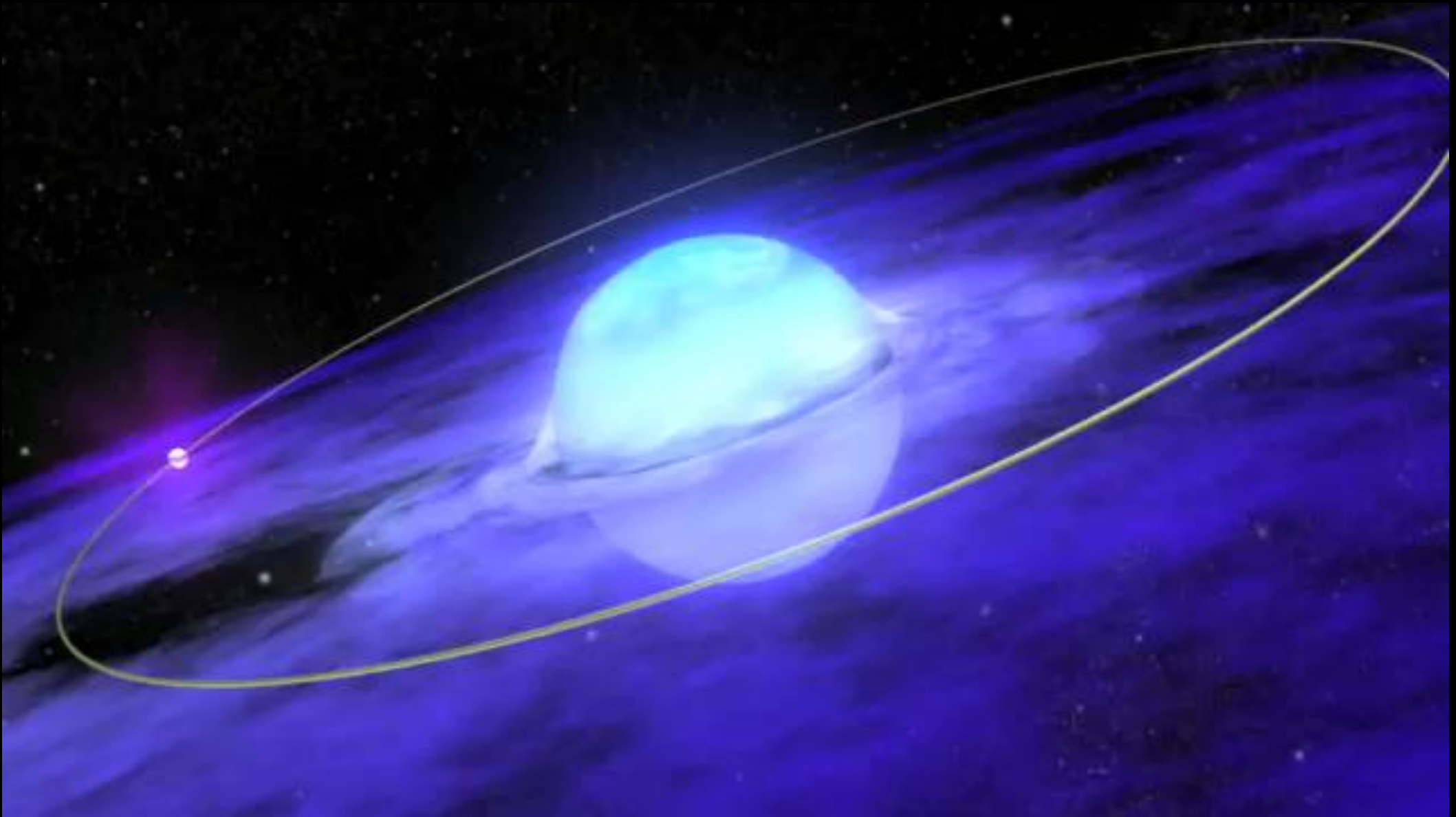


Multiwavelength studies of Be X-ray binaries

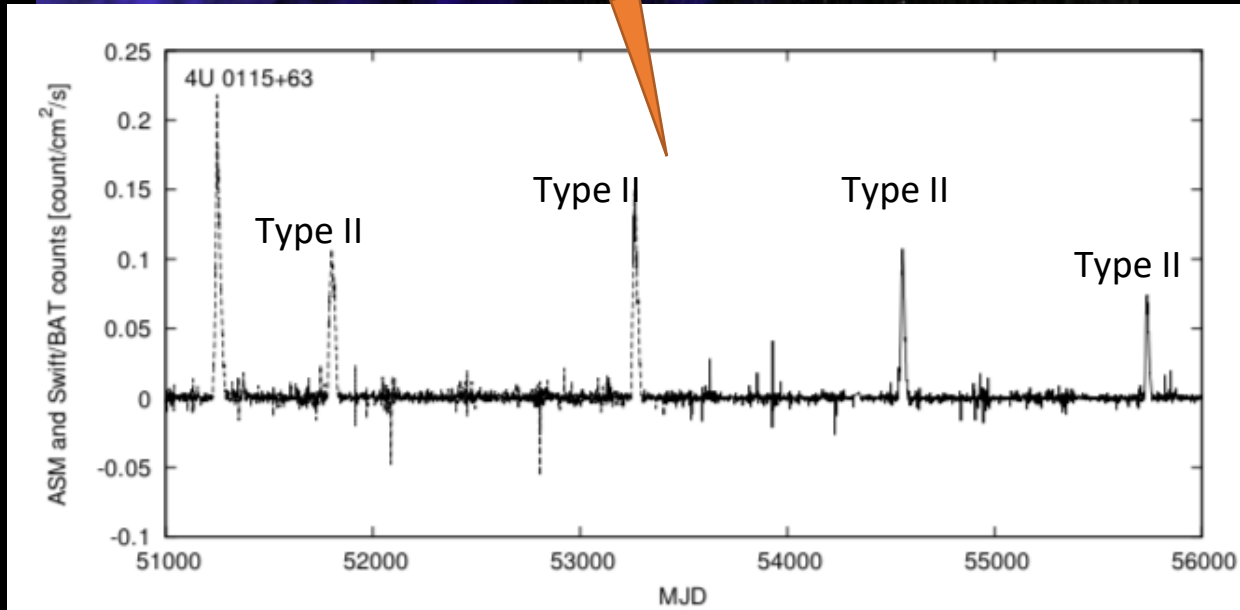
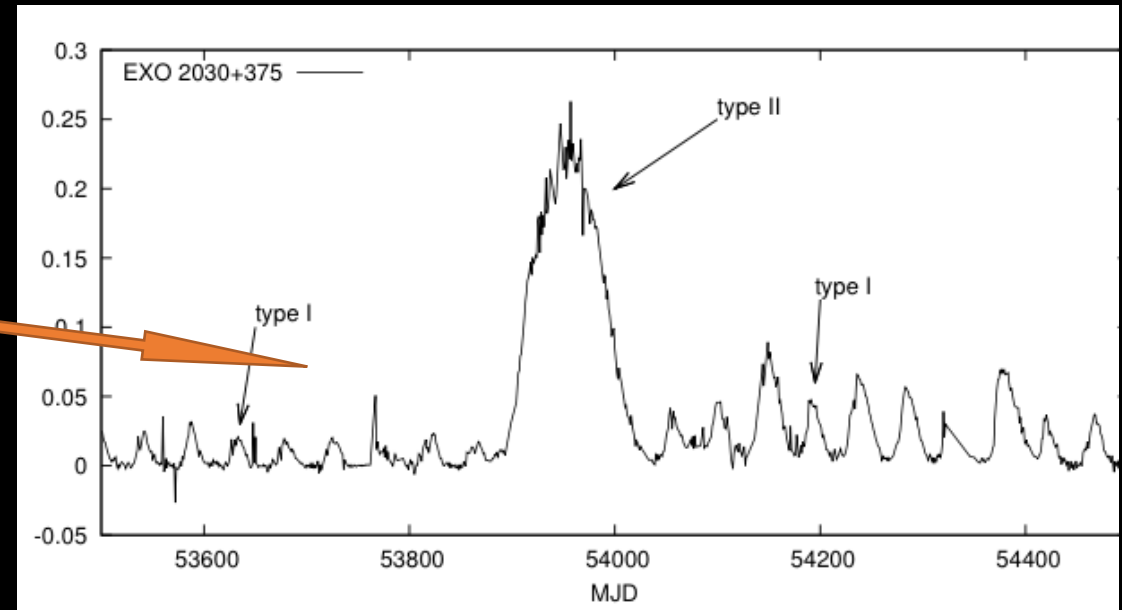
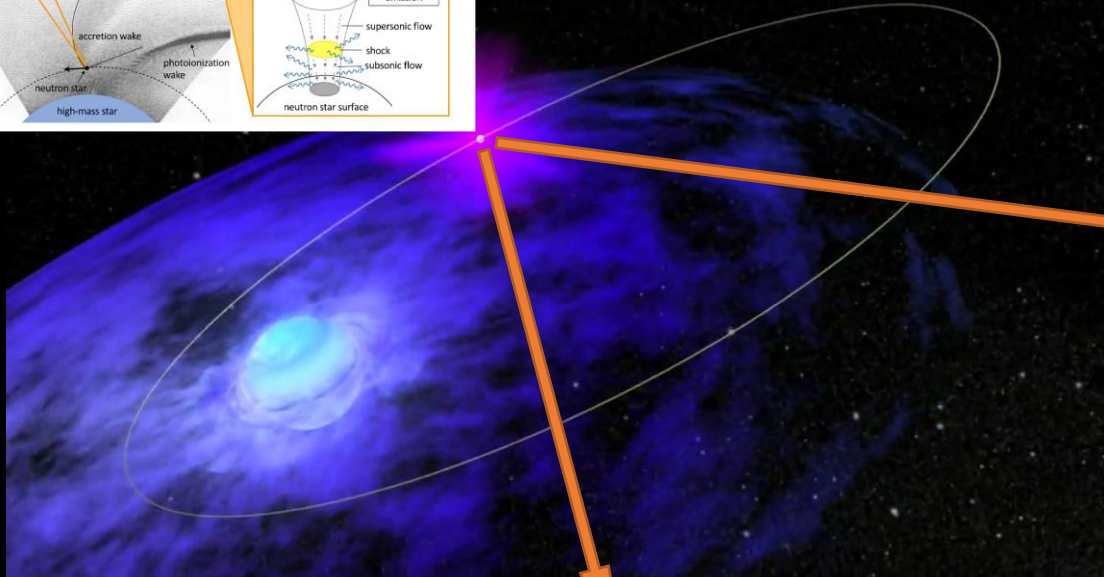
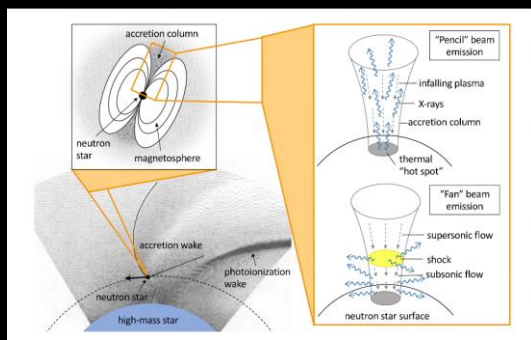
Itumeleng Monageng
et al.



