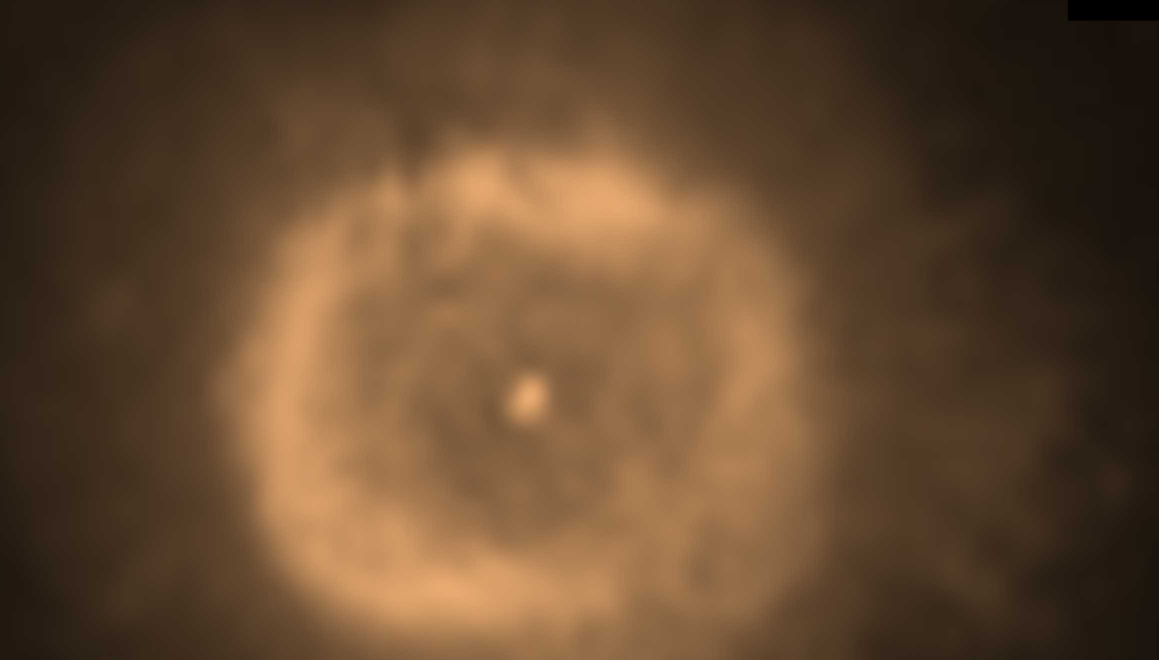
Distance mapping technique and 3-D modeling of BD +30 3639



Akras Stavros
Instituto de Astronomia,
Universidad Nacional Autónoma de Mexico

Collaborators: Steffen Wolfgang (Mexico/Germany), Boumis Panayotis (Greece)

10th Hellenic Astronomical Conference Ioannina,
5-8 September 2011 (Greece)

Characteristics

1. Nebula

i. It is a young (~800 yrs), compact (4 x 6 arcsec) nebula

ii. Rectangular shape with a non-uniform emission around the ring (Harrington et al. 1997)

iii. Prolate nebula oriented almost pole-on with low density polar regions (Bryce & Mellema 1999)

iv. Faint optical halo

2. Central Star

i. WR8 (T_{eff}= 40 kK, log(L/L_{sun})=4.71, dM/dt=1.3 10^{-5} M_{sun}/yr (Leuenhagen Hamann & Jeffrey 1996)

ii. Wind fluctuations in the spectrum of central star (Acker et al. 1997)

Characteristics

3. Distance

i. Expansion parallax method:

2.80 kpc (Masson 1989), 2.68 kpc (Hajian 1993), 1.50 kpc (Kawamura & Masson 1996), 1.20 kpc (Li et al. 2002)

ii. Statistical methods:

0.73 kpc (Daub 1982) , 1.16 kpc (Cahn et al. 1992) , 1.84 kpc (Van de Steene & Zijlstra 1995) , 2.14 kpc (Phillips 2004) , 2.57 kpc (Phillips 2005)

