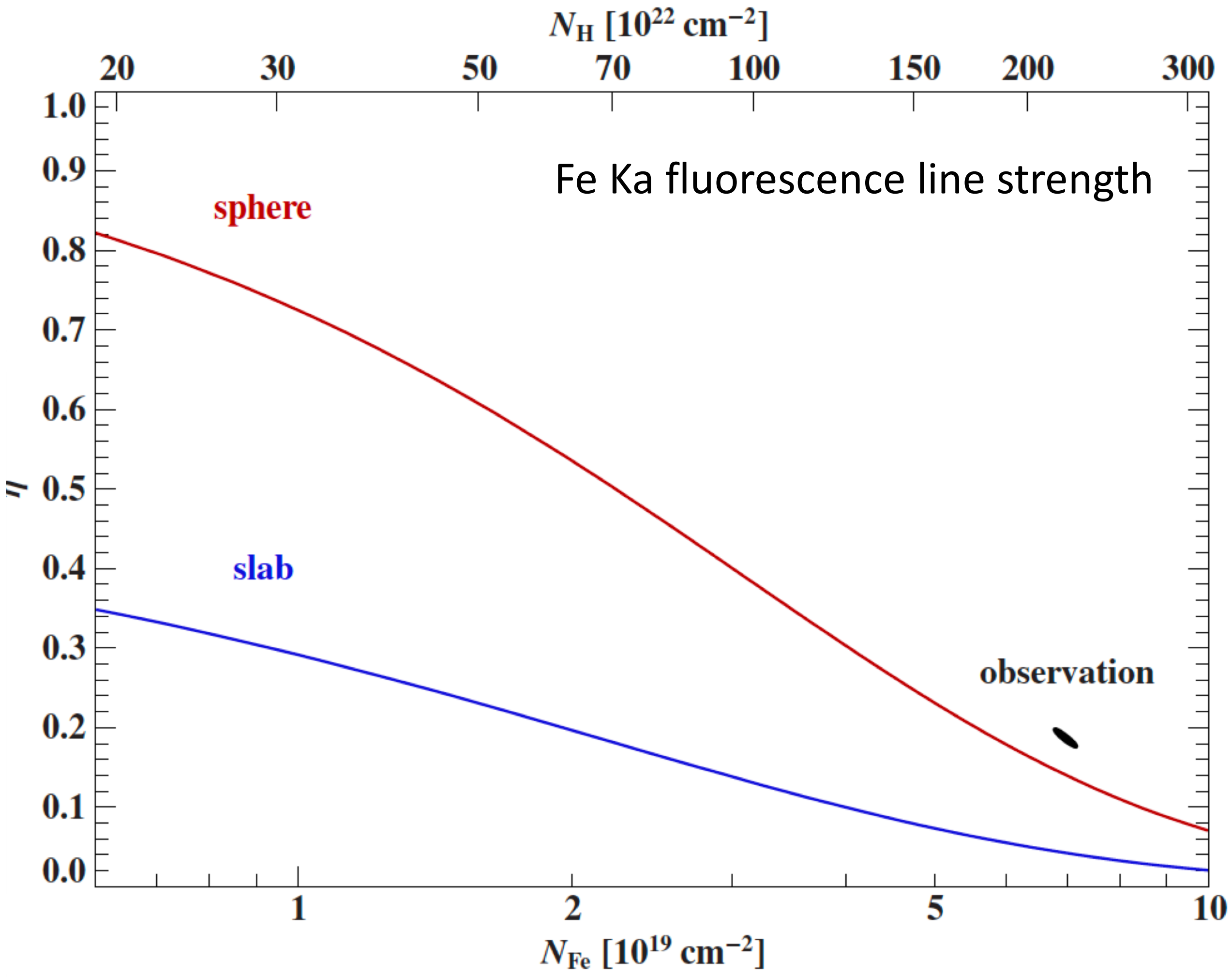
NuSTAR and XMM-Newton observe a dusty shroud sparkling in X-rays

