SYMBIOTIC SYSTEMS IN RADIO

Jennifer Weston, Green Bank Observatory

NRAO Postdoc Symposium
March 28th, 2017

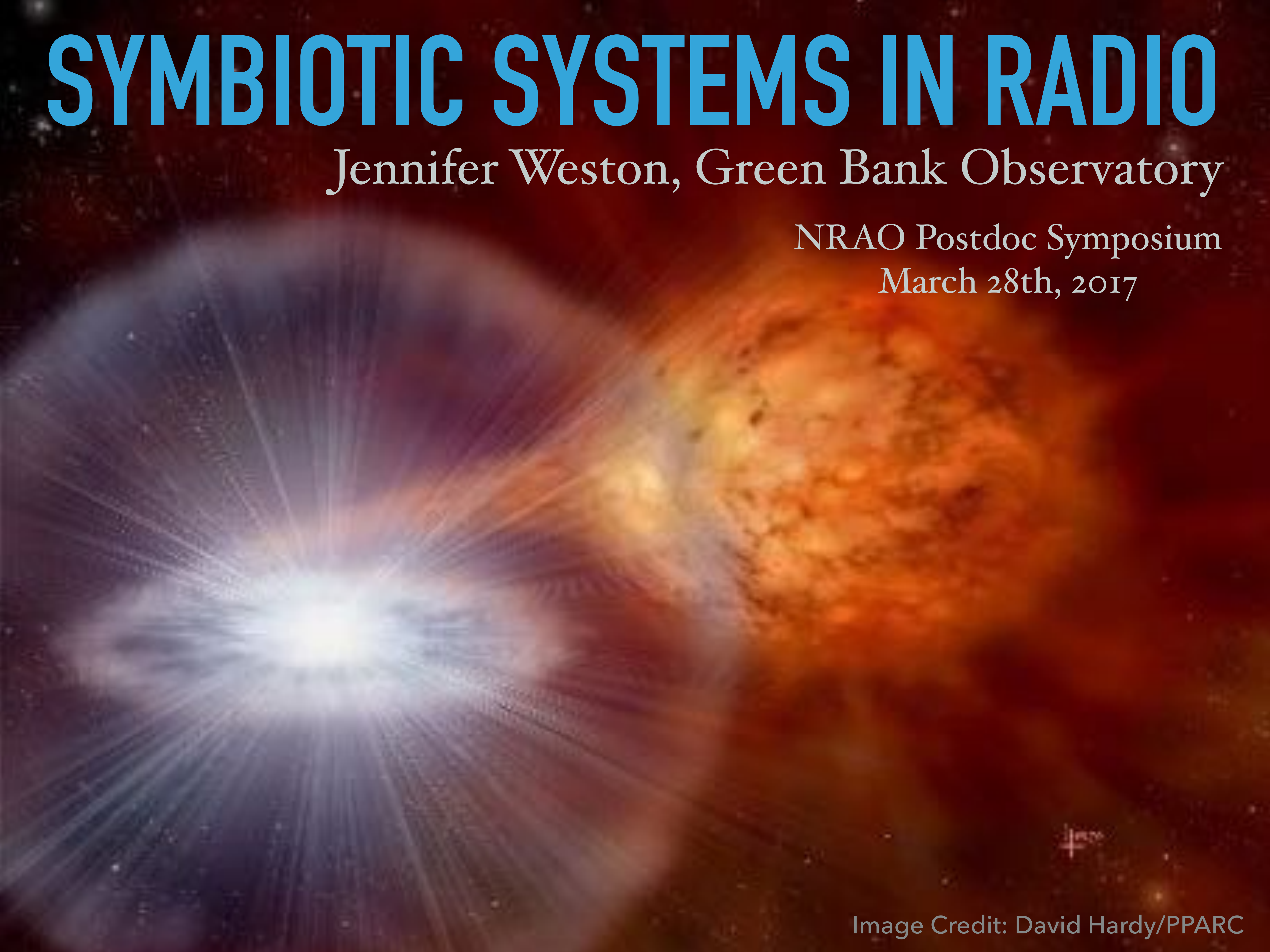

Image Credit: David Hardy/PPARC

Open Questions

* Why do some produce nova eruptions and others do not?
* What fraction of symbiotics have shell burning vs being predominantly accretion driven?
* What constraints can we place on the mass transfer rate?
* What is the predominant mechanism for radio emission?
    * The WD photoionizing the RG wind (STB model), or shocks and collisions between the winds of the two stars?
* What fraction of symbiotic systems produce jets/bipolar outflows?
* Are outflows like jets anchored in the accretion disk (as in X-ray binaries and quasars)?
* How are these outflows shaped?
    * Dense torus of material loosely collimating material, or accretion disk launching a collimated jet?

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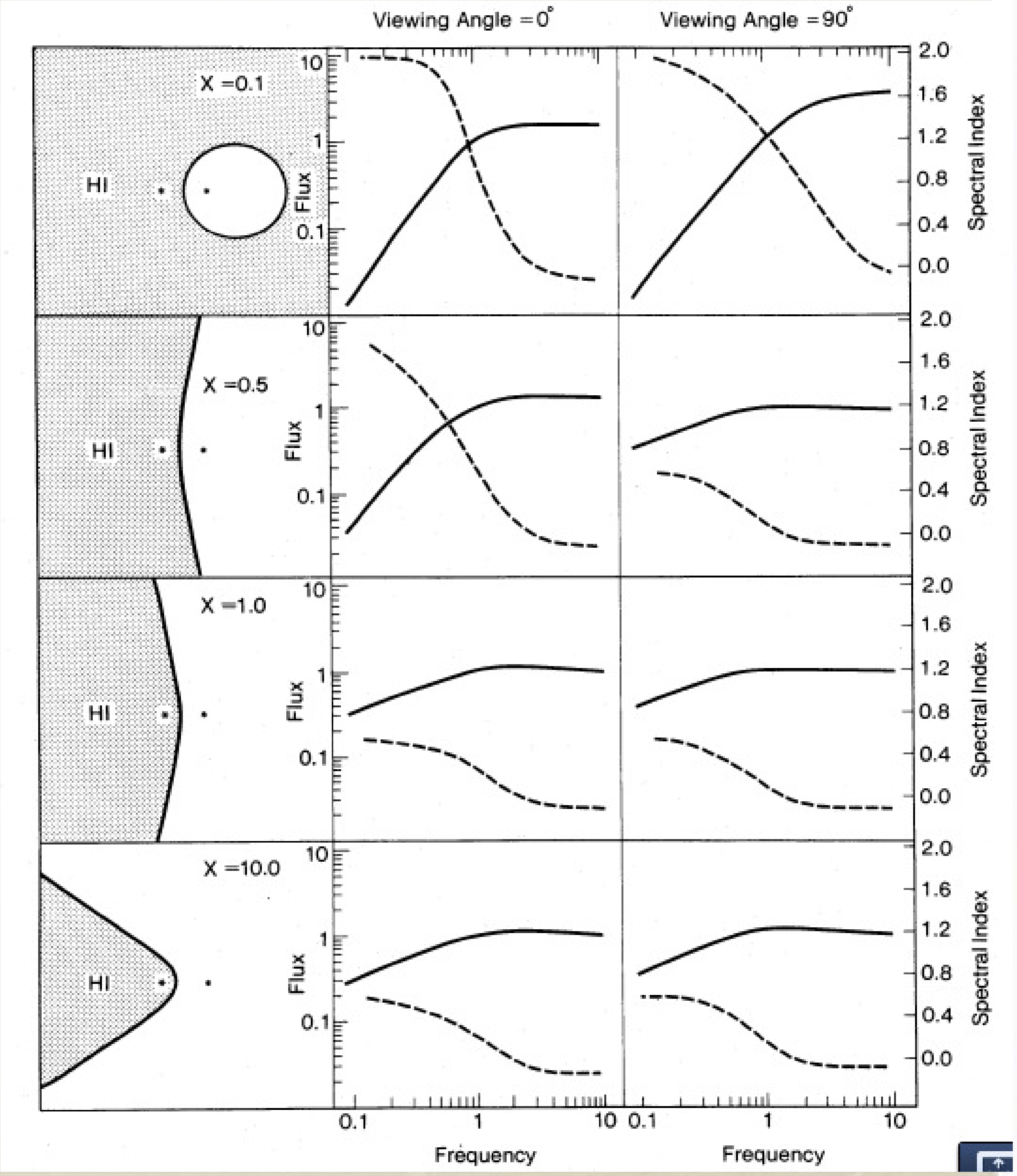
Past radio observations of symbiotics

- ~200 known symbiotic systems
- General properties of symbiotics from the Seaquist & Taylor surveys in 80's and 90's roughly consistent with STB model
  - however, in some cases, shocks between the WD and RG winds appear to dominate, especially in more active systems.
- Some correlation between RG type and brightness of system in radio, may indicate correlation between accretion rate and flux density.
- Only ~dozen symbiotics have spatially resolved extended structure.
- Roughly *~5%* have been shown to have transient jets

