The magnetic field of the evolved star W43A

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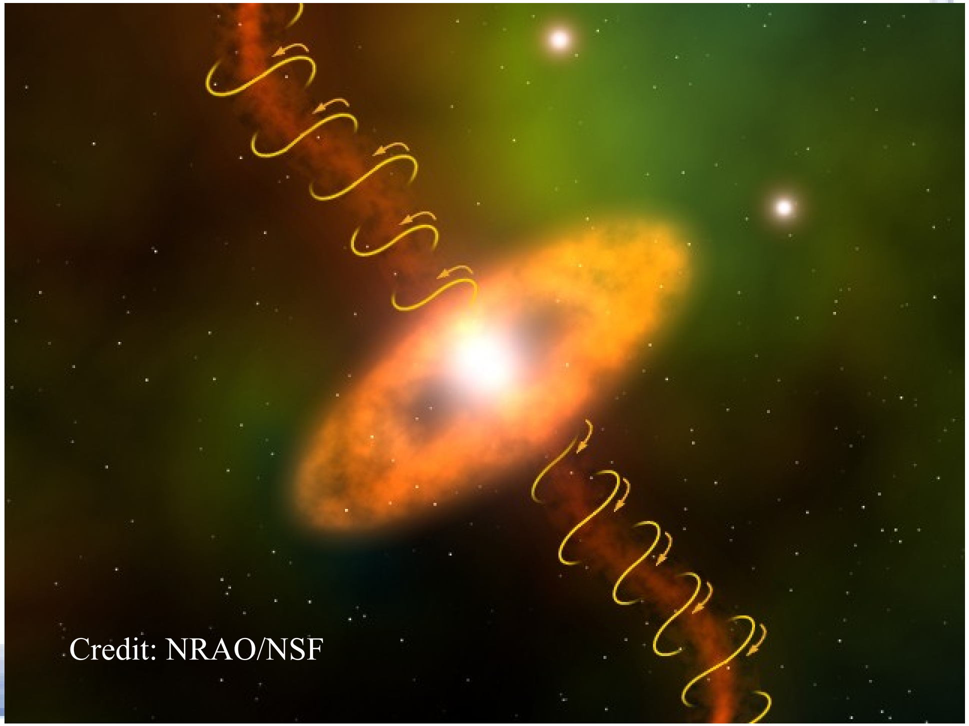


