

# Be X線連星のフラックス周期解析 及び多波長長期変動解析

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# Be star

Be star: O-**B** type **e**mission line star

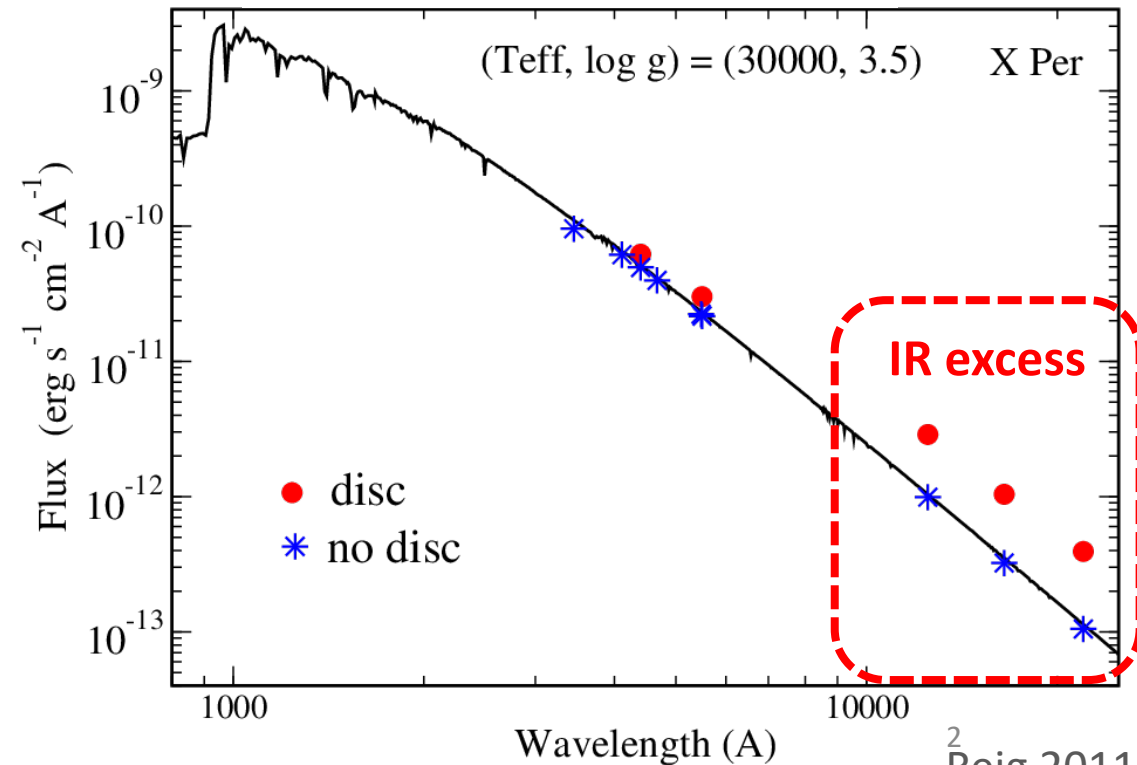
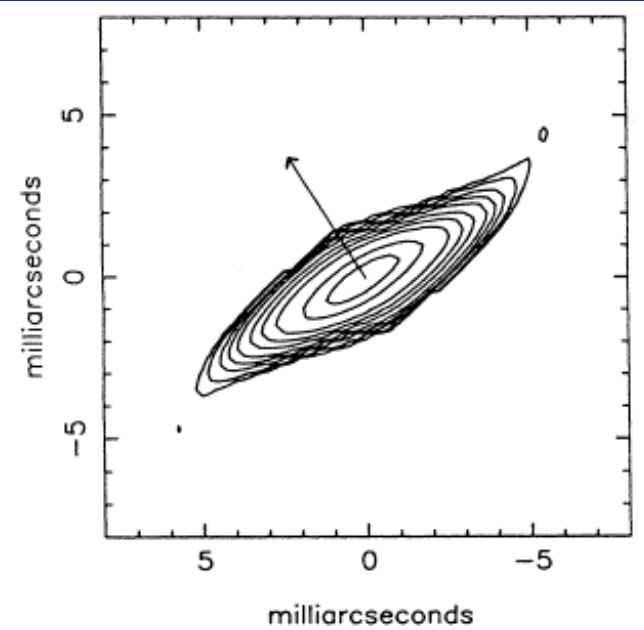
- Circumstellar disk
- IR excess