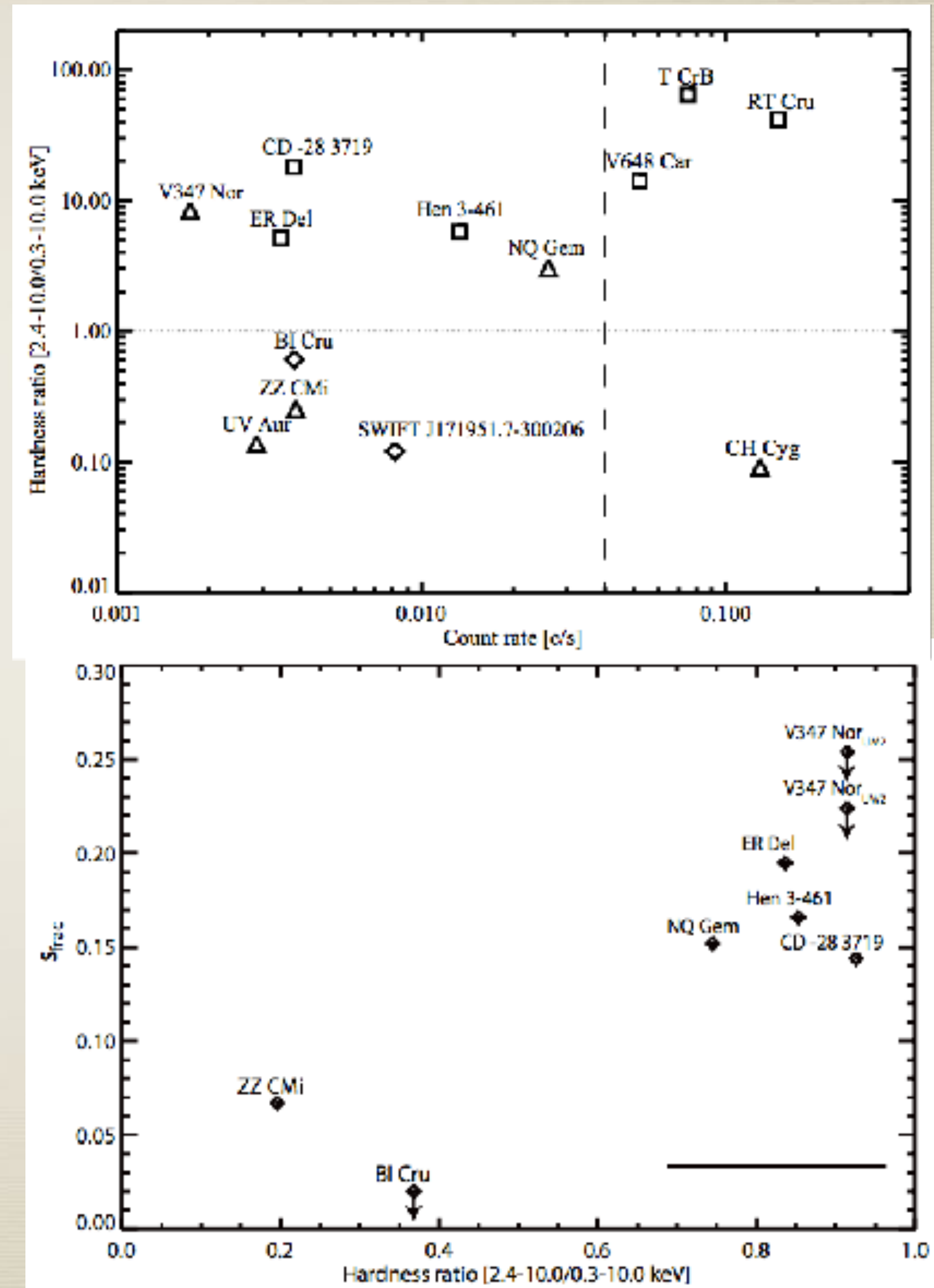
The STB model

* Hot WD ionizing the RG wind
* Shape of the ionization front can be described as a dimensionless constant:
  * $X(L, \dot{M}, v, a) = \frac{4\pi a L}{\alpha}\left(\frac{m_H v}{\dot{M}}\right)$
  * Expected 0.1 <X <10
* Spherical, centrally peaked, and steady state
* Dominated by thermal emission
* Different expectations for shell burning vs accretion driven systems



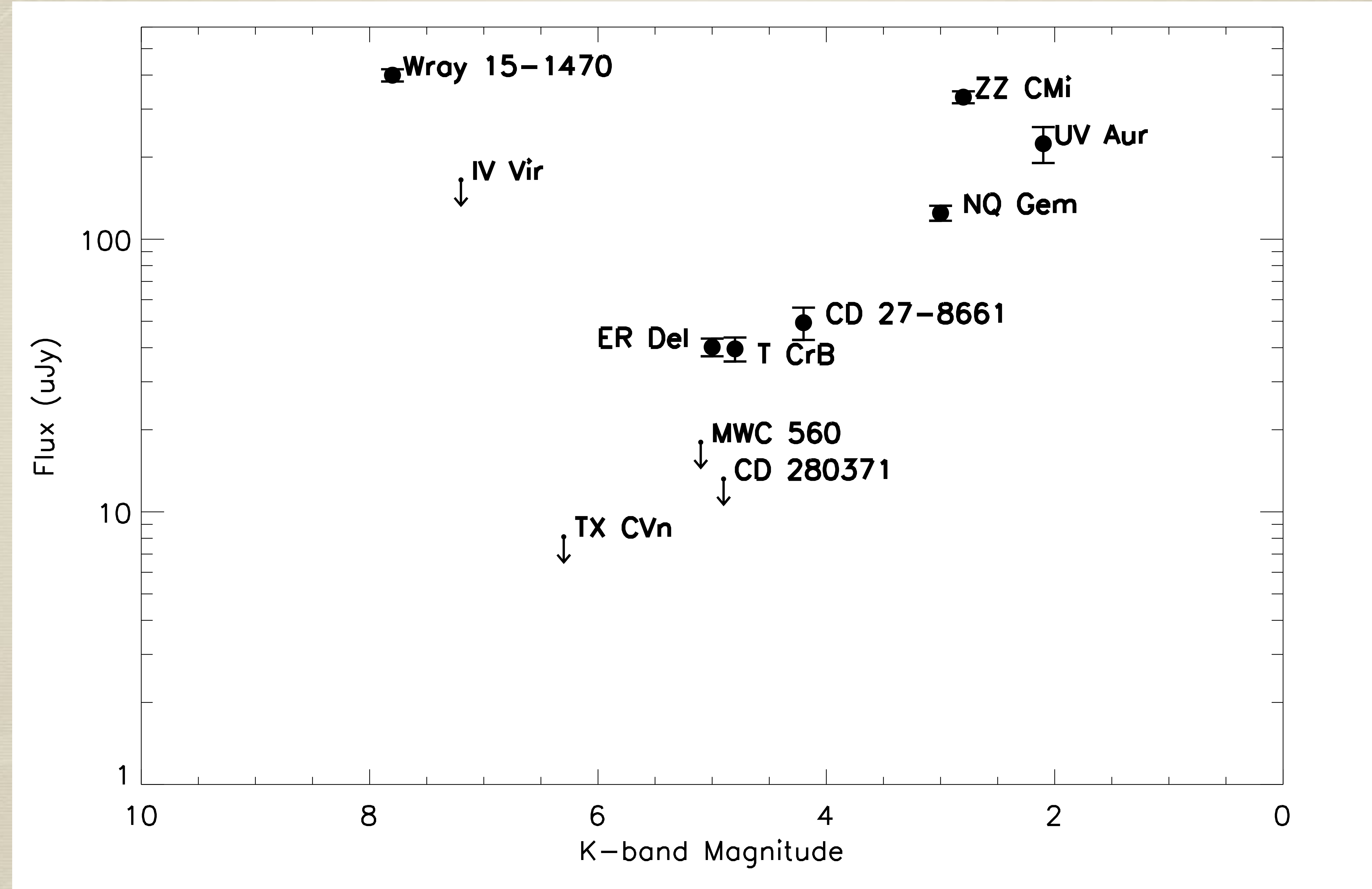
Accretion vs Shell burning symbiotics

- Shell burning systems:
  - Hotter, more luminous WDs
  - Stronger emission lines
  - Easier to detect to large distances
  - Super-soft X-rays
- Accretion driven systems:
  - May make up majority of symbiotics
  - Offers a more 'direct' view of mass transfer
  - UV flickering
  - Highly absorbed hard X-rays



