# THE MORPHO-KINEMATICS OF PLANETARY NEBULAE WITH BINARY CENTRAL STARS

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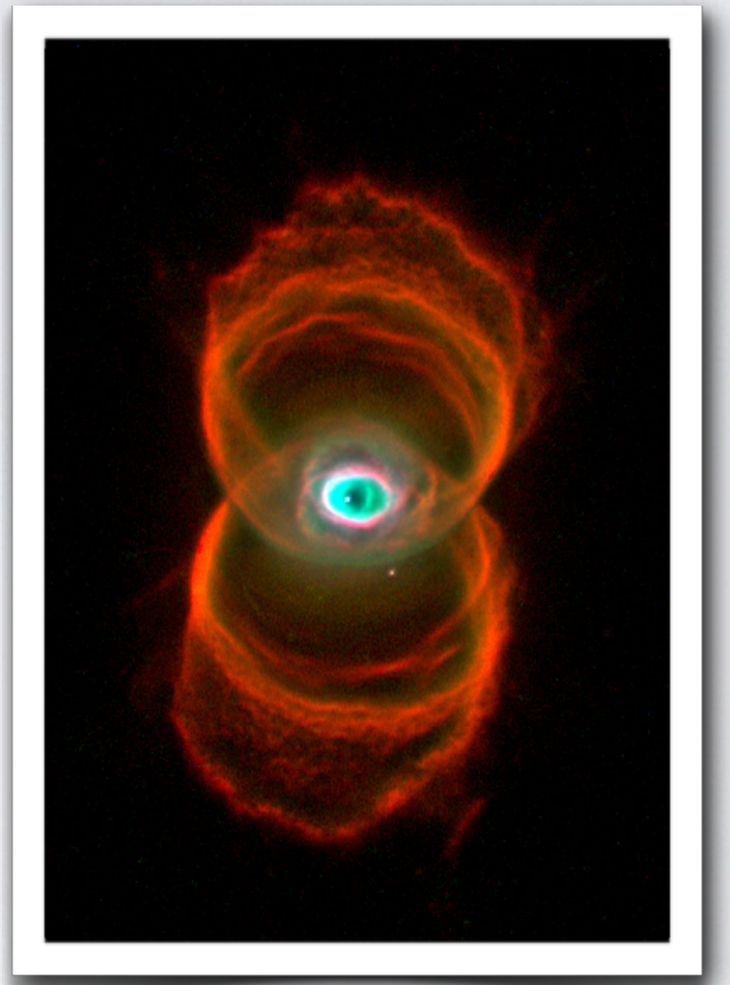
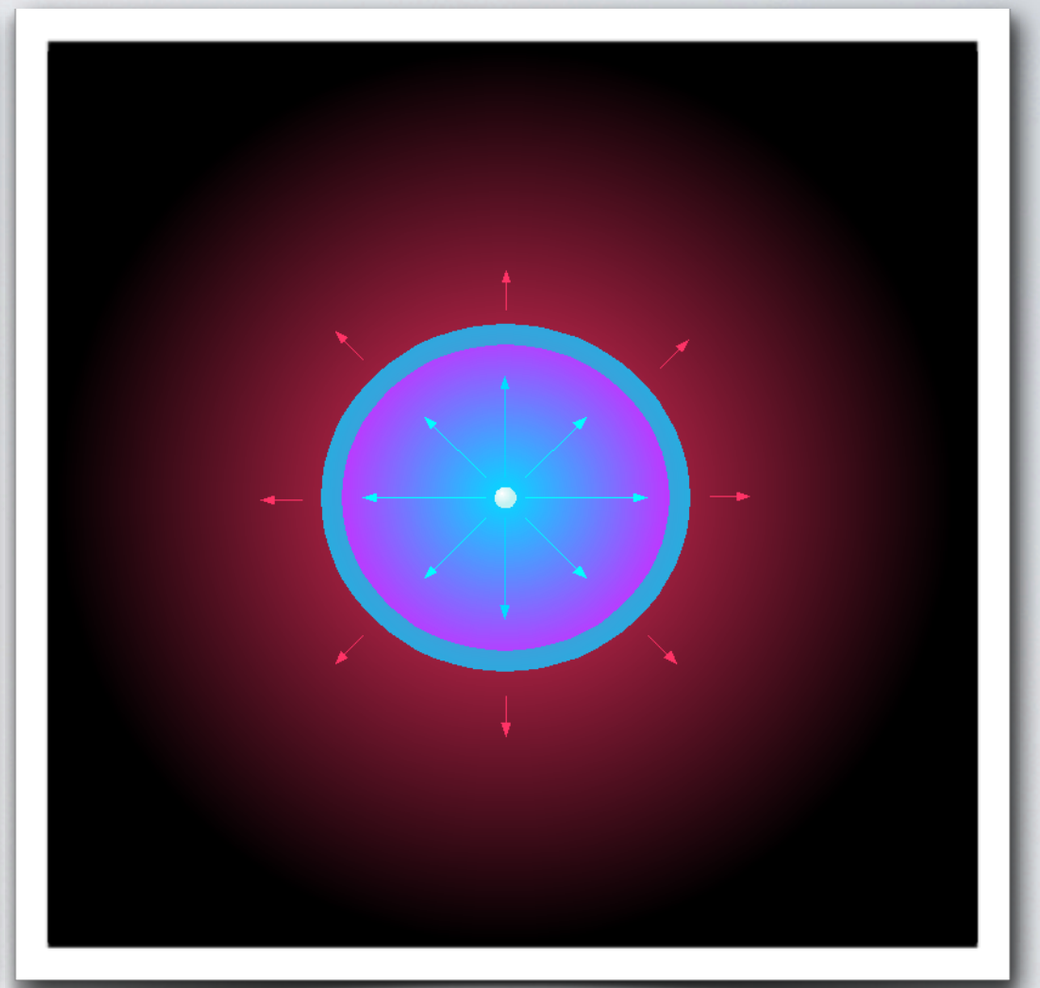
# 1. HISTORY - ASPHERICAL PLANETARY NEBULAE

e.g. De Marco 2009, PASP, 121, 316

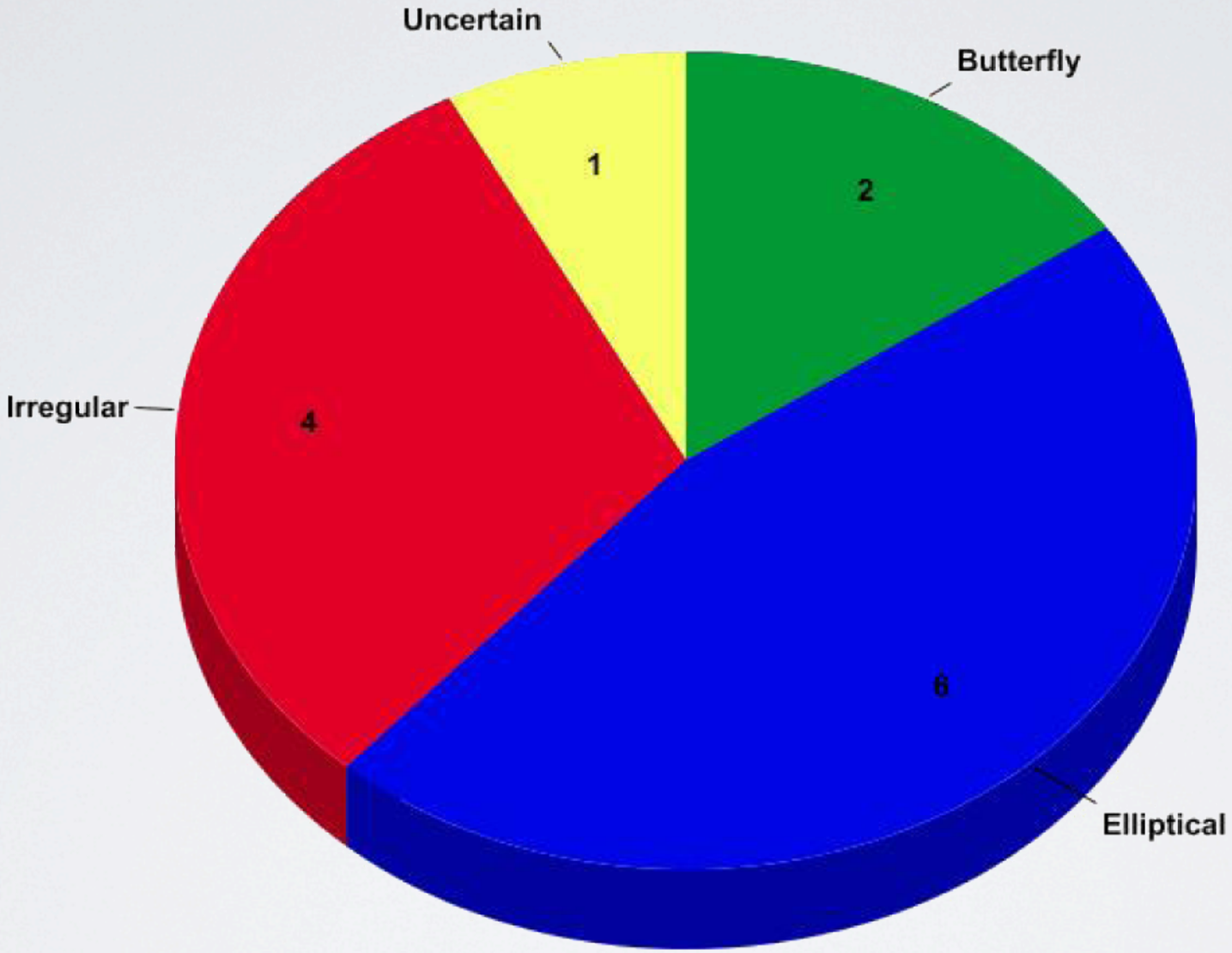
- Stellar rotation
- Magnetic fields
- Binaries!