4. KINEMATICS

i. Higher expansion velocity in [O III] than in [NII] lines:

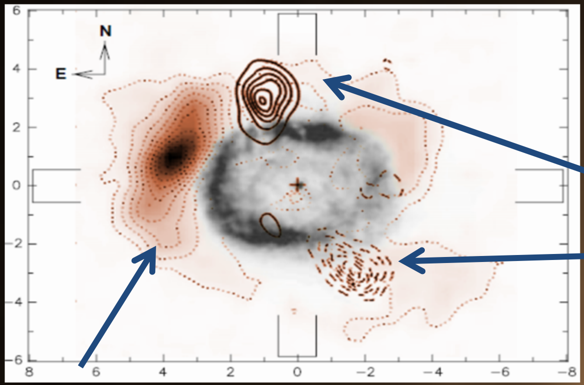
V_{exp}([N II])=28 ±1 km/s, V_{exp}([O III])=35.5 ± 1 km/s (Bryce & Mellema 1999)

V_{exp}([NI I])=42 km/s, V_{exp}([O III])=79 km/s, V_{exp}([O II])= 62 km/s (Medina 2006)

ii. High-moving collimated outflows (up to 80 km/s) in polar direction (NE-SW)

Previous studies

Molecular gas

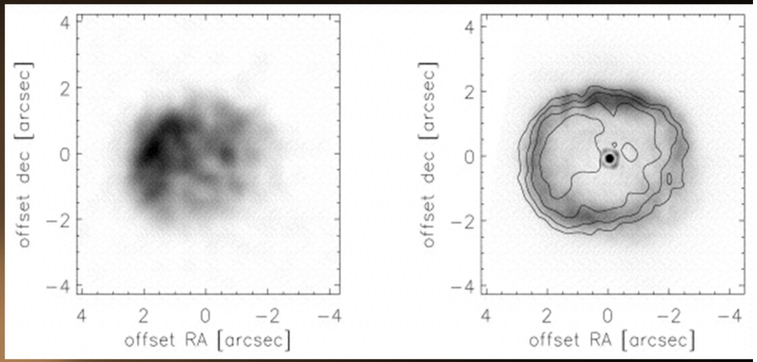


High velocity CO molecular lobes

H_2 molecular gas emission

Bachiller et al. 2000

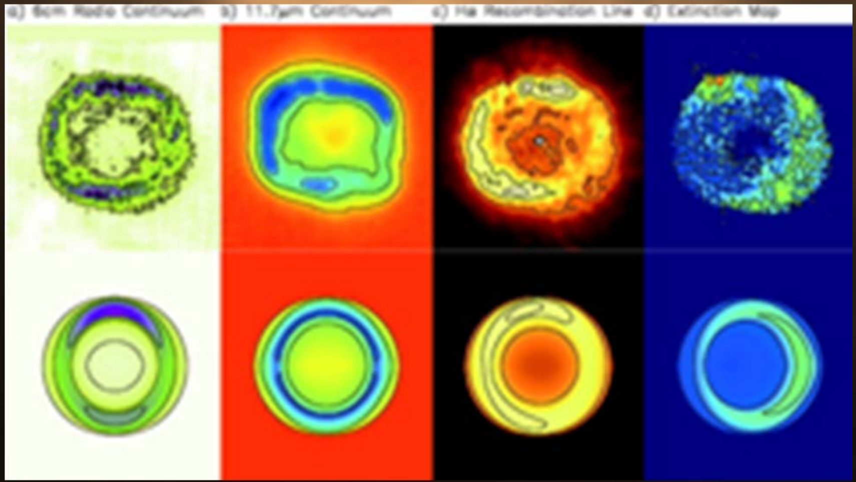
X-ray emisison



Kastner et al. 2002

Strong X-ray emission→ hot bubble (10^6 K) → strong wind-wind interaction.

