



Spectro-polarimetric study of GX 9+9 using IXPE and AstroSat

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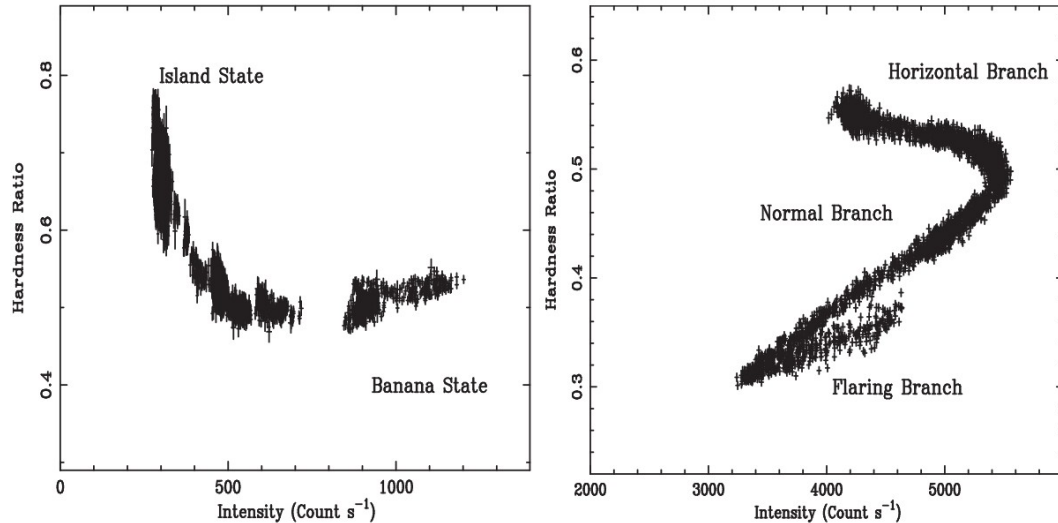
U R Rao Satellite Center (URSC)

Indian Space Research Organization (ISRO)

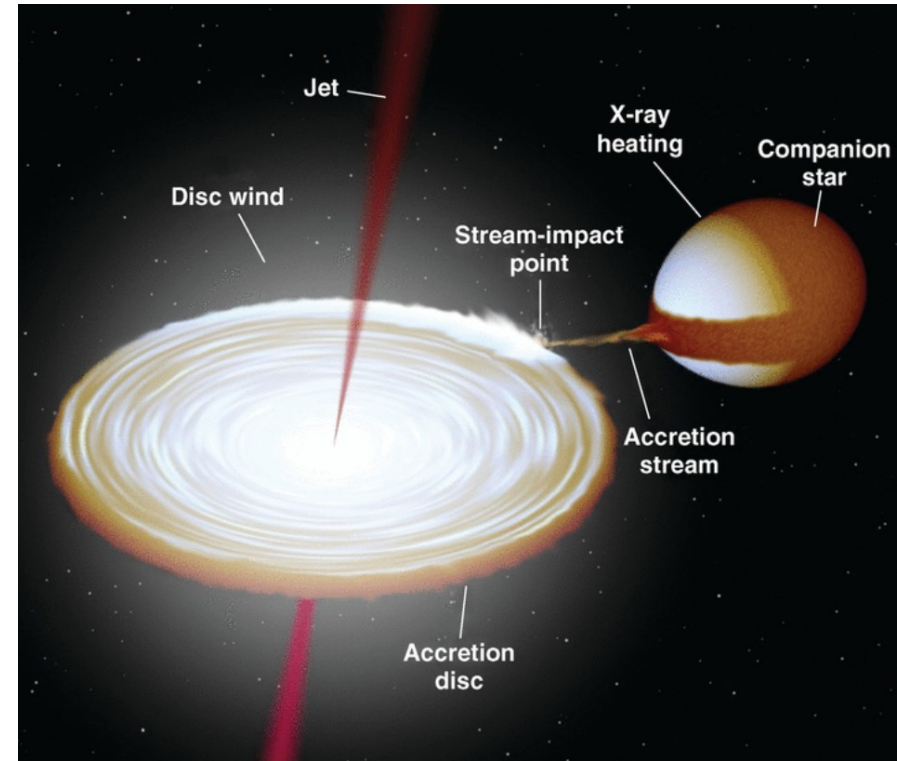
Collaborators: Dr Vivek K Agrawal, Kiran M Jayasurya

Neutron Star Low Mass X-ray Binaries (NS - LMXBs)

- Weakly magnetized ($B \sim 10^{8-10}$ G) NS accreting from low mass companion via roche lobe overflow
- Highly variable
- Classified as atoll and Z sources...