• Periodic flux oscillations

- ~% amplitude, hours-days scale
- Rotation & Pulsation

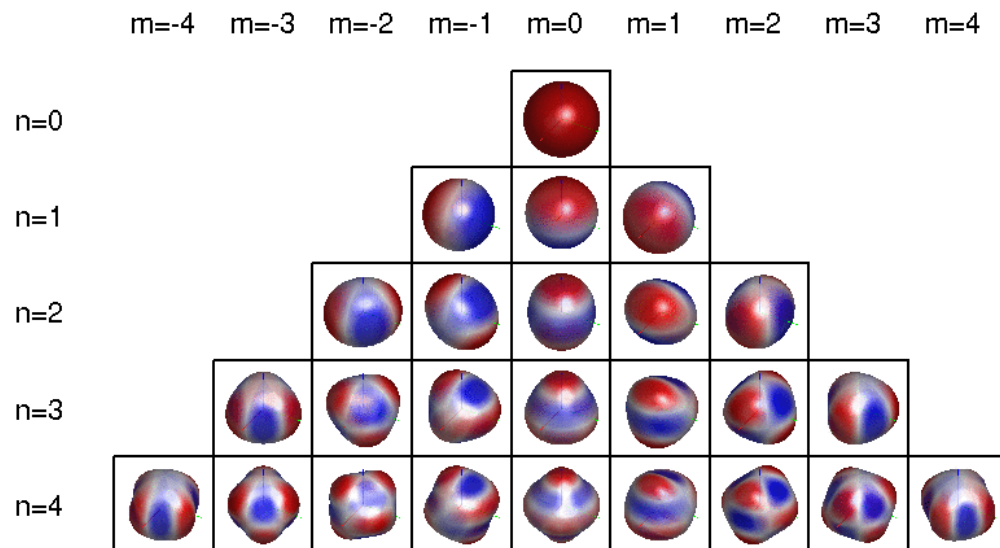
• Unknown mass ejection mechanism

- Rotation
- **Non-radial pulsation**
- Magnetic field

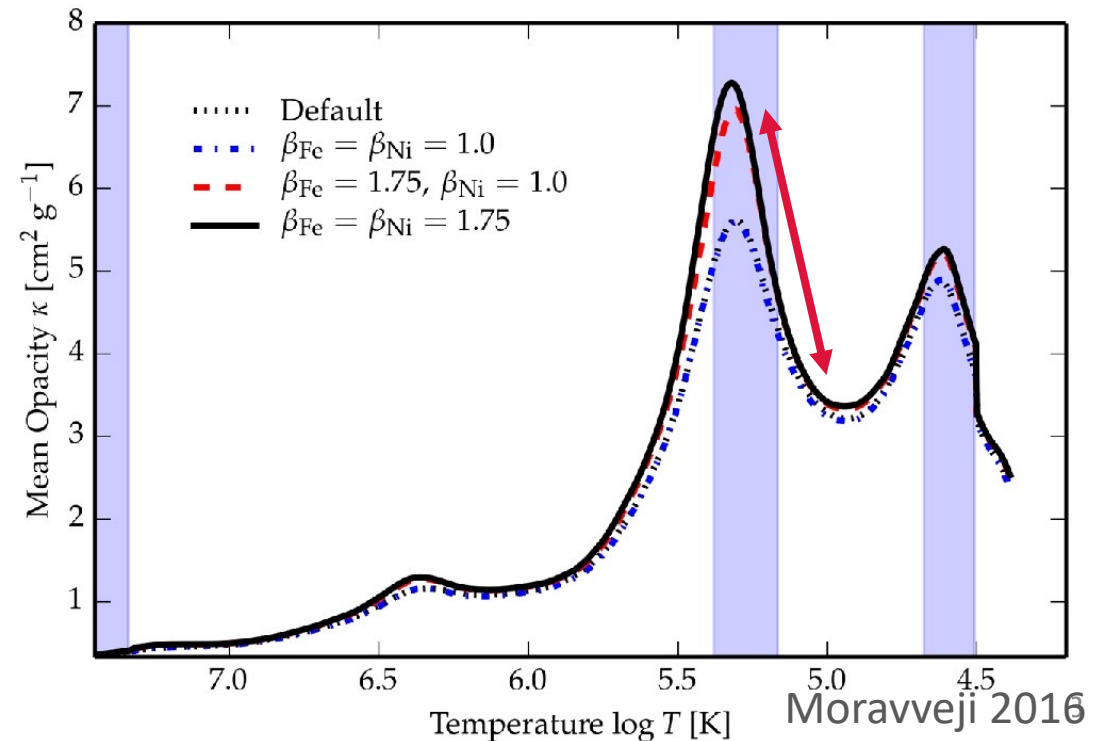


# Stellar pulsations

- Pulsation: standing waves making the star to expand & contract
- Local brightness variation by gravity darkening

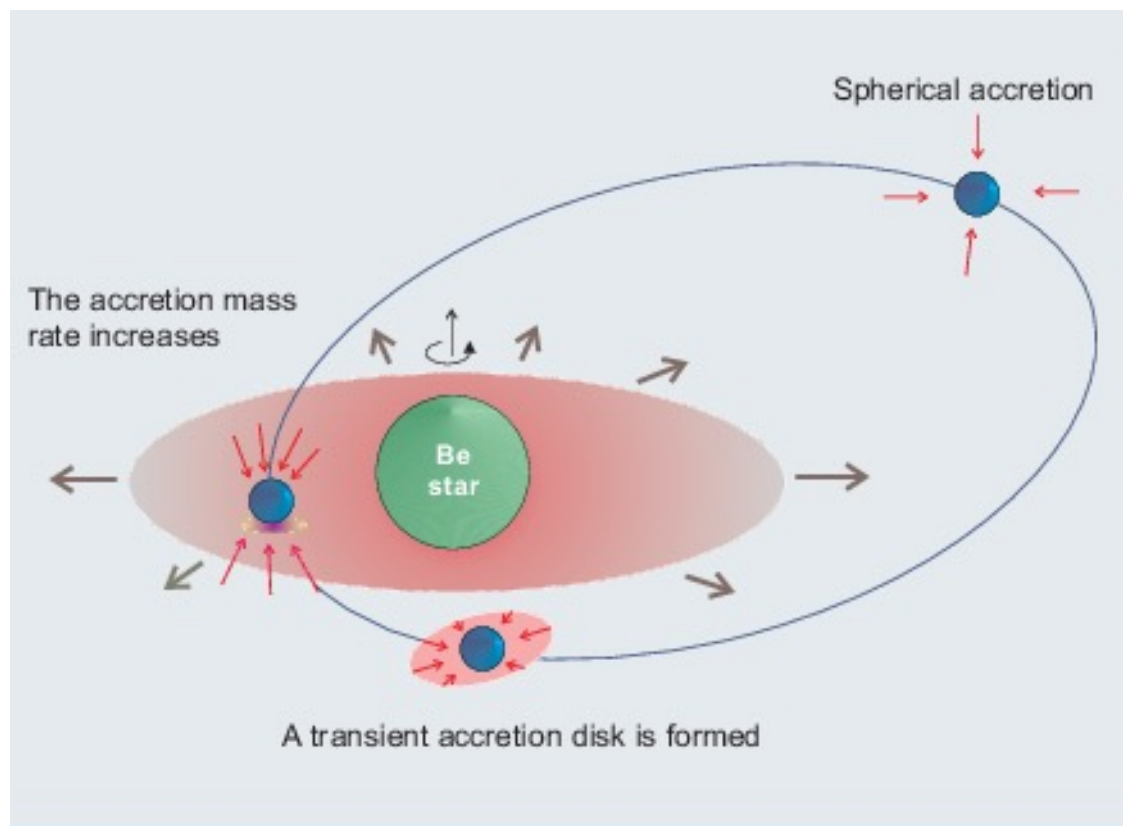


- Driven by  **$\kappa$ -mechanism**
  - $T$  &  $\kappa$  correlation
  - Positive feedback on  $T$  variations