Be X-ray binaries

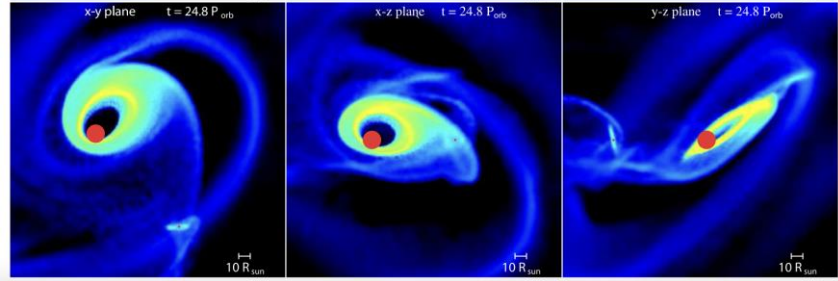
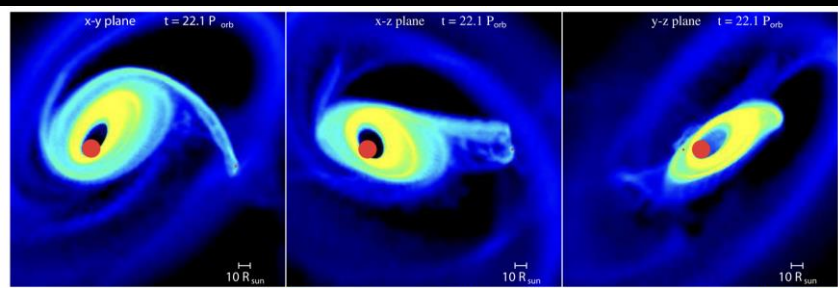
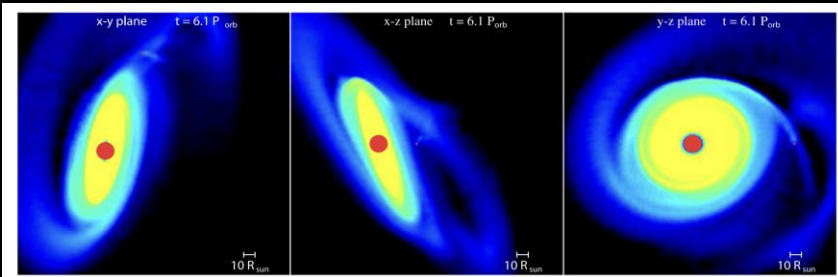
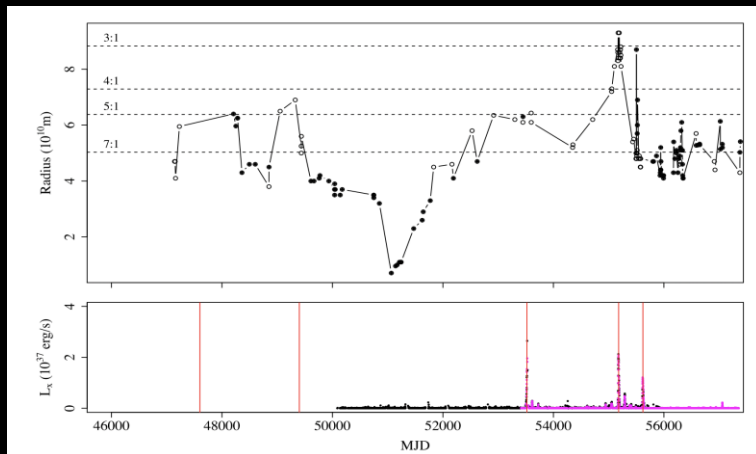


X-ray emission



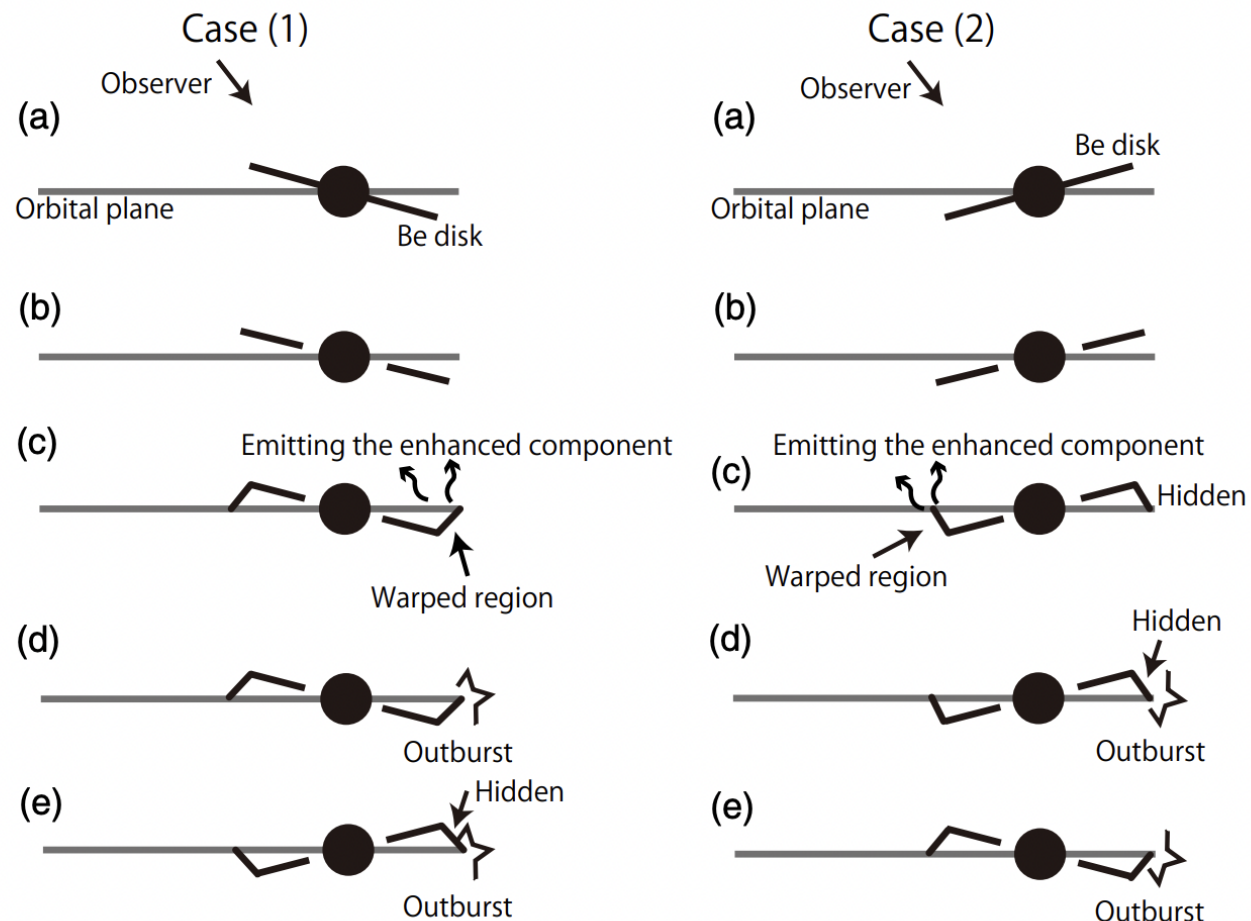
- **Type I (normal) outbursts:**
 - regular in occurrence and generally associated with periastron passage of neutron star.
 - X-ray luminosity below 10^{37} erg/s
- **Type II (giant) outbursts:**
 - appear less frequently and not associated with any particular orbital phase.
 - X-ray luminosity $> 10^{37}$ erg/s
 - Last longer

Origin of Type II/Giant outbursts?