Luna et al 2013

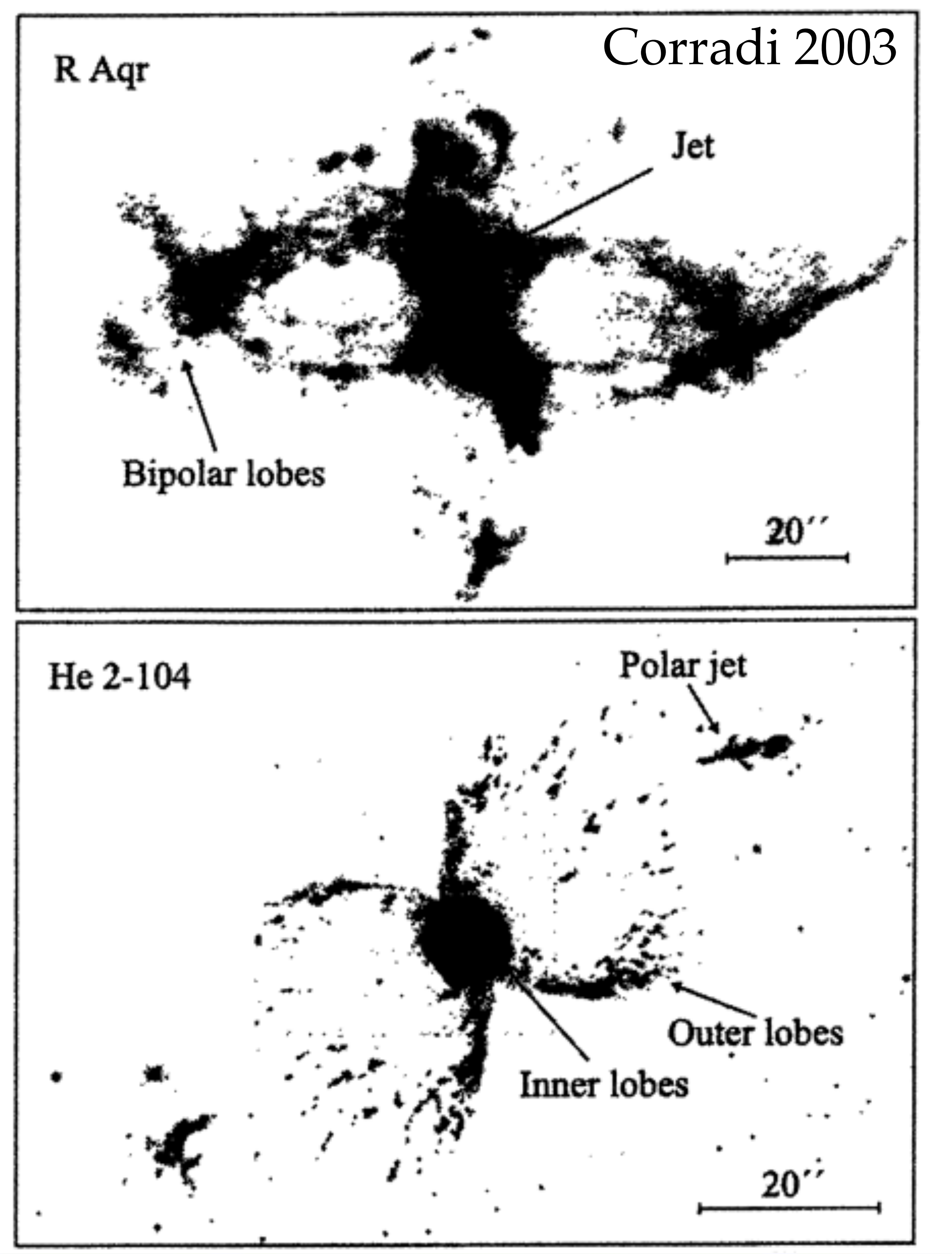
Results of Accretion Survey



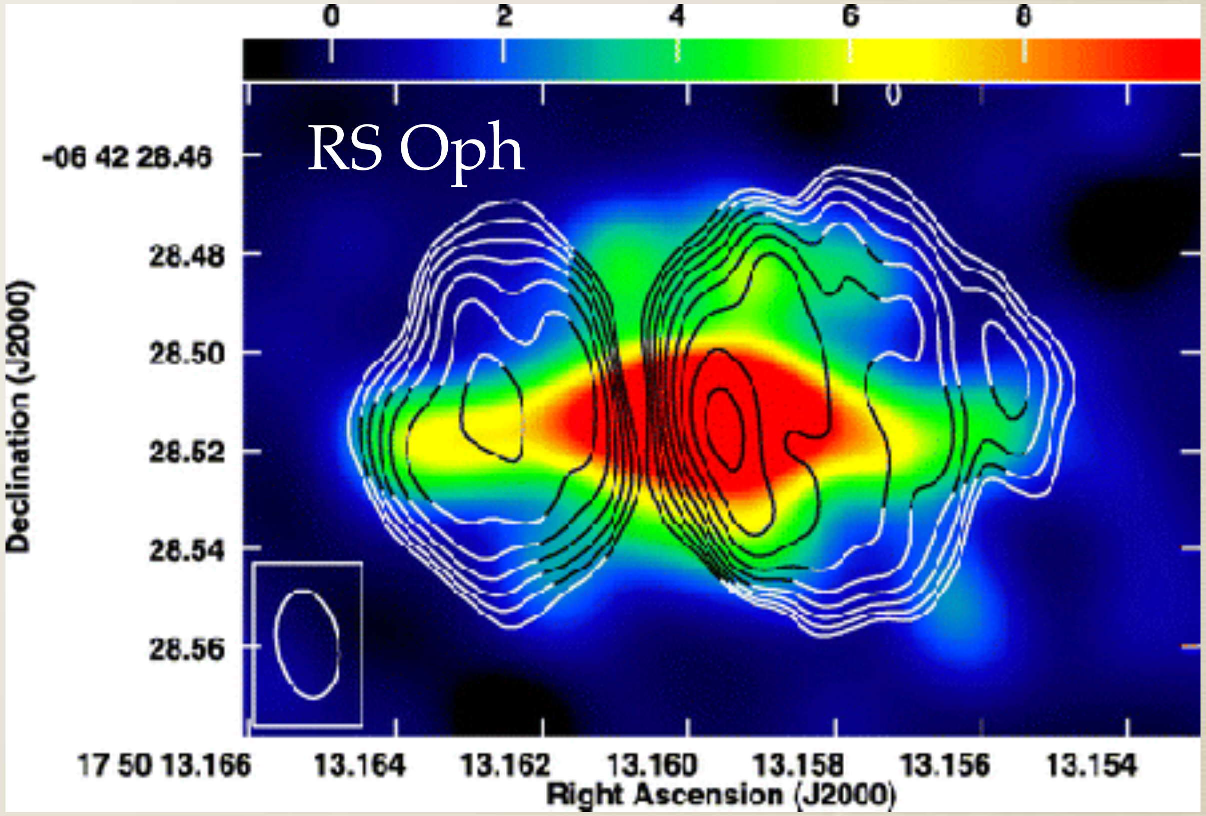
Results of Accretion Survey

- First radio detections of 8 symbiotic systems:
  - TX CVn, UV Aur, T CrB NQ Gem, ZZ CM, ER Del, CD-27 8661, WRAY 15-1470, MWC 560
  - Strong upper limits on remaining 3
- Roughly half were on the order of 10 μJy. Remaining systems were still much fainter than the average symbiotic from Seaquist 1990 survey. (STB consistent)
- We found in-band spectral indexes of 6 sources. 3 were consistent with prediction of α~-1.3.
  - However, the other 3 sources were either only tentatively symbiotic (NQ Gem, ZZ CMi) or only tentatively accretion driven (WRAY 15-1470).
  - Alternatively, they may have outburst or shocks which flatten their spectra
- No correlation between donor star type and flux density (STB consistent)
- No strong correlation between distance and brightness (using K and V band as proxies)

