Long-term Dynamical Evolution of Wind Accreting Interacting Binaries

Margarita Karovska (SAO)

Introduction

Chandra's sub-arcsecond resolution offers unprecedented opportunities for detailed studies of accretion phenomena in interacting binaries at X-ray wavelengths, where the signatures of accretion processes are very prominent.

Long-term study of interacting binaries using the highest available spatial resolution at X-ray wavelengths is a key to understanding the mass transfer and accretion processes in these evolving dynamical systems.

Among the interacting binaries, Symbiotic systems are of a particular astrophysical interest, since they have been invoked as a potential progenitors of asymmetric Planetary Nebulae, and of at least a fraction of SN Type Ia – key cosmological distance indicators

These systems provide great targets for studying accretion processes, jets, and outbursts, especially in interacting binaries with focused wind mass accretion, on time scales from days to decades.

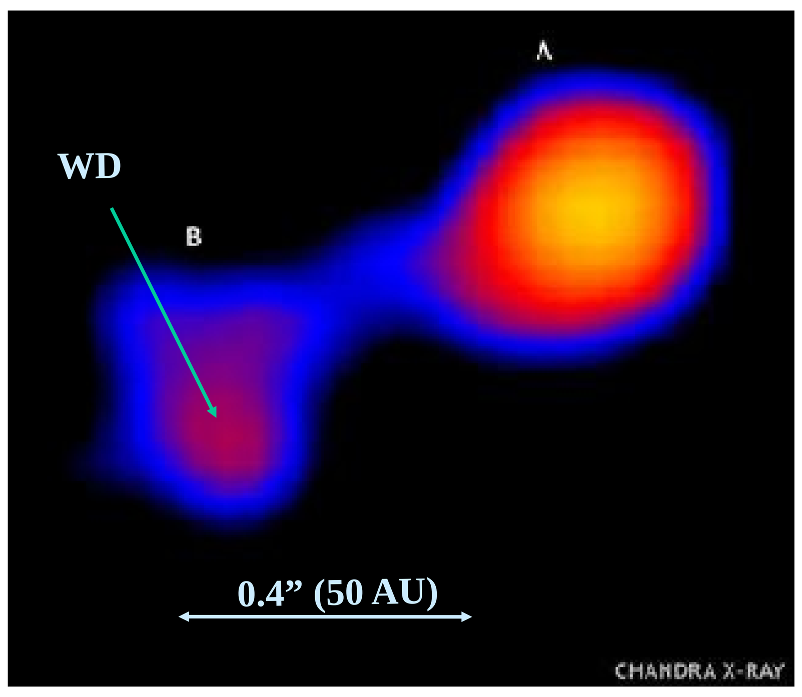

Fig 1. - Mira AB system resolved by Chandra. PSF deconvolved image shows a "bridge" between the components of this detached system (0.5" separation) detecting for the first time a mass flow from Mira A (red giant) toward Mira B (WD) – a direct evidence of gravitationally focused wind accretion.