# Be/X-ray binary (BeXB)

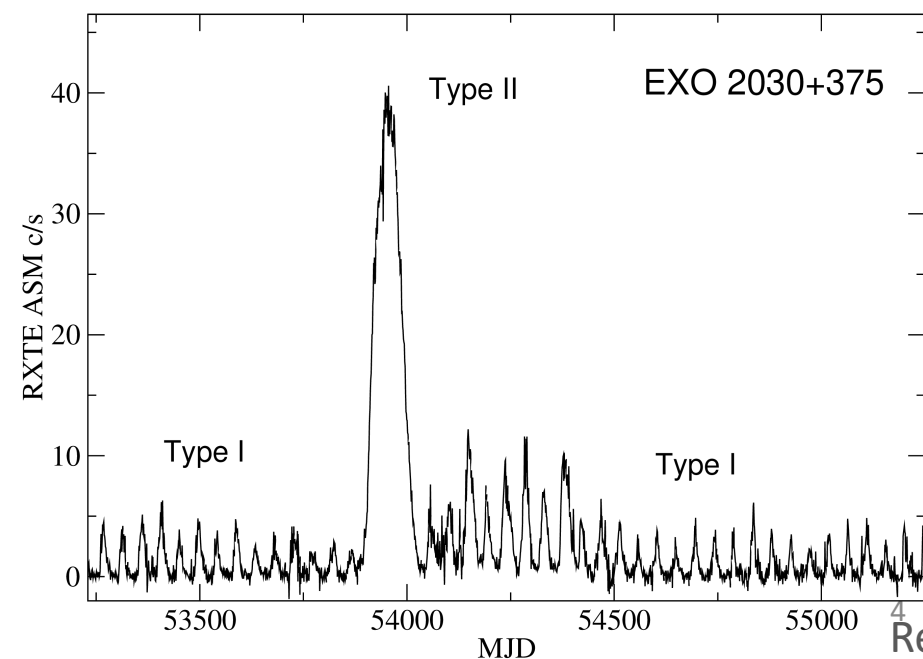
BeXB: compact star & Be star binary



Orellana & Romero 2005

Two types of X-ray outbursts

	Duration	Luminosity
<b>Normal (type-I)</b>	$< P_{\text{orb}}$	$\lesssim 10^{37}$ erg/s
<b>Giant (type-II)</b>	several $P_{\text{orb}}$	$\gtrsim 10^{38}$ erg/s



Reig 2011

# Our motivation & methodology

- Motivation

- **Constrain a relationship between Be star activities and circumstellar disks in BeXBs**

- Mass ejection of Be stars
    - Giant outbursts of BeXBs

- Methodology

- Analysis of long-term activities of 17 galactic BeXBs

- Be star activities  $\Leftrightarrow$  TESS light curves
    - Circumstellar disk  $\Leftrightarrow$  multi-wavelength light curves

