

中性子星X線連星Aql X-1の アウトバーストに於ける X線・可視光放射機構

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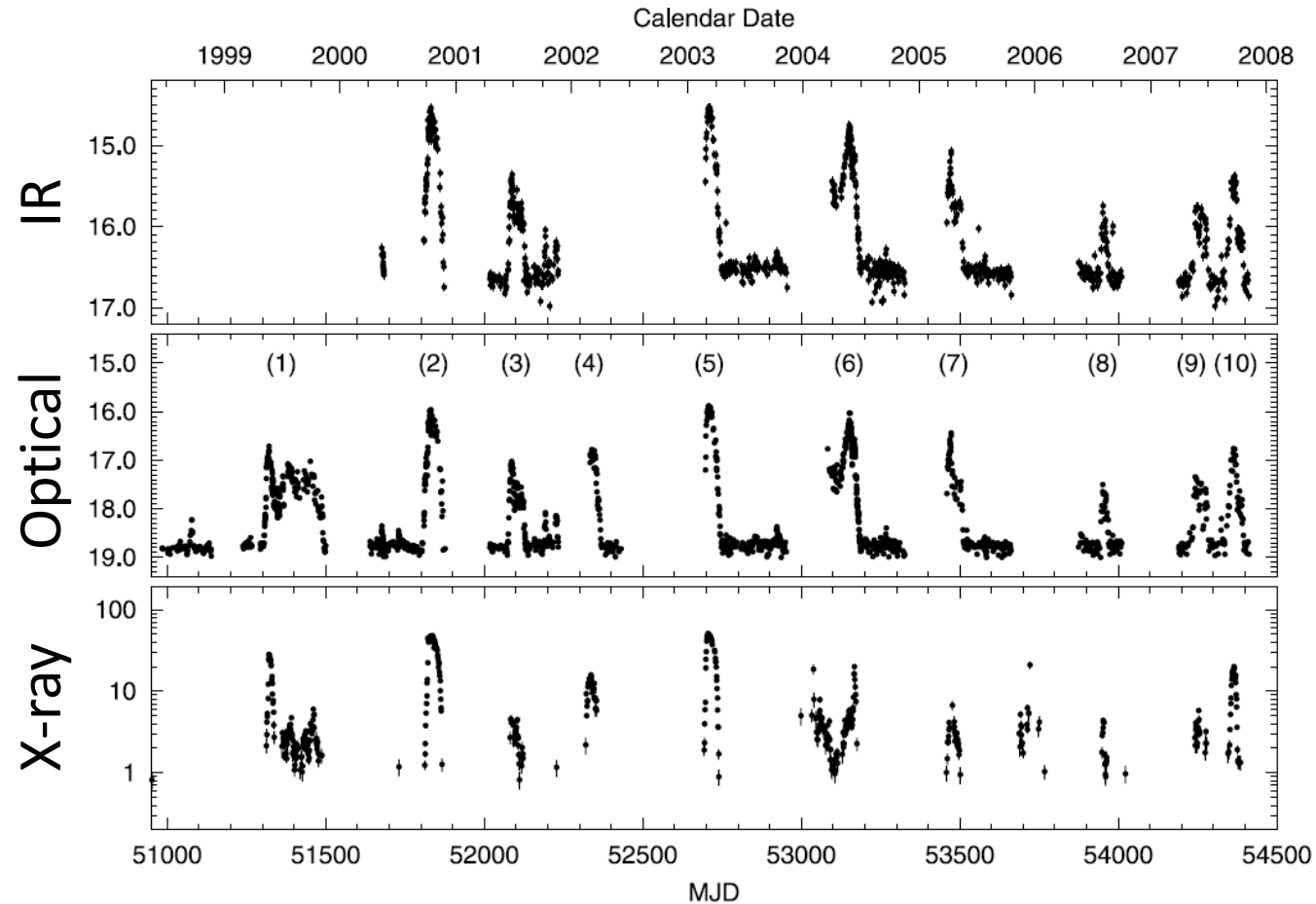
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MAXI team