Moritani et al. (2013)

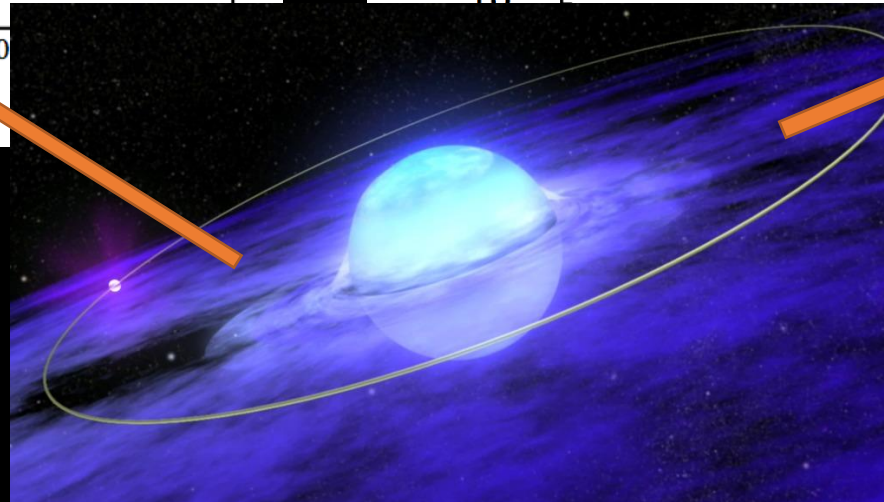
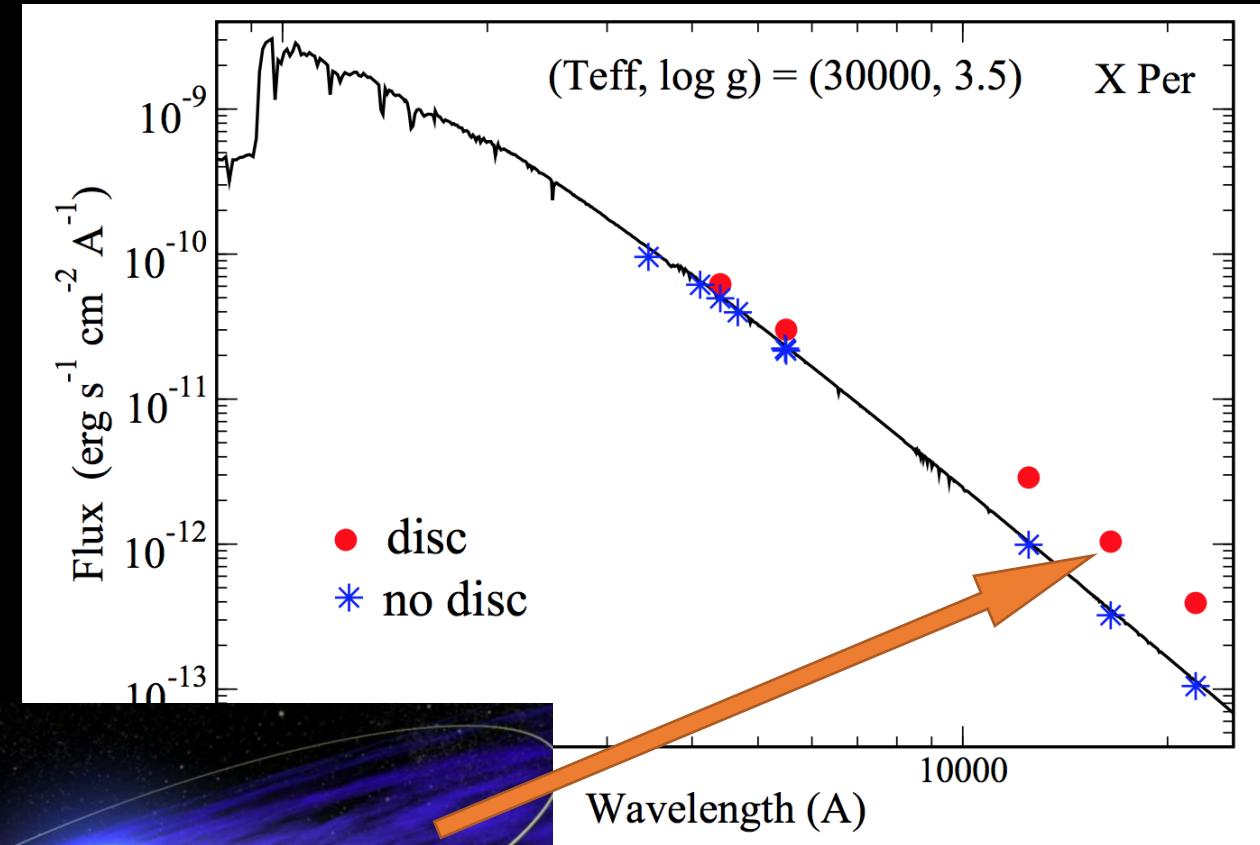
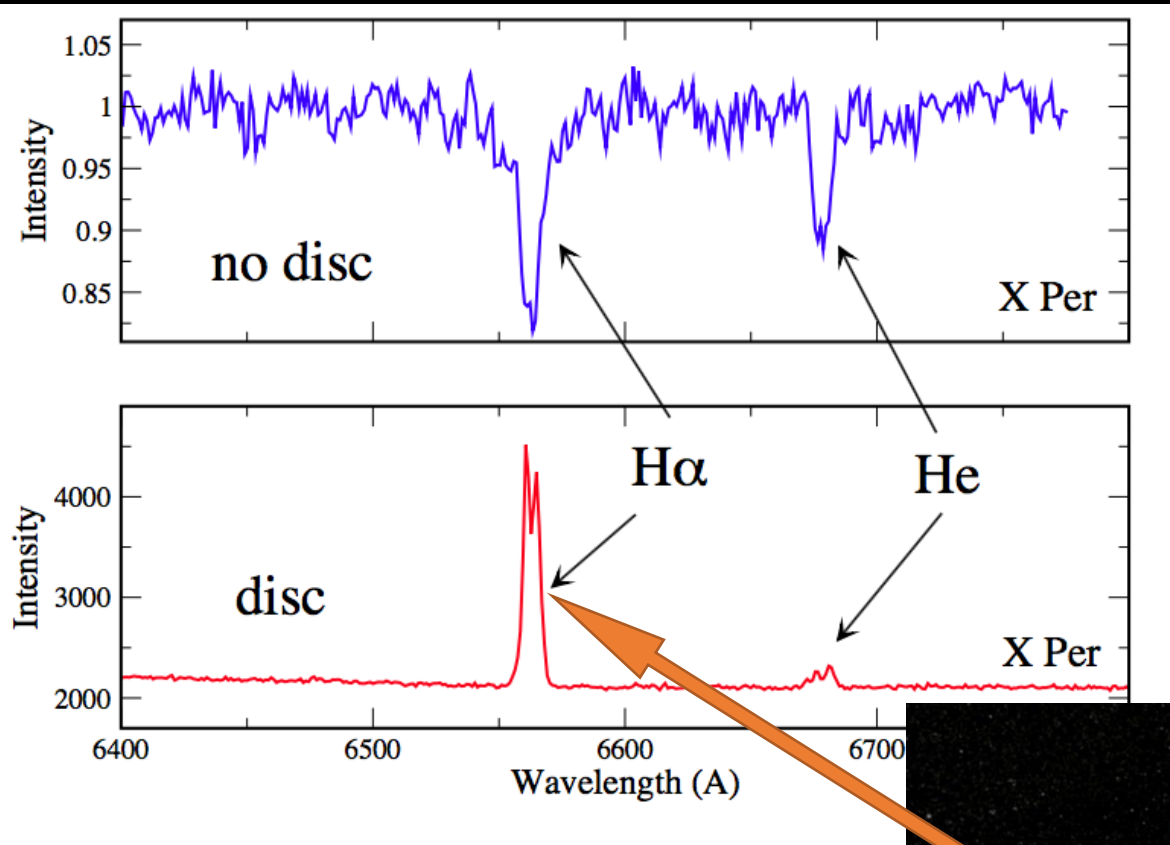
Warped Be disc?



