The magnetic field of the evolved star W43A

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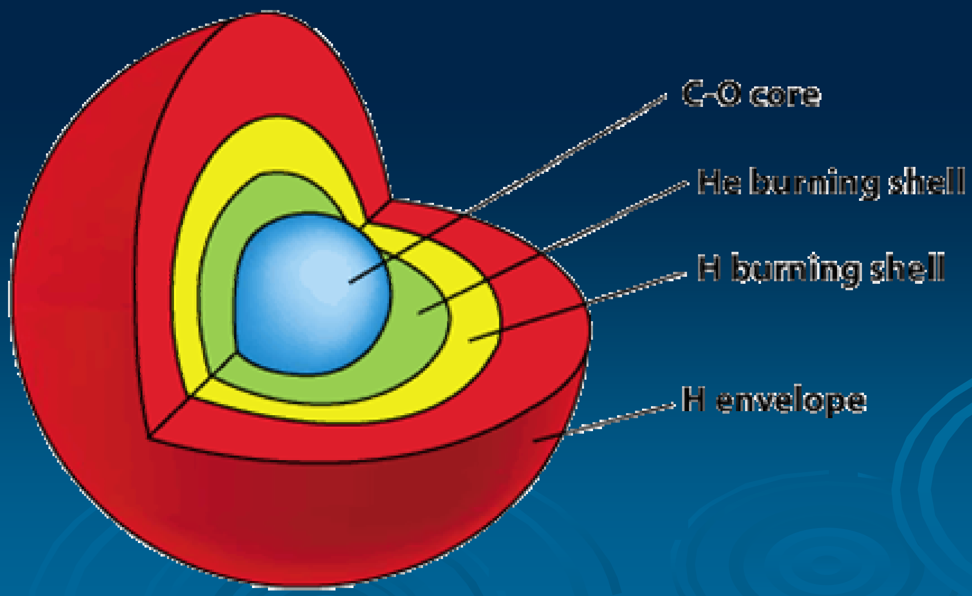
AGB Stars

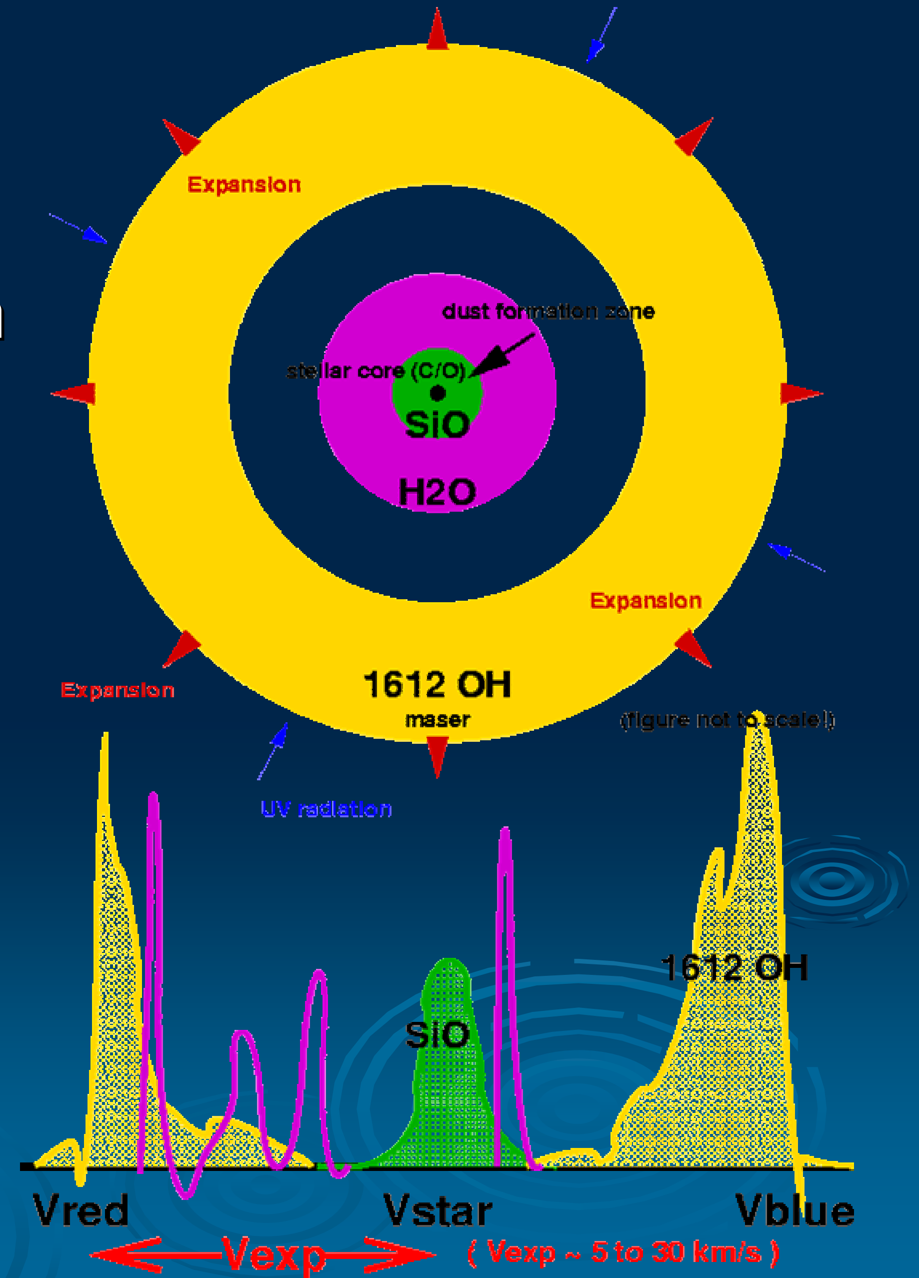
- In the AGB phase the stars are characterized by an inert carbon-oxygen core, surrounded by two separate nuclear burning layers - an inner layer of Helium and an outer layer of Hydrogen
- At these late stages of stellar evolution, matter can easily be lifted off from the stellar surface and can be expelled into space