Outflows from Symbiotics



Sokoloski et al 2008



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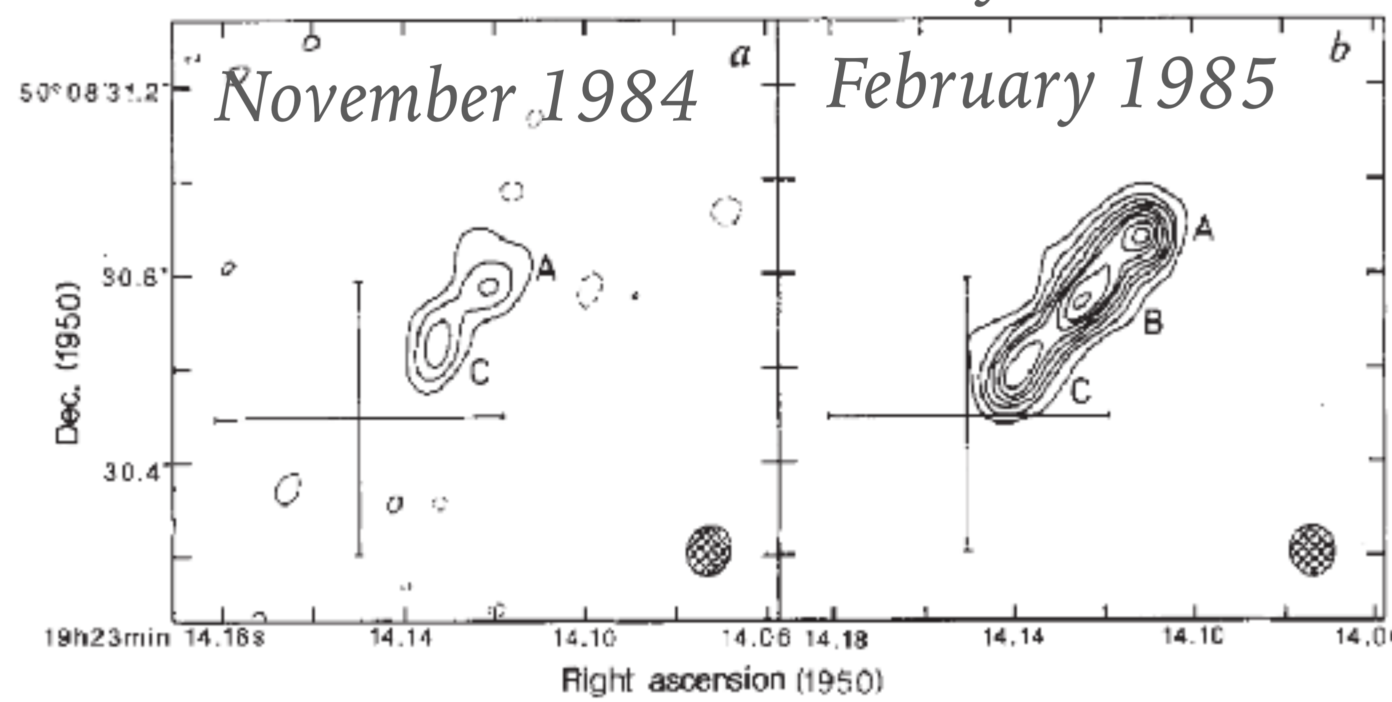
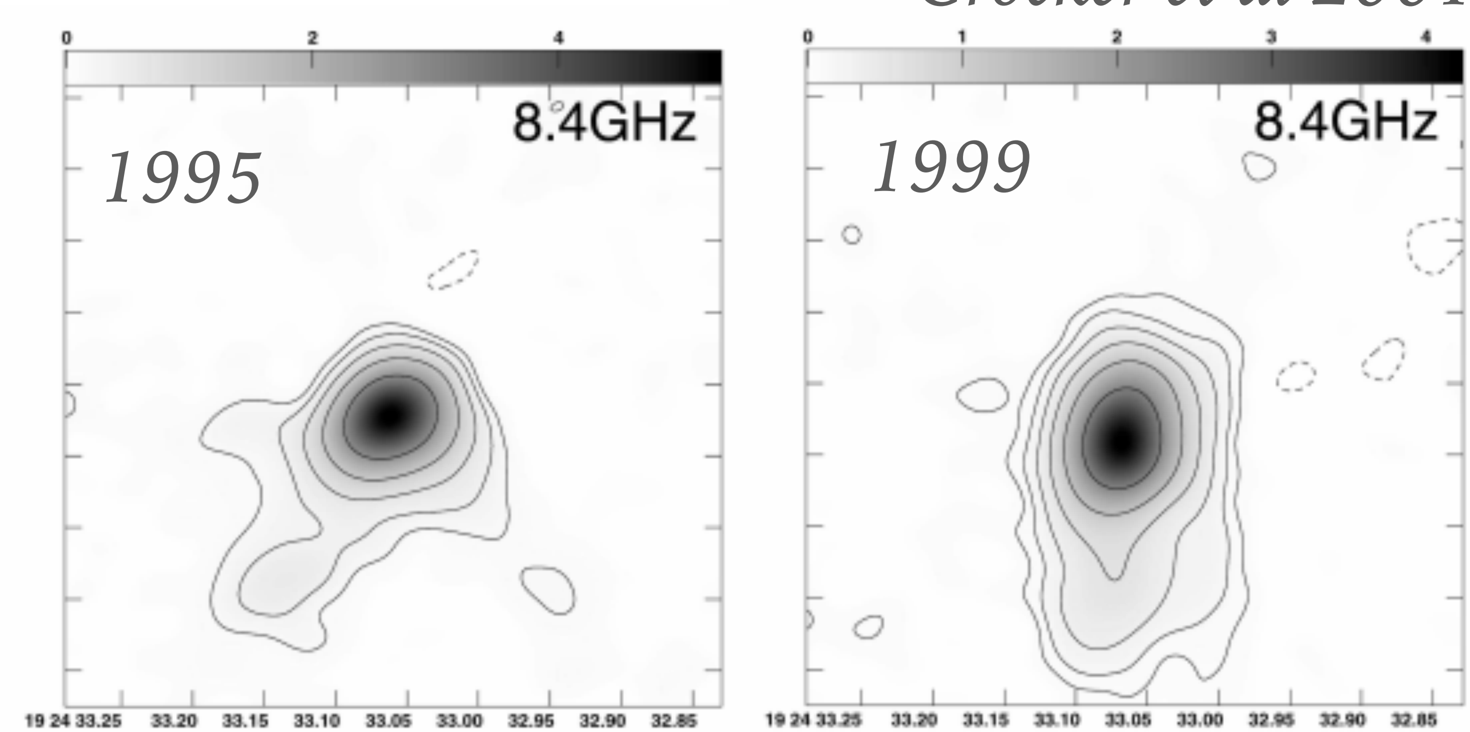
CH Cyg

- Accretion powered symbiotic
- D~245 pc
- Multiple observations of a processing radio jet — most recently by Karovska et al. (2010) in late 2008
- Jet production often associated with changes in optical brightness
- Variability in radio brightness not thoroughly monitored or well understood

