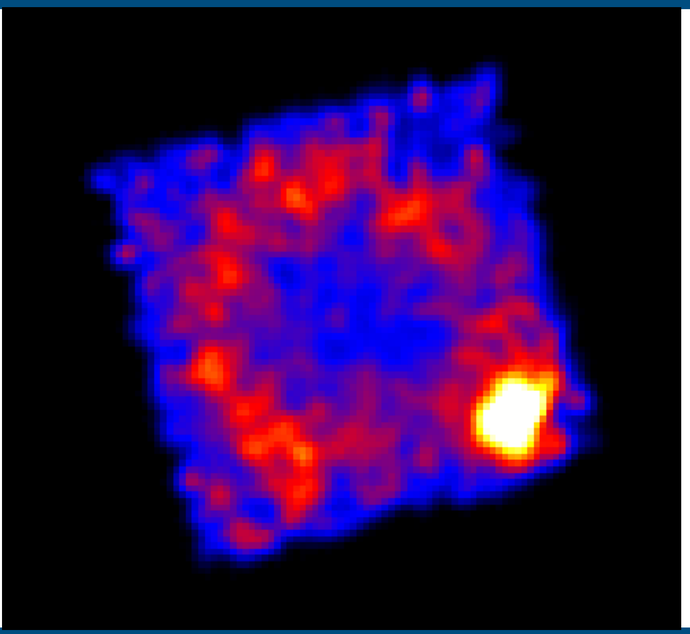
Dust scattering echo around MAXI J1421-613 detected by Suzaku and Swift follow-up observations



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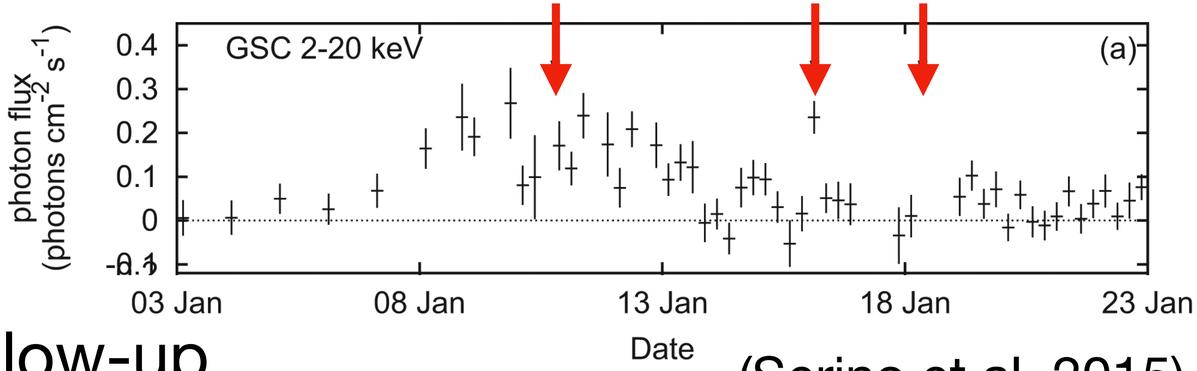
KN et al. 2020, PASJ, 72, 827
KN et al. 2023, AdSR. 71, 1074

