



# **Identification of Candidate Be/X-Ray Binaries using Archival Swift SMC Survey Data**

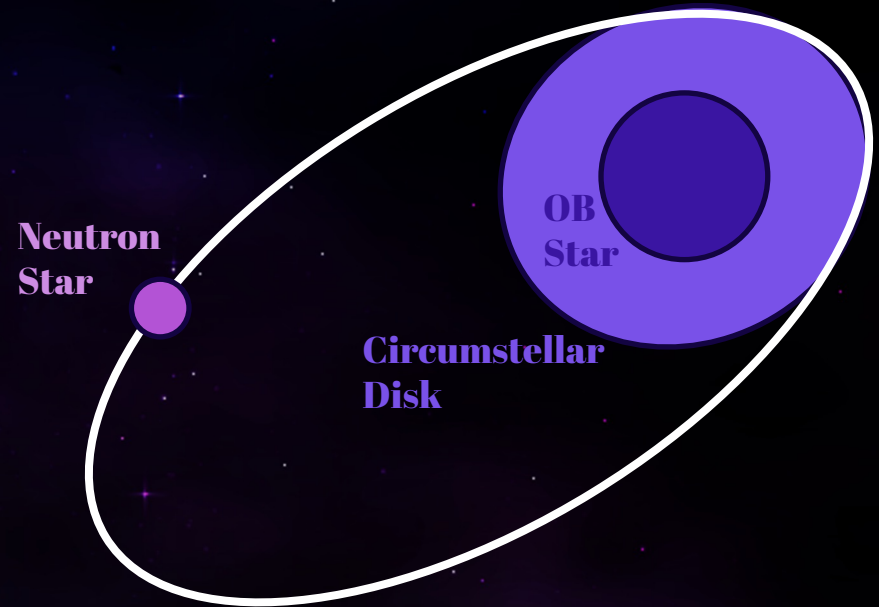
**Thomas Gaudin**

**PSU Lunch Talk - 3/26/24**

**Co-Authors: Jamie Kennea, Malcolm Coe, Iumaleng Monageng, Lee Townsend, Andrzej  
Udalski, David Buckley, Phil Evans**

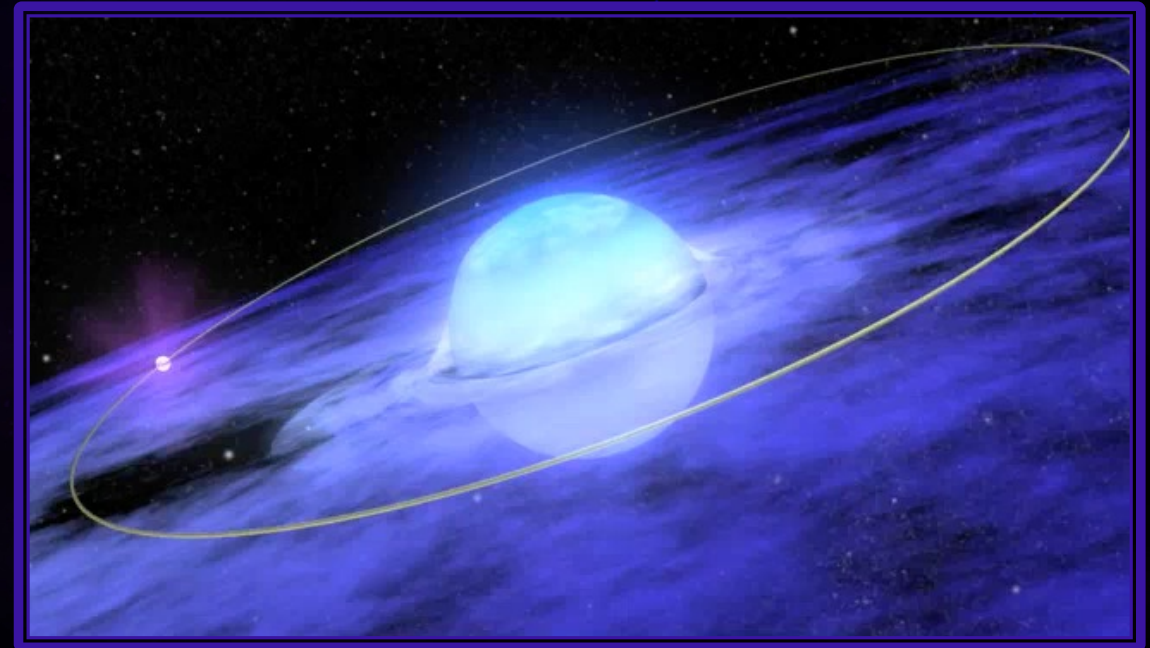
# Introducing Be/X-ray Binaries (BeXRBs)

- 2 main components:
  - OBe Main Sequence Star
  - Compact Object (typically a Neutron Star)
- Also contain:
  - Circumstellar “decretion” disk
  - Moderately eccentric orbit ( $e \sim 0.3\text{--}0.5$ )
  - Orbital Periods of  $\sim 10\text{--}100$ s of days



# BeXRBs as X-ray Transients

- Be/X-ray Binaries spend most of their time in a quiescent state
- Transient X-ray “Outbursts” can occur in 2 different ways:
  - **Type I Outburst:**
    - Occurs near periastron passage
    - $L_X \sim 10^{36} - 10^{37}$  erg/s
  - **Type II Outburst:**
    - Lasts longer than single orbital period
    - $L_X \gtrsim 10^{37}$  erg/s