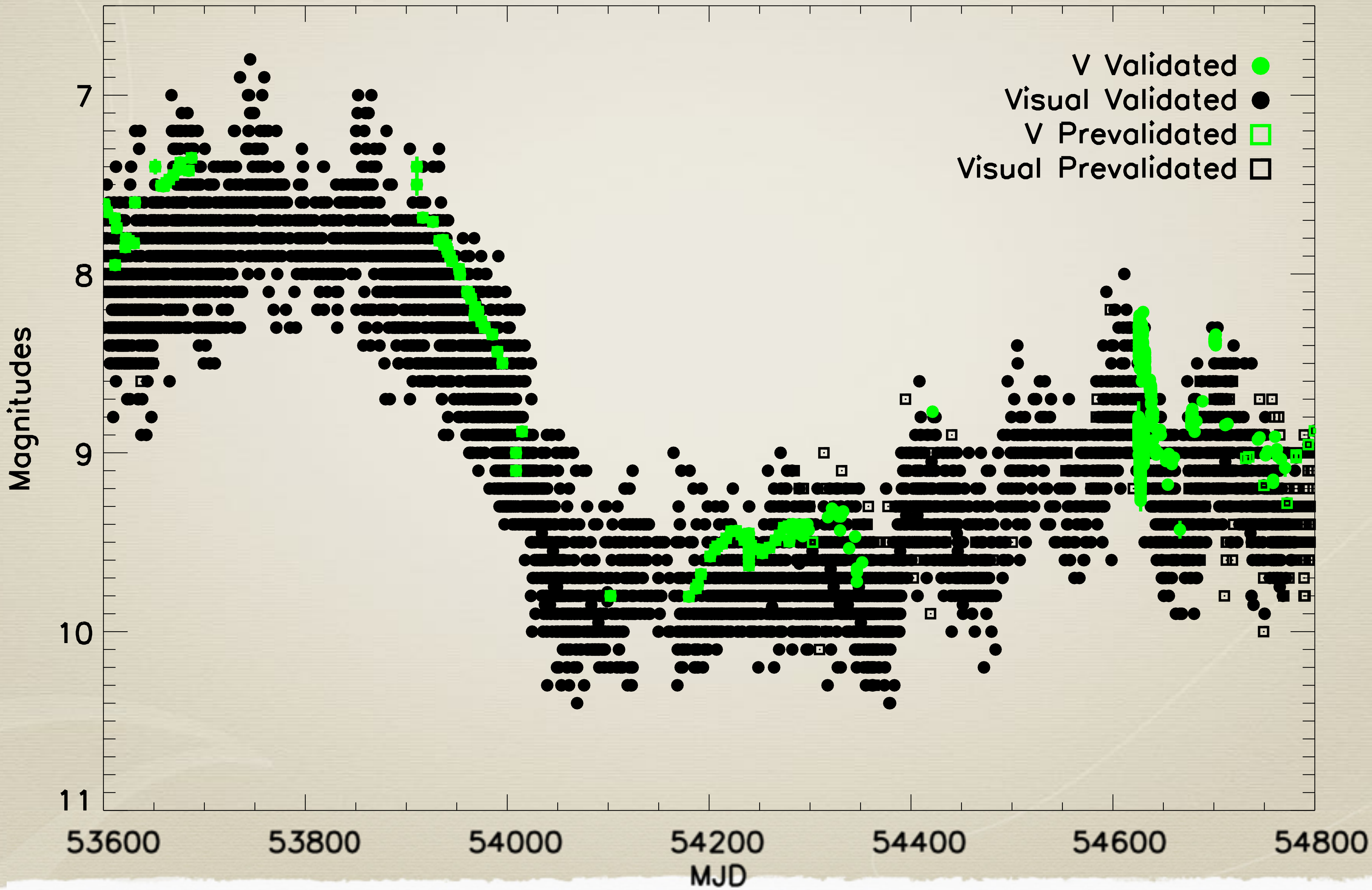
Taylor et al 1986



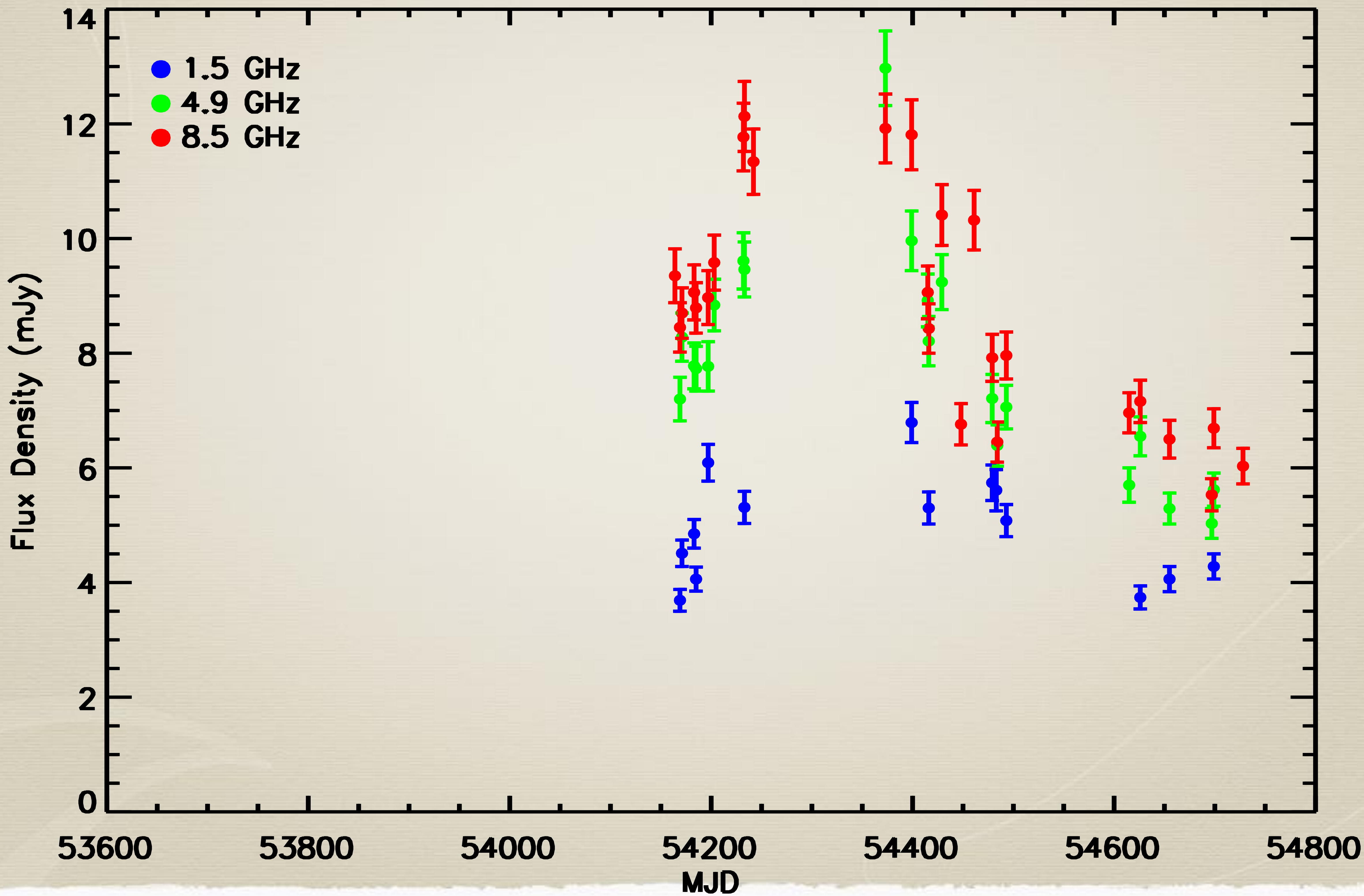
Crocker et al 2001



CH Cyg Optical Light Curve



CH Cyg Radio Light Curve



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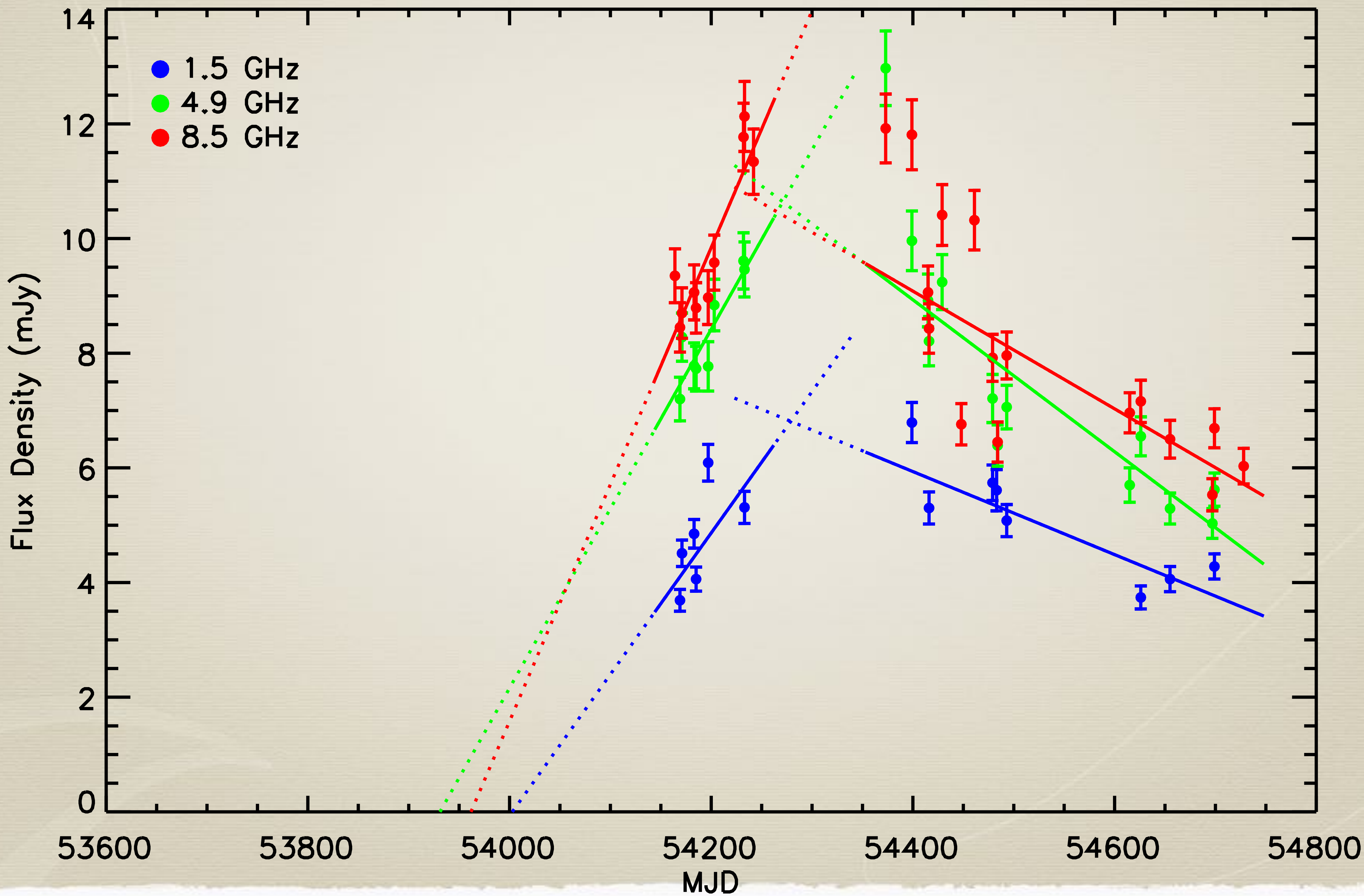
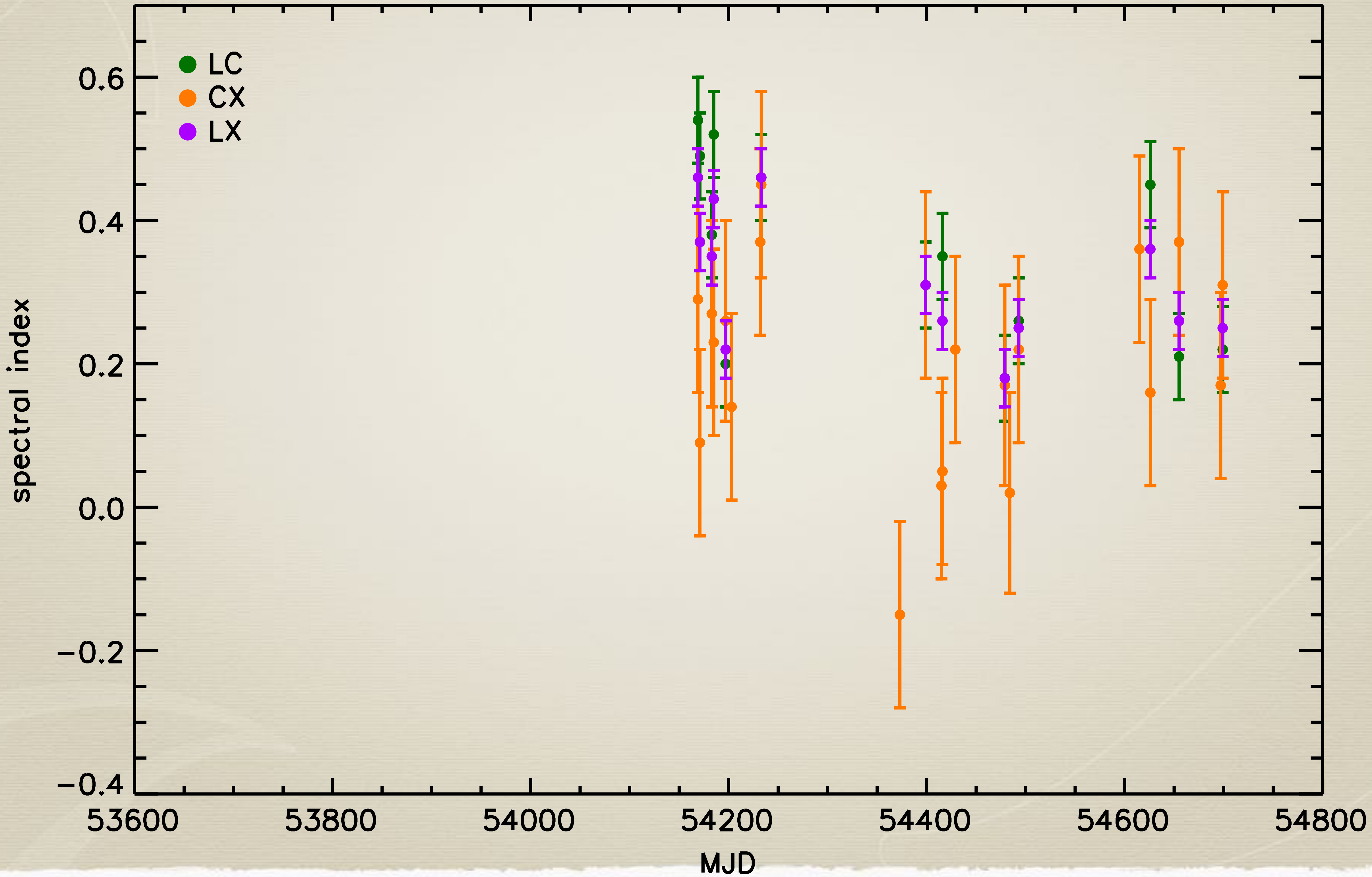