第12回 光赤外線大学間連携ワークショップ

Aql X-1

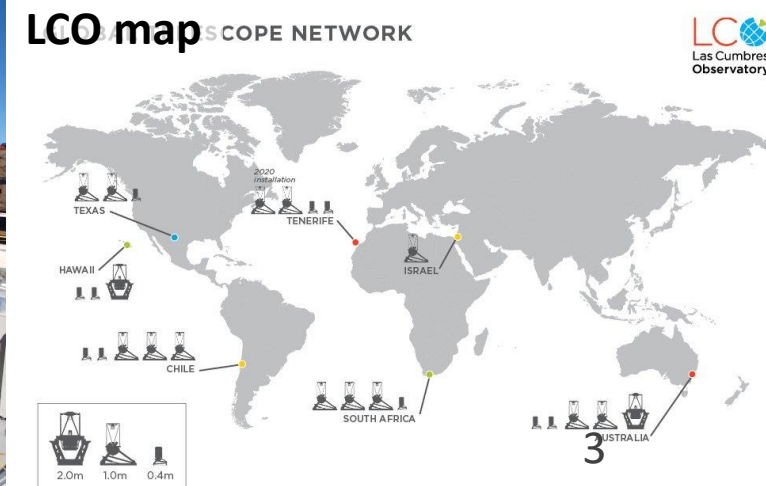
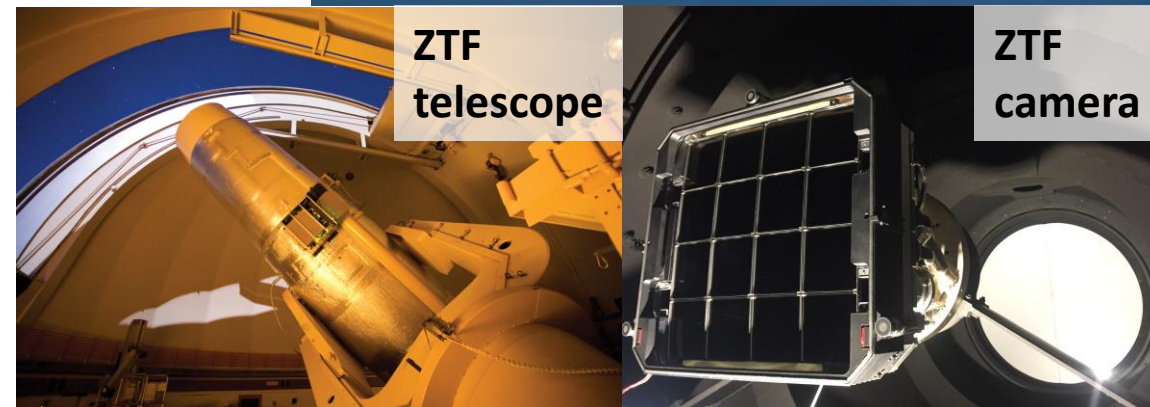
- A low-mass X-ray binary of 0.8- $1.5M_{\odot}$ neutron star and K-type star
- Outbursts in a wide range of wavelengths
 - \approx once/year



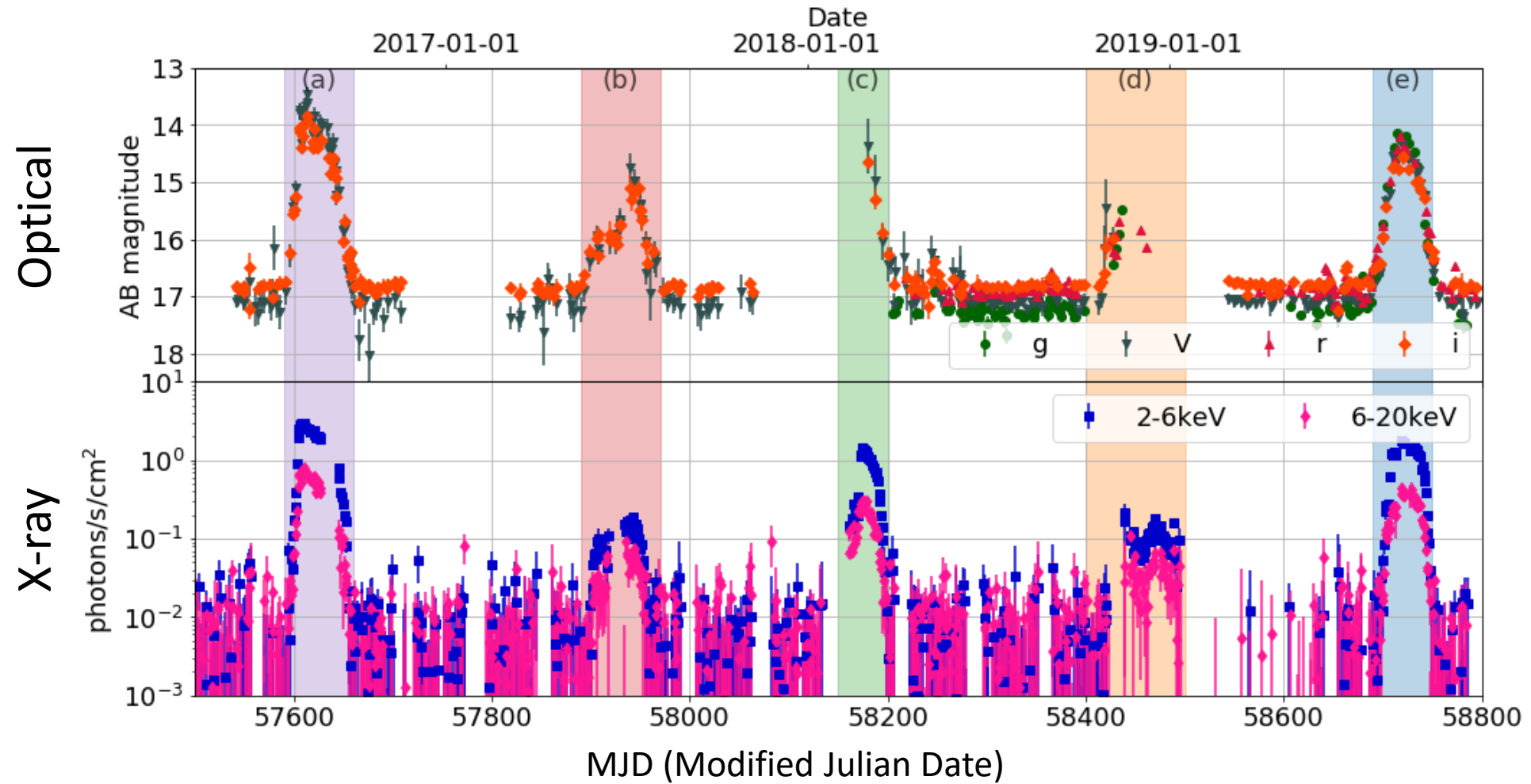
(Maitra & Bailyn, 2008)