Circumstellar Envelopes of AGB Stars

- Circumstellar envelopes of evolved stars are very rich environments
- H_2O, OH and SiO Masers happen in the envelopes of evolved stars

- The OH maser is emitted from the outer regions of the wind blowing away from the star
- OH maser has a double peak structure, that correspond to the front and back side of the OH shell



Asymmetric Planetary Nebulae

- Planetary nebulae often has an asymmetric structure
- This asymmetry originates from the AGB phase

Asymmetric Planetary Nebulae

- Collimated jets which are observed in a number of PNe (Imai et al. (2002)) and precession of these jets most likely explains the observed asymmetries. These jets may be formed in the AGB phase undergoing a transition to a PN (Sahai & Trauger (1998), Imai et al. (2002)).

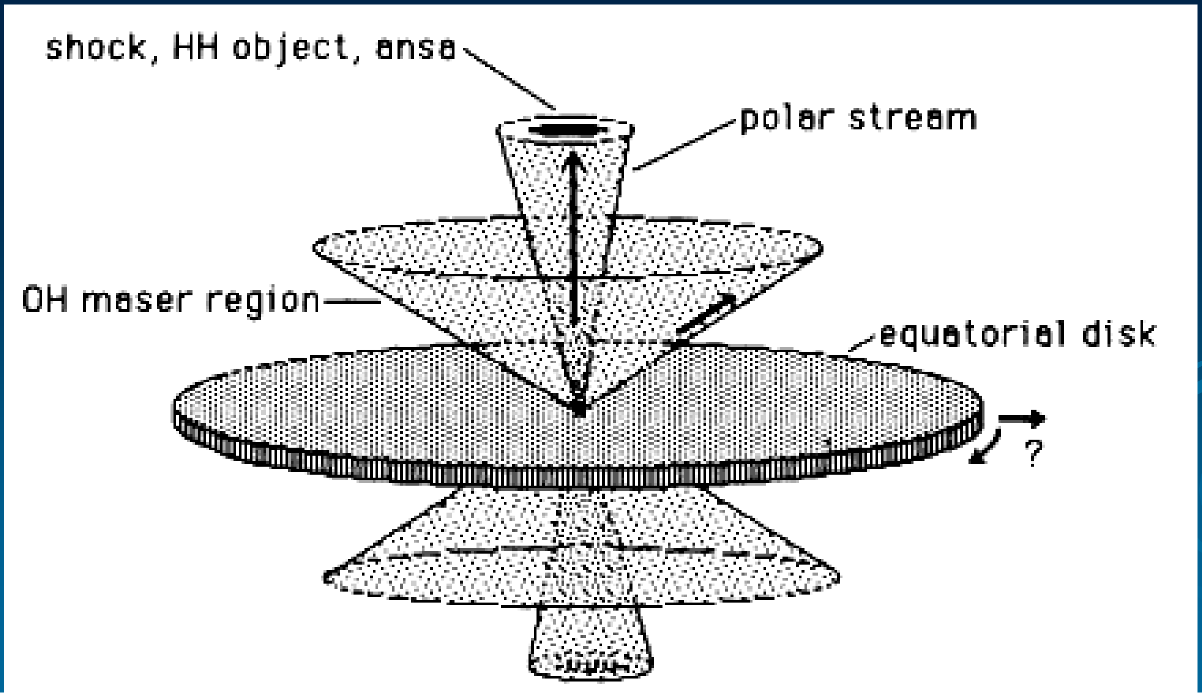