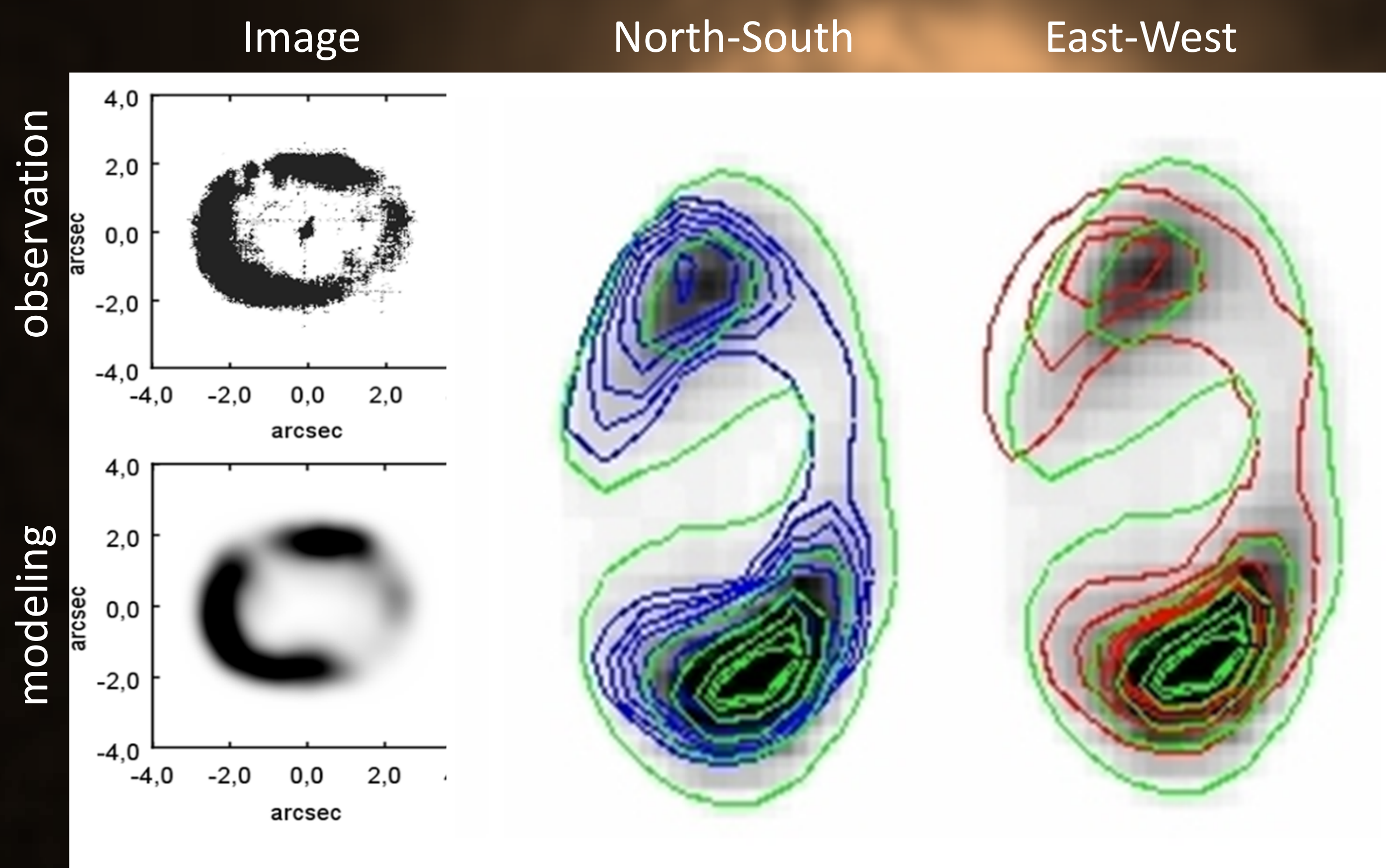
Modeling



Lee & Kwok 2005

Morpho-kinematic code SHAPE (Steffen et al. 2011): [N II] emission lines

Optical images (Harrigton et al. 1997) & PV diagrams (Bryce & Mellema 1999)



Rotation:(-23, -20, 0)

