The study of planetary nebulae and ionized stellar outflows with 3D-NTT

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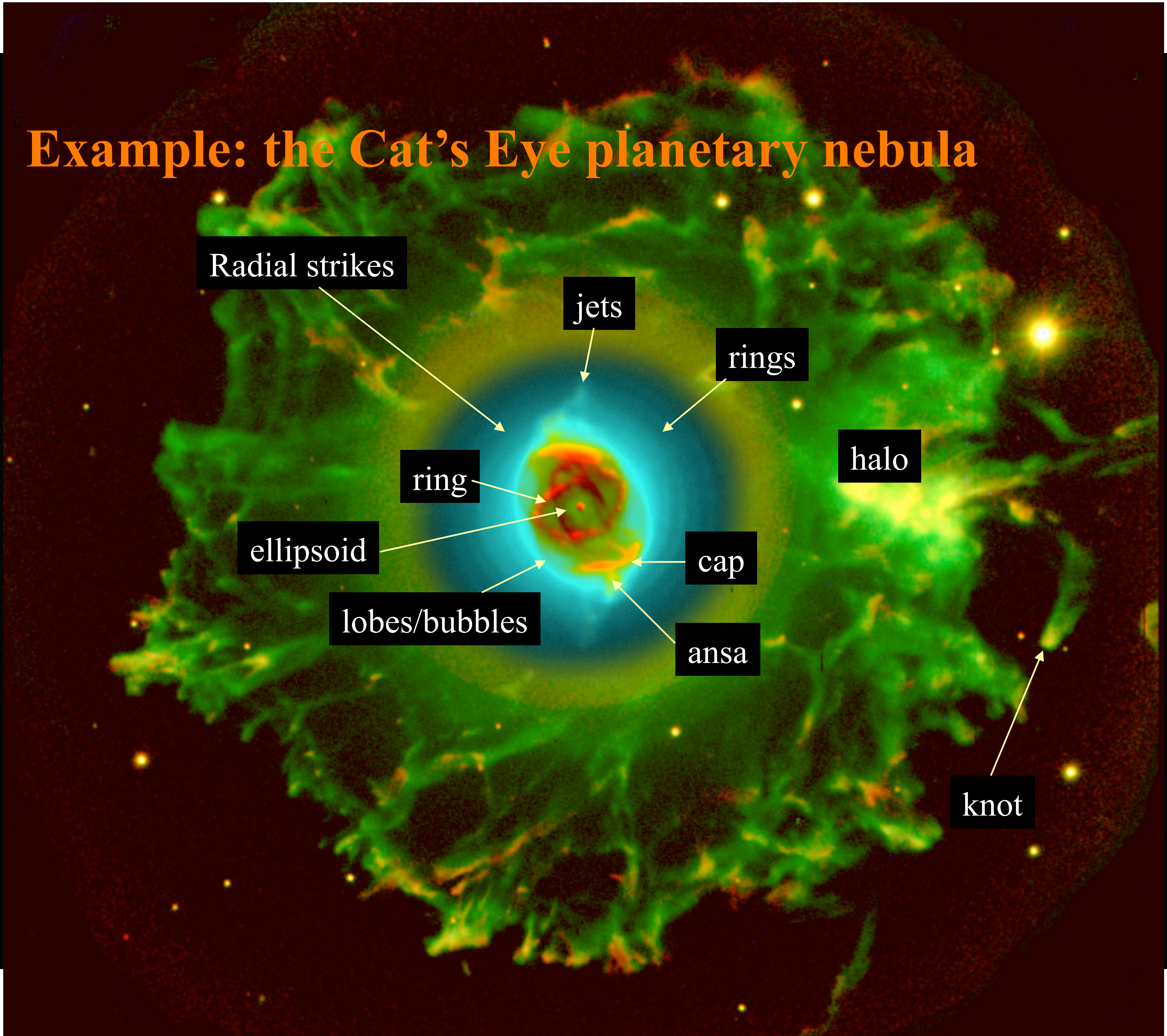
Background

- Mass loss from stars is a complex and poorly understood phenomenon
- Extraordinary variety of shapes displayed by planetary nebulae and other stellar ejecta.
- Any kind of symmetries are found at small and large scales.
- Multiple outflows seen in the same object
- Origin of this anisotropy still uncertain.
- Strong magnetic fields when the stellar envelope is lost?
- Aspherical post-common envelope ejection?
- Fast collimated winds from accretion discs?