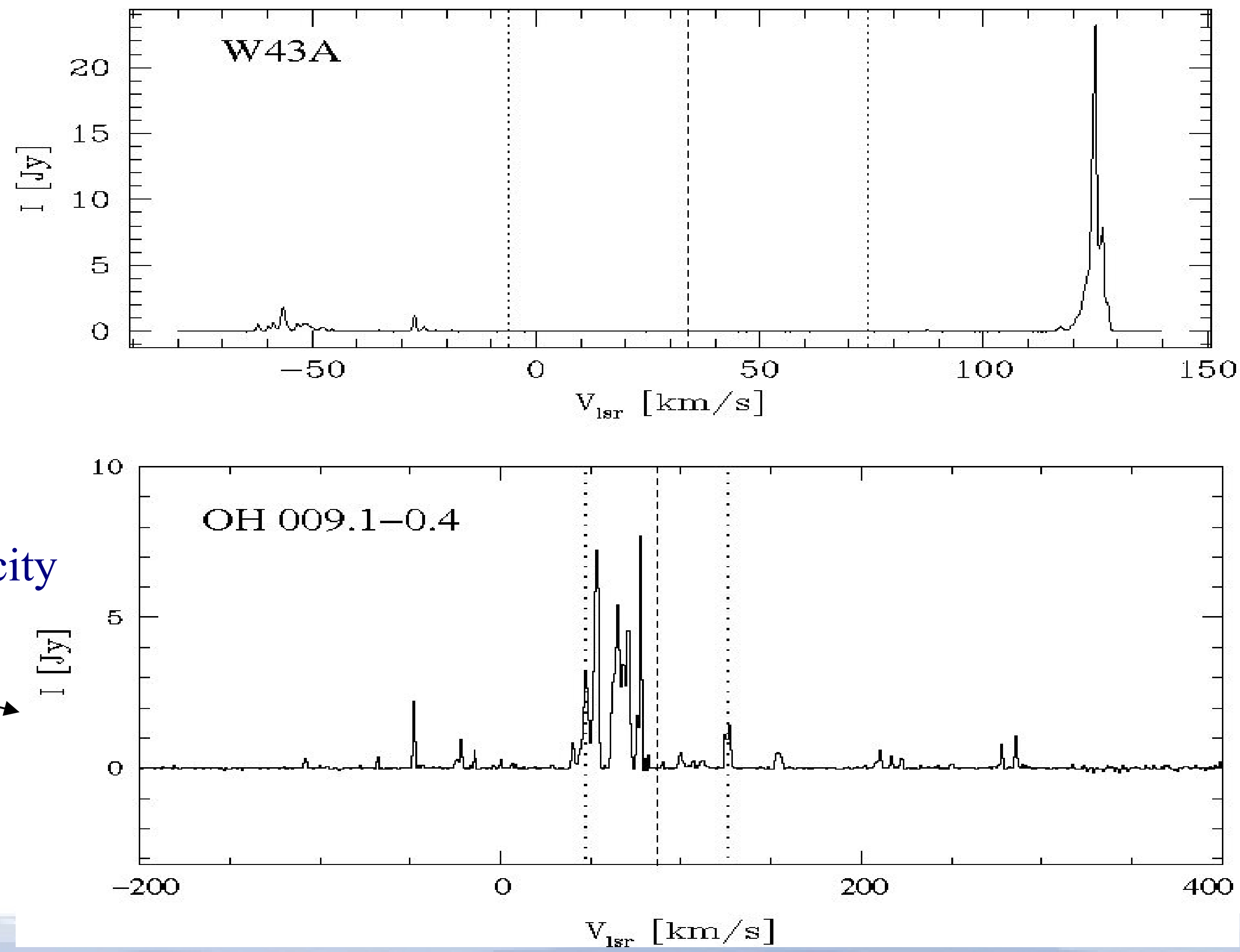
Credit: NRAO/NSF

Outline

- Asymmetric planetary nebulae
- Water fountain sources
- Observations of the OH maser region of W43A
- Results
- Conclusion

Water fountain objects

-Approaching the post-AGB evolutionary stages, there are however, a growing number of objects that show deviations from the regular CSE picture. Among these, an important class are the so called water fountain sources that exhibit a **large velocity extent** in the water maser region (e.g. Likkel et al. 1992) and for which interferometric observations have revealed **highly collimated jets** (Imai 2002).



