Maser emission in Planetary Nebulae

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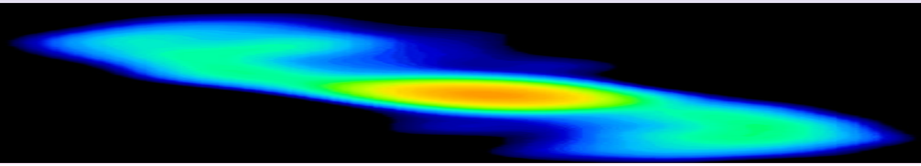

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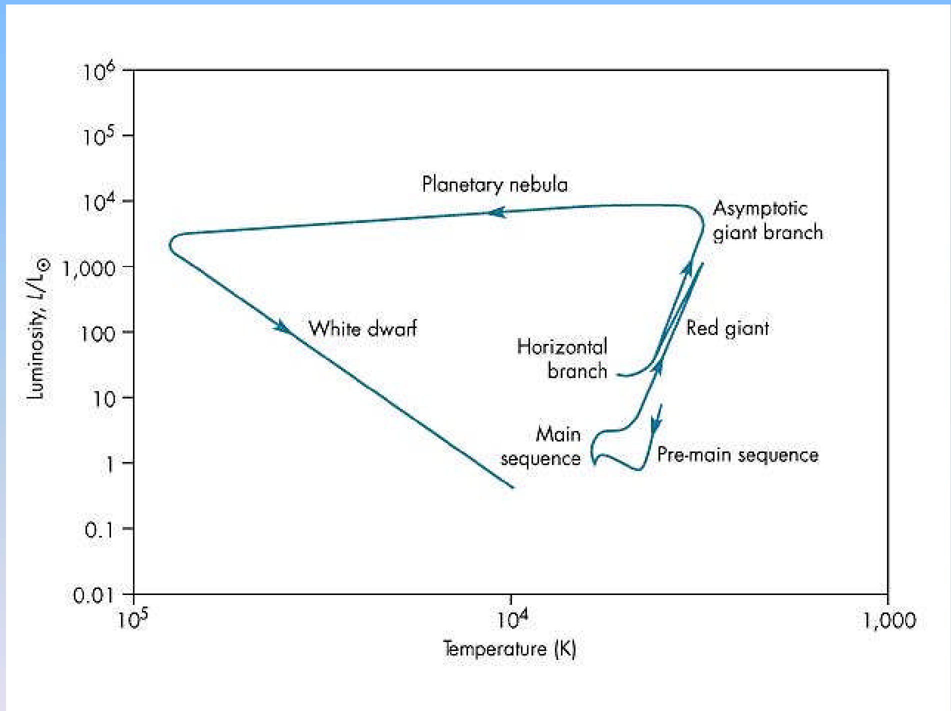
OUTLINE

- Introduction
- Young PNe with OH and H_2O masers
- K 3-35 and IRAS 17347-3139
- Kinematics of H_2O masers in K 3-35
- Equatorial magnetic field in K 3-35 ?
- Summary

Introduction

Planetary nebulae represent a final stage of stellar evolution

- After completion of H and He core burning, the star evolves to the AGB.
- The mass loss rate in the AGB could be $\geq 10^{-6}\ M_{sun} year^{-1}$.
- Envelope of gas and dust. The star no longer detectable in the optical.
- At the top of the AGB phase the gravity contracts the core. Ionization begins and a PN is formed.



Introduction

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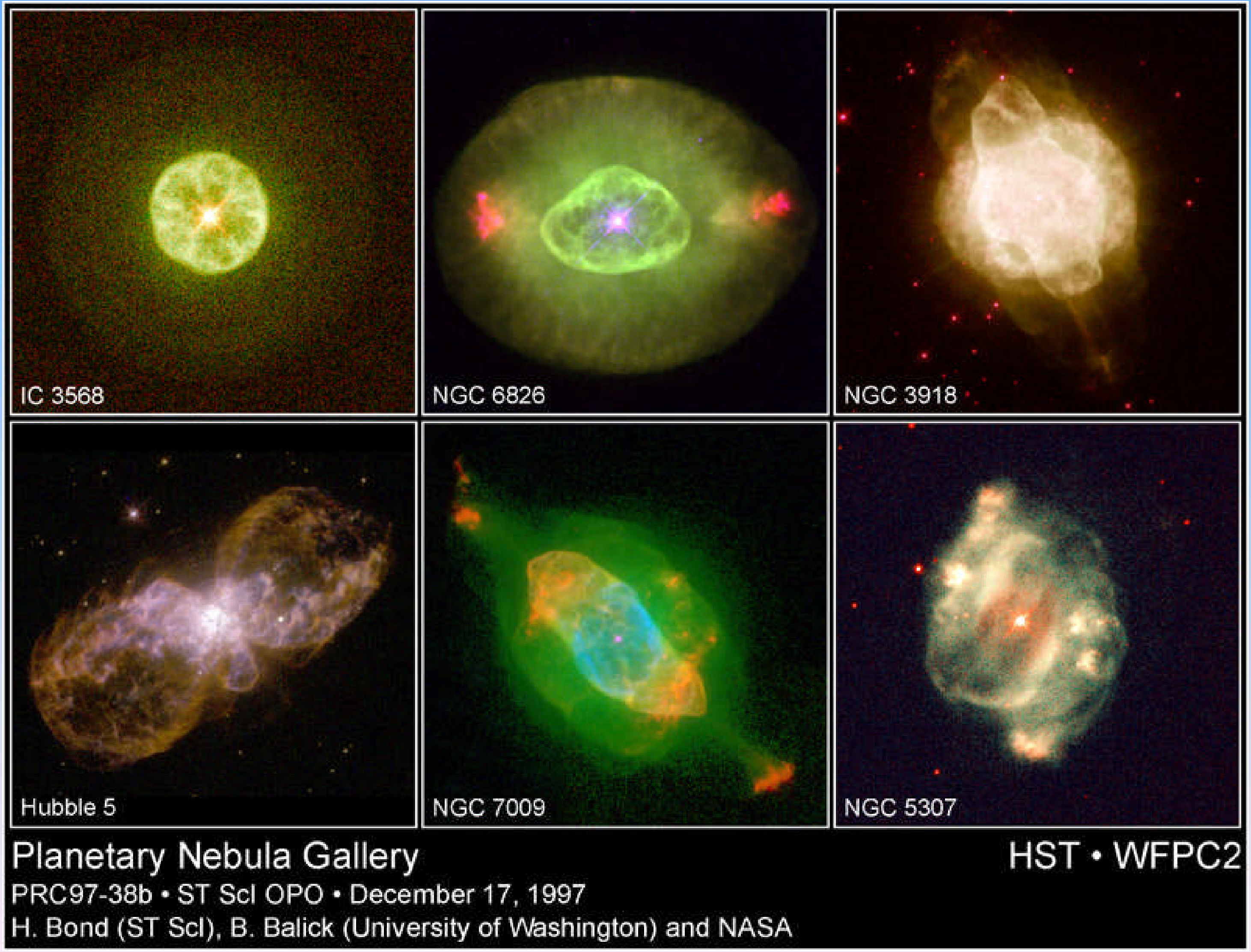
Lifetime 10^4 years

- Most of the PNe (~75%) show asymmetrical morphologies



When are the asymmetric structures in PNe formed?