# 1. HISTORY - THE BEGINNING

## Bond & Livio 1990, ApJ, 355, 568




The problem: *Fraction of non-spherical PNe (≳80%) much larger than fraction known to contain close-binary nuclei (~15%)*

# 1. HISTORY - DEEPER IMAGERY

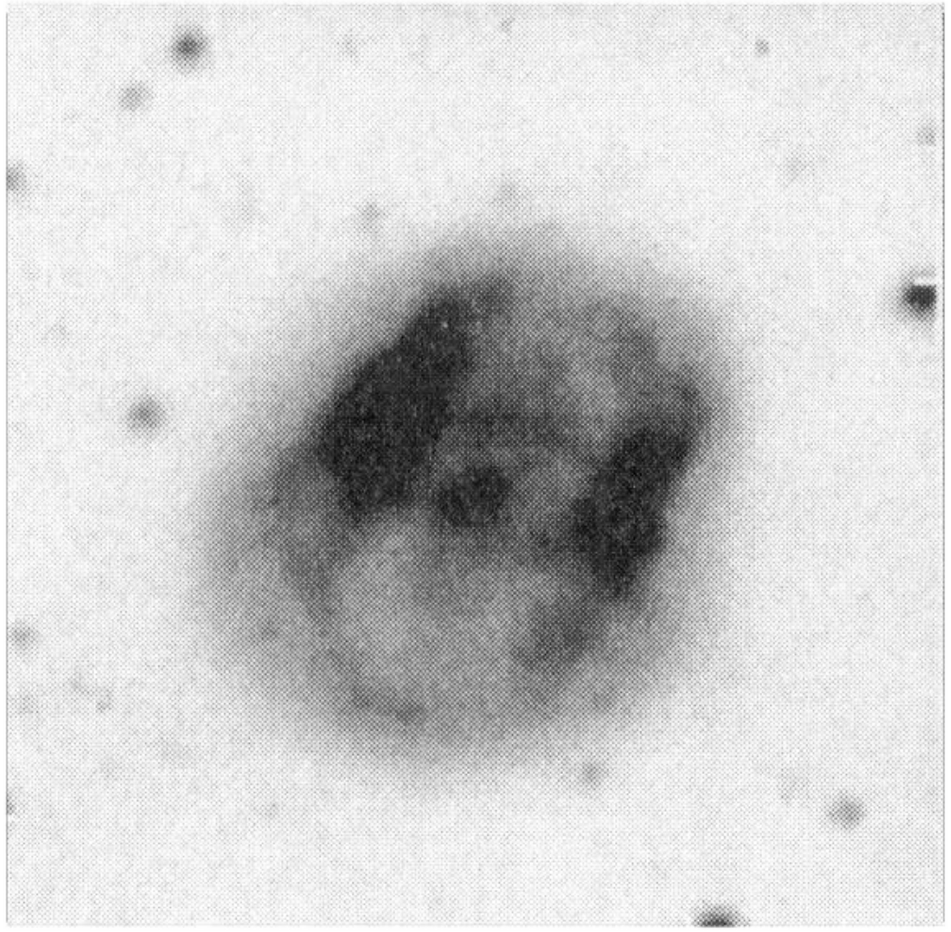
Pollacco & Bell 1997, MNRAS, 284, 32

- Deep narrowband Hα+[NII] imagery reveals extremely interesting features

- Only 4 PNe but all bipolar/elliptical

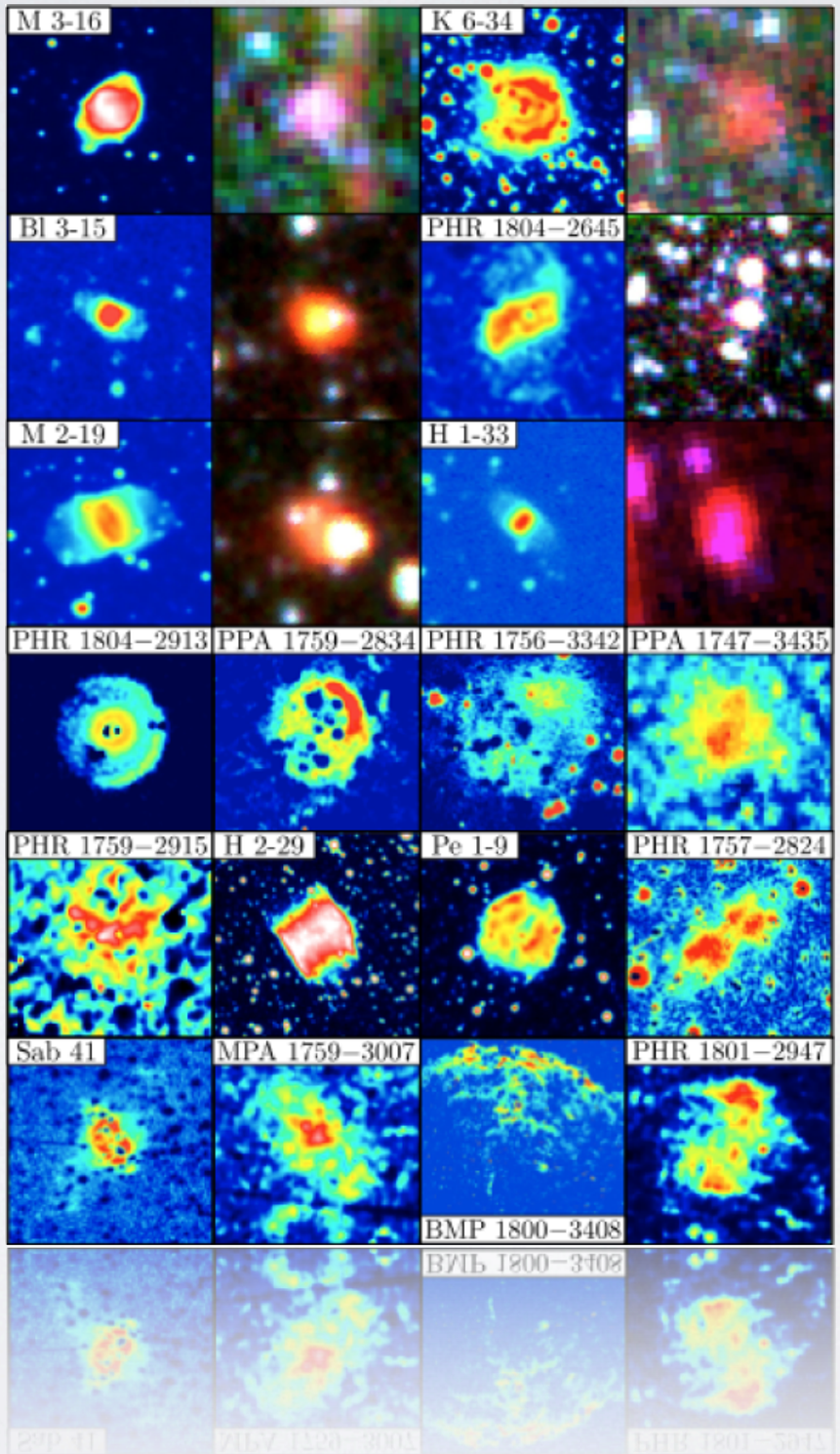
- 3/3 apparent inclination matches (nebular axis-orbital plane)

