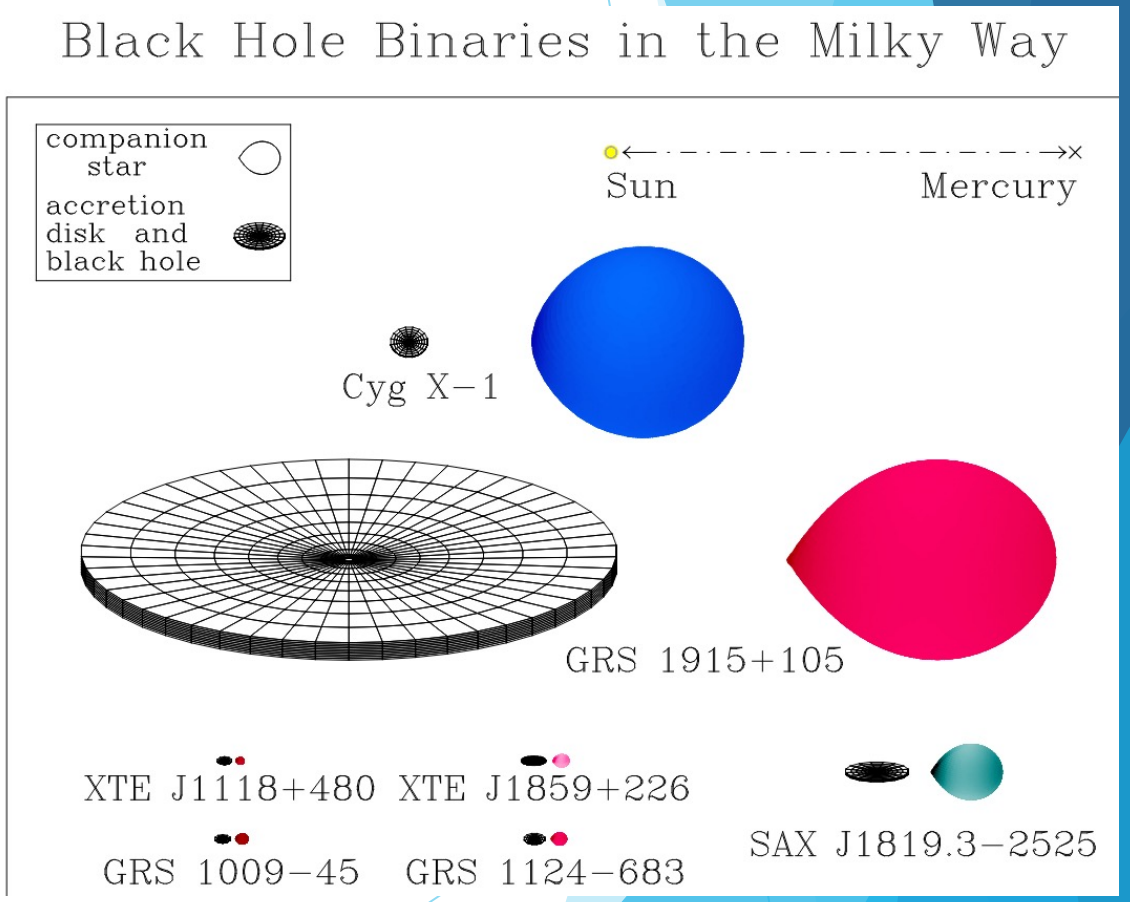
High-energy emission of Microquasars with INTEGRAL and SVOM

Tristan Bouchet, CEA/AIM

Black Hole X-ray Binaries

- X-ray binaries = compact object accreting from normal star
- Accretor = Stellar Black Hole ($M > 3\ M_{Sun}$)
- Very close orbit → **Roche Lobe overflow**
- Visible during outbursts lasting a few months
- ~60 Stellar BH found