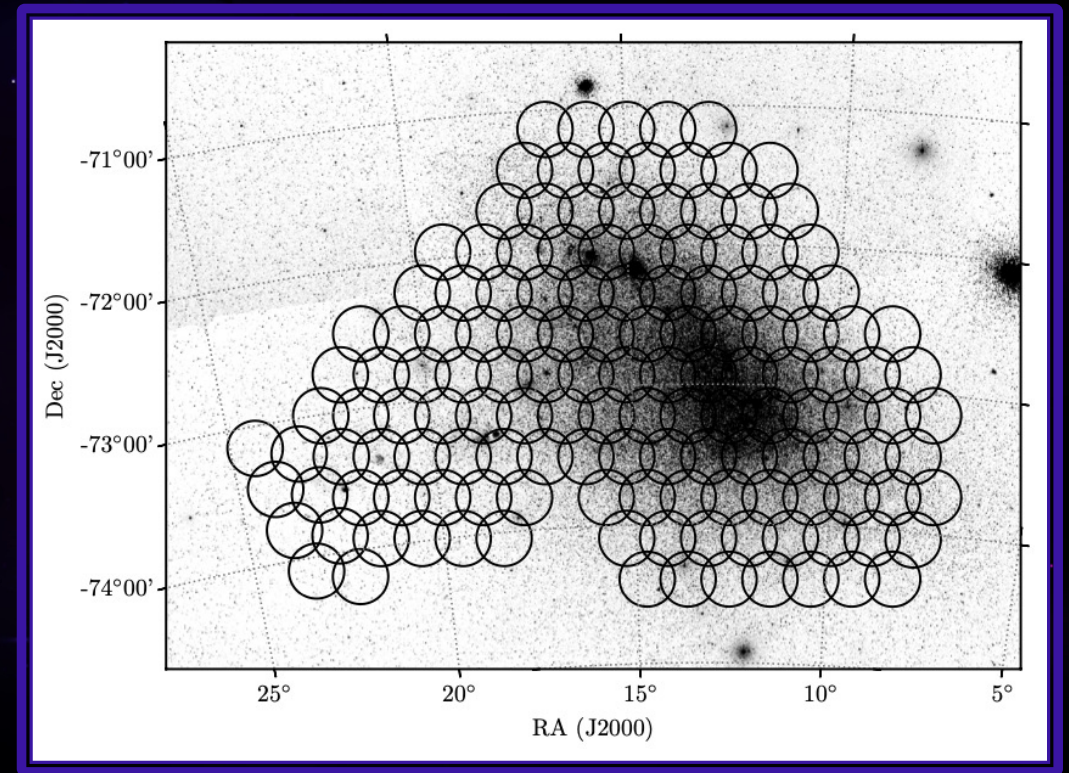


*Image Credit: Walt Feimer, NASA/Goddard Space Flight Center*



# S-CUBED: The Swift SMC Survey

- Survey of the Small Magellanic Cloud using Swift Observatory
- Designed to discover and monitor BeXRBs:
  - Weekly observing cadence
  - 142 observed tiles
  - ~60s exposures
  - Utilizes both UVOT and XRT
- 1900+ X-ray sources detected to date
- Several new BeXRBs found



*Image Credit: Kennea et al. 2018*

# The Search for Quiescent BeXRBs

- New Be/X-ray binaries are still regularly discovered in the SMC (see: *Maitra et al., 2023*)
  - Evidence suggests that the known BeXRB population of the galaxy is incomplete
- BeXRBs are primarily identified via X-ray outbursts and emission line spectroscopy
  - Not feasible for the entire S-CUBED database

How do you identify BeXRBs that have never gone into outburst?

We need a new method!

The background of the image is a deep blue space filled with numerous small, bright stars. Two large, glowing blue spheres, resembling planets or moons, are positioned on the right side of the frame. A faint, diagonal streak of light, possibly a comet or a distant galaxy, is visible in the lower right corner. The overall aesthetic is cosmic and ethereal.

# Archival Analysis Method



# Candidate Identification

- Sources were filtered based on their X-ray properties in the **S-CUBED Database**:
  - Remove all sources not flagged as “Good”
  - Remove all sources with a soft photon index ( $\Gamma > 1.5$ )
  - Keep all sources with no spectral fit

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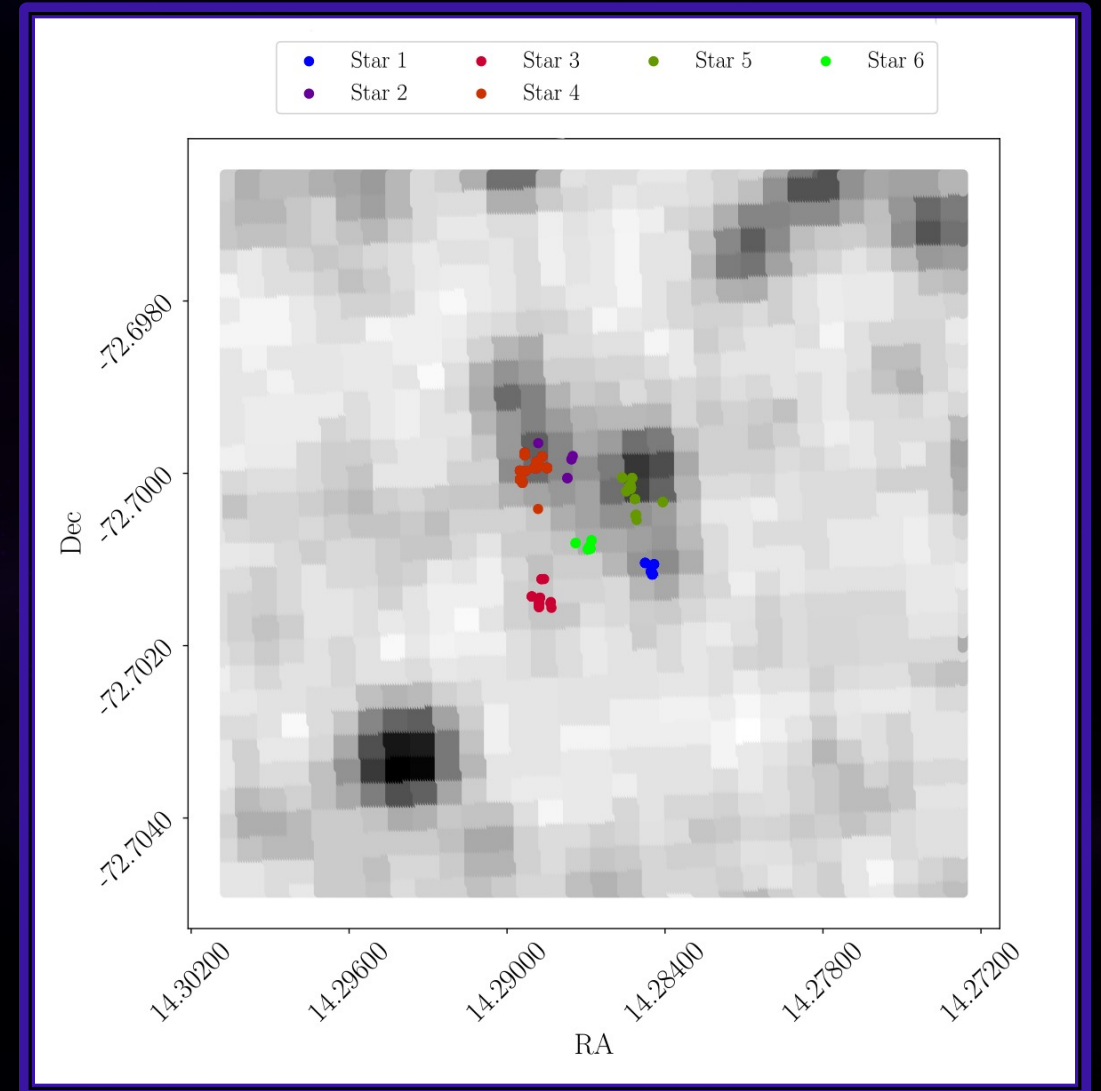
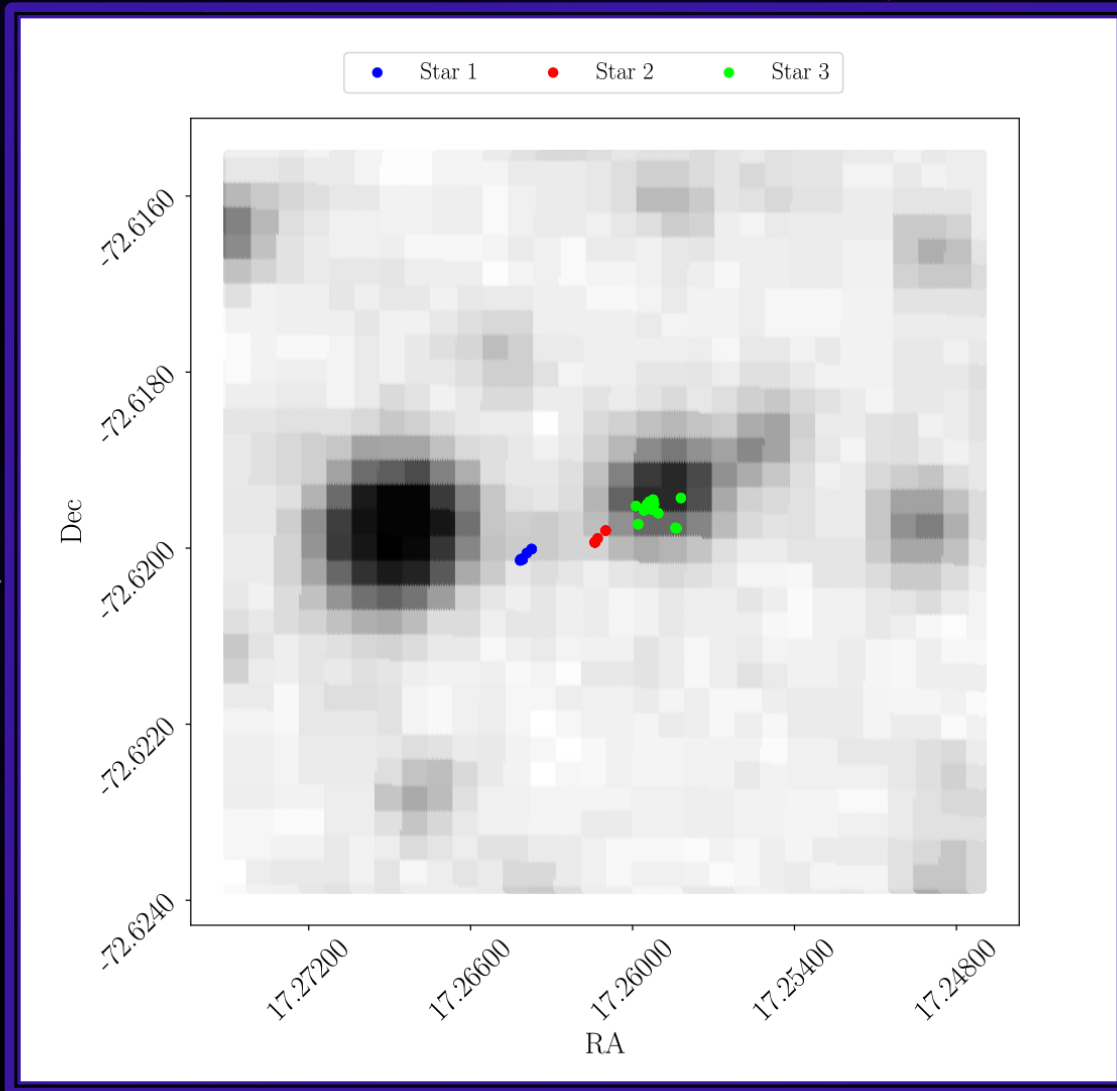
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- Removed sources with known X-ray emitters nearby using **SIMBAD**:
  - Known/Candidate HMXBs, Active Galactic Nuclei, Young Stellar Objects, Supernova remnants