AGB winds

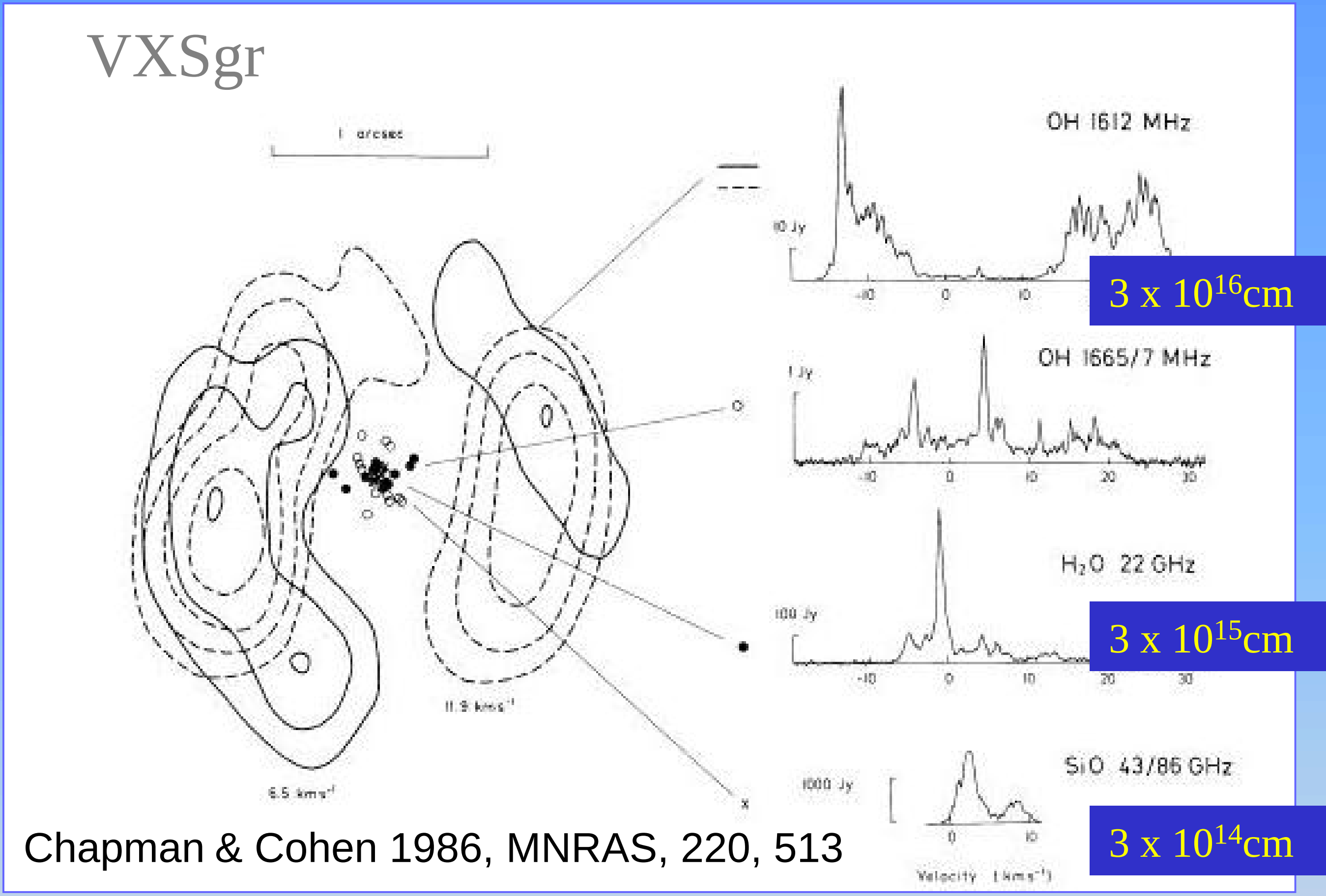
spherical (?)

Transition time scale
~1000 years (Kwok 1993)

PNe

asymmetric ✓

OH, H_2O and SiO masers can be detected in AGB stars

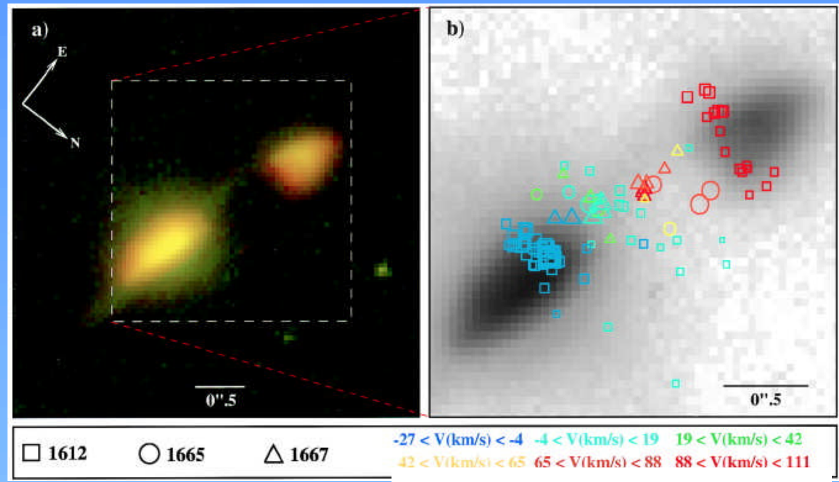


Chapman & Cohen 1986, MNRAS, 220, 513

- Masers stratified in the envelope due to chemical and excitation conditions (Reid & Moran 1981; Elitzur 1992)

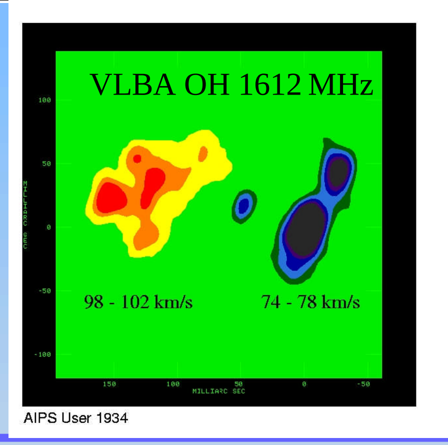
- If we consider an isotropic shell expanding at ~10 km/s, then when the slow wind stops, masers will "disappear" in a time scale of ~10, 100 and 1000 years for the SiO, H_2O and OH, respectively (Gómez, Moran & Rodríguez 1990).

IRAS 16342-3814
(Sahai et al. 1999)

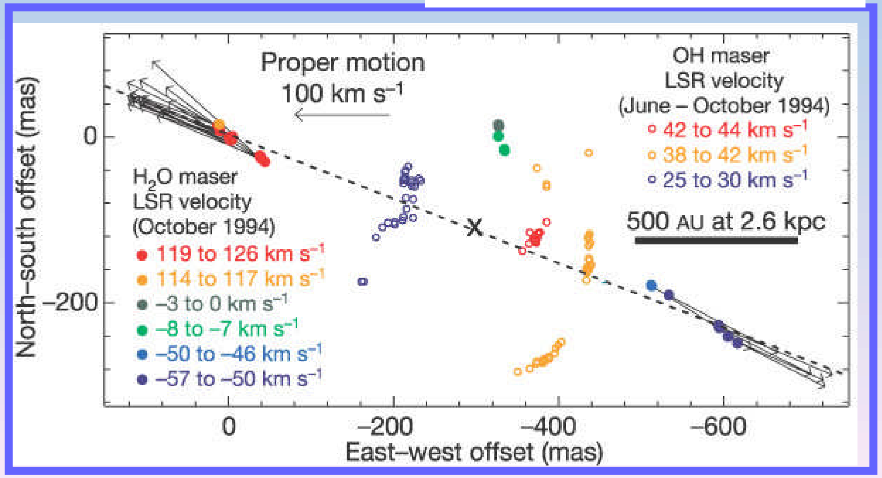


Proto PNe

OH 37.1- 0.8
(Gómez et al. 1999)