Introduction: MAXI J1421-613

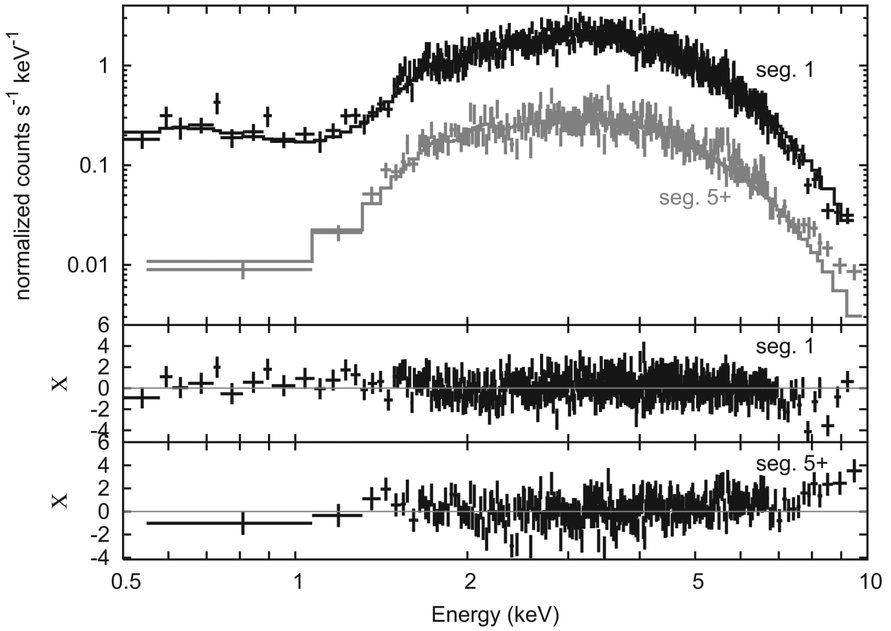
- Detected by the MAXI Nova Alert System on 9 January, 2014 (Morooka et al. 2014).
- Showed at least three type I X-ray bursts (Bozzo et al. 2014; Baumgartner et al. 2014)
  → neutron-star LMXB
- Swift, Suzaku, and Chandra performed follow-up observations (Serino et al. 2015).
- Spectra during the outburst can be explained by wabs × nthComp ($N_H = 4.8\times10^{22}$ cm^{-2}、$\Gamma = 2.1$)
- Assuming the empirical maximum luminosity of X-ray bursts, 3.8×10^{38} erg/s (Kuulkers et al. 2003), the maximum distance to the source was estimated to be 7 kpc. (Serino et al. 2015)

(Serino et al. 2015)

type I X-ray bursts



(Serino et al. 2015)



This study: revisit follow up observations

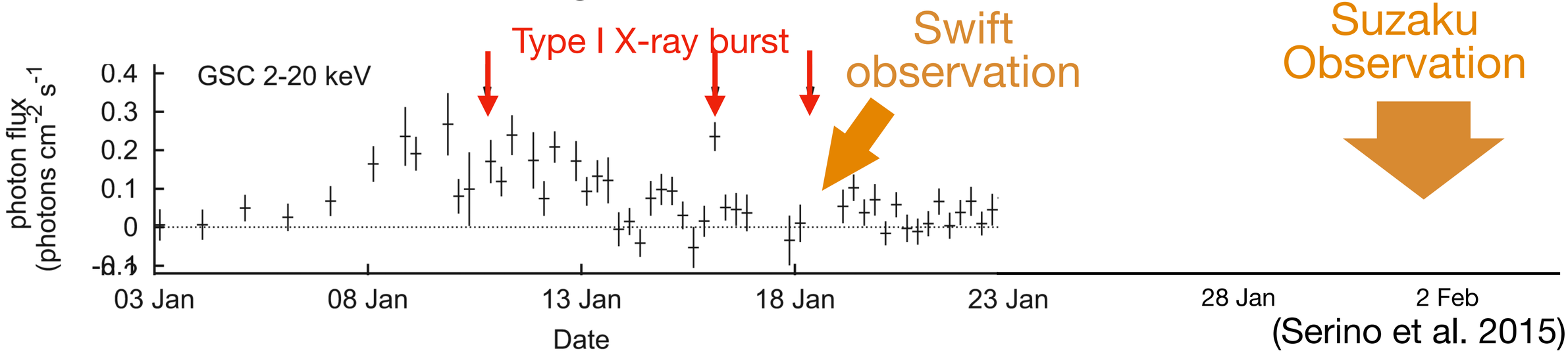
Swift/XRT

Date: 2014 January 18 (9 days after the MAXI alert and just after the 3rd type I X-ray burst)
Exporsure time: 6 ks
XRT Mode：PC (2-dimensional imaging)

Suzaku/XIS

Date: 2014 January 31– February 3 (21 – 24 days after the MAXI alert)
Exposure time: 48.8 ks

