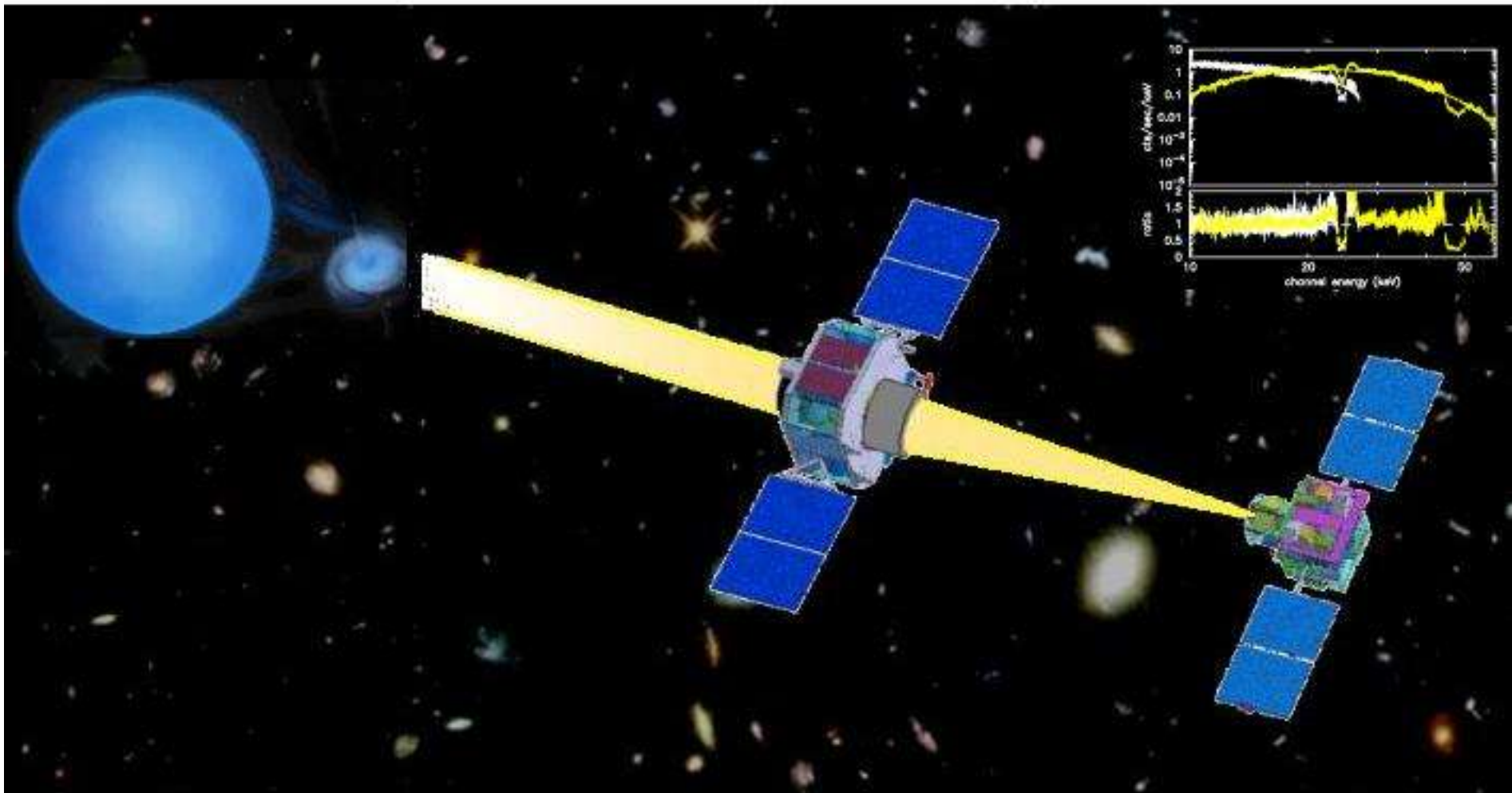


X-raying Accretion Columns

Cyclotron line studies with SIMBOL-X

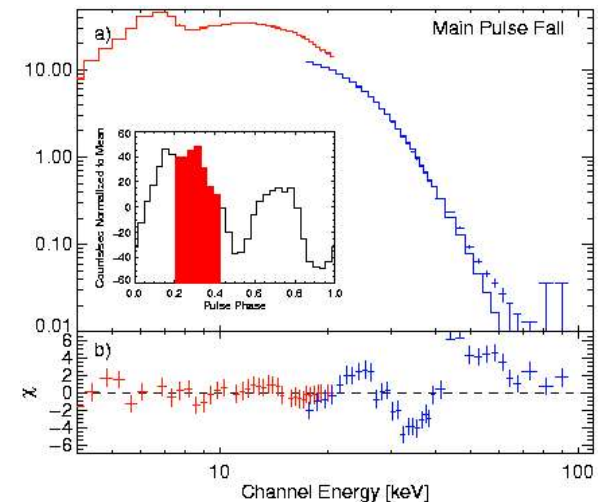
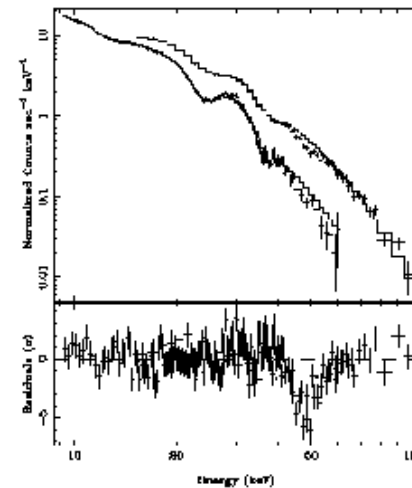
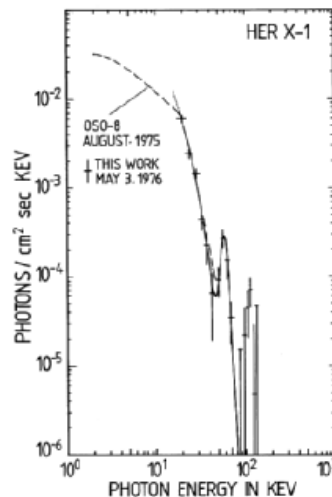
- ◆ Observations
- ◆ Cyclotron line formation
- ◆ Cyclotron line diagnostics
- ◆ Mission comparison



Observations

- Many accreting X-ray pulsars show broad 'absorption' line features varying with pulse phase in their spectra. Currently ~15 known sources plus several candidates – including 3 isolated NS.

- Examples:
Her X-1,
4U 0115+63,
GX 301-2,
...



- Lines neither atomic nor nuclear, but *cyclotron resonance scattering features*.

Cyclotron line formation

- ◆ Electron energies are quantized perpendicular to B field in “*Landau states*”.

$$E_n = m_e c^2 \sqrt{1 + \left(\frac{p_{par}}{m_e c}\right)^2 + 2n \frac{B}{B_{crit}}}$$

- ◆ For $B \ll B_{crit}$ energy spacing reduces to classical *cyclotron energy*.

$$E_{cyc} \equiv \frac{\hbar e}{m_e} \times B \approx 12 \left(\frac{B}{10^{12} \text{ G}}\right) \text{ keV}$$

- ⇒ *Resonant* cross sections for electron/photon scattering.
- ⇒ Emission region opaque for photons with $h\nu \approx n \times E_{cyc}$
- ⇒ 'Absorption' line features

Cyclotron line diagnostics

- ◆ Cyclotron line energies most direct measure of B.

- ◆ Relativistically corrected line varies with pulse phase
⇒ information about emission geometry.