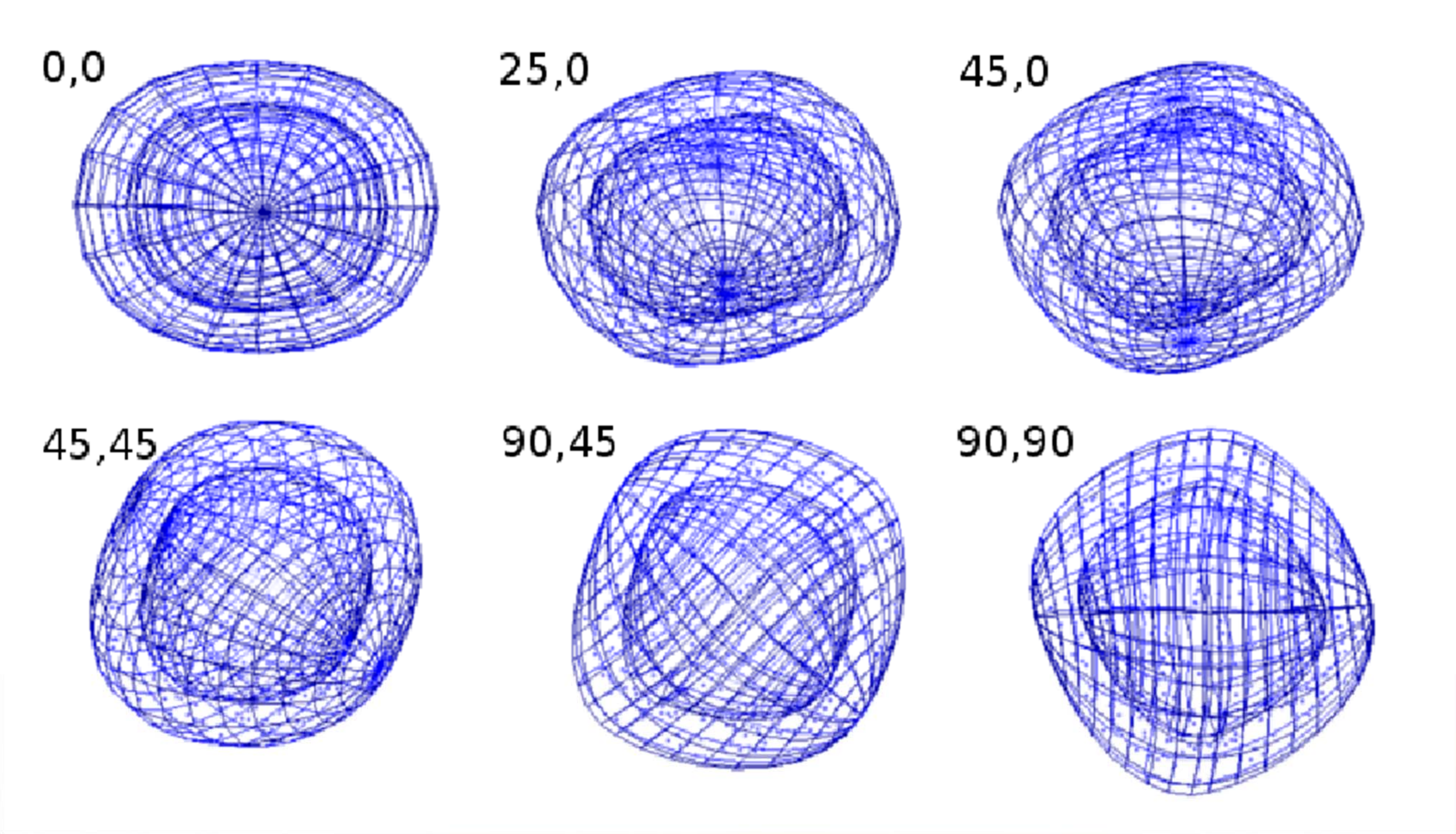
Vradial=28*r/250

Vnoise=2.5 km/s

Vcylindrical=30km/s

Vnegative=-25 km/s

3-D structure of BD +30

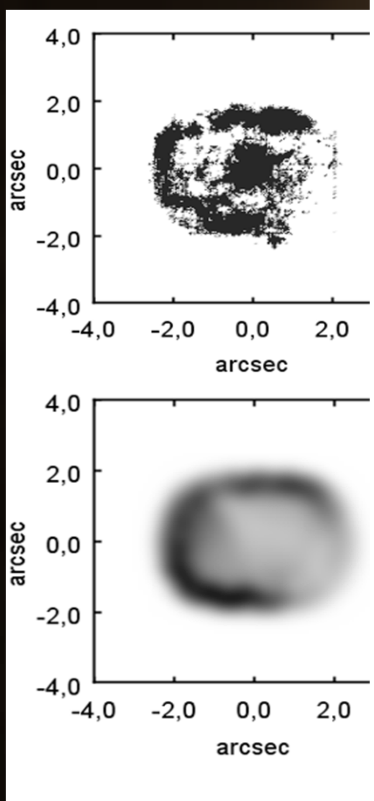


