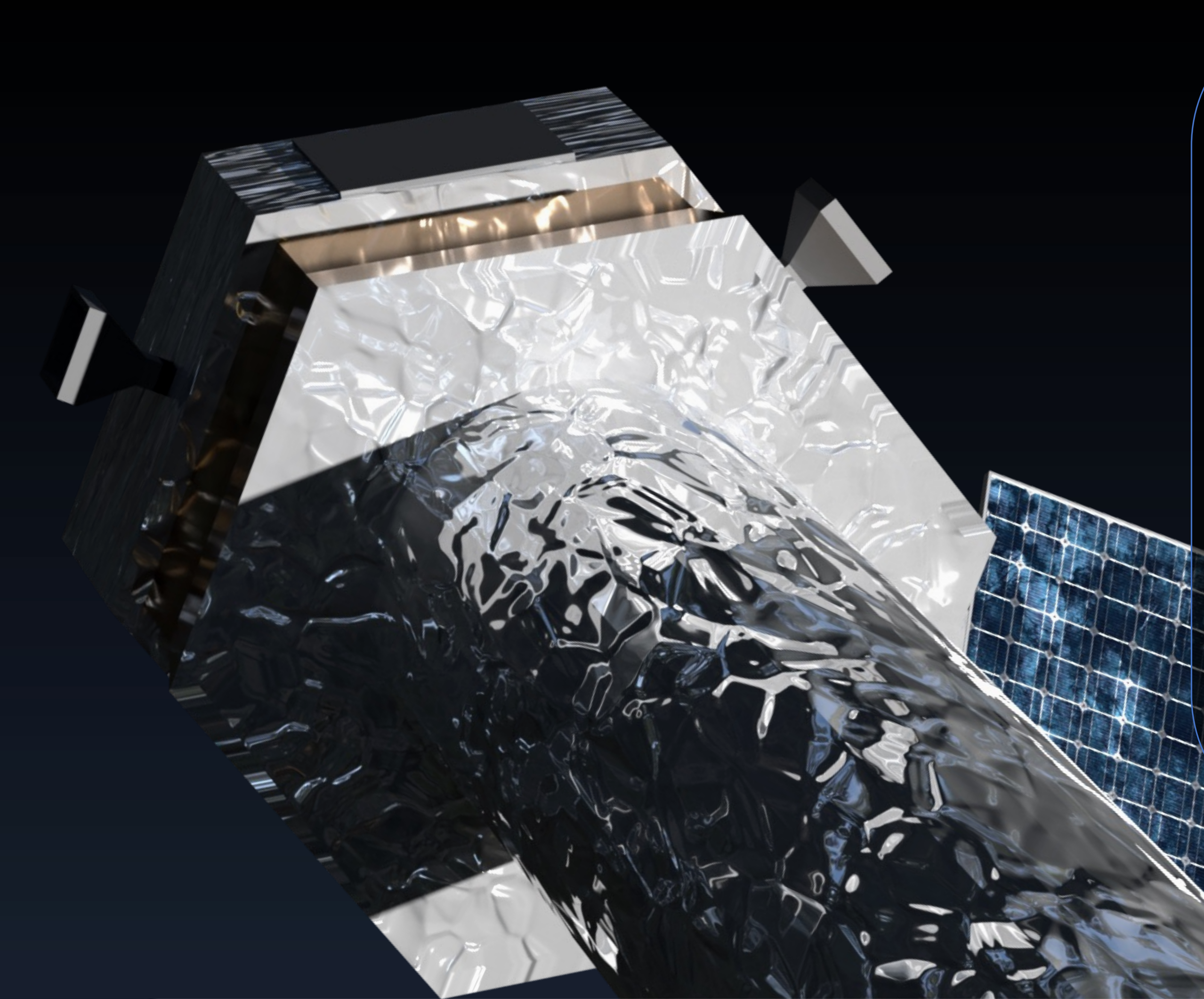

The High Energy X-Ray Probe (HEX-P): Unveiling Accretion Around Neutron Stars

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Overview:

HEX-P is a probe-class mission concept that will combine high spatial resolution X-ray imaging (<10 arcsec FWHM) and broad spectral coverage (0.1-200 keV) with an effective area far superior to current facilities (including XMM-Newton and NuSTAR) to enable revolutionary new insights into a variety of important astrophysical problems. HEX-P will characterize X-ray binary systems over an unprecedented range of fluxes, energies, and time-scales, allowing us to answer questions about binary evolution, neutron star (NS) physical properties, and feedback into their environment. We present spectral simulations of accreting neutron stars to demonstrate the power of the HEX-P observatory. We show that HEX-P will **(1)** detect cyclotron line features above 80 keV, directly measuring B-fields stronger than ever before; **(2)** provide constraints on neutron star radii with higher accuracy using X-ray reflection modeling; **(3)** yield unique information about the accretion geometry and accretion state in these systems for the whole range of mass accretion rates from ULX-like luminosities to the onset of the propeller effect or quiescence; and **(4)** characterize the diverse environments these systems live in, including stellar winds and dust shrouds, intervening Be-star disks or warped accretion disks, as well as outflows. More information on HEX-P, including the full team list, is available at hexp.org.

High Mass X-ray Binary Science:

- NS HMXBs have a stellar companion of ≥10 $M_\odot$
- Accretion occurs through capture of stellar winds or as the NS passes through the stellar decretion disk
- HMXBs harbor NSs with strong magnetic fields
- We perform simulations based off literature at a few different luminosity regimes to demonstrate the power of HEX-P to reveal the properties of accretion onto highly magnetized NSs

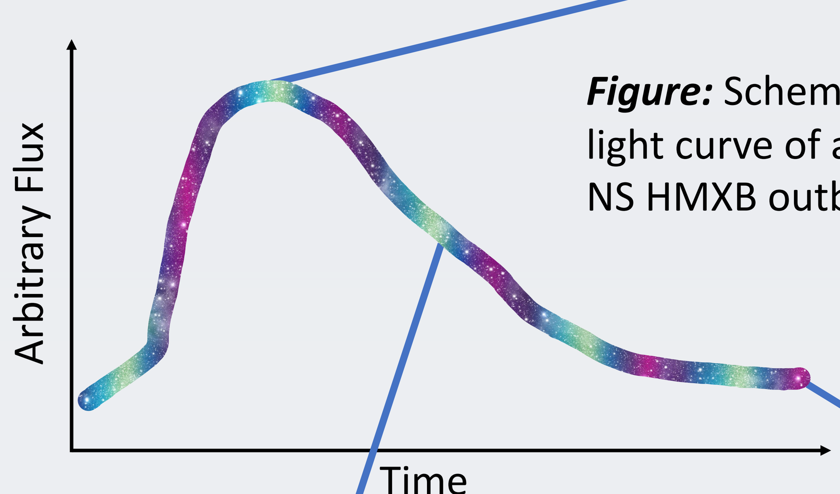
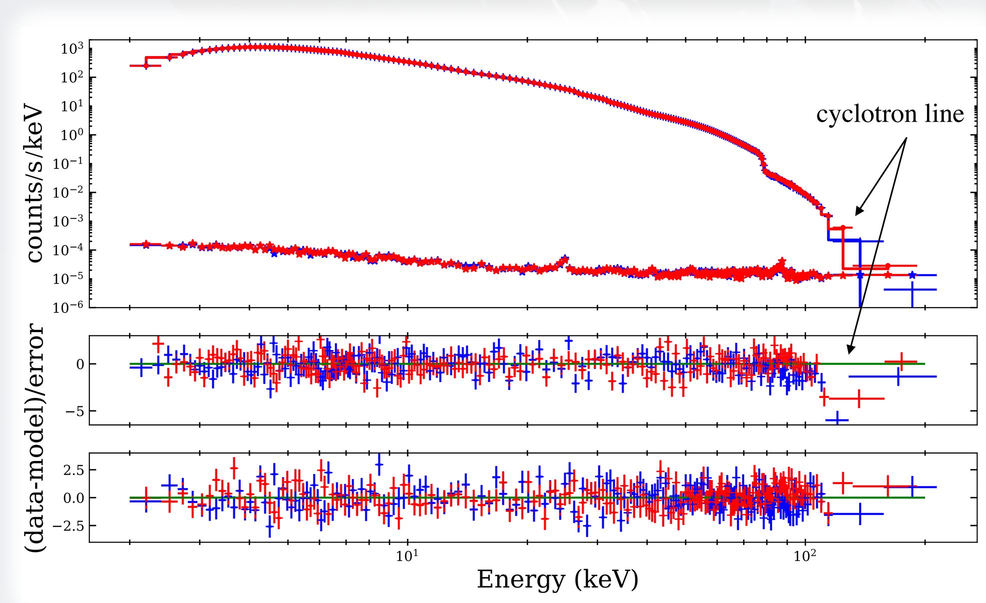