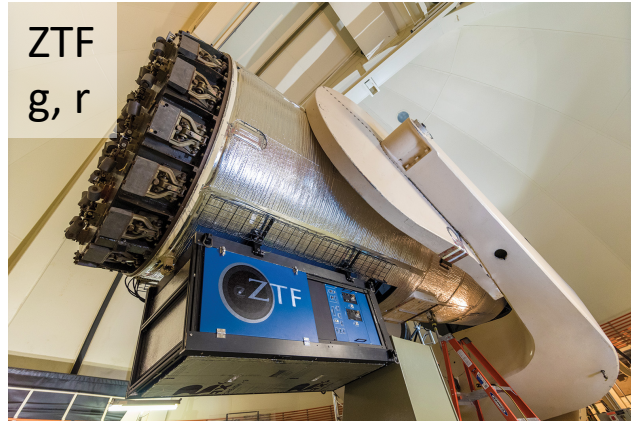
# Observations

## Optical & NIR

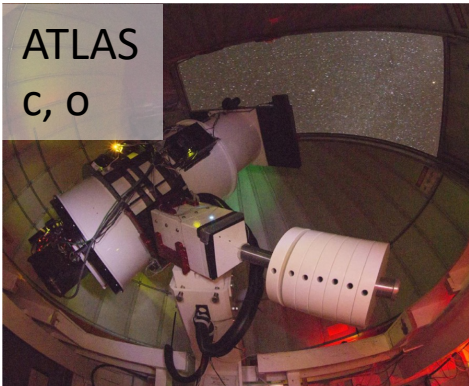
TESS



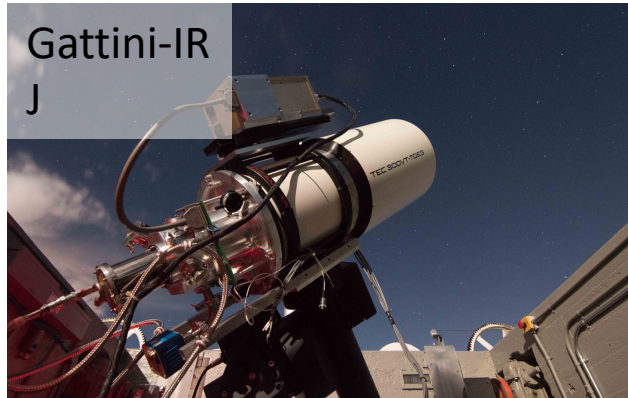
ZTF  
g, r



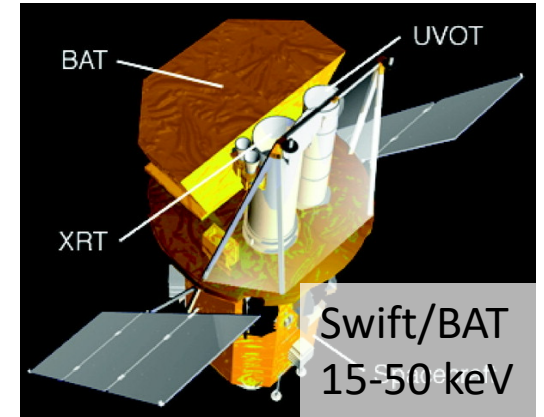
ATLAS  
C, O



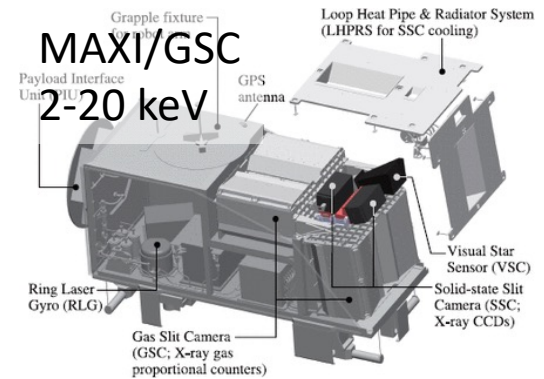
Gattini-IR  