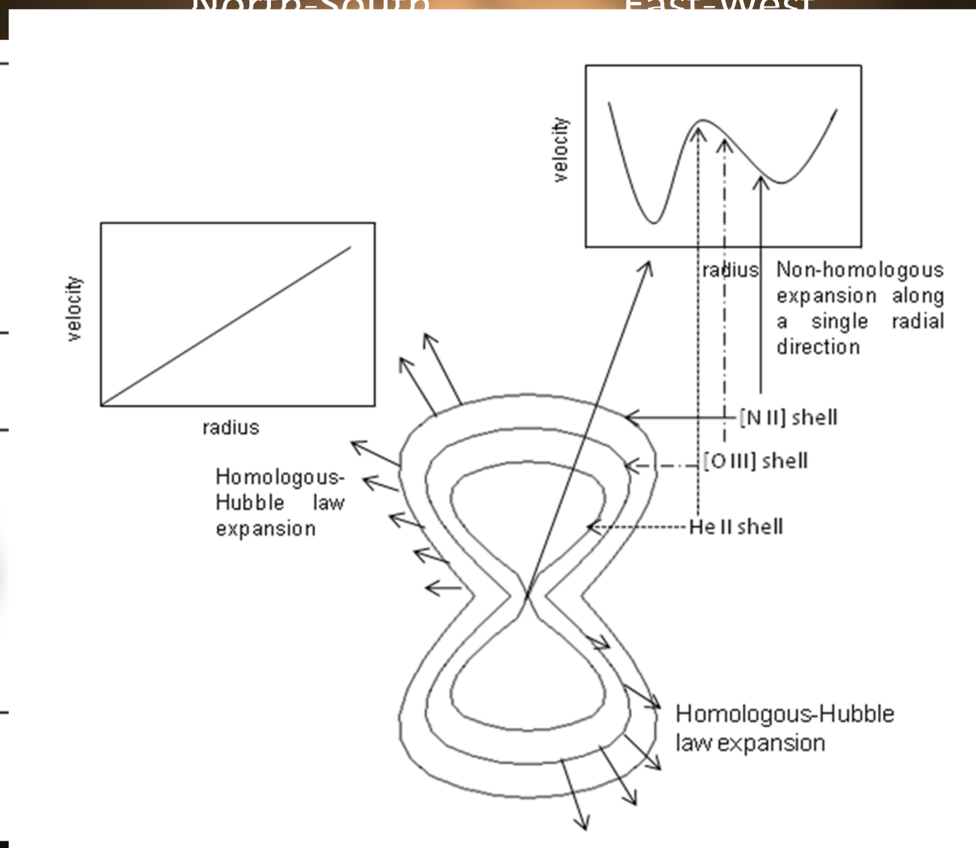
Morpho-kinematic code SHAPE (Steffen et al. 2011): [O III] emission lines

Image North-South East-West

observation

modeling





Rotation:(-20 -20, 0)