- Magnetic fields can also have an important role in shaping the circumstellar envelope (CSE) of evolved stars which could produce asymmetries during the transition from a spherical symmetric star into an aspherical PN. Theoretical models have shown that magnetic fields could lunch and collimate such jets through a dynamo interaction between the fast rotating core and the slow rotating envelope of the evolves stars (Blackman et al. (2001)).

W43A

- Water Fountain source in which H_2O maseres occur at much larger velocity separation that the lower density OH maser region.

-The high velocity H_2O emission arises at the tips of a high velocity jet. A strong shock is responsible for collisional excitation of H_2O molecules.

-OH maser occurs at a conical region closer to the star.

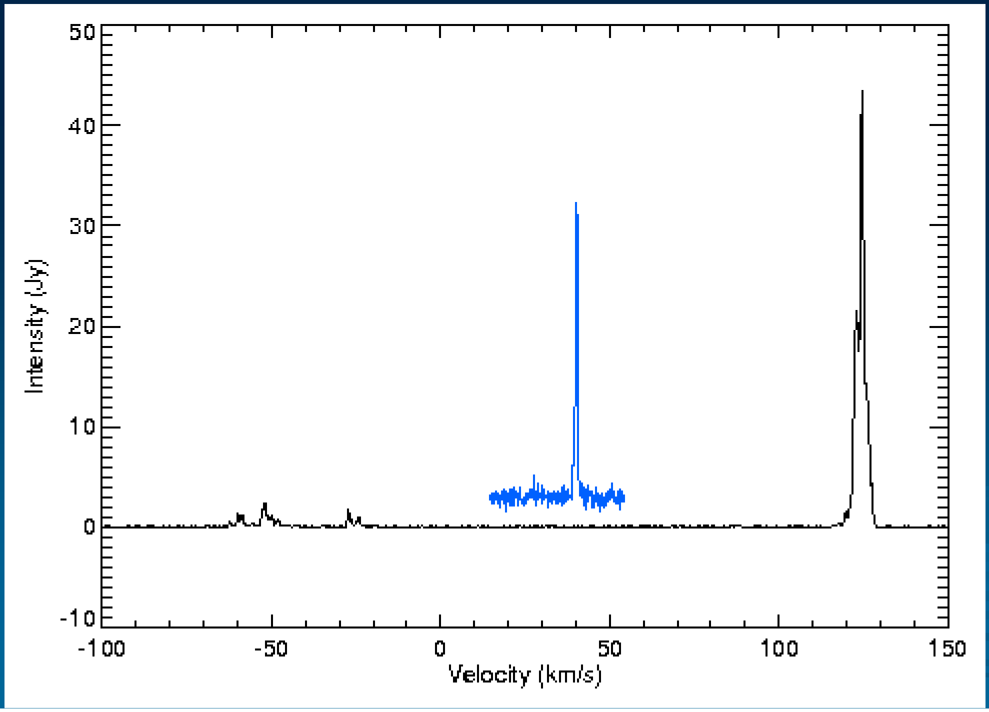


OH Maser Polarization Experiment

- The water fountain source,W43A, were observed at 1612 MHz with MERLIN in Spectral line mode
- The aim of this experiment is to measure the magnetic field strength and structure of this water fountain source in the OH maser region