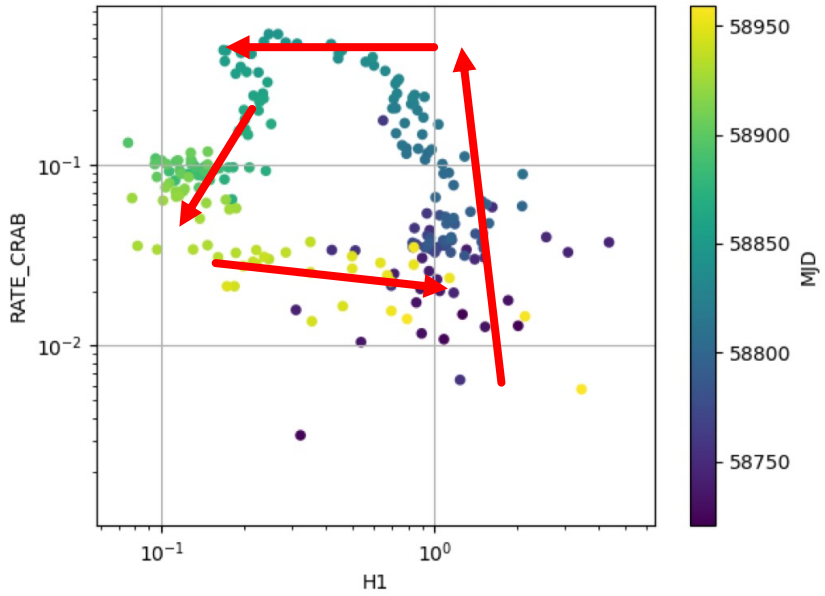


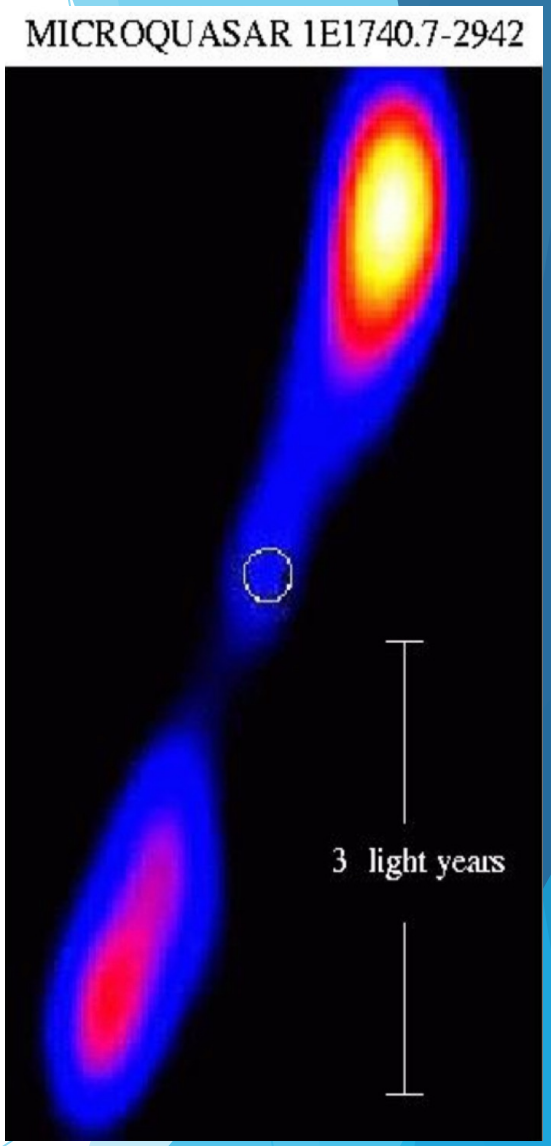
Remillard & McClintock (2006)

What is a Microquasar?

- Relativistic jet at both pole of binary → scaled-down quasar

- Synchrotron radio emission
- **Soft state / Hard state**
- Hints to different emission processes





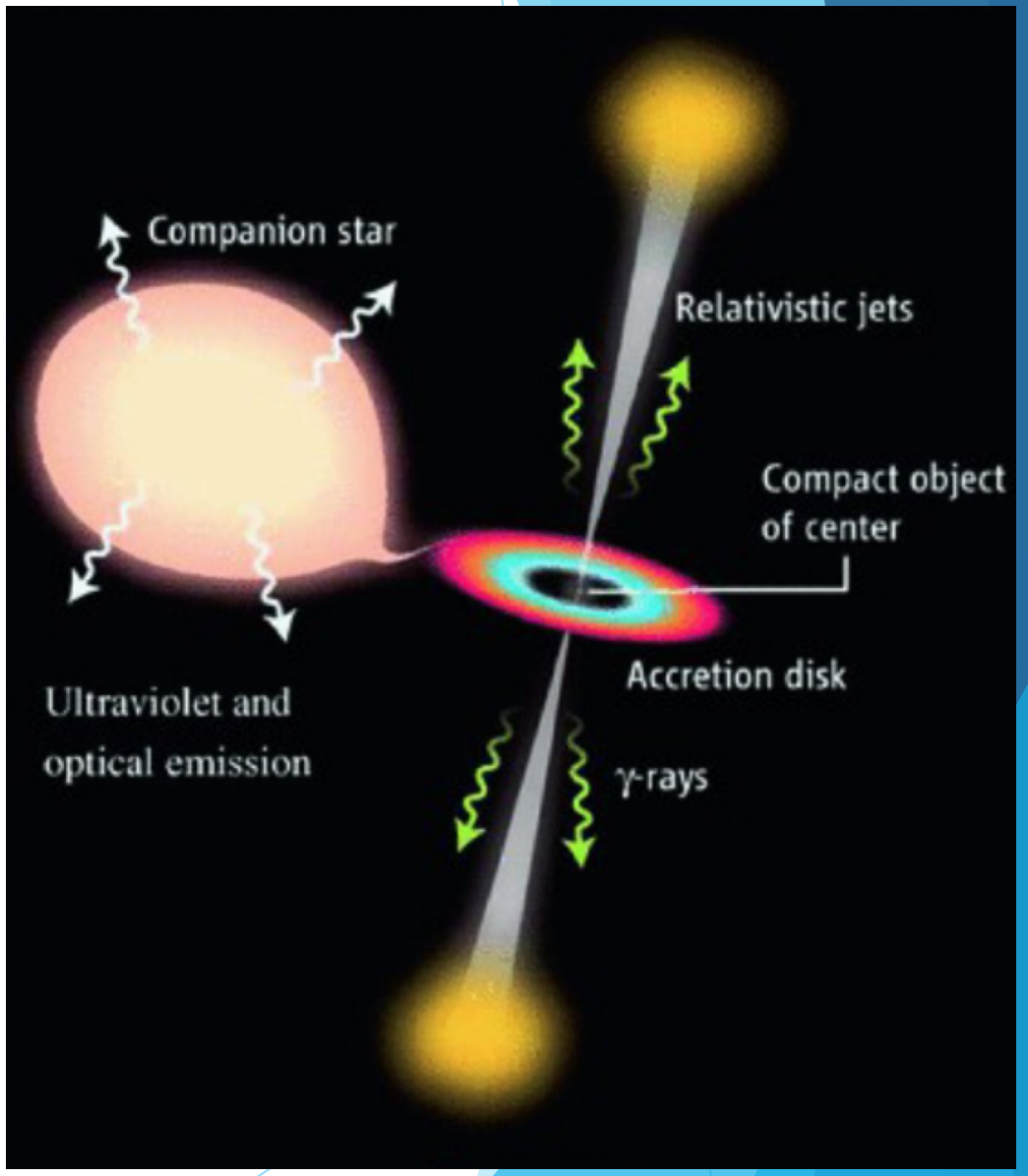
Mirabel (1992)