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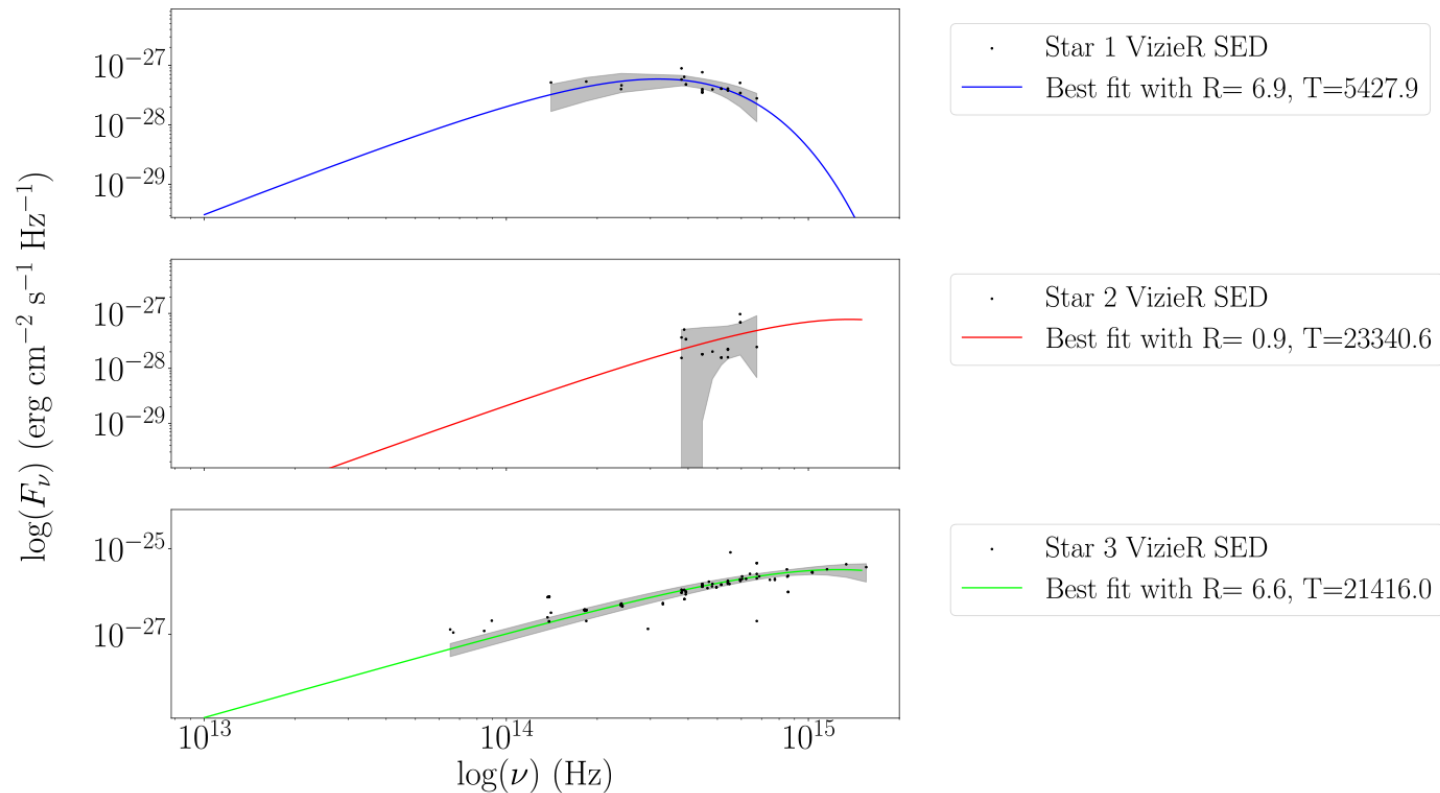
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- Searched for bright stars ( $11.0 < B < 16.5$ ) nearby using **VizieR**