Example: the Cat's Eye planetary nebula



Significance

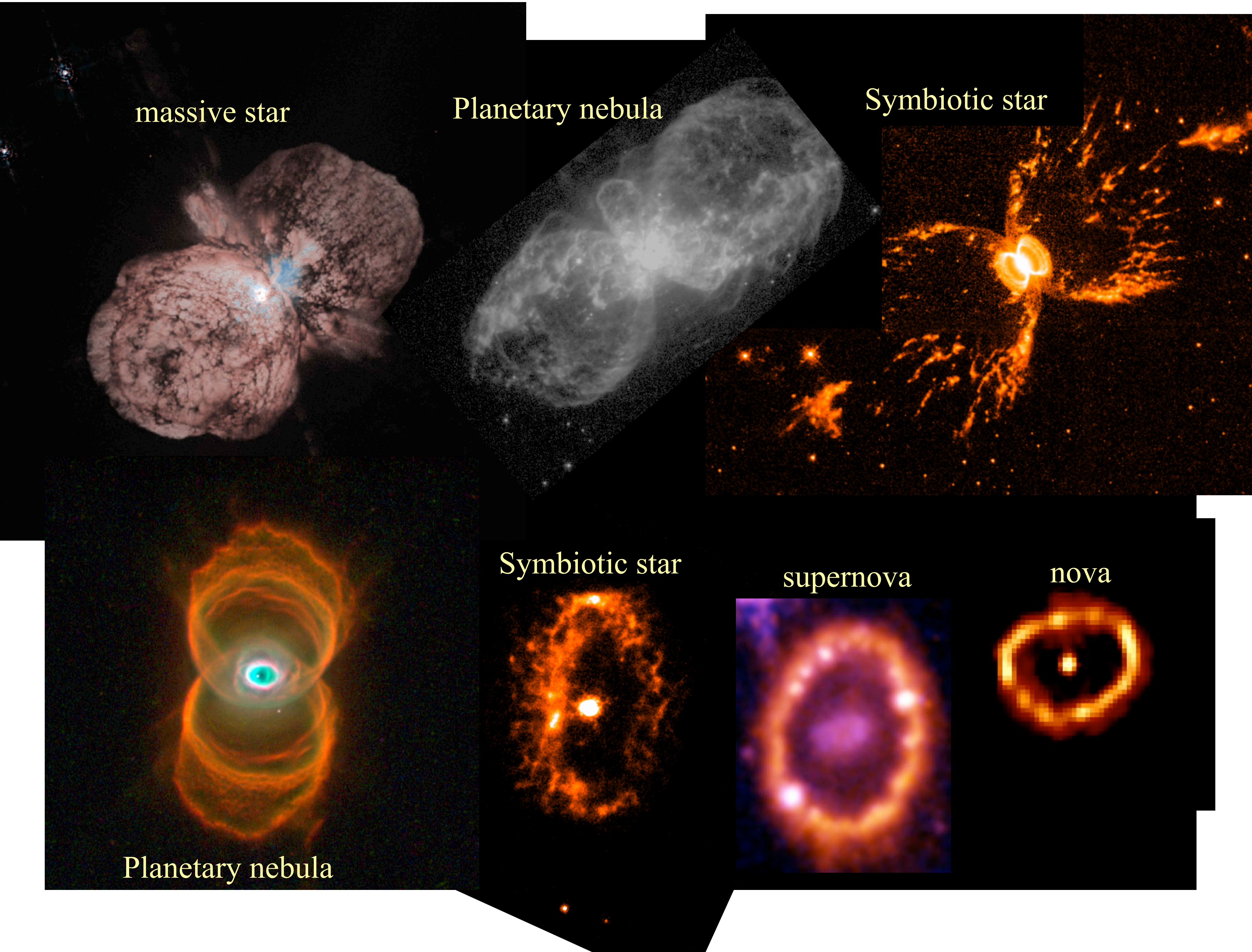
• *Trait d'union* between stellar and galactic evolution.