Emission in Microquasars

- Accretion disk (kT ~ 1 keV)
- Inverse Compton Scattering (10-100 keV):

→ Photons from the disk up-scatter on hot electrons of the corona

- Reflection on disk, Fe Kα line
- **Above 100 keV: Non-thermalized electrons? Base of the jet?** electron-positron annihilation?
- **Polarization?**



Variability

- **Quasi-periodic oscillations** (QPOs)

- Low-frequency (< 100 Hz)

→ instabilities in accretion disk or corona

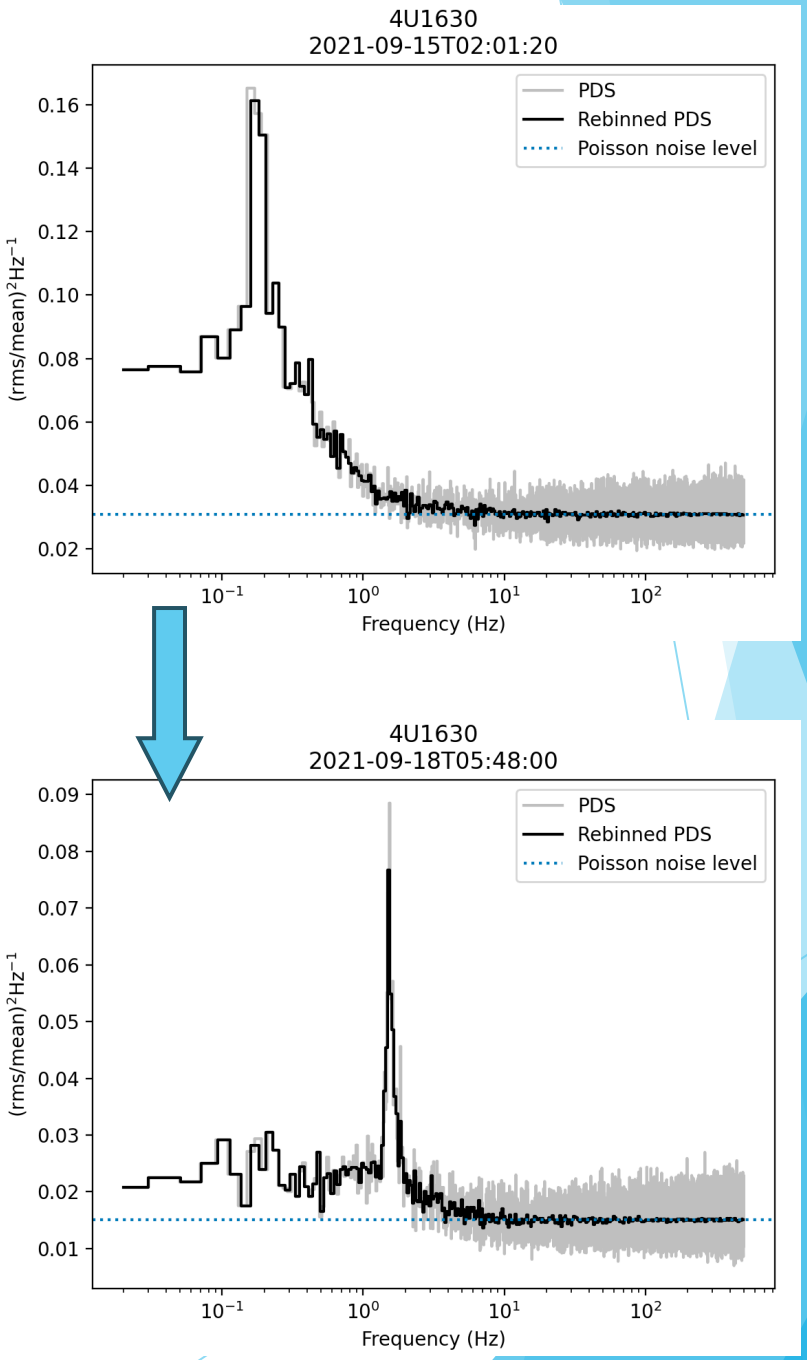
→ Lense-Thirring precession around BH

- High-frequency (> 100 Hz)

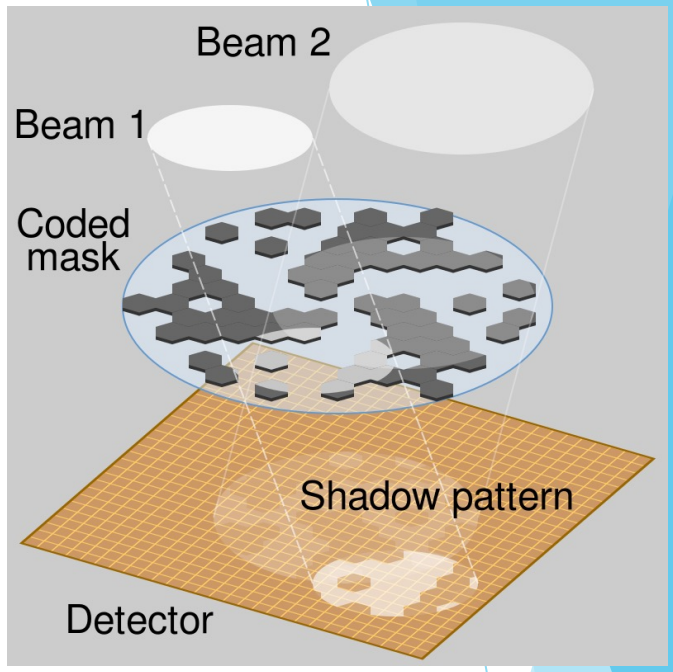
→ matter near ISCO

- mHz QPO (< 1 Hz)

→ global oscillation of disk?



