Pleasantness Review*

Department of Physics, Technion, Israel

The role of jets: from common envelope to nebulae

Nice 2015

Noam Soker

Essential collaborators (Technion): Amit Kashi, Muhammad Akashi, Ealeal Bear, Oded Papish, Danny Tsebrenko, Avishai Gilkis, Efrat Sabach, Sagiv Shiber, Ron Schreier

•Dictionary translation of my name from Hebrew to English (real!):
Noam = Pleasantness
Soker = Review

Short Summary

JETS

This research was not supported by any grant

Summary: Issues in dispute

Issue / Process	Most others	My view which is	
Common envelope α_{CE} parameter	Parameter commonly used		
Grazing envelope evolution (GEE) NEW	Never heard about this NEW	T	
Supernova Ia Remnants	Four different other scenarios		
Core-collapse supernovae	By neutrinos		

Summary: Issues in dispute

Issue / Process	Most others	My view which is	strongly supported by
Common envelope α_{CE} parameter	Parameter commonly used	**Problematic.** **Instead use Jets and migration** **(but no jets for WDs !!)**	
Grazing envelope evolution (GEE) NEW	Never heard about this NEW	**Takes place in many cases**	
Supernova Ia Remnants	Four different other scenarios	The **core degenerate** scenario: SNIP (Danny Tsebrenko)	
Core-collapse supernovae	By neutrinos	**Neutrino mechanisms have a generic problem.** **Explosion by jets**	

Summary: Issues in dispute

Issue / Process	Most others	My view which is	strongly supported by
Common envelope α_{CE} parameter	Parameter commonly used	**Problematic.** **Instead use Jets and migration** **(but no jets for WDs !!)**	my wife and three kids
Grazing envelope evolution (GEE) NEW	Never heard about this NEW	**Takes place in many cases**	**Orsola de Marco** **(but she doesn't know it yet)**
Supernova Ia Remnants	Four different other scenarios	The **core degenerate** scenario: SNIP (Danny Tsebrenko)	my psychiatrist
Core-collapse supernovae	By neutrinos	**Neutrino mechanisms have a generic problem.** **Explosion by jets**	The clerk in charge of early retirement in the Technion.

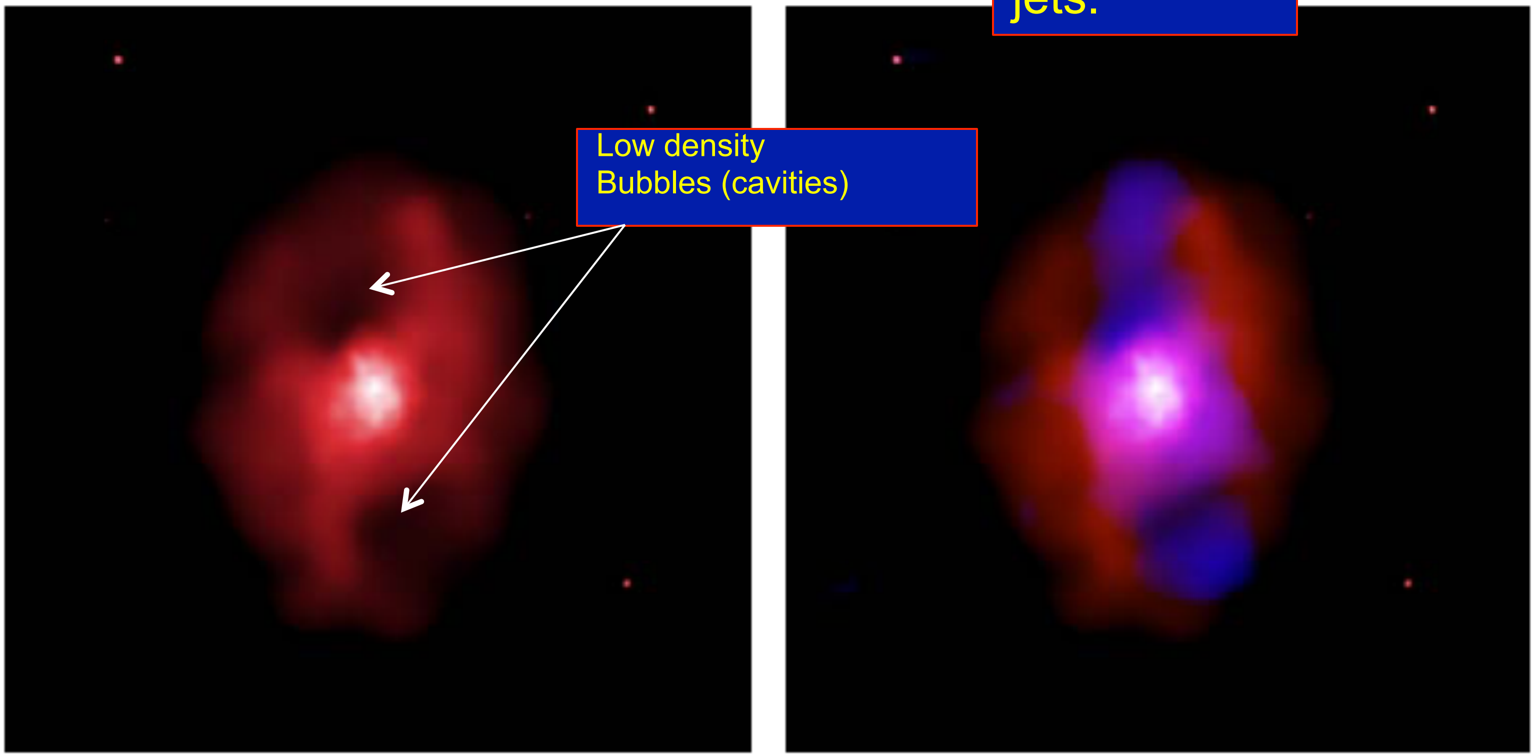
Pleasantness Review:

The role of jets:
from common envelope to nebulae

(1) **What we see**
(2) What we see and simulate
(3) What we simulate but don’t see
(4) What we don’t see and did not simulate yet.

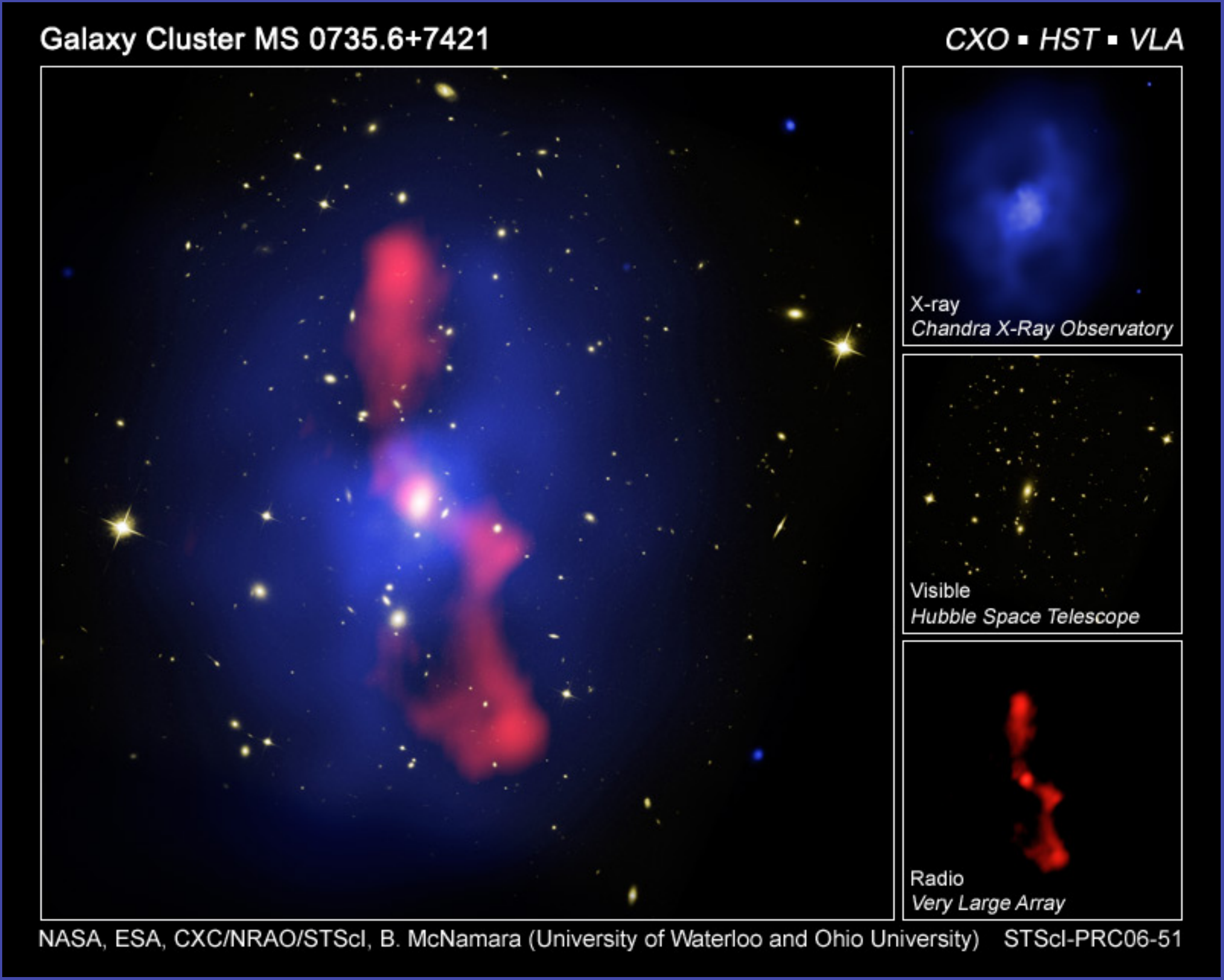
Red: X-ray

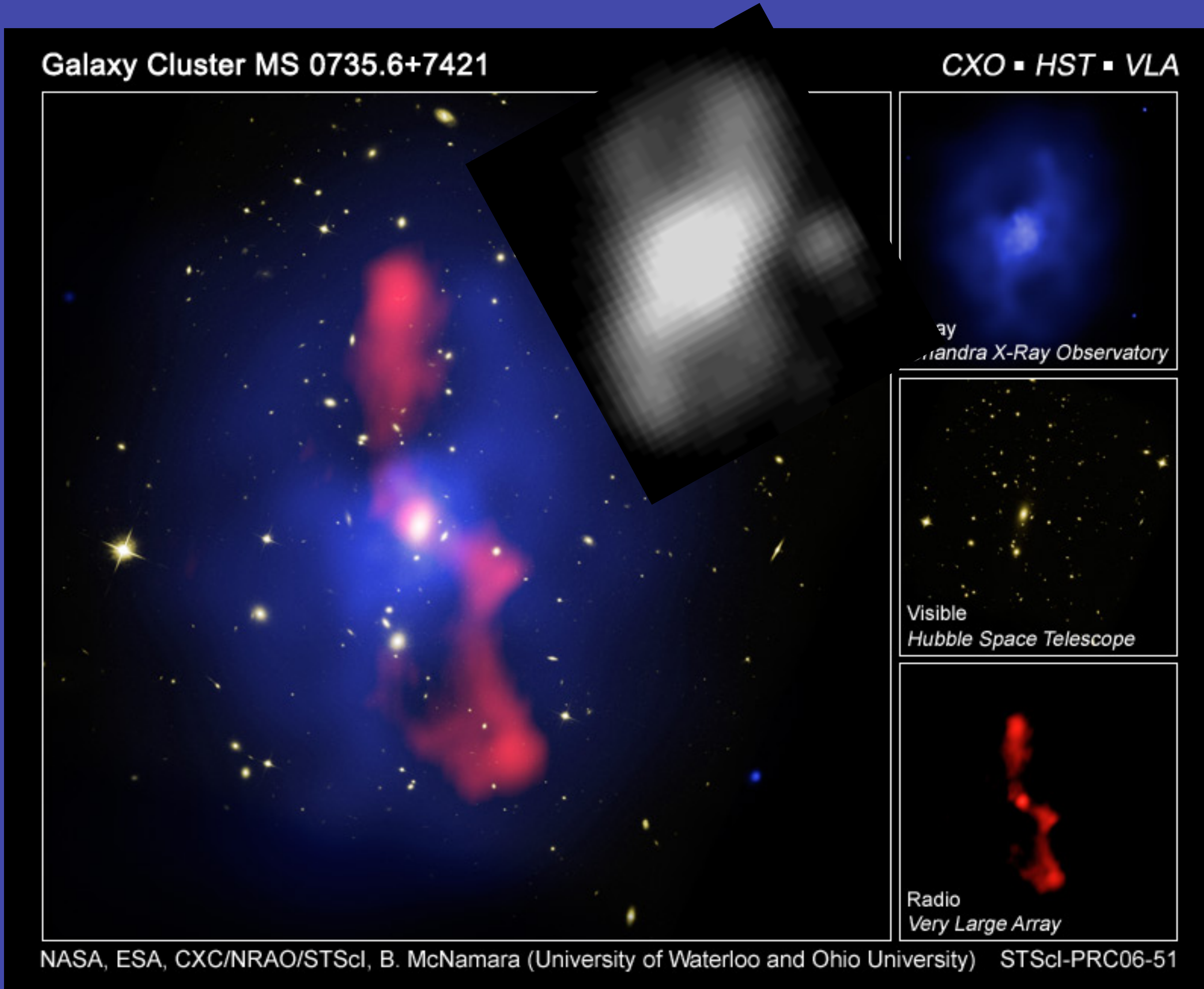
Blue: radio implying jets.



