Pleasantness Review*

Department of Physics, Technion, Israel

Nebulae powered by a central explosion

Garching 2015

Noam Soker

Essential collaborators (Technion): Muhammad Akashi, Danny Tsebrenko, Avishai Gilkis, Oded Papish,

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

A very short summary

JETS

This research was not supported by any grant

A short summary

Must Include JETs
(MIJET)

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A full Summary

People who simulate the following cases **Must Include JETs [MIJET]**

(a) Explosions of core collapse supernovae (PhD projects of Oded Papish and Avishai Gilkis). **[mijet]**

Note! Can be a single star !!

In planetary nebulae shaping we need a companion to supply angular momentum and energy. Here we have stochastic angular momentum accreted onto a newly born neutron star.

A full Summary

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(a) Explosions of core collapse supernovae (PhD projects of Oded Papish and Avishai Gilkis). **[mijet]**

(b) The circumstellar matter of some type Ia supernovae (Danny Tsebrenko poster and PhD thesis). **[mijet]**

(c) Common envelope evolution. **In many cases a <u>Grazing Envelope Evolution</u> (GEE) will occur** (Soker 2015). **[mijet]**

(d) The shaping of bipolar planetary nebulae. **[mijet]**

(e) The formation of equatorial rings (Muhammad Akashi). **[mijet]**

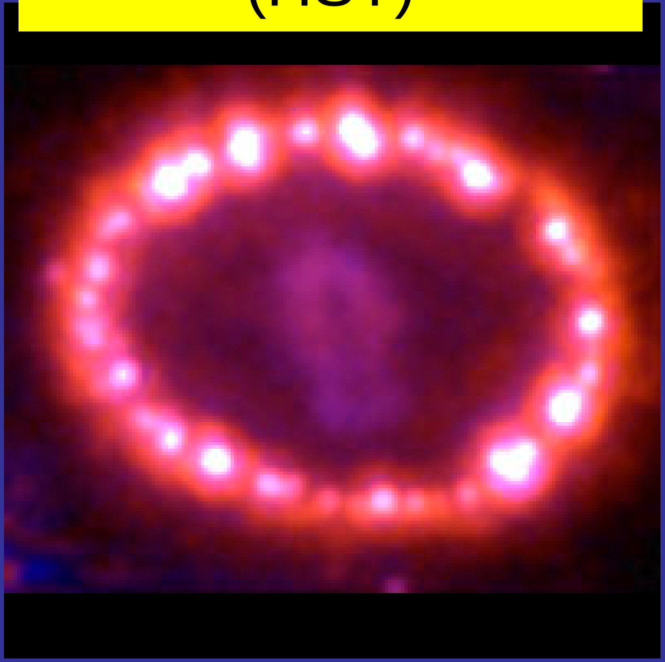
(f) Supernova impostors, like Eta Carinae and SN 2009ip. **[mijet]**

(g) ILOTs (intermediate luminosity optical transients, like V838 Mon). **[mijet]**

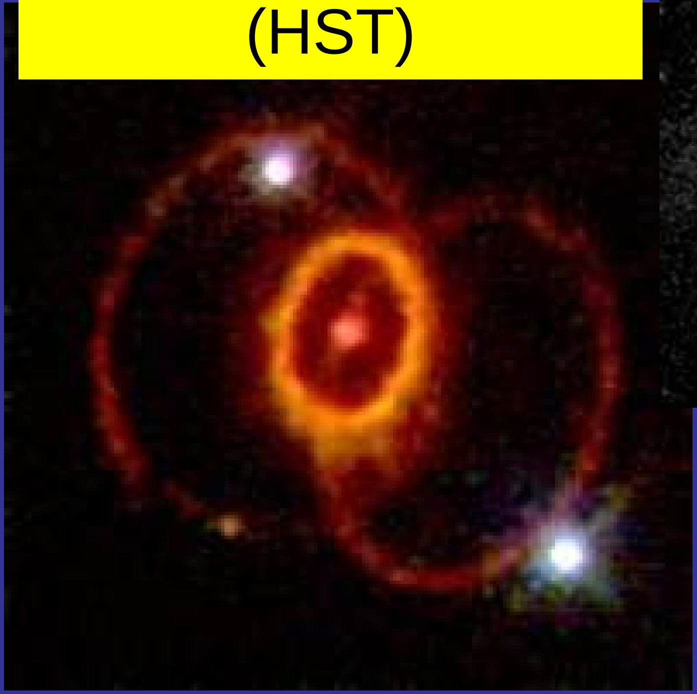
Supernova 1987A: A triple-ring nebula powered by core collapse supernova explosion.