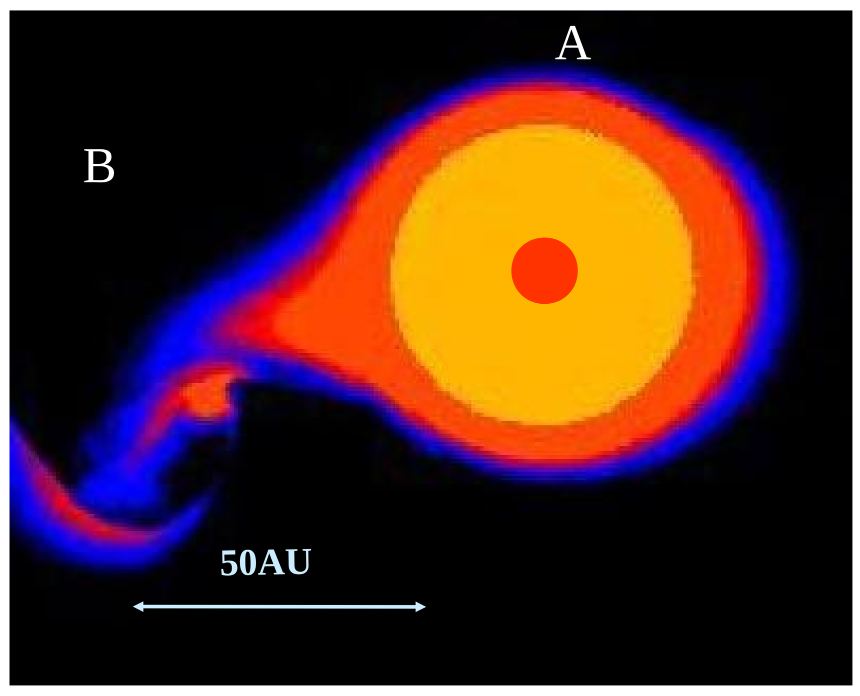

Fig. 2 - Accretion model (hydrodynamical simulations, de Val Borro, Karovska & Sasselov, 2009; 2016) showing Roche Lobe Overflow-like accretion in Mira AB due to gravitationally focused wind, for a wind accelerating region in the Mira A's extended dust envelope at 30AU (yellow circle). Red circle – Mira's "photosphere".

Chandra View of Nearby Symbiotics

Chandra has provided us, for the first time, with spectacular views of the inter-binary and circumbinary environments of several nearby Symbiotics (eg. Mira AB, CH Cyg, R Aqr), reaching their sub-arcsecond structures.

High-angular resolution imaging and spectroscopy have shown dramatic changes in the spatial and spectral distribution of the emission in these systems on time scales of years. These include detections of significant variability of the accretion rates on the WD companion, and changes in the environments, including due to outbursts, jets and outflows.

However, there are many aspects of the wind accretion that are not yet understood. In the next decade, Chandra observations will determine the characteristics of the long-term dynamic evolution of the wind accretion-related activity in interacting systems, and will identify the origin and causes.

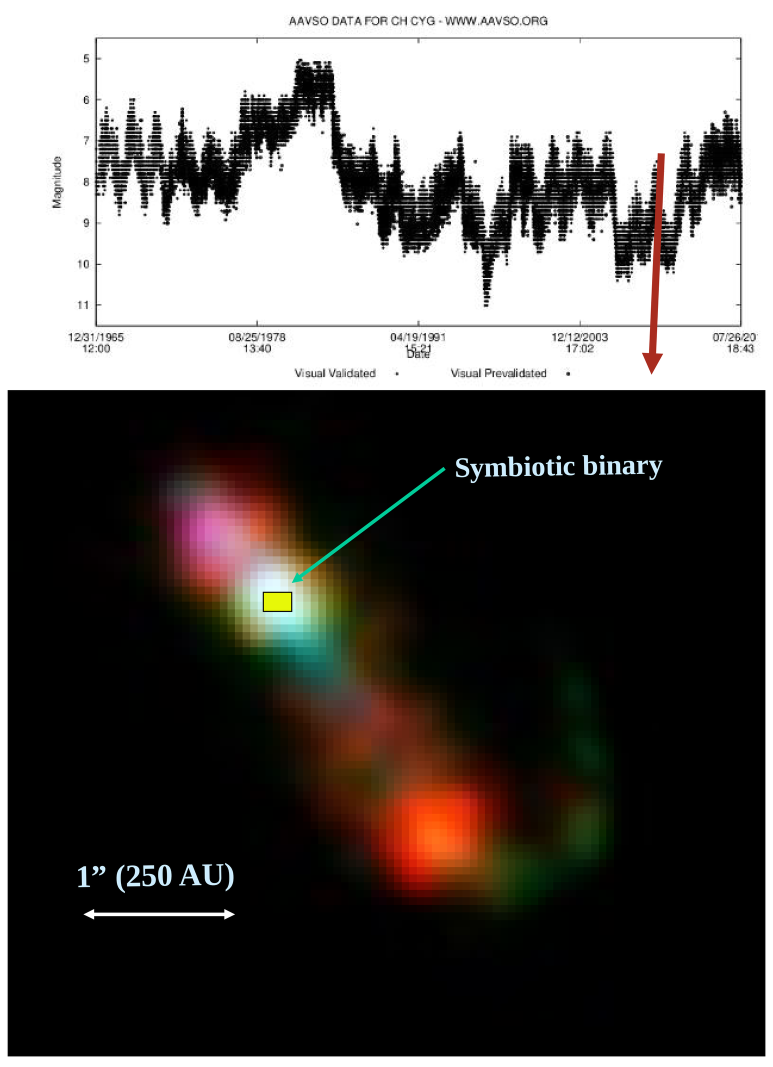

Fig 3. – CH Cyg jet at sub-arcsec resolution: Chandra (red), HST (green), & VLA (blue). PSF simulation was used to deconvolve the Chandra image(s) which show multiple jet structures, including a counter-jet at <1" NE from the central binary, and a region of interaction with the surrounding circumstellar shell at ~2" to the SW. Significant evolution of jet activity, detected over few years, indicates jet precession and dynamic interaction with the circumbinary environment. Also displayed is the long-term AAVSO LC of CH Cyg, showing spectacular variability over time.