# Determining Stellar Parameters: Identifying Stars



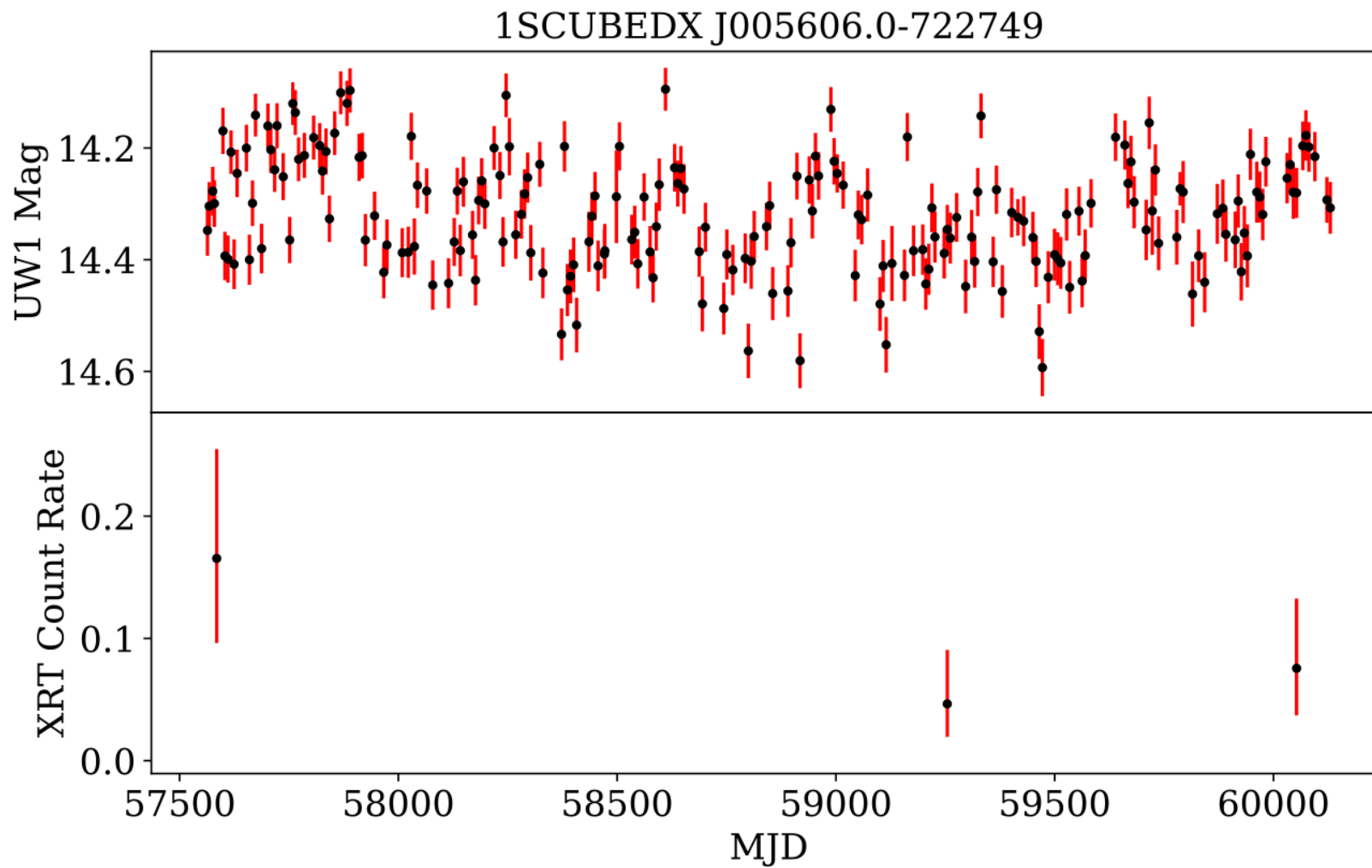
# Determining Stellar Parameters: Curve Fitting

$$F(\nu, R, T) = \pi \left( \frac{R_*}{D} \right)^2 \left( \frac{2 h \nu^3}{c^2} \right) \left( \frac{1}{e^{\frac{h \nu}{k T}} - 1} \right)$$





# Ultraviolet Variability



# Candidate Sources

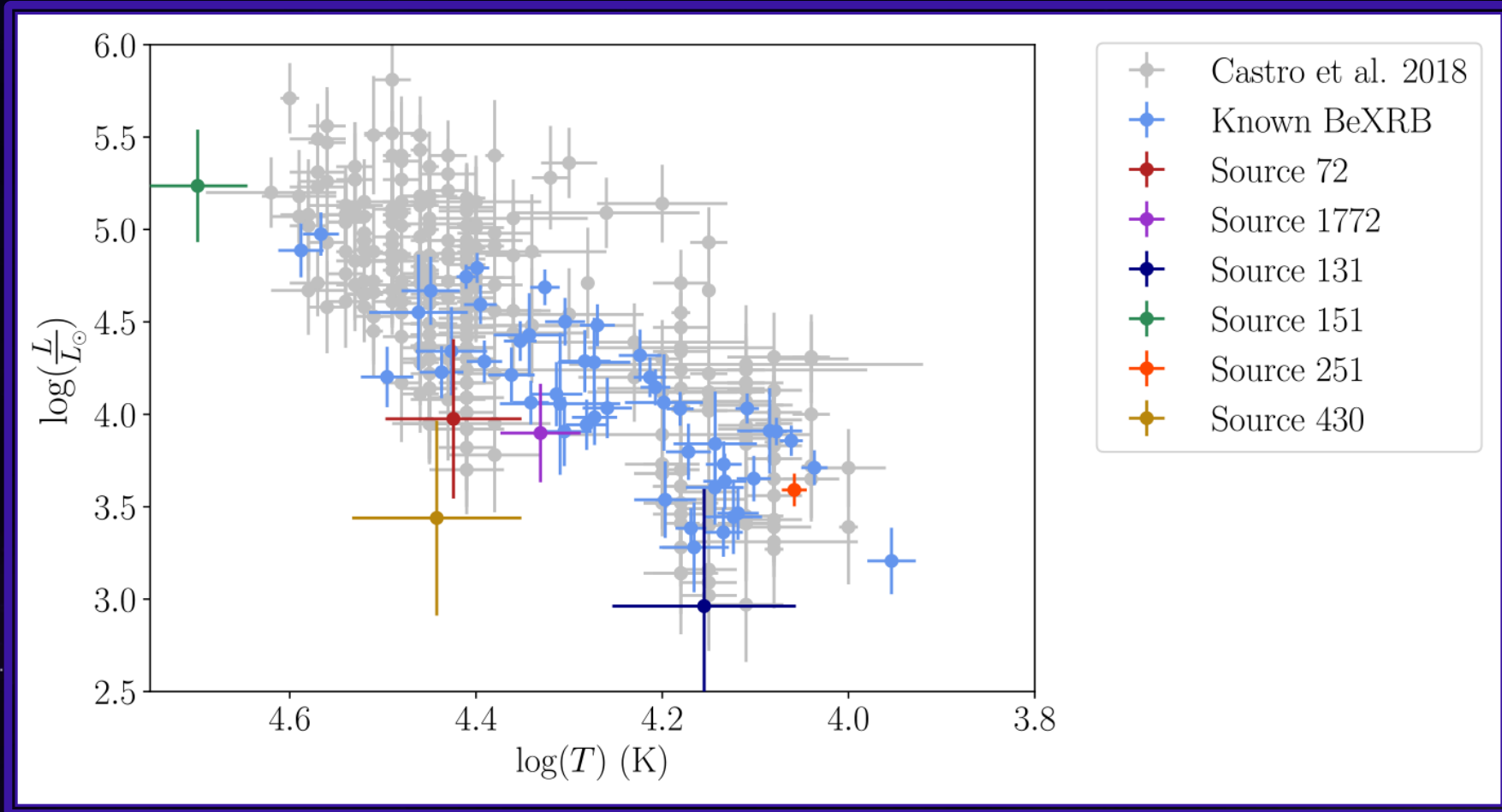
The background of the slide is a deep space image. It features a dark blue to black gradient, peppered with numerous small, bright stars of varying colors (white, blue, orange). Two large, prominent spiral galaxies are visible, one in the upper right and one in the lower right, their arms glowing with a mix of blue and white light. A faint, diagonal streak of light, possibly a comet or a distant galaxy, is visible in the lower right quadrant.