• Some hot questions:

1) Are the majority of planetary nebulae produced by interacting binary stars?

2) How do rotation and magnetic fields affect the surface chemical enrichment of stars?

3) Which is the origin of the most collimated outflows observed?


massive star
Planetary nebula
Symbiotic star
Planetary nebula
Symbiotic star
supernova
nova

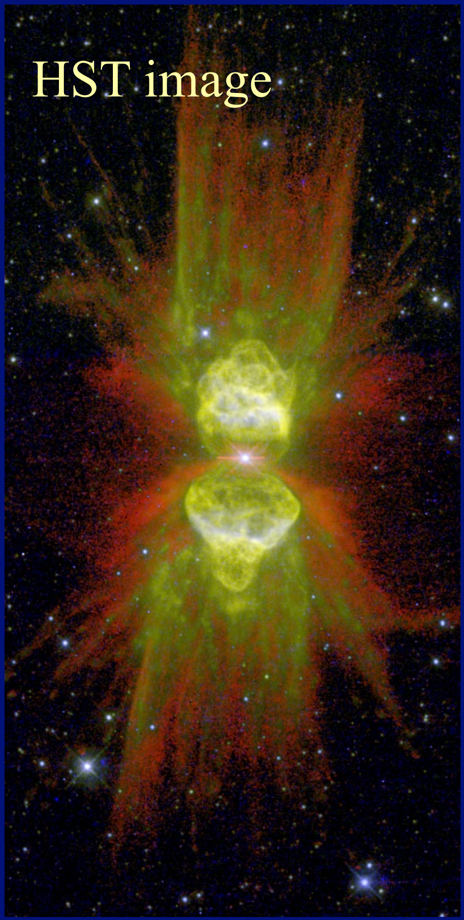
Why 3D-NTT?