Instruments & Data

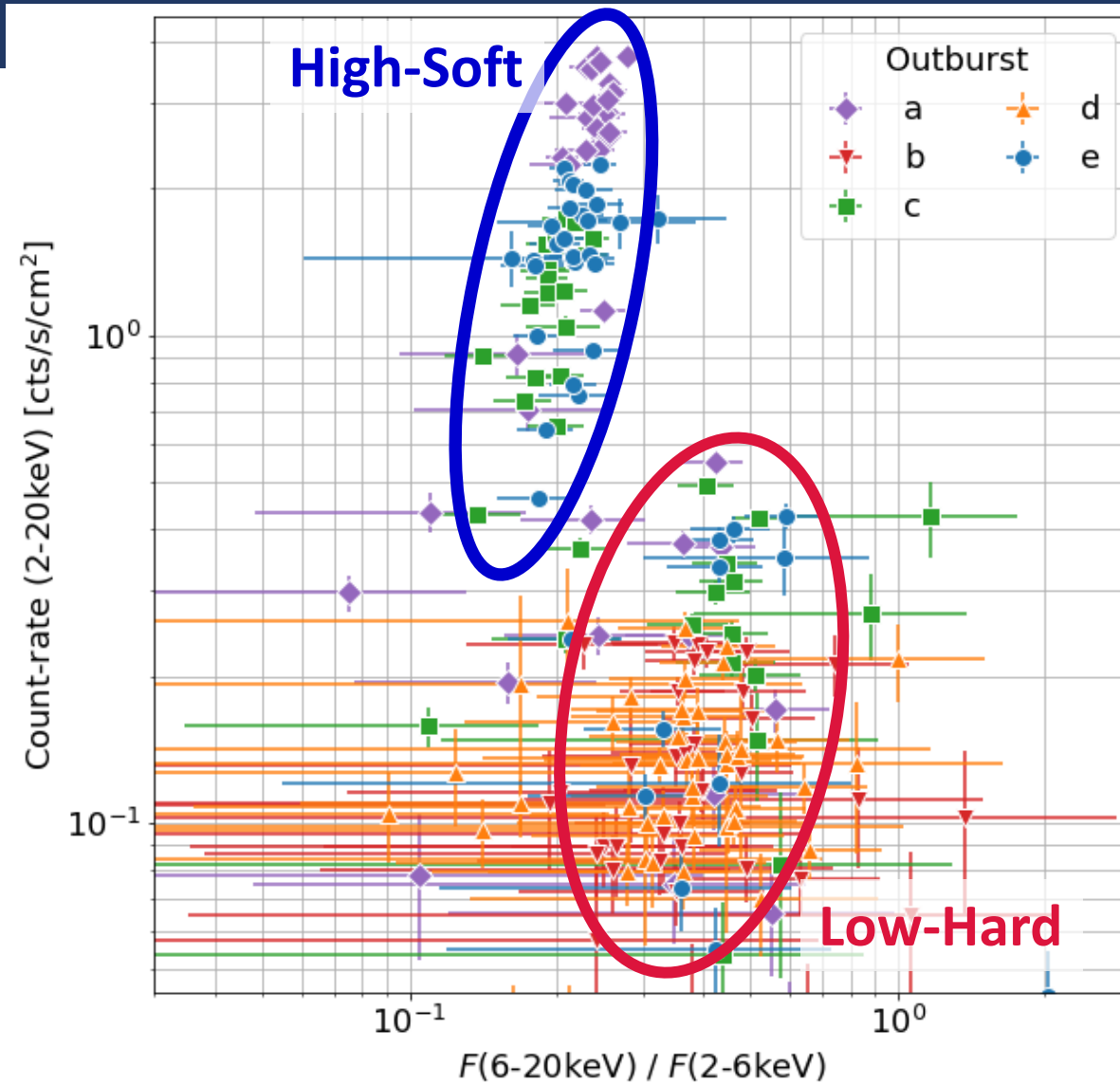
	Energy band	Period
ZTF	g', r'	2018/3/17 ~ 2019/12/31
LCO	V, i'	2016/3/16 ~ 2019/11/25
MAXI	2-6keV 6-20keV	(about same period as LCO)