Abell 41



# I. HISTORY - BIGGER SAMPLE

Miszalski et al. 2009, A&A, 505, 249



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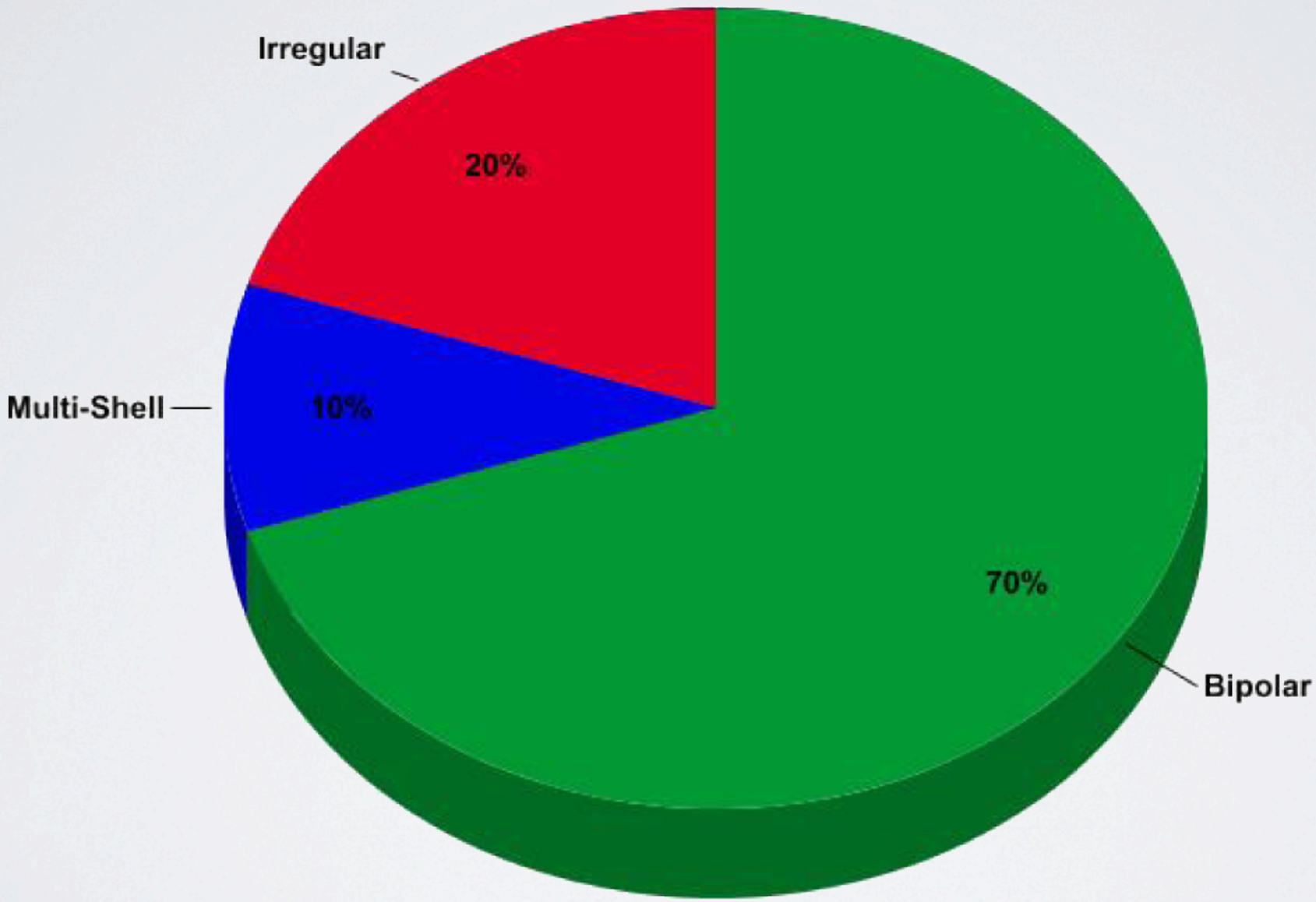
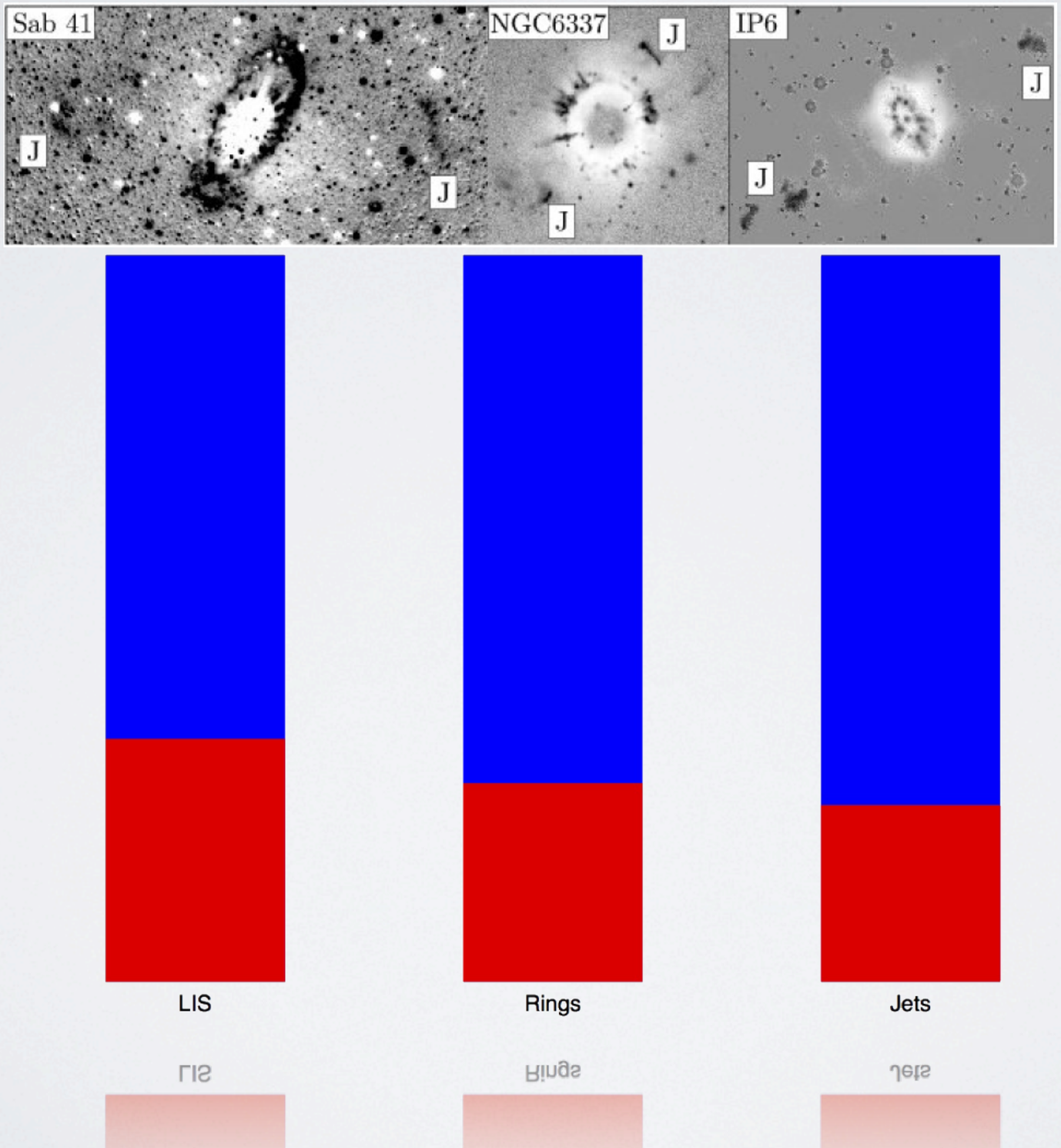