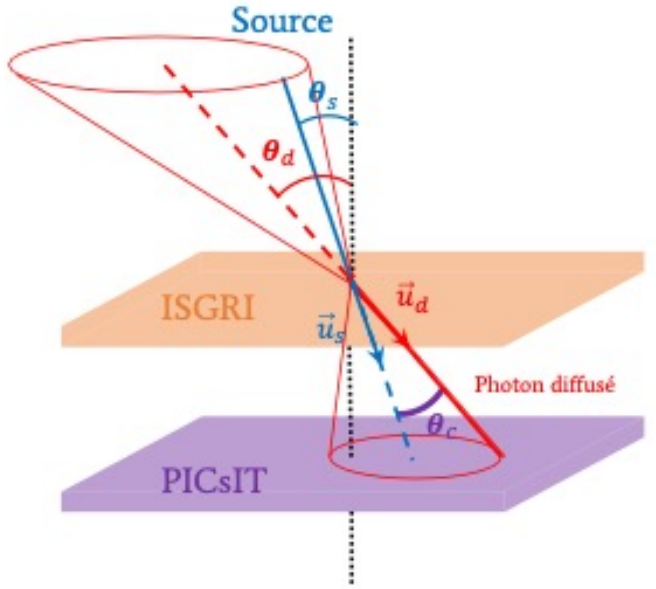
How to see in gamma-rays?



- E > 100 keV → Too high for refraction/reflection!
- Simple solution: **Coded mask** (+ some linear algebra)
- Another solution: **Compton scattering**

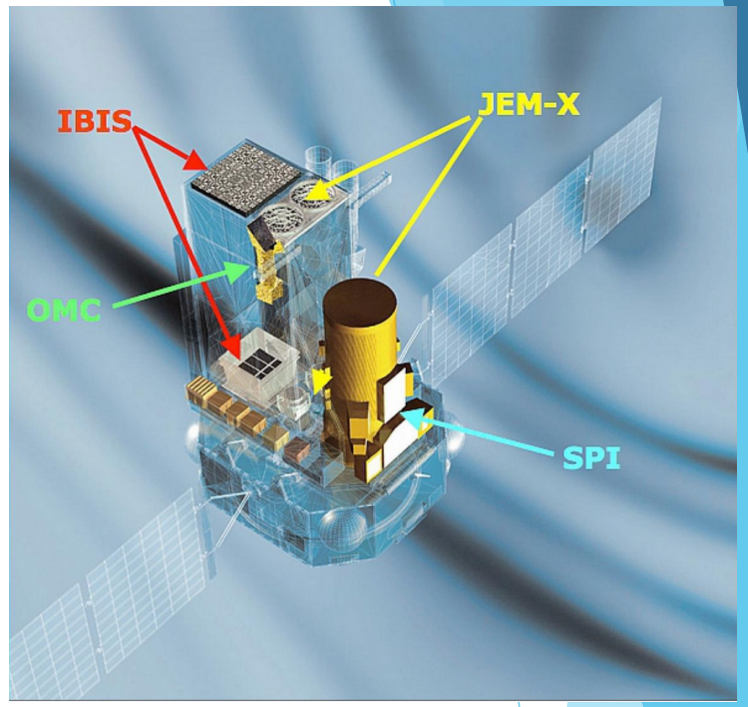
→ can see polarization

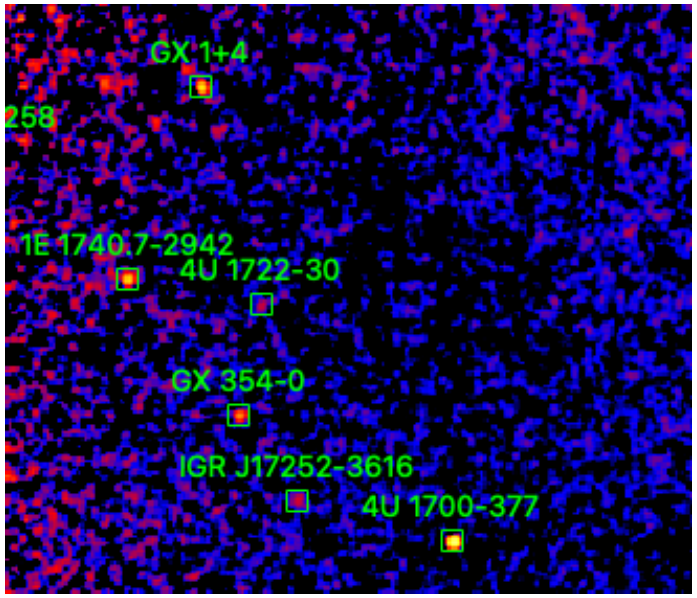
$$\cos\theta_{\mathrm{Com}} = 1 - \frac{m_e c^2}{E_2} + \frac{m_e c^2}{E_1 + E_2},$$