Figure: Schematic light curve of a typical NS HMXB outburst

At High Luminosity (>10^{38} erg/s): Find Cyclotron Lines Above 80 keV

- Report of a cyclotron line at ~142 keV in the Galactic 9.8 s pulsating ultra-luminous X-ray source Swift J0243+6124[2], which is a record for a directly measured magnetic field



❖ HEX-P will detect a similar line in a 20ks phase-resolved bin with the energy of the line constrained at ~3%!

Low Mass X-ray Binary Science: NS Radius Constraints

- NS LMXBs have a stellar companion of ~1 $M_\odot$
- Mass transfer occurs through an accretion disk formed via Roche-lobe overflow
- The accretion disk must truncate at the surface of the NS (if not prior to it), hence measuring the location of the inner disk radius provided an upper limit on the NS radius
- 100 ks HEX-P exposure based on reflection modeling of Cygnus X-2 which has a measured mass of M = 1.71+/-0.21 $M_\odot$[1]

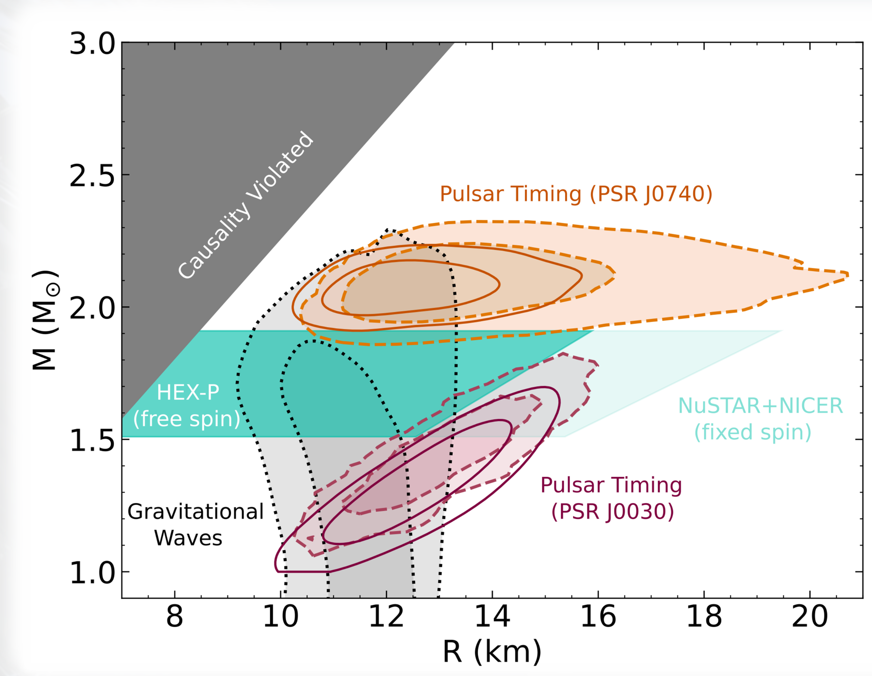


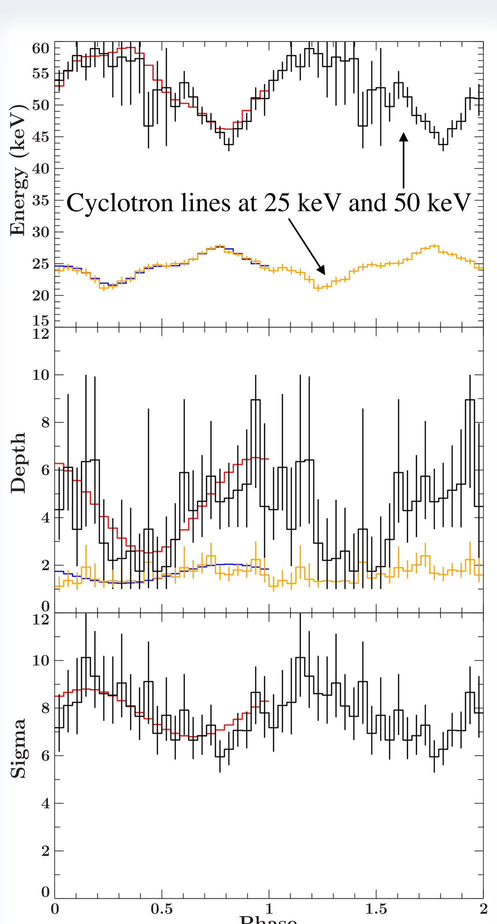
***Figure:** Mass (M) and radius (R) constraints from NS gravitational wave events[6] and NICER pulsar light curve modeling[4,5,7,8] in comparison to reflection modeling of Cygnus X-2 from literature[3] and with HEX-P.*

❖ HEX-P's large effective collecting area, broad X-ray passband, and energy resolution provides high enough S/N to independently constrain the inner disk radius and dimensionless spin parameter, therefore pushing down the upper limit on the NS radius by >2 km!

Intermediate Luminosity (~10^{36} erg/s): Phase Dependence of Cyclotron Resonance Scattering Feature

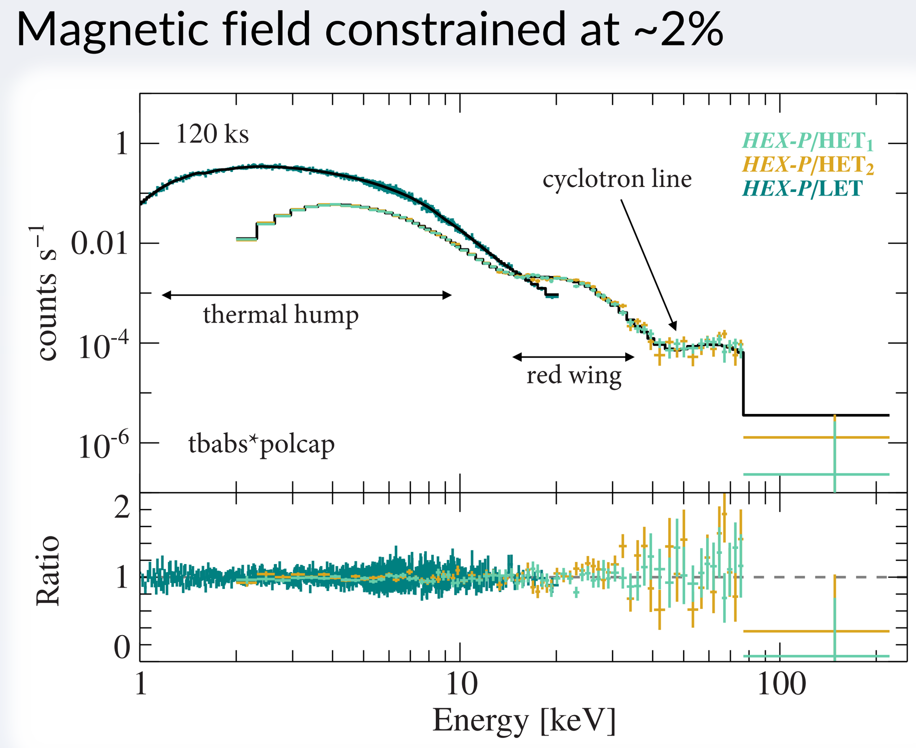
- Based on Vela X-1 (Camille Diez+ 2023, in prep)
- HEX-P simulation of a 50 ks observation resolving the 283 s pulse into 25 spectra
- Input parameters recovered at 1-10%