Vradial=36*r/225

Vnoise=2.5 km/s

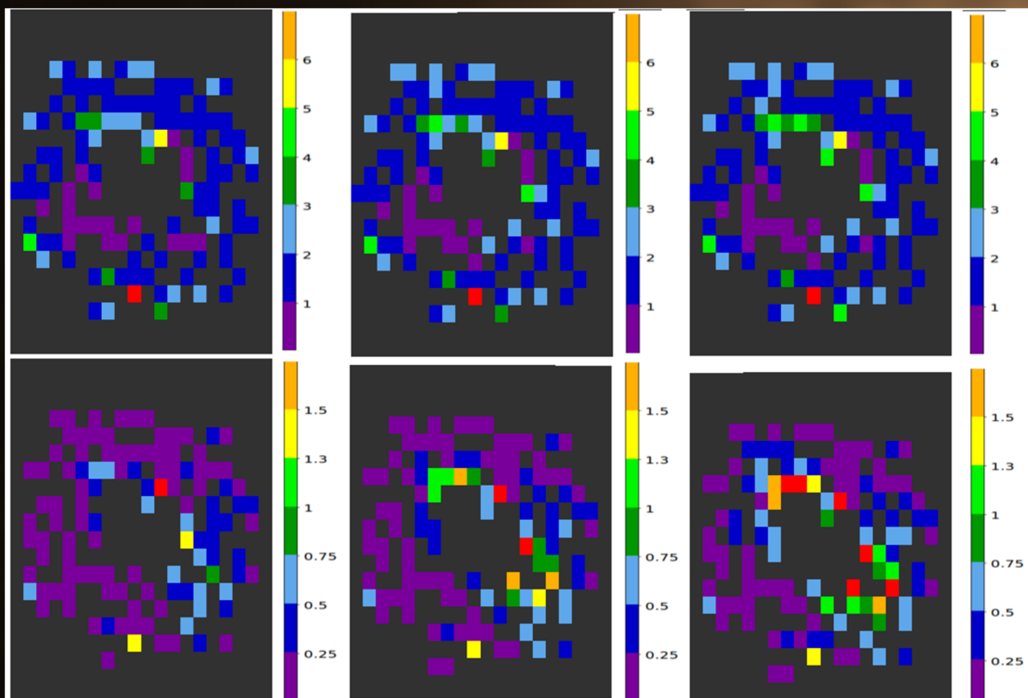
Vcylindrical=45km/s

Vnegative=-25 km/s

Distance mapping technique

$d=V_t/(d\theta/dt)$

178 proper motion measurements by Li et al. (2002)



$D = D_{Li} * a * b = 1.20 * 1.04 * 1.12 = 1.40$ kpc

a= correct factor if the cylindrical velocity component is used.
b= correct factor due to the difference between the pattern velocity on the sky and the material velocity (Mellema 2004).

i. The higher cylindrical component the higher mean distance of BD 30:

0 km/s → 30km/s → 45km/s

1.35 kpc →1.40 kpc →1.45 kpc

ii. If the size of boxes becomes bigger, the distance will be systematically higherand it has to be chosen carefully (Akras et al. in preparation) .

iii. The error maps show clearly the difference between these models.

Conclusions

- BD +30 is a prolate nebula seen almost pole-on (20^o-23^o).
- We found evidence for an interaction between the east part of nebula and the H_2 molecular gas.
- The internal velocity field of BD +30 follows a non-homologous velocity law probably a V- or W-type expansion law (V_{exp}([O III]) = 1.5 V_{epx}([N II])), since a homologous velocity field is not capable to explain the higher velocities in the inner regions of the nebula.
- Higher expansion velocities in the inner regions of a nebula are observed mostly in prolate/pole-on nebula with WR central star. (e.q. BD +30, NGC 6751, M 1-1).

→ Is it a random phenomena?

- It's distance determined at 1.40 ± 0.15 kpc for a cylindrical velocity component of 30 km/s.
- The advantage of our new method compared to the previous methods is that SHAPE code can model simultaneously a complex object with a complex velocity field.