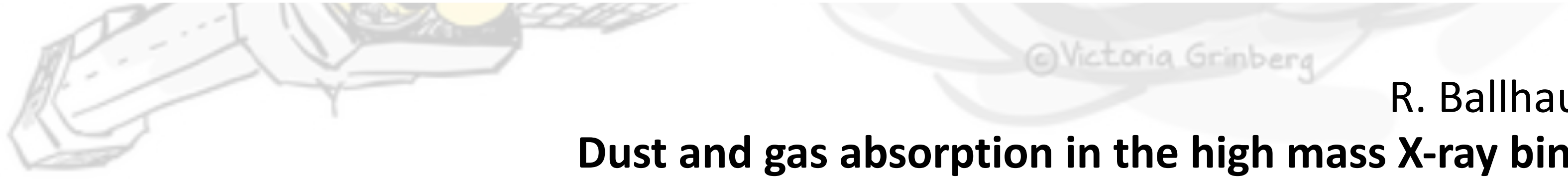


R. Ballhausen et al, A&A, 2020
Dust and gas absorption in the high mass X-ray binary IGR J16318-4848

NuSTAR and XMM-Newton observe a dusty shroud sparkling in X-rays





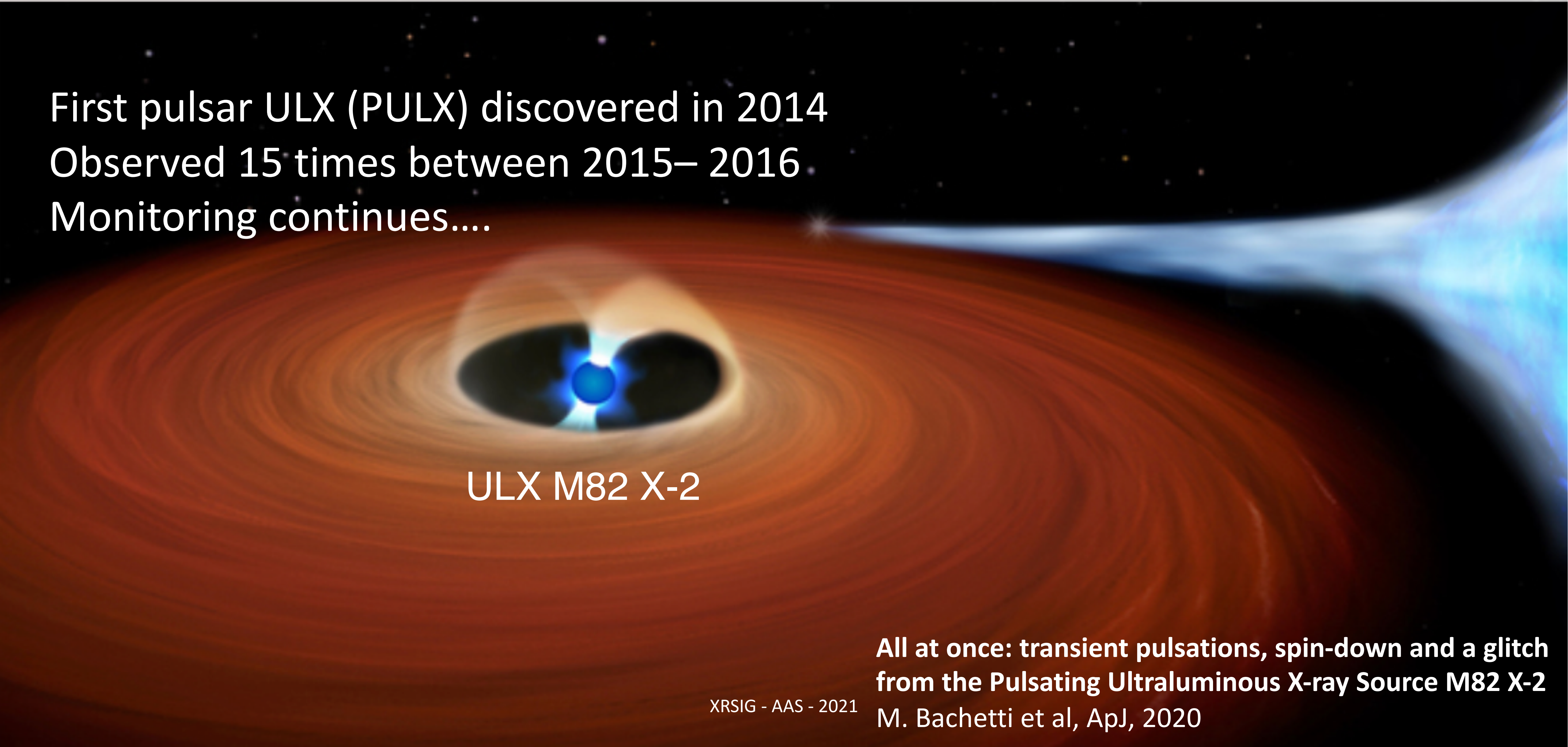


R. Ballhausen et al, A&A, 2020

Dust and gas absorption in the high mass X-ray binary IGR J16318-4848

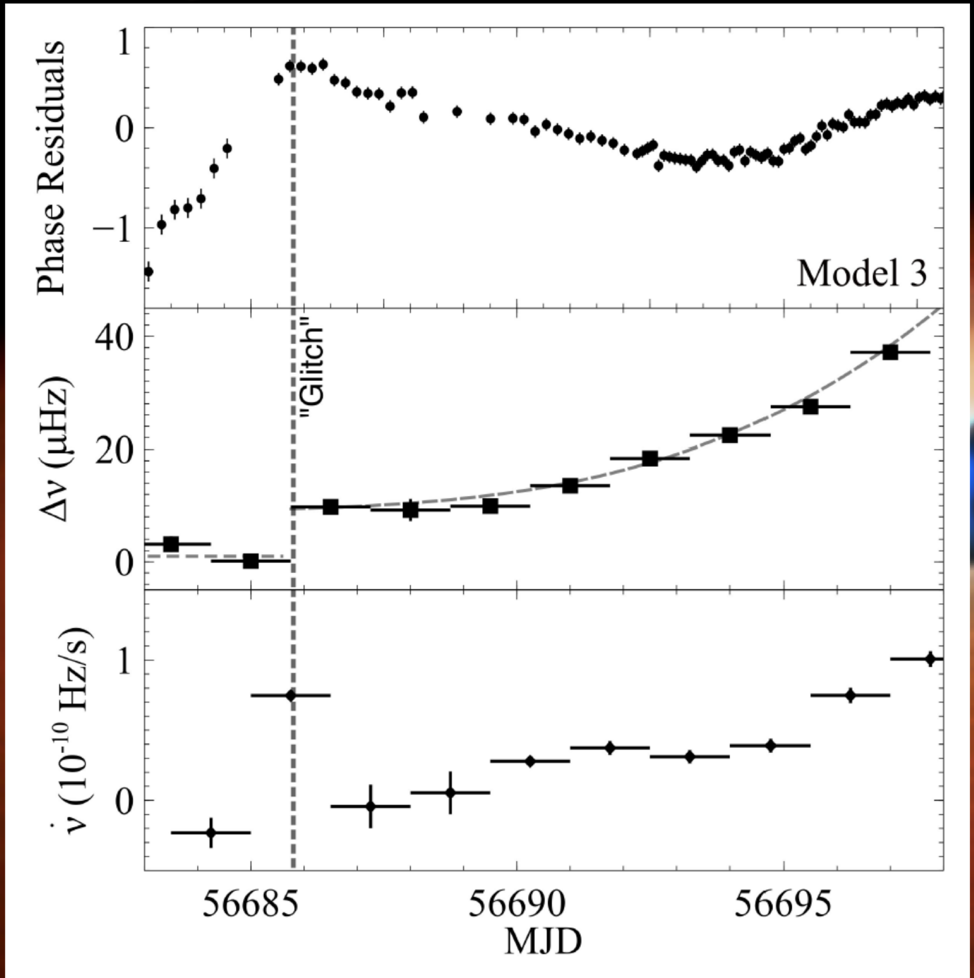
Monitoring the First Ultraluminous Pulsar