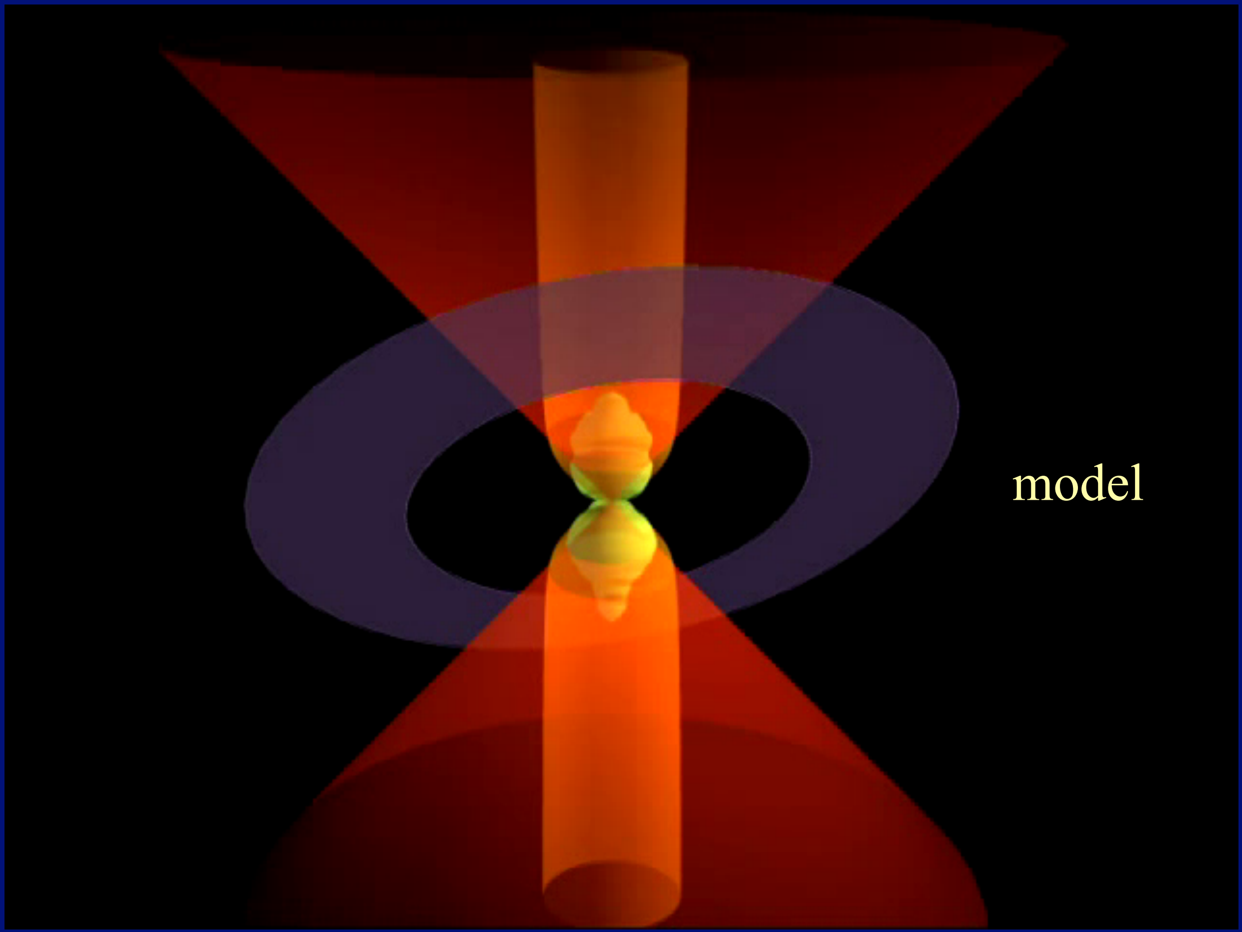
- The first step to progress in the field is to fully reveal the 3D geometry and dynamics of stellar ejecta.

- Integral-field spectro-imaging (e.g. Perot-Fabry-Perot) is the most powerful way to get information on three of the dimensions (x,y,v_{radial}) of the phase space. Ideally, one would also like to add the expansion in the plane of the sky through multi-epoch high resolution images, providing other two dimensions. The examples of the planetary nebula Mz 3 and the symbiotic nova He 2-147 follow.