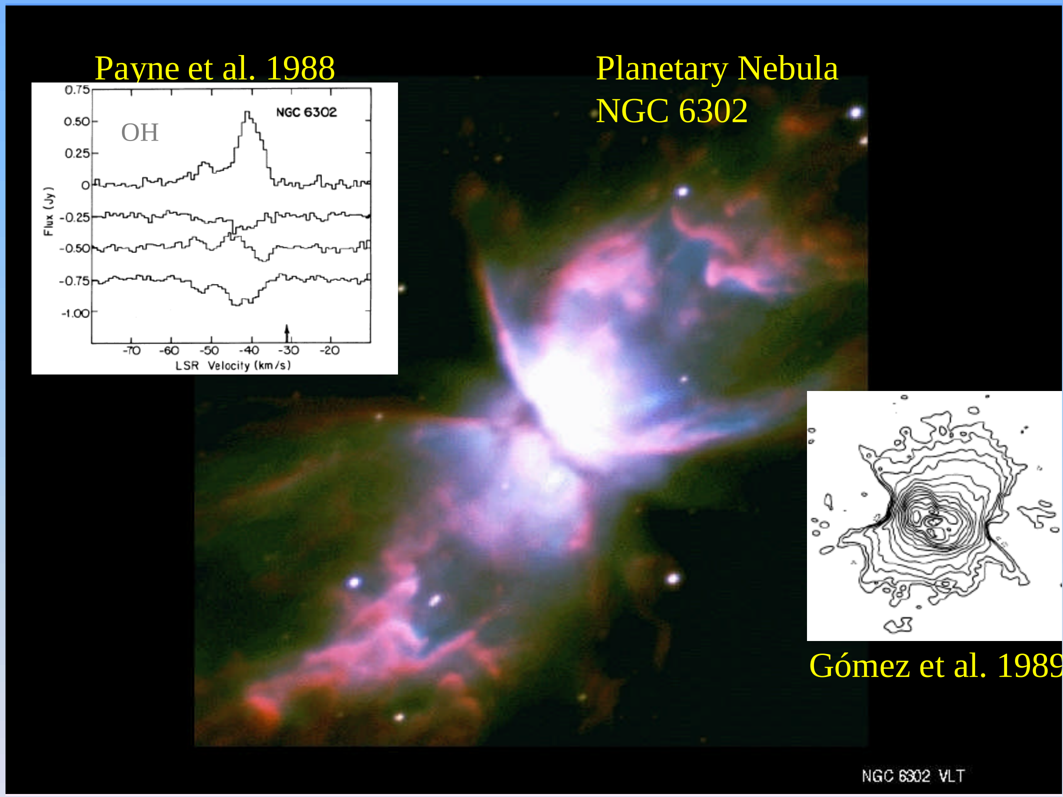


W43A
(Imai et al. 2002)



We will talk of young planetary nebulae (where ionization is already present), but that retain OH and H_2O maser emission.

Several surveys have been carried out to search for OH masers in PNe (e.g. Johansson et al. 1977; Caswell et al. 1981; Bowers & Knapp 1989; Zijlstra et al. 1989; Sevenster & Chapman 2001).



- The presence of OH maser suggests that a neutral envelope is still present in the PN, implying that it is young.

OH maser emission in PNe

- M 1-92 (Lépine & Rieu 1974)
- Vy 2-2 (Davis et al. 1979)
- NGC 6302 (Payne et al. 1988)
- IC 4997 (Tamura et al. 1989)
- K 3-35 (Engels et al. 1985)

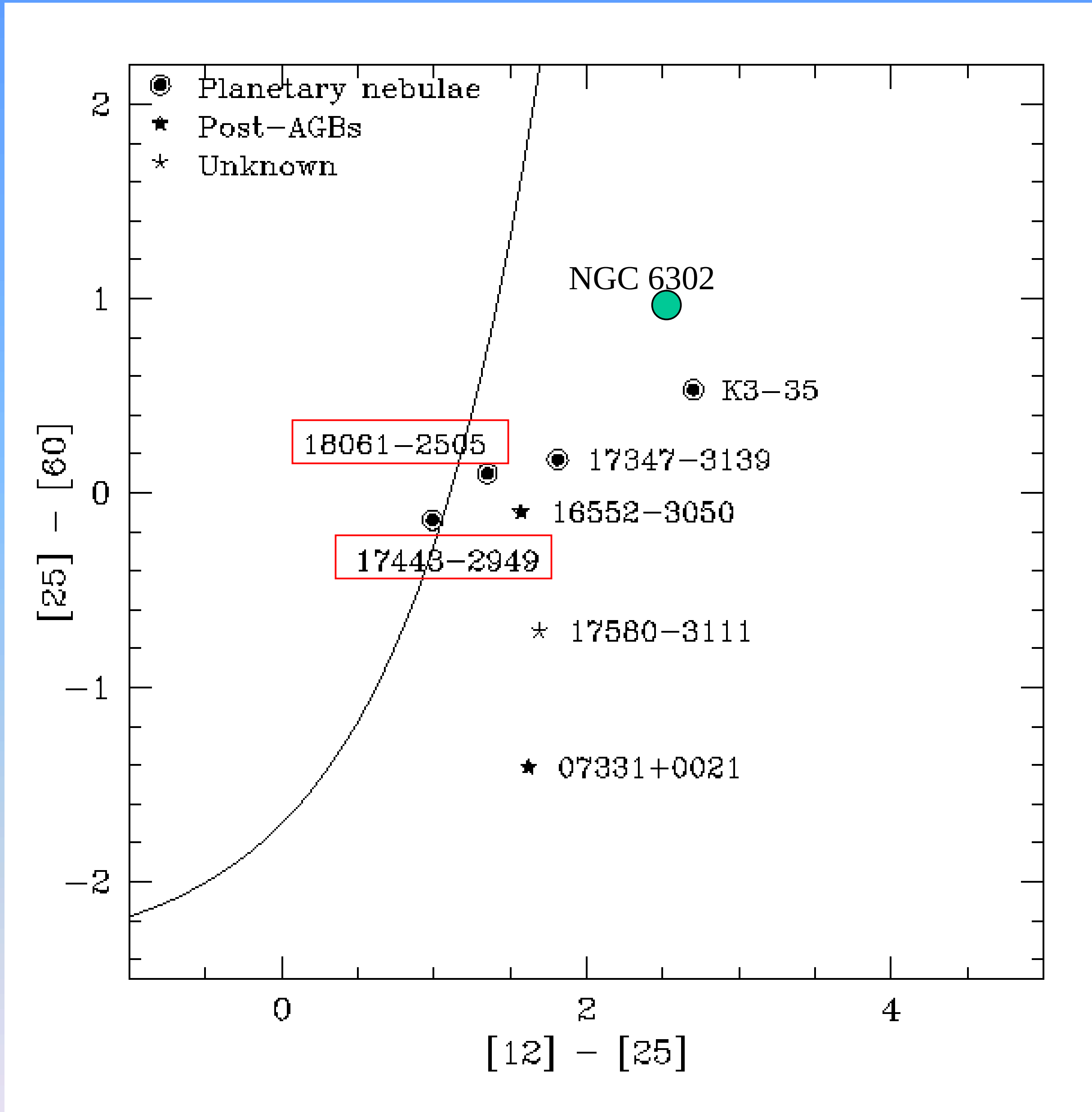
H_2O maser emission

Miranda et al. 2001

De Gregorio-Monsalvo et al. 2004.