The galaxy cluster MS 0735.6+7421: An X-ray image (red), and the radio image (blue) added in the right panel (From Brian McNamara and collaborators). The edge-to-edge linear scale is about one million light year.

(McNamara, B. and collaborators)


Galaxy Cluster MS 0735.6+7421
CXO ▪ HST ▪ VLA
X-ray
Chandra X-Ray Observatory
Visible
Hubble Space Telescope
Radio
Very Large Array
NASA, ESA, CXC/NRAO/STScI, B. McNamara (University of Waterloo and Ohio University)
STScI-PRC06-51



Galaxy Cluster MS 0735.6+7421
CXO ▪ HST ▪ VLA
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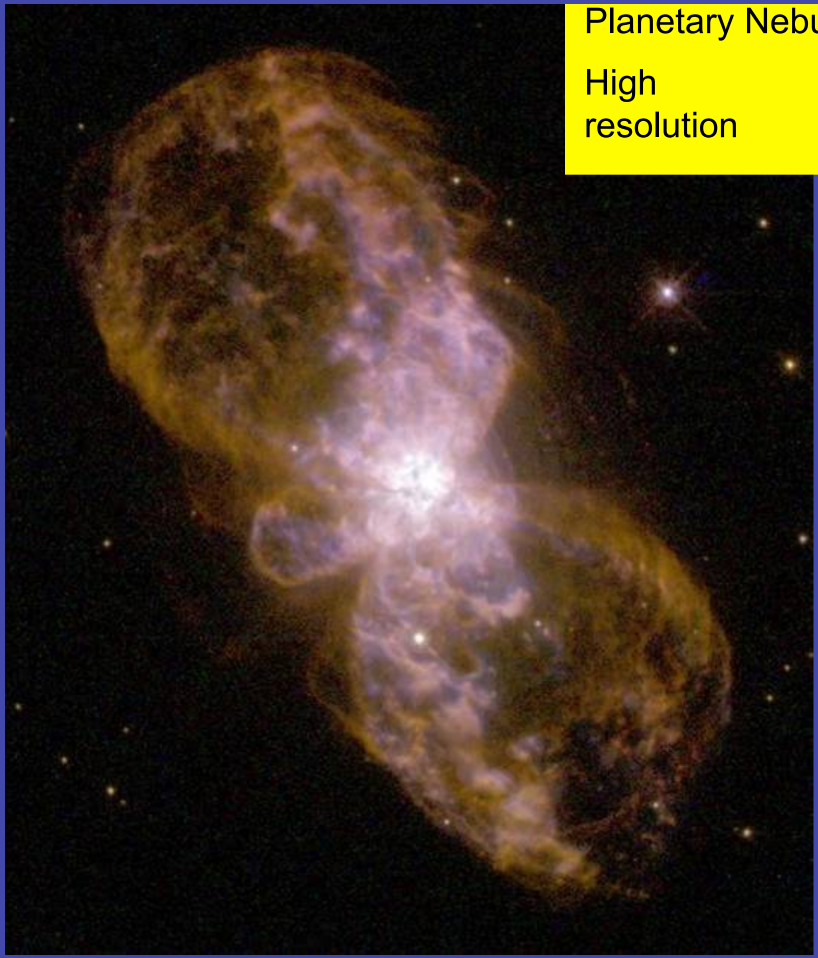
STScI-PRC06-51

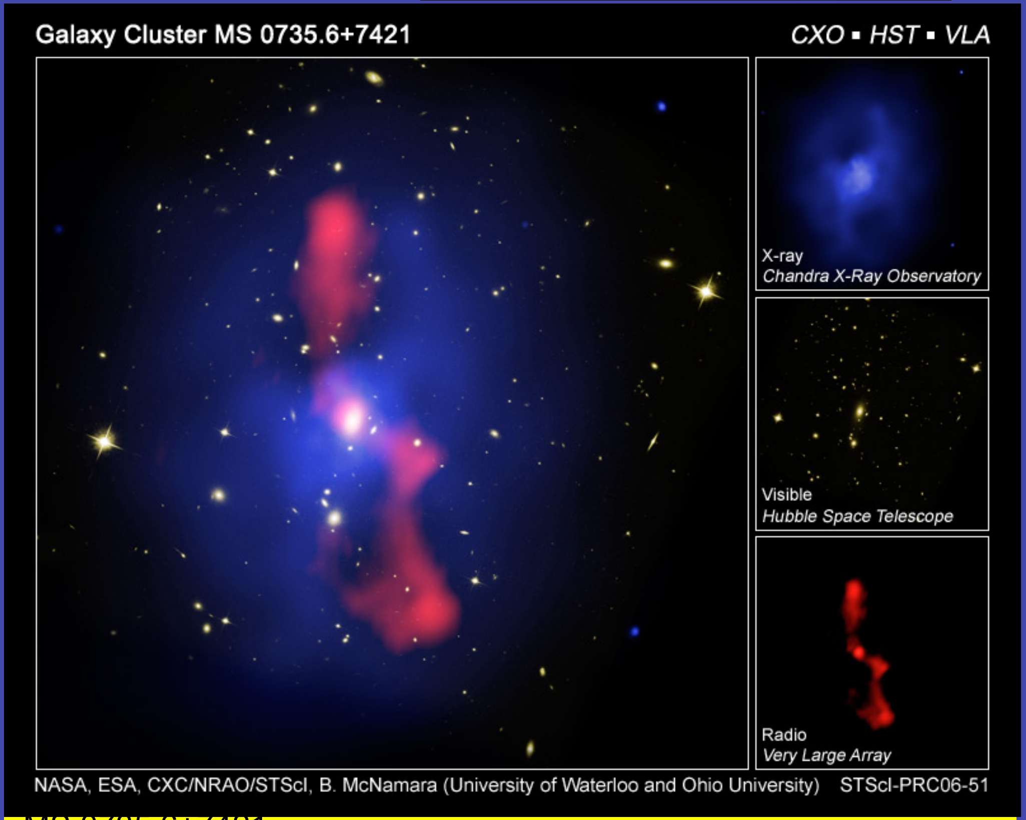
Planetary Nebula Hb 5:

High resolution

Low resolution



Shaping by jets



MS 0735.6+7421

A cluster of galaxies

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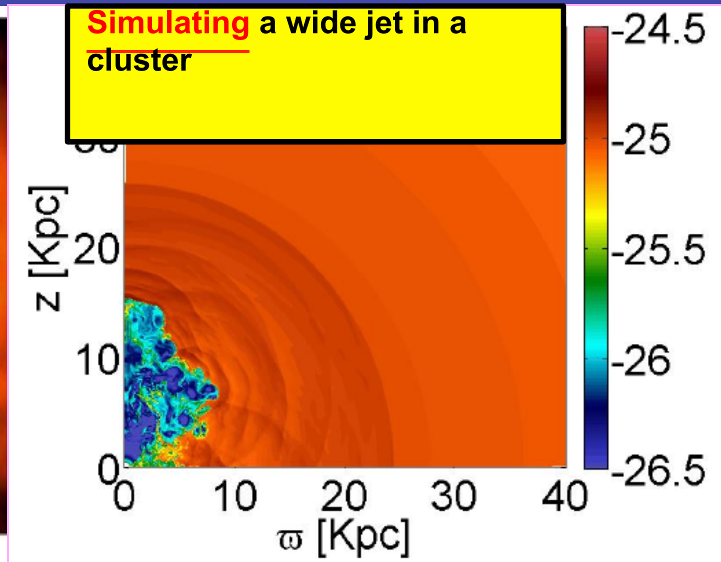
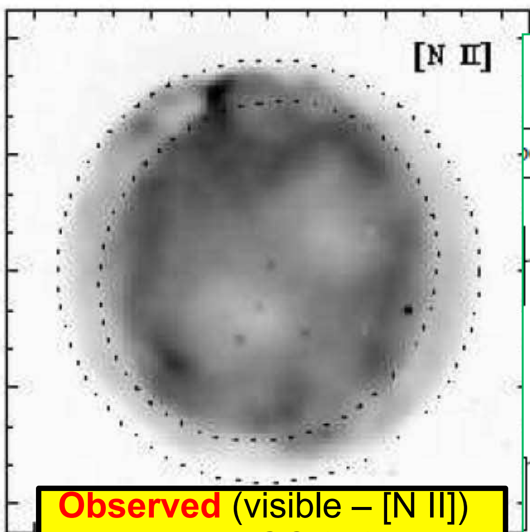
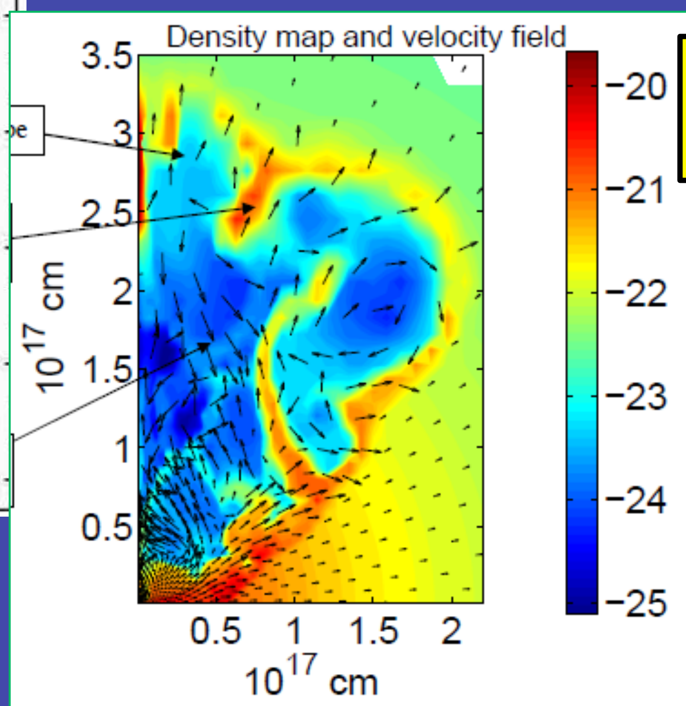
Observed (X-ray) bubbles in the Perseus cluster of galaxies

Simulating a wide jet in a cluster





Observed (visible – [N II]) bubbles in NGC 3587



Simulating bubble formation in planetary nebulae (Akashi & Soker 2012)

6 orders of magnitude difference in size

12-15 orders of magnitude difference in mass an energy

The Necklace planetary nebula (Form Romano Corradi et al. 2011):

A binary central star with P=1.16 days.