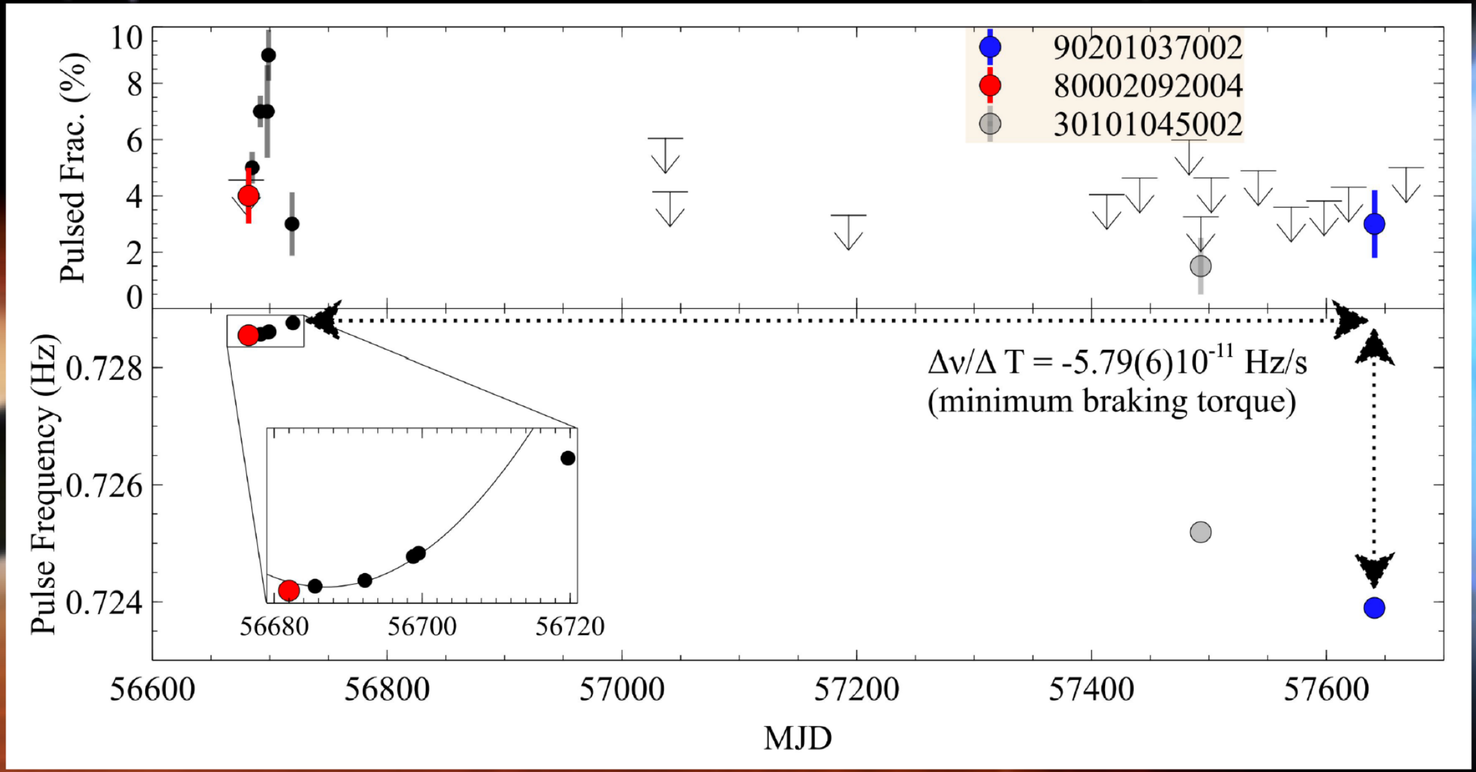
First pulsar ULX (PULX) discovered in 2014
Observed 15 times between 2015– 2016
Monitoring continues….



All at once: transient pulsations, spin-down and a glitch from the Pulsating Ultraluminous X-ray Source M82 X-2
M. Bachetti et al, ApJ, 2020

Monitoring the First Ultraluminous Pulsar

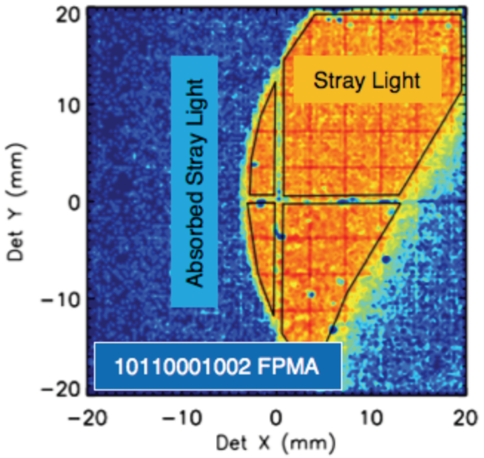


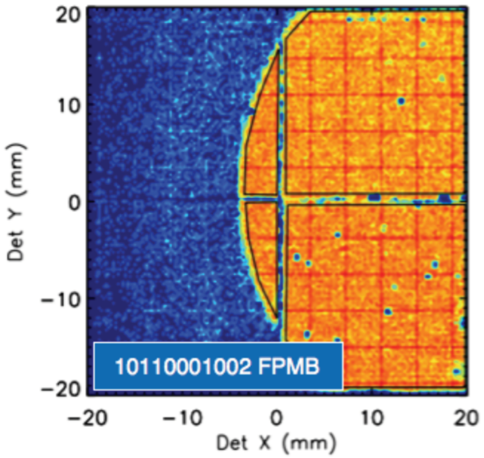


All at once: transient pulsations, spin-down and a glitch from the Pulsating Ultraluminous X-ray Source M82 X-2
M. Bachetti et al, ApJ, 2020