Mz 3

Santander-Garcia et al. 2004 A&A 426, 185



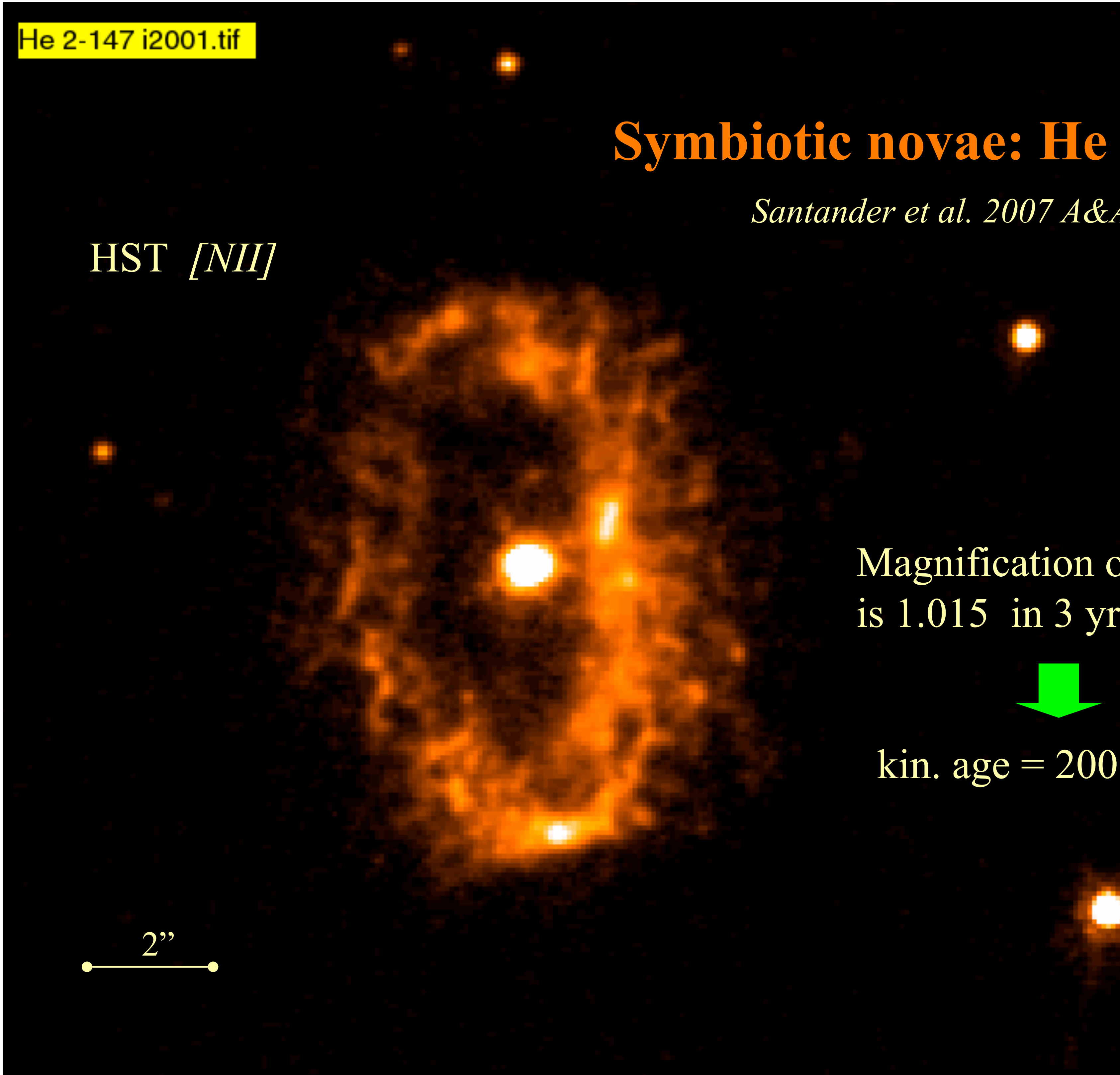


The intrinsic 3D shape and the rapid sequence of (explosive) events producing the four distinct outflows of the nebula were reconstructed by means of HST+NTT images and NTT long-slit spectra at R=50000 taken <u>at many P.A.s</u>.

3D-NTT can do it quicker and better!