# 2. BINARY INDICATORS?

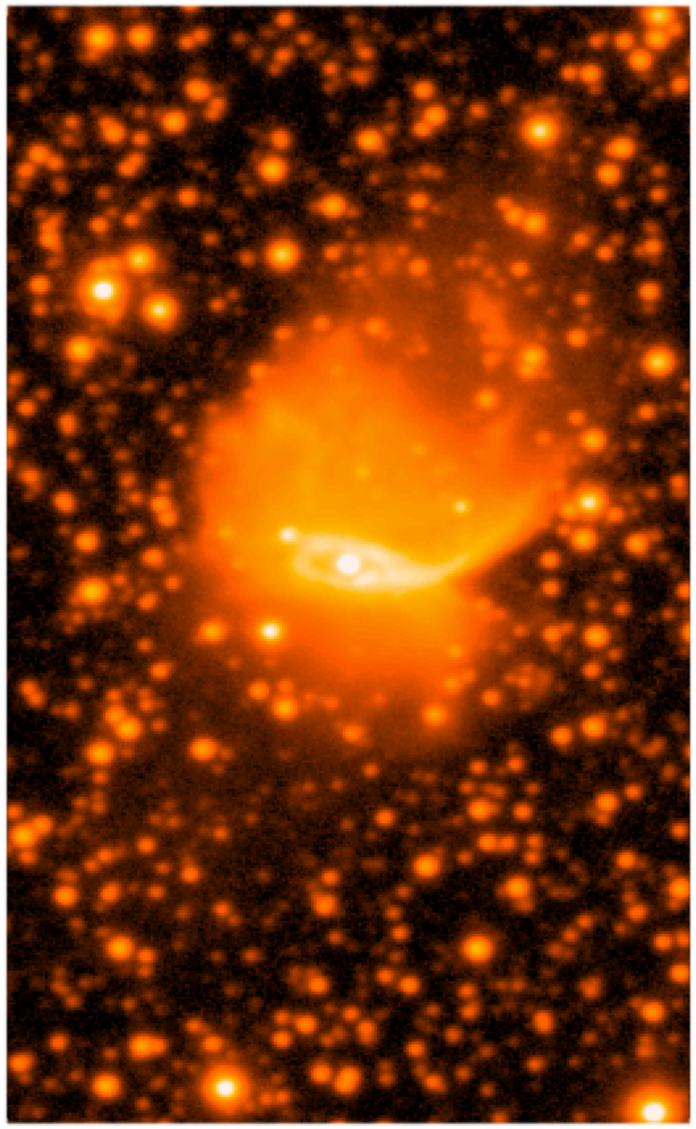
Miszalski et al. 2009, A&A, 505, 249

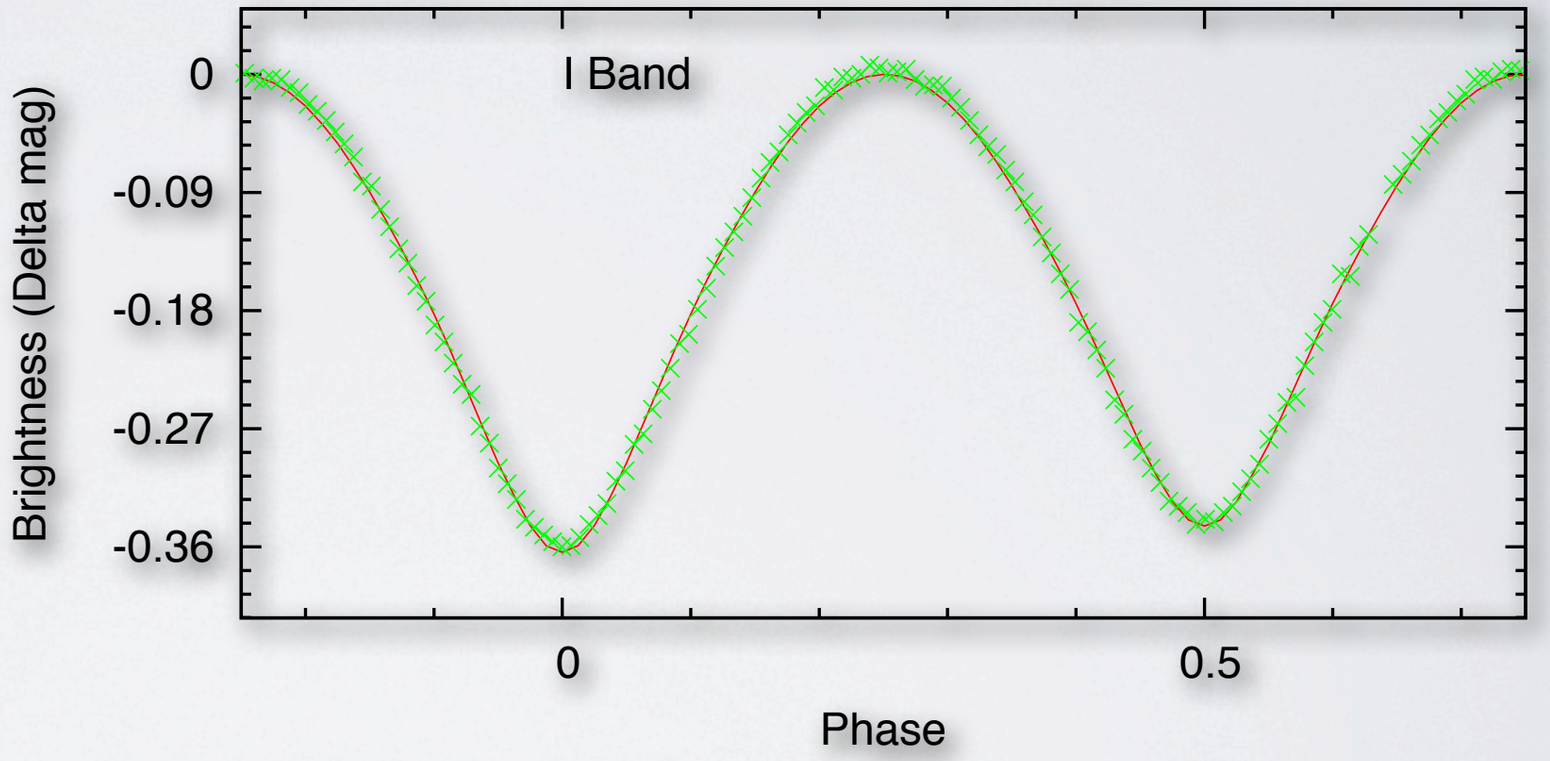


# 2. BINARY INDICATORS!

Santander-García et al., in preparation

Hen 2-428



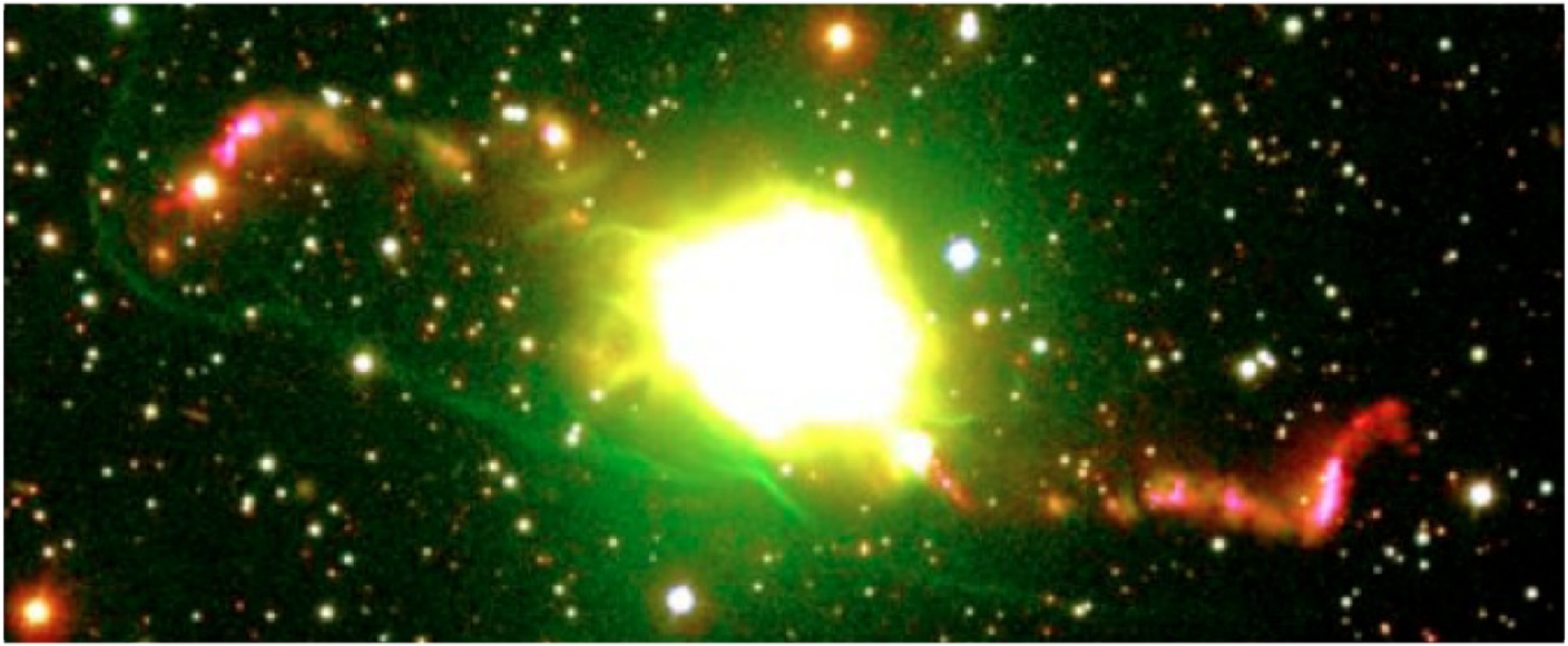



P = 4.2 hours

# 2. BINARY INDICATORS!

Boffin et al. 2012, Science, 338, 773

Fg 1