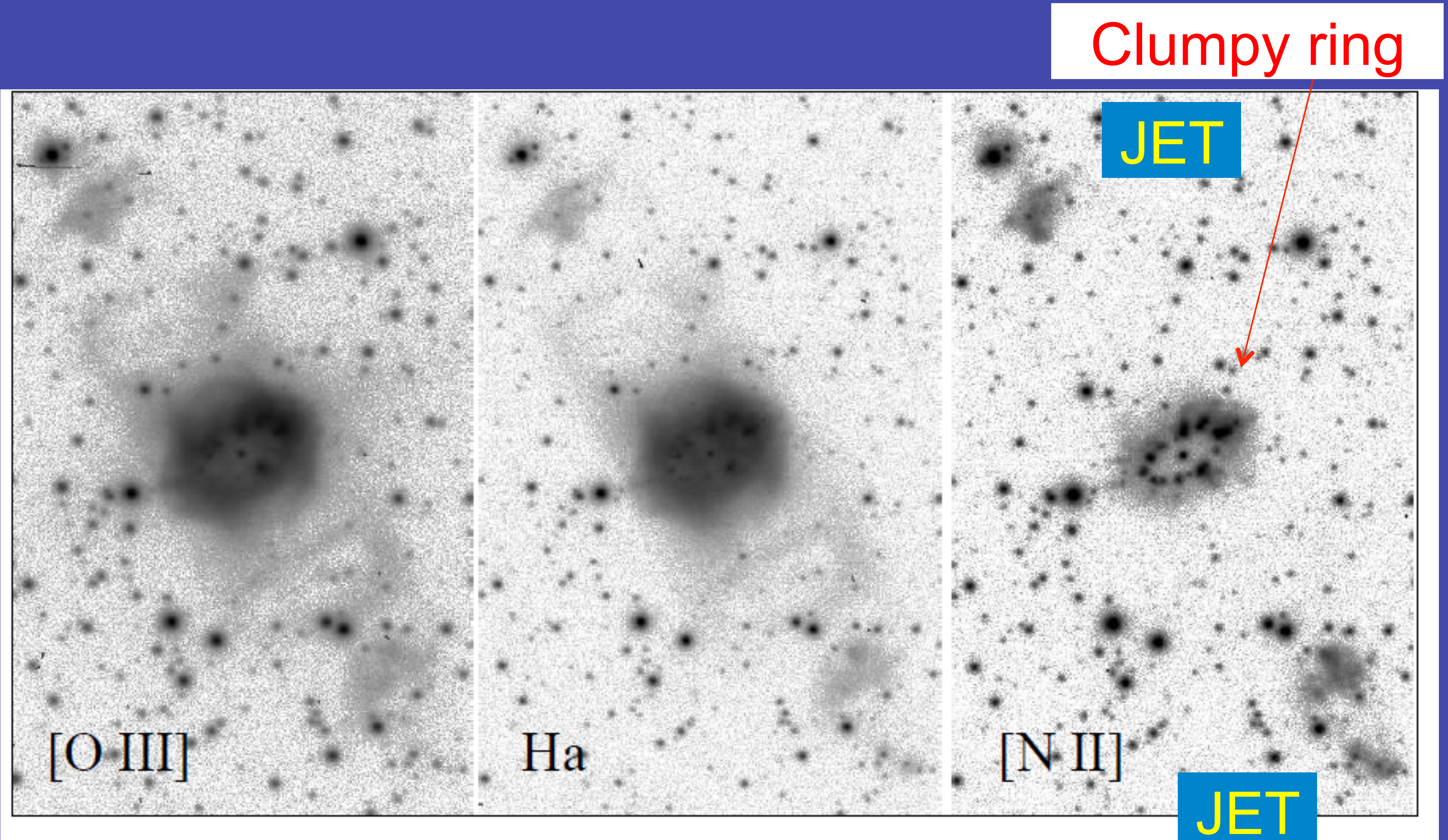


Figure 1. The NOT images of IPHASXJ194359.5+170901 in a log intensity scale. The field of view is 70″×110″ in each frame. North is up and East is left.

An equatorial dense and clumpy ring

Necklace Planetary nebula

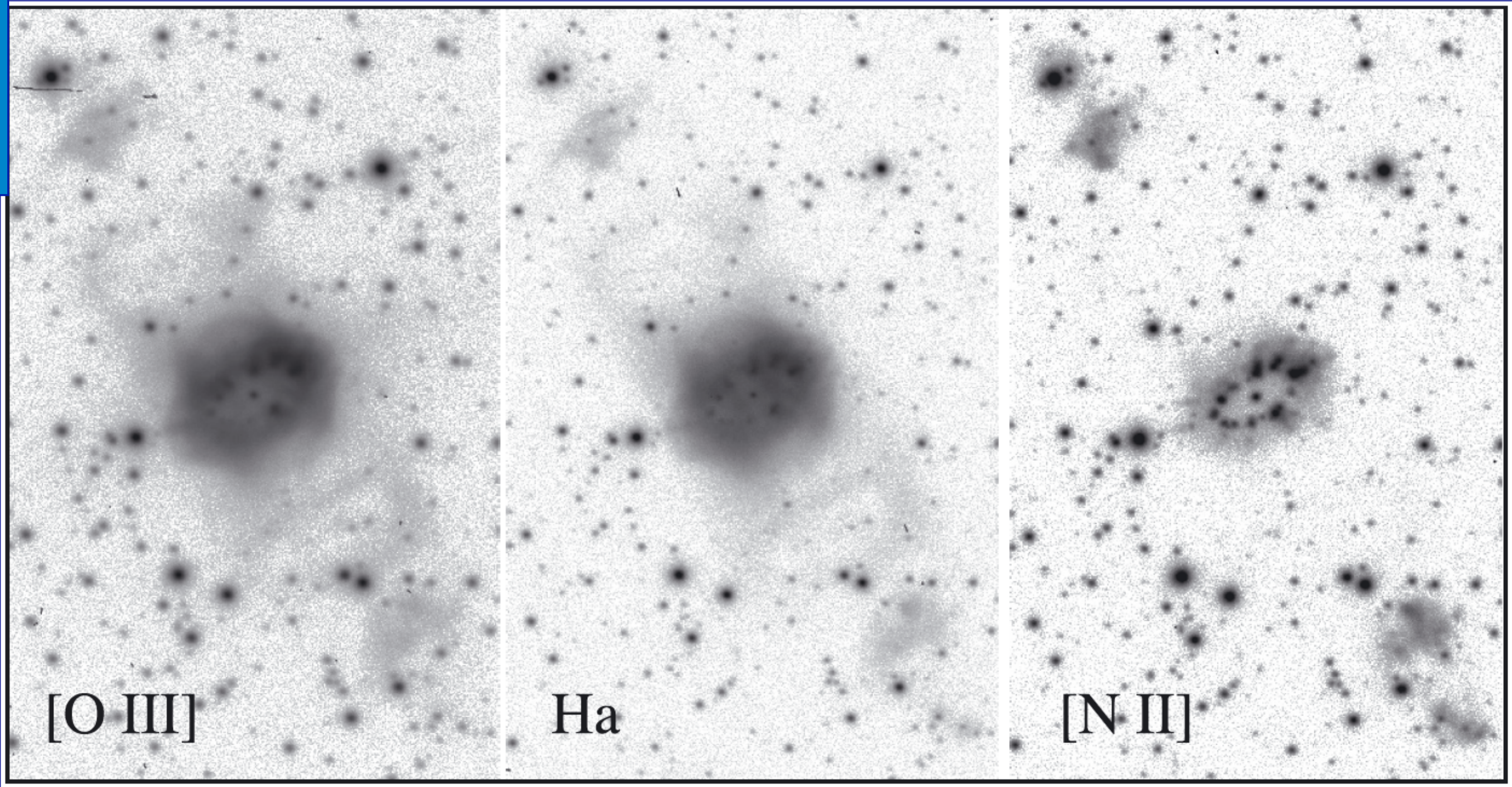
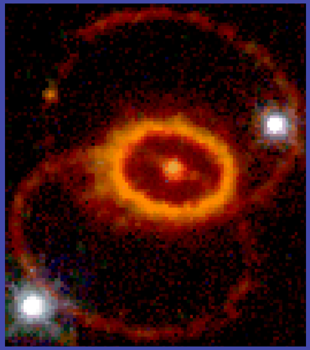
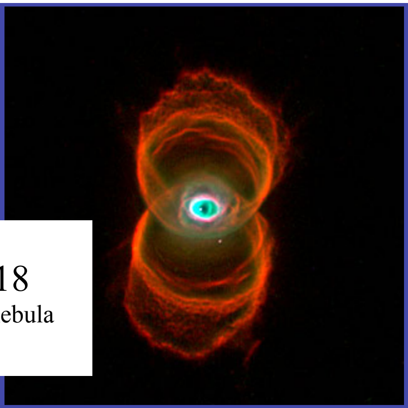


Figure 1. The NOT images of IPHASX J194359.5+170901 in a log intensity scale. The field of view is 70 × 110 arcsec^2 in each frame. North is up and east is left.