GSC Light curve of MAXI J1421-613

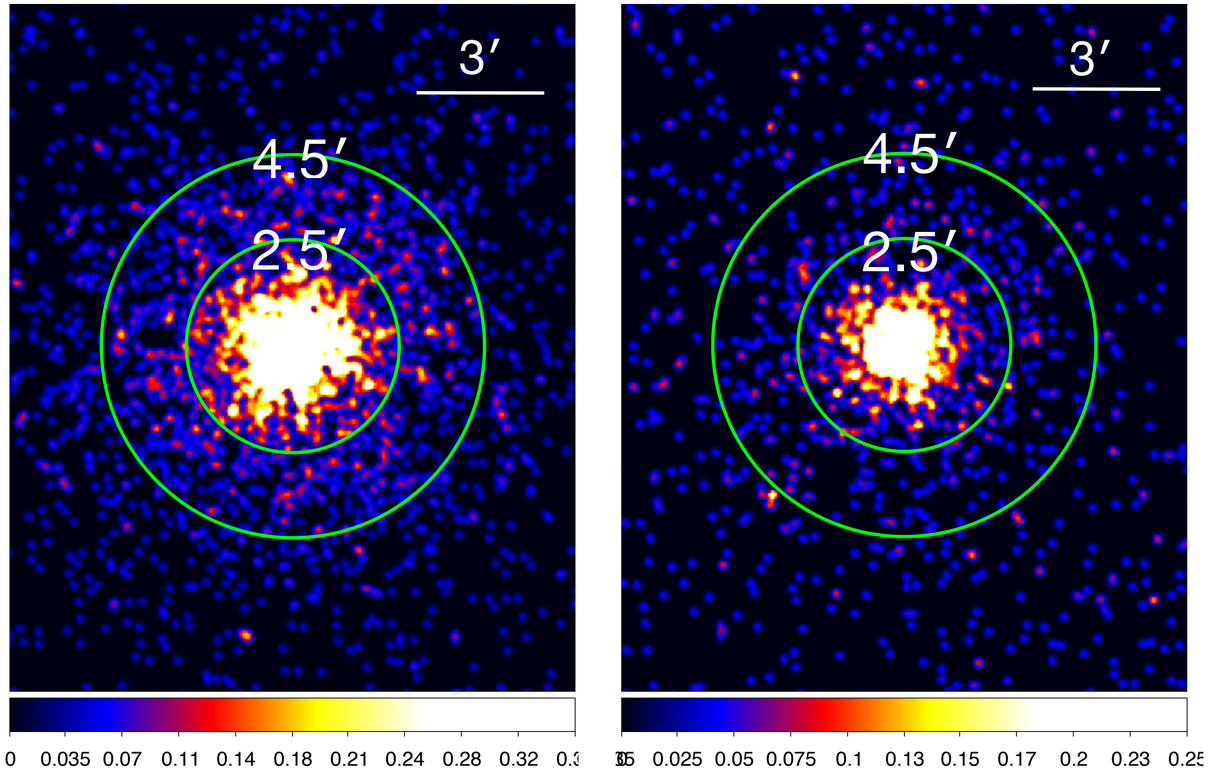


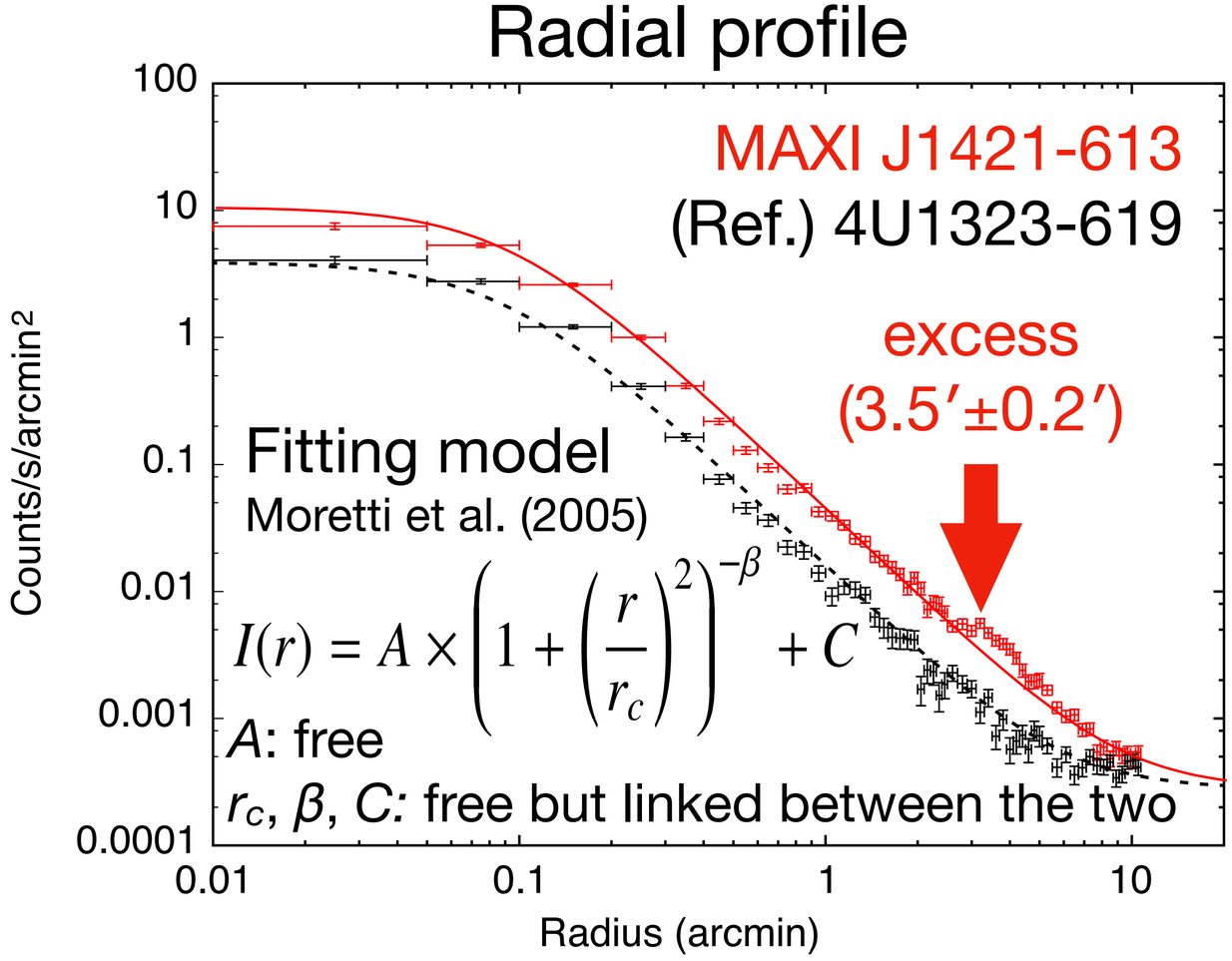
(Serino et al. 2015)