# SOMETHING ABOUT THE MORPHOLOGIES...

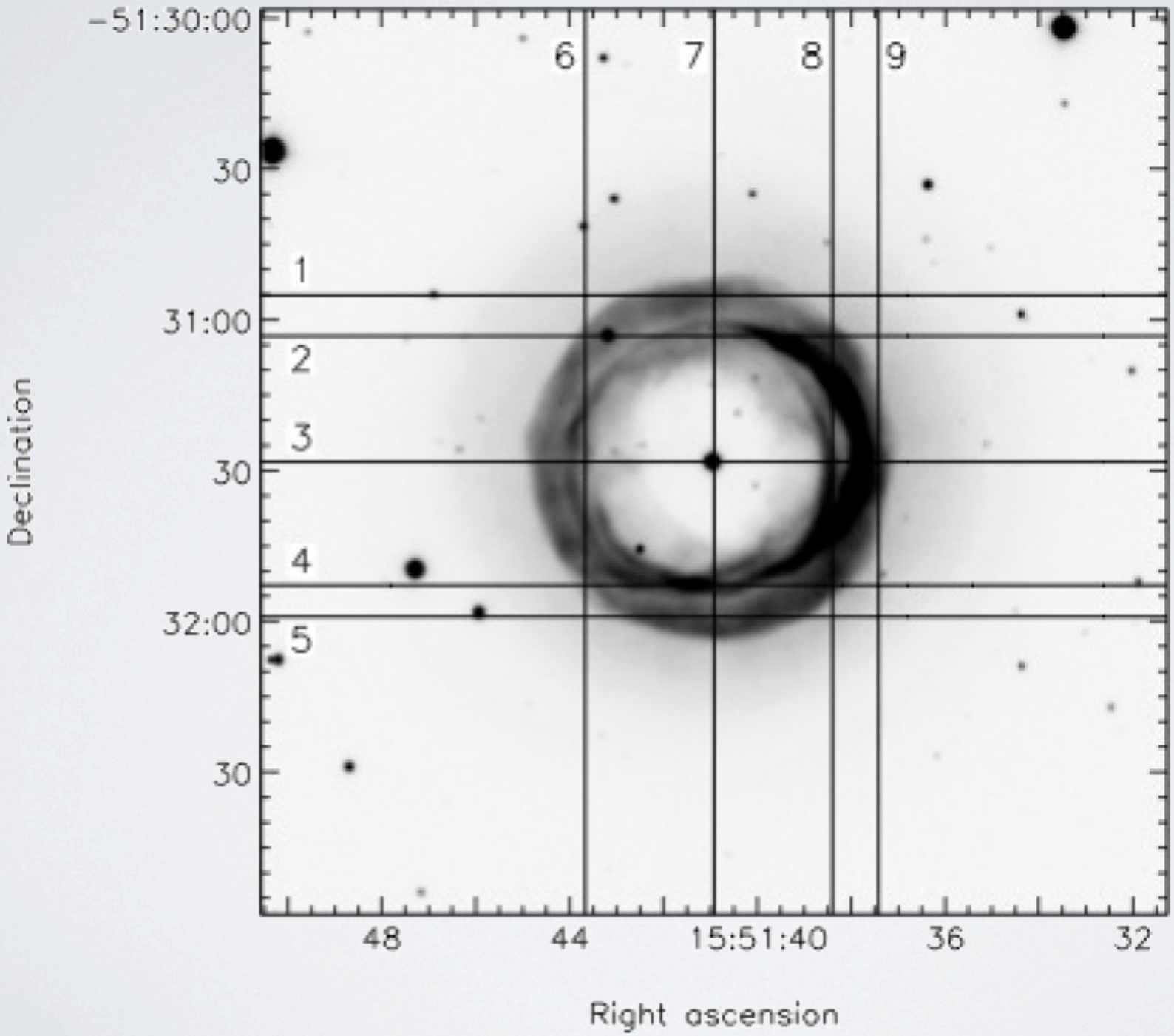
- Bipolars prevail
- No round nebulae. Irregulars/multiple shells?
- Imagery can be highly ambiguous
- Limited information from images alone...

# 3. KINEMATICS - AN EXAMPLE

## Sp I

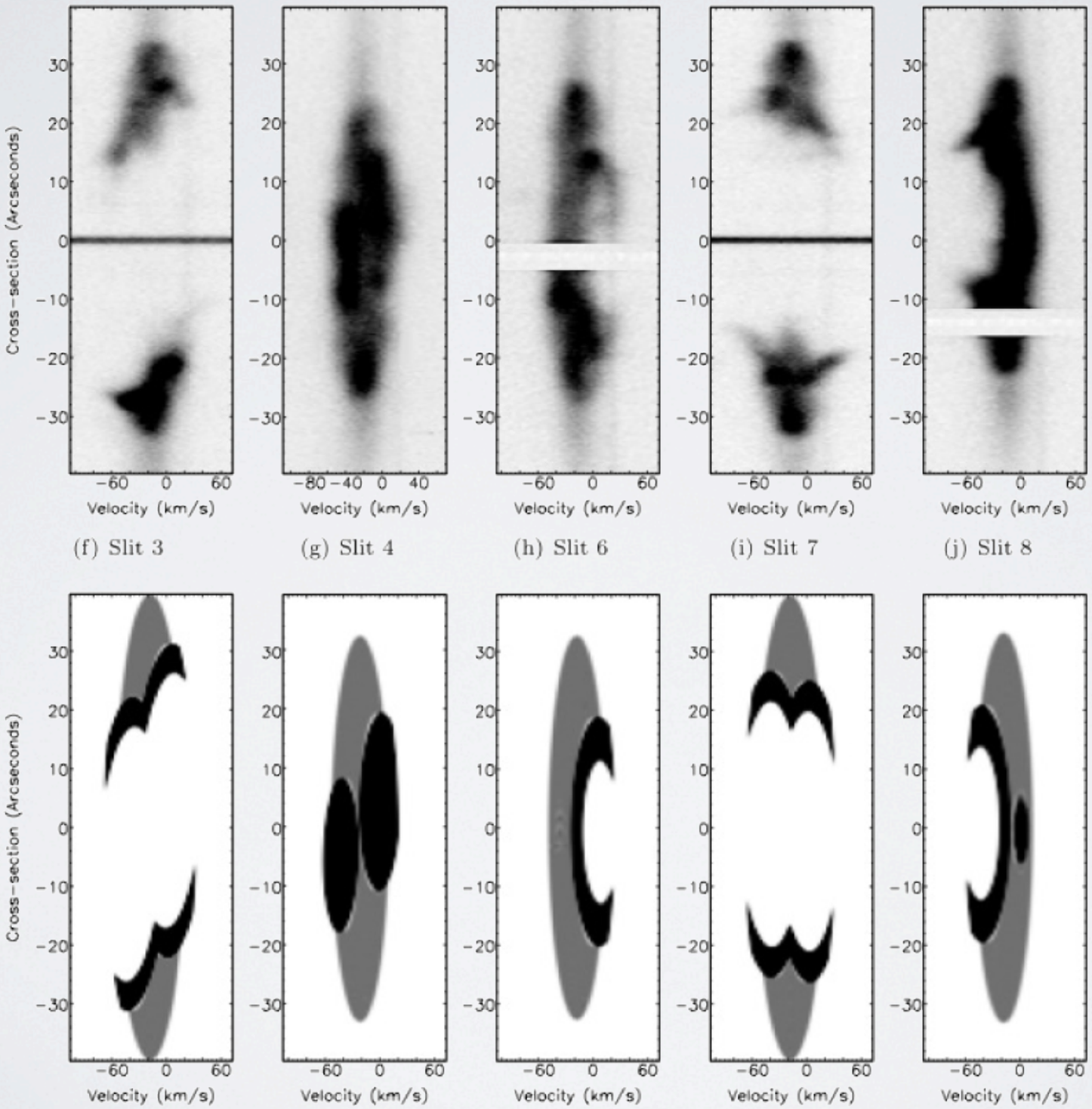
# 3. KINEMATICS - AN IMAGE MIGHT BE WORTH 1000 WORDS...