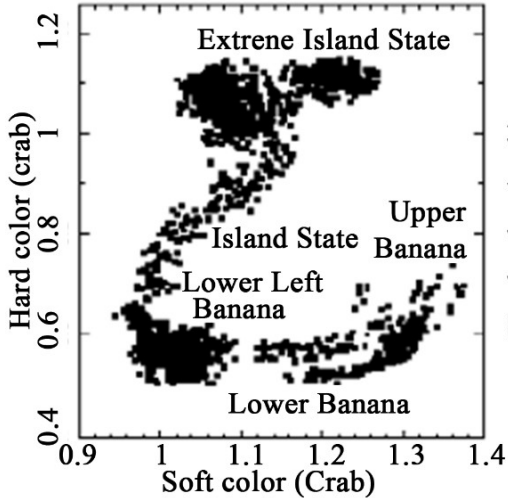
Church et al. (2014)



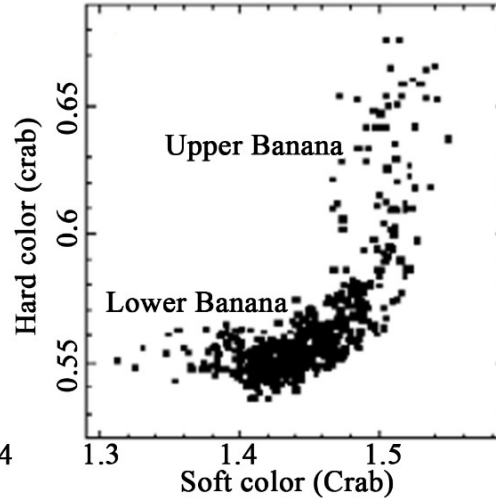
Low mass X-ray Binary system: schematic

Neutron Star Low Mass X-ray Binaries (NS - LMXBs)

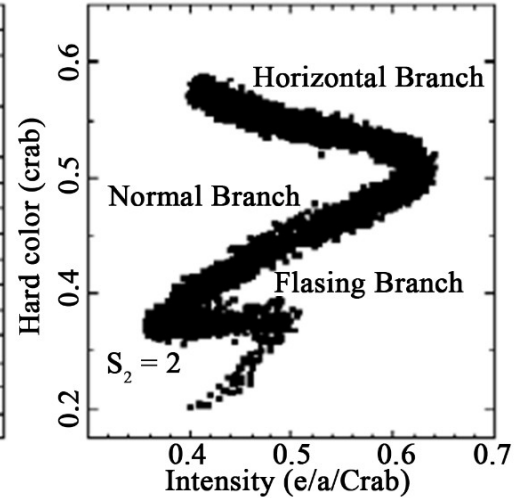
- Mainly divided into 3 categories:



LHS atoll source
($L \sim 10^{36}$ ergs/s)



HSS atoll source
($L \sim 10^{37} - 10^{38}$ ergs/s)



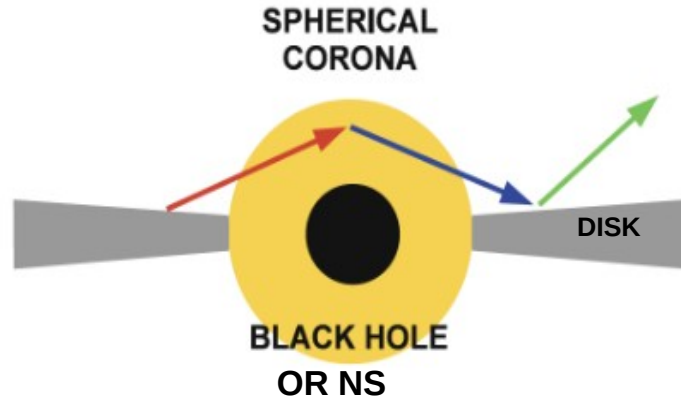
HSS Z-source
($L > 10^{38}$ ergs/s)

Van der Klis (2006)

- Timescale of variations – hours to days
- ‘Eastern’ vs ‘Western’ model scenarios