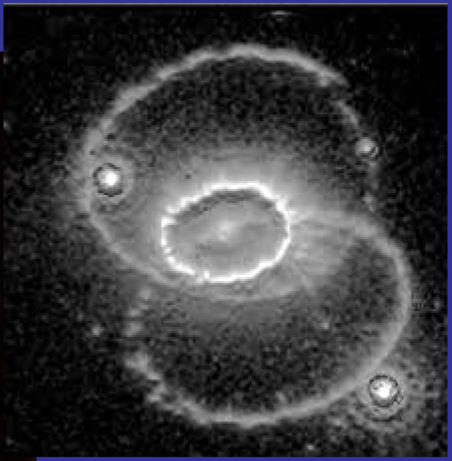
Evolution (Philipp Podsiadlowski et al.) and the rings (Soker et al.) require binary merger.

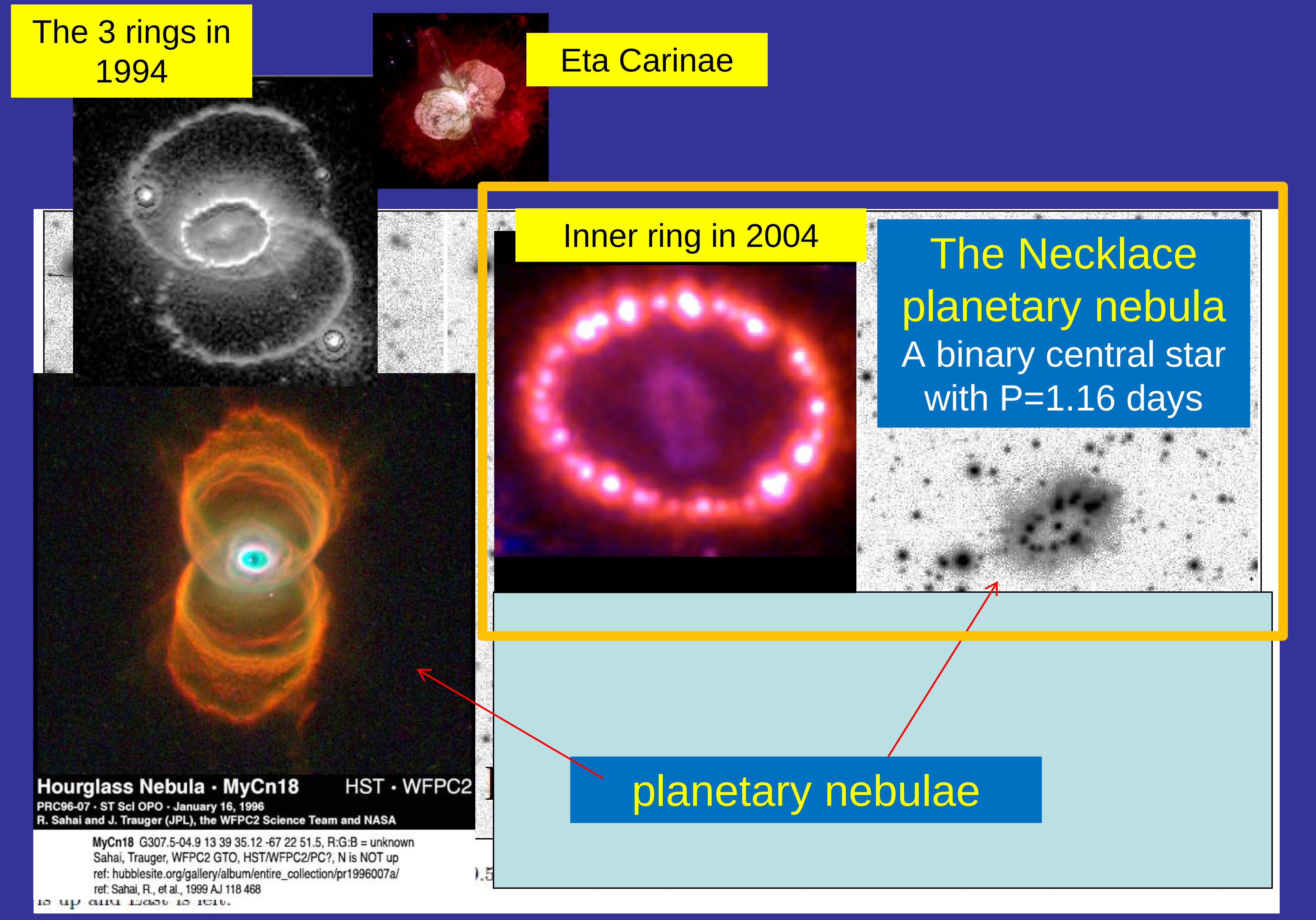
Inner ring in 2004 (HST)