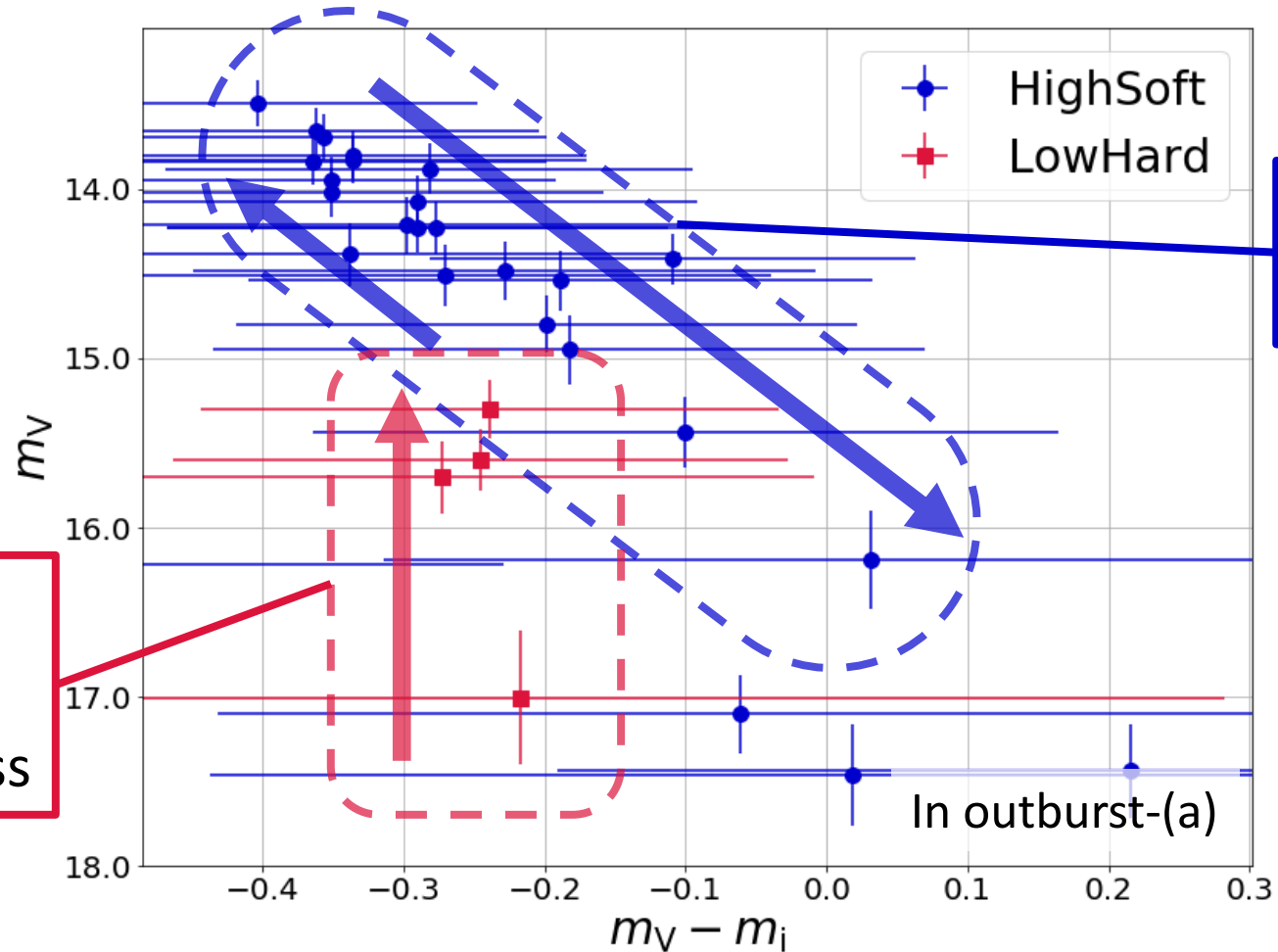
Lightcurves



X-ray state transition



Optical brightness & color

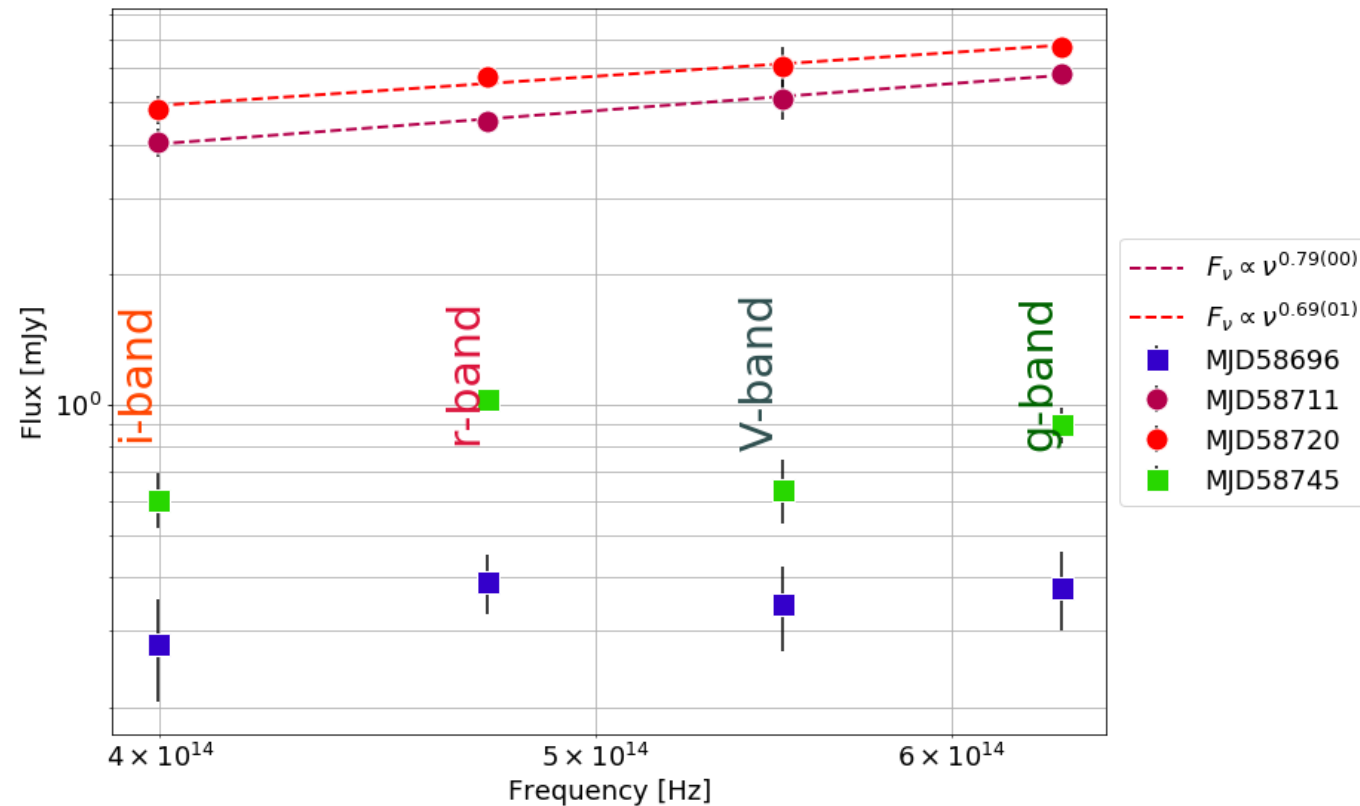


High-Soft
bluer when brighter

Low-Hard
poor correlation
in color & brightness