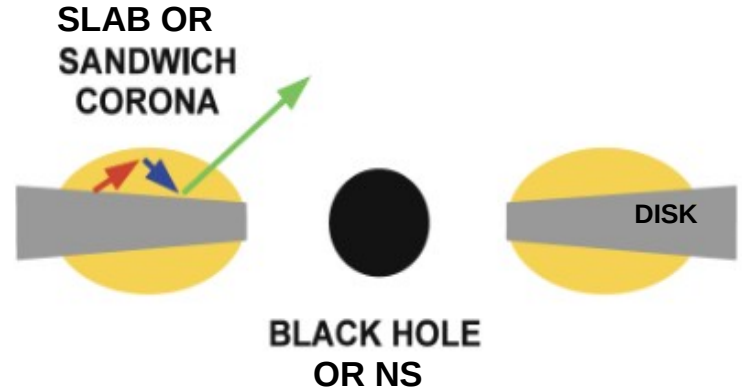
Neutron Star Low Mass X-ray Binaries (NS - LMXBs)

Bambi et al. (2017)



'Eastern' model

(Mitsuda et al. 1984)



'Western' model

(White et al. 1988)

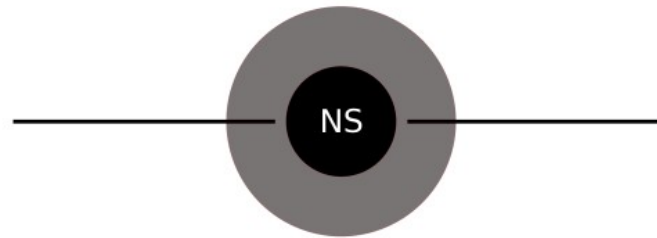
- Thermal (NS/BL/Disk) + Non-thermal (Comptonised) + Reflection?
- Spectroscopy is **degenerate**
- **Polarimetry can probe the geometry of accretion flow...**

Origin?
Location?
Geometry?

Slab/Sandwich



Spherical



Wedge

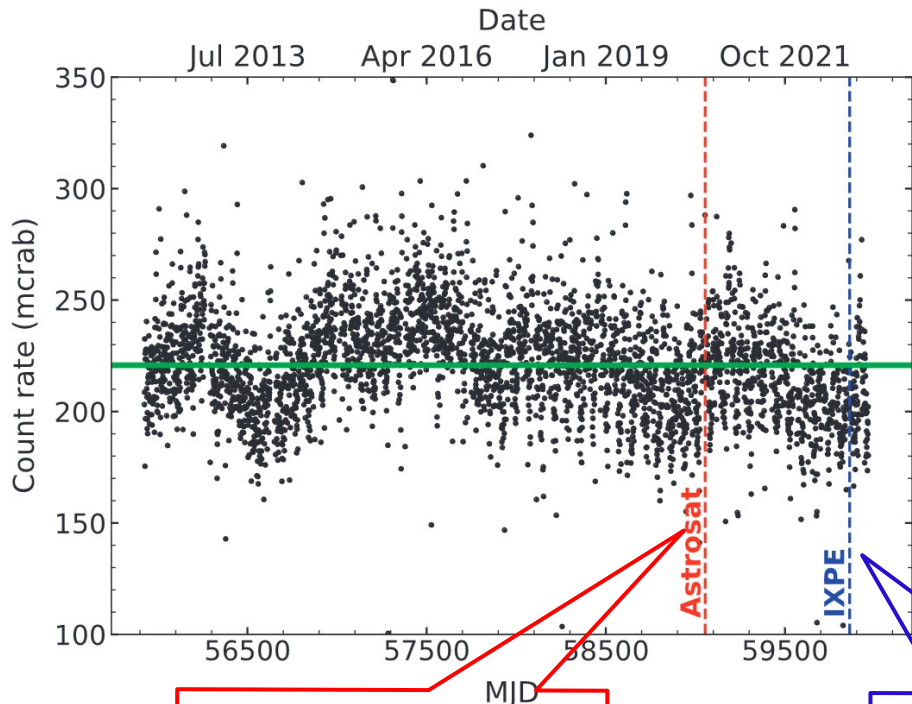


Different possible corona geometries. *Capitanio et al. 2023*

- Discovered in 1967 by a sounding rocket experiment
- Accreting from early M-class dwarf
- Classified as **bright atoll-type NS binary** (~ 200 mcrab in 2 – 20 keV)
 - Similar class as GX 9+1, GX 3+1, GX 13+1
- Persistent atoll, usually found in the high soft state
- 4.2 h orbital period – from optical and X-ray modulations
- Distance $\sim 5 - 7$ kpc (Galactic bulge object)
- Inclination estimates $\sim 40 - 60^\circ$
- **Multiple spectral models produce spectroscopically degenerate fits**