Results- W43A Spectrum

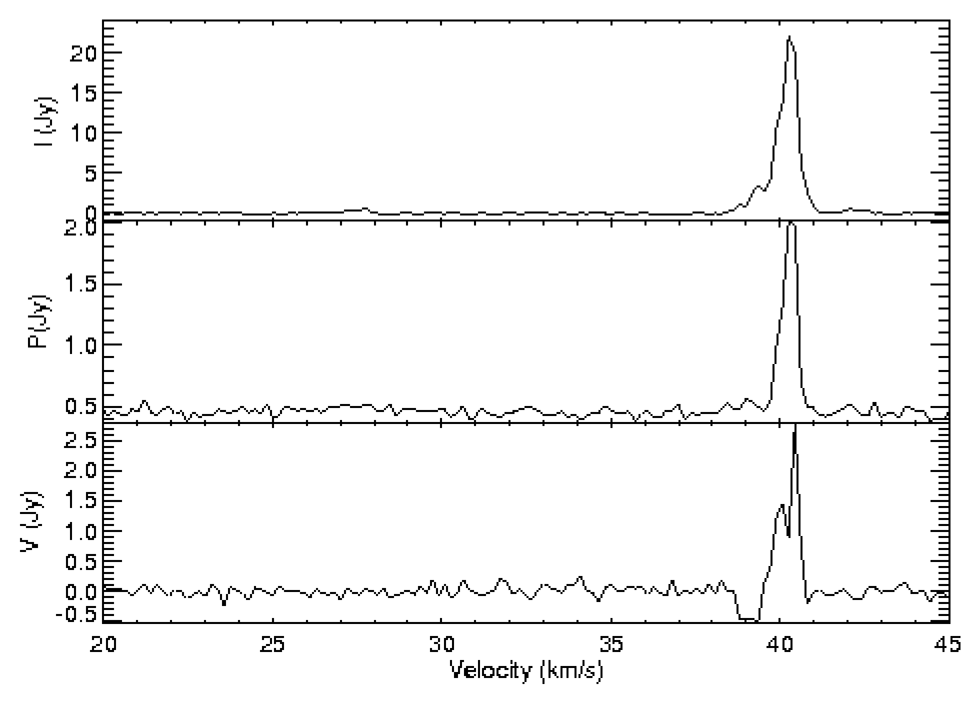
- Spectrum of the OH and H_2O maser regions of W43A obtained from MERLIN and GBT observations, respectively.
- The figure clearly illustrates the water fountain nature of the evolved star W43A as H_2O masers occur outside the OH maser in a much larger velocity range. The figure also shows the double peak structure of the OH maser around the same line of sight velocity (34.3 km/s).