SN 1987A
Supernova remnant

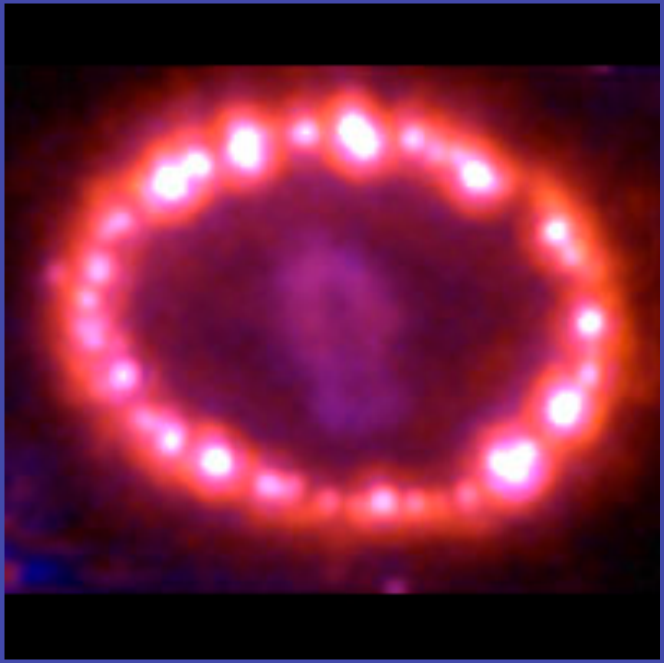




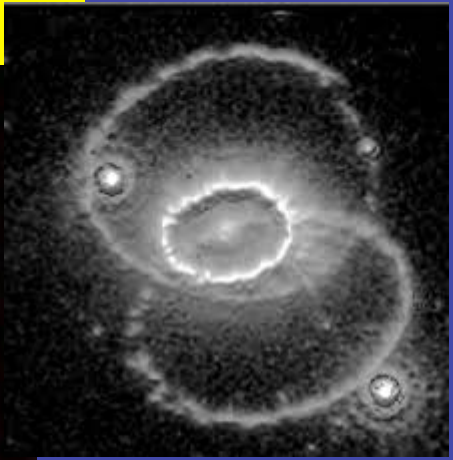
MyCn 18
Planetary nebula

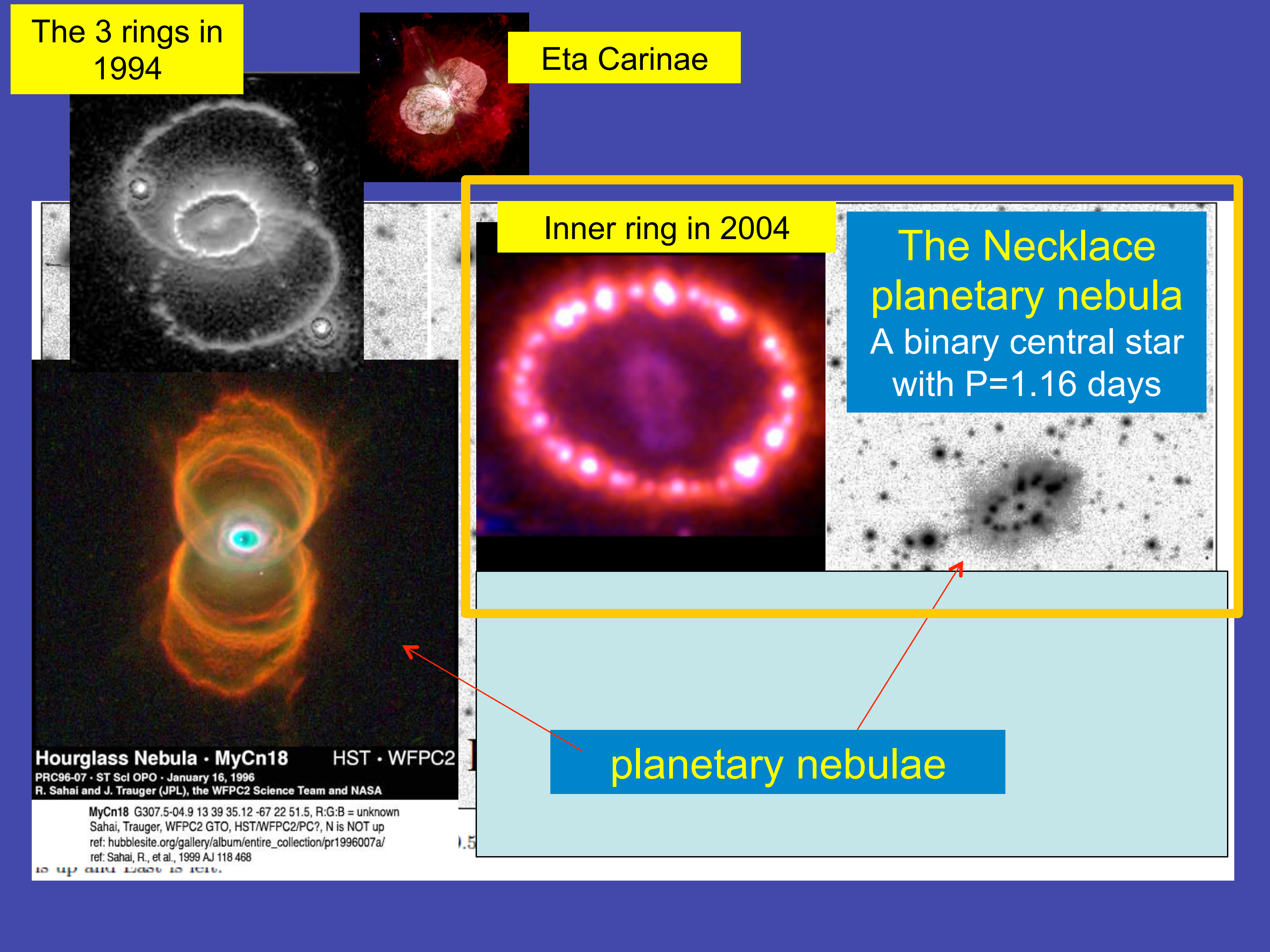
Supernova 1987A evolution (Philipp Podsiadlowski et al.) and the rings (Soker et al.) require binary merger.

Inner ring in 2004 (HST)



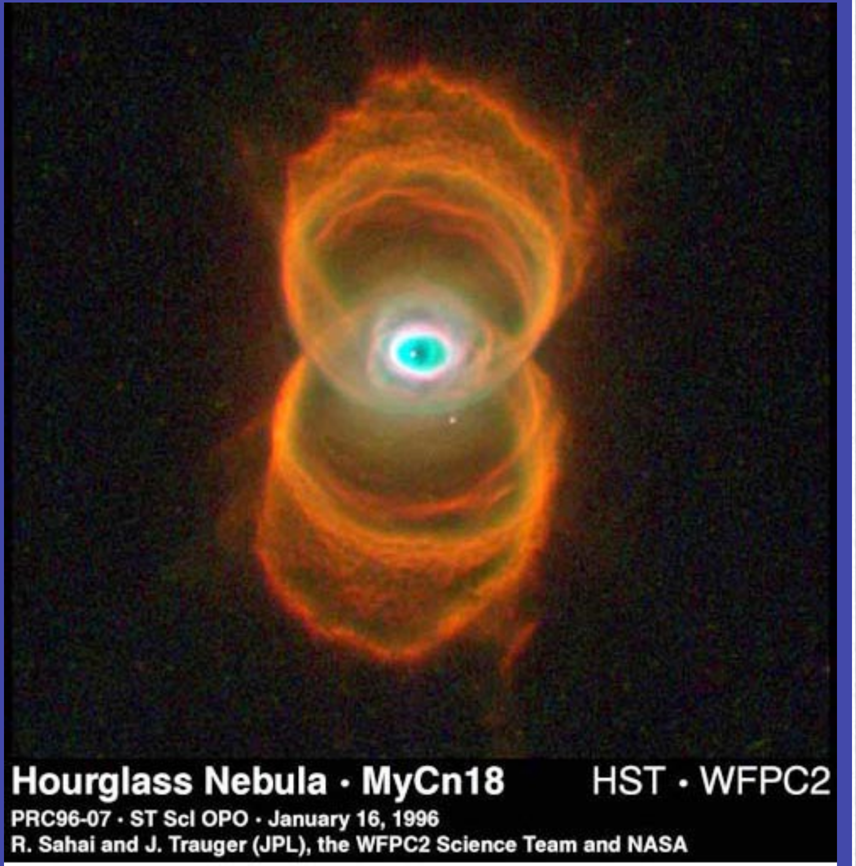
The 3 rings in 1994 (HST)





The 3 rings in 1994
Eta Carinae
Inner ring in 2004
The Necklace planetary nebula
A binary central star with P=1.16 days
Hourglass Nebula · MyCn18
HST · WFPC2
PRC96-07 · ST ScI OPO · January 16, 1996
R. Sahai and J. Trauger (JPL), the WFPC2 Science Team and NASA
MyCn18 G307.5-04.9 13 39 35.12 -67 22 51.5, R:G:B = unknown
Sahai, Trauger, WFPC2 GTO, HST/WFPC2/PC?, N is NOT up
ref: hubblesite.org/gallery/album/entire_collection/pr1996007a/
ref: Sahai, R., et al., 1999 AJ 118 468
planetary nebulae

MyCn18 planetary nebula (Form Sahai et al and O'Connor et al.).



MyCn18 G307.5-04.9 13 39 35.12 -67 22 51.5, R:G:B = unknown
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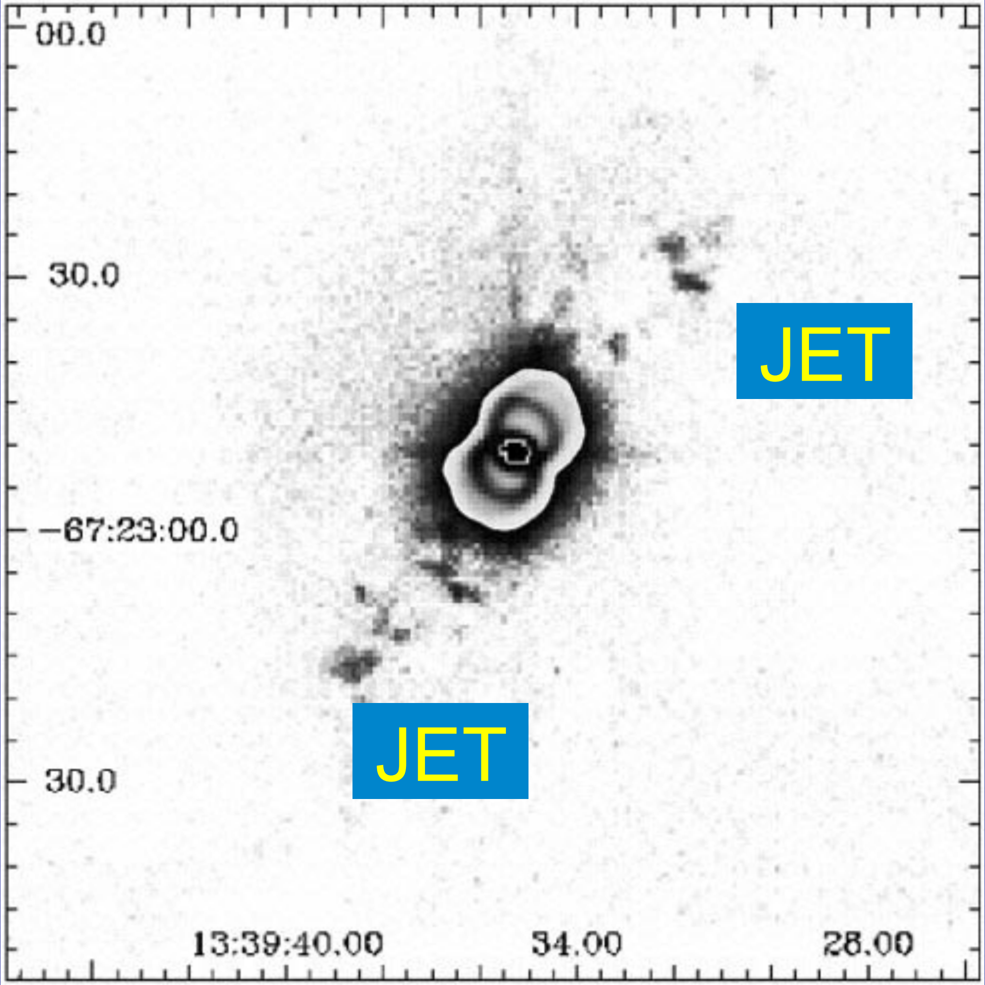


MyCn 18 G307.5-04.9 13 39 35.12 -67 22 51.5 Ha + [NII]
Ref: O'Connor, J.A., Redman, R.P., Holloway, A.J, Bryce, M., Lopez, J.A. & Meaburn, J. 2000, ApJ, 531, 336

(Form David Jones et al. 2015, Last Friday)