- OH 349.36-020
- OH 0.9+1.3
- IRAS 7207-2855
- PK 356+2.1
- IRAS 17347-3139
- IRAS 17371-2747
- IRAS 17375-2759
- IRAS 17375-3000
- IRAS 17443-2949
- IRAS 17580-3111

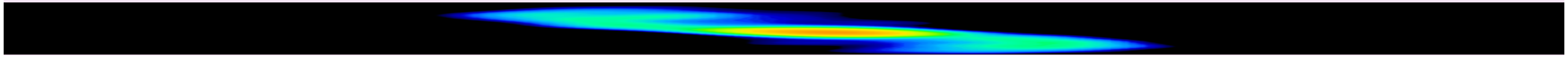
(Zijlstra et al. 1989)



Suárez, Gómez, Morata 2007, A&A, in press.

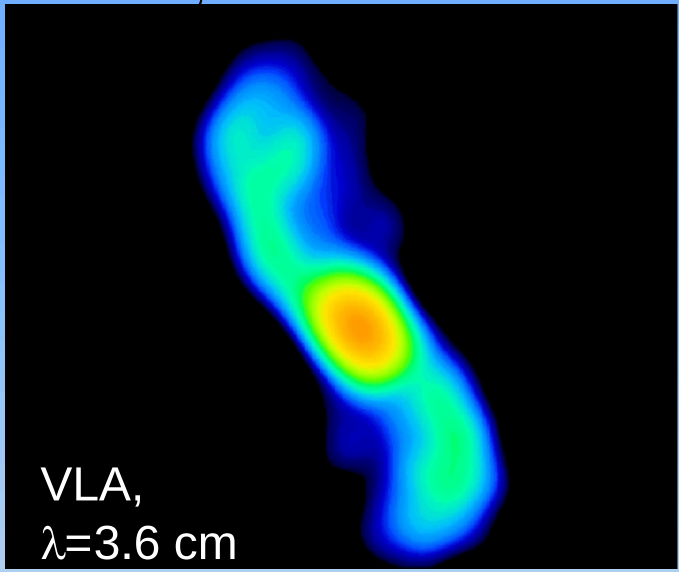
- Recently, Suárez et al. 2007, detected two new PNe with H_2O maser emission, using the Robledo de Chavela antenna.
- VLA observations are in progress.

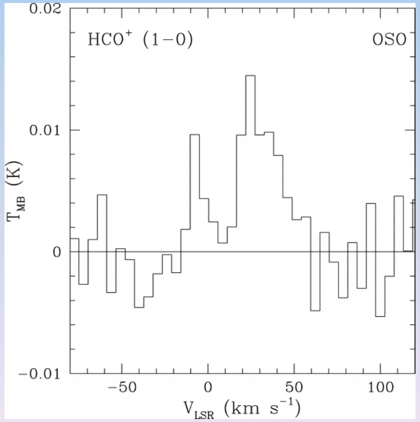
K 3-35 and IRAS 17347-3139



K 3-35 the first PN with H_2O maser.

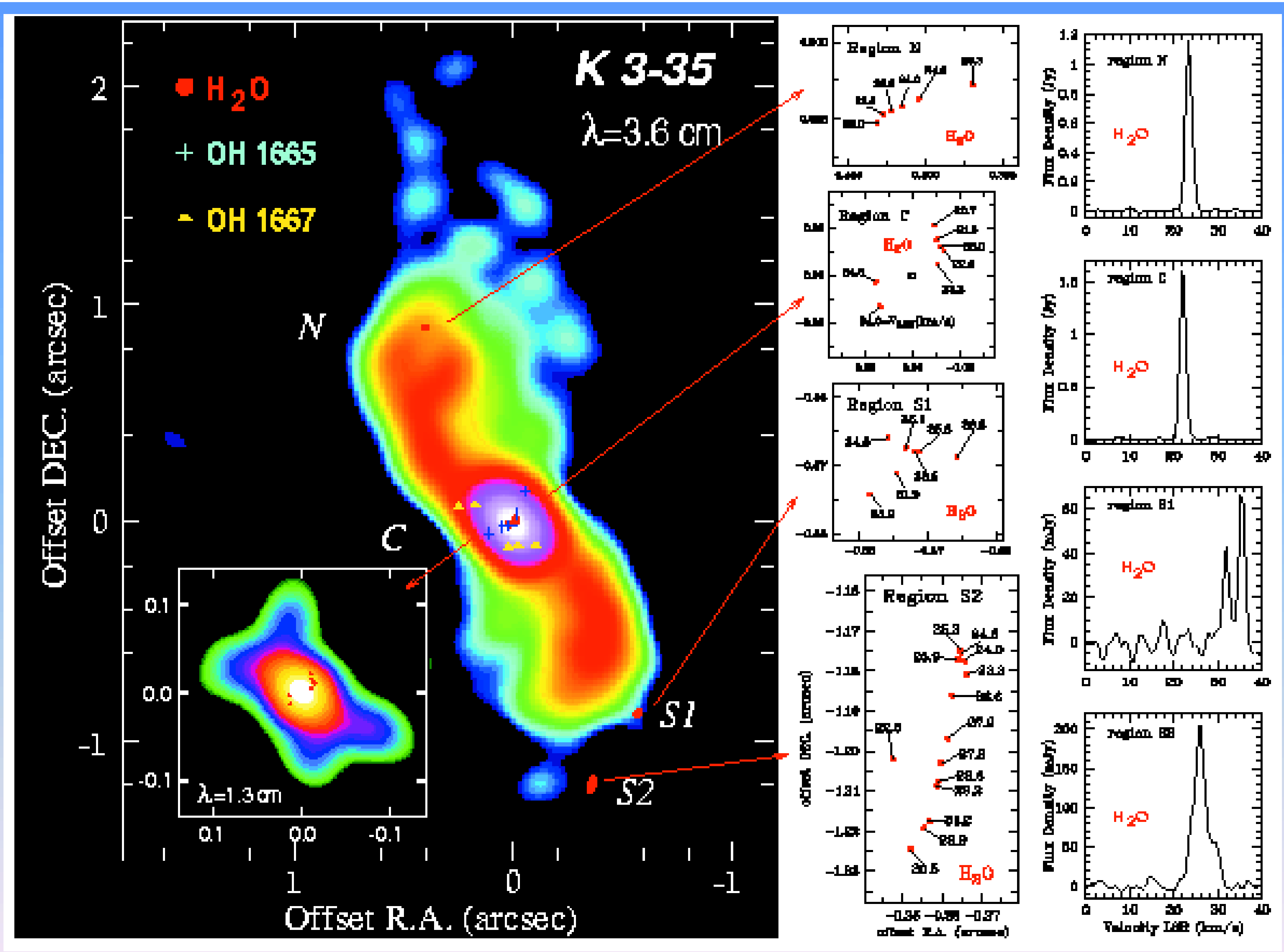
Miranda, et al. 2001





Tafoya, et al. 2007

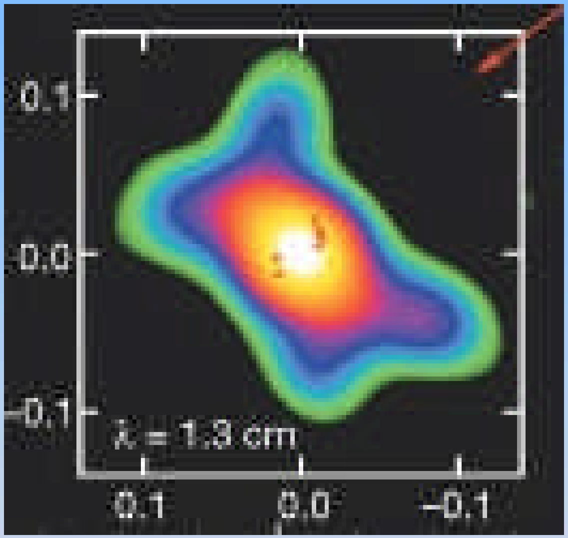
- Is an emission nebula with bipolar jets (Aaquist & Kwok 1989; Aaquist 1993; Miranda et al. 2000; Miranda et al. 2001)
- Broad CO lines (Engels et al.1985; Dayal & Bieging 1996; Huggins et al. 2005; Tafoya et al. 2007)
- HCO^+(1-0) (Tafoya et al. 2007)
- OH and H_2O masers were detected but the association was unclear (Engels et al. 1985; Aaquist 1993)
- Miranda et al. 2001 using the VLA confirmed the association of OH and H_2O maser emission with K 3-35.