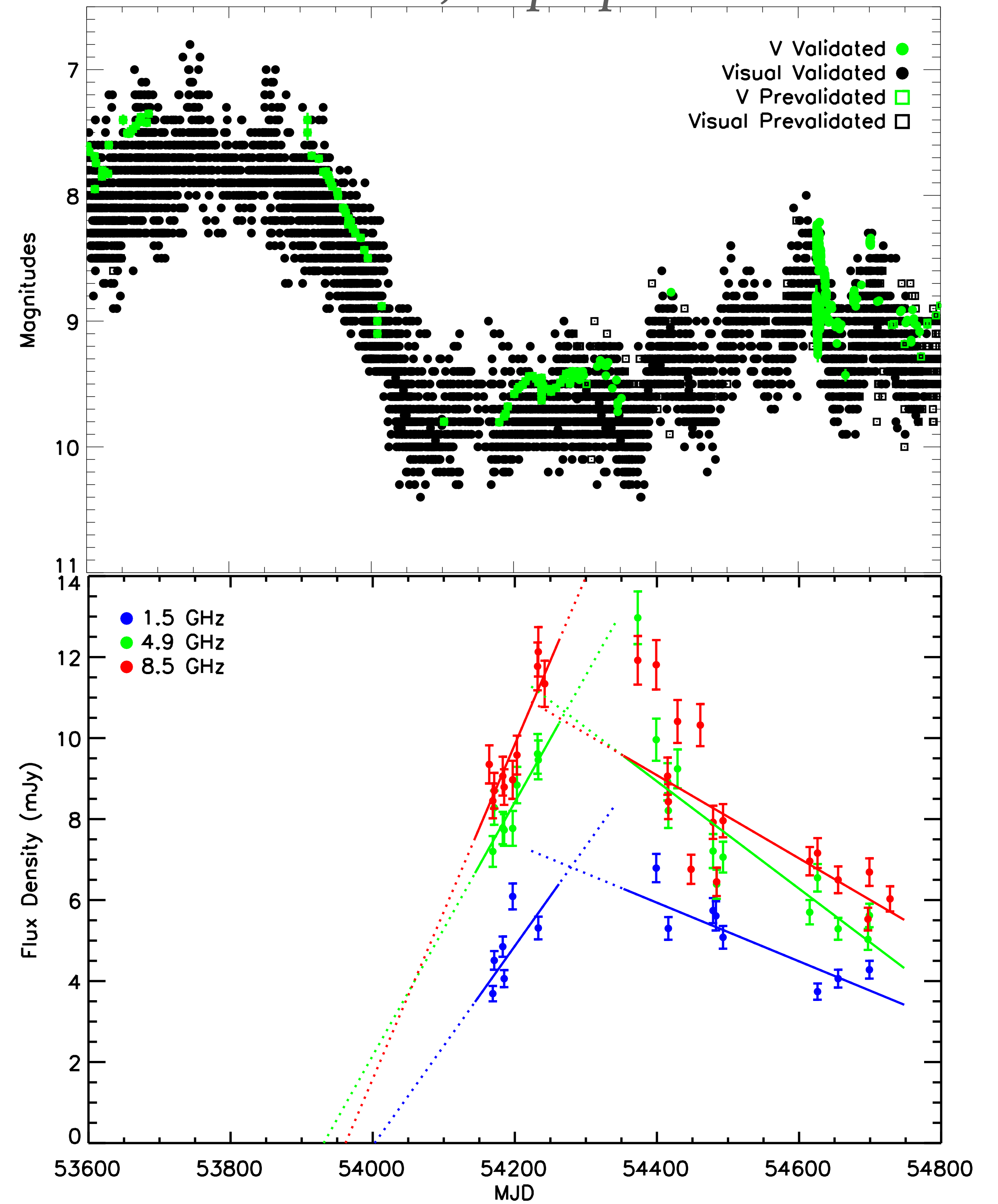
CH Cyg Spectral index



CH Cyg Radio Brightness

- Spectral index fairly constant during observations, close to optically thin.
- No signatures of synchrotron emission
- Increase in radio flux density likely due to continued mass outflow
- This outflow lasted ~1 year, beginning near the middle or end of the optical decline
- Estimating mass outflow from size of jet gives M_{ej}~2.7×10^{-7} $M_{\odot}$, a larger mass than expected from accretion theory.

Weston et al 2017, in prep



CH Cyg Imaging

* Multiple observations of a resolved, developing radio jet

* Projected expansion (with v~990-1920 km/s) is consistent with velocities in previous observations.

* Precession period of P~12000 days (on order twice the orbital period), precession cone angle ~55.4°, larger than previously thought.