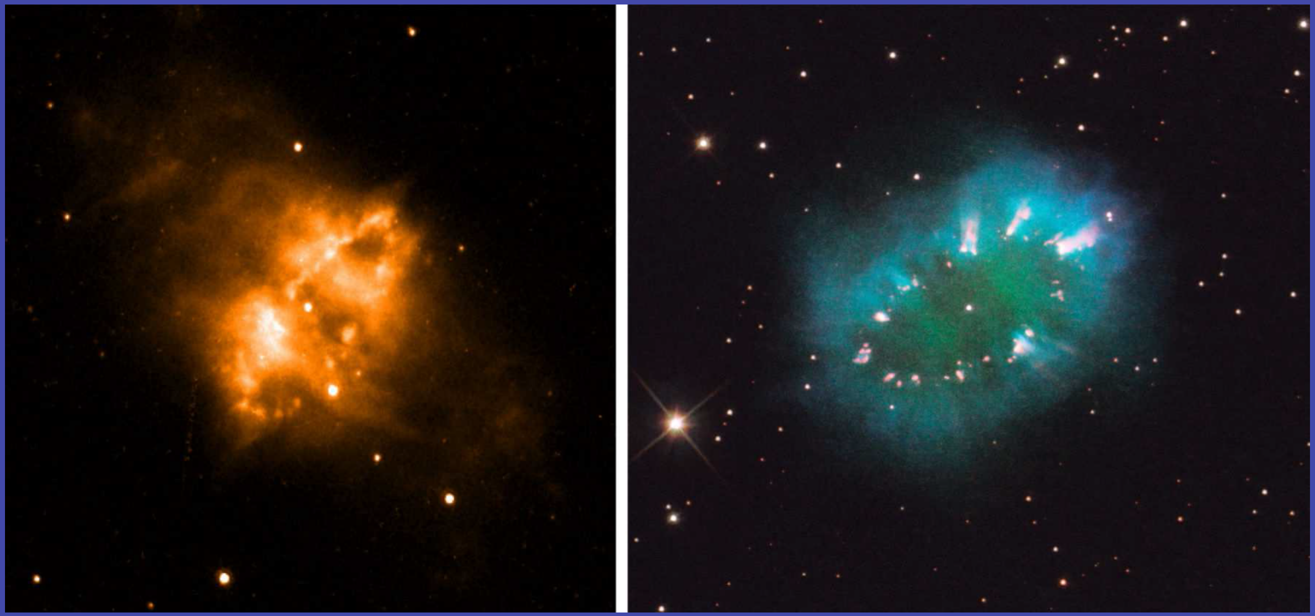
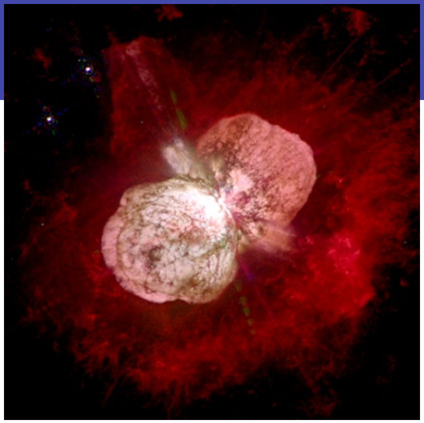
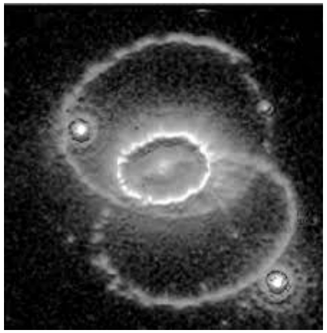


Fig. 2. HST images of Hen 2-161 (left, see also Sahai et al. 2011) and The Necklace (right; Corradi et al. 2011) highlighting their
remarkably similar appearances (elongated with knotty waists).

* The outer rings of 1987A and Eta Carinae were shaped by jets.





A main sequence companion accretes mass and launches opposite jets (in some planetary nebulae and in symbiotic nebulae the companion is a WD)

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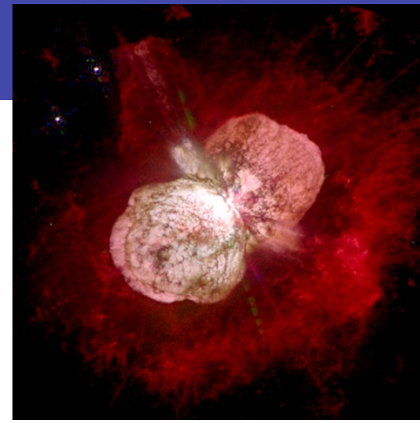
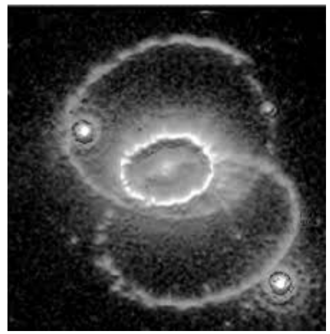
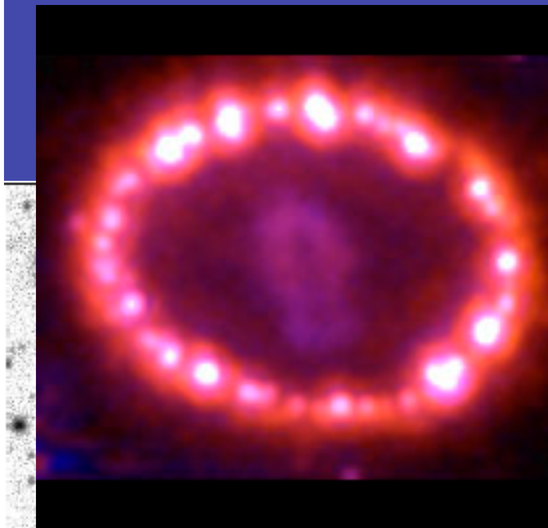


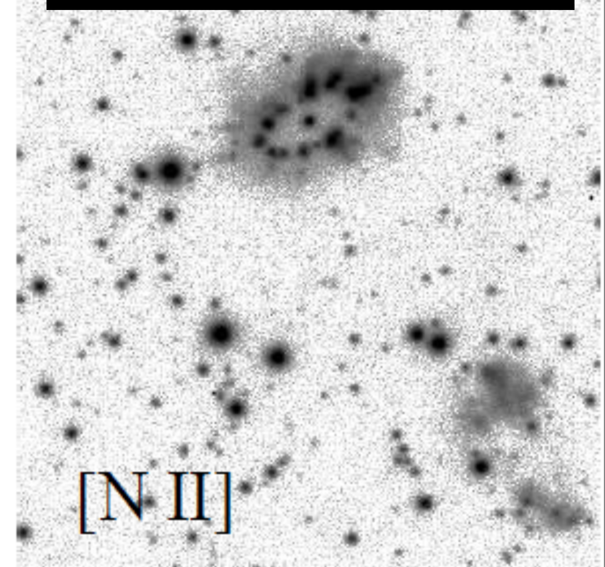


* Inner ring:

<u>Our proposal:</u>

Such rings are formed in a synchronized systems (companion outside the envelope), but during a <u>Darwin unstable</u> phase.





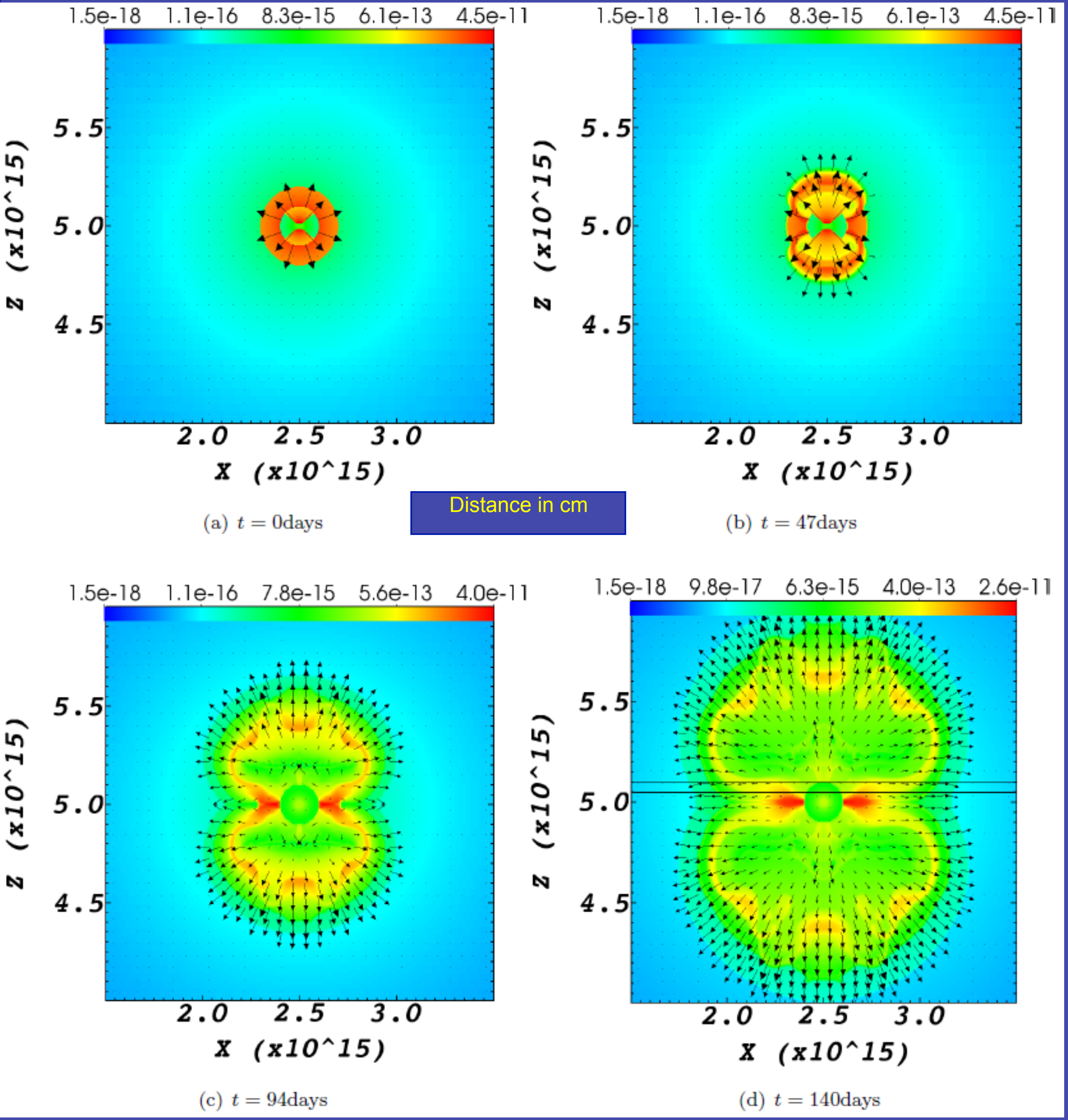
eld of view is 70″×110″ in each frame. North

New results of Full 3D simulations of jets. (Muhammad Akashi et al. , 2015).

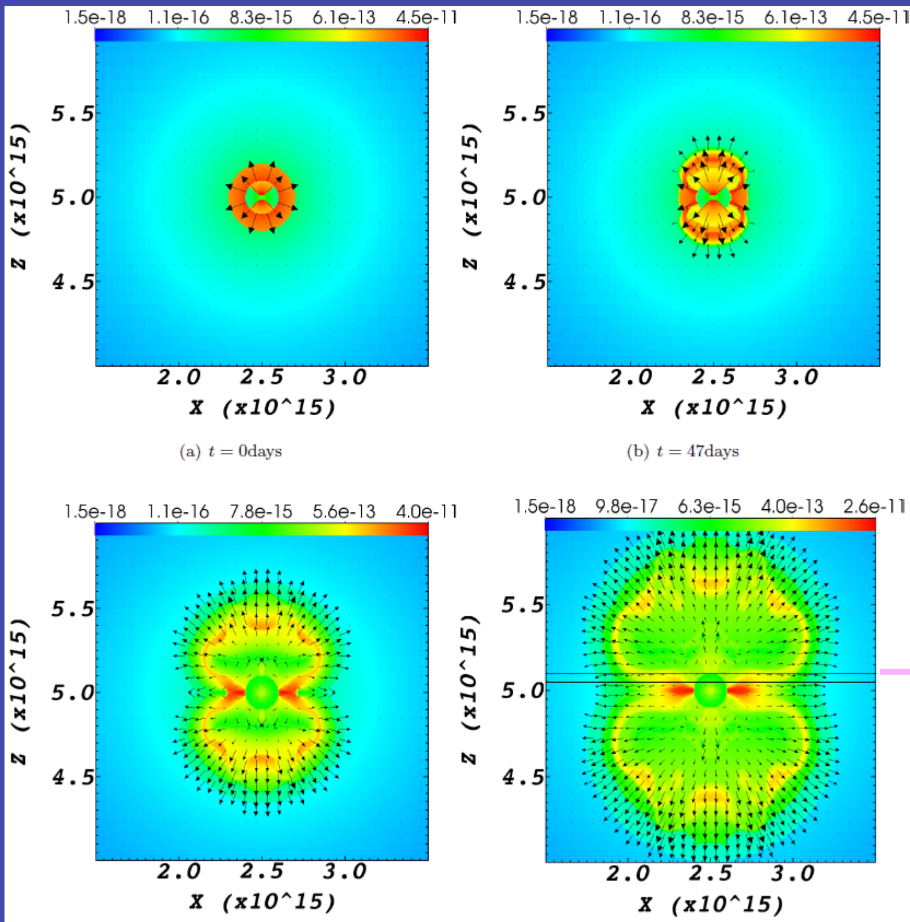
Spherical slow wind + wide jets (half opening angle of 50 degrees). Jet speed 1000 km/s.

