X-ray Evolution of the Symbiotic Binary R Aqr : 2000-2005

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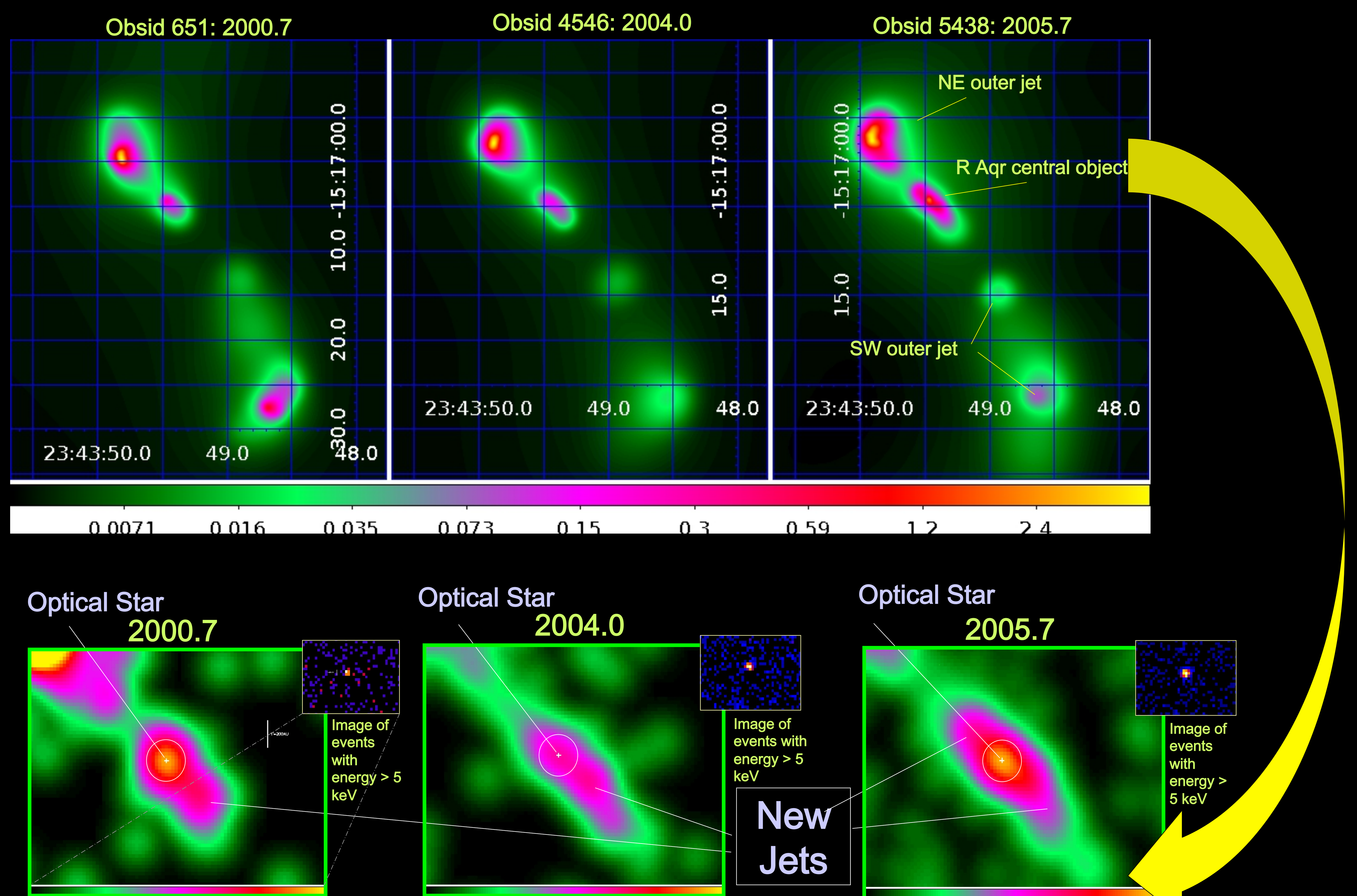
ABSTRACT

The Chandra observation of the nearby symbiotic system R Aqr taken in 2005.7 is analyzed and compared to the 2 earlier observations of this system in 2000.7 and 2004.0. Spectral fitting reveals significant variability on this time frame, with changes seen in the hardness ratio and the fluxes of emission lines. The most marked changes occur in the Fe K alpha line and nearby complexes, indicative of changes in the accretion activity. The extended jets have moved outward with a projected speed of over 500 km/s during this period. We find evidence for new jet formation on a time scale of months or years. This series of observations gives a unique view of white dwarf wind accretion in a binary system as well as jet formation and evolution. We acknowledge NASA contract NAS 8-03060 to the Smithsonian Astrophysical Observatory.



2000.7 X-ray image of R Aqr for energies 0.2-2 keV (circle shows extraction region).

2004.0 X-ray image of R Aqr for energies 0.2-2 keV.

2005.7 X-ray image of R Aqr for energies 0.2-2 keV

The above images have been processed with identical calibrations and converted to units of counts per sec. The pixels have been re-sampled to 1/4 pixel resolution and then adaptively smoothed with a Gaussian kernel. The same scaling range was used for all 3 images.