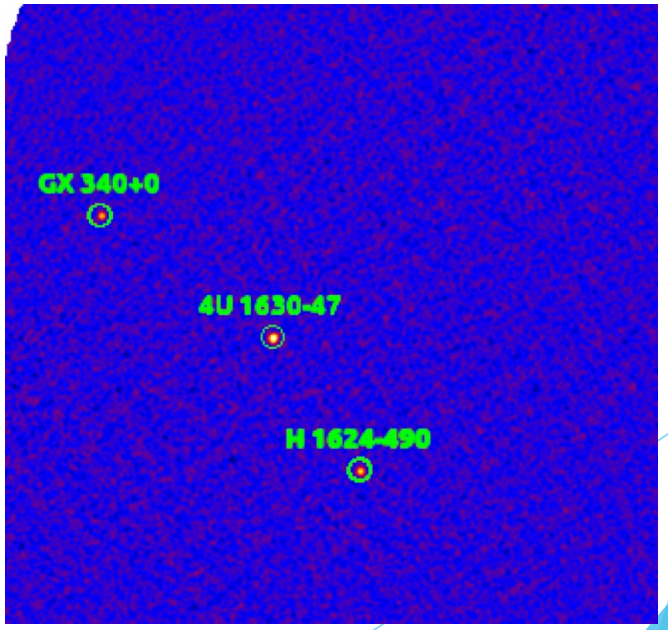
The INTEGRAL satellite

- Launched in 2002, still in activity
- Spectro-imager **between 3 keV and 2 MeV**