The interaction takes place very close to the binary system, when photons have no time to diffuse out.

It is not the regular momentum or energy conserving cases.

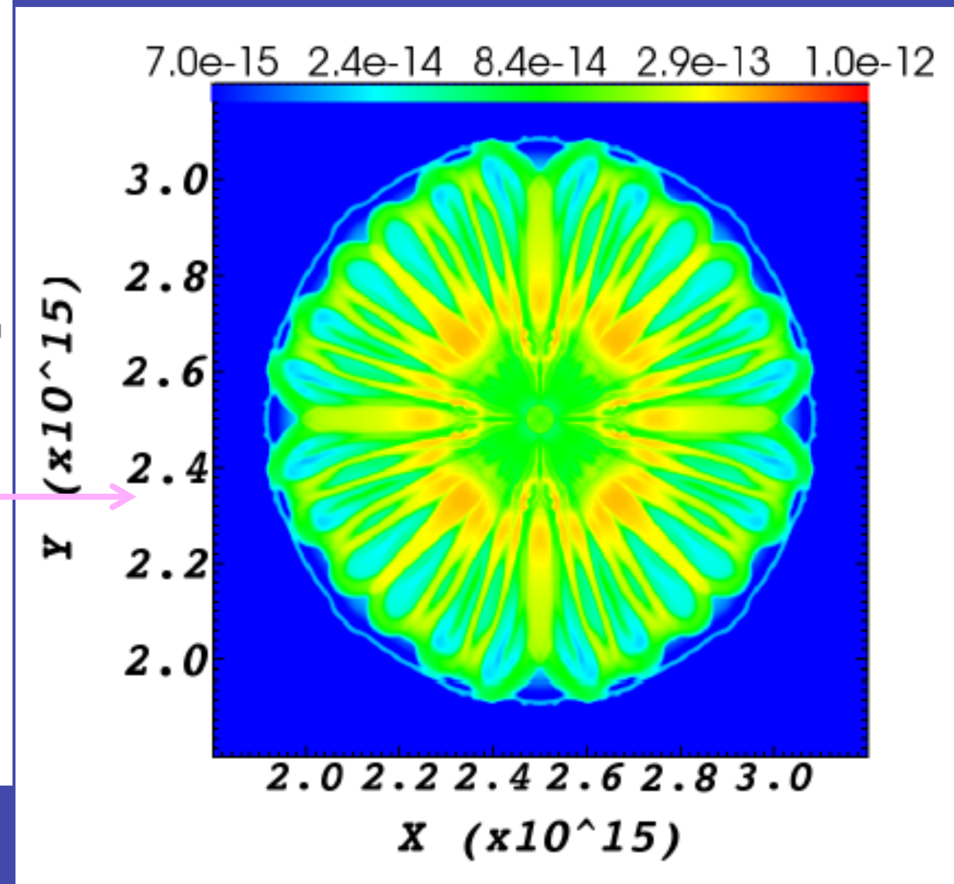


Instabilities in the plane will lead to the formation of clumps



(a) $t = 0$days (b) $t = 47$days

(c) $t = 94$days (d) $t = 140$days



(d) $t = 140$days

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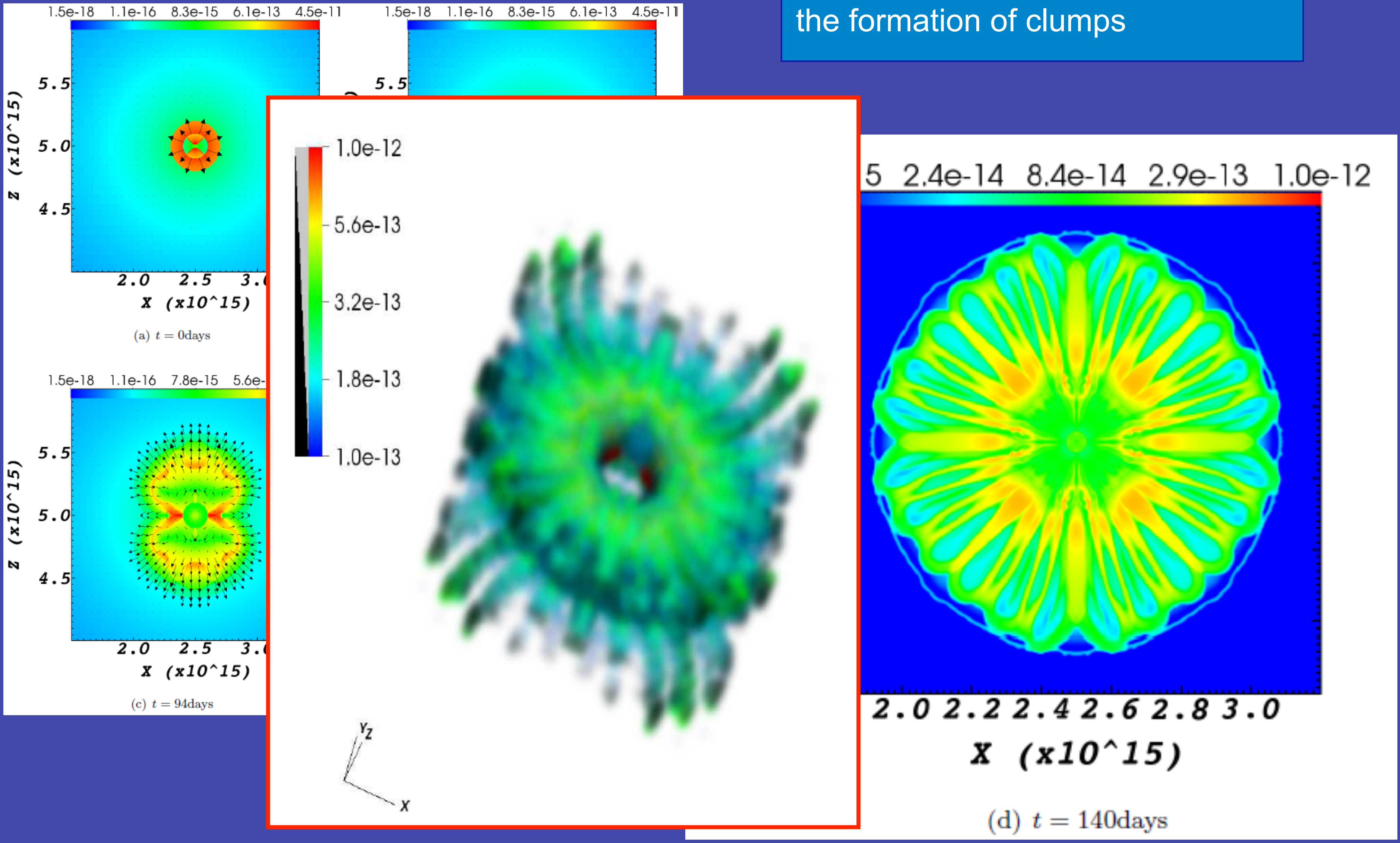
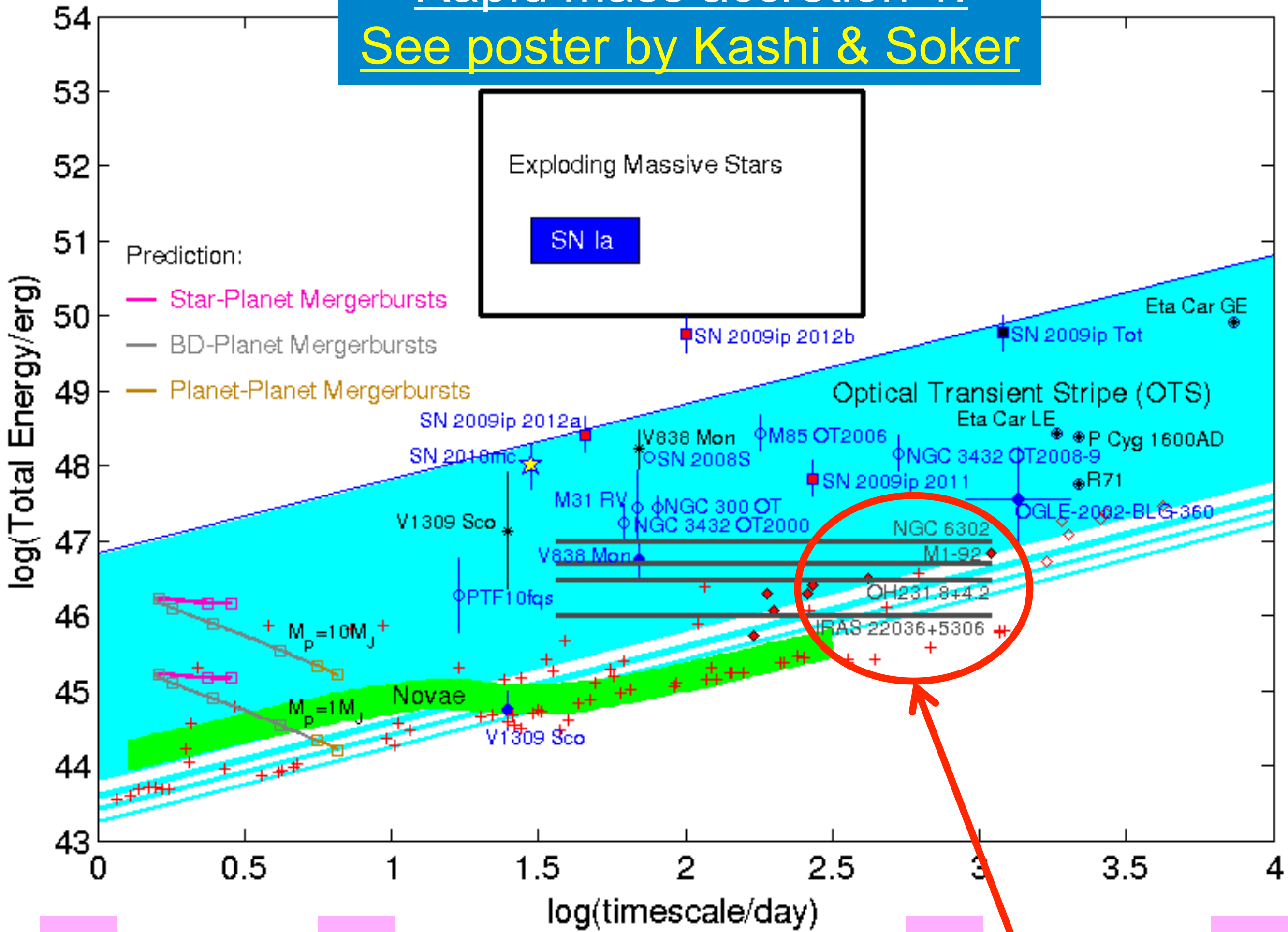


Rapid mass accretion 1: See poster by Kashi & Soker

Total (Kinetic +radiation) log(E/erg)



0 **1** **3** **4**

Log(time/day)

Suggestion (Soker & Kashi 2012):
Some bipolar planetary nebulae and pre-PNe were formed by ILOTs.