X-ray images: discovery of annular emission

Swift (1–5 keV)

MAXI J1421-613 (ref.) 4U 1323-619

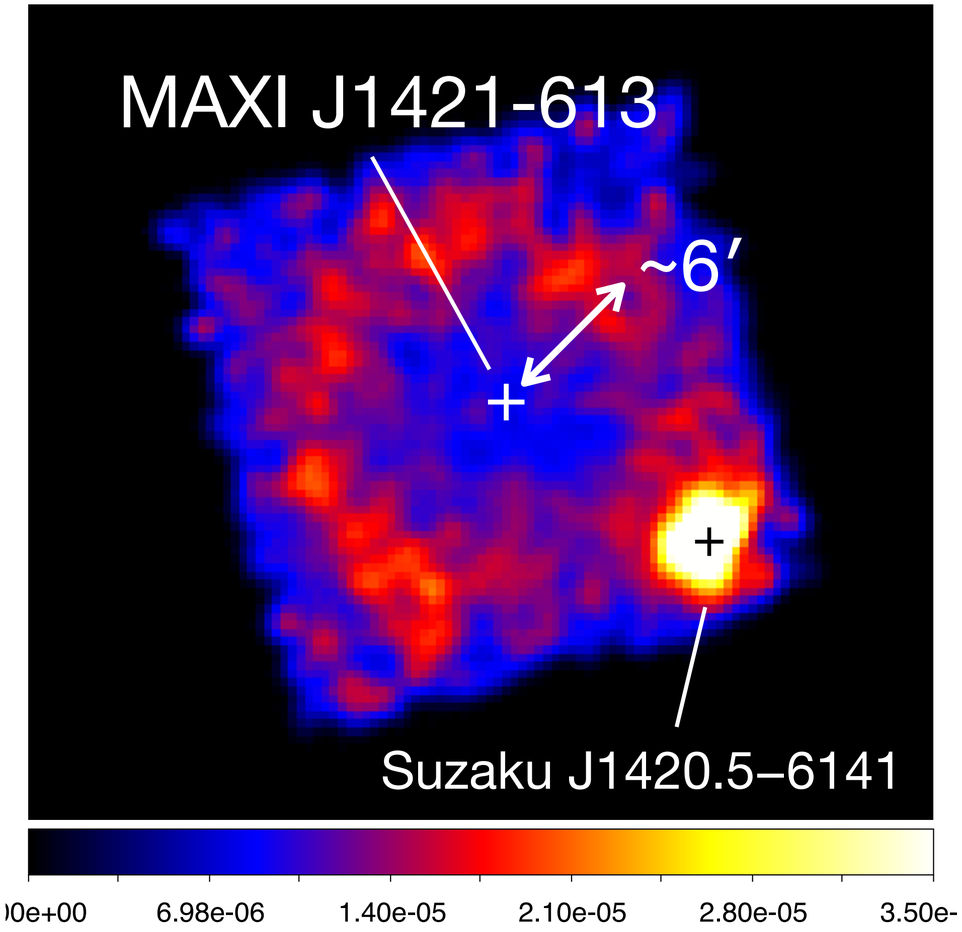




Swift found an annular emission of 3.5′ radius around MAXI J1421-613.