Jones et al. 2012, MNRAS, 420, 2271



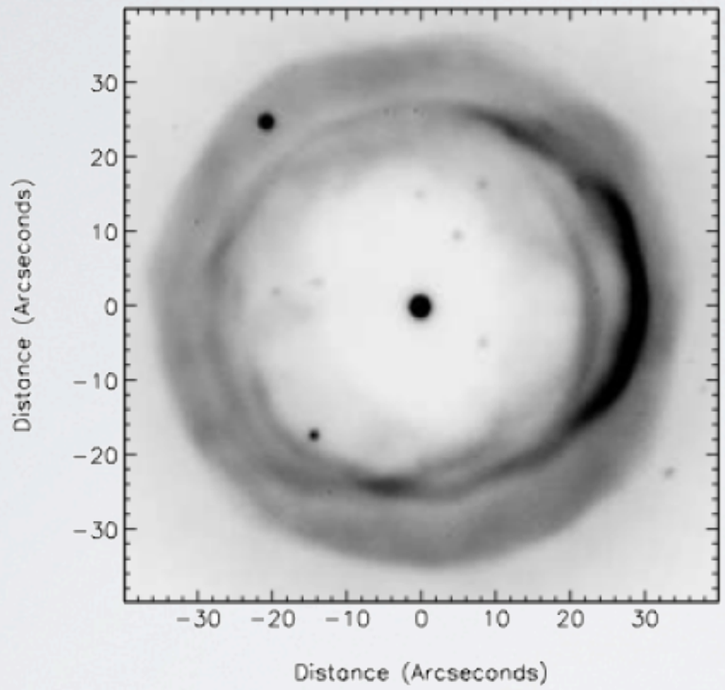
# 3. KINEMATICS - ...BUT A SPECTRUM IS WORTH 1000 IMAGES!