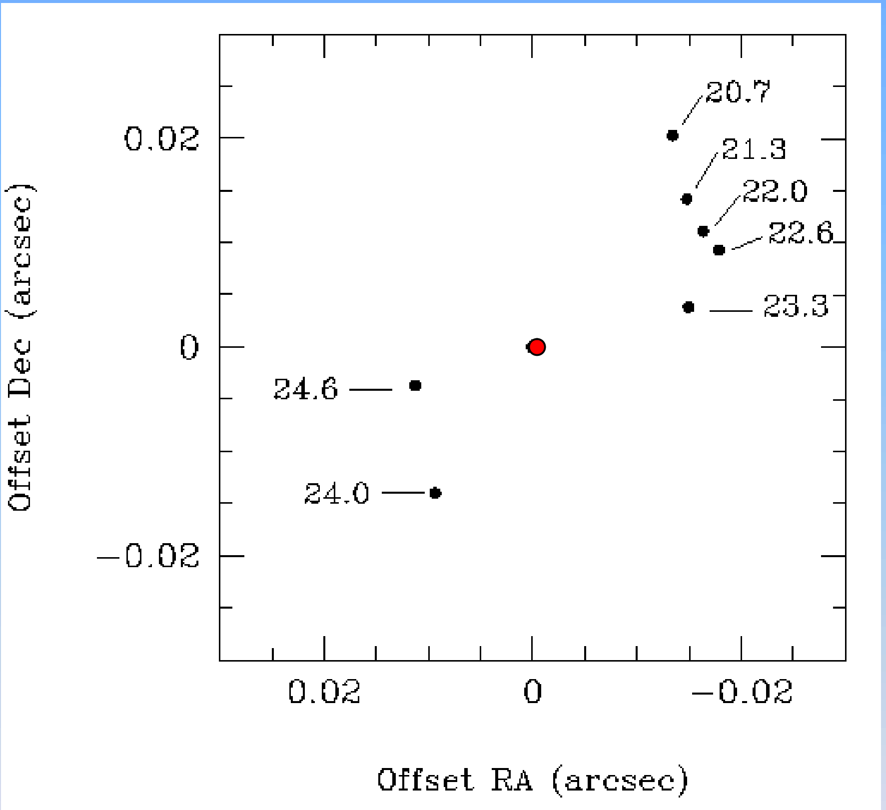
(Miranda, Gómez, Anglada & Torrelles 2001, Nature, 414, 284)

Water masers in K 3-35 are located at a projected distance of 85 AU from the peak continuum emission suggesting the presence of an equatorial disk.