Conclusions

- Our results show that wind accretion in Symbiotic binaries can result in a Roche Lobe Overflow-like accretion via a stream flow, or focused wind accretion.
- Hydrodynamical models of wind accreting systems predict that the accretion rates can rise to over 10% of the mass loss from the giant. These rates are an order of magnitude higher than the accretion rates predicted by the simple Bondi-Hoyle wind accretion calculations.
- Several snap-shots of nearby Symbiotic systems show dynamic environments in the central binary regions, with accretion-related jet activity and multiple outbursts.
- In the next decade, observations using Chandra at its maximum resolving power, combined with multi-wavelength (UV, optical, IR, Radio) high-angular resolution observations, will provide crucial information on the accretion-related mechanisms causing outbursts and jets, and on the variable accretion rates onto the WDs -- a key element in understanding the single-degenerate path to SN Ia.
- Careful calibration of the Chandra PSF structure at a sub-arcsec level is of a great importance, and will allow over the next decade unprecedented studies of the X-ray emission from the inner regions of diverse astronomical sources, eg. from YSOs & interacting binaries, to AGN -- reaching features at angular scales as small as 0.1".

Chandra at Ultimate Angular Resolution

Key to successful Chandra high-spatial resolution studies of inner regions of interacting binary systems, including Symbiotics and many other astrophysical sources, is an accurate knowledge of the energy dependent 2-D HRMA + instrument PSF (including the pileup effects).

Detailed calibration of the sub-arcsec PSF will provide a powerful basis for accessing the fine scale structures which appear blurred in the direct images (even after applying the SER techniques). By applying deconvolution techniques (e.g., Richardson-Lucy, EMC2), one can then reach the ultimate 0.1" angular resolution.

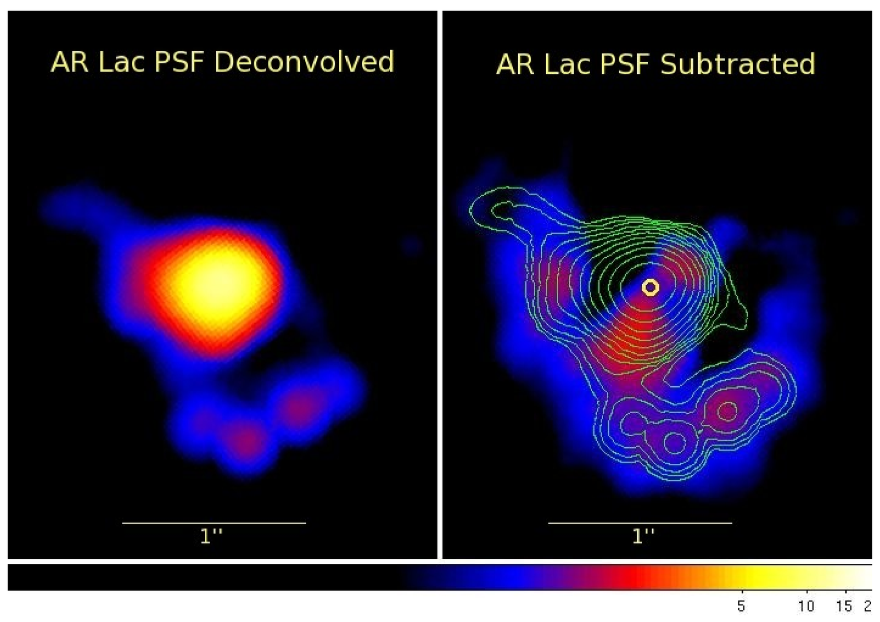

Fig. 4 - Images of the Chandra PSF showing sub-arcsec artifacts that need to be modeled in the future to allow detailed study of sub-arcsec structures in a variety of astronomical sources, including inner regions of interacting binaries. (*vis http://cxc.harvard.edu/ciao/caveats*)

References

Karovska, M. *et al.* 2005, ApJ, 632 L137 — Karovska, M. *et al.* 2010, ApJ, 710, L132 — de val-Borro, M., Karovska M., & Sasselov, D. 2009, ApJ, 700, 1148 — de val-Borro, M., Karovska, M., & Sasselov, D., 2016, *in prep.*

Acknowledgments:

M. Karovska acknowledges support provided by NASA grants HST GO-NAS12761, and Chandra G002-13031, and support from the Chandra X-ray Center NASA Contract NAS-03060