The 3 rings in 1994 (HST)

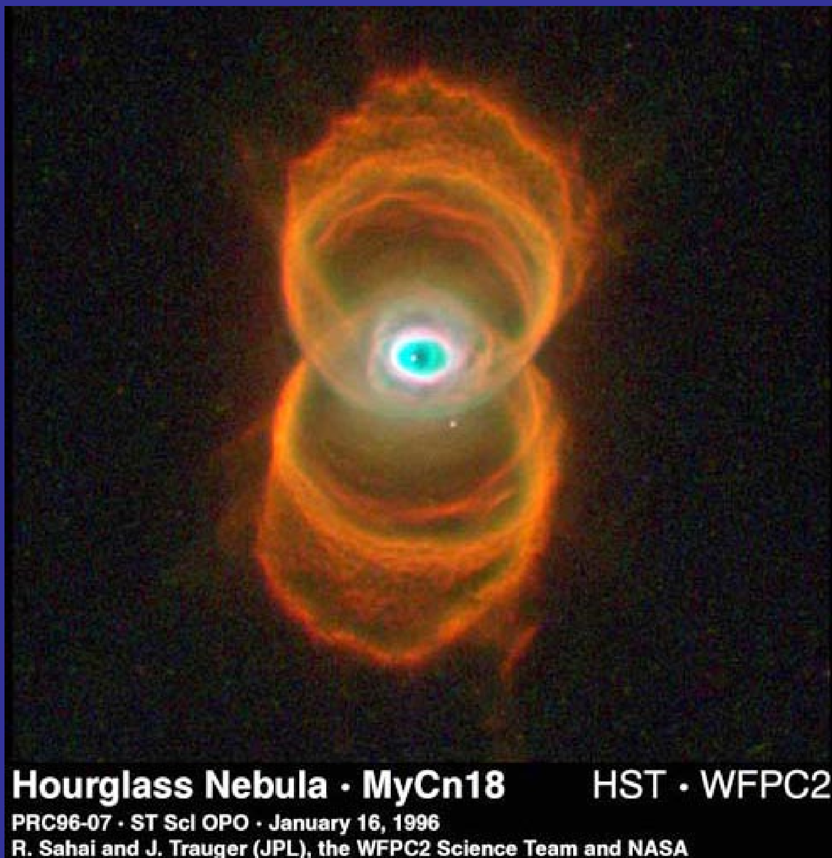






The 3 rings in 1994
Eta Carinae
Inner ring in 2004
The Necklace planetary nebula
A binary central star with P=1.16 days
Hourglass Nebula · MyCn18
HST · WFPC2
PRC96-07 · ST ScI OPO · January 16, 1996
R. Sahai and J. Trauger (JPL), the WFPC2 Science Team and NASA
MyCn18 G307.5-04.9 13 39 35.12 -67 22 51.5, 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.).