PNe with WR central stars

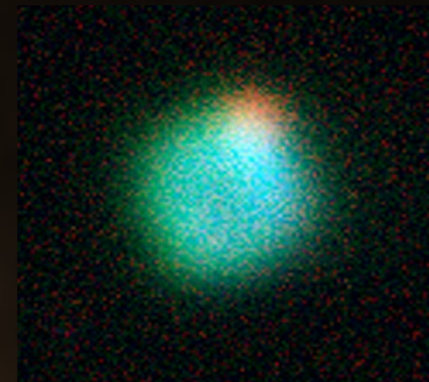
name	CS	Prolate	V He II	V He I	V OIII	V OII	V N II	Radius Ha [a]
NGC 6751	WC6	OK/pole-on	-	81	66	64	60	45
NGC 40	WC8	OK/face-on	-	40	47	37	36	18[b]
NGC 2022	pn	?	49	47	40	-	37	14
BD +30	WC9	OK/pole-on	-	-	79	62	42	6
K 3-61	WC4/5	?	-	51	48	-	46	~7.2x6.3[d]
IC 351	wl/WR [c]	ok/pole-on(PA=10)	34	34	36	35	28	~3.5 [c]
M 1-1	pn	Bip/pole-on	-	57	57	36	38	3[f]
NGC 6369	WC4	pole-on	63	67	64	76	57	35
Hb4	WC3/4	?	42	31	32	47	34	15.5
M 1-32	WC4/5	pole-on	-	76	89	63	65	7
NGC 1501	WC4	OK/oblate?	66	61	58	-	51	28x24[b]

Medina et al. 2006

BD+30 3639 G064.7+05.5 19 34 45.23 +30 30 58.9, R:G:B = log[NII], log(Ha), log[OIII]
HST/WFPC2/PC1 N is NOT up. HST archives: 5403 (Harrington) & 8390 (Hajian)
ref: Harrington, J.P., Lame, N.J., White, S.M., & Borkowski, K.J. 1997 AJ 113 2147

NGC 6571 G029.2-05.9 19 05 55.56 -05 59 32.9, R:G:B=log(Ha+[NII]),both,log[OIII]
ref: Schwarz, H.E., Corradi, R.L.M., Melnick, J 1992 A&A Suppl, 96, 23
image files courtesy R Corradi.   N is NOT up. See ref for orientation.

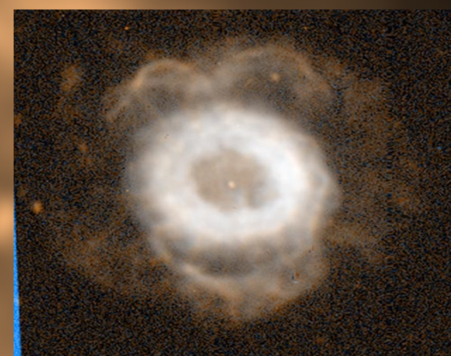
NGC 2022 G196.6-10.9 05 42 06.23 +09 05 10.8, R:G:B=log(Ha+[NII]),both,log[OIII]
ref: Schwarz, H.E., Corradi, R.L.M., Melnick, J 1992 A&A Suppl, 96, 23
image files courtesy R Corradi.   N is NOT up. See ref for orientation.



K 3-61 G096.3+02.3 21:30:00.6 +54:27:30 R:G:B = log[NII], log(Ha), log[OIII]
"The IAC morphological catalog of northern galactic planetary nebulae"
A. Manchado, M.A. Guerrero, L. Stanghellini, M. Serra-Ricart, 1996, ed. IAC

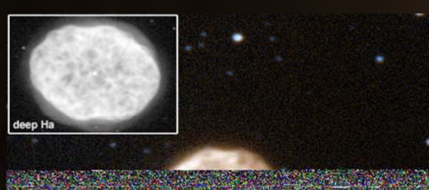
IC 351 G159.0-15.1 03:47:32.9 +35:02:49, R:G:B=log(Ha+[NII]), both, log[OIII]
"The IAC morphological catalog of northern galactic planetary nebulae"
A. Manchado, M.A. Guerrero, L. Stanghellini, M. Serra-Ricart, 1996, ed. IAC

M 1-32 G011.9+04.2 17 56 19.98 -16 29 04.0, R:G:B=log(Ha+[NII]), both, log[OIII]
ref: Schwarz, H.E., Corradi, R.L.M., Melnick, J 1992 A&A Suppl, 96, 23
image files courtesy R Corradi.   N is NOT up. See ref for orientation.