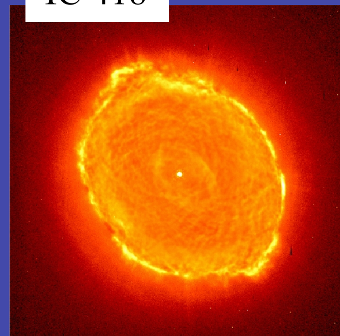
Rapid mass accretion 2:

Jones, Boffin, Rodriguez-Gil, Wesson, Corradi, Miszalski, & Mohamed
(June 2015)
support the claim of rapid accretion as suggested by the jet-feedback mechanism:
" . . . all main-sequence companions, of planetary nebulae . . . display this [envelope] “inflation”. . . . Probably related to rapid accretion, immediately before the recent common-envelope phase, . . "

Other Objects shaped by jets. Note Type Ia Supernova Remnants

MyCn 18

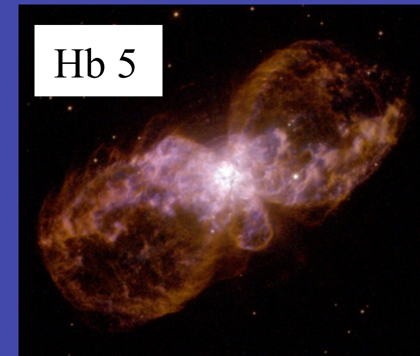
IC 418

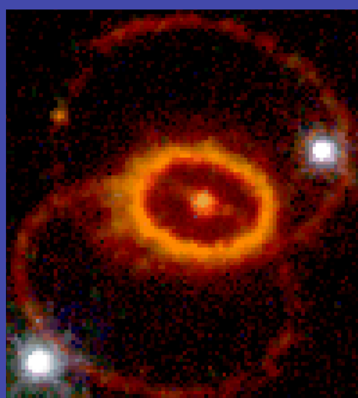


NGC 6302

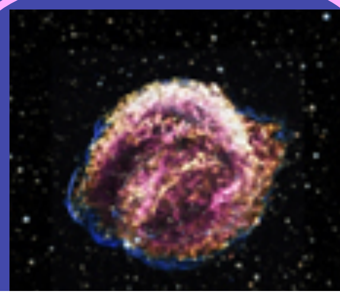
$\dot{M}_{\rm MS} \approx 0.01 M_{\odot}\ {\rm yr}^{-1}$

Hb 5



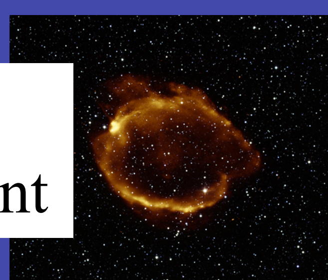


SN 1987A



Kepler SN remnant (Type Ia)

G299-2.9 SN remnant



Young star S106 IR in star forming region

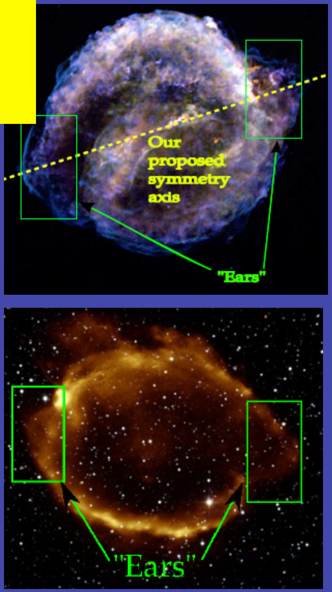
Eta Carinae

Accretion rate onto a main sequence companion (via a disk with jets)

$\dot{M}_{\rm MS} \approx 1 M_{\odot}\ {\rm yr}^{-1}$

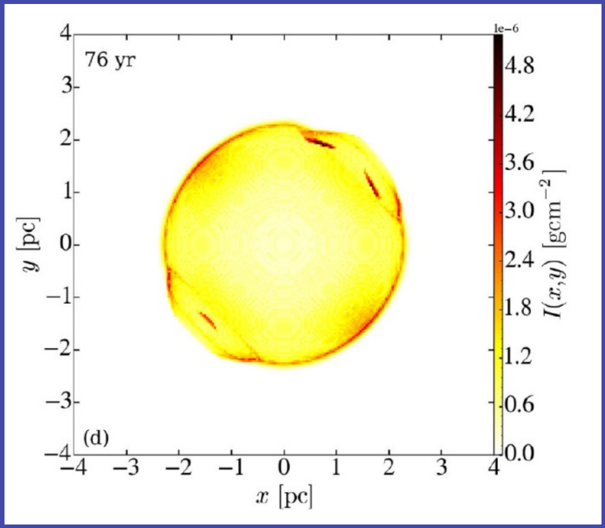
Planetary nebulae

Remnants of supernovae Ia



Jets might be common in pre - SN Ia,

(Tsebrenko & Soker 2013, 2015a)



SNIP: Supernovae Inside Planetary nebulae

See poster by

Danny Tsebrenko & Soker

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We suggest that core collapse supernovae are exploded by jets launched from the newly formed neutron star (or black hole).

This is the **jittering-jets model**.

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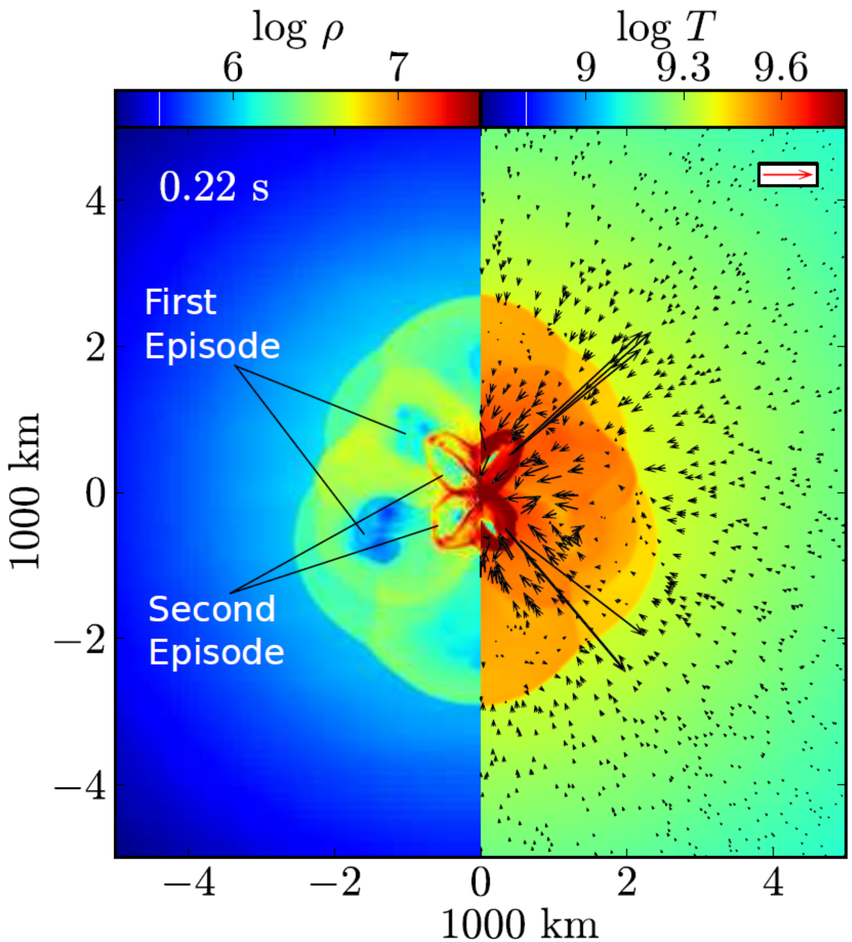
A 2D axi-symmetric simulation with 2 jets-launching episodes.

PhD project of **Oded Papish**



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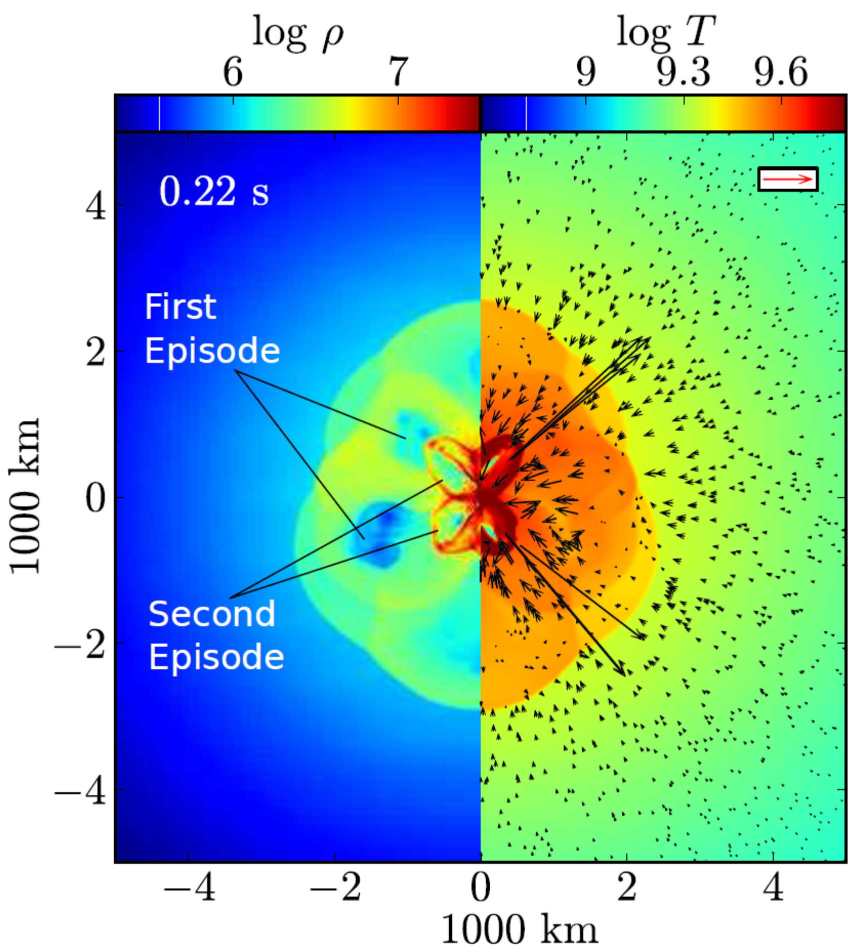
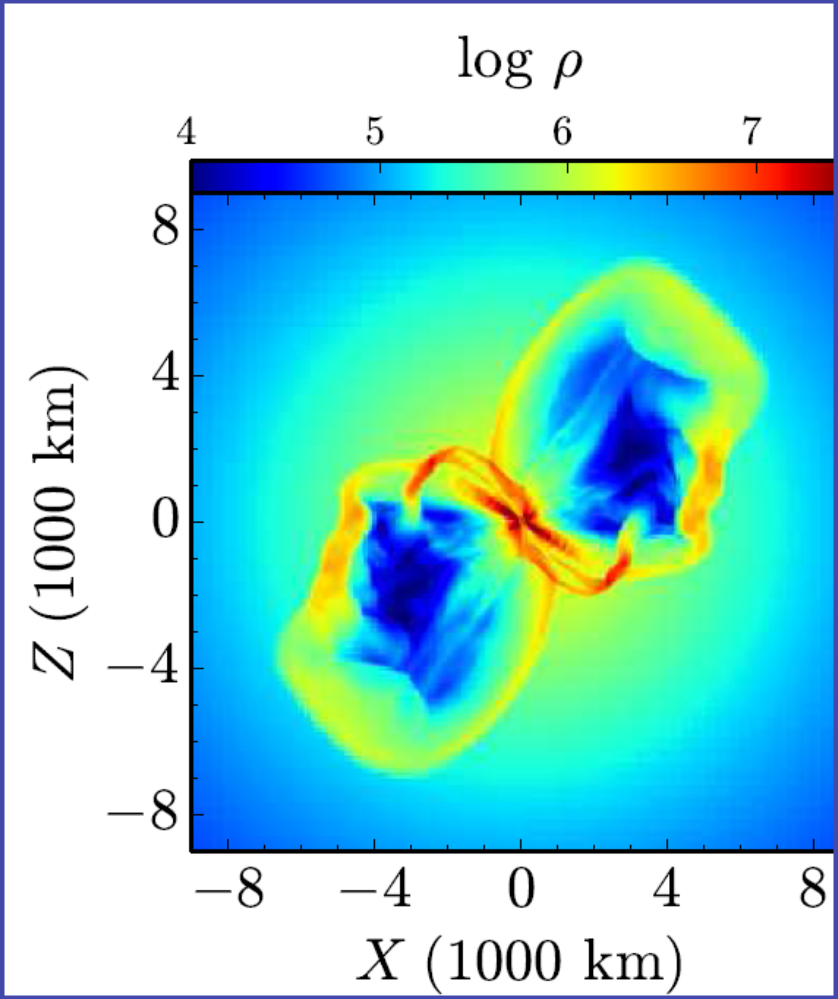


Main challenge:
To supply angular momentum to form accretion disks.