J



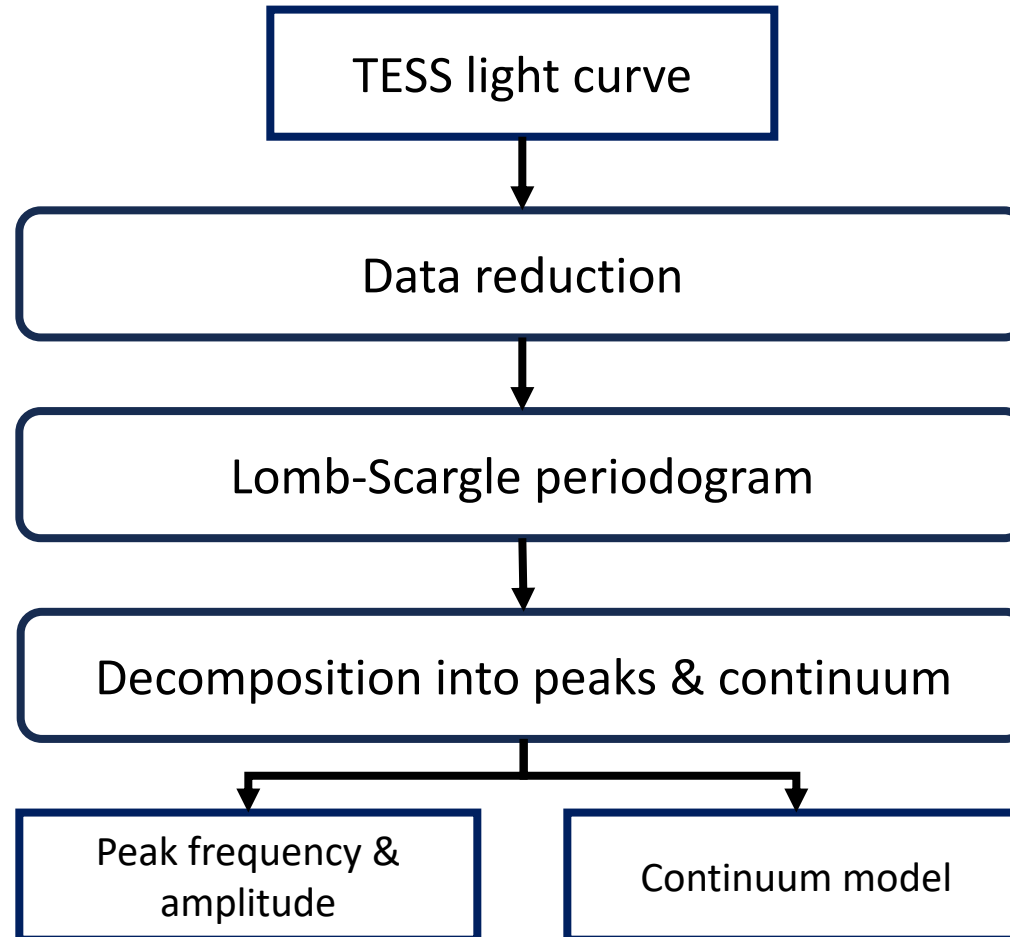
## X-ray



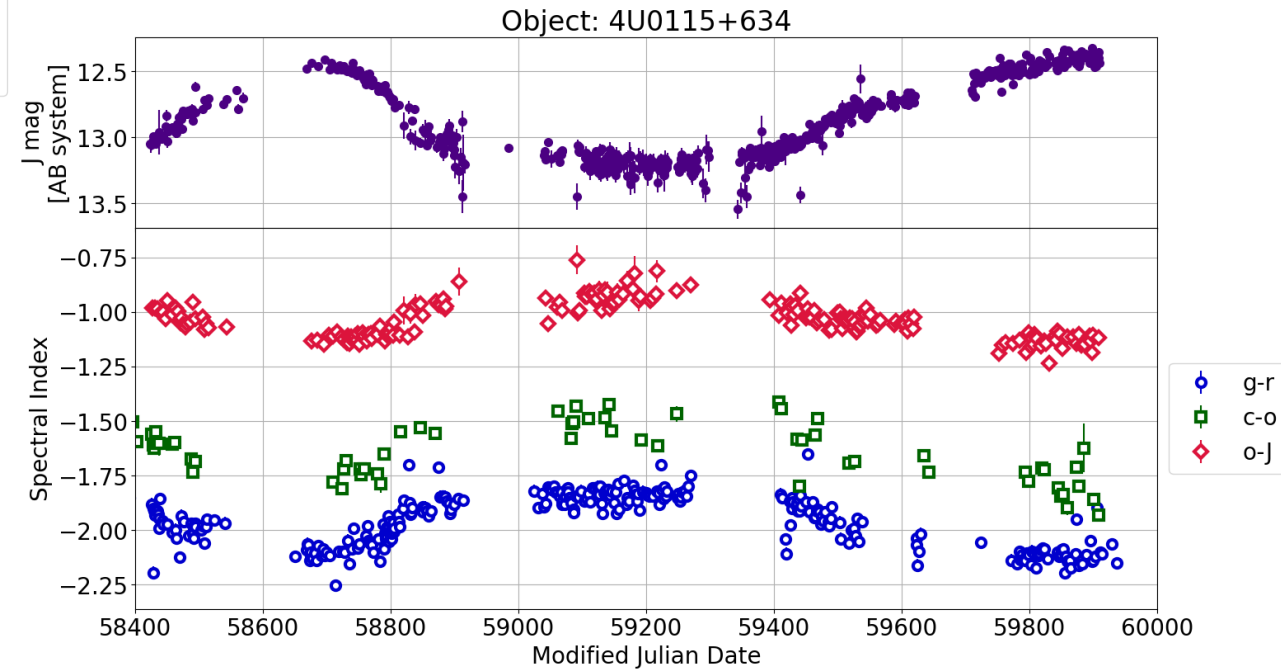
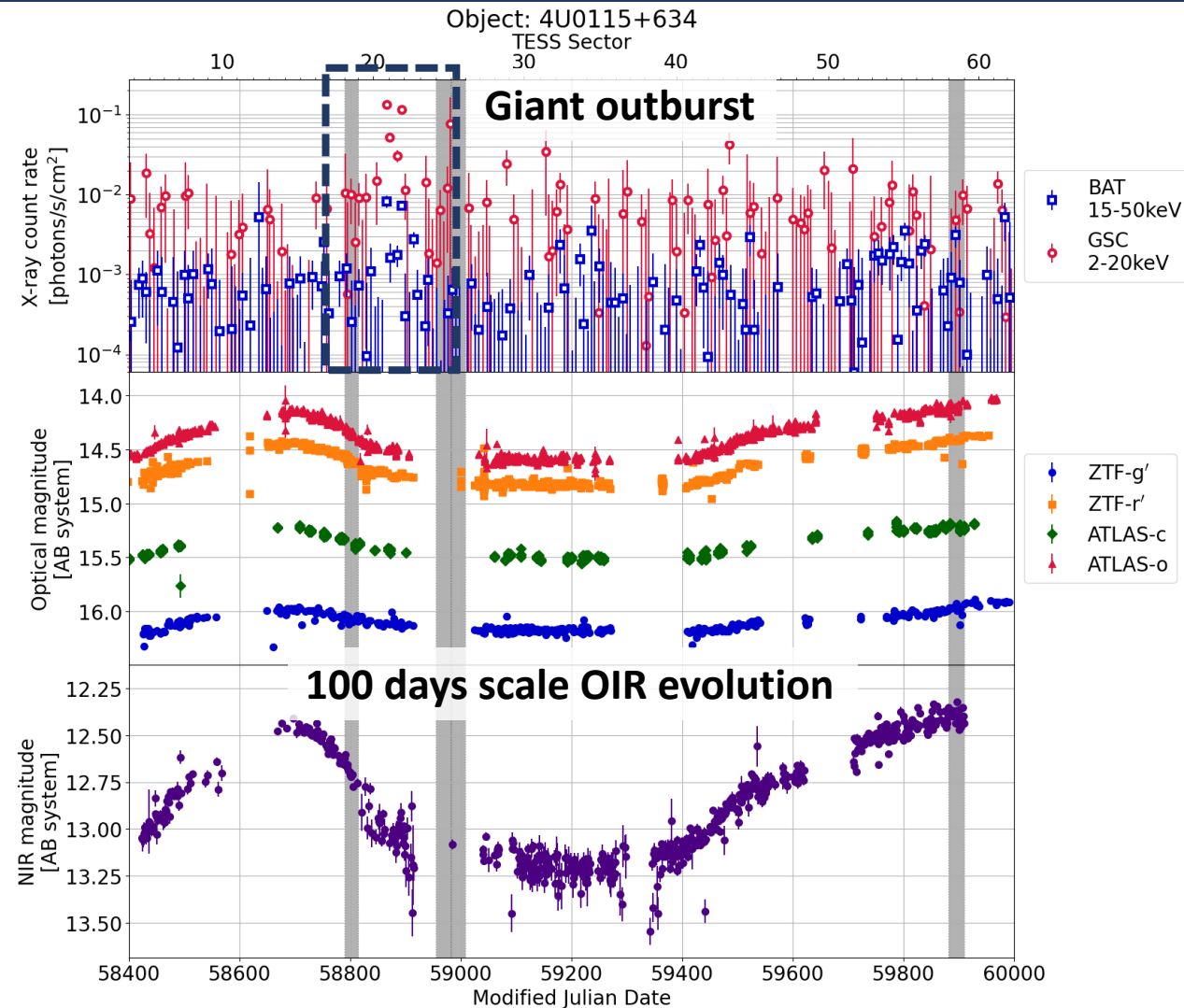
MAXI/GSC  
2-20 keV



# Analysis procedure of flux periodicity



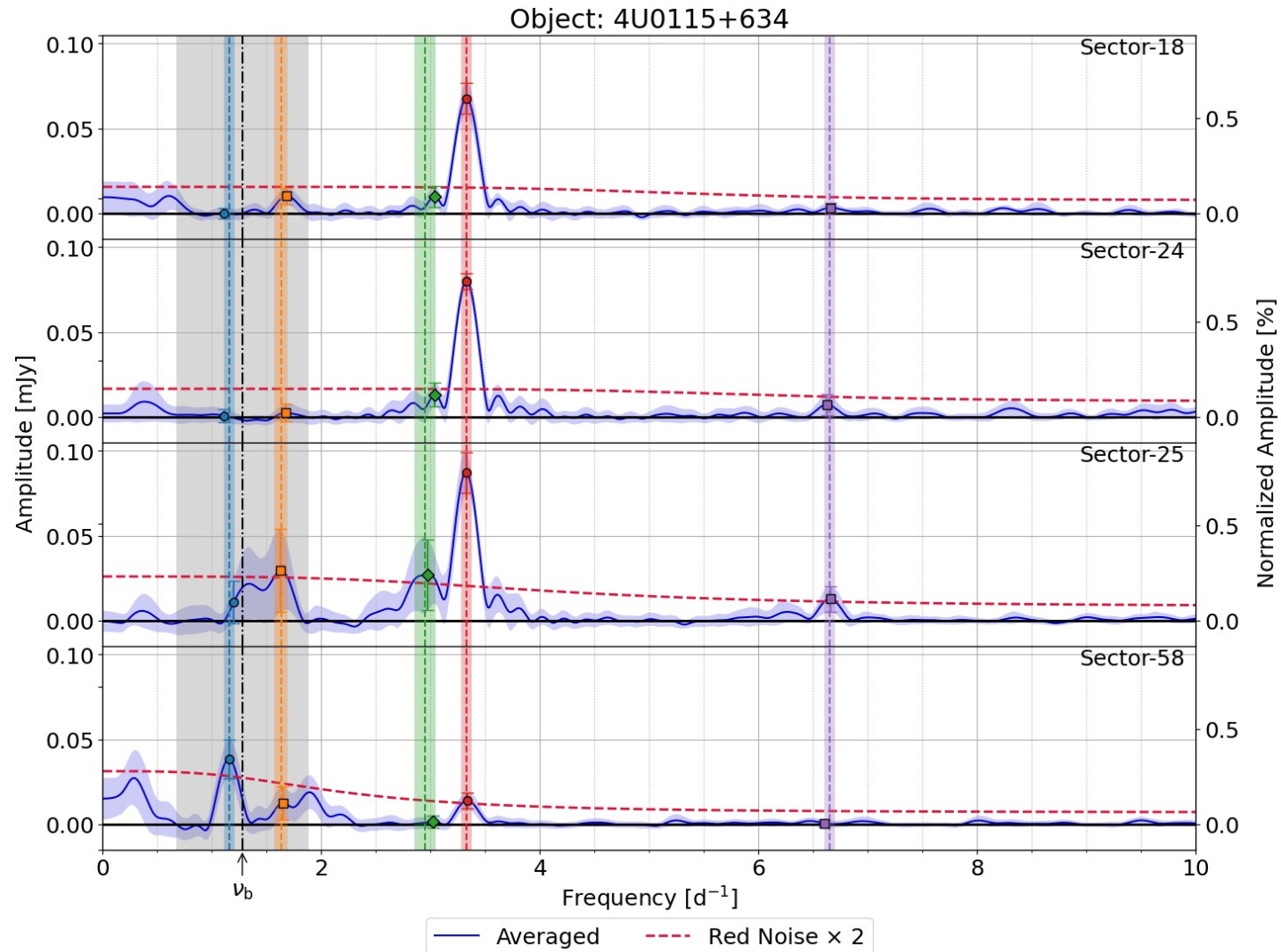
# Light curves (4U0115+634)