❖ HEX-P will allow unprecedented views of the magnetic field configuration, emission pattern, and accretion column physics close to the surface of the NS!



At Low Luminosity (~10^{34} erg/s): Measure Surface B-Field Strengths

- Based off GX 304-1[9]
- Magnetic field constrained at ~2%

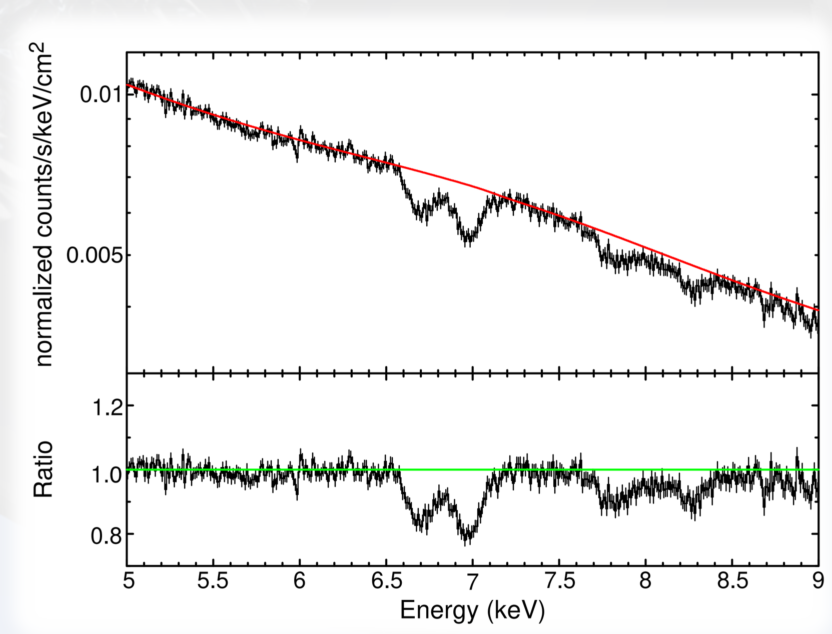


❖ HEX-P will be able to observe direct pole emission at low-L accretion regimes due to large effective collecting area, thereby enabling measurements of B-field strengths at the NS surface!

Accretion Geometry from Absorption Lines

- 40 ks simulation of 4U 1916-053 based on Chandra observations[10] with two absorbers (one at rest, one blue-shifted at 0.017c)

❖ HEX-P's large effective collecting area provides high S/N observations of absorption lines in dipping sources, thus enabling study the structure of the outer disk and the mass transfer process!



HEX-P
HIGH ENERGY X-RAY PROBE

References:
[1] Casares et al. 2010, MNRAS, 401, 2517 [2] Kong et al. 2022, ApJL, 933, L3; [3] Ludlam et al. 2022, ApJ, 927, 112; [4] Miller et al. 2019, ApJL, 887, L24; [5] Miller et al. 2021, ApJL, 918, L28; [6] Raaijmakers et al. 2021, ApJL, 918, L29; [7] Riley et al. 2019, ApJL, 887, L21; [8] Riley et al. 2021, ApJL, 918, L27; [9] Sokolova-Lapa et al. 2021, A&A, 651, A12; [10] Trueba et al. 2020, ApJL, 899, L16