Eccentric Be disc?

Martin et al. (2014)

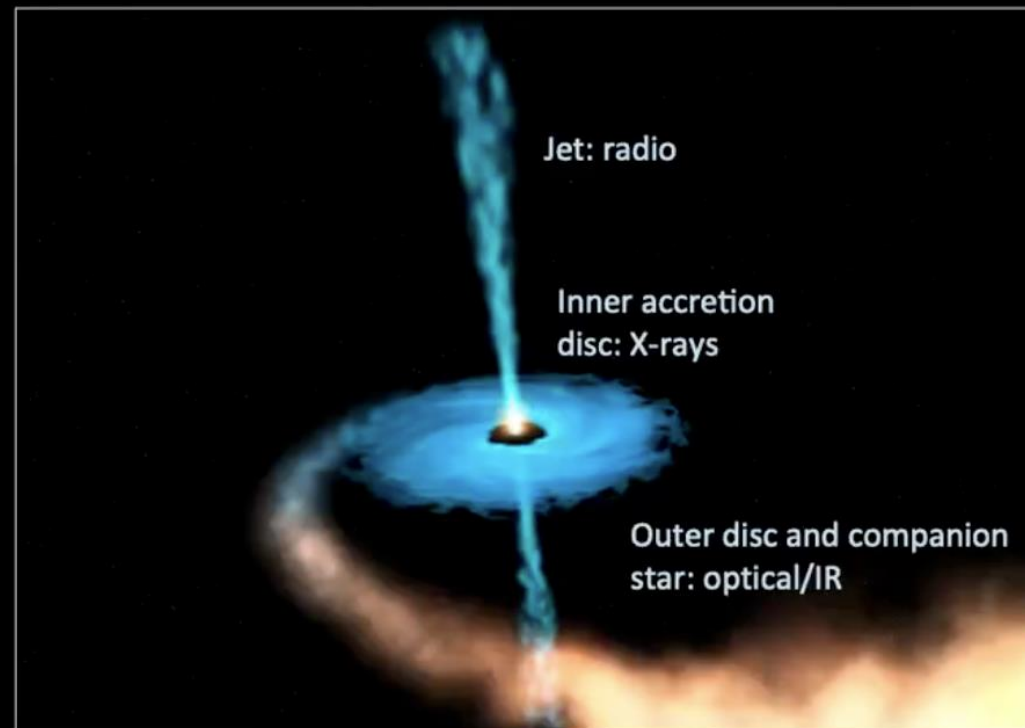
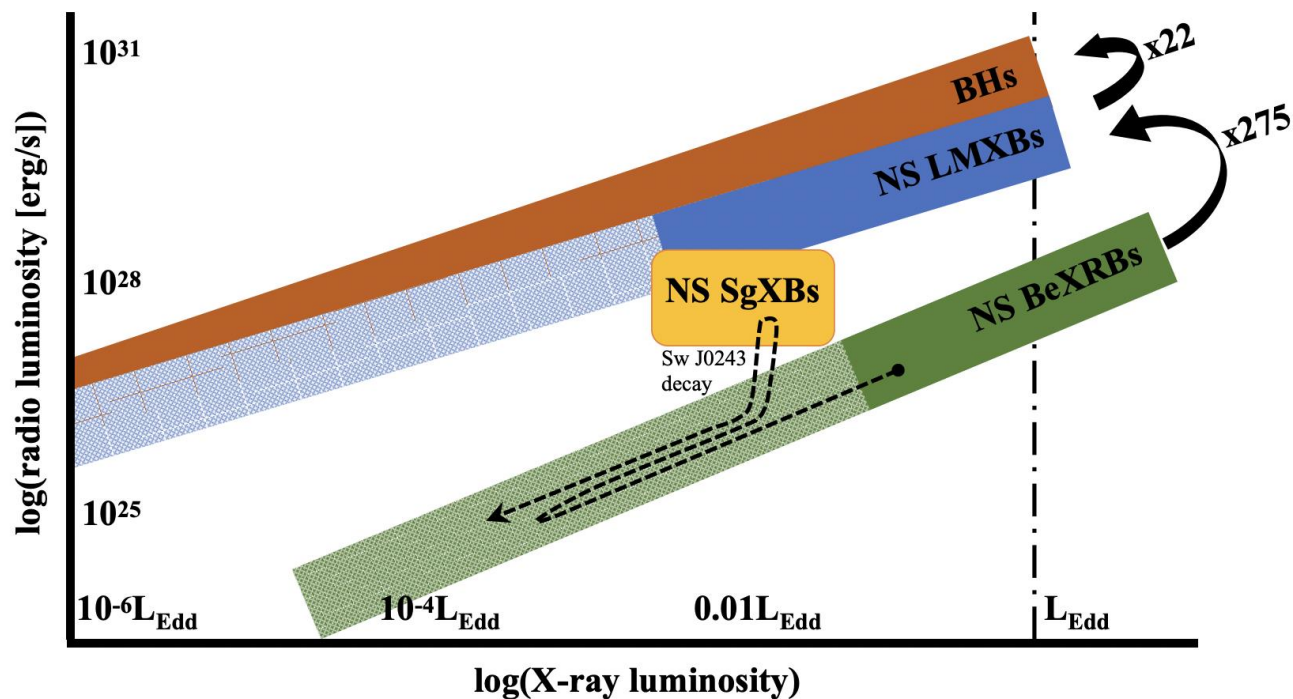
Optical/Infrared emission



Radio emission from Be X-ray binaries

- Radio detections from Galactic objects undergoing Type II outbursts
 - Quasi-simultaneous radio and X-ray observations show a consistent luminosity correlation
 - Similar to BH and NS LMXBs: coupling between inflow (X-ray) and jet outflow (radio).
 - Radio luminosity observed during Type II outbursts is weaker at the same X-ray luminosity than in LMXBs.
 - Radio emission interpreted as jet emission (alternative models proposed)

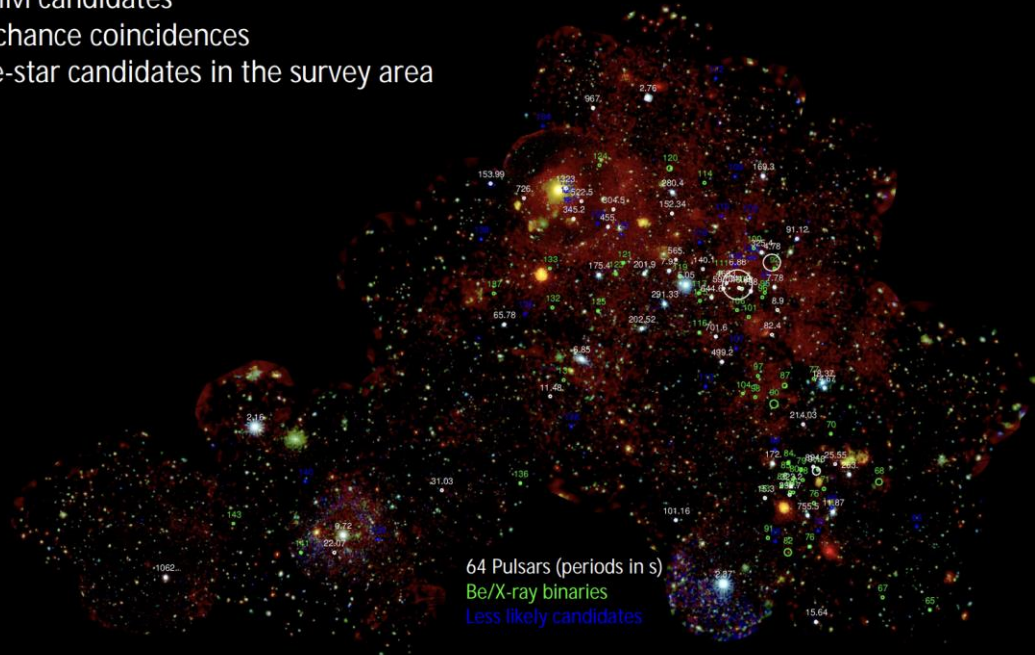
van den Eijnden et al. (2022)