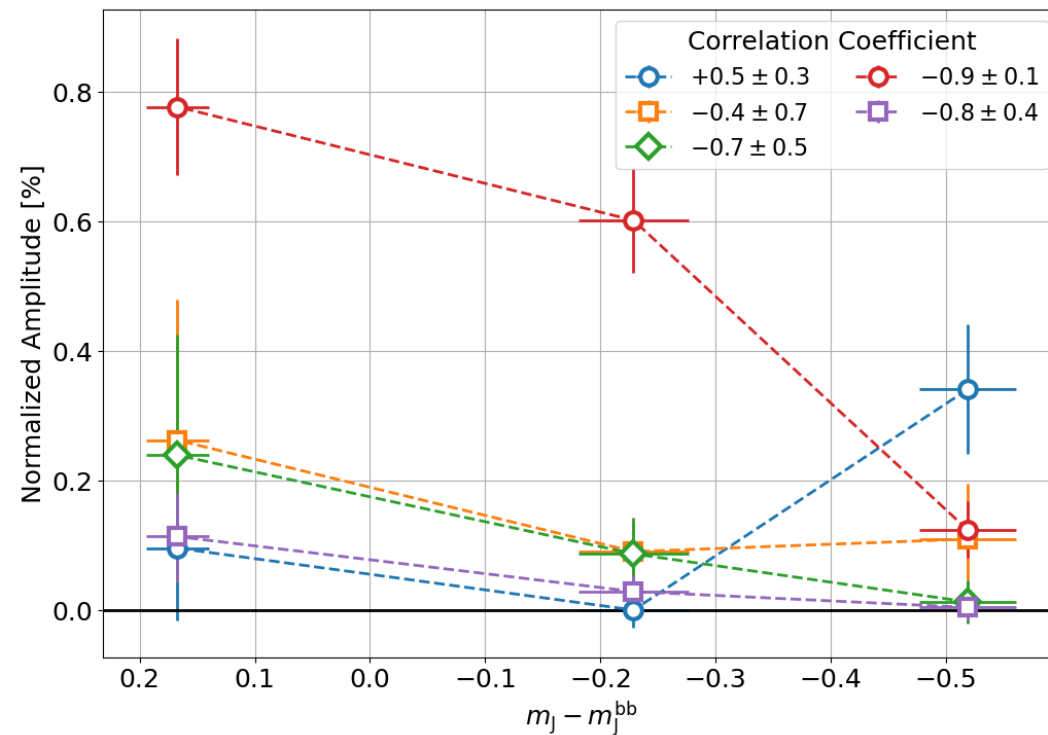
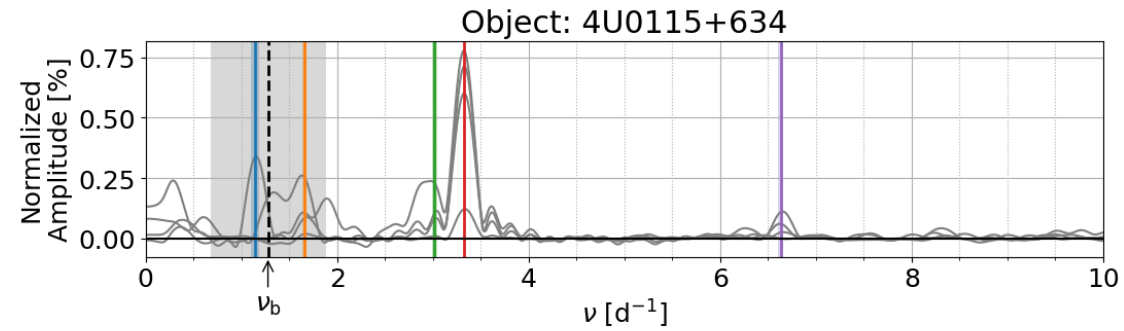
**Redder when brighter**