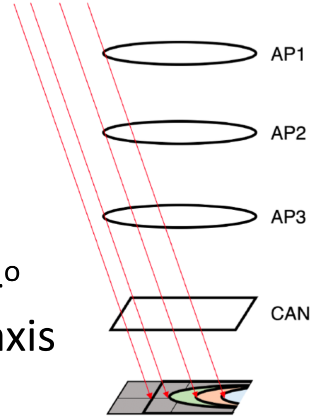
StrayCats Everywhere!

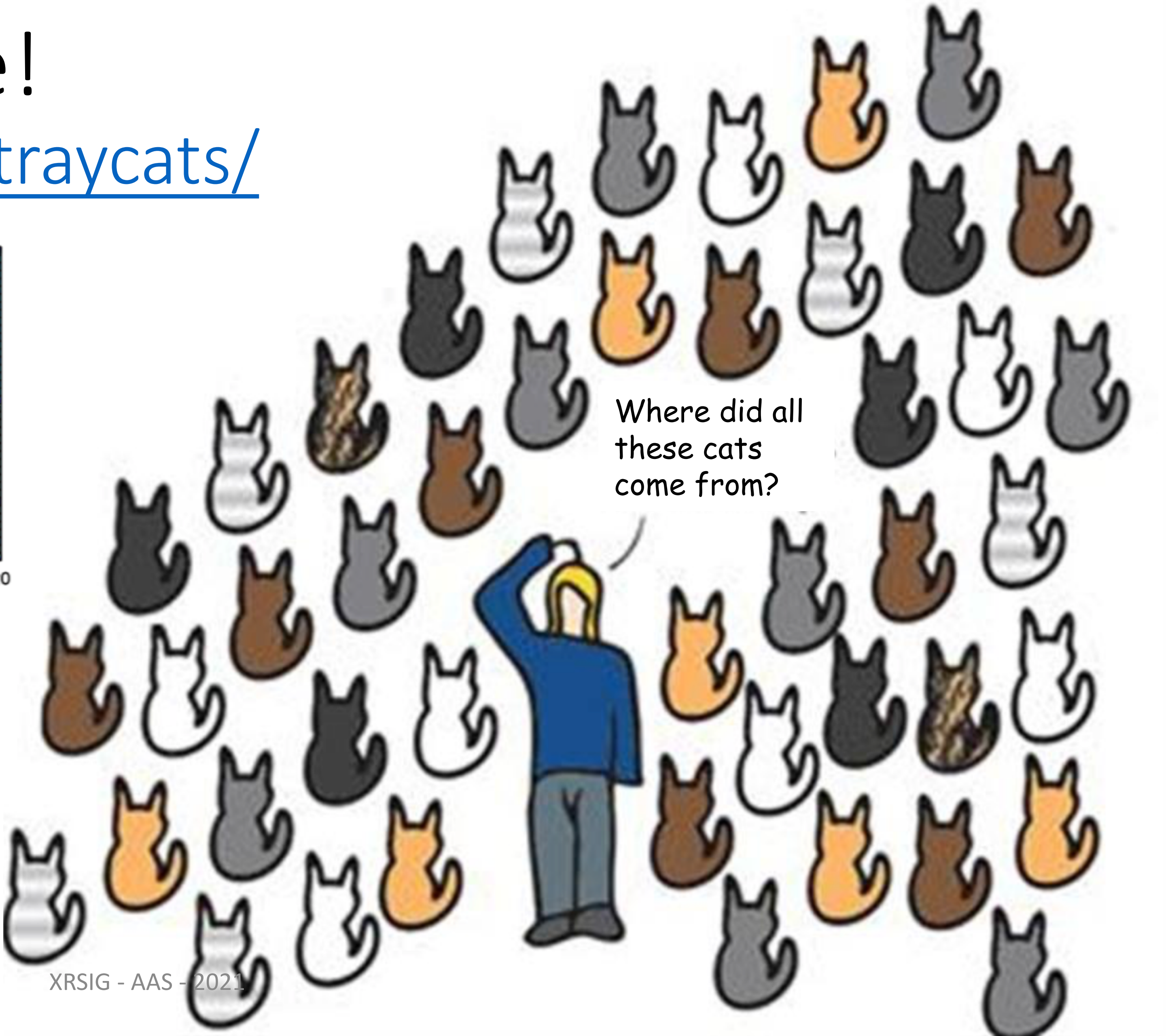
https://bwgref.github.io/straycats/

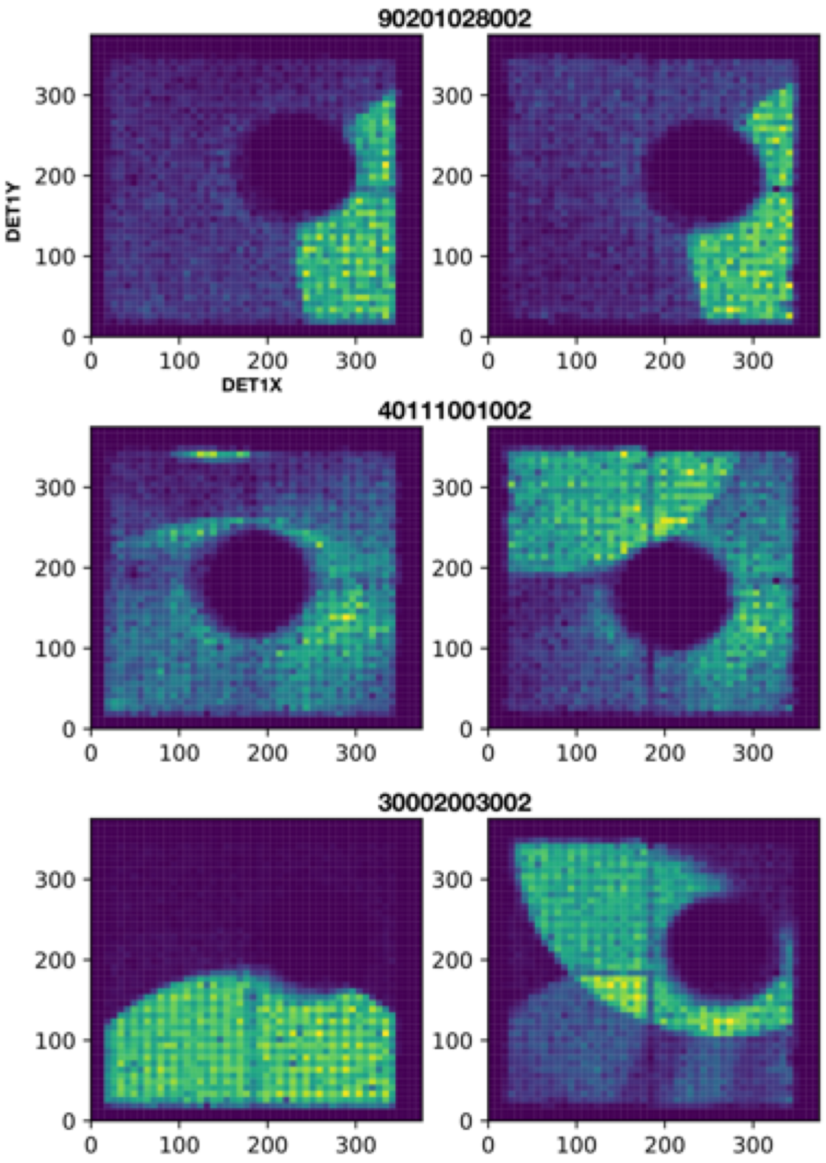




1 – 4º
Off-axis





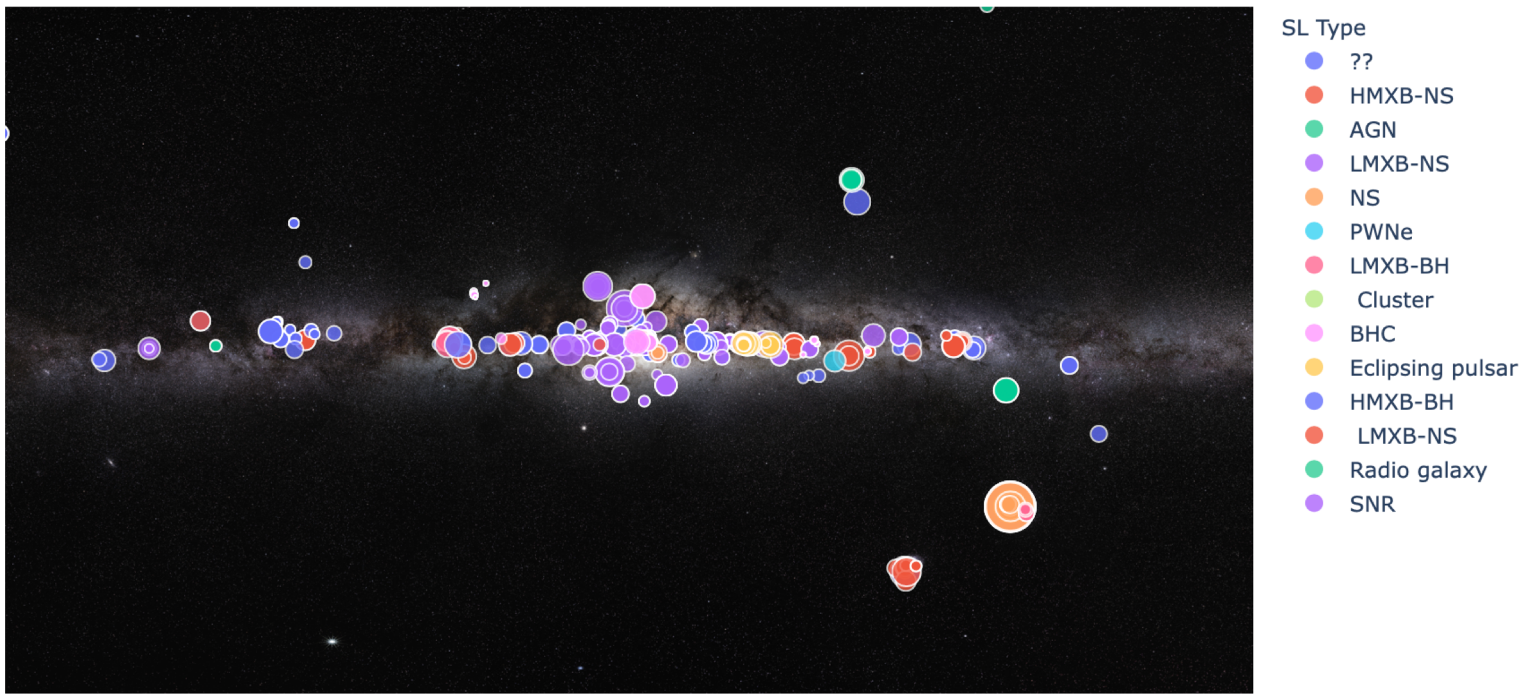


https://bwgref.github.io/straycats/

Systematic Search through entire NuSTAR database