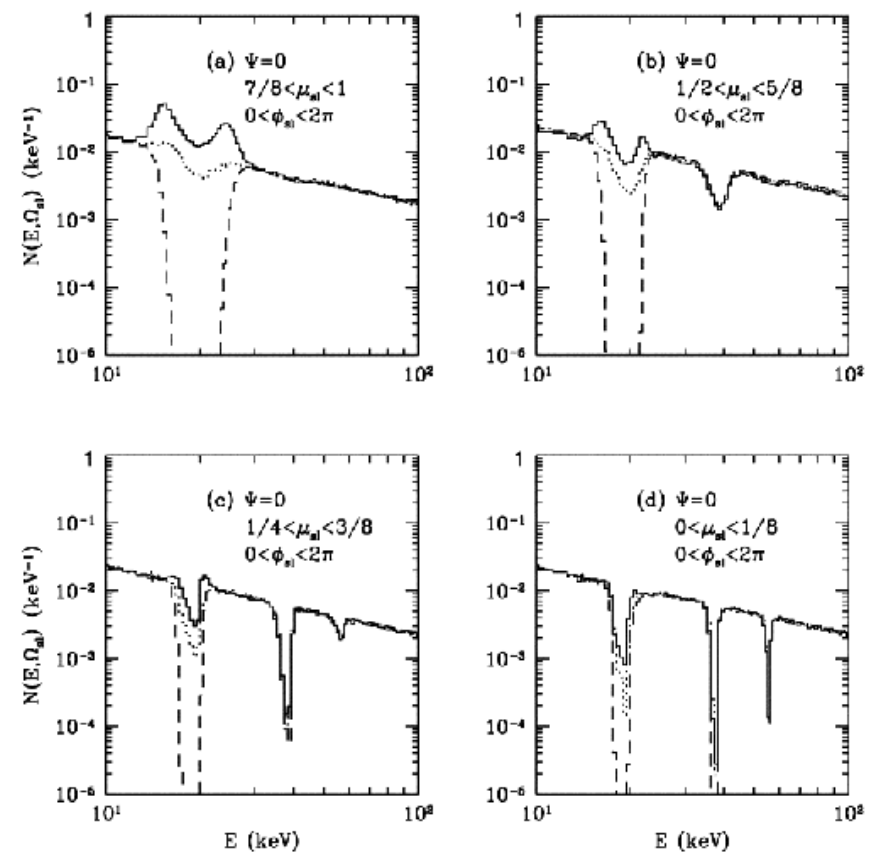
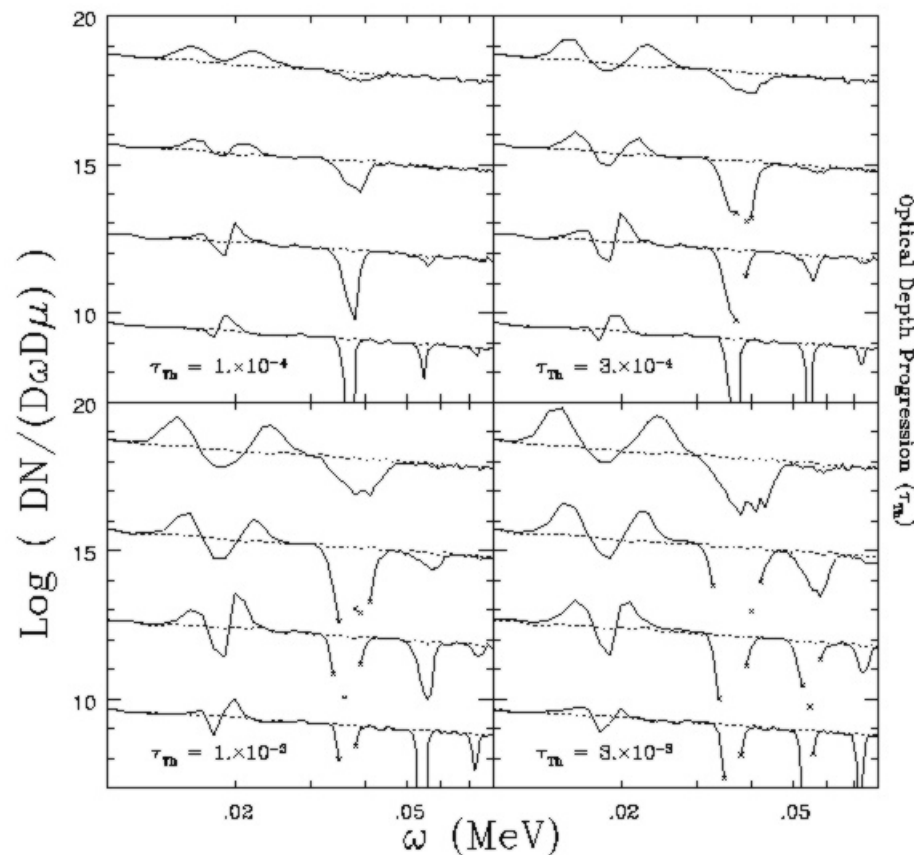
$$E_n = m_e c^2 \left(\frac{\sqrt{1 + 2n \left(\frac{B}{B_{crit}} \right) \sin^2 \theta} - 1}{\sin^2 \theta} \right)$$