# Amplitude spectrum (4U0115+634)

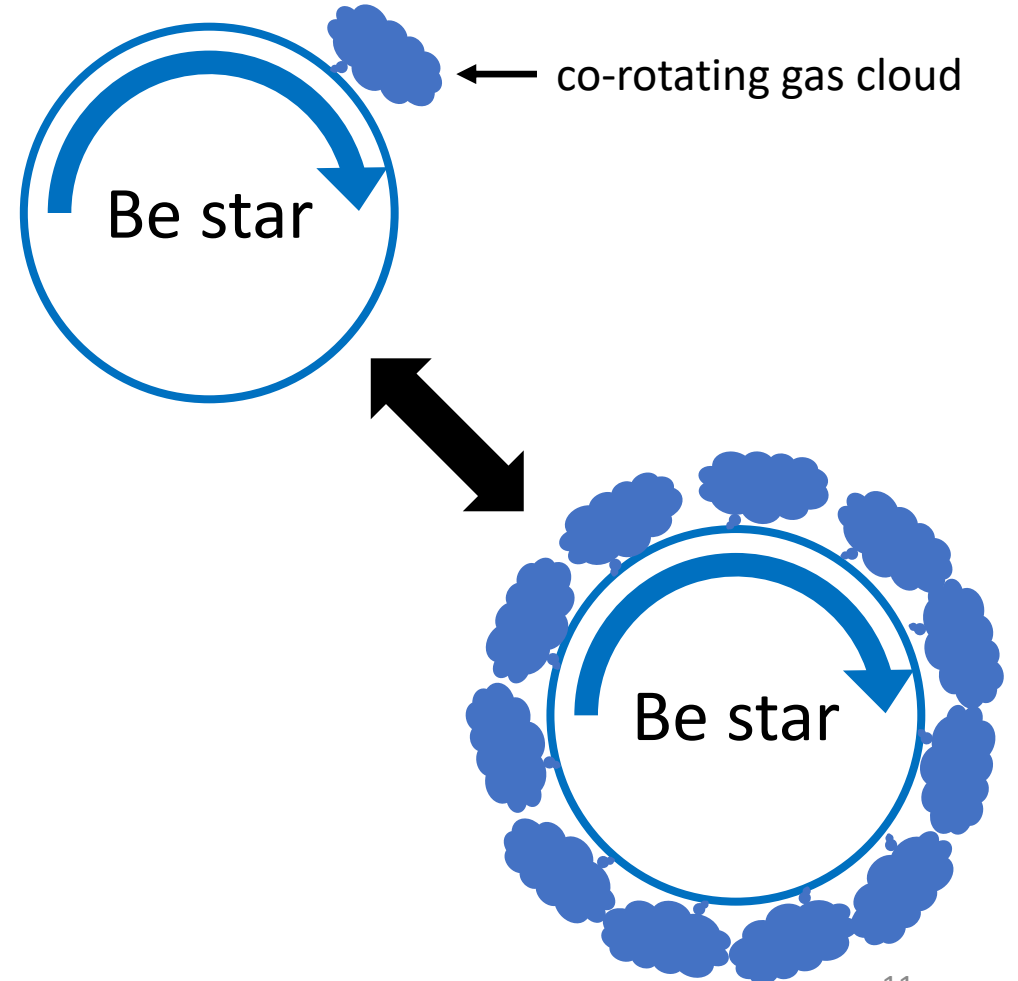


# Periodicity & IR excess (4U0115+634)



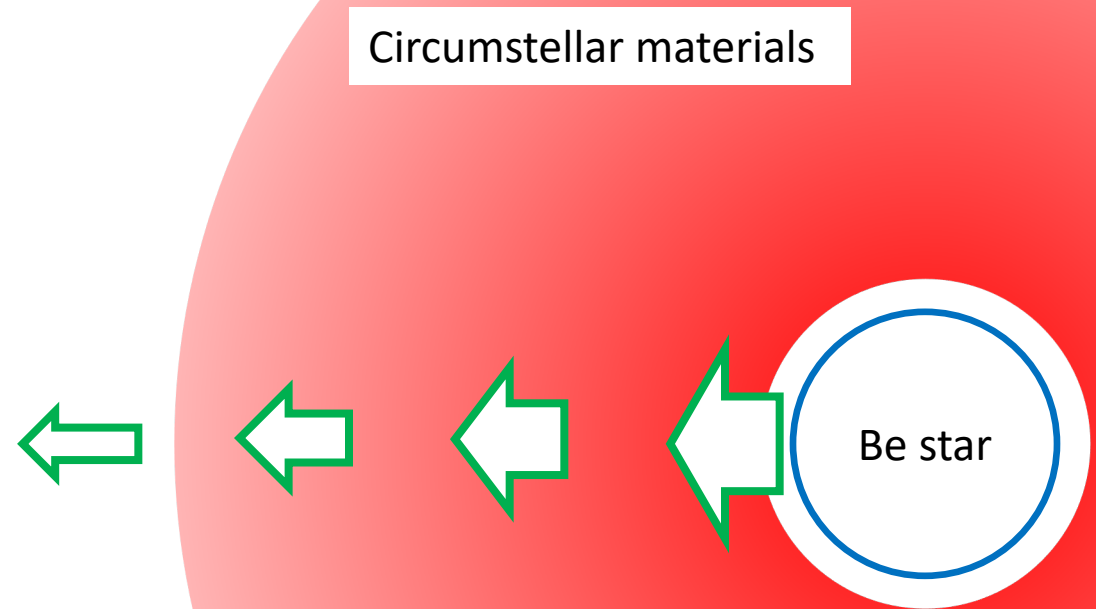
# Co-rotating gas clouds scenario

- Rotation-derived flux oscillations  
↔ co-rotating gas clouds (Balona 2020)
- Mass ejection smoothed the gas cloud density?
- Cannot apply to the pulsations
  - Non-correlated peaks are pulsations?



