Chandra Observations of R Aqr's Non-Relativistic Outer Jets

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Three epochs of Chandra X-Ray observations of R Aquarii, combined with VLA radio data, reveal non-relativistic, evolving outer jets. The multi-wavelength spectral energy distribution indicates that the X-rays from the outer jet are thermal, in contrast with the inner jets, which are non-thermal (see Nichols et al, this conference). The outer-jet emission from both the northeast (NE) and southwest (SW) jets is compatible with shock heating of material ejected from the compact object in R Aquarii. The X-ray-bright region of the NE jet is moving outward with an apparent bulk velocity of 600 km/s, which is faster than the 150 km/s motion of the radio-bright portion of the jet. The jet in the NE is still a strong source of X-rays in the second epoch (2004.0), whereas the X-ray emission from the SW jet faded between 1999.8 and 2004.0. The disappearance of the southern outer X-ray jet is consistent with adiabatic expansion and cooling,implying a low density environment in the SW. New Chandra x-ray observations of the system will reveal greater details of the processes and environment driving the evolution of the outer jets.

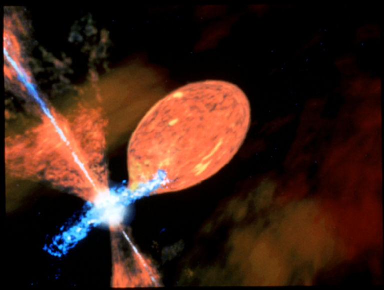
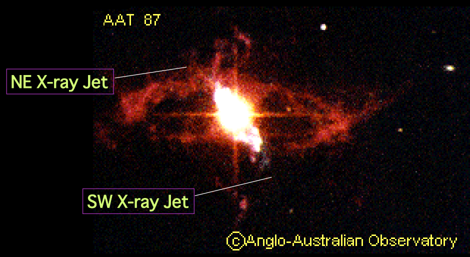


Image Credit: *Dana Berry (STScI)*

R Aquarii: Binary System

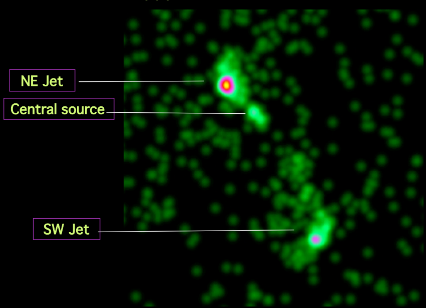
The binary star system R Aquarii contains a Mira variable red giant accreting onto a hot companion most likely a white dwarf. The system is embedded in a dense nebula. A jet is found propagating to the northeast (NE) and southwest (SW) of the central system. An artist`s rendition of the system is to the left. To the right is an optical image of the system. The jets observed with Chandra extend beyond what has been observed in the radio, optical and UV thus far.



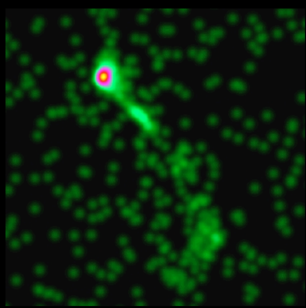
Stellar Jets: Chandra observations

The bright X-ray emission in the NE jet moved with a tangential motion equivalent to 600 km/s in the 3.3 yr time interval between the two Chandra observations. The shape of the NE jet changed which could indicate compression on the eastern edge. The SW jet, easily seen in the 2000.7 observation, primarily due to O VII emission, is essentially absent in the 2004.0 observation. The jet continues to evolve in the recent 2005.8 Chandra observation. See Kellogg et al poster at this conference.

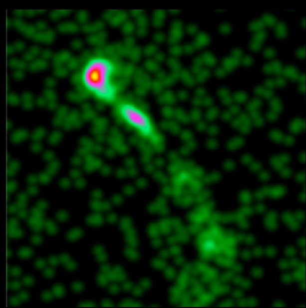
2000.7

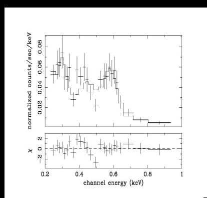


2004.0

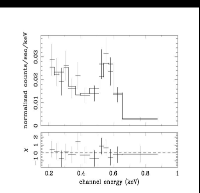


2005.8

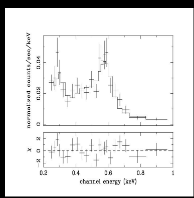




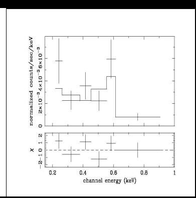
2000.7 X-ray spectrum of NE jet



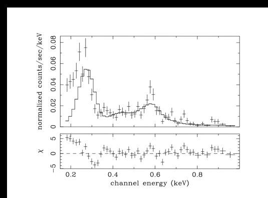
2000.7 X-ray spectrum of SW jet



2004.0 X-ray spectrum of NE jet



2004.0 X-ray spectrum of SW jet



2005.8 X-ray spectrum of NE jet

What does the X-ray data tells us about the jets?

The short time scales that occur in the evolution of this system requires frequent observations as several wavelengths. One of the most interesting findings was that the radio and X-ray jet were not co-spatial. The radio jet is moving at ~150 km/s whereas the apparent motion of the X-ray jet is almost 600 km/s. From past studies of the nebula surround R Aqr, estimates for the density of the nebula are $n=10^{4-5}$ cm^{-3}. Using the observed X-ray intensities, the density of the NE X-ray bright spot was $n=200$ cm^{-3} and for the SW $n=100$ cm^{-3}. This low density and the disappearance of the SW X-ray bright spot suggest that the spot cooled by adiabatic expansion within the 3.3 years between the 2000.7 and 2004.0 observations. We are continuing to discuss mechanisms for shock heating of the outer jets such as reverse shocks as well as a bow shock model.

Acknowledgements

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