PhD of **Avishai Gilkis:**
Convection in pre-collapse core and instabilities lead to stochastic accretion disk formation, and to **jittering jets.**



A simulation of 3-pairs of opposite jets launched within 0.15 seconds inside a core of a massive star just after the formation of the new neutron star.

A full 3D simulation.

We argue that such jets explode massive stars.

PhD of Oded Papish

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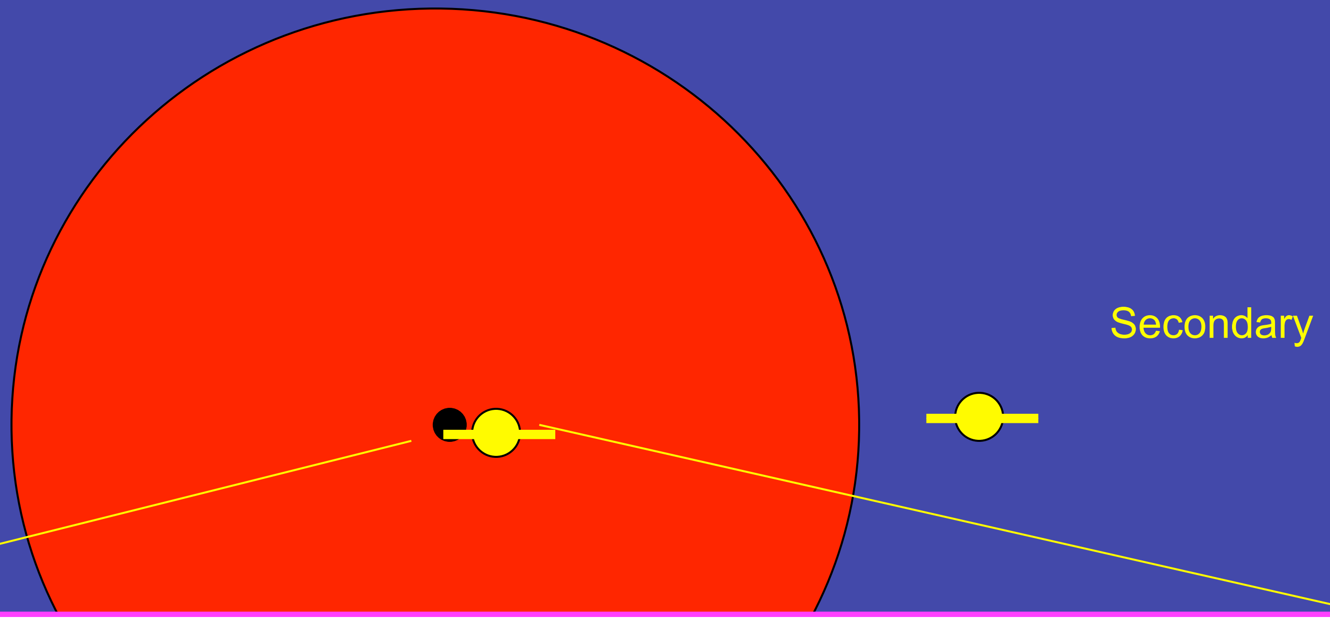
Jets during the common envelope phase, and the grazing envelope evolution (GEE).



$$E_{\rm bind} \equiv \alpha_{\rm CE} \frac{G M_{\rm core} M_2}{a_{\rm final}}$$

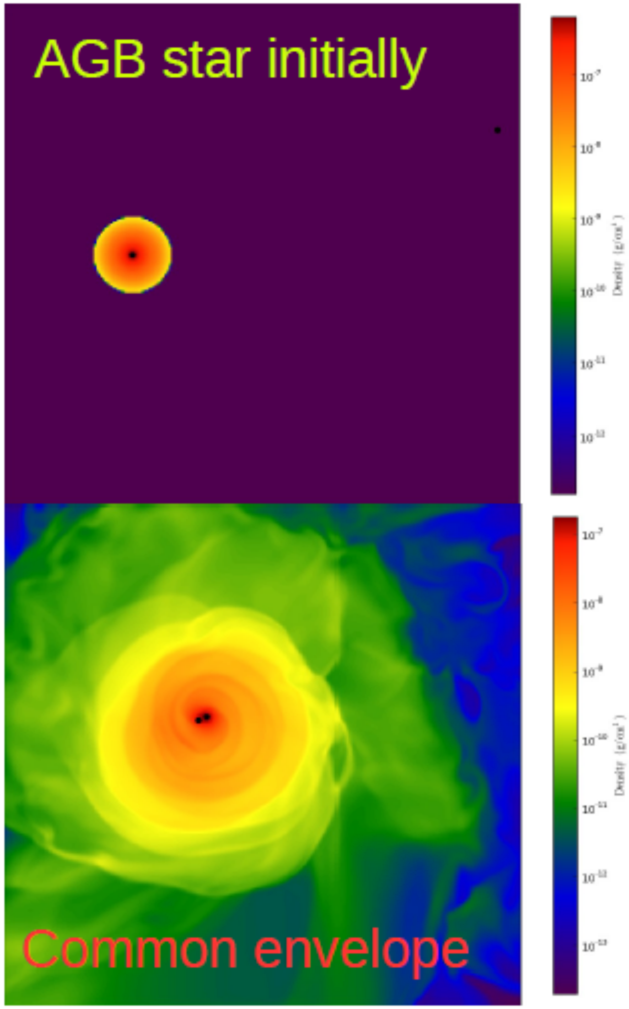
at $2a_{\rm final}$ only $0.5E_{\rm bind}$ has been released, at $4a_{\rm final}$ only $0.25\,E_{\rm bind}$.

Not enough envelope mass to take angular momentum and energy!!

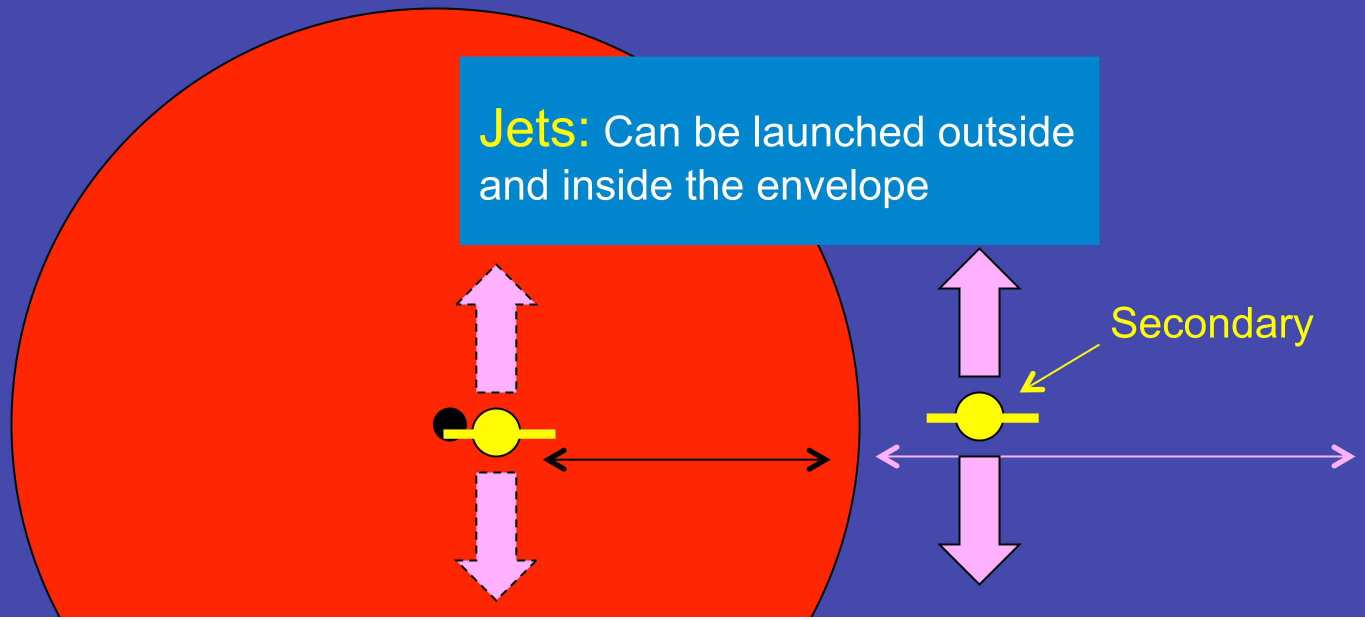
(See Soker, N. 2013, NewA, 18, 18 for mor edetails on the problem with $\alpha_{\rm CE}$).

Common envelopes

-Most of the envelope is just lifted, not unbound (e.g. Passy et al. 2012, Iaconi et al. in prep, Staff et al. in prep).
-The bound mass must fall back, which can lead to more inspiral and unbinding (Kuruwita et al. In prep).



From Jan Staff



<u>Jets</u> are launched and remove the envelope (neutron stars and main sequence, but not white dwarfs).

(Soker, N. 2014, accepted by astro-ph; arXiv:1404.5234)

Final common envelope process by <u>migration</u> and accretion from circumbinary gas, as in young stars.

**** Outcomes: (1) More mergers at the end of the CE**
(might lead to a Type Ia supernova in case of a WD companion).
(2) In some cases when jets are efficient in removing gas, a <u>Grazing Envelope Evolution</u> (GEE).

Summary:

From well observed jet-shaping of nebulae around stars, and in clusters of galaxies, where energy is deposited by jets, we argue that jets play major roles in other cases.

Issue / Process	Most others	My view which is	strongly supported by
Common envelope α_{CE} parameter	Parameter commonly used	**Problematic.** **Instead use Jets and migration** **(but no jets for WDs !!)**	my wife and three kids
Grazing envelope evolution (GEE) NEW	Never heard of. So, see **Soker, N., 2015, ApJ, 800, 114**	**Takes place in many cases**	**Orsola de Marco (but she doesn't know it yet)**
Supernova Ia Remnants	Four different other scenarios	The **core degenerate** scenario: SNIP (Danny Tsebrenko)	my psychiatrist
Core-collapse supernovae	By neutrinos	**Neutrino mechanisms have a generic problem.** **Explosion by jets**	The clerk in charge of early retirement in the Technion.
Very high accretion rates to a companion main sequence star	Not possible NEW	**0.01-1 Mo/yr** **Shiber, Schreier, Soker** (2015), **astro-ph, accepted**	All of the above