- ◆ Scattering cross sections are complex functions of B, θ , n, kT, ...

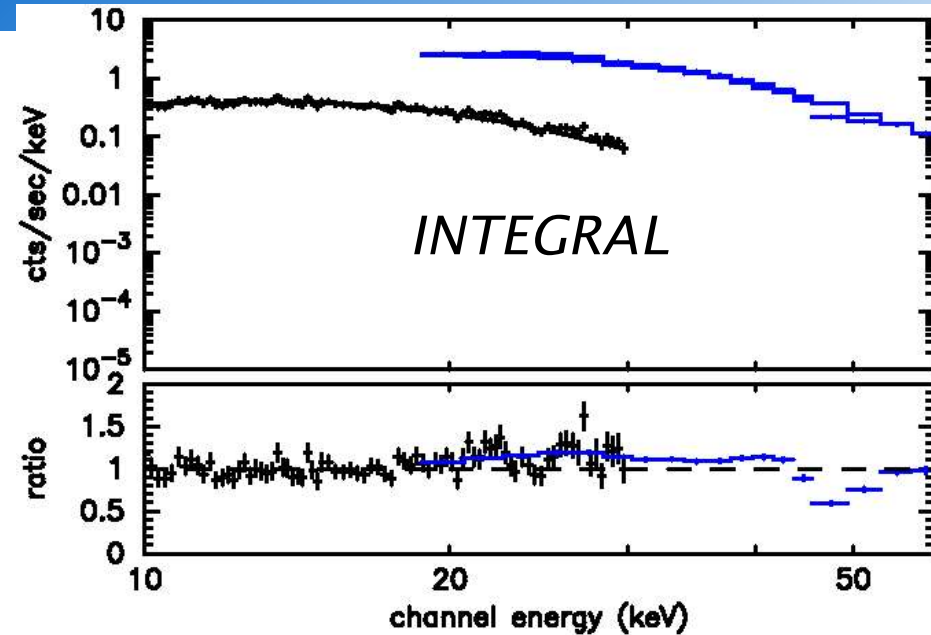
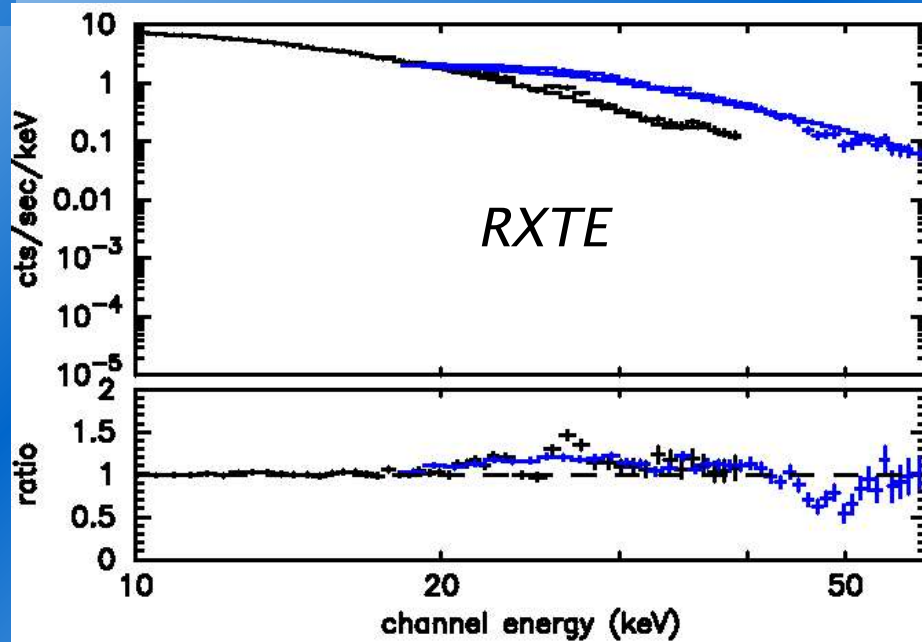
⇒ Powerful diagnostic of physical parameters in emission region *if modeled and resolved in energy and time by observations!*