Results

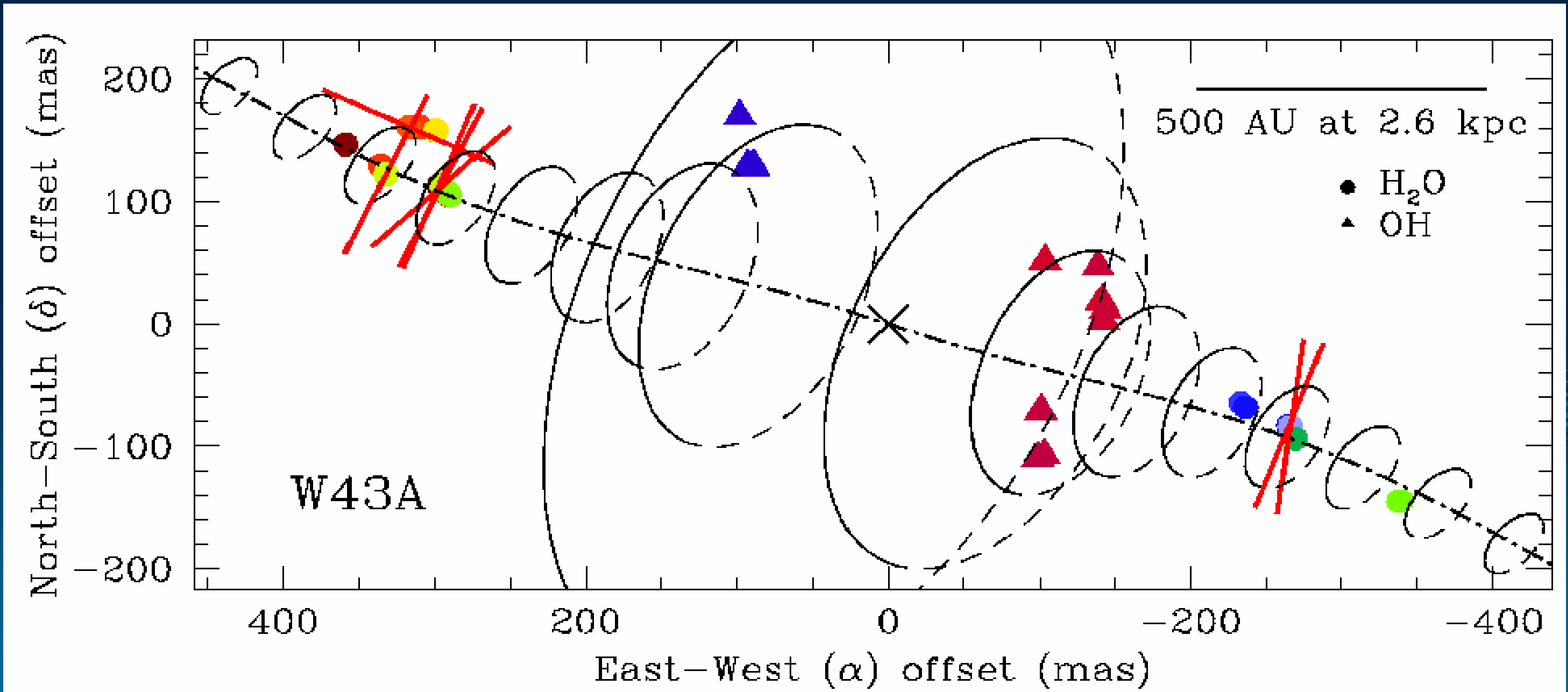
The velocity profile of the integrated flux of each channel in the I (total intensity), V (circular polarization) and P (polarization intensity or linear polarization) data cubes. The velocity spectrum of the total intensity cube is a typical double peaked profile with velocity in the range 27-43 km/s; despite the fact that W43A is an evolved star and has a much higher velocity in the H_2O maser region (in the range -53 to 126 km/s).

Most of the emission in the total intensity profile was detected in linear and circular polarization spectra. The peaks in the polarization intensity and circular polarization spectra are 10% linearly and 12% circularly polarized.