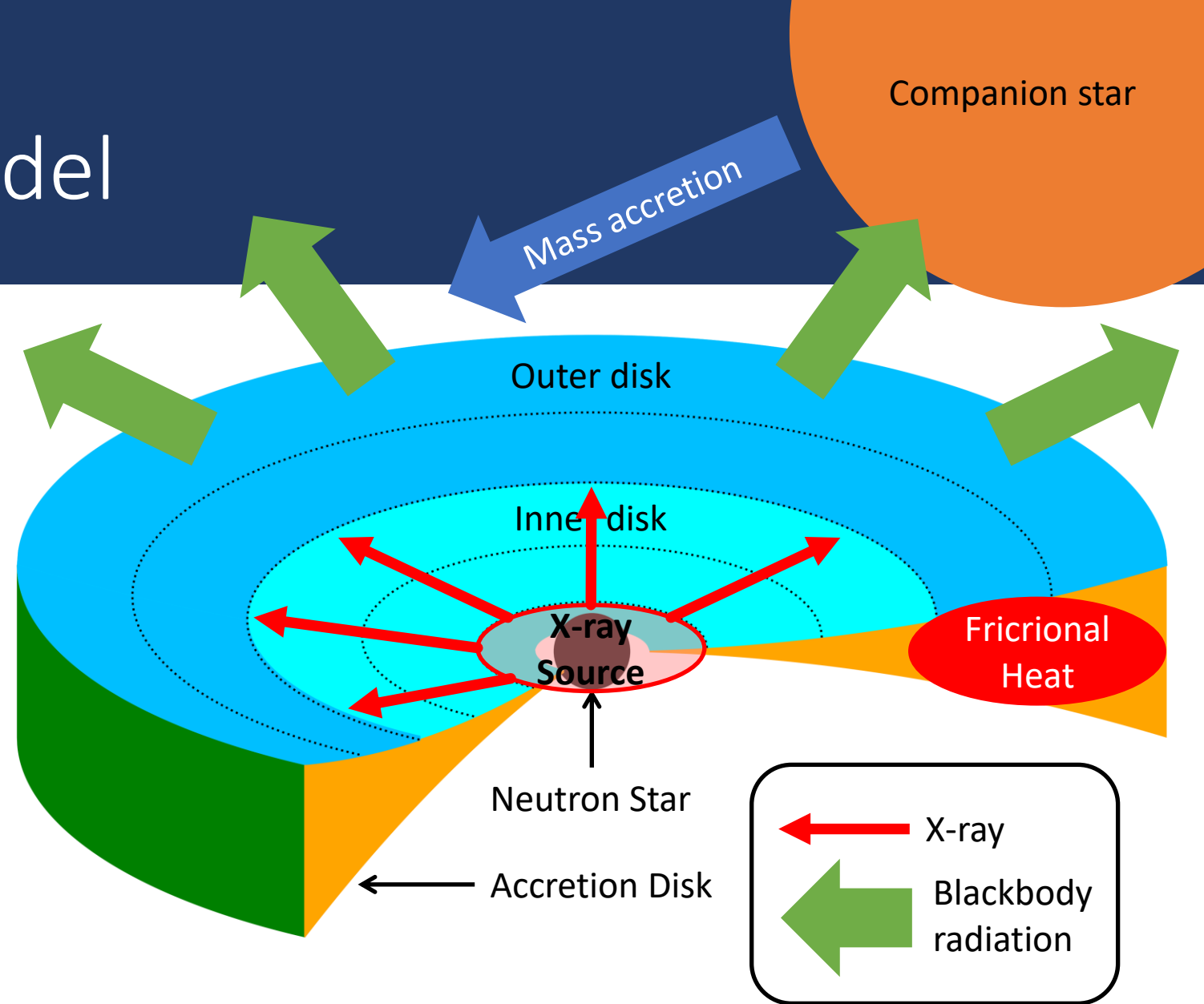
Optical spectrum @outburst-e

- PowerLaw-like spectrum in High-Soft state
 - $F_\nu \propto \nu^{0.7-0.8}$
 - Consistent with the irradiated disk model
- Not a simple spectrum in Low-Hard state