Jones et al. 2012, MNRAS, 420, 2271

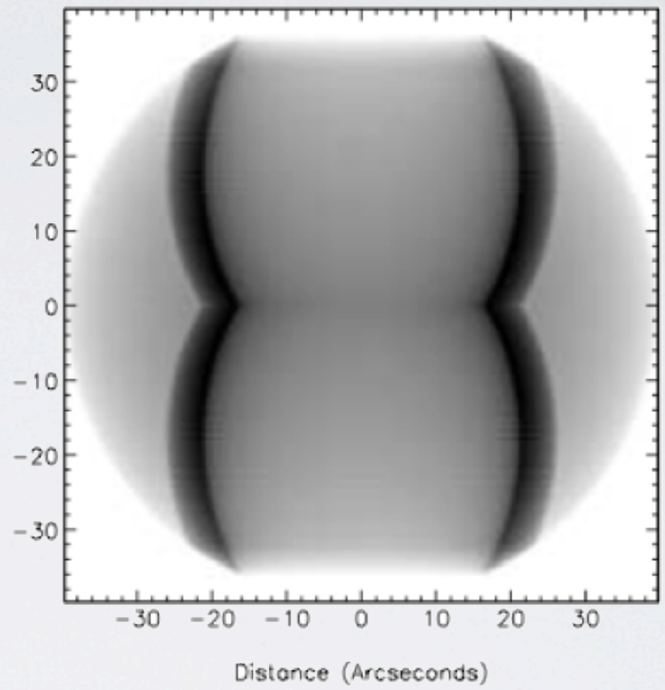


# 3. KINEMATICS - NOW IN 3D!

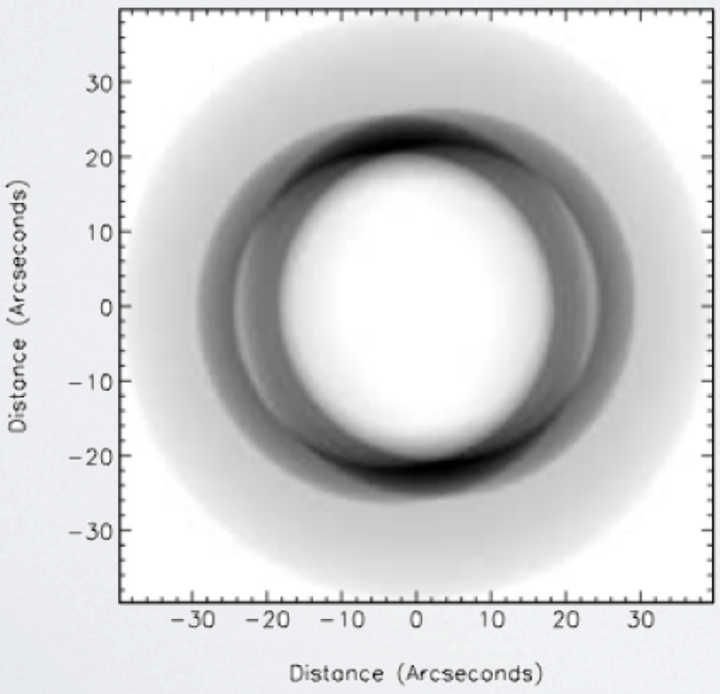
Jones et al. 2012, MNRAS, 420, 2271



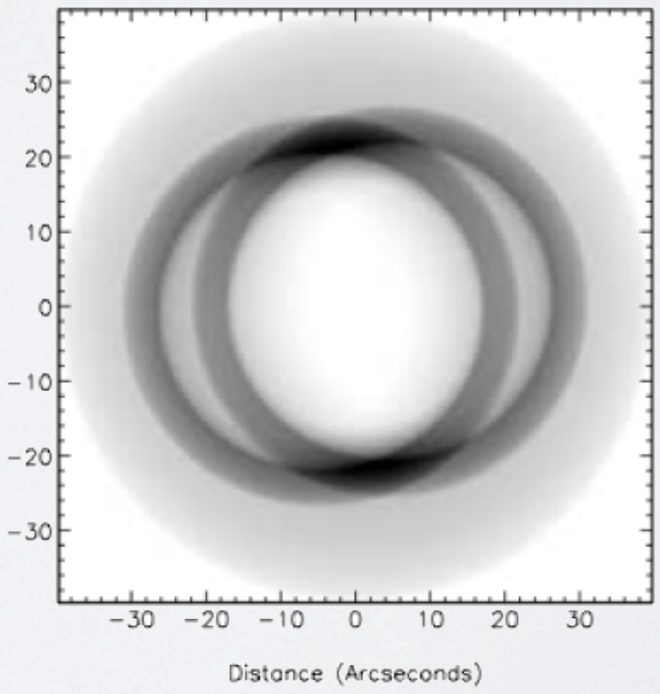

(a) [O III] $\lambda$5007 Å




(b) 90°




(c) 10°

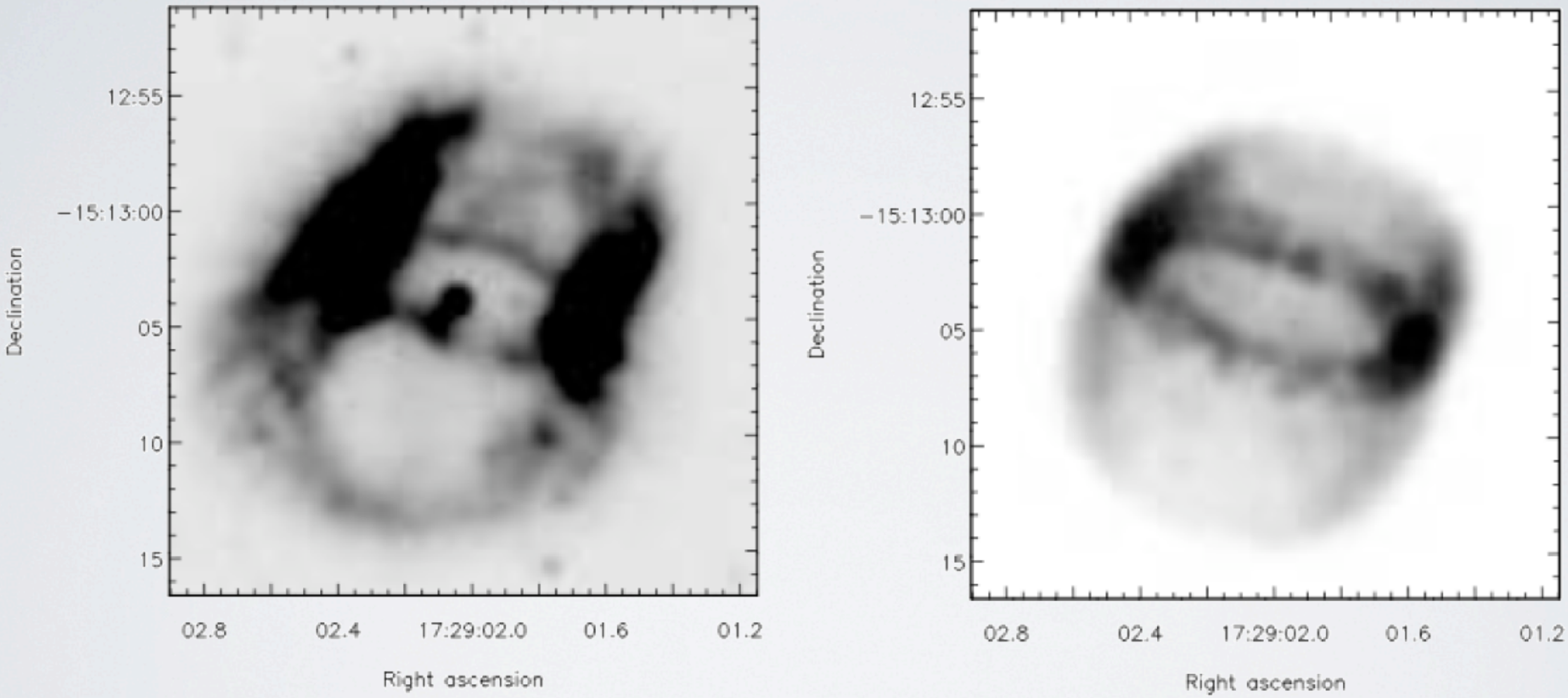



(d) 15°

# 3. KINEMATICS - GETTING THE MORPHOLOGY RIGHT

Jones et al. 2010, MNRAS 408, 2312

## Abell 41

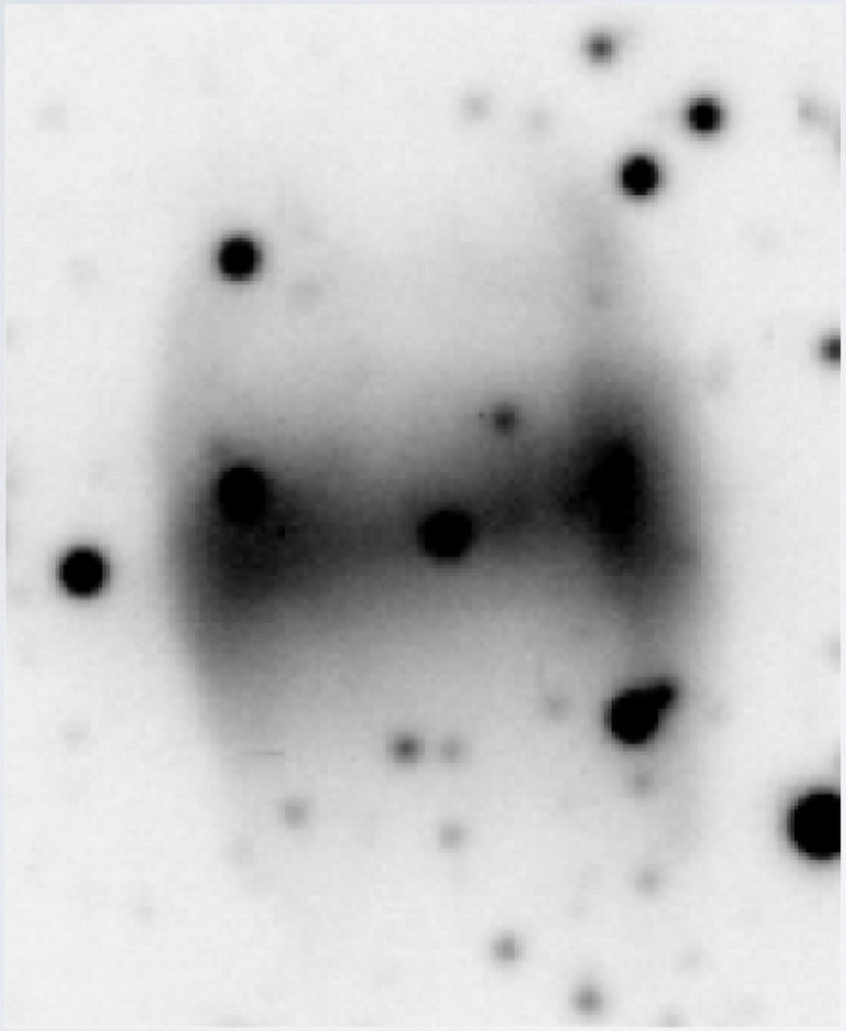



~~Elliptical~~ → Bipolar

# 3. KINEMATICS - GETTING THE MORPHOLOGY RIGHT

Tyndall et al. 2012, MNRAS, 422, 1804

## HaTr 4

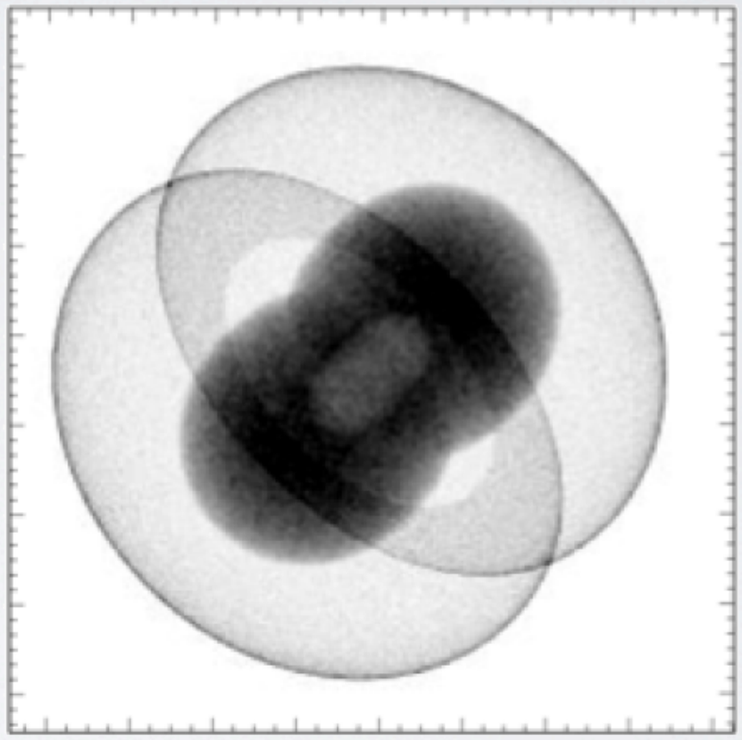


~~Bipolar~~ → Elliptical

# 3. KINEMATICS - GETTING THE MORPHOLOGY RIGHT

Huckvale et al. 2013, MNRAS, 434, 1505