X-ray images: discovery of annular emission

Suzaku (2–5 keV)

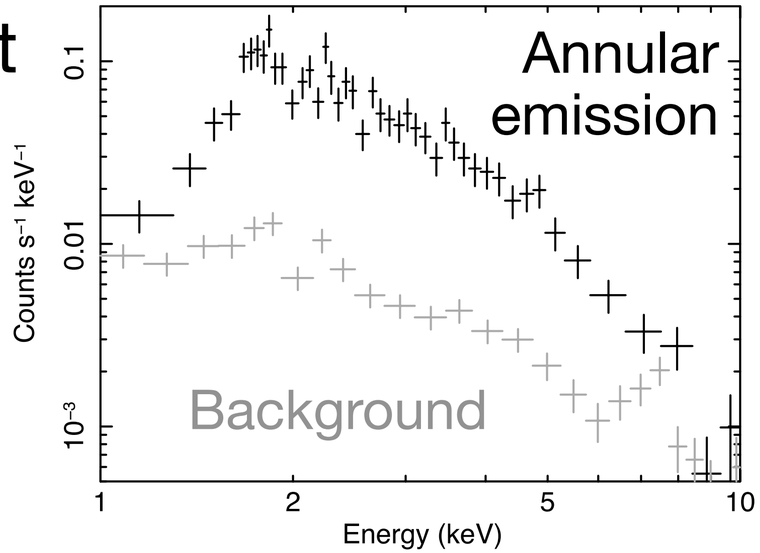


- No significant X-ray emission was found at the position of MAXI J1421–613.
- A clear annular emission of ~6′ radius was found around MAXI J1412–613.
- During the 3-day observation, the radius expanded from 5.4′±0.2′ to 5.9′±0.2′.
- Annular emission can be dust scattering of the short outburst.

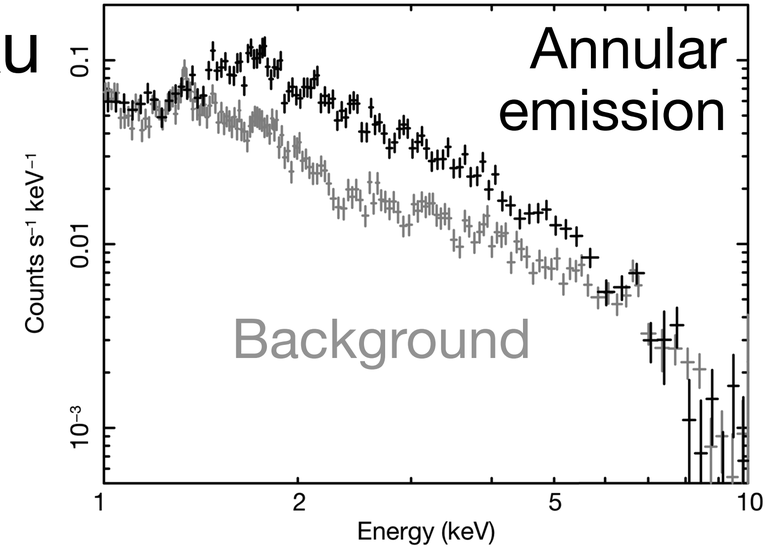
X-ray spectra of the annular emission

The annular emission exceeds the background emission in the 1.5–6 keV band.

Swift



Suzaku



Model: `phabs×powerlaw`

Parameters	Swift	Suzaku
N_H (10^{22} cm^{-2})	3.7 (fix)	3.7 ± 0.5
Γ	3.6 ± 0.2	4.2 ± 0.3
Flux* (10^{-11} erg/s/cm^2)	11.5 ± 0.7	2.5 ± 0.1
χ^2/d.o.f	12.6 / 9	123.1/113

* Unabsorbed 2–5 keV flux

Discussion: origin of the annular emission

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- Photon index Γ ~ 4 is larger than the value for MAXI J1421−613 of ~2.1 by ΔΓ~2.

  differential cross-section of X-ray dust scattering
  (in optically thin limit; e.g. Draine 2003)

$$\frac{d\sigma}{d\Omega} \propto E^{-\Gamma} \quad (\Gamma=2)$$

  The annular emission is due to the dust-scattering echo of MAXI J1421-613.