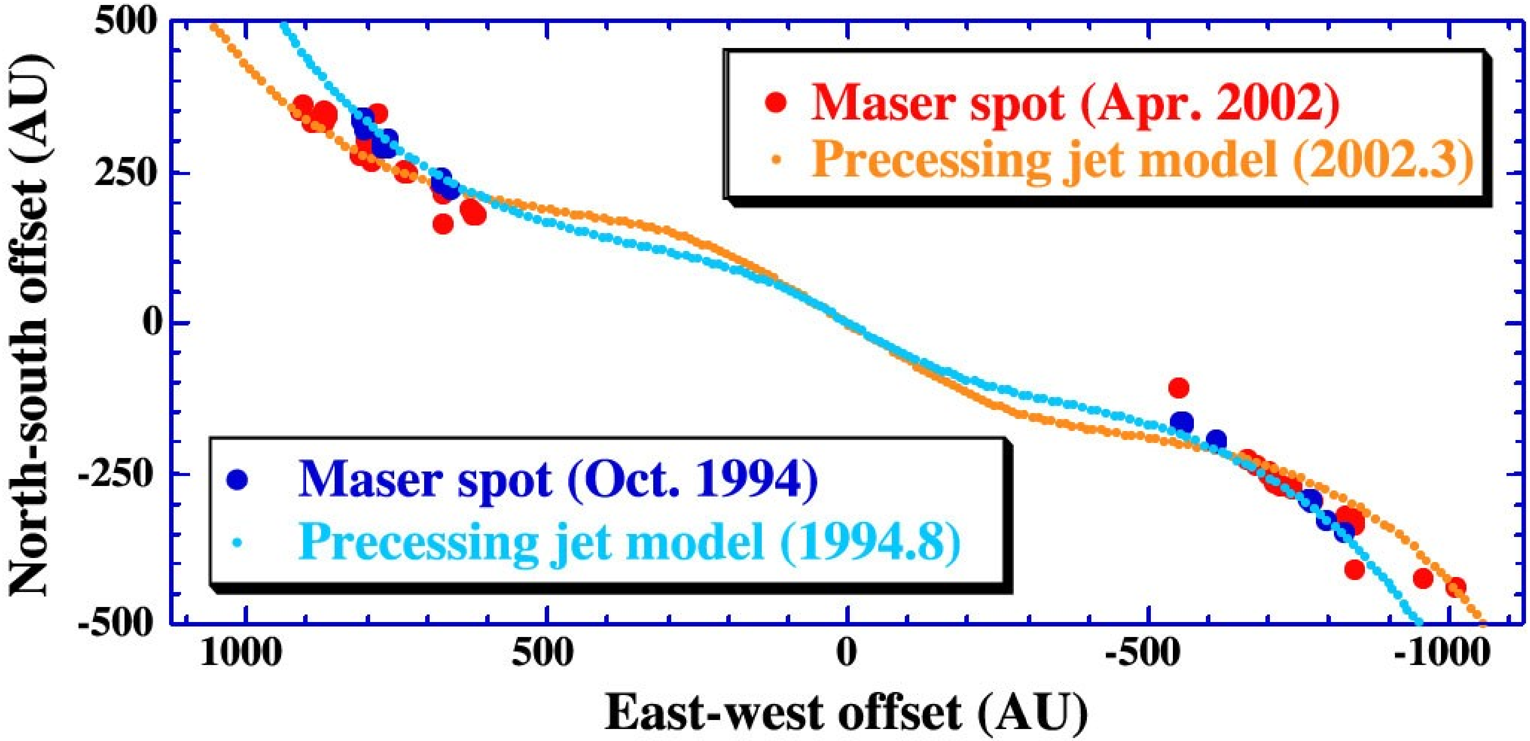
400 km/s velocity extent

Largest velocity extent for any H2O maser source

Walsh et al. 2009

W43A

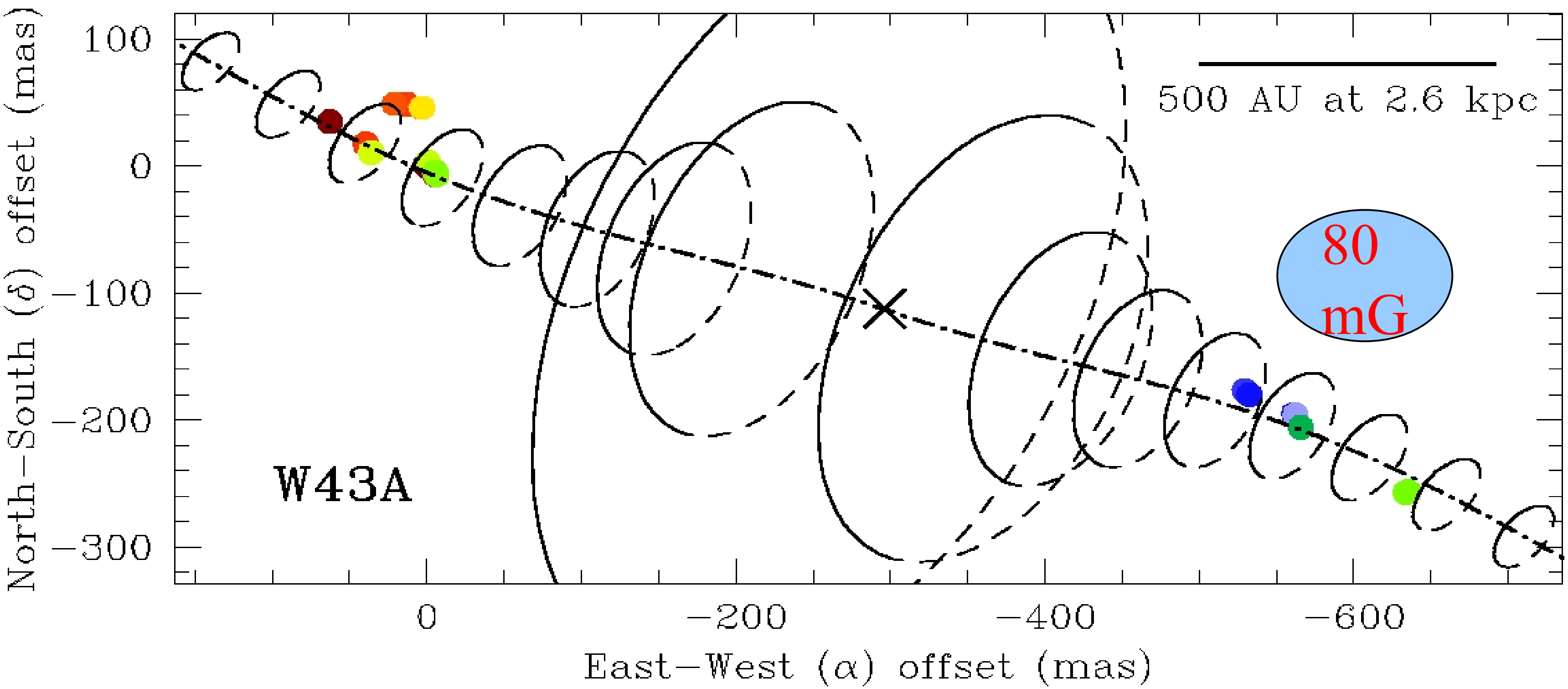
- W43A is the archetypal ‘water fountain’ source
- The H_2O masers exist in a precessing jet



(Imai et al. 2002)

W43A

- Polarization observations have indicated that the jet is magnetically collimated B ~ 80 mG (Vlemmings et al. 2006)



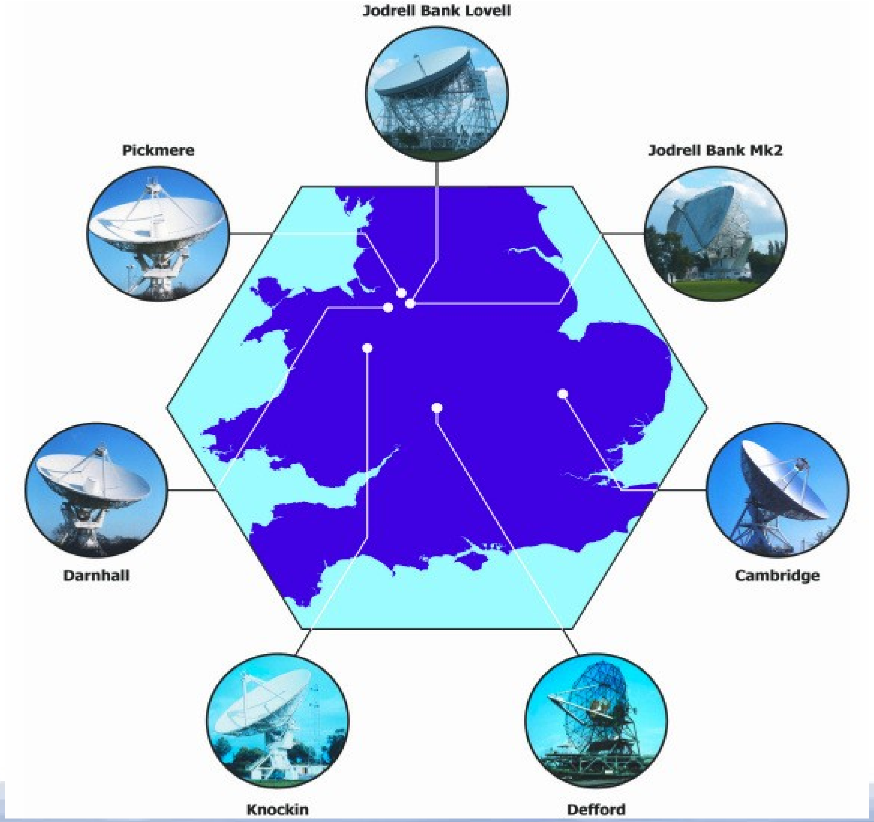
OH maser polarization of W43A

- Investigate the large scale magnetic field in the OH maser region of W43A.