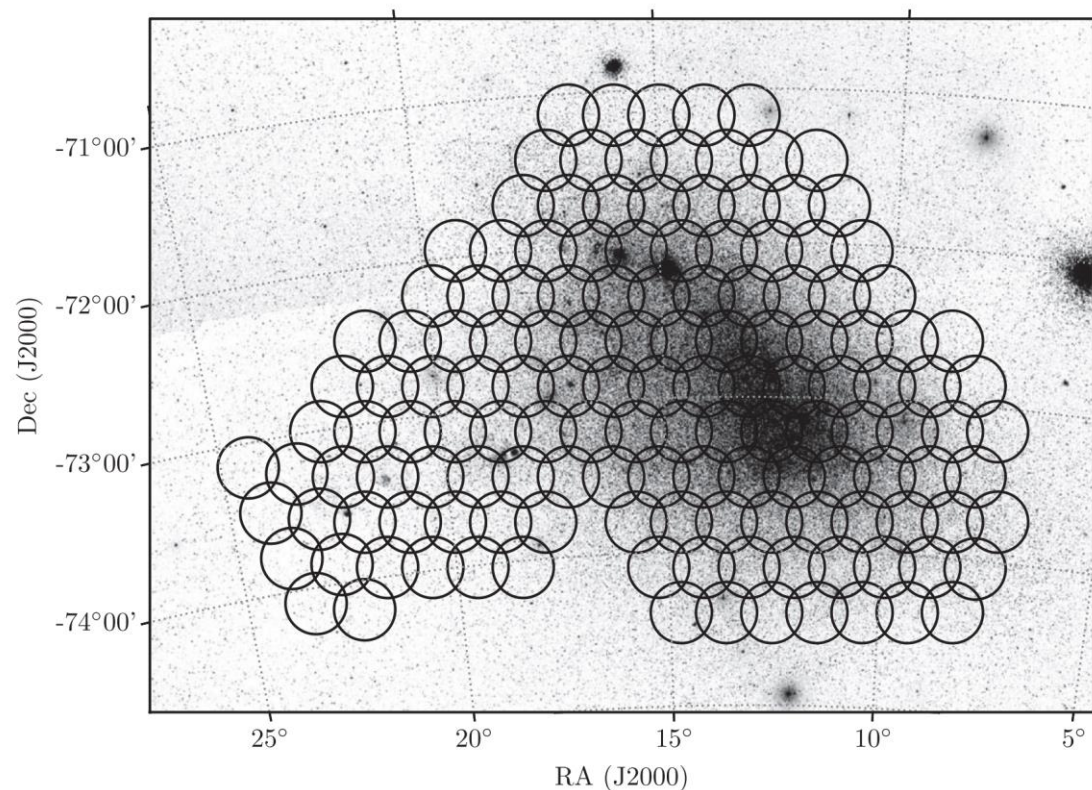
Be X-ray binaries in the SMC: S-CUBED

- High-cadence, shallow X-ray survey.
- 142 tiles every week (60 s exposures per tile).
- Discovery and monitoring of X-ray outbursts.

Sturm et al. 2013:
45 new XMM candidates
 16.6 ± 3.4 chance coincidences
~16,600 Be-star candidates in the survey area