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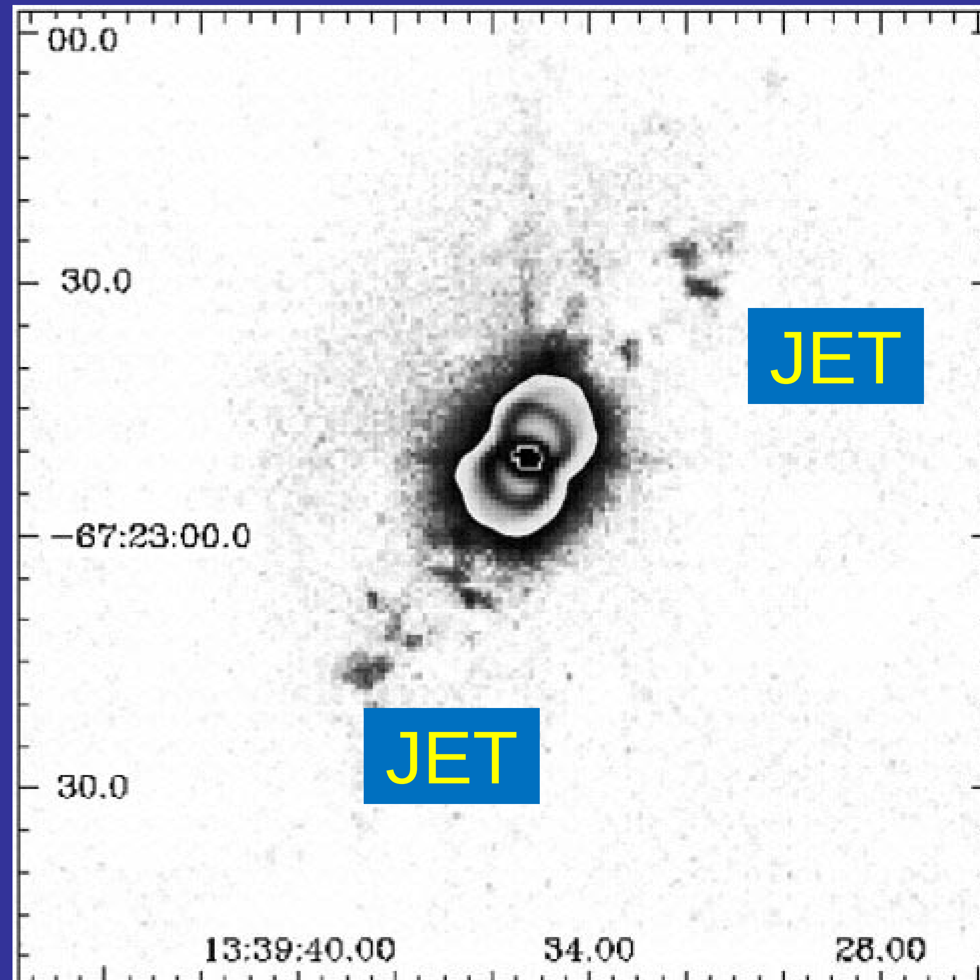


MyCn 18 G307.5-04.9 13 39 35.12 -67 22 51.5 Ha + [NII]
Ref: O'Connor, J.A., Redman, R.P., Holloway, A.J, Bryce, M., Lopez, J.A. & Meaburn, J. 2000, ApJ, 531, 336

(Form David Jones et al. 2015)

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

A binary central star with P=1.16 days.