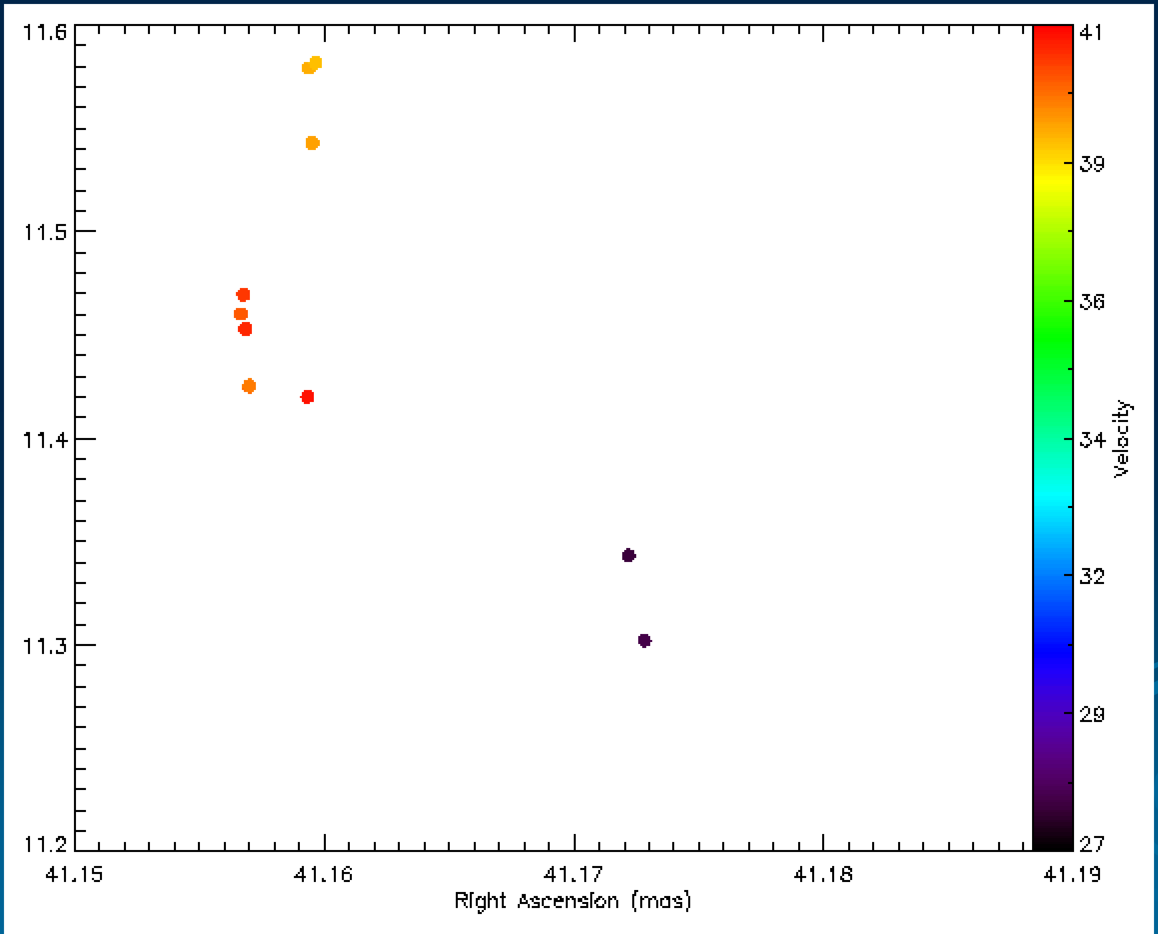
Distribution of H_2O and OH masers

- spatial distribution of the OH maser features of W43A together with H_2O maser positions.



Results

- OH maser spots (redshifted and blueshifted). The OH maser features detected for W43A are color coded according to their LSR velocity.