IBIS/ISGRI

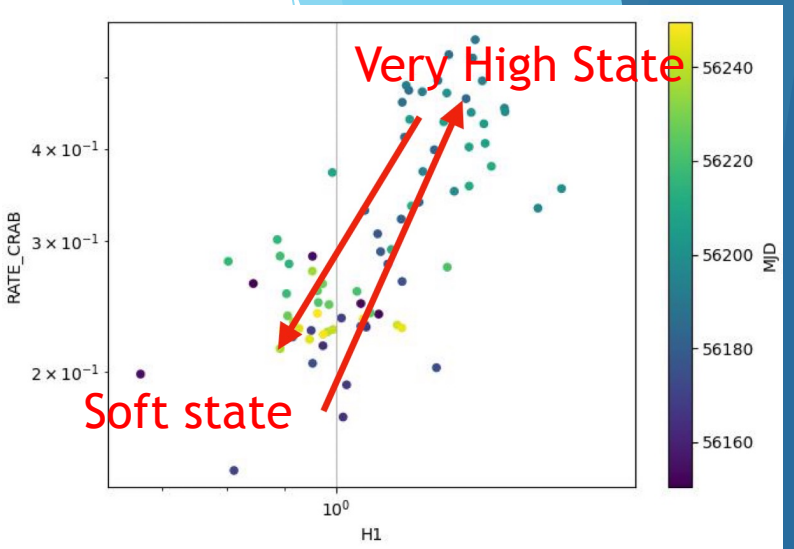


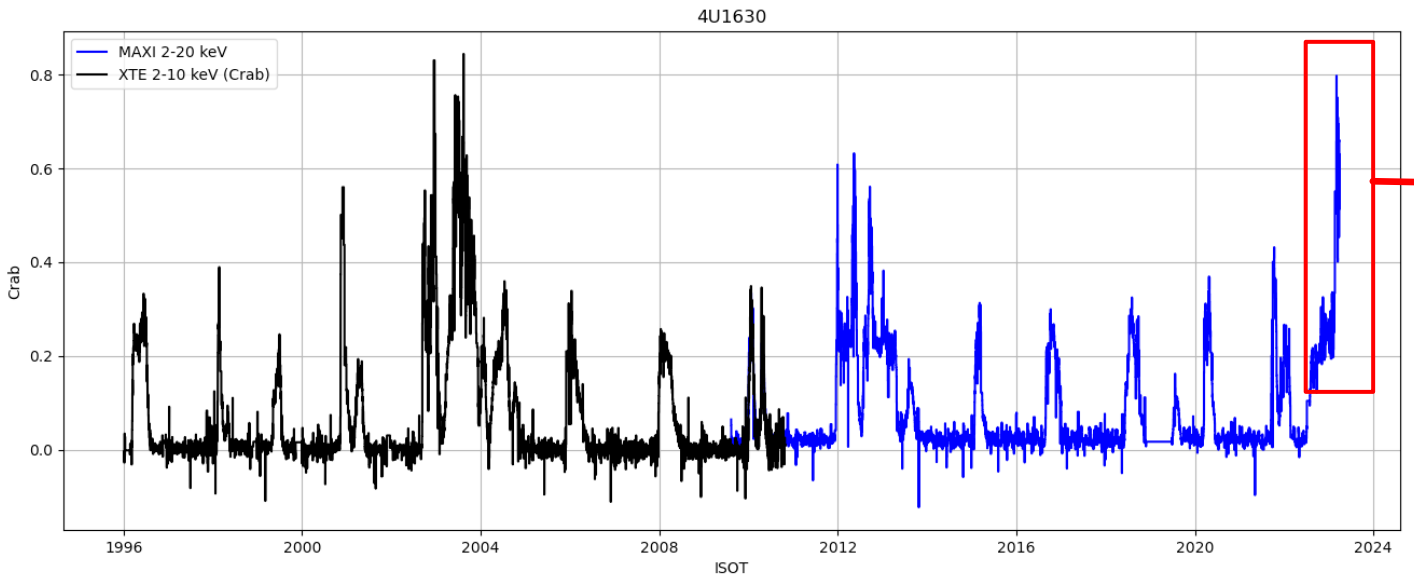
JEM-X

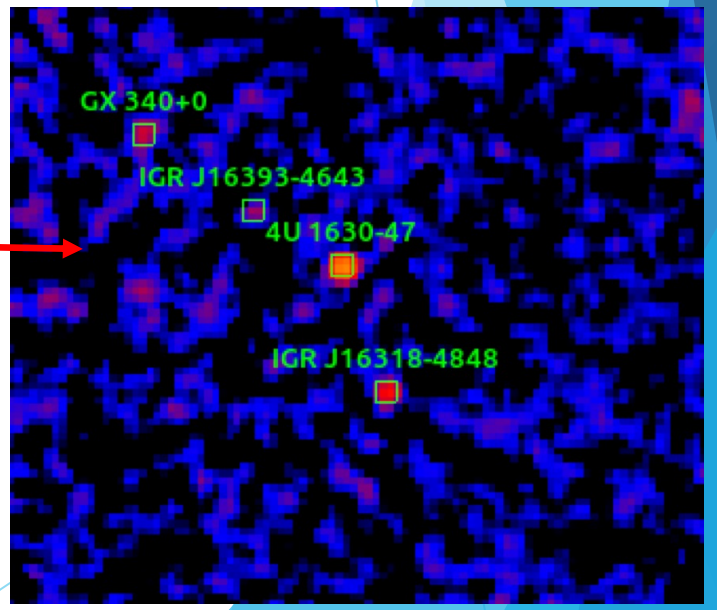
Some news from the Norma arm

- **4U 1630-47**, a strangely recurring BH located in the Norma galactic arm

- Major outburst happening now, detected by INTEGRAL in gamma-ray

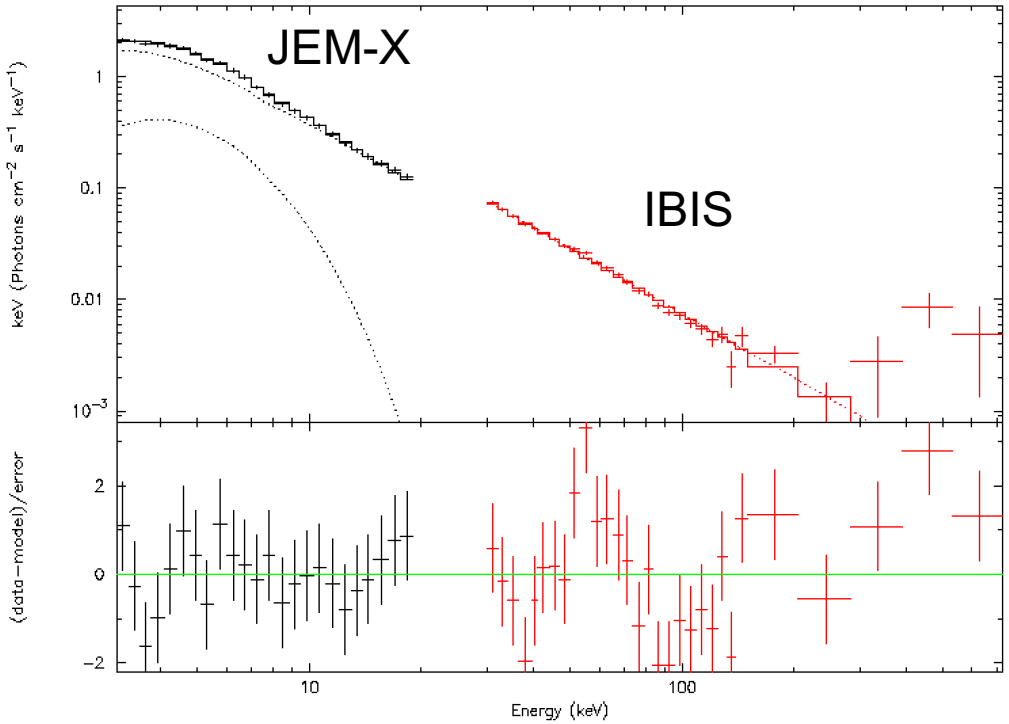




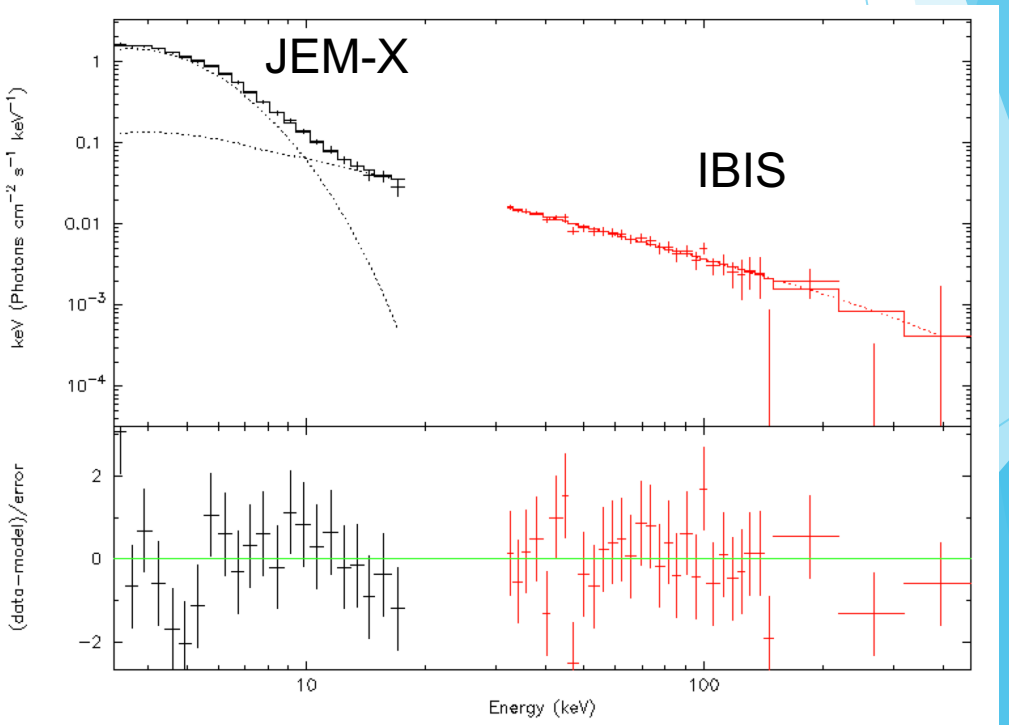


Outburst evolution with INTEGRAL

- Accretion disk (kT ~ 1.4 keV) + Inverse Compton scattering (kT_e ~ 120 keV)