Symbiotic novae: He 2-147

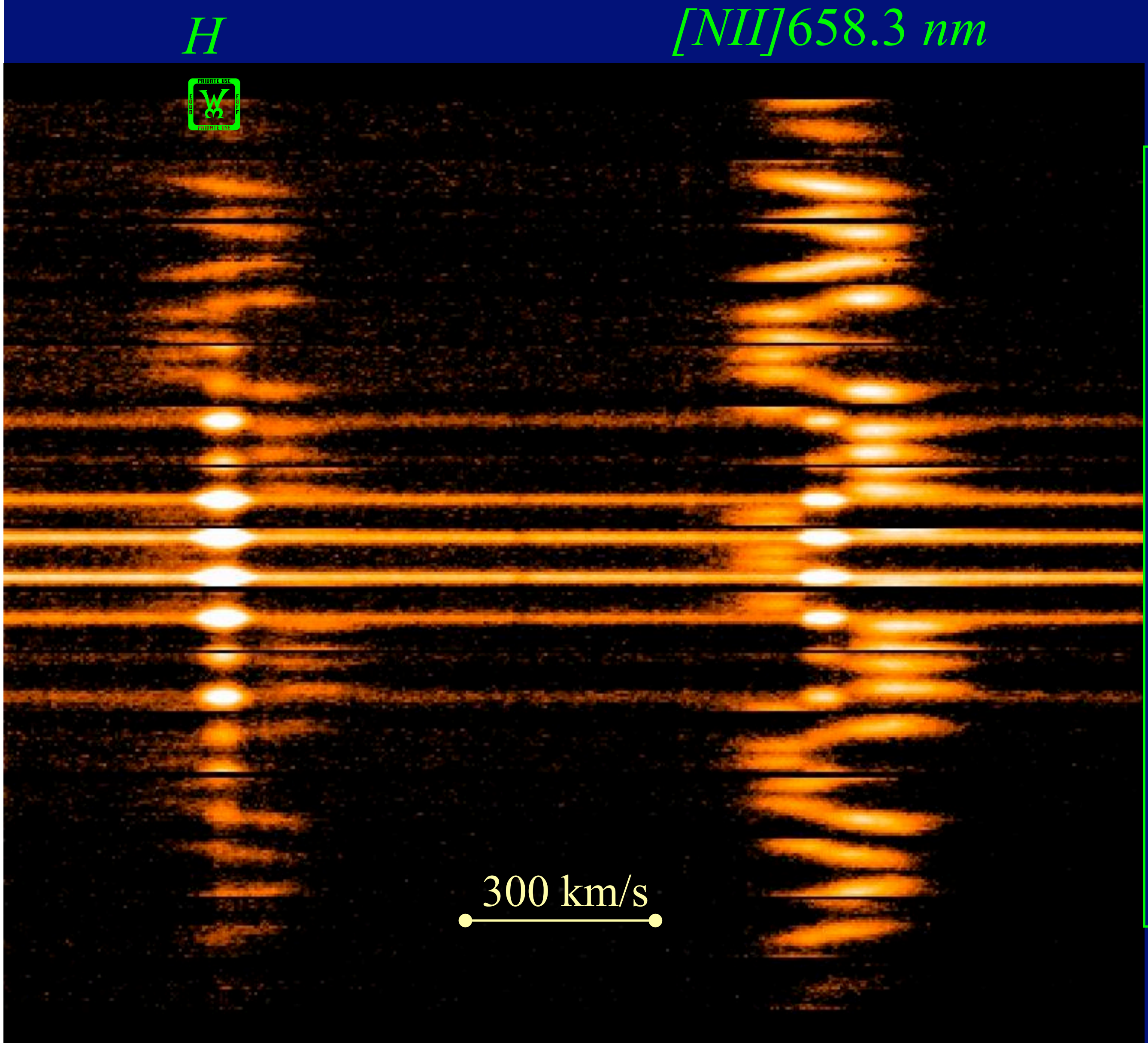
Santander et al. 2007 A&A 465 481



Magnification of nebula is 1.015 in 3 yr

kin. age = 200 yr

Symbiotic novae: He 2-147



VLT+FLAMES

Argus IFU:

300 fibres (0”.3)