Cyclotron line diagnostics

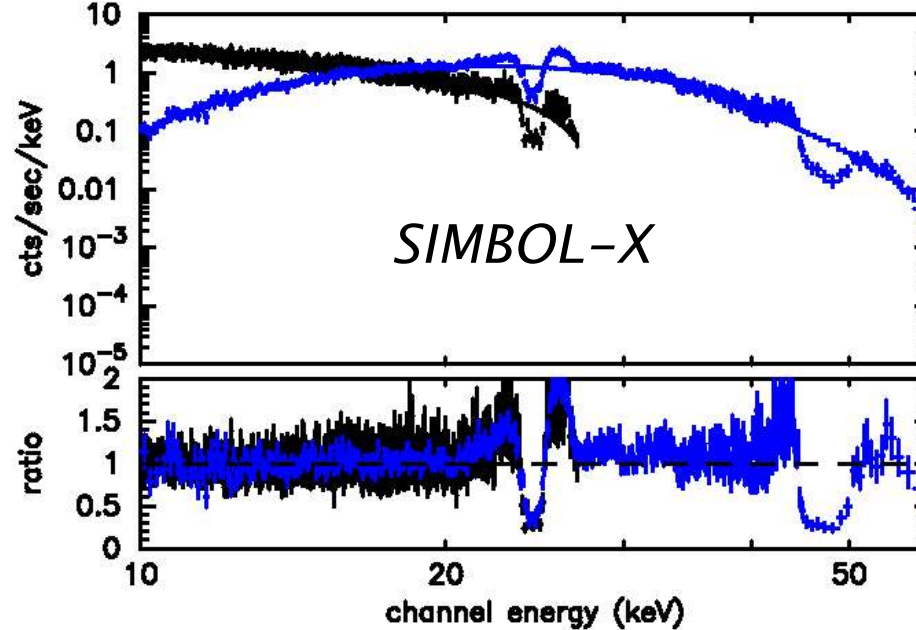
- Independent Monte-Carlo calculations (Araya & Harding 1996, 1999; Isenberg et al. 1998) show complex fundamental line shapes depending on emission region parameters and obs. angle:



Resolving power compared



Simulated accreting pulsar spectra with fundamental at ~25 keV (based on MC spectra of Araya & Harding)



SIMBOL-X would resolve lines in short integration times

Summary

- ◆ Cyclotron lines are *common features* of accreting pulsars.
- ◆ In principle they hold *great diagnostic power* for the parameters of the emission region – which up to today is still not well understood!
- ◆ Currently we are *limited in spectral or temporal resolution* to test detailed models ⇒ mostly rough, empirical results.
- ◆ **SIMBOL-X** will allow *detailed model comparison* with *high temporal resolution* bringing us closer to actual physics.