# Companion Stellar Parameters

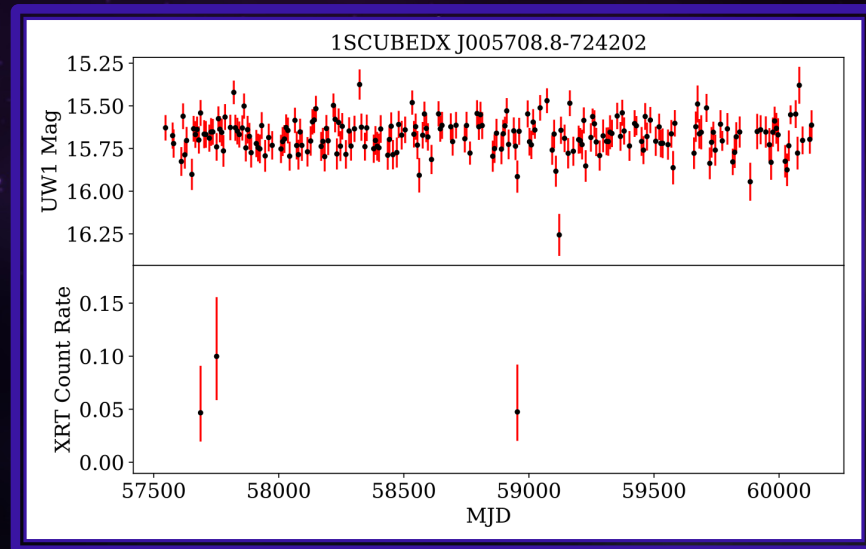
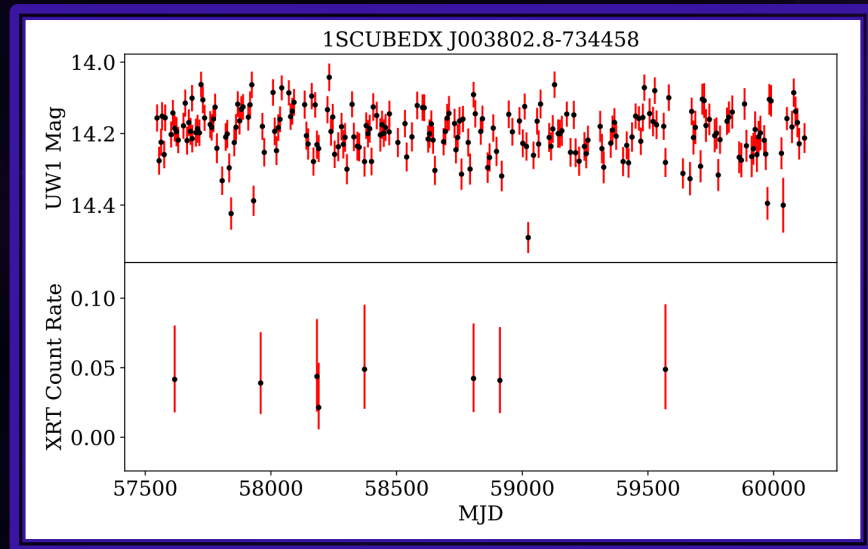
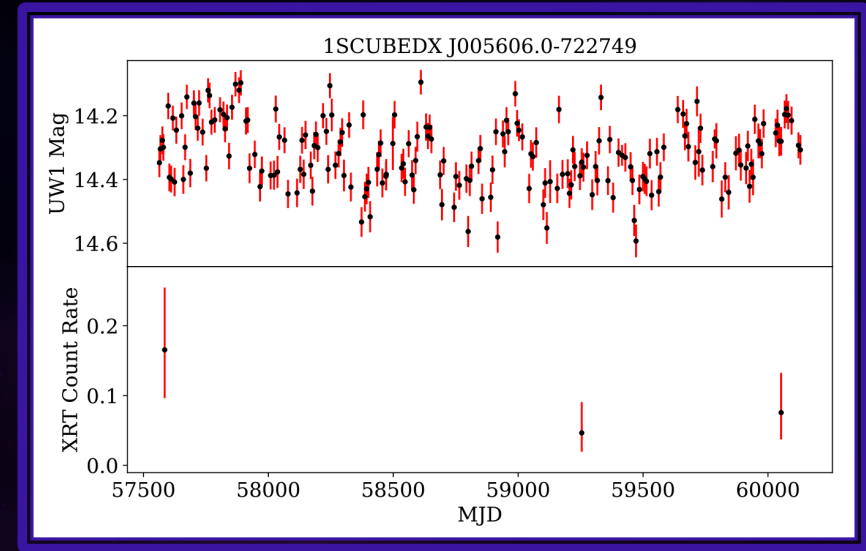
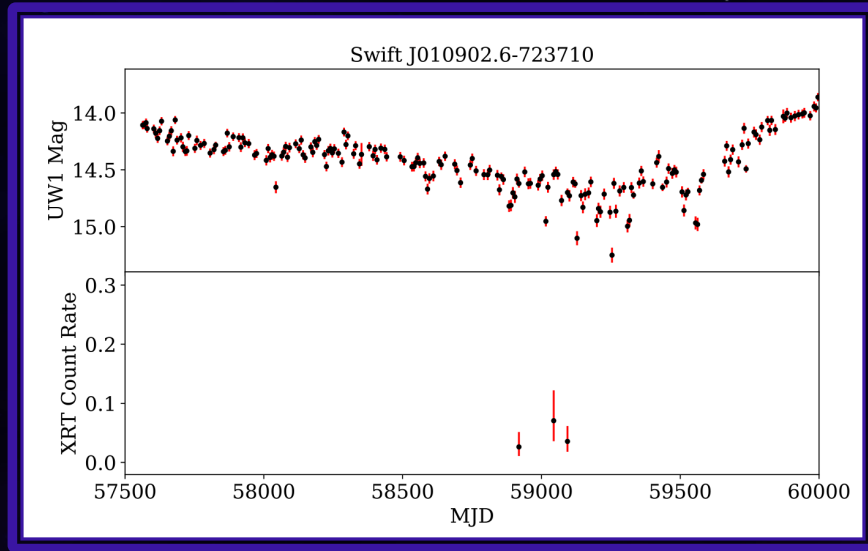
Source ID	Temperature (K)	Radius ( $R_{\odot}$ )
1SCUBEDX J005606.0-722749	$31500 \pm 5900$	$3.9 \pm 0.67$
1SCUBEDX J010203.7-715130	$16000 \pm 3300$	$4.5 \pm 1.0$
1SCUBEDX J011535.0-731931	$50000 \pm 5800$	$5.62 \pm 0.55$
1SCUBEDX J003802.8-734458	$12100 \pm 410$	$15.3 \pm 0.6$
1SCUBEDX J005708.8-724202	$15600 \pm 4000$	$4.99 \pm 1.44$
Swift J010902.6-723710	$21400 \pm 2000$	$6.6 \pm 0.67$