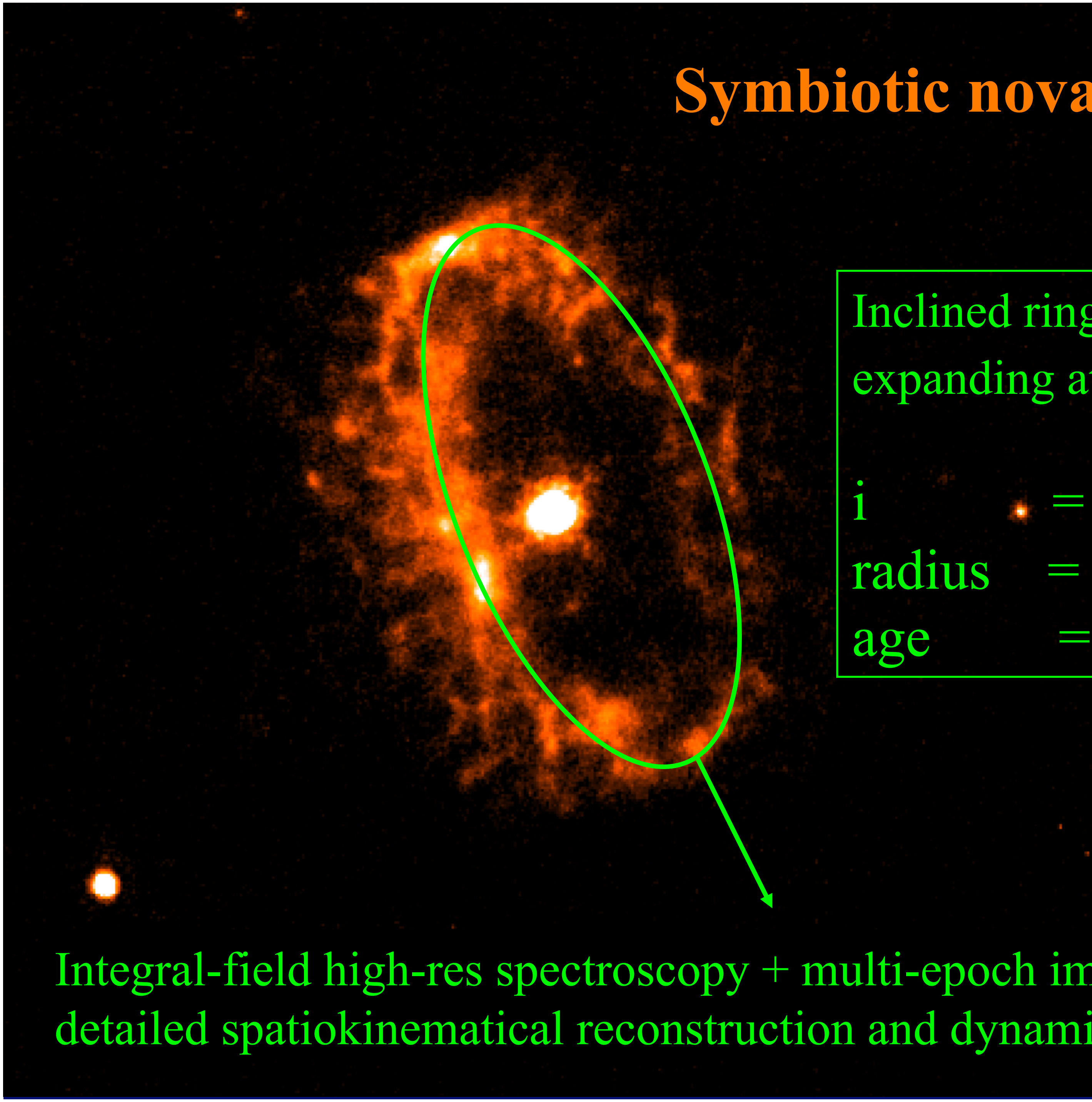
f.o.v. 6”.6 x 4”.2

seeing 0”.65

R=25000

10 min exposure

Symbiotic novae: He 2-147



Inclined ring of shocked gas expanding at 100 km s-1

i = 55^{o}

radius = 5000 a.u.

age = 200 yr

Integral-field high-res spectroscopy + multi-epoch images → detailed spatiokinematical reconstruction and dynamical modelling

Targets → instrument requirements

[OIII]500.7 nm and [NII]658.3 nm and Halpha

The resolution and FSR depend on the expansion velocity of the targets. It is mandatory to resolve the different (>=2) components along the line of sight in a significant fraction of the nebula. The Table on next slide provides a summary of this requirement.

Adequate software to measure the multiple components of the velocity profiles at each pixel needed.

Spatially resolved physico-chemical studies can be instead done with the Tunable Filter mode

Targets and spectral resolution/FSR (typical figures):

Type	$V_{expansion}$ [km s^{-1}]	R needed	FSR needed	Feasible with 3D-NTT?
Classical PNe	10-50	30000	120	**Yes**
Bipolar PNe, outflows/jets from symbiotic stars and similar objects	30-300	15000	600	**Yes**
Classical novae	500-1500	5000	3000	**?**
LBV outflows	20-700	30000	1500	**?**