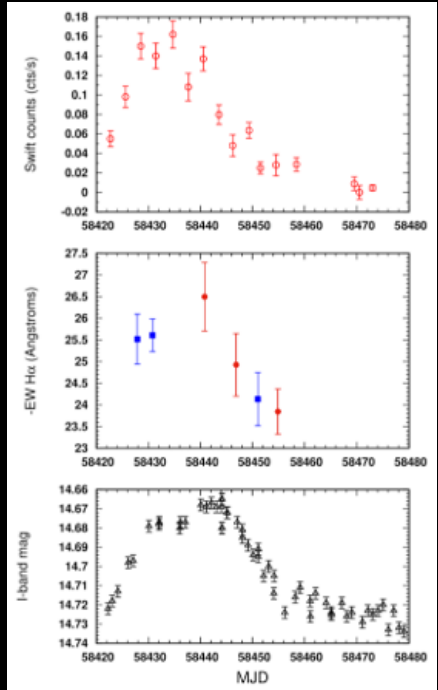


Kennea et al. 2018

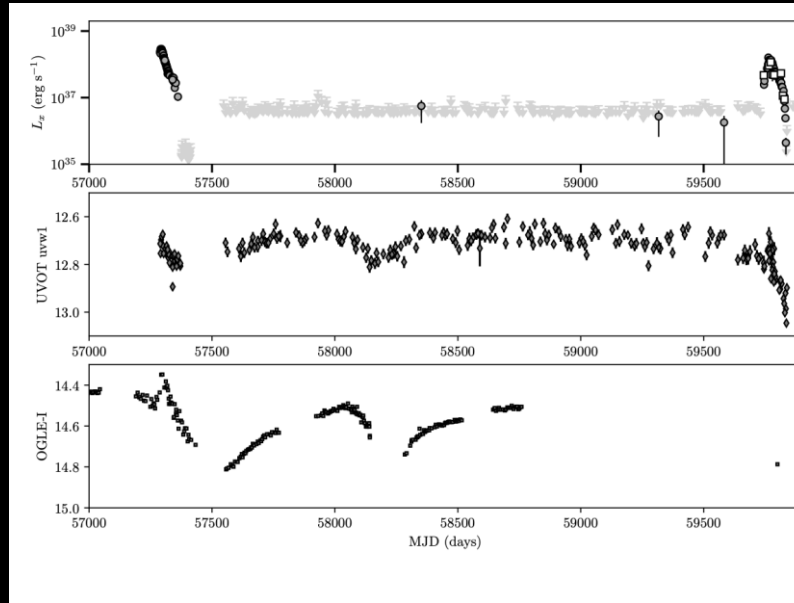


Be X-ray binaries in the SMC: S-CUBED

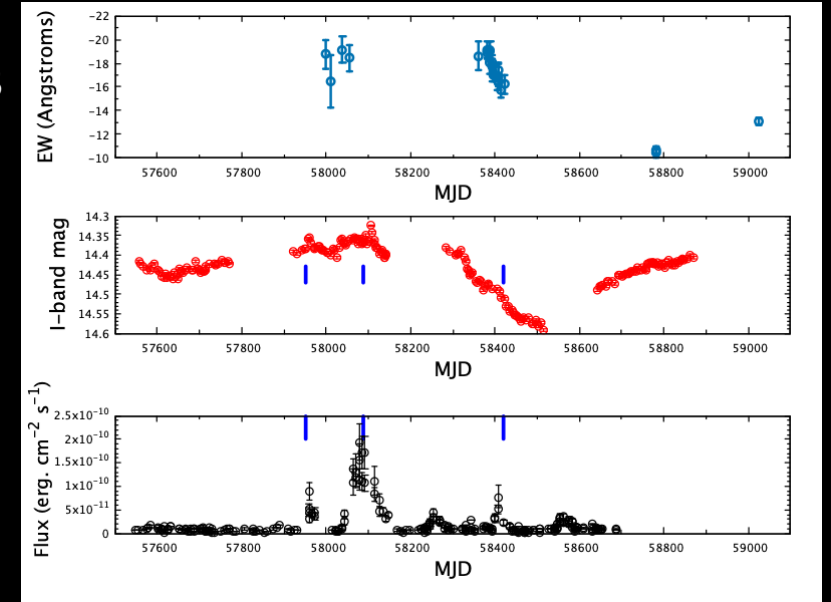
SXP 91.1



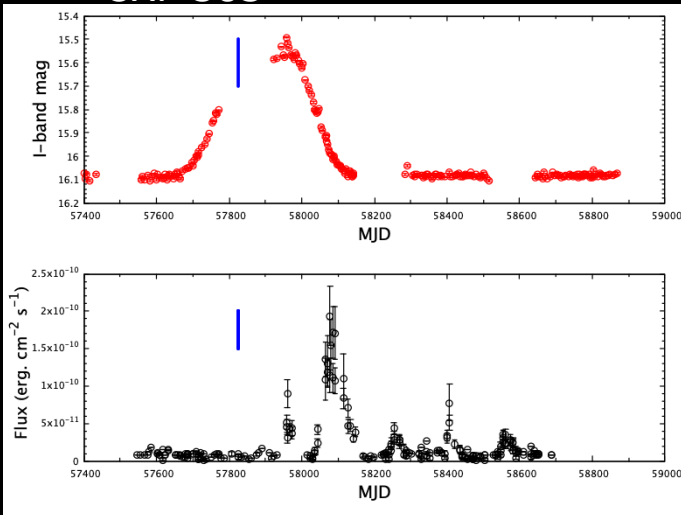
SMC X-2



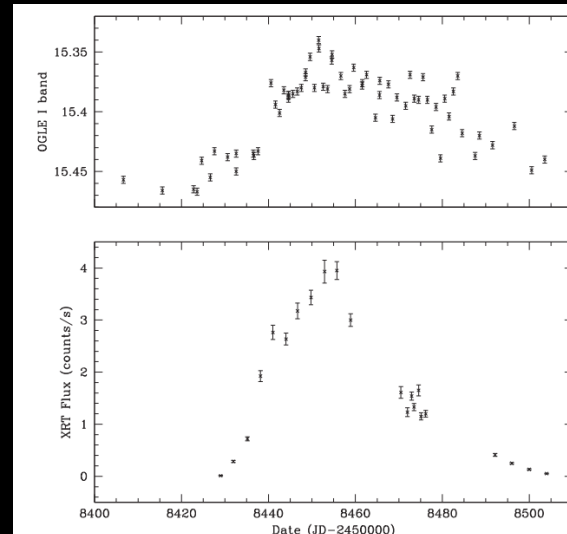
SXP 15.3



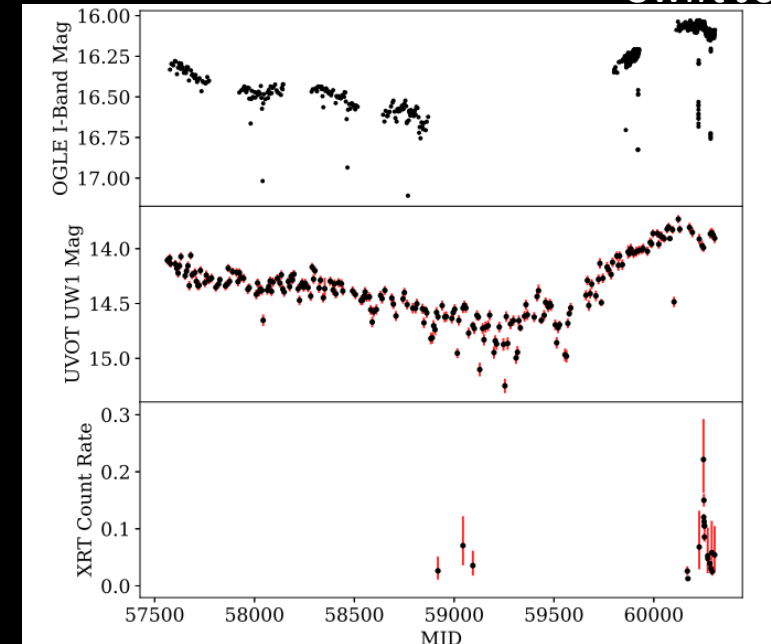
SXP 305



SXP 4.78



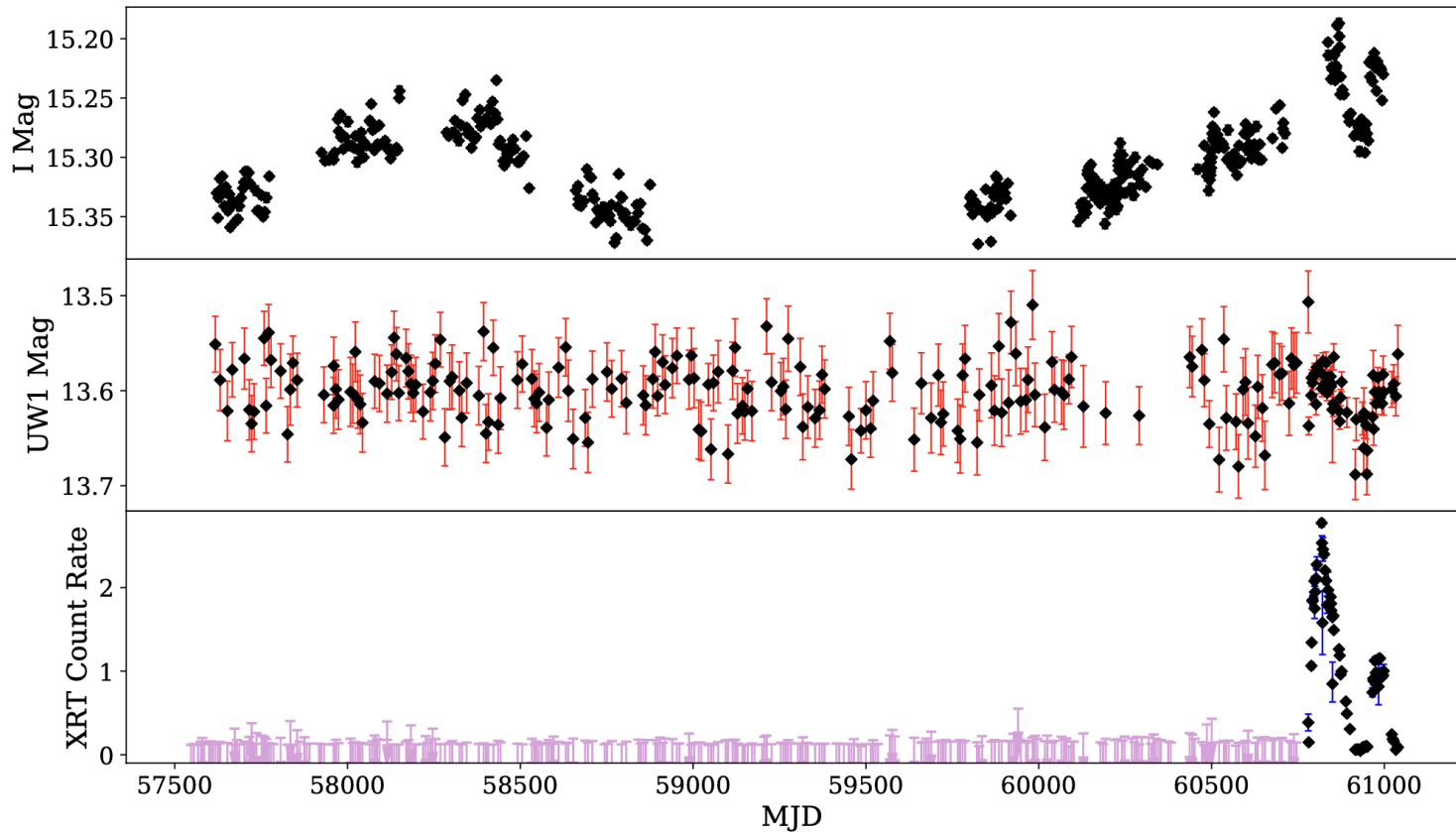
Swift J010902.6



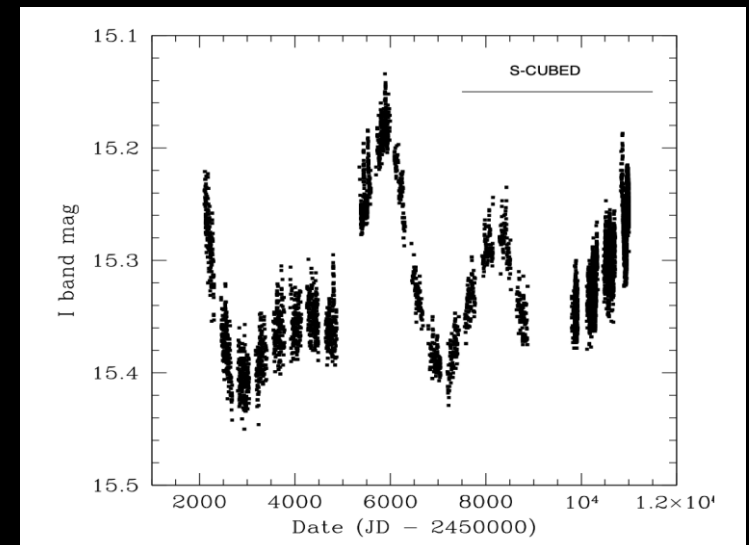
The 2025 near-Eddington double X-ray outburst of SXP 31.0

- **Orbital period of 90.53 ± 0.07 days and unknown eccentricity.**
- **Pulse period of 31.0 s**
- **Discovered in 1998 using RXTE during a Type II outburst.**
- **Optical counterpart identified as a B0.5V – B1Ve star with IR excess.**
- **H-alpha images revealed extended structure:**
 - **Supernova remnant?**
 - **Bow shock?**
 - **Ionised HII region?**
- **Multiwavelength campaign using Swift XRT, UVOT, OGLE and SALT during a period of X-ray activity**