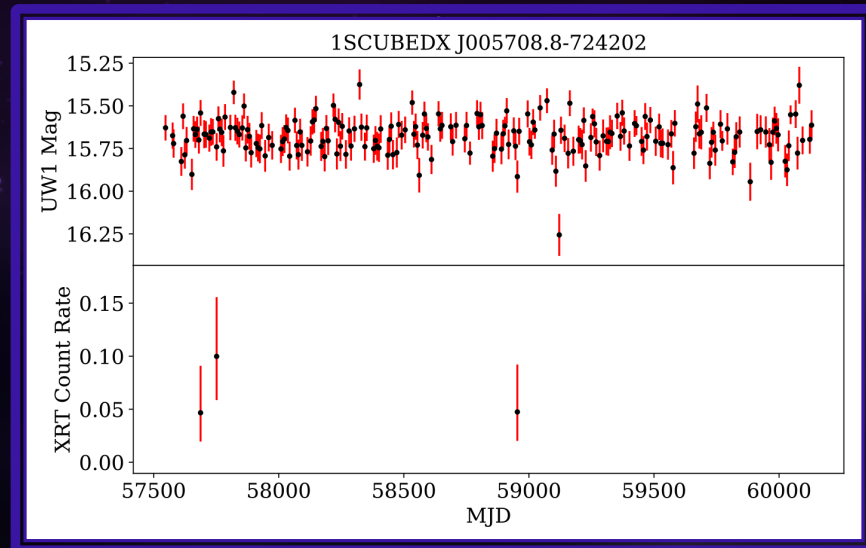
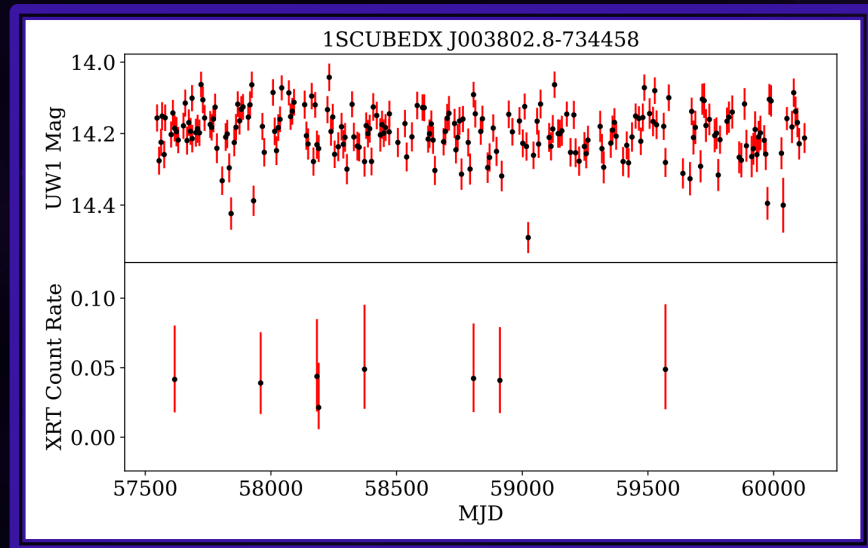
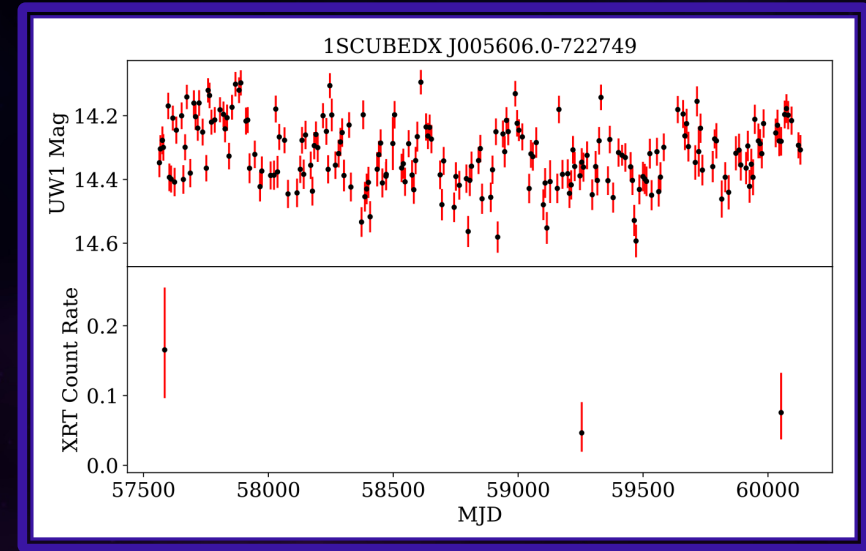
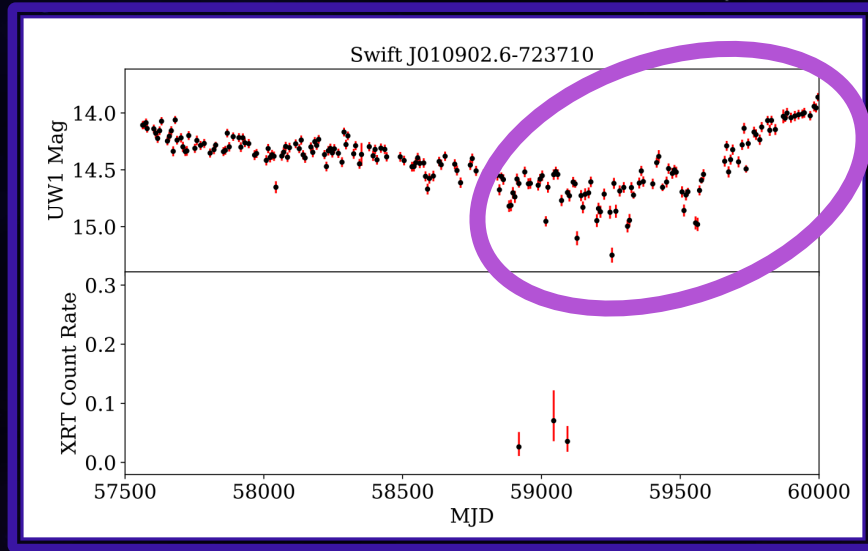
# Companion Stellar Parameters