- Possible excess above 300 keV?



March 2023 observations



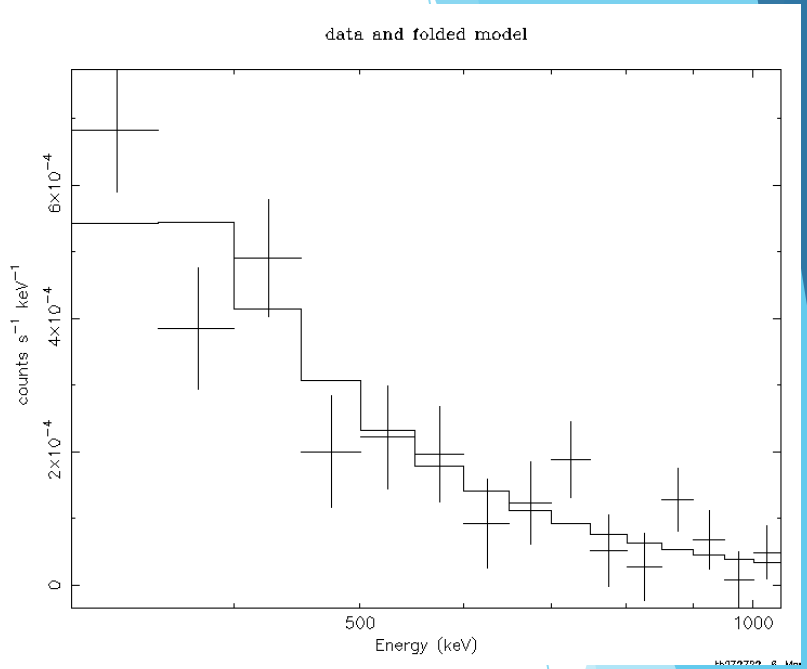
April 2023 observations

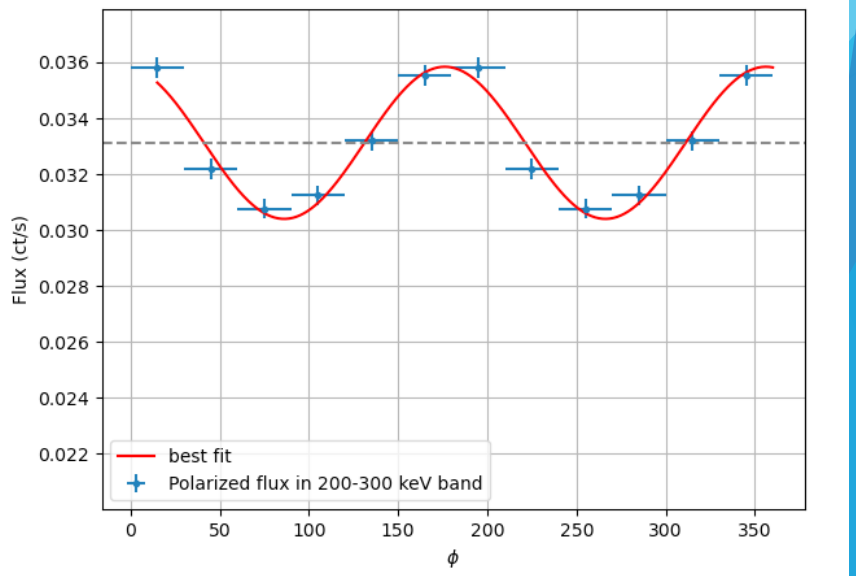
IBIS Compton-mode

- Using 2 parallel detectors on INTEGRAL (ISGRI + PICsIT)
- Developped by P. Laurent at CEA

- Spectra above 300 keV
- Crab nebula=standard source (Γ ~ 2.3 ± 0.3)

- Compton scattering angle depends on polarization
- Cygnus X-1, Crab nebula, or any bright gamma source
- Allows to find Polarization angle and fraction