Observations and data analysis

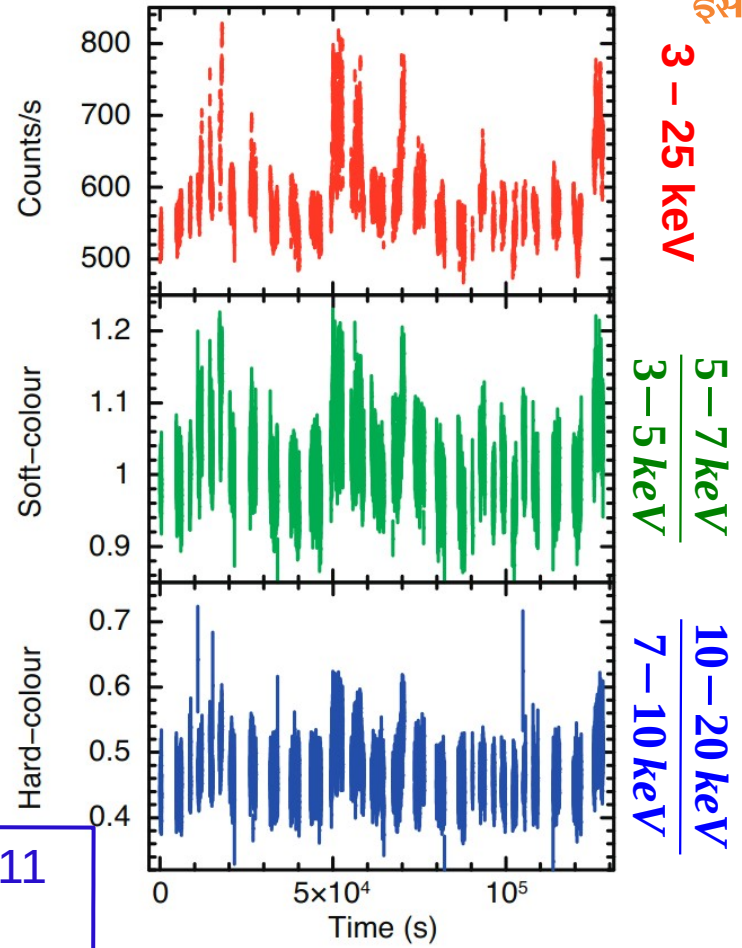
MAXI/GSC 2 – 20 keV light curve



2020 July 25 – 27
(56 ks)

2022 Oct 9 – 11
(92 ks)