V(LSR)= 24 +/- 2 km/s

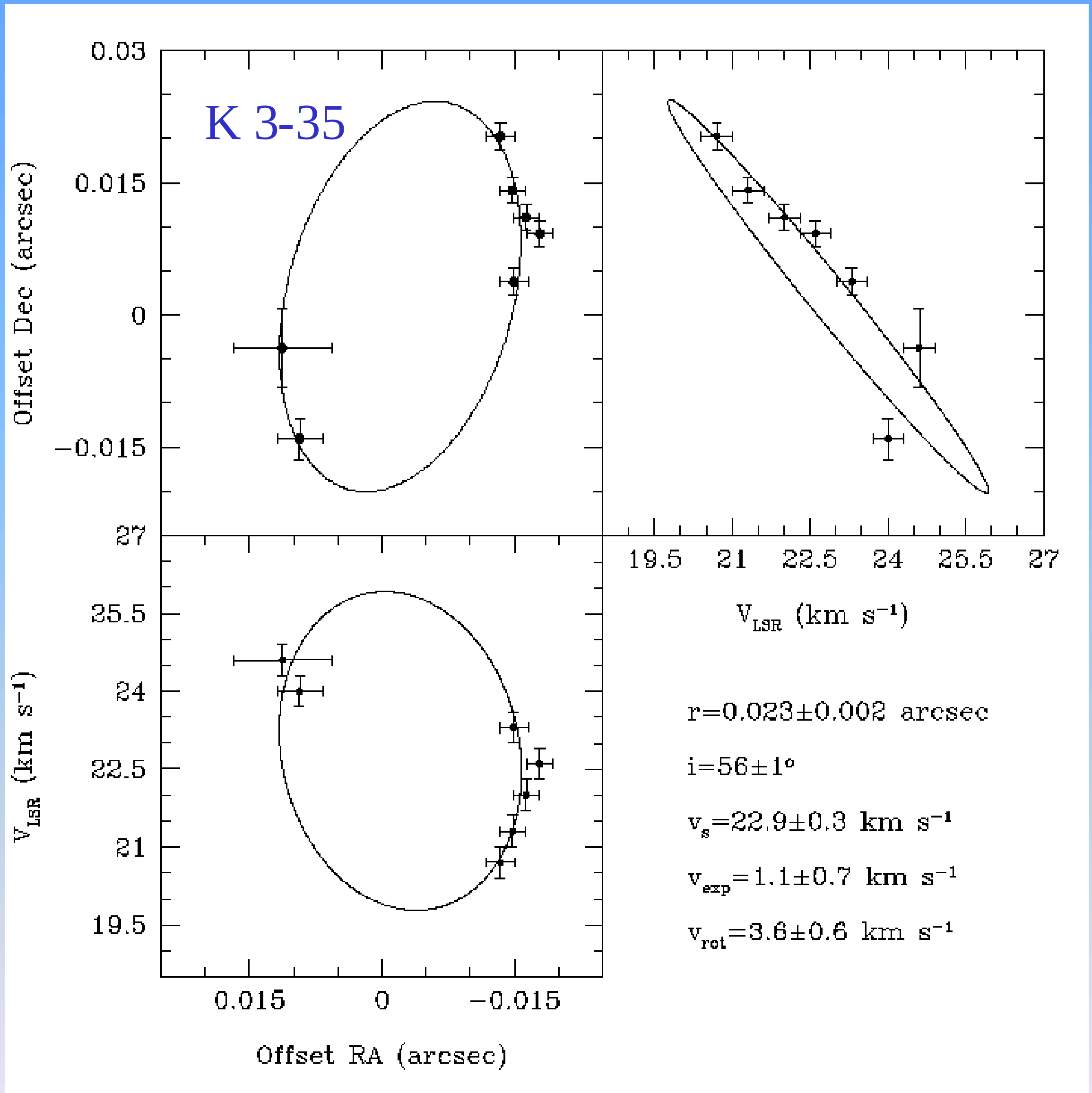


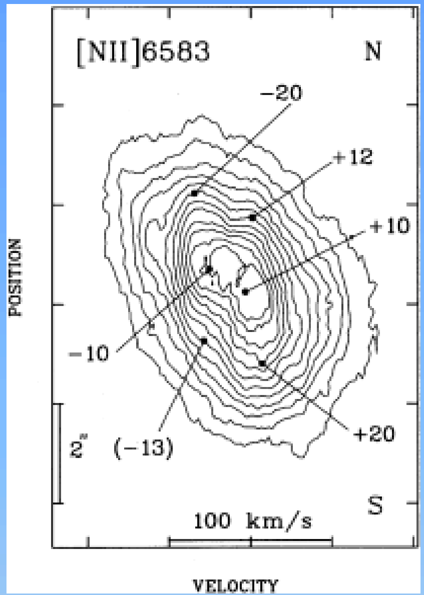
Miranda et al. 2001



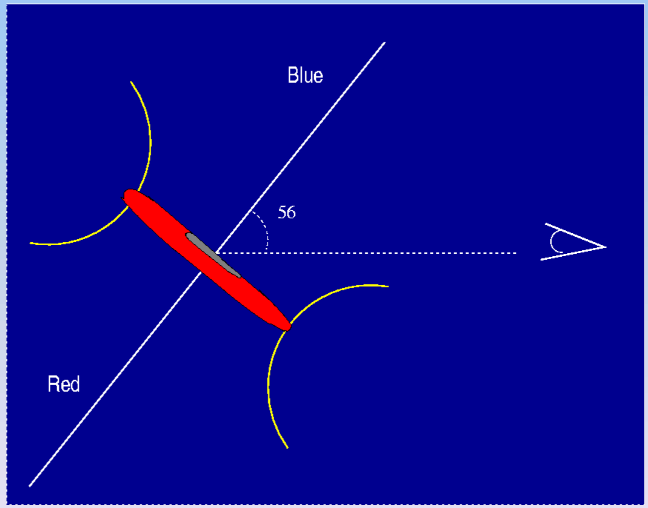
The velocities of H_2O masers are blueshifted with respect to the systemic velocity.

EXPANDING AND ROTATING DISK





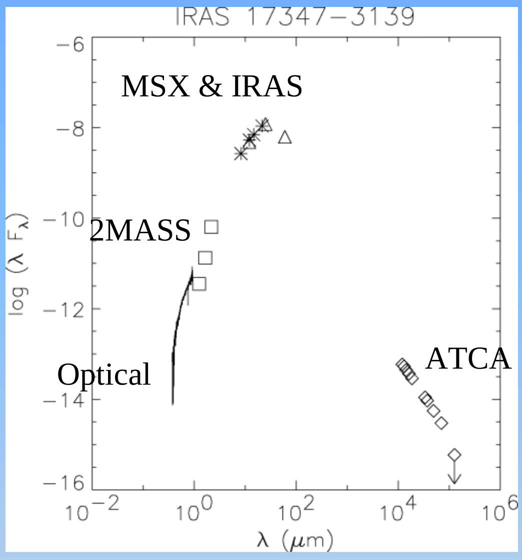
Miranda et al. 2000



Uscanga et al. 2007

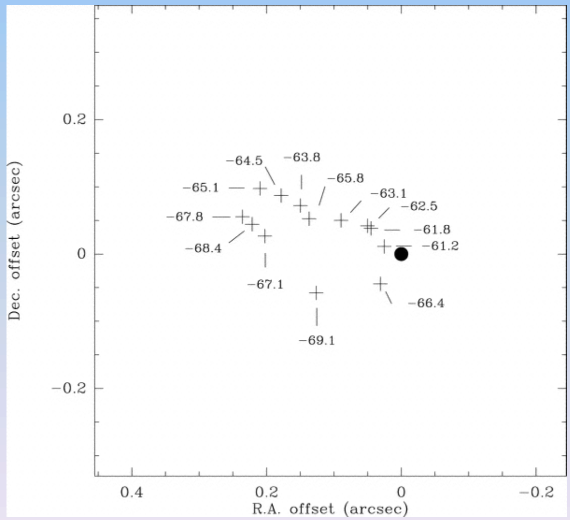
Kinematics of H_2O masers in IRAS 17347-3139

IRAS 17347-3139 the second PN with H_2O maser emission.

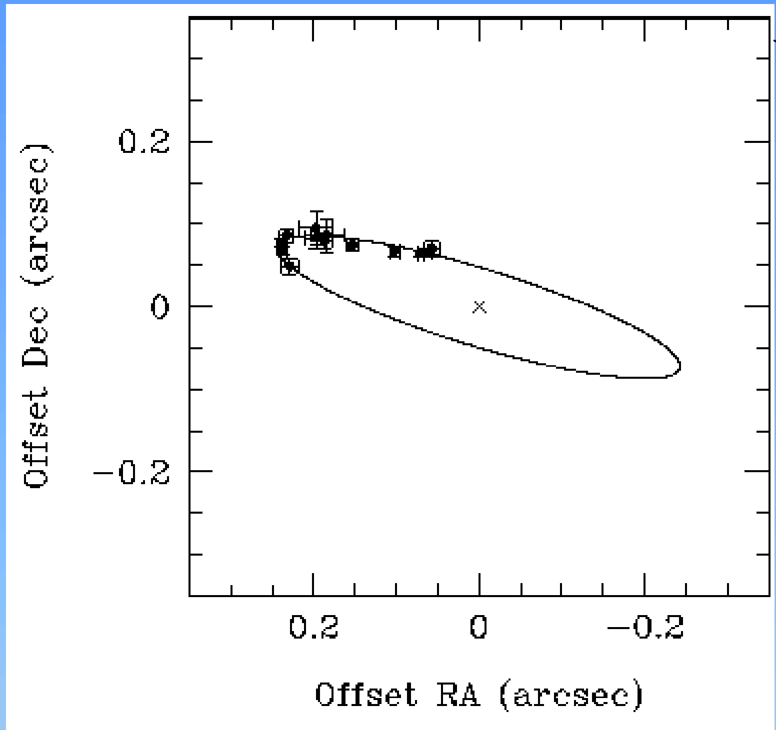


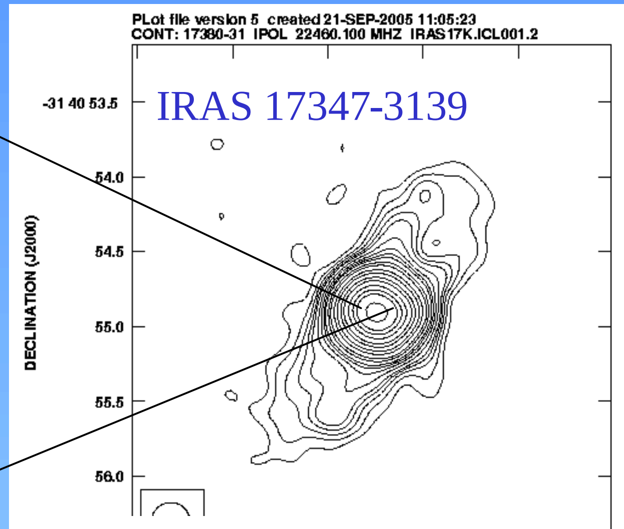
- Strong IRAS source. The SED peaks at 60 μm (Gómez et al. 2005).
- Estimated distance 0.6-8 kpc (Gómez et al 2005)
- OH 1612 MHz (Zijlstra et al. 1989; Tafoya 2007, see poster)

- A search for H_2O masers, with the 70 m antenna of Robledo de Chavela, in 27 sources, we detected only IRAS 17347-3139 (De Gregorio-Monsalvo et al. 2004).