## Abell 65



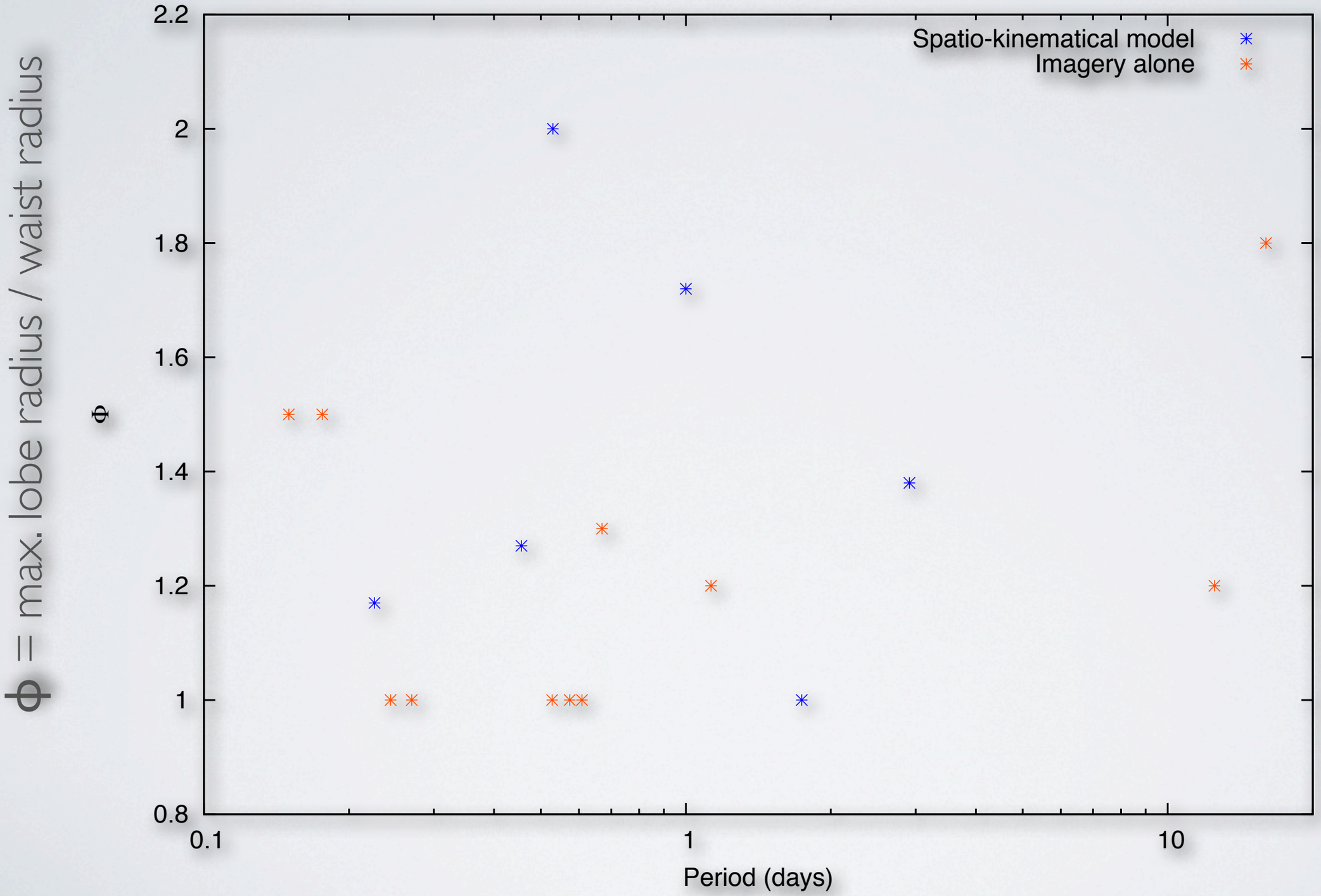
Multiple shell

# 4. AND NOW WHAT? - MORPHOLOGIES

- Bipolars?
- Ellipticals?
- Irregulars?
- LIS?
- Jets?
- Rings?

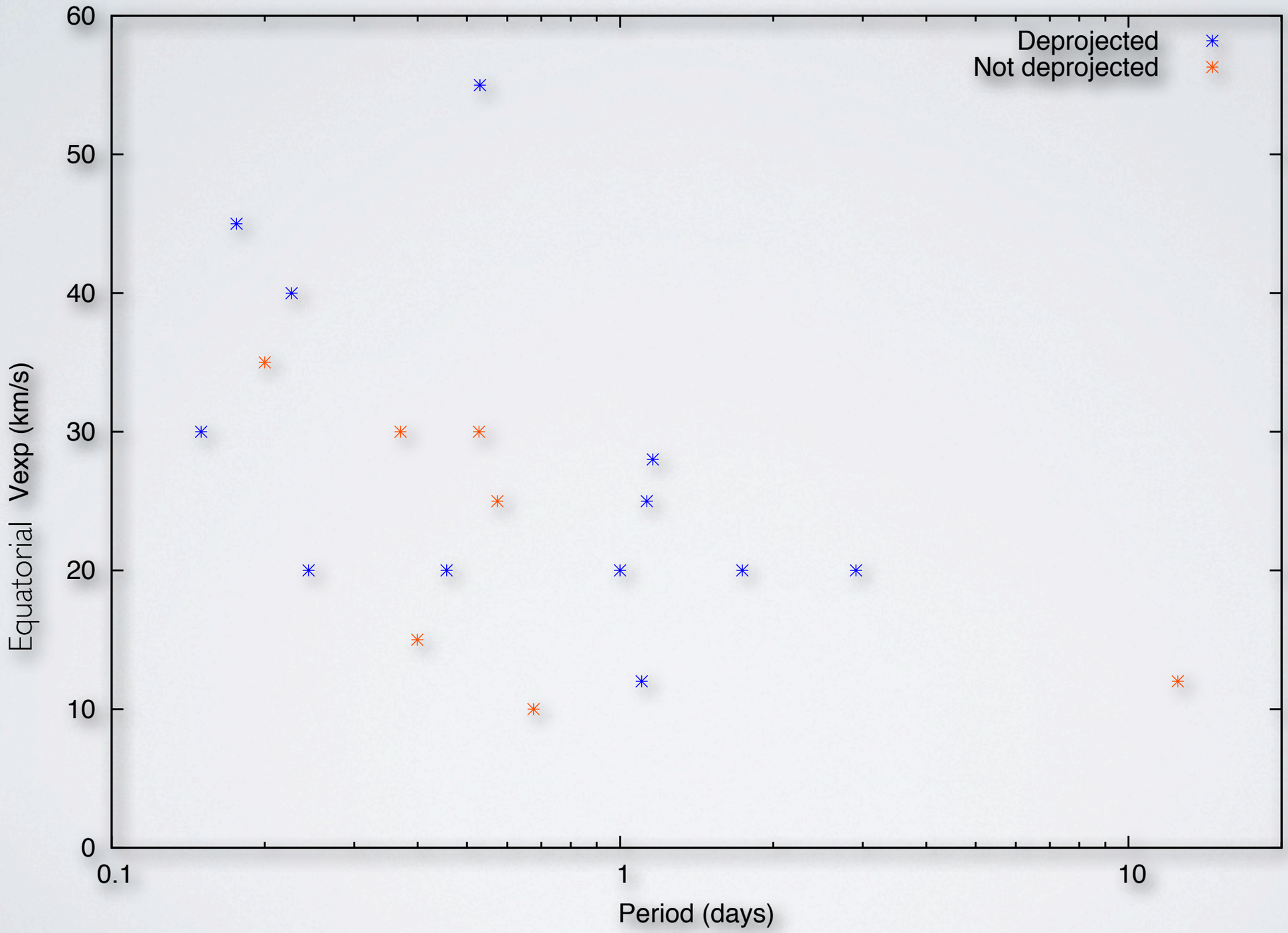
# 4. AND NOW WHAT? - MORPHOLOGY LINKED TO PERIOD?

Jones et al., in preparation



# 4. AND NOW WHAT? - EXPANSION VELOCITY LINKED TO PERIOD?

Jones et al., in preparation



# 5. SUMMARY

- Companion stars are a definite shaping agent for non-spherical PNe (100% rate inclination match!). Perhaps the only one?

- Morphologically disparate, but some features dominate:
  - ✓Bipolars
  - ✓Rings
  - ✓Jets
  - ✓Filaments

- No strong link to current knowledge of central binary