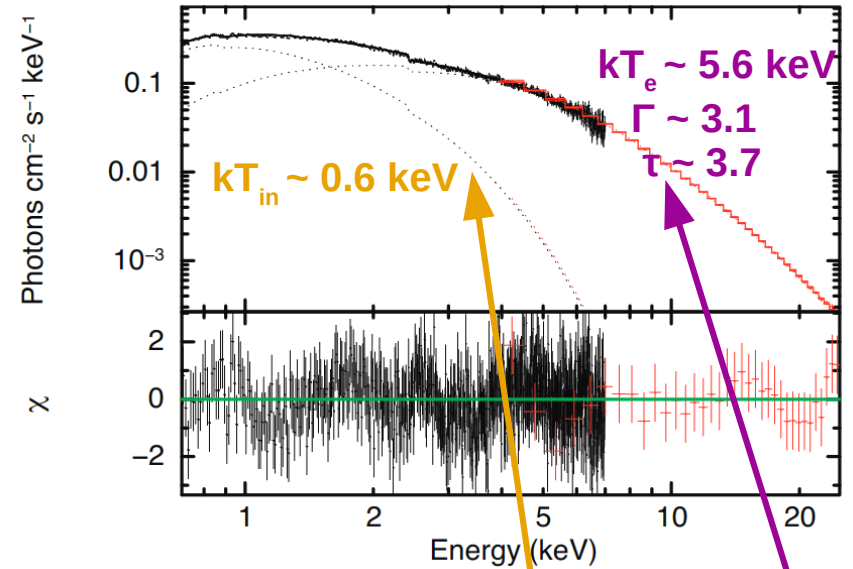
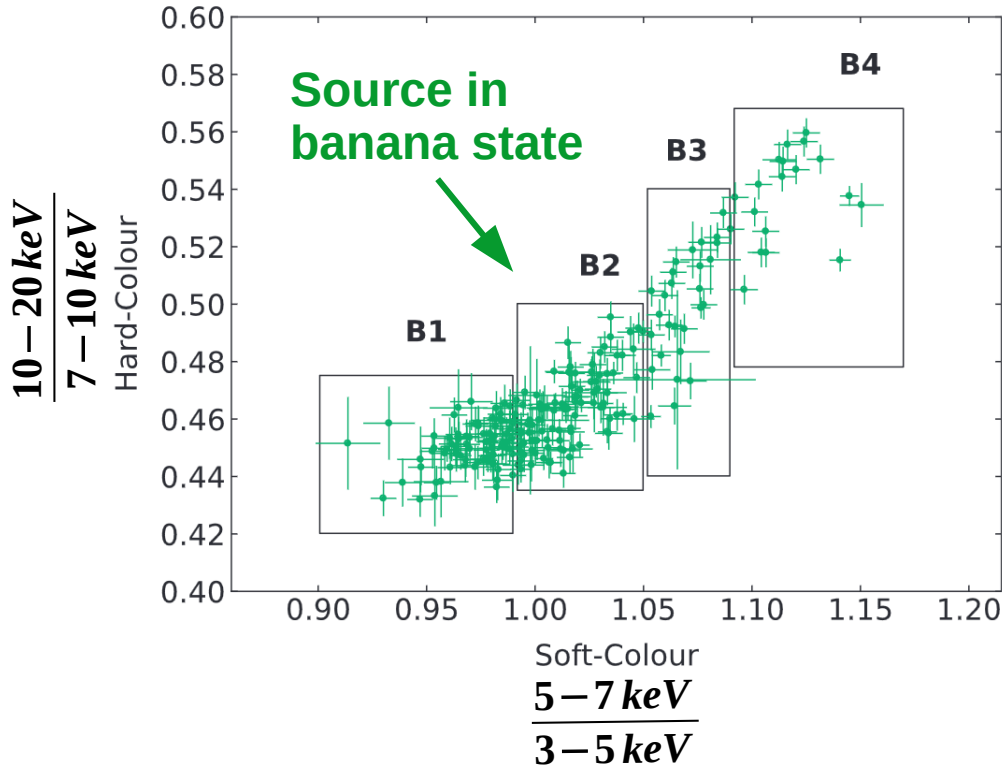
AstroSat / LAXPC



Results: spectral analysis

AstroSat / SXT + LAXPC
(0.7 – 7, 4 – 25 keV)