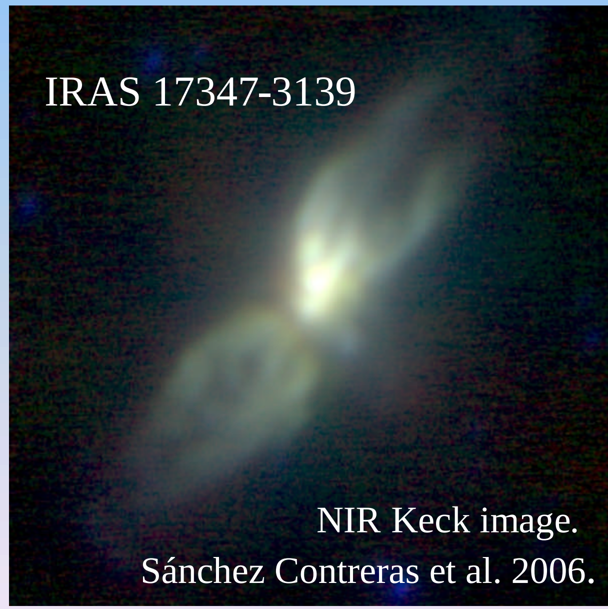


VLA H_2O masers





VLA 1.3 cm continuum
Tafoya, et al 2007



NIR Keck image.
Sánchez Contreras et al. 2006.

- A kinematic model suggests that the water masers could be tracing one edge of an equatorial disk (Uscanga et al. 2007).

Equatorial magnetic field in K3-35?

Evidence of magnetic fields in PNe

Circumstellar envelopes

Magnetic fields of ~ mG at distances from 100 -1000 AU

- OH 0.9+1.3 by OH circular polarization (Zijlstra et al. 1989; Szymczak & Gérard 2004)
- NGC 7027, NGC 6537, and NGC 6302 by polarimetry of magnetically aligned dust grains (Greaves 2002; Sabin et al. 2007).
- K 3-35 by OH circular polarization (Miranda et al. 2001, Gómez et al. 2005)

Central Stars

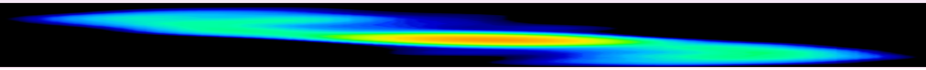
Magnetic fields of kG from the central stars

•NGC 1360, LSS 1362 by optical spectro-polarimetry (Jordan et al. 2005)

Observations

Very Large Array (VLA), USA..

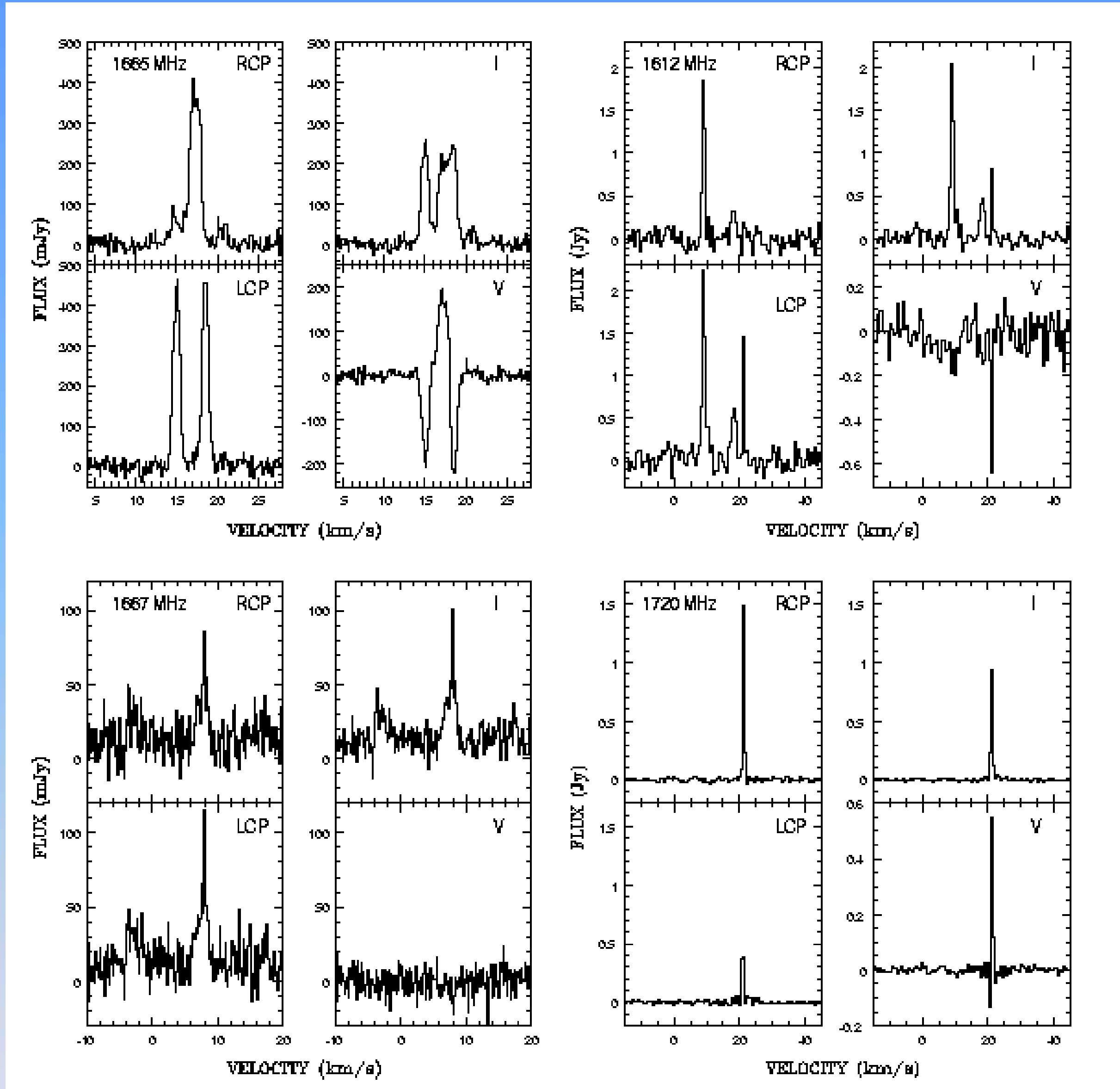
- VLA observations of the 1612, 1665, 1667 & 1720 MHz OH maser emission from K3-35
- Spatial resolution ~1”
- Relative positional accuracy between masers of ~mas
- Spectral resolution
  ~0.14 km/s (1665 & 1667 MHz)
  ~0.53 km/s (1612 & 1720 MHz).