R Aqr:

DISTANCE - 200 pc
orbital: *i* ~70°, period ~44 yr
first WD binary system known to have X-ray jets

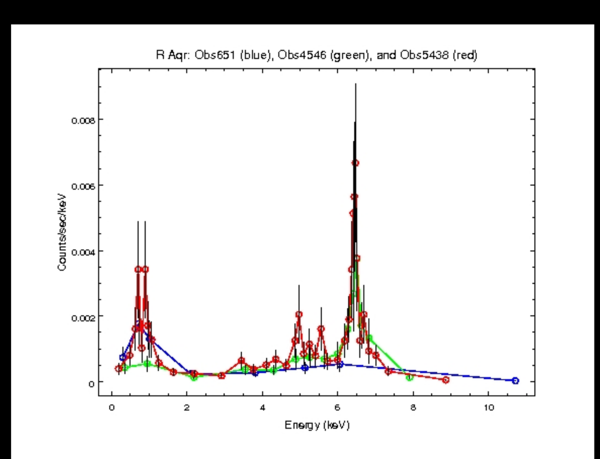
White dwarf	Mira Variable
WD with accretion disk	~387 d period
	M5 spec type
~ 1 Mo	1.75M

Morphology Changes

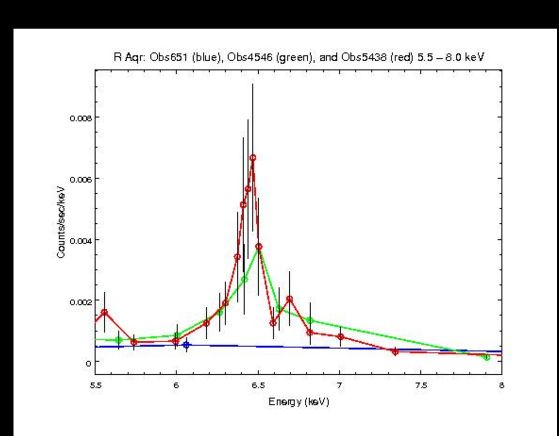
The figures at the left are the three Chandra observations, time-ordered from left to right., showing the NE outer jet, the central object, and the SW outer jet structures. The NE jet has bulk velocity of about 500-600 km/s over the 5 year period. The SW jet structure shows knots that fade and reappear with time. The X-ray emission in these outer jets is probably caused by interaction with a surrounding nebula.

New Jet Production

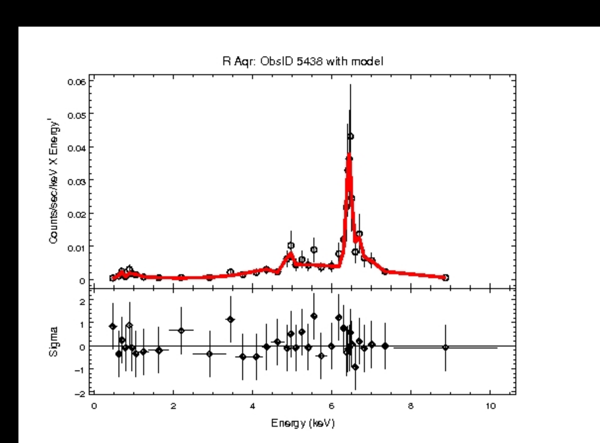
The soft X-ray morphology has changed significantly in the 5 year period covered by these observations. Between 2000.7 and 2004.0 the soft emission became clearly bimodal, with lower flux at the position of the optical star. In 2005.7, the SW extension that we interpret as a new jet has continued to develop and a new extension to the NE is seen.



Overplot of the spectra from 3 Chandra observations: blue (2000.7), green (2004.0), red (2005.7).



Overplot of the Fe K alpha region from 3 Chandra observations: blue (2000.7), green (2004.0), red (2005.7).



2005.7 spectrum of 1.5" region around X-ray source. Data are binned at 10 counts per bin. Model is described below.

Spectral Fits

We show one of the best fit spectral models for obsid 5438 (2005.7). This model is described by

Phabs[nH]*(kTlow[kT]+kThigh[kT]+comptb[kTbb,kTe,log(A)]+diskline[keV])+Gauss_Fe17+Gauss_FeK+Gauss_CaXX

In addition to this combination of models, many other models were tried that include cooling flow, reflection, and combinations of all of these model components. We cannot eliminate all of these other models based on chi2 and cstat statistics, so the model shown here should not be considered a unique solution.

Comparing the spectra from the three observations in 2000.7, 2004.0, and 2005.7, it is obvious that the hard X-rays have increased greatly in flux over time. On the other hand, the soft X-rays have a greater flux by a factor of 2 in the first and third observations, compared to the second observation. The Fe K alpha line strengthened considerably in the last observation. The hardness ratios for the 3 observations indicate this marked variability in the R Aqr spectra with time.

Hardness ratio (h to s): 2000.7 = 0.2300, 2004.0=0.7746, 2005.7=0.4748

Conclusions:

- Significant increase in hard X-ray emission, likely produced in the accretion disk boundary layer, implies increased accretion activity or ionization of the disk by the base of the jets or other processes. The changes are not related to periastron.
- Increasing or variable accretion substantiated by the good fit of Compton scattering and diskline model for the 2005.7 observation.
- Hardness ratios for the 3 observations show the remarkable variability with time for both hard and soft X-rays.
- The periodic production of new jets implies a variable accretion rate or disk ionization on the order of 1.7 yr which seems to be related to changes in the Mira wind due to its pulsations.
- Virtually continuous production of new jet structures on time scales of less than 3-5 years
- SW jet structure was composed of knots that vary in X-ray emission
- NE jet structure was coherent and collimated, moving outward with a bulk motion of more than 500 km/s, with a recent curved trajectory that indicates it was encountering the wall of the surrounding nebula.

References:

Nichols, J., DePasquale, J., Kellogg, E., Anderson, C., 2007, ApJ, 660, 651.
Kellogg. E., et. Al. 2007, ApJ, 664, 1079.
Kellogg, E., Pedelty, J. A., Lyon, R. G., 2001, ApJ 563:L151-L155.