Results- Zeeman Splitting

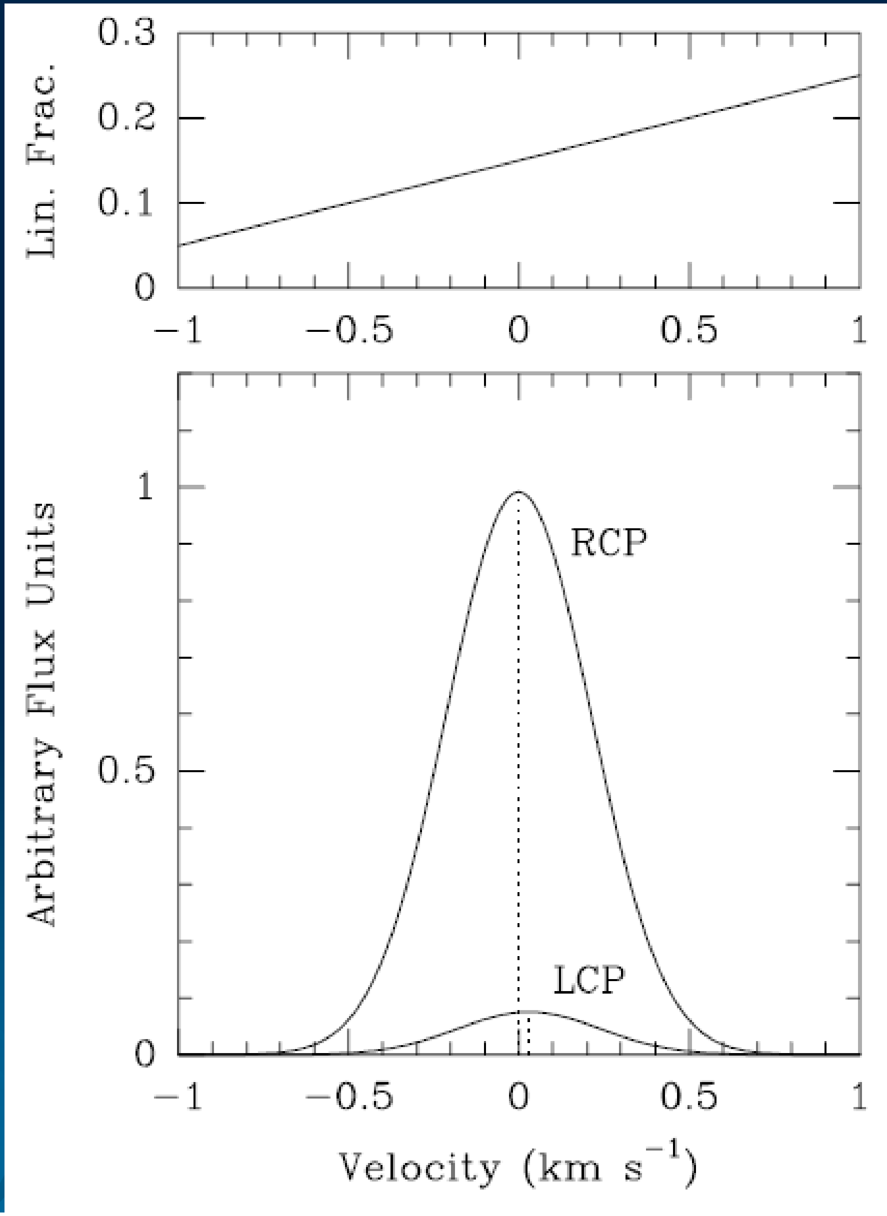
Feature	RA 18 47	Dec -1 05	Peak Flux (Jy beam^{-1})	V_{rad} (km s^{-1})	Δv_l (km s^{-1})	Δv_z (km s^{-1})	B (μG)
1	41.15933	11.4200	1.1	41	0.59	0.01	50
2	41.15684	11.4500	2.4	40.8	0.59	0.01	55
3	41.15676	11.4694	6.1	40.6	0.59	0.01	59
4	41.15666	11.4600	21.0	40.2	0.58	0.01	59
5	41.15952	11.5428	2.0	39.5	0.62	0.02	85
6	41.15938	11.5790	3.8	39.3	1.54	0.04	165
7	41.17281	11.3021	0.2	27.9	0.43	-0.17	-
8	41.17217	11.3431	0.6	27.7	0.6	0.0004	-

Non-Zeeman Effects

- When the magnetic field orientation varies along the amplification path. The linear polarization component will be seen as weak emission. In the presence of velocity gradient the linear polarization component may be shifted in velocity with respect to the circular component. This effect would manifest itself as a velocity gradient between RCP and LCP.

- In the case of W43A, however, the RCP and LCP fluxes are in the same range.

Fish & Reid 2006



Instrumental polarization

- We imaged the unpolarized source, 3C84, in all polarization states and obtained the fractional linear and circular polarization which may account as leakage. Our results shows 3% linear and 1% circular polarization. The relative low level of instrumental polarization could not affect the measured velocity shift between the right and left circular polarized spectra.

Conclusions

- The magnetic field and jet characteristics of W43A have previously been reported from H_2O maser polarization observations in relation to the formation of aspeherical planetary nebulae. Here we present the detection of the magnetic field of 100 μG in the OH maser region surrounding the collimated jet. This confirms that a large scale magnetic field is present in W43A, which likely plays a role in collimating the jet.

- The velocity shift between right and left circular polarized features is much less than the maser line width and thus the observable polarization properties may be reduced. However, we have investigated the significance of other effects which may result in the misinterpretation of the measured magnetic field. There is no effect that could contribute in our measurement at μG scales.
- Amiri et al. 2009

Thank you!