Highlighting XMM-Newton's Role in Time Domain Studies of Neutron Star and Black Hole X-ray binaries in Nearby Galaxies

Silas Laycock[1]

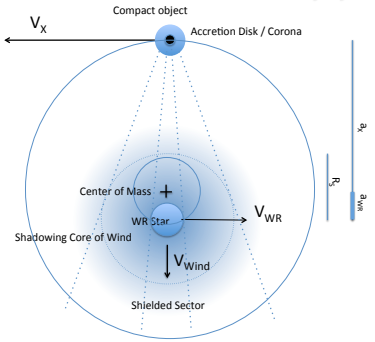
Rigel Cappallo[1], Jun Yang[1], Dimitris Christodoulou[1], James Steiner[2]

(1) UMass Lowell, Center for Space Science and Technology (2) MIT

Abstract

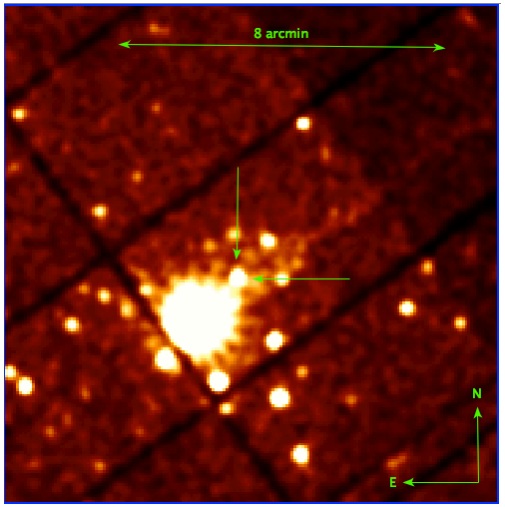
XMM-Newton's combination of large effective area, superior event timing, and wide field imaging have provided a powerful capability for time-domain studies of nearby X-ray binary populations. In its first 15 years XMM has accomplished groundbreaking monitoring surveys for X-ray binaries; complemented by RXTE, Chandra, and Nustar. Over the next decade XMM's capabilities will complement a new generation of missions including Astrosat, NICER, Athena. This paper highlights the role of XMM-Newton in combination with other missions, in exploring the HMXB populations of the Small Magellanic Cloud and IC 10. Both are nearby dwarf starburst galaxies, yet their ages and evolutionary scenarios are very different, the consequences of which have led to contrasting X-ray binary populations. In the SMC the definitive sample of X-ray binary pulsars assembled by RXTE is revealing fundamental accretion physics when probed by XMM. Finding and characterizing IC 10's youthful X-ray binaries required the combination of XMM together with Chandra and Nustar. Key results include the revelatory finding of an X-ray irradiated wind masking the mass-function in the WR +BH binary X-1 and the measurement of the BH's spin. Such studies have wide relevance to stellar/ galactic evolution, implications for black hole masses and formation channels for BH+BH binaries.

A New Model for the IC 10 X-1 BH+WR Binary System



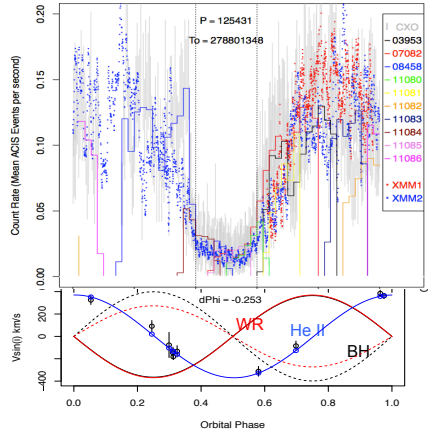
- The wind is fully photo-ionized by X-rays from the compact object
  - Optical spectral lines can only arise in the shielded sector of the wind
  - Free electron scattering will dominate the orbital profile.
- The wind core radius of 8 R_{sun} is inferred from the eclipse profile
- Location of the Center of Mass depends upon the nature of the compact object, which is now unconstrained by any dynamical evidence.
  - For a 24 M_{sun} black hole, the CM lies midway
  - For a lower mass BH the CM lies inside the WR star's envelope

XMM-Newton image of the Dwarf Starburst Galaxy IC10



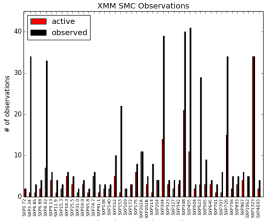
>100 sources are seen, including new transients in every observation.
XRBs including the BH+WR binary IC 10 X-1 are monitored over time

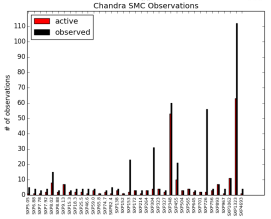
X-ray Lightcurve of a BH binary reveals a Phase Offset between the Radial Velocity Curve and the Eclipse

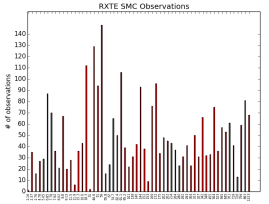


- We obtained a high-precision ephemeris by folding a decade's worth of X-ray light-curve segments on a series of trial periods spanning the 3σ uncertainty region for the orbital period reported by Silverman & Fillipenko (2008).
- XMM-Newton and Chandra data were analyzed separately, yielding two sets of flux-minima, most of which are mutually exclusive.
- The dense core of the WR star's stellar wind produces long-duration eclipses.
- Optical RV points folded modulo our X-ray ephemeris show an offset of ¼ orbital cycle.
- At mid-eclipse the He II line has its greatest doppler velocity shift towards us.
- The orbital motion of WR star should trace the red line
- RV is likely a projection of the stellar wind, not the orbital motion of the binary.

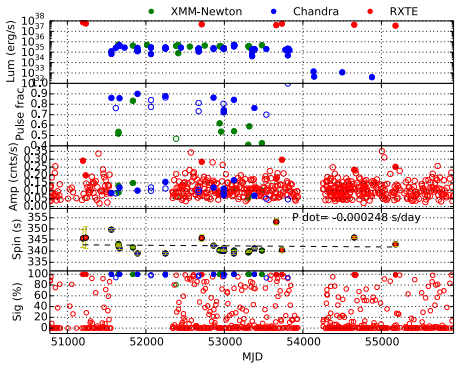
The Magellanic Clouds have been observed hundreds of times by XMM-Newton, Chandra and RXTE







Our Pulsar Pipeline produces a 3-Satellite Library of Data Products to Explore Pulsar Physics



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