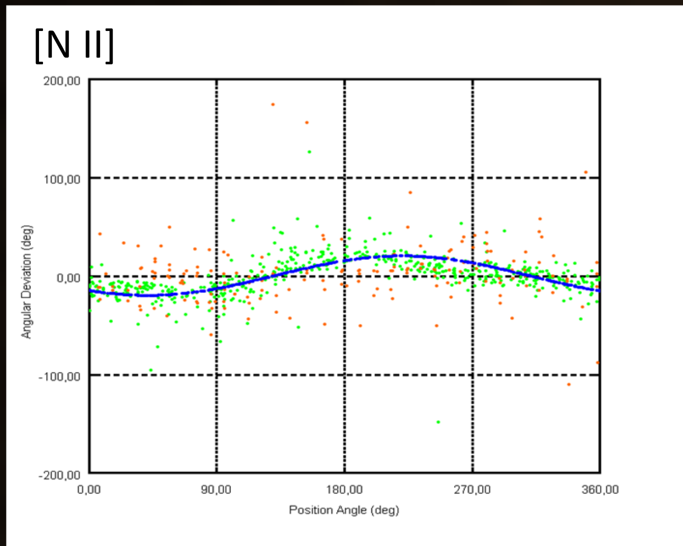


NGC 6369 G002.4+05.8 17 29 20.44 -23 45 34.2, R:G:B=log(Ha+[NII]),both,log[OIII]
ref: Schwarz, H.E., Corradi, R.L.M., Melnick, J 1992 A&A Suppl, 96, 23
image files courtesy R Corradi.   N is NOT up. See ref for orientation.

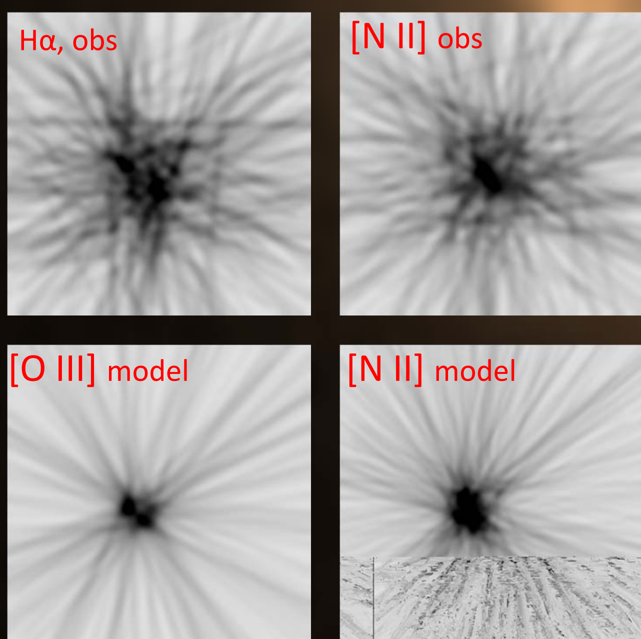
Hb 4 G003.1+02.9 17 41 52.76 -24 42 08.1, R:G:B = log(F658N), both, log(F656N)
HST/WFPC2/PC, HST archives, WFPC2 Associations, GO6347 (Borkowski), N is NOT up
ref: http://www.astro.umd.edu/~jph/



Angular deviation



i. A sinusoidal pattern around zero
ii. Expansion somewhat faster along the position angle 40-45 and 215-225 degrees.
iii. The position angle's difference between the CO outflows and optical outflows is 20 degrees.



Criss-cross map

i. The kinematic center of the expanding nebula is located approximately 0.5 arcsec away from the central star.
ii. Indications of a cylindrical velocity component along the NE-SW direction