AstroSat / LAXPC
Color-color diagram

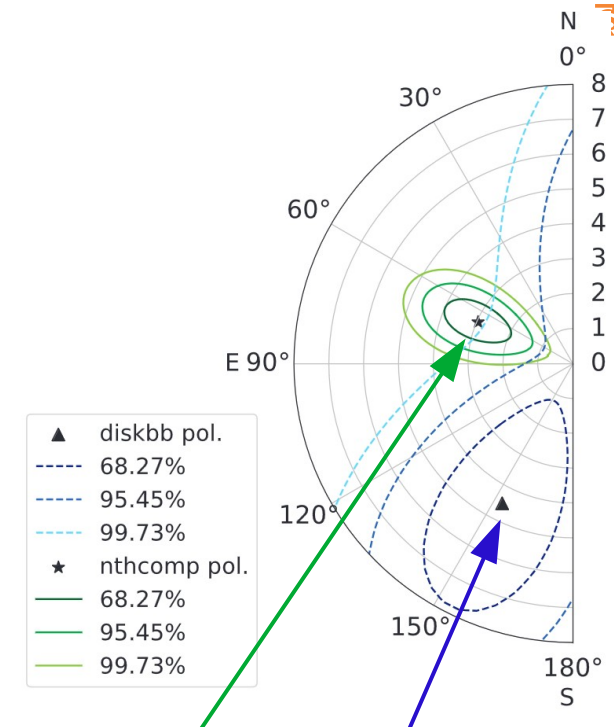
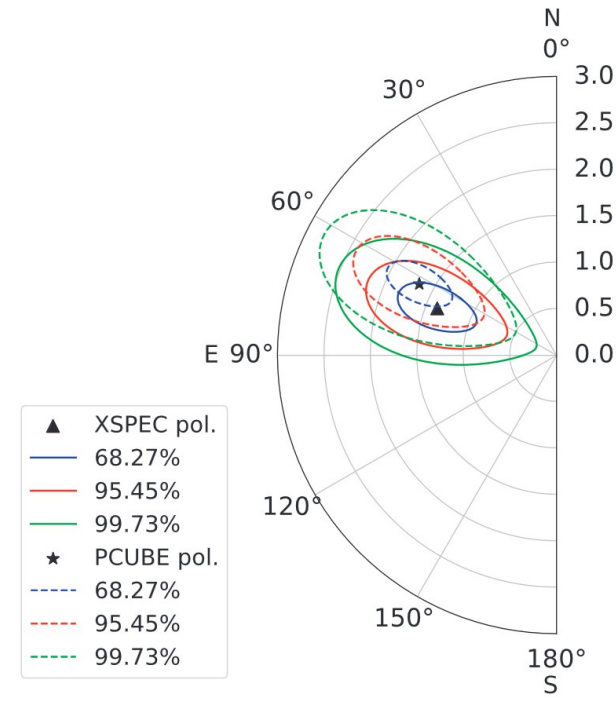
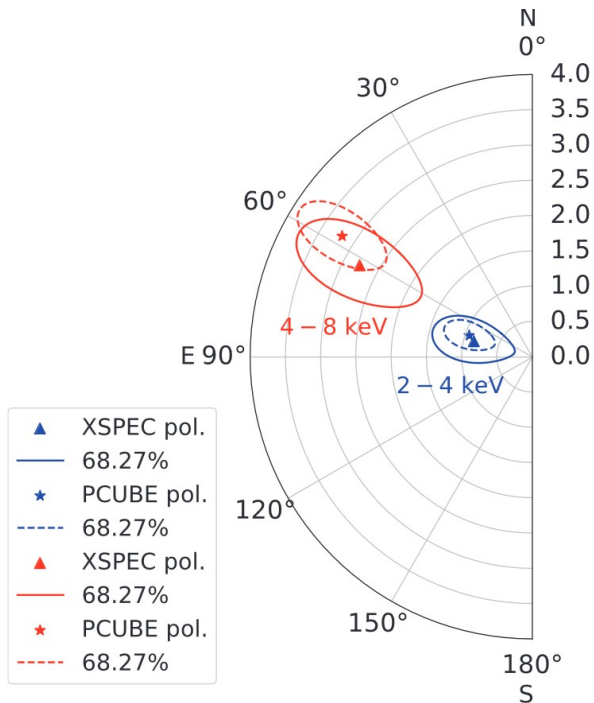


Model 1 (eastern-like): **diskbb** + **nThcomp**
(seed: single T BB)

vs

Model 2 (western-like): **body** + **nThcomp**
(seed: multi T BB)