# UV Light Curves



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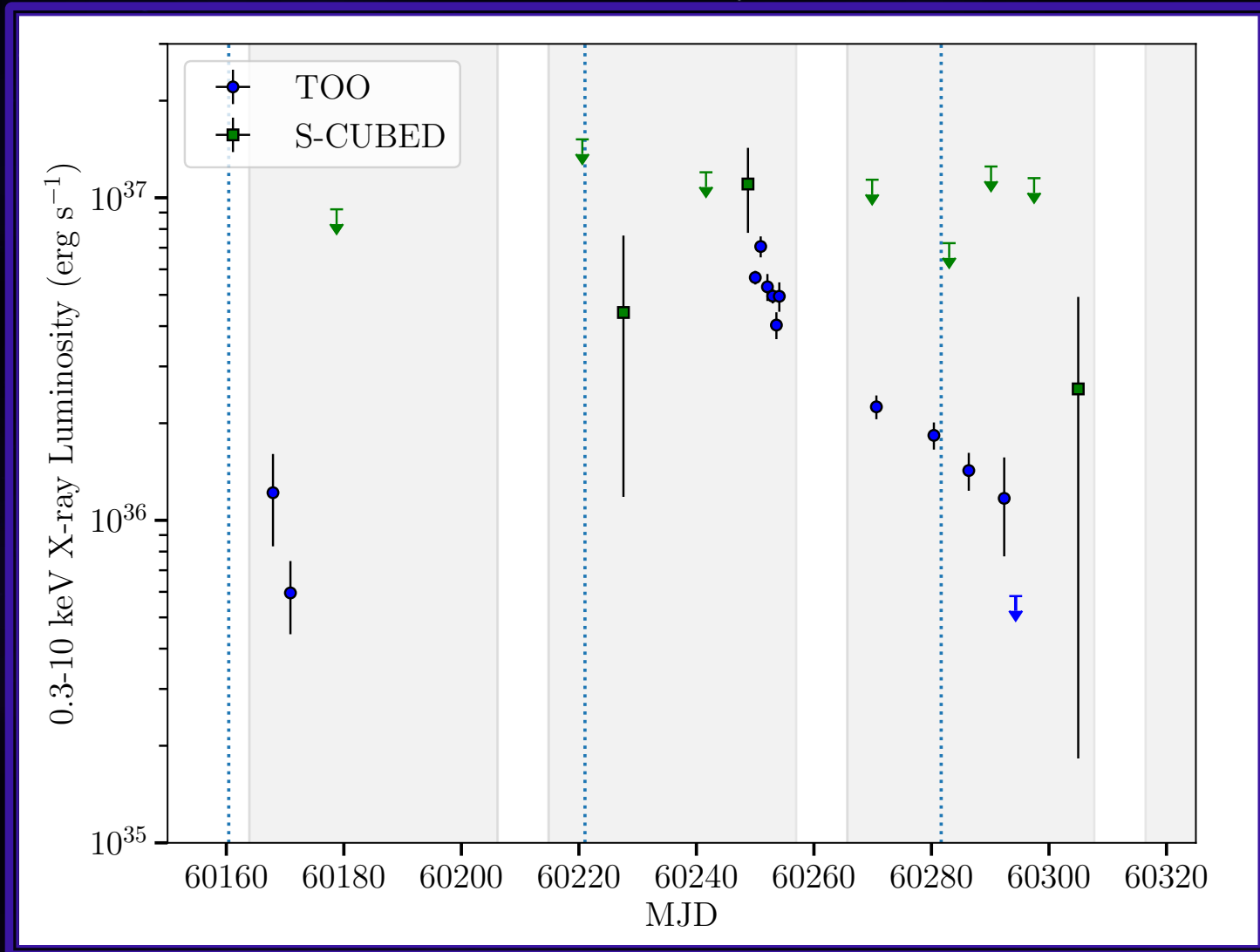




The background of the image is a deep space scene. It features a dark blue to black gradient. Scattered throughout are numerous stars of varying sizes and colors, including bright white and yellow ones, and some fainter, reddish-orange ones. Two large, prominent spiral galaxies are visible. One is in the upper right, showing a bright core and distinct spiral arms. The other is in the lower right, also showing a bright core and spiral structure. The overall effect is a sense of vastness and cosmic scale.

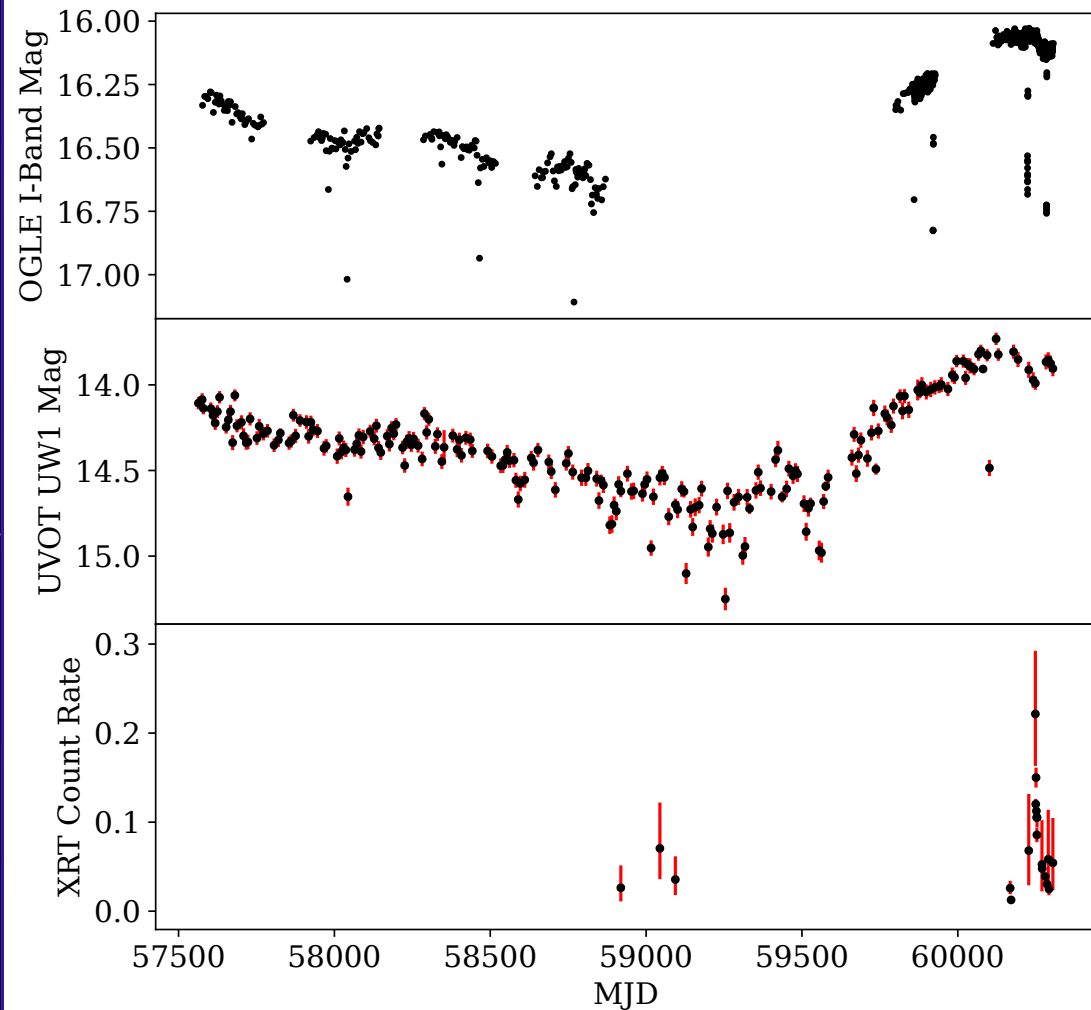
# The Outburst of Swift J010902.6-723710