- Flux of the annular emission observed by Suzaku is ~20% of that observed by Swift.

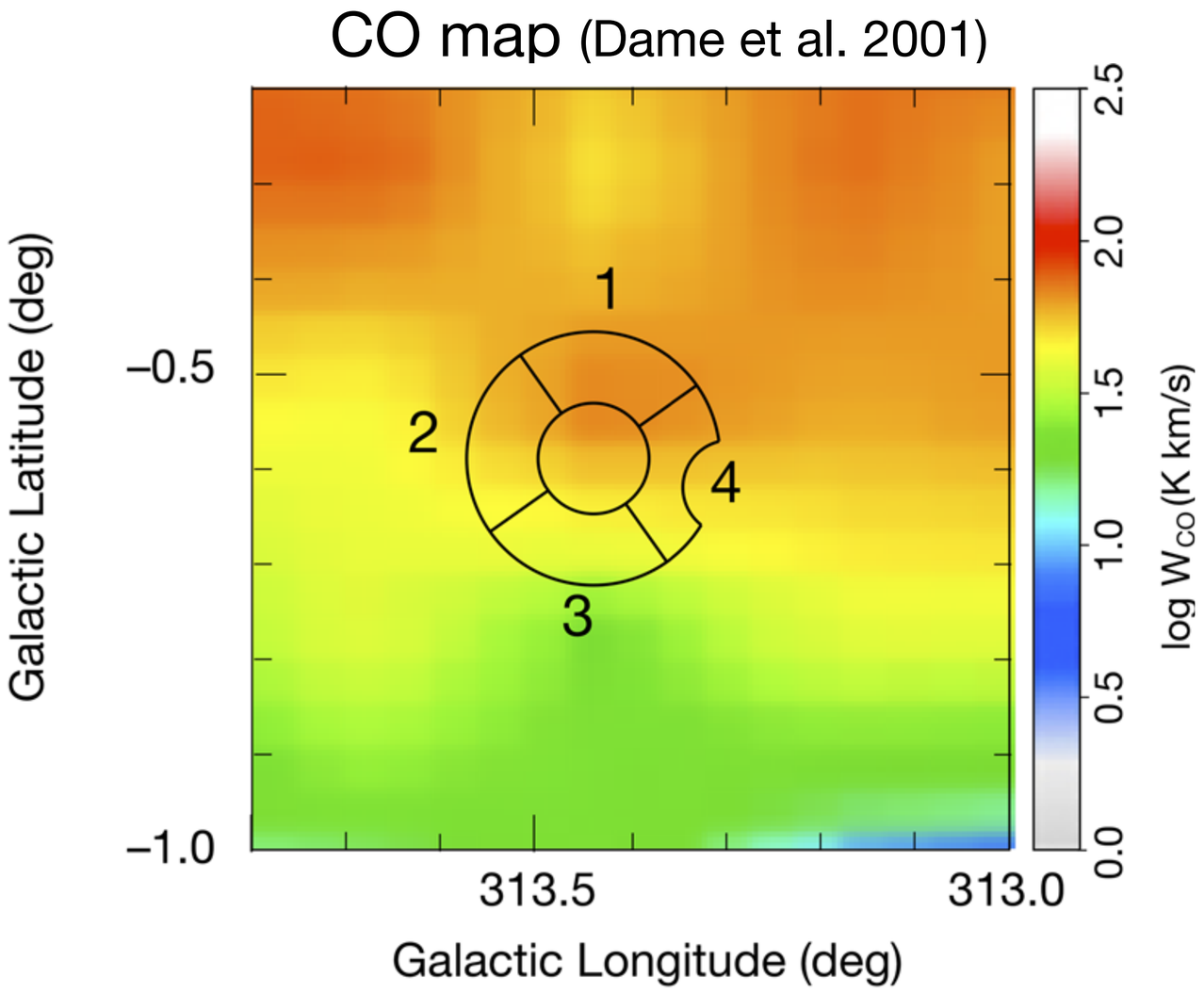
  differential cross-section of X-ray dust scattering
  (e.g. Heinz et al. 2016; Draine 2003)