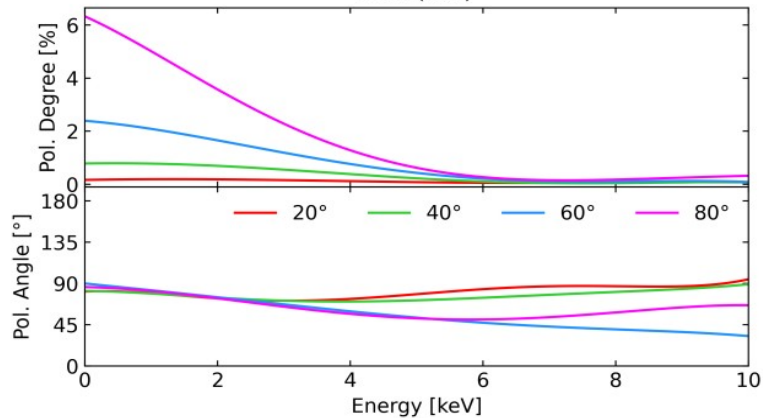
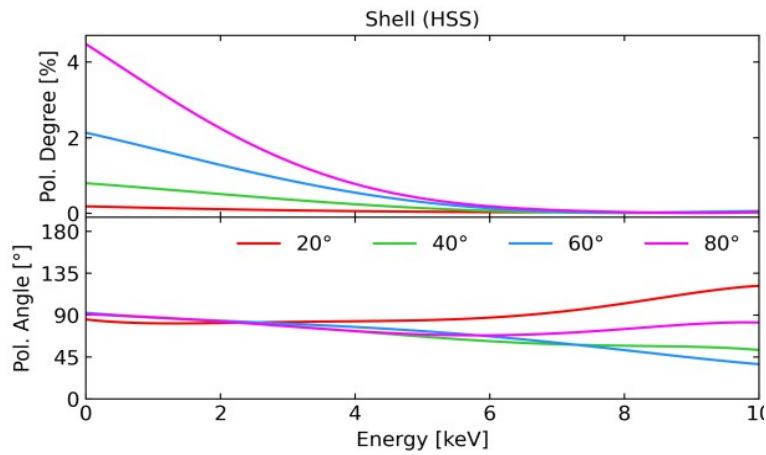
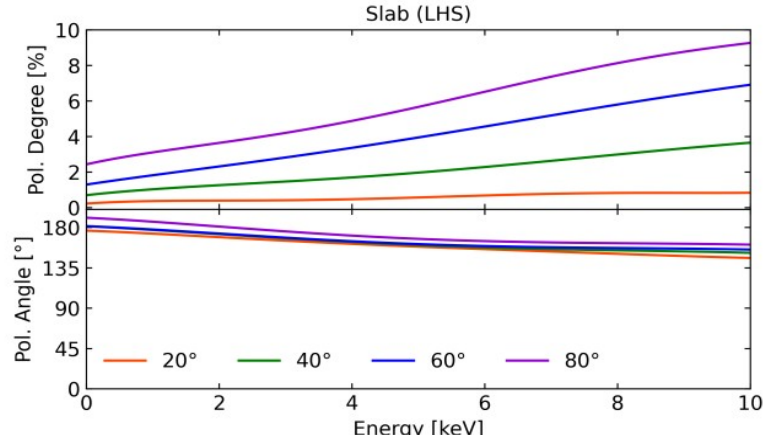
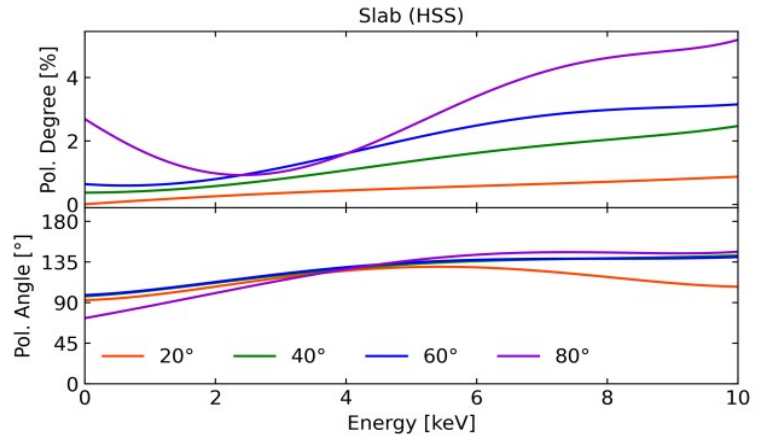
Produce equivalent fits



	2 – 4 keV	4 – 8 keV	2 – 8 keV
PD (%)	~ 1 %	3.2 ± 0.7	1.7 ± 0.4
PA (deg)	...	57.6 ± 6.4	62.6 ± 6.7

diskbb PD ~ 4.5 % (1σ)
(weak detection)

nThcomp PD ~ 3 % ($> 3\sigma$) , PA ~ 66°
Unable to constrain with Model 2



- Simulation: GR MC code (MONK, Zhang et al. 2019)
- Inputs: NS params, \dot{M} , disk params, geometry of Comptonising region
- NS + disk + corona
- Disk intrinsically polarized/unpolarized

*PD and PA variation with energy for different geometries, states, inclination angles.
Gnarini et al. (2022)*

Conclusions

- First report of polarization from an atoll-type NS LMXB
- Best fit from spectro-polarimetry:
 - Thermal emission from accretion disk (weak/no polarization)
 - Compton scattered component from corona is polarized
- Absence of radio data... is PA aligned to system symmetry axis?
 - ✓ e.g. Cyg X-2, Sco X-1
- Comptonized emission possibly originates in BL / transition layer
 - ✓ Shell-type corona geometry?

Thank you for your attention!