# X-Ray Light Curve

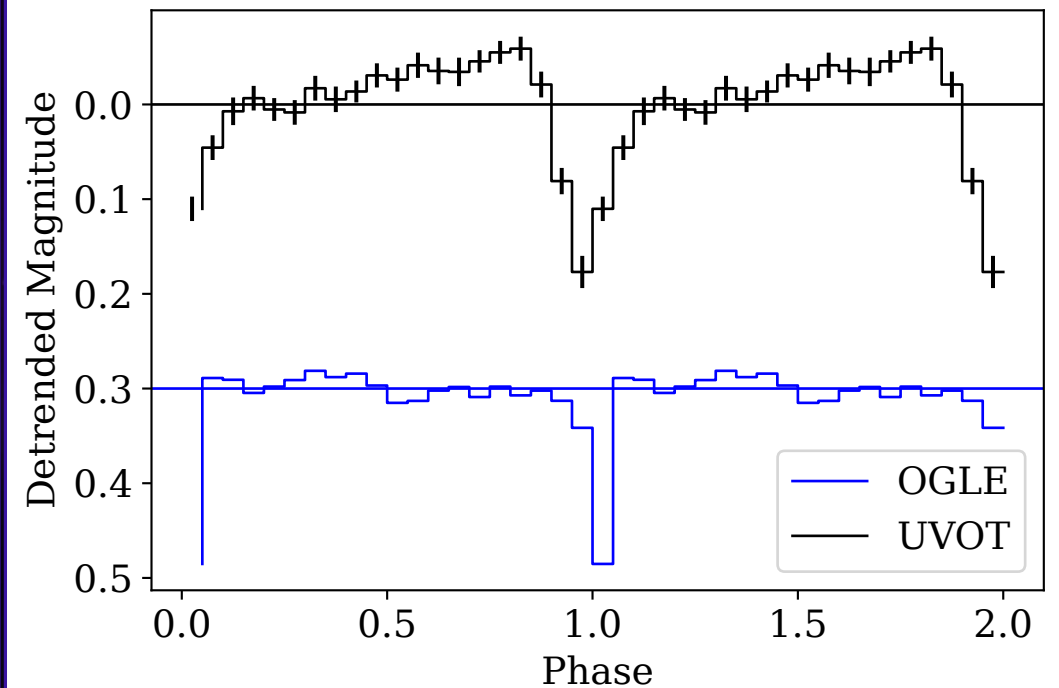


Pulsar Spin Period: 182s  
Decay time: ~77 Days

# Multi-Wavelength Variability



Orbital Period: 60.623 days  
Size of Eclipsing Body:  $3.3 R_{\odot}$





# Implications

- The eclipsing object must be a persistent accretion disk that surround the Neutron Star
  - Lack of secondary eclipse rules out a main sequence star
  - Size rules out Neutron Star or Exoplanet
  - Present in 26 years of OGLE data

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  - LXP 168.8 (Maggi et al. 2013)
  - SXP 5.05 (Coe et al. 2015)

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  - LXP 168.8 (Maggi et al. 2013)
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- Serves as direct confirmation of the Archival Analysis Method

# Conclusions

- We establish a new method for the detection of Be/X-ray Binaries using a combination of Swift SMC Survey data and Archival IR-UV data
  - Relies on UV variability and SED-fitting of blackbody curves to SMC stars
- We argue for the detection of 6 new candidate Be/X-ray Binaries using this new method
- We present the confirmation of one of these systems via X-ray outburst
  - SXP 182 becomes the 3<sup>rd</sup> confirmed eclipsing BeXRB

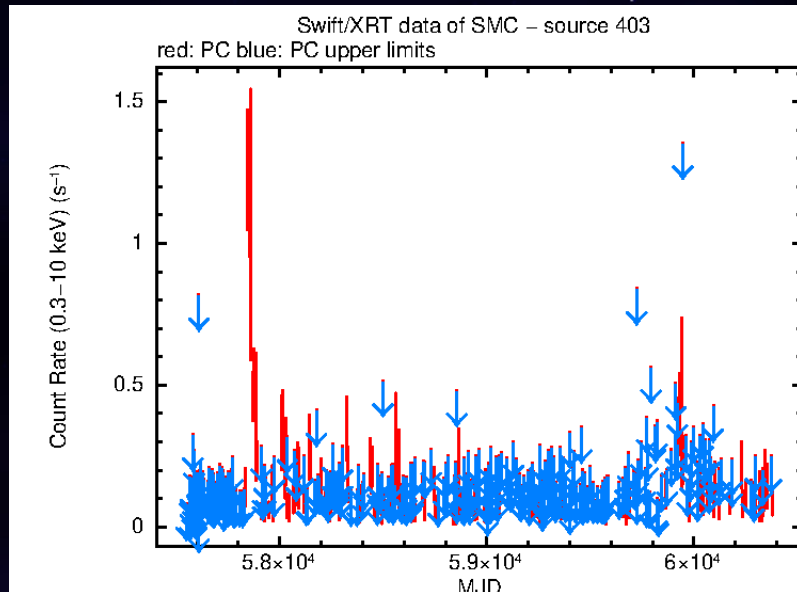
Paper on the newly discovered SXP 182 is now on ArXiv!



# Questions?

**CREDITS:** This presentation template was created by **Slidesgo**, and includes icons by **Flaticon** and infographics & images by **Freepik**

# S-CUBED Data Products

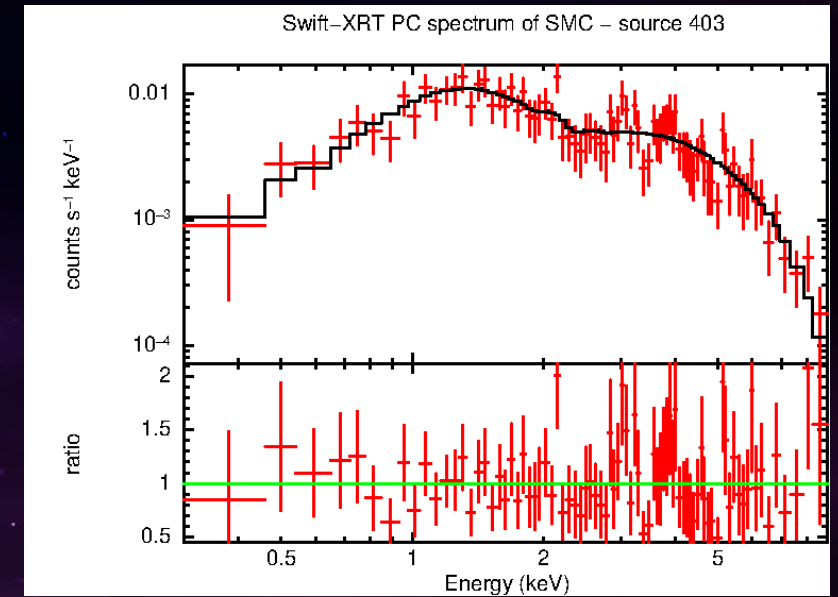
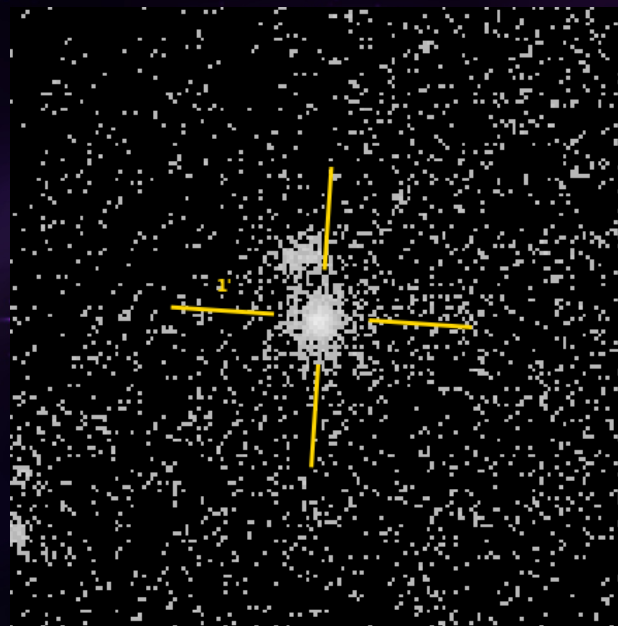


## X-Ray Light Curve

- Identify outbursts
- Flux monitoring
- Upper limits from non-detections

## X-Ray Image

- Source Position
- Source Error region
- Detection Flag



## X-Ray Spectrum

- Fit to absorbed power law
- Column Density
- Photon Index