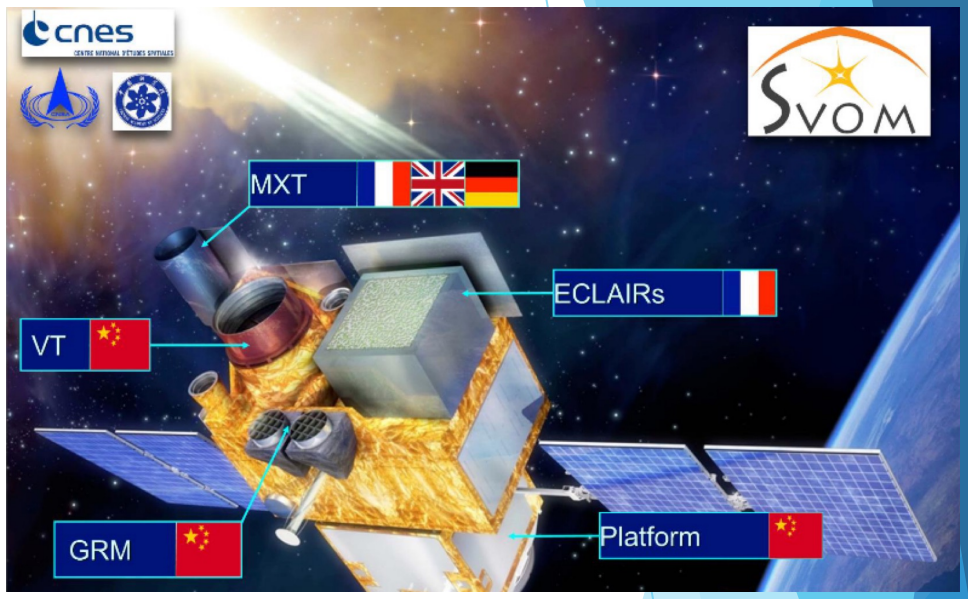


For the future

- SVOM mission, launch December 2023

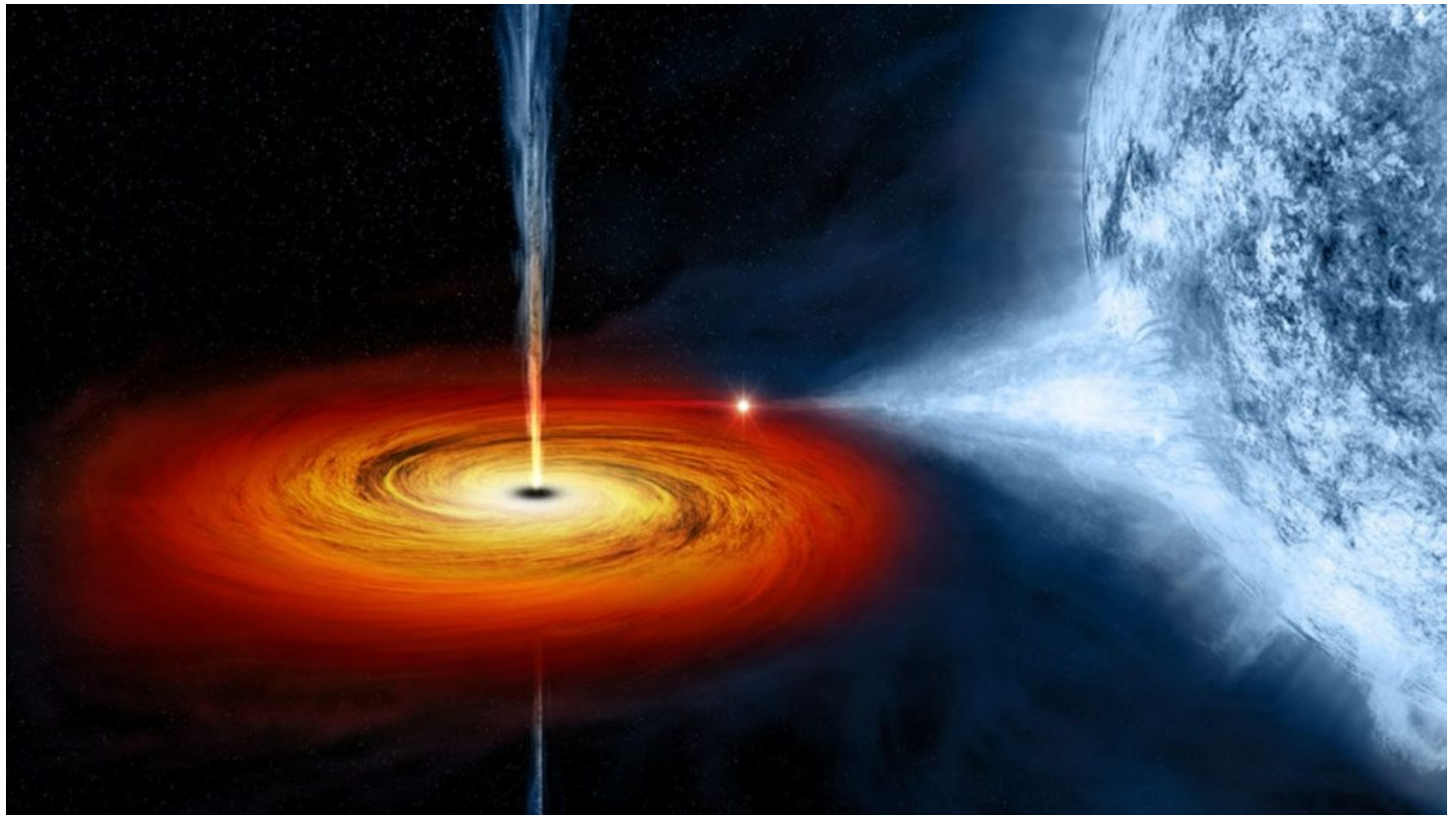
→ ECLAIR: spectro-imager at **4 – 150 keV,** will help monitor BH activities in hard X-ray

→ MXT: ‘lobster-eye’ optics at **0.2 - 10 keV**



- COSI mission, launch 2026

→ Compton telescope, **200 keV - 5 MeV**



Questions? Comments?