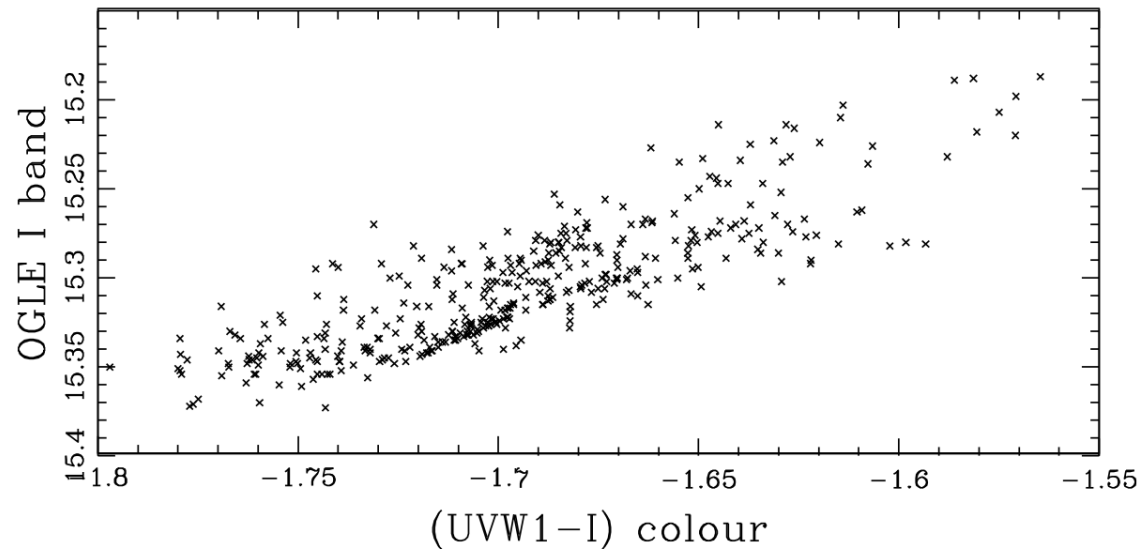
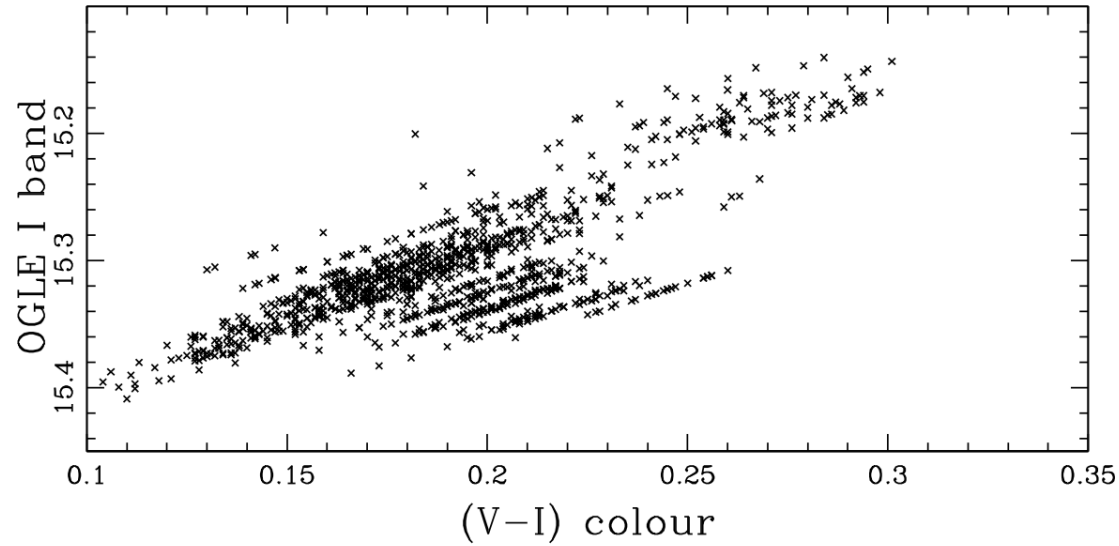
X-ray/UV/Optical photometric variability



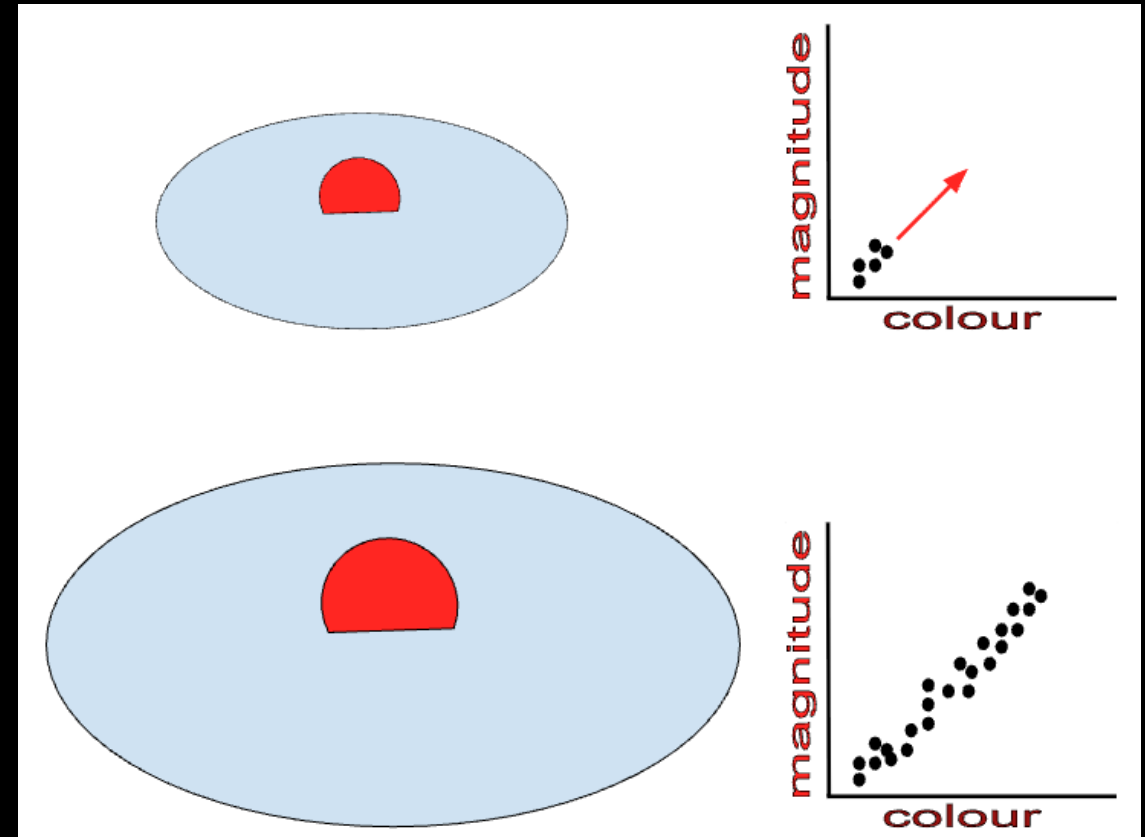
- Detected for the first time with SCUBED monitoring (after 9 years of monitoring). ToO requests followed with exposure times 1ks – 5ks.
- UV and IR/optical brightness trace structural changes in the inner and outer regions of the Be disc.
- 24 years of monitoring with OGLE I-band:
 - Long-term variability on timescales of years
- Surprising lack of UV variability:
 - Non-global disc variability.



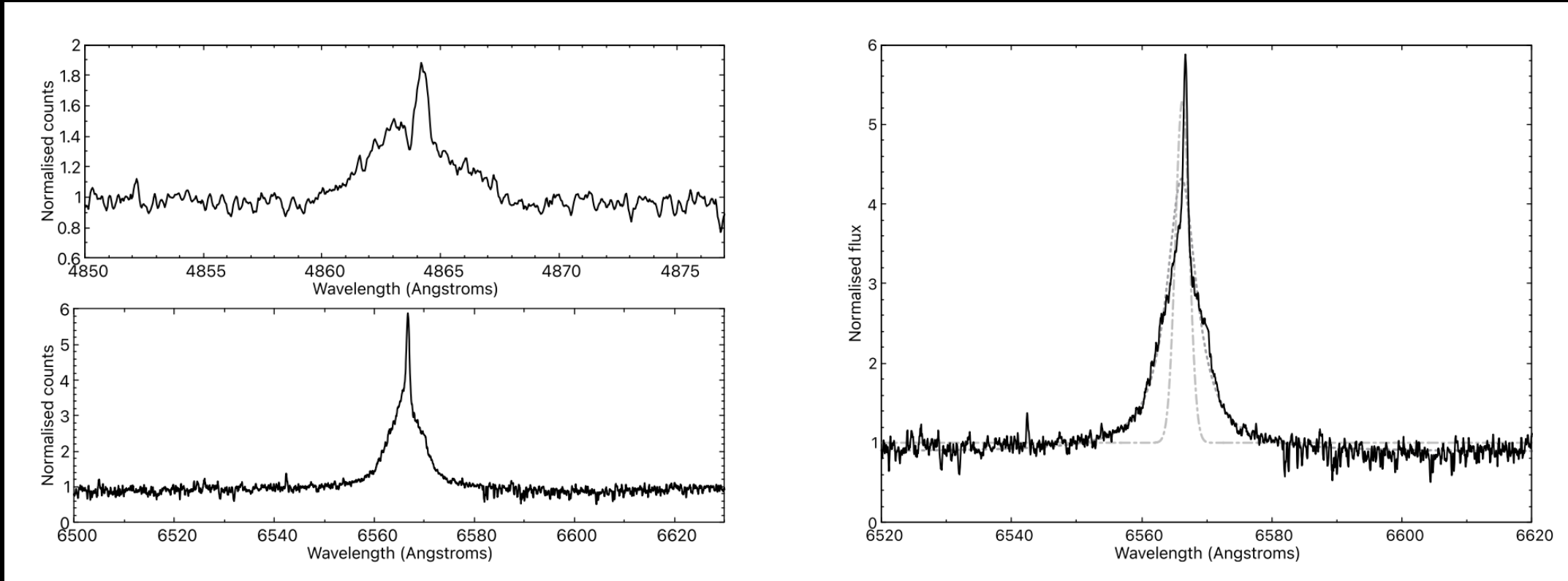
UV/Optical photometric variability



- Long-term colour changes over time $\rightarrow$ Be disc temperature profile changes.
- Strong correlation between colour and magnitude $\rightarrow$ intermediate/low inclination angle of the Be disc
- Steeper rate of change of colour in $(UVW1-I)$ than in $(V-I)$ plot.