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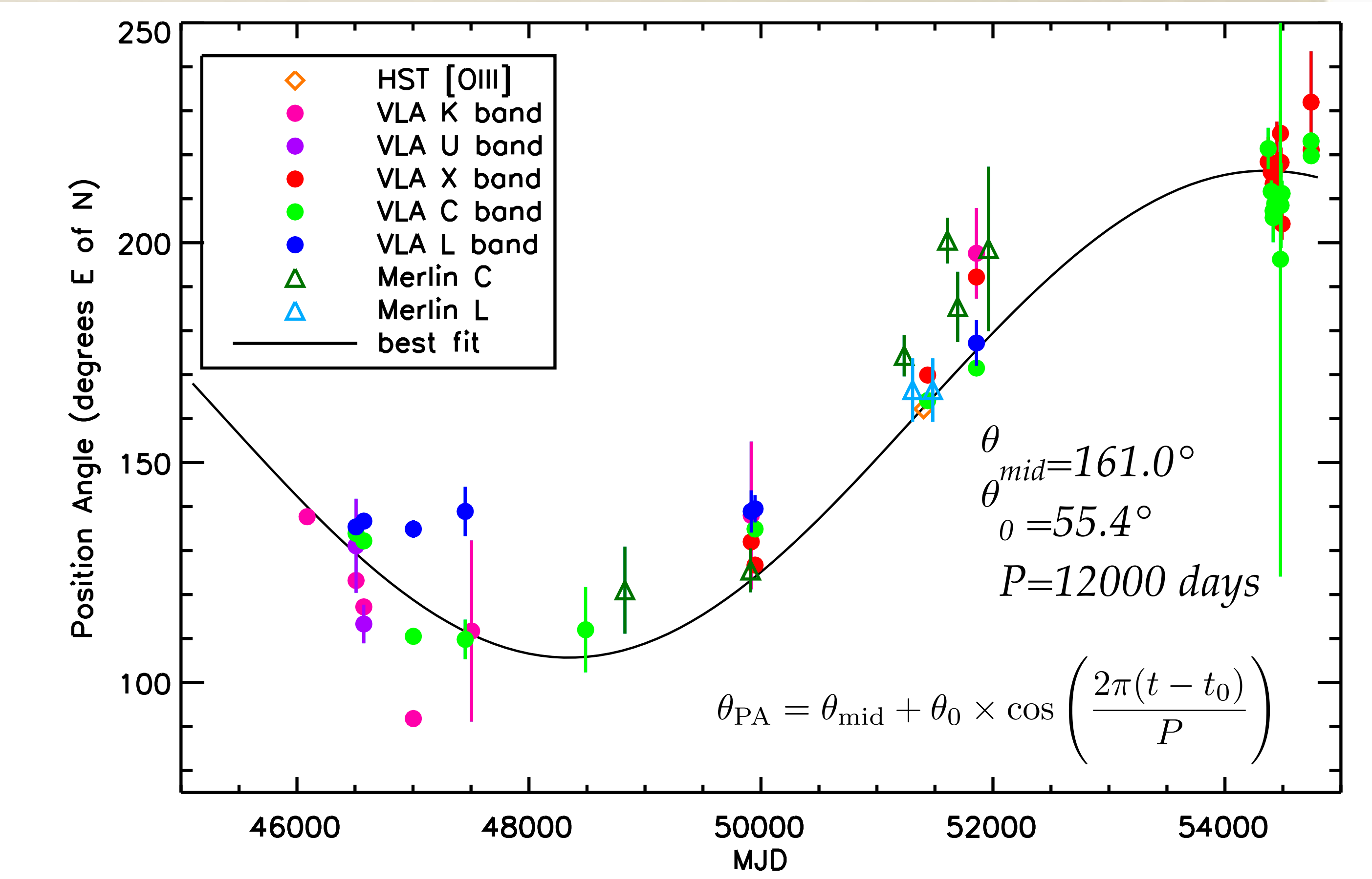

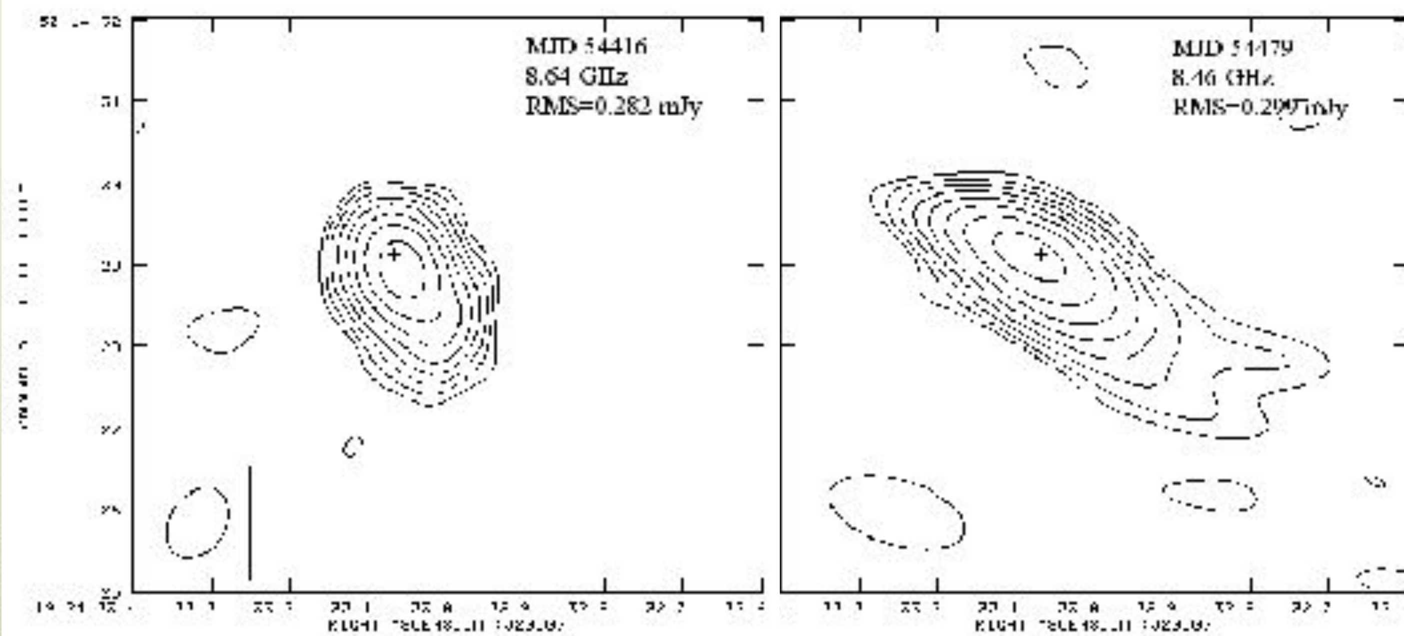

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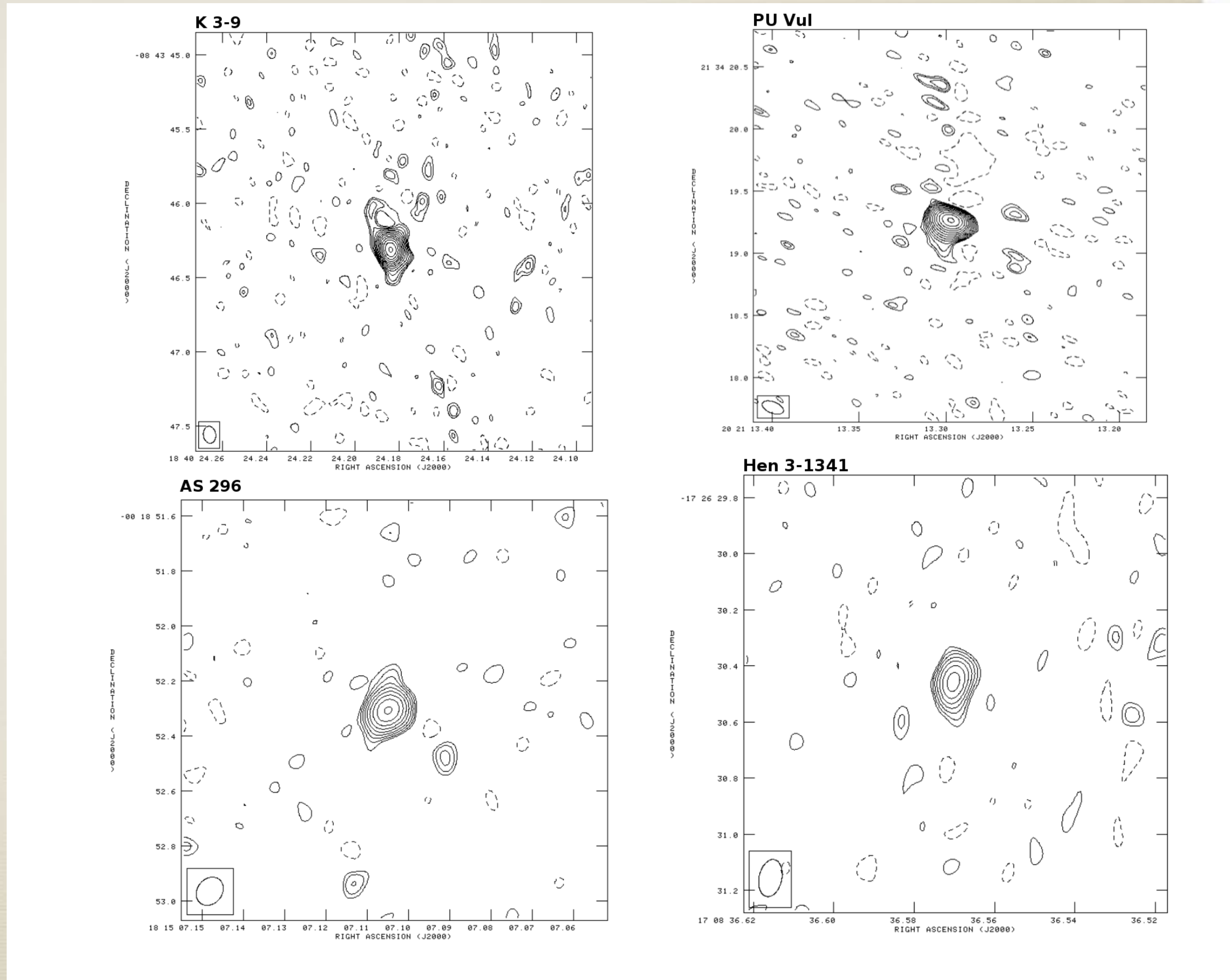
Survey of Symbiotic Nebulae

- Original Survey:
  - 11 radio bright symbiotics without any resolved imaging
  - taken with the VLA in 2008-2009 prior to the upgrades
- Expanded Survey:
  - 9 radio bright symbiotics (3 of which were also in the original survey)
  - Taken with the VLA in 2014 after the recent upgrades

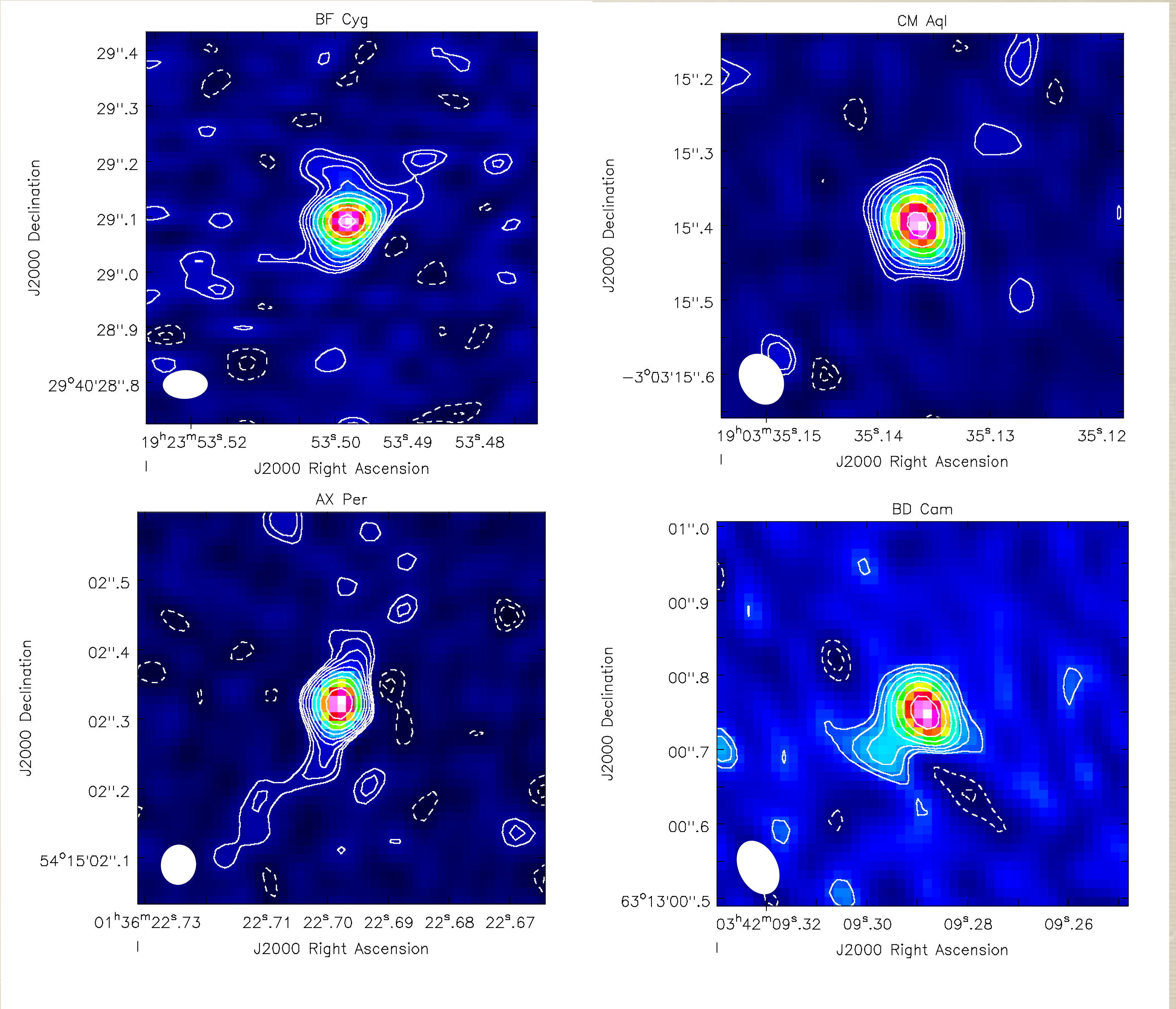
Original Survey Results

- Resolved 4/11 sources
  - first ever resolved radio images of these objects
  - 2 have resolved structure
- Radio detection of 10/11 sources
- Extreme radio variability in one object: BF Cyg, which was a non-detection



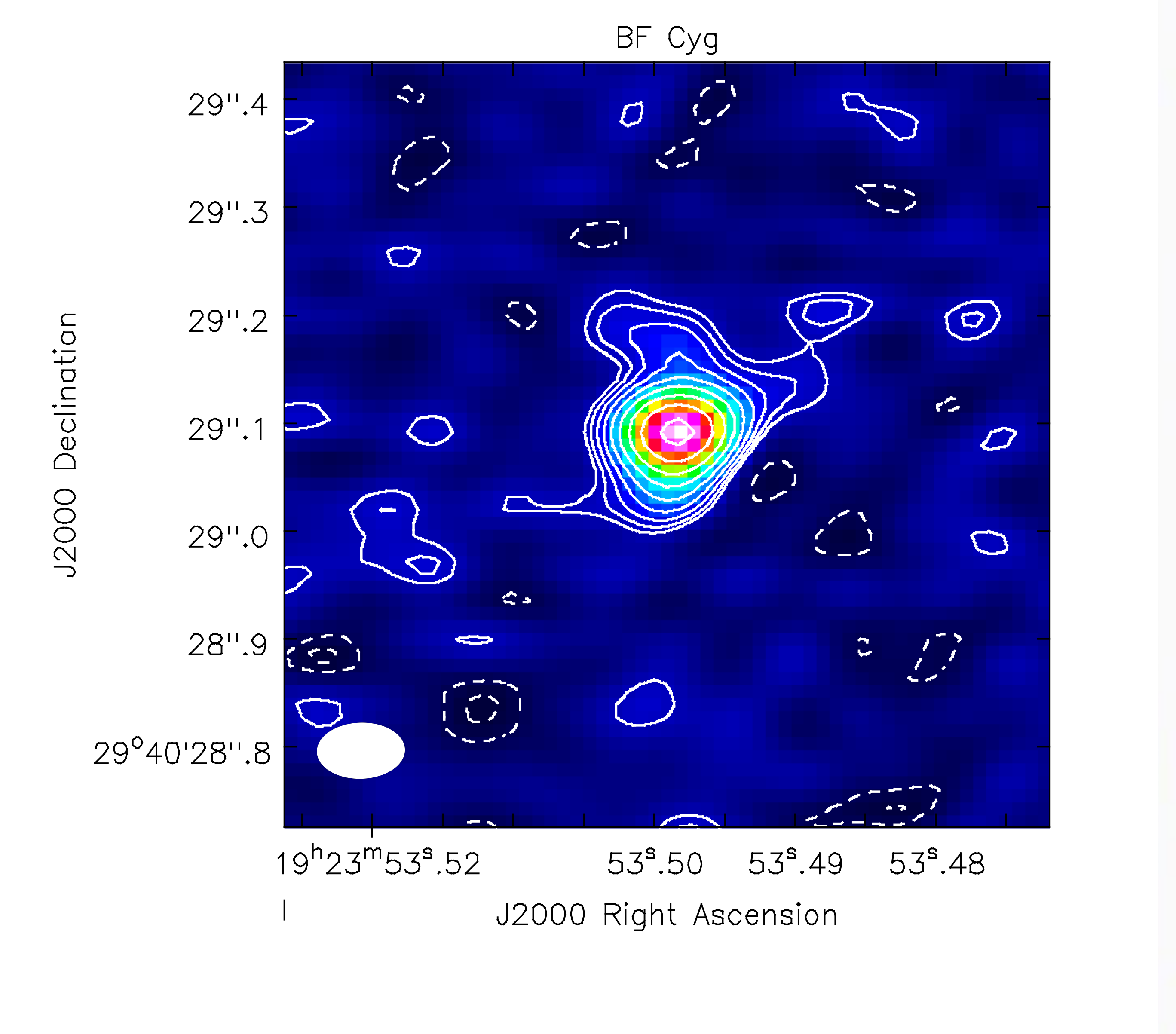
Expanded Survey Results

* Resolved 8 out of 9 sources
    * AG Dra, which was not resolved, has shown resolved extension in prior images
* In band spectral indexes were to be consistent with optically thin thermal emission (albeit with large error bars) in all but one case
* We should now be able to do a much deeper imaging survey of symbiotic nebulae



BF Cyg

- Non detection in the original (<170 μJy), detected with signs of extension in the expanded (730 μJy)
- Spectroscopic monitoring showed the production of a jet in 2009 which became bipolar in 2012
- Therefore, increase in brightness may be due to jet production
- Given their relative distances, CH Cyg should be roughly 240x the brightness of BF Cyg, but this is not the case — BF Cyg is brighter than we expect. This is consistent with the fact that BF Cyg is a shell burning system and CH Cyg is purely accretion powered.



General Thoughts

* Shocks from outflows may play a significant role in the development of symbiotic systems.
* While the simple STB model may provide a general explanation for the radio behavior of these systems, individual objects must be treated with care, as shocks, outflows, etc, can cause large deviations from the expected norm.
* Observations of symbiotics in radio has a lot of unexplored potential!

Questions?