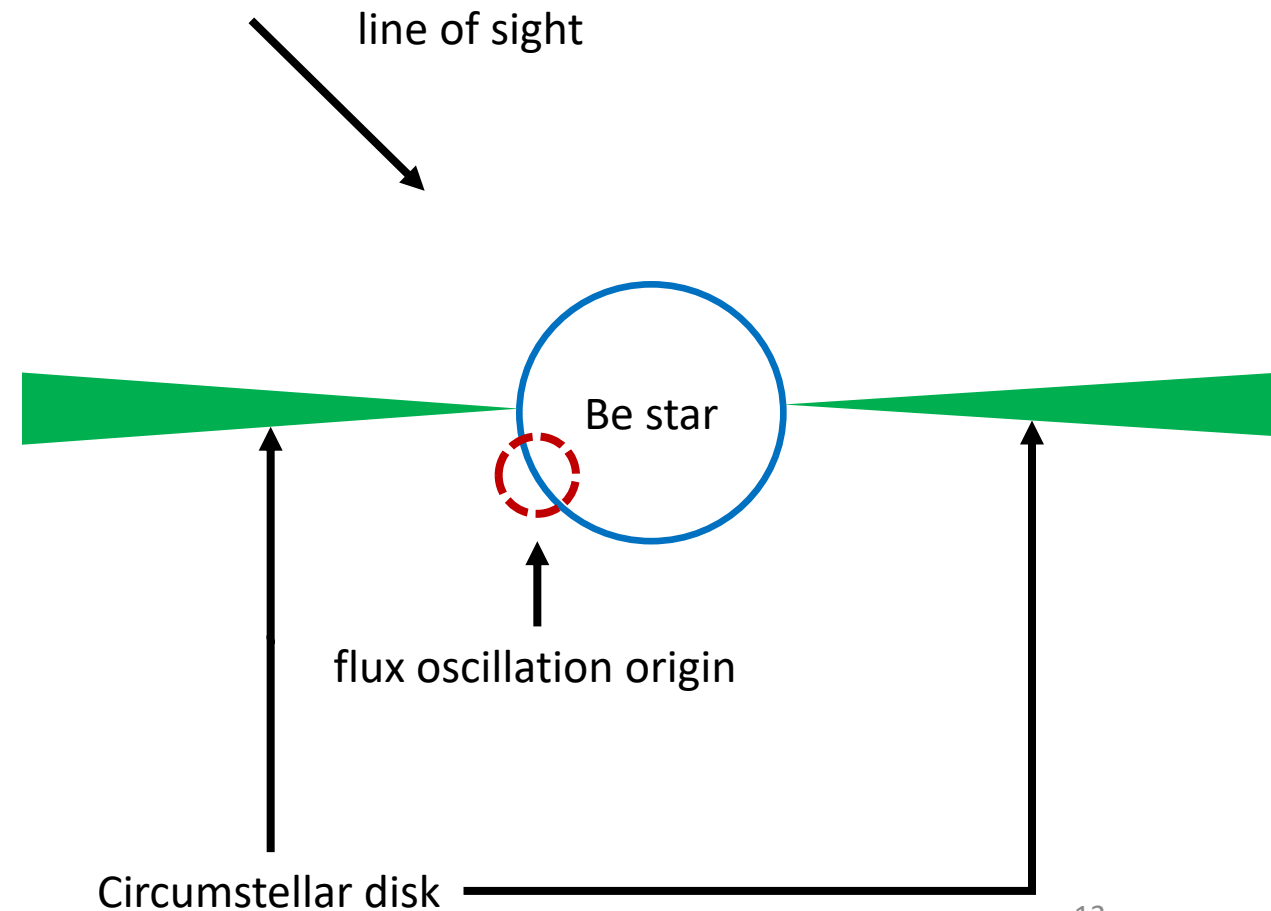
# Fully covered photosphere scenario

- Photons from Be star reprocessed by circumstellar materials (e.g., stellar wind)
- Requirements for 80% reprocessing:
  - $10^{12} \text{ cm}^{-3}$  or  $10^{-11} \text{ g/cm}^3$  ( $r = R_*$ )
  - $\sim$  inner circumstellar disk
  - $\sim$  stellar wind  $\times 100$
- Cannot explain non-correlated peaks



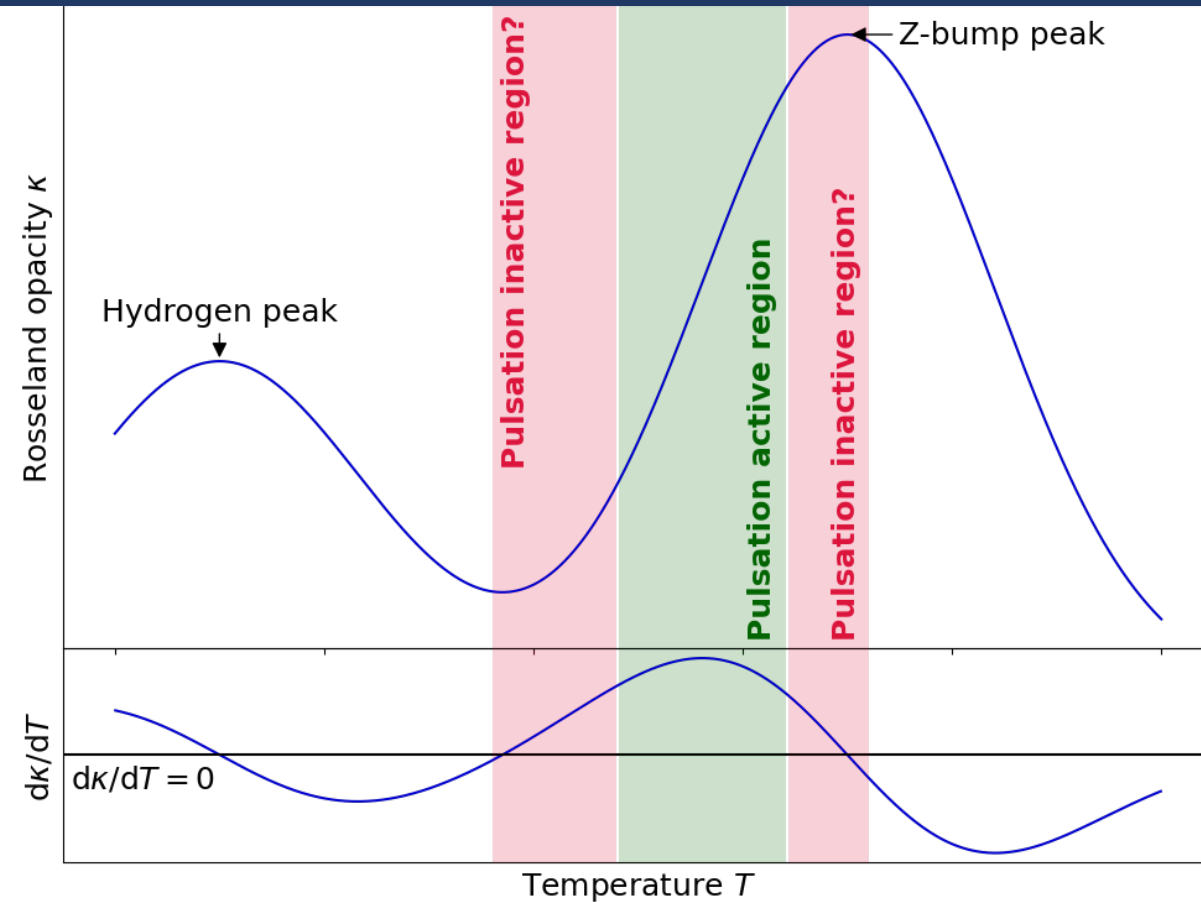
# Partially covered photosphere scenario

- Assumption:
  - Local brightness difference of the photosphere produces flux oscillations by pulsations
- Applicable to higher-order pulsations
  - Difficult to explain maximum peaks
- Rotation linked features should exist in power spectrum



# Be star internal state transition scenario

- Assumption:
  - Amplitude of pulsation itself varied
  - Pulsations do **not** contribute to the mass ejection
- Contrary to the conventional idea
- Cannot explain rotation-derived peaks



# Summary

- We analyzed the optical flux periodicity and the long-term multi-wavelength light curves for 17 galactic BeXBs.
- We found the anti-correlations between amplitudes of flux oscillations and IR excess.
- Pulsations may not contribute to the mass-ejection.