Spectroscopic variability (SALT)

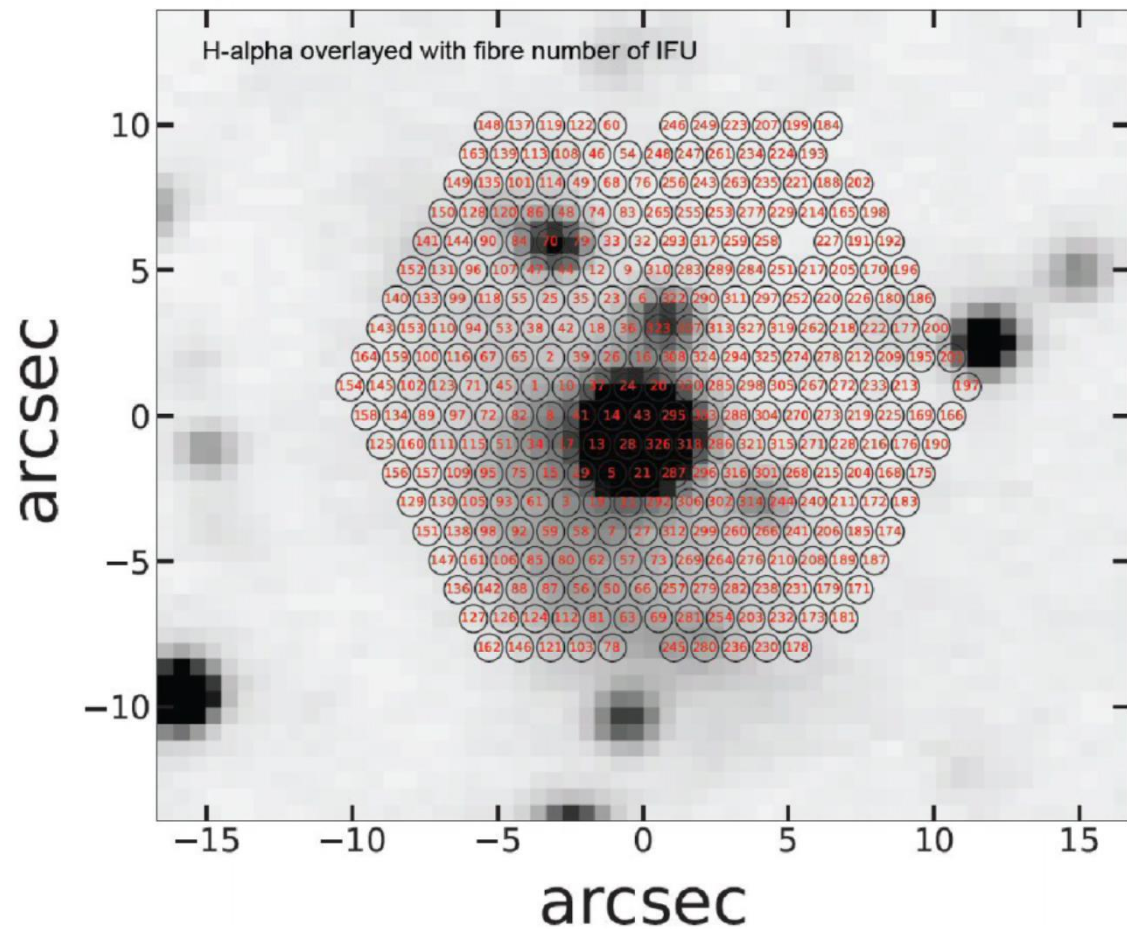


- **Multicomponent emission line :**
 - Narrow emission superimposed on broader component
 - Narrow emission likely originates from surrounding extended emission while the broad component is likely from the Be disc.
- **Disc size is comparable to neutron star semi-major axis:**
 - Direct physical interaction between NS and Be disc
 - Tidal interaction temporarily enhances the disc surface area

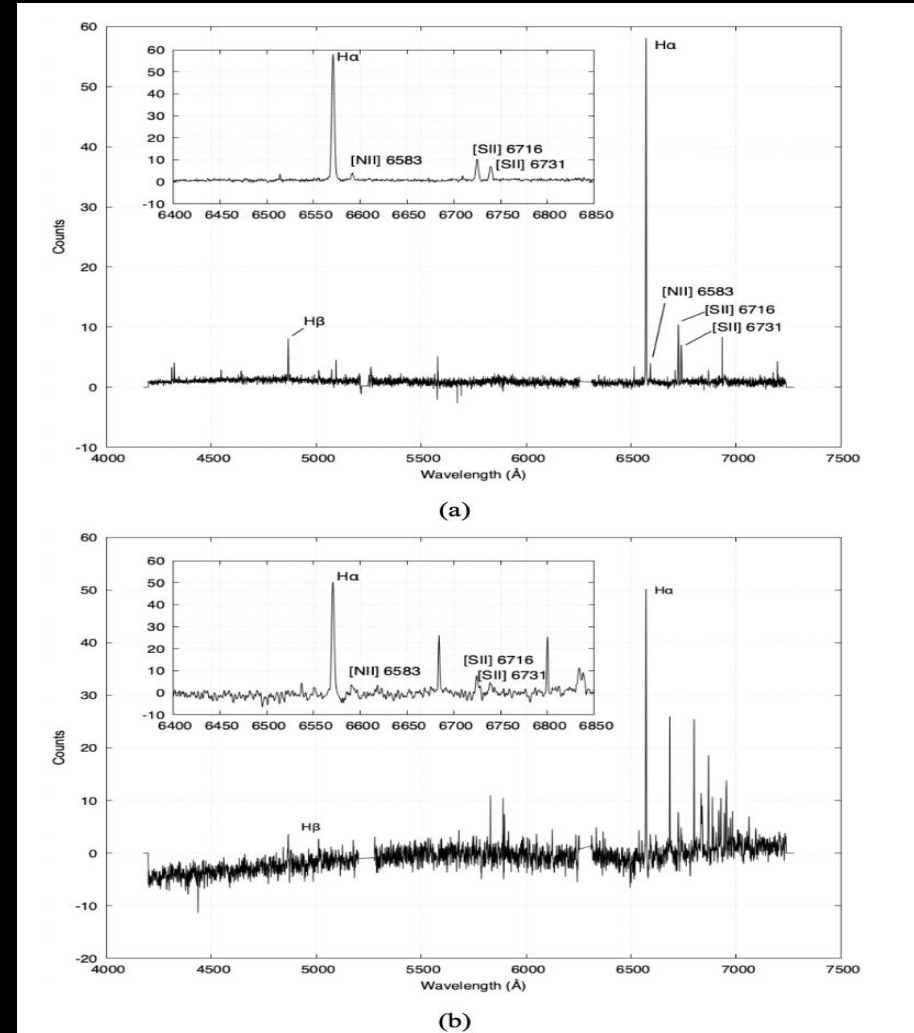
$$R = \frac{GM \sin^2 i}{(0.5\Delta V)^2},$$

$$\log\left(\sqrt{\left(\frac{R_{OB}}{R_{cs}}\right)}\right) = [-0.32 \times \log(-EW)] - 0.2.$$

SALT imaging



- Extended halo that dominates the SW of SXP 31.0
- Slit Mask Integral Field Unit observations to investigate the nature of the extended halo:
 - Comparison of the [S II] and H-alpha emission lines.
 - [S II]/H-alpha ratio of 0.2 – 0.3, which strongly indicates that the emission is from an HII region (photoionisation) instead of supernova remnant or bow shock (shock excitation).



Summary

- Enhanced X-ray activity of the SMC Be X-ray binary, SXP 31.0, for the first time in 26 years!
- Unusual back-to-back Type II outbursts:
 - Possible multiple epochs of mass outflow from the Be star.
 - Accretion from an eccentric Be disc due to Kozai-Lidov oscillations?
- Nature of the extended surrounding halo:
 - Chance coincidence with HII region (not due to SNR or bow shock)