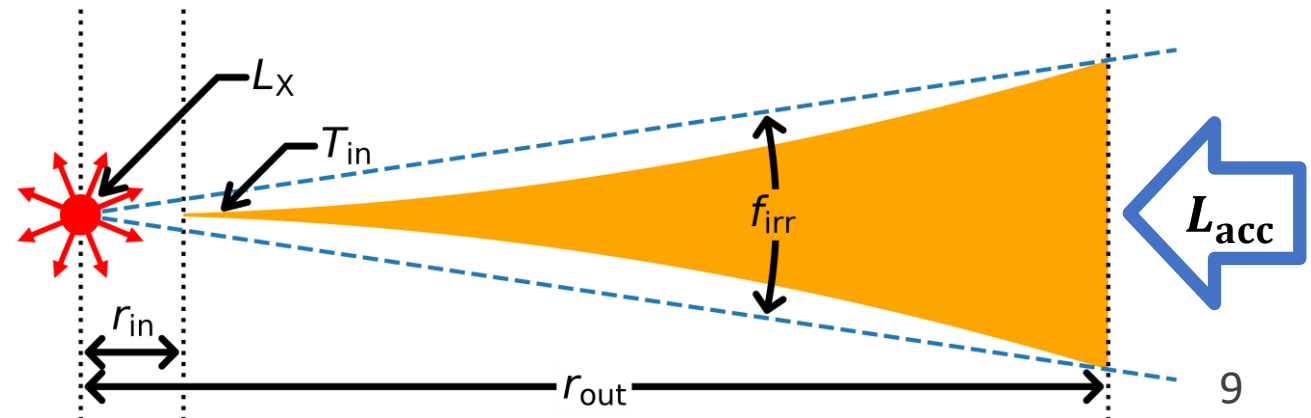
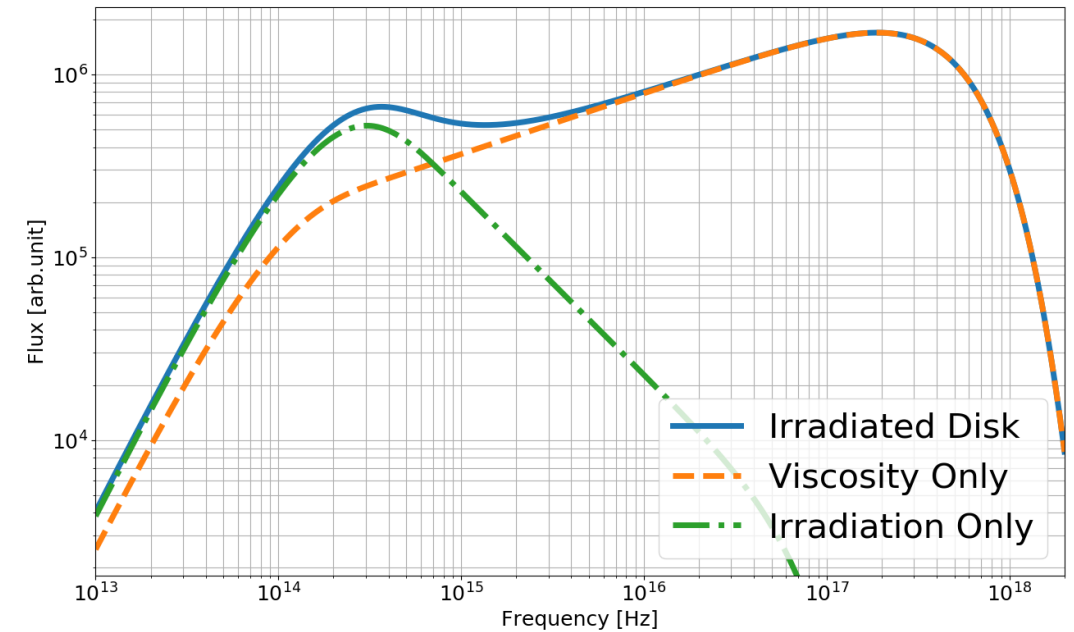
Irradiated Disk model

- Heat source:
 - Friction due to viscosity
 - X-ray irradiation from the disk center
- Cooling:
 - Blackbody radiation