$$\frac{d\sigma}{d\Omega} \propto \theta^{-\alpha} \quad (\alpha=3\text{–}4)$$

  radius of the scattering echo ∝ scattering angle

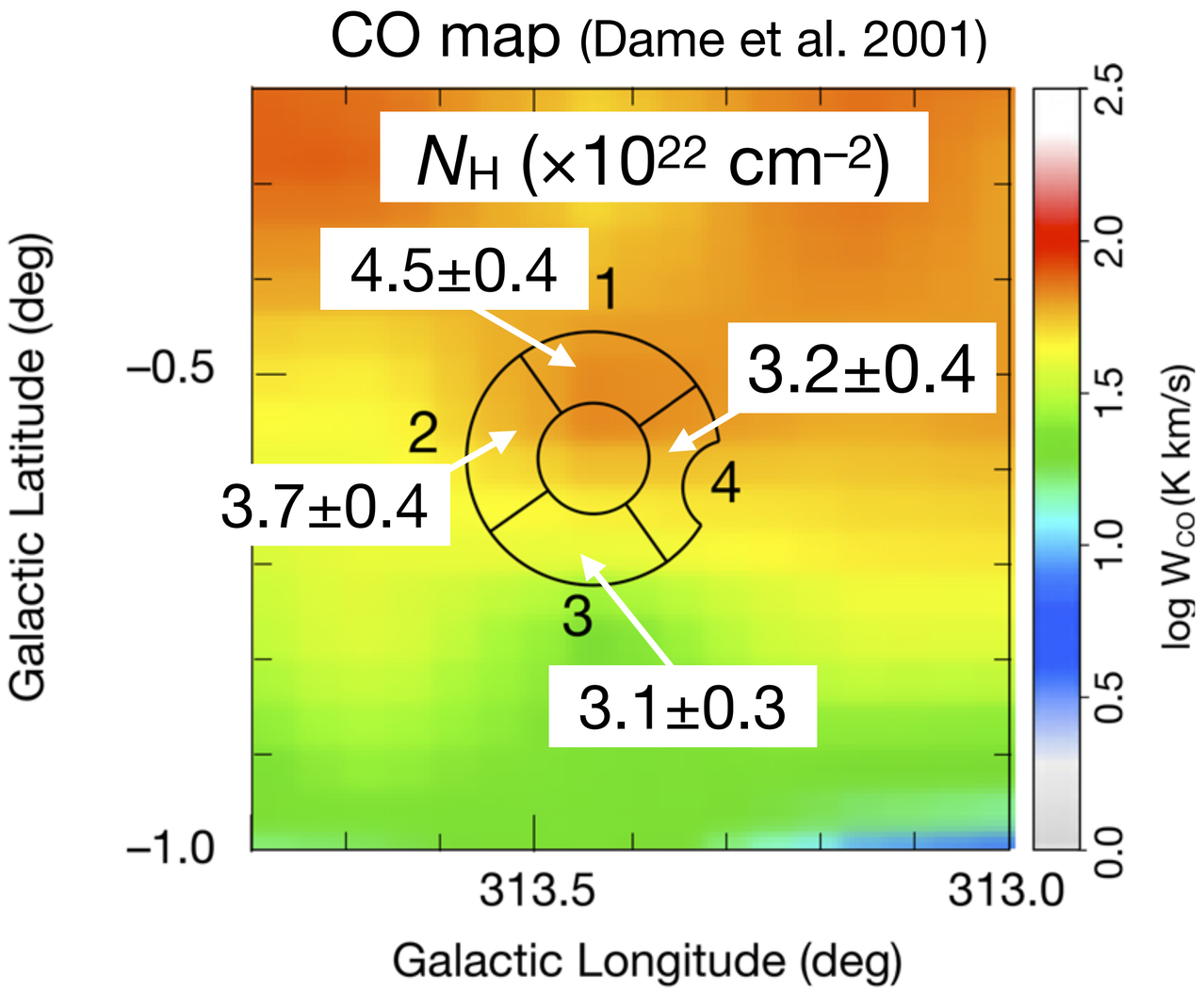
  dσ/dΩ decreases to ~20% as the radius of the annular emission expands from 3.5′ (Swift) to 5.6′ (Suzaku).
  Flux decrease is also explained by the dust scattering scenario.