K 3-35

1665 MHz

1612 MHz



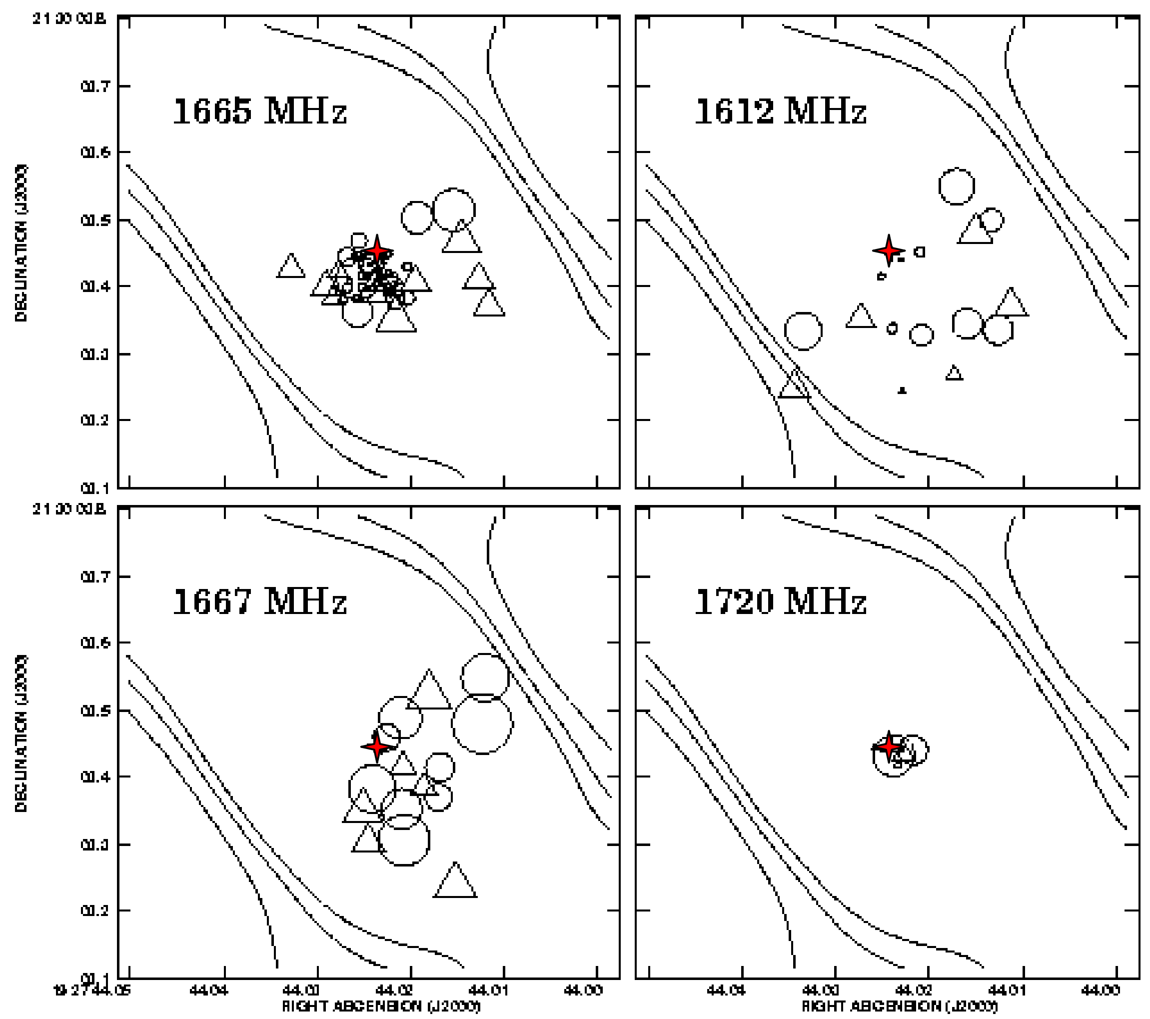
1667 MHz

1720 MHz

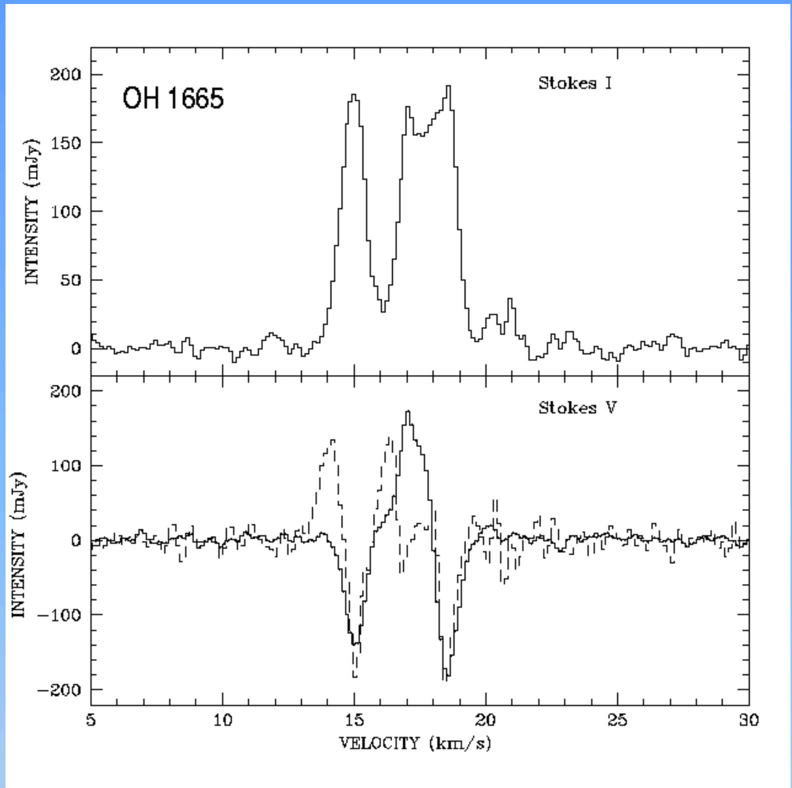
The strong levels of circular polarization in the OH 1665 MHz >50% suggest the presence of a magnetic field in K 3-35.

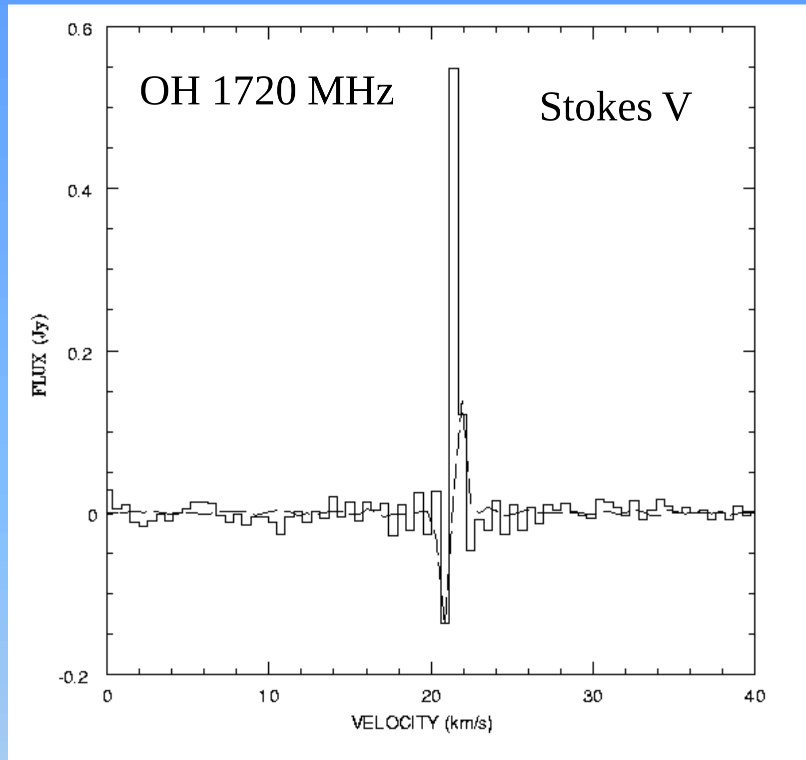
Gómez et al. 2007

K 3-35



This is the only one PN where the OH 1720 MHz transition is observed. Its position is coincident with the radio continuum peak.





If at least one Zeeman pair is present in the 1665 and 1720 MHz transitions, we can estimate the magnetic field.

$V_{obs} \cong C\, B_{los}\, dI/d\nu$ Hz μG^{-1}
(Crutcher et al. 1993; Yusef-Zadeh et al. 1996)

1665 MHz: C= 3.27

1720MHz: C= 0.65

B_{los}~ 0.14 mG

B_{los}~ 0.75 mG

Radius=250 AU

Radius=120 AU

Summary

- The presence of H_2O and OH masers in PNe suggests that these objects are very young in them.
- K 3-35 and IRAS 17347-3139 are until now the only PNe with H_2O maser emission.
- K 3-35 is the only one PN where the OH 1720 MHz transition is detected.
- Kinematic is consistent with masers located in rings but modeling uncertain.
- There is evidence of mG magnetic fields in K 3-35.

THANK YOU