Model formula

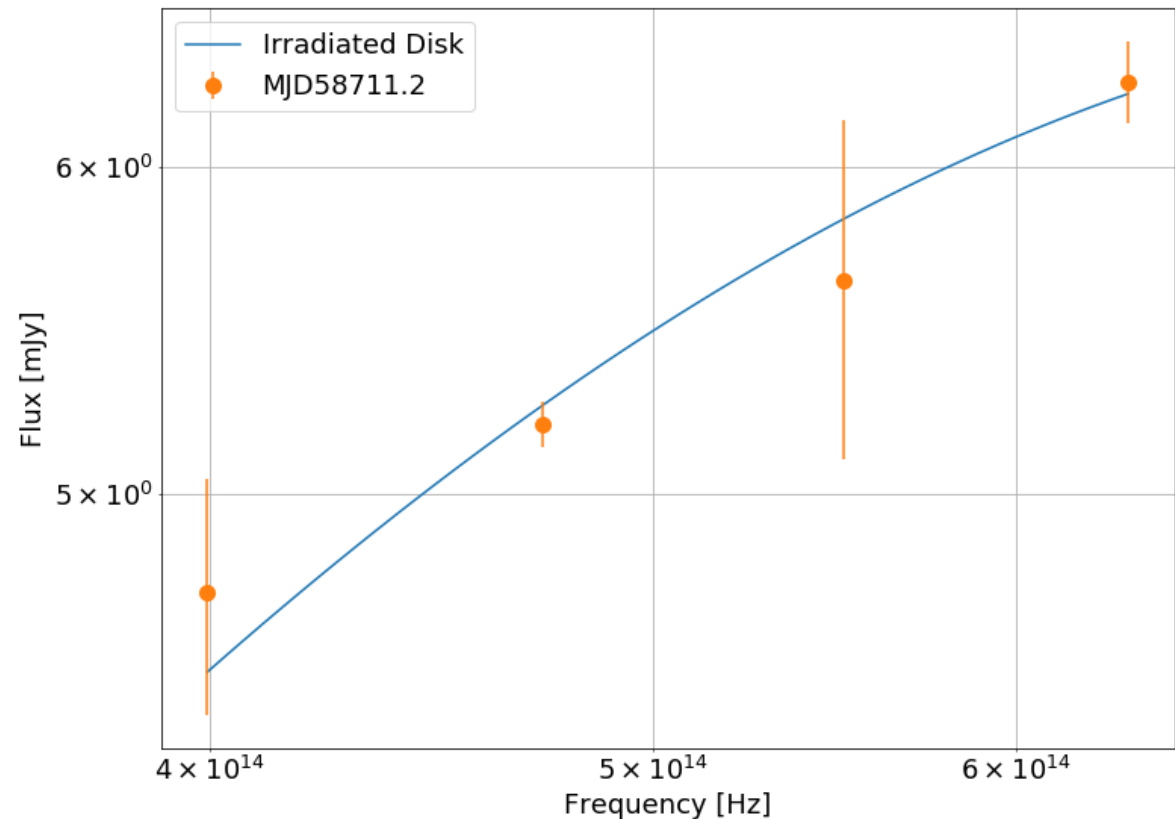
- $S(\nu) = \int_{r_{in}}^{r_{out}} \frac{2h\nu^3}{c^2} \frac{1}{e^{h\nu/k_B T} - 1} \cdot 2\pi r dr$
- $\sigma T^4 = \sigma T_{in}^4 \left\{ \left(\frac{r}{r_{in}} \right)^{-3} + f_{out} \left(\frac{r}{r_{in}} \right)^{-2} \right\}$
- $\sigma T_{in}^4 \propto L_{acc} = \frac{GM\dot{M}}{2r_{in}}$
- $f_{out} \propto f_{irr} \frac{L_X}{L_{acc}}$



Spectral fitting with irradiated disk model

- Fitted optical spectrum near the peak of outburst-(e) with irradiated disk model
- **The model consistent with observed optical spectrum**

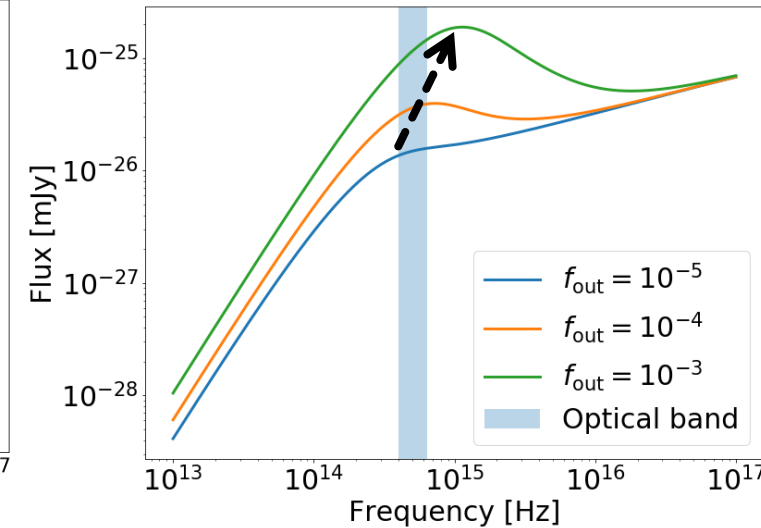
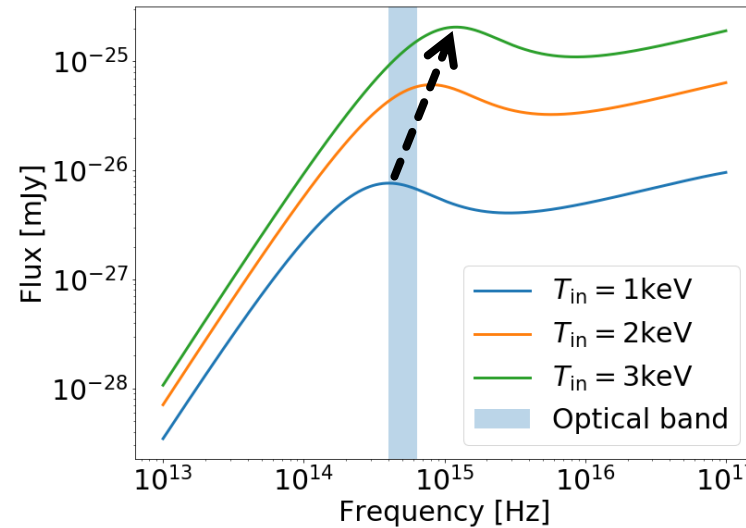
Parameters	Value
r_{in}	$9.8 \times 10^5 \text{ cm}$
r_{out}	$1.3 \times 10^{11} \text{ cm}$
$k_{\text{B}}T_{\text{in}}$	2.05keV
f_{out}	0.2×10^{-3}