Discussion: CO map



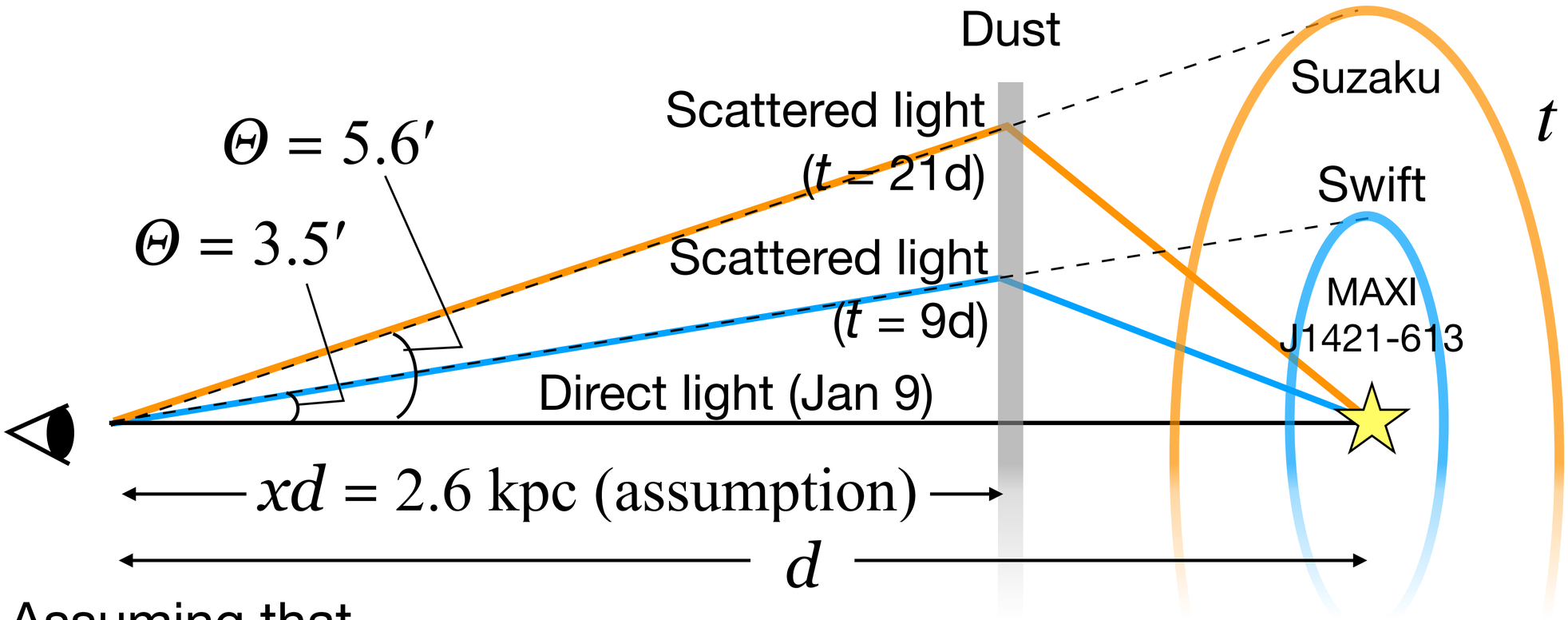
- CO cloud was found towards the annular emission, and its distance is 2.6 kpc.
- We divided the annular region into quadrants and extracted a spectrum from each quadrant to obtain N_H.
- N_H correlates with the CO distribution.
- MAXI J1421-613 is located behind the CO cloud.

Discussion: CO map



- CO cloud was found towards the annular emission, and its distance is ~2.6 kpc.
- We divided the annular region into quadrants and extracted a spectrum from each quadrant to obtain N_H.
- N_H correlates with the CO distribution.
- MAXI J1421-613 is located behind the CO cloud.

Discussion: distance to MAXI J1421-613



$$t = \frac{1}{2c}\frac{xd}{1-x}\Theta^2$$

(Trumper & Schonfelder 1973)

Assuming that

- the direct light was radiated on Jan. 9, at which the outburst peaked in the flux.
- the dust layer responsible for the annular emission is located at the same position as the CO cloud ($xd = 2.6$ kpc).

→ We estimated the distance to MAXI J1421– 613 to be ~3 kpc.

Summary

Our study catches a very rare chance of the dust-scattering echo !

- We discovered an annular emission around MAXI J1421-613, which is discovered by MAXI on 9 January 2014, in Suzaku and Swift follow-up observations.
- The Swift follow-up observation (18 Jan) found an annular emission of 3.5′ radius whereas the Suzaku observation (31 Jan to 3 Feb) detected an annular emission of 6' radius around MAXI J1421-613.
- The spectra and time evolution of flux and radius of the annular emission are well explained by the dust scattering echo.
- We estimate the distance to MAXI J1421-613 to be ~3 kpc assuming that the dust layer is at the same location as the CO cloud in front of MAXIJ1421-613.