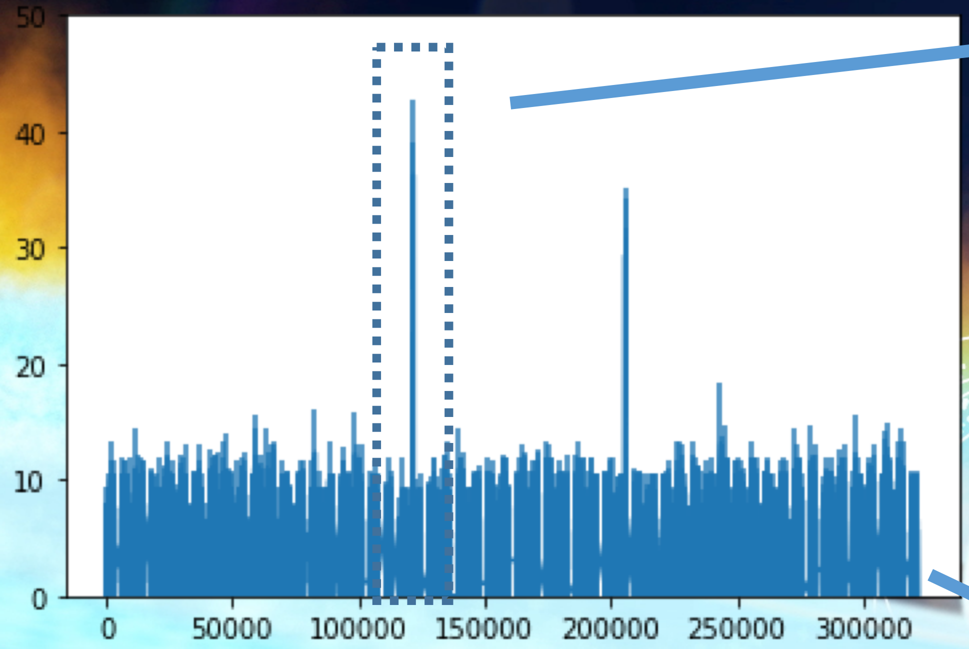
>400 telescope fields identified

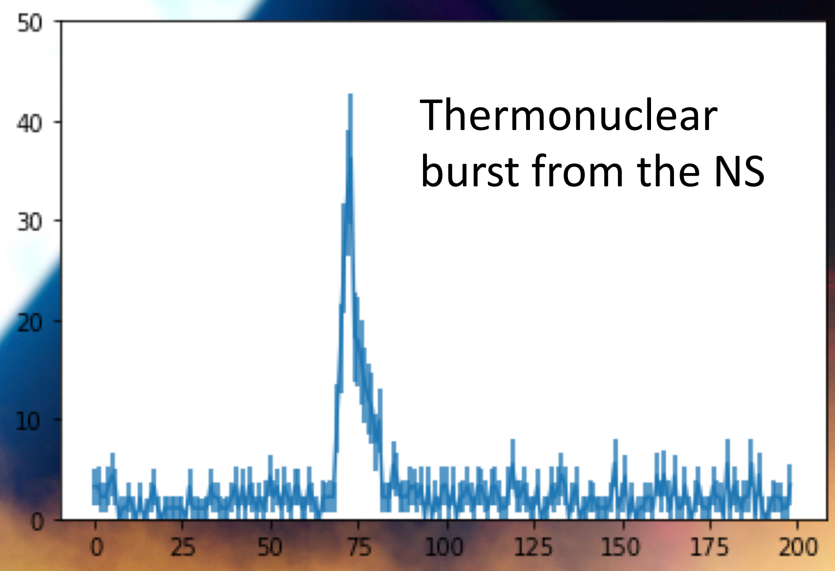
>70 confirmed sources

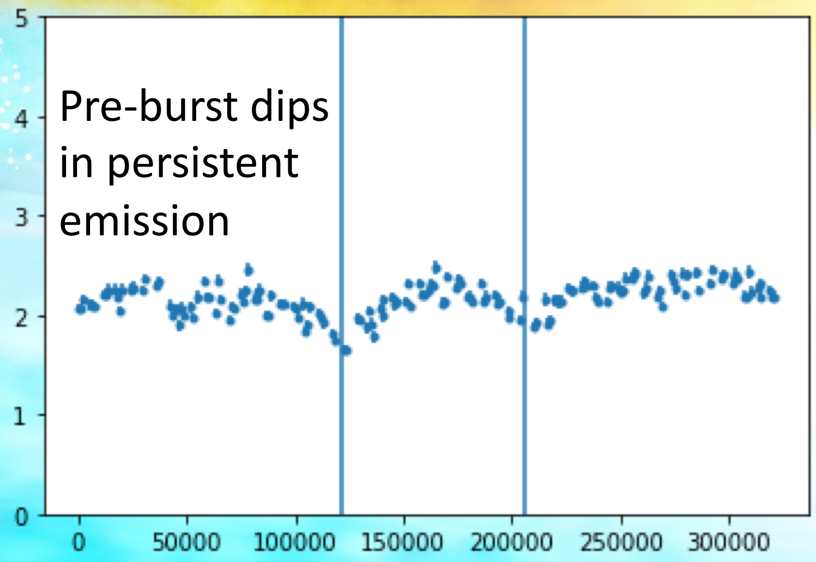


Grefenstette et al, (2021) submitted

GS 1826:
Type I X-ray Bursts







Broken "Clocked Burster"?

Previously only 40 ks of pointed time on this source

***Should* have had many more bursts during this observation…**

Several more observations of similar length and other bursters

NuSTAR STATUS

- Launched in June 2012, 8.5 years in orbit
- Lifetime:
  - no consumables
  - Orbit stability (10+ yr)
  - health of instruments (5+ yr)
- Scientific status:
  - GO observer program now includes large programs (> 500 ms)
  - Coordination: NuSTAR time is offered in almost every other high-energy GO program
  - New coordinated opportunities with ART-XC and IXPE
  - Transient events very popular. 1-2 ToO’s per week!
- Successor: none