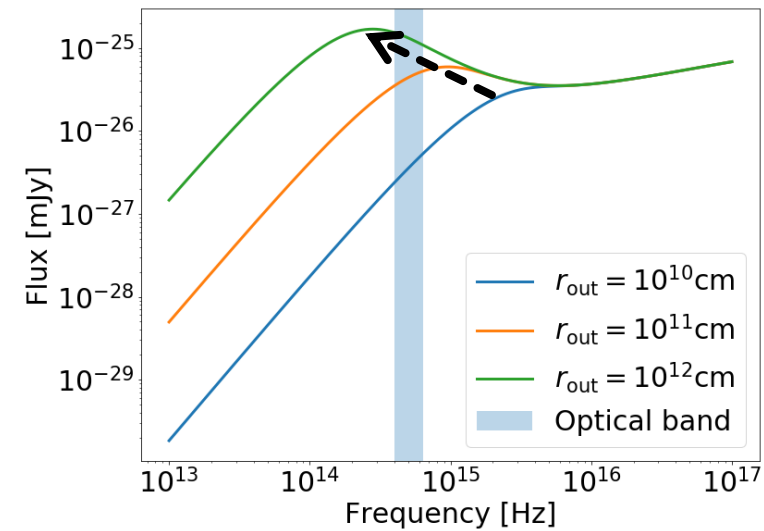
Parameter dependency of spectral shape

- When parameters changes:

- T_{in} : bluer when brighter
- f_{out} : bluer when brighter
- r_{out} : redder when brighter
- (observed): bluer when brighter

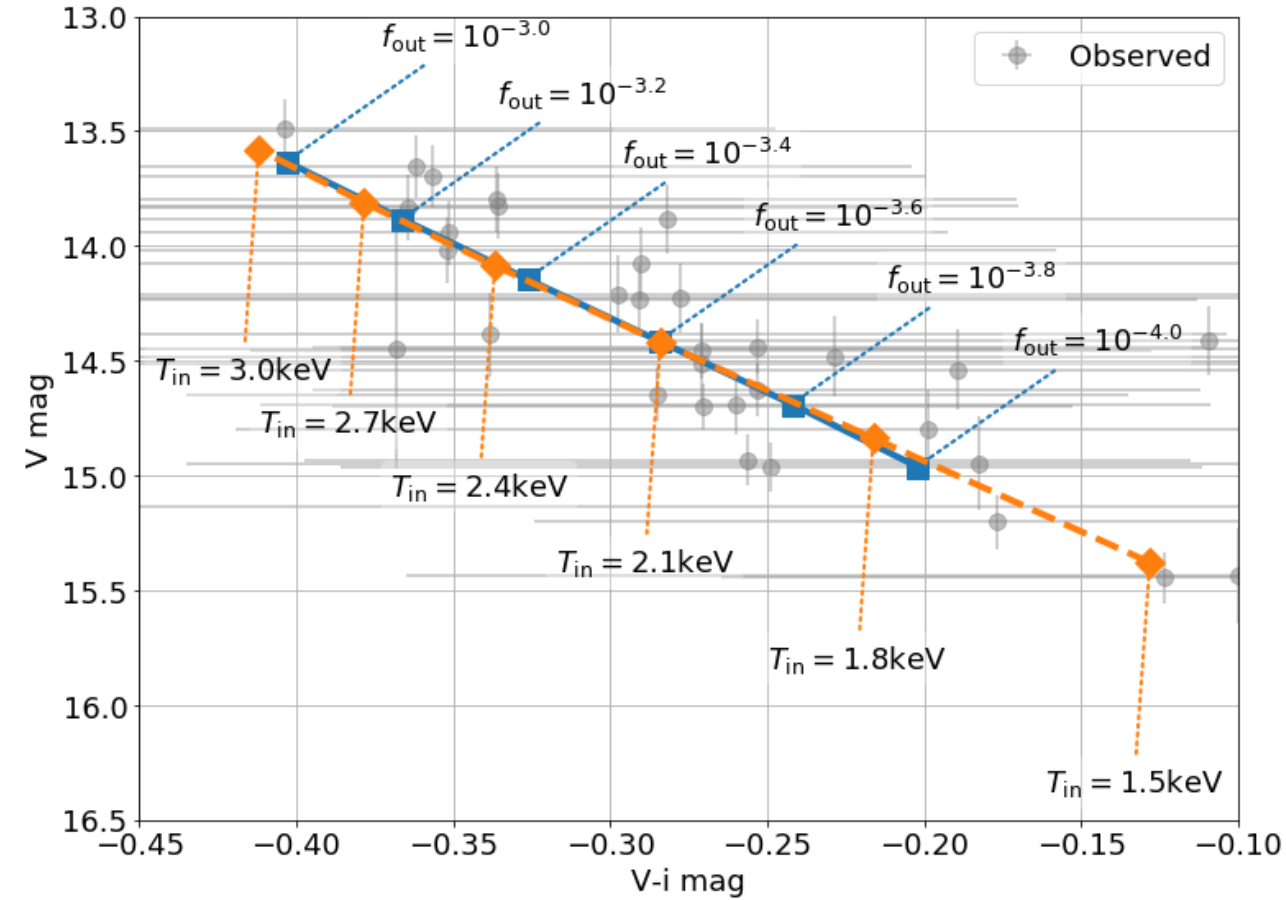


- Change of r_{out} inconsistent with the observed variations



Optical variations due to parameters

- Observed optical variations consistent with changes of T_{in} or f_{out}
 - **The irradiated disk model consistent with observed optical variation in High-Soft state**



Summary

- Analyzed optical & X-ray lightcurves of Aql X-1 using 3.7 years data of MAXI, ZTF and LCO
- Obtained following observational results
 - State transition between Low-Hard & High-Soft state in X-ray
 - Changes in optical variations linked to X-ray state transitions
- Observed optical variations in High-Soft state consistent with the irradiated disk model