- **MERLIN** observations: 1612 MHz full polarization spectral line mode

  Beam size: 0.3 * 0.2 arcsec

  Spectral resolution: 0.2 km/s



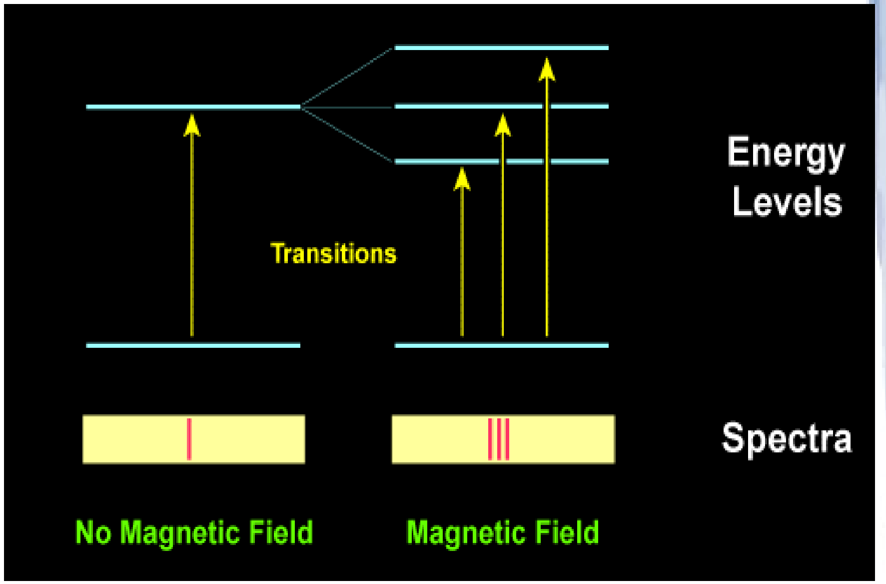
GBT observations

- Dual polarization receiver of the lower K band
- FWHM: 33"
- Velocity coverage: 2700 km/s
- Spectral resolution: 0.164 km/s

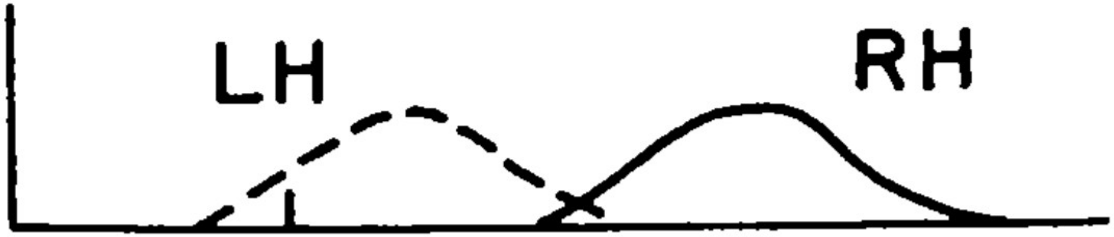
Determining the Zeeman splitting

- Split of spectra lines into multiple closely spaced lines, in the presence of an external magnetic field.

- The Zeeman splitting causes a velocity shift between the RCP and LCP spectra

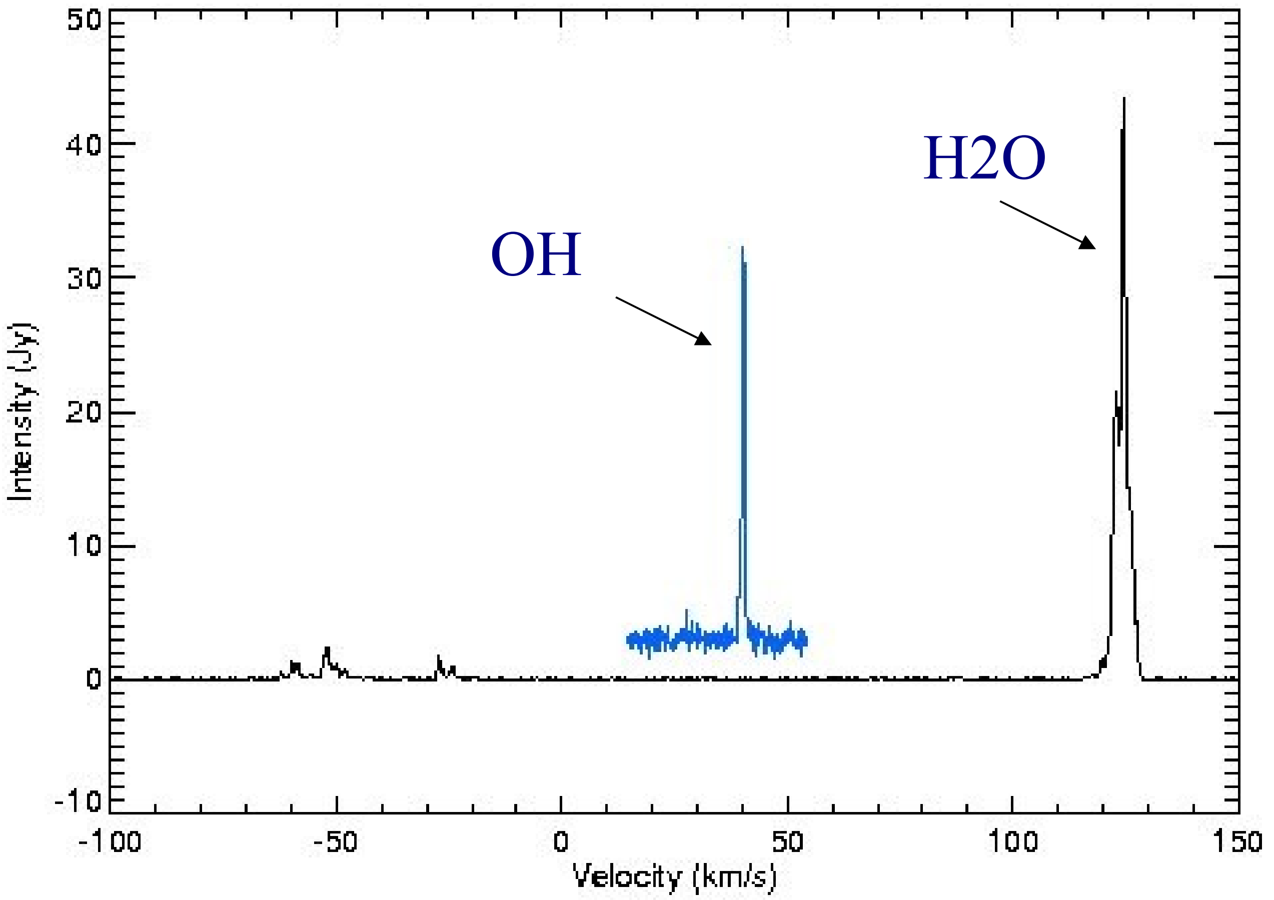


The **cross-correlation** method is used to determine the Zeeman effect. The RCP and LCP spectra are cross-correlated to determine the velocity separation.



Spectra of W43A

- The velocity range for the OH (27 to 43 km/s) is much less than the H_2O (-53 to 126).



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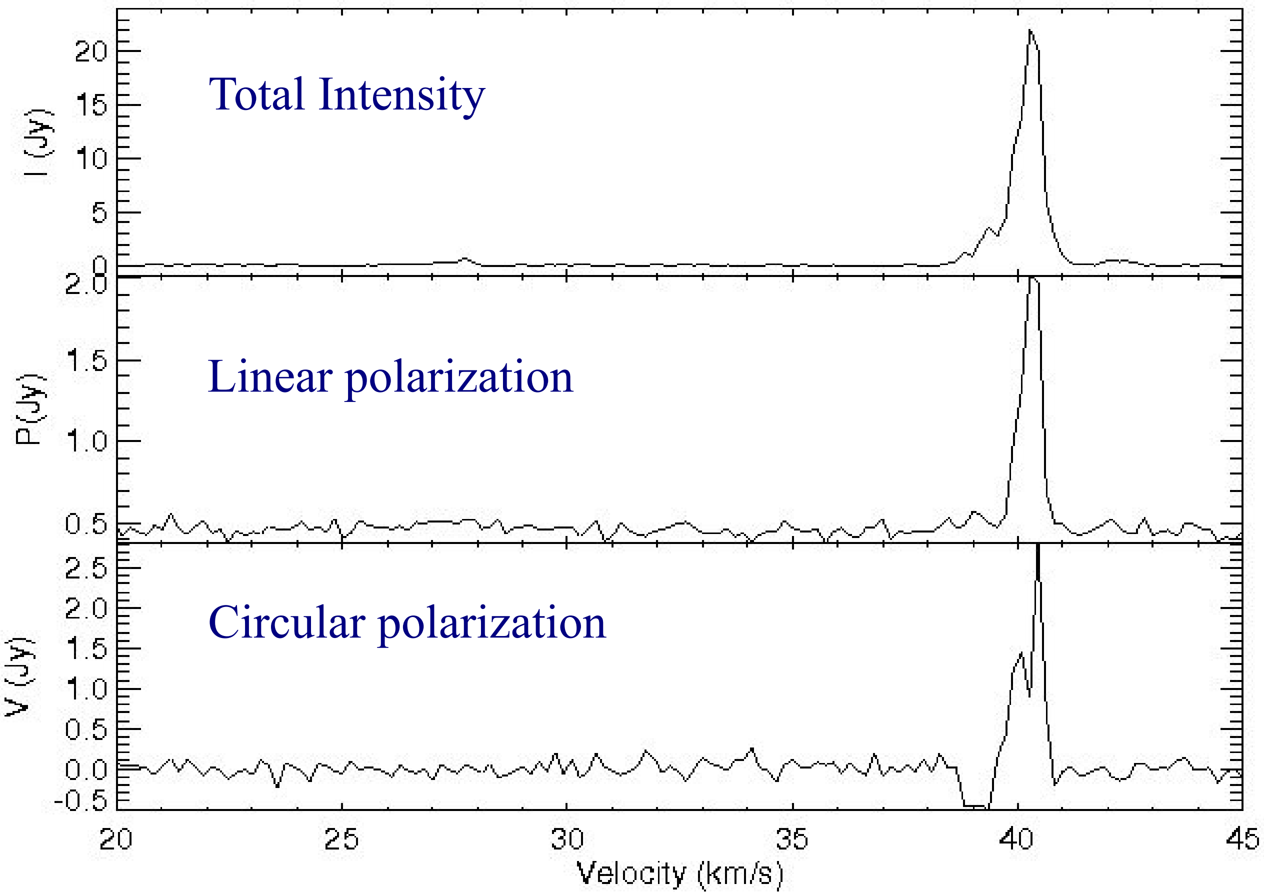
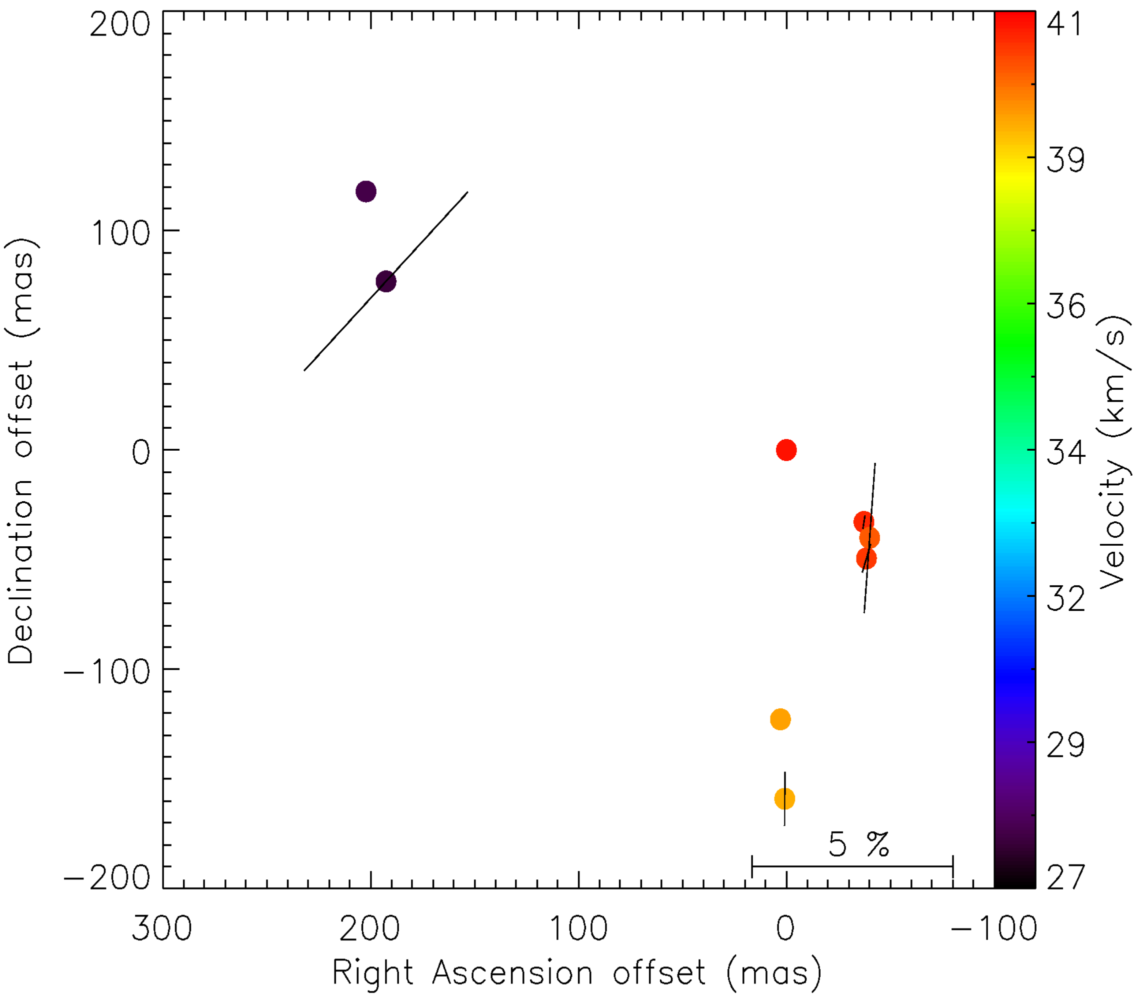
Polarization spectra

- Most of the emission in the total intensity spectrum was also detected in the linear and circular polarization spectra.
- The emission is dominated by the redshifted peak. (10% circular and 12 % linearly polarized.)



OH maser spatial structure

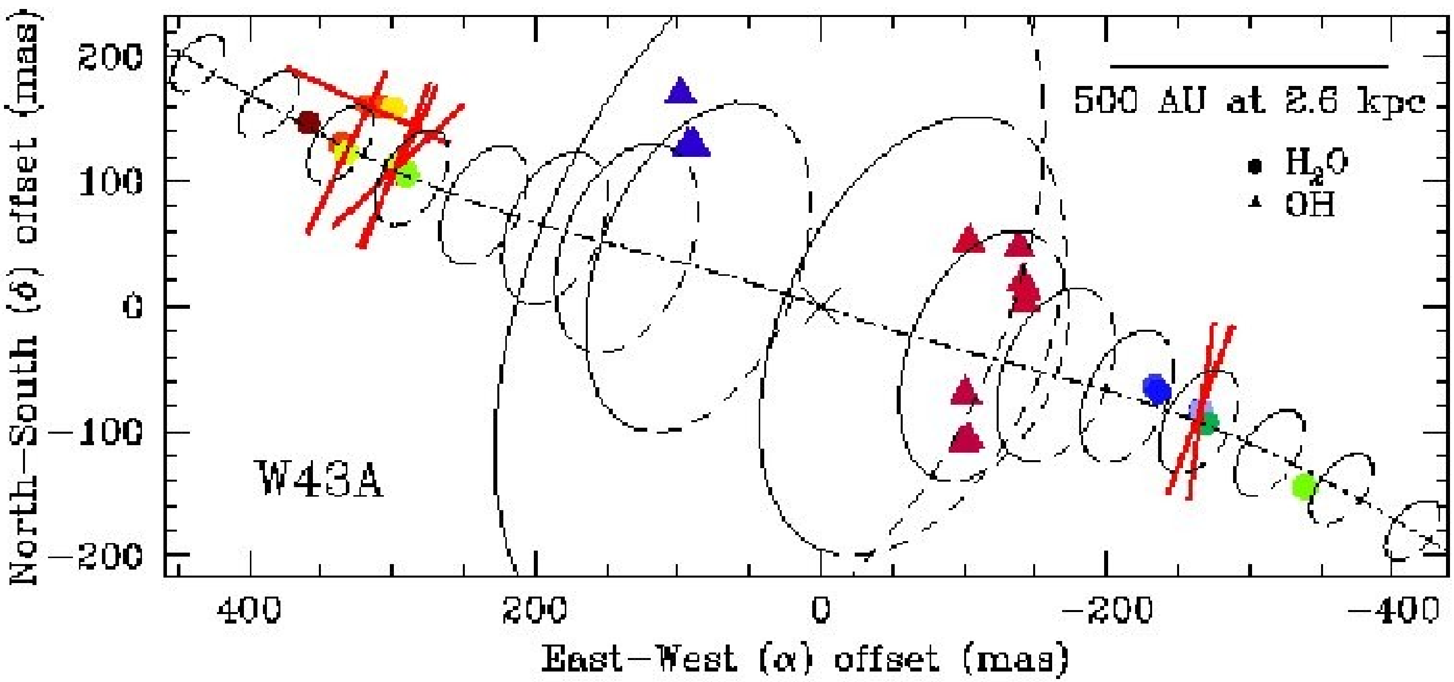
- The OH masers detected for W43A, color-coded according to their LSR velocities.
- The vectors scaled according to the linear polarization fraction.
- Faraday rotation makes the determination of the magnetic field morphology difficult !



W43A

- On average, we detected a magnetic field of ~ 100 micro-gauss in the OH maser region of W43A. This value is consistent with the estimated magnetic field of ~ 70 micro-gauss extrapolated from H2O maser polarization observations.
- Polarization observations have indicated that the jet is magnetically collimated B ~ 80 mG (Vlemmings et al. 2006)

The 1612 MHz OH and 22 GHz H2O masers of W43A



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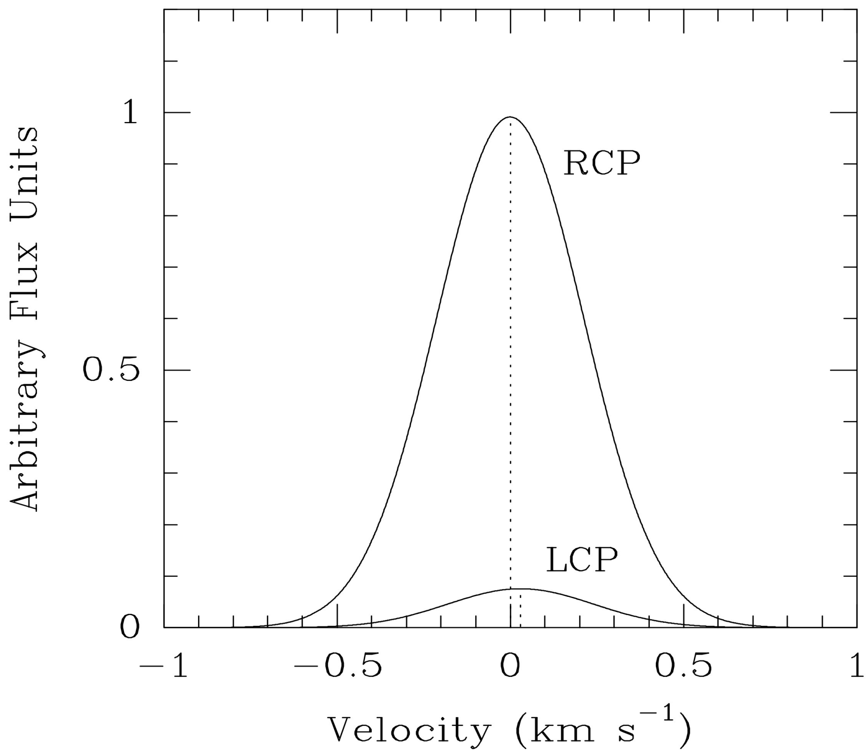
OH maser polarization

- The Zeeman splitting is less than the maser line width by a factor of 50.
- Spectral blending of individual maser features could decrease the observed circular polarization by a factor of 2 (Sarma et al. 2001)
- Alternatively, the relative low level of the detected magnetic field could originate from other non-Zeeman effects.

Non-Zeeman effects

Observational effect: The emission is right elliptically polarized. The LCP peaks the linear polarization. If there is also a velocity gradient along the amplification path, the linear polarization component may be shifted in velocity with respect to the circular polarization component (Fish & Reid 2006).



Non-Zeeman effects

-The **propagation of strong linear polarization** can create circular polarization (Wiebe & Watson 1998). For up to 12 % linear polarization fraction, the generated circular polarization in the OH maser region of W43A is 0.25%.

-Instrumental polarization. 3C84 3% linear and 1% circular fraction

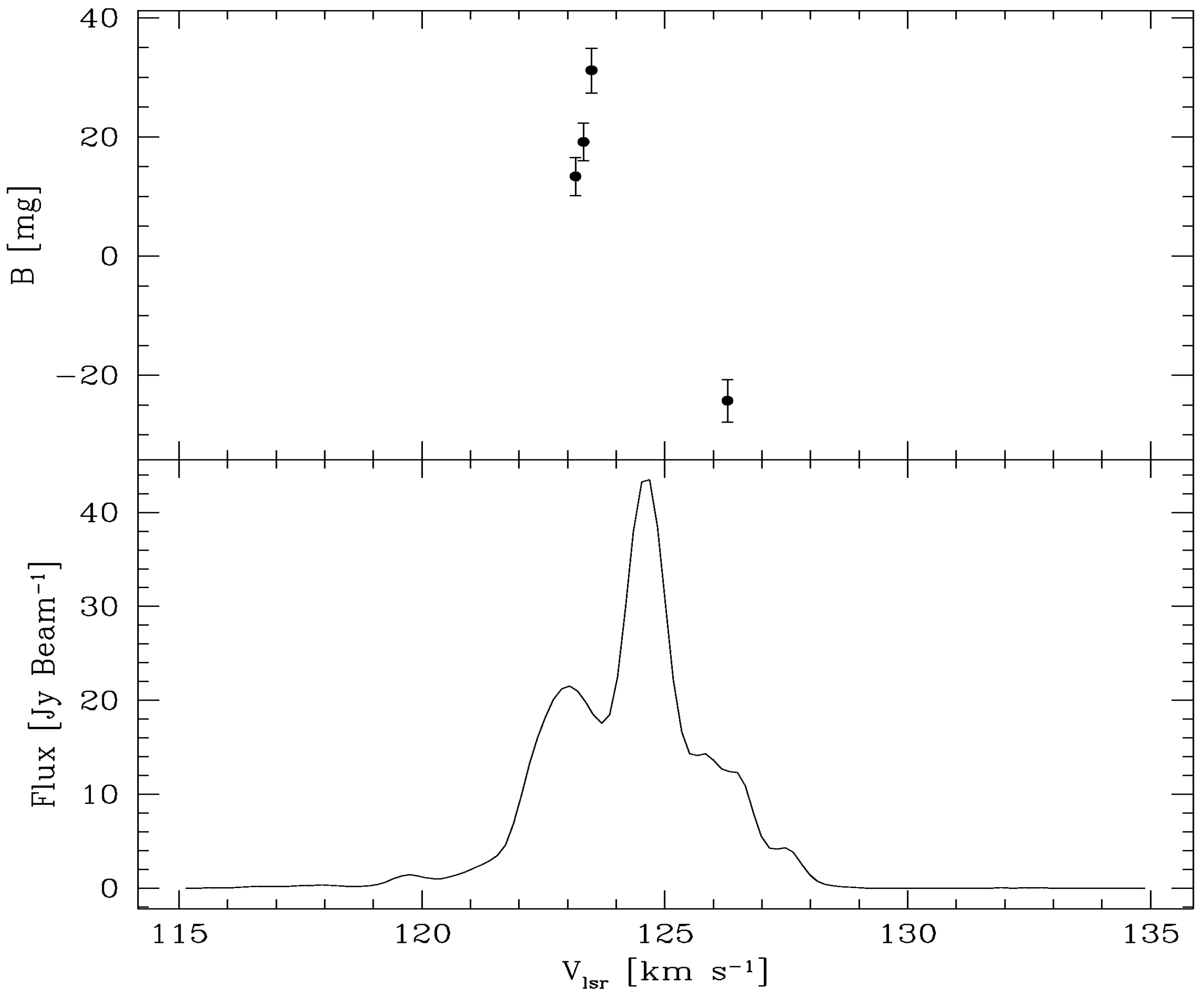
-We rule out all non-Zeeman effects, and conclude that the observed circular polarization arises from Zeeman splittig.

GBT Observations

the magnetic field strength measured for the red-shifted part of the spectrum.

B: 31+/- 8 to -24+/- 7 mG

The total intensity spectrum of the red-shifted H2O masers of W43A obtained from the GBT observations.



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OH maser expansion of W43A

- From our MERLIN observations, we measured a separation of 0.28+/- 0.2 arcsec.
- Previous observations of these source revealed a separation of 0.21+/- 0.03 arcsec

(Diamond & Nyman 1988).

- The measured expansion is 0.07+/- 0.03 arcsec/26.5 yrs (2.67 +/-1.37 mas/yr): This corresponds to an expansion velocity of ~ 18 km/s

Conclusion

- Non-spherical shape of the PNe is related to outflows, originating from the AGB phase.
- Magnetic fields are responsible in collimating the jets
- We rule out any other non-Zeeman effect that could generate the measured circular pol.
- **A large scale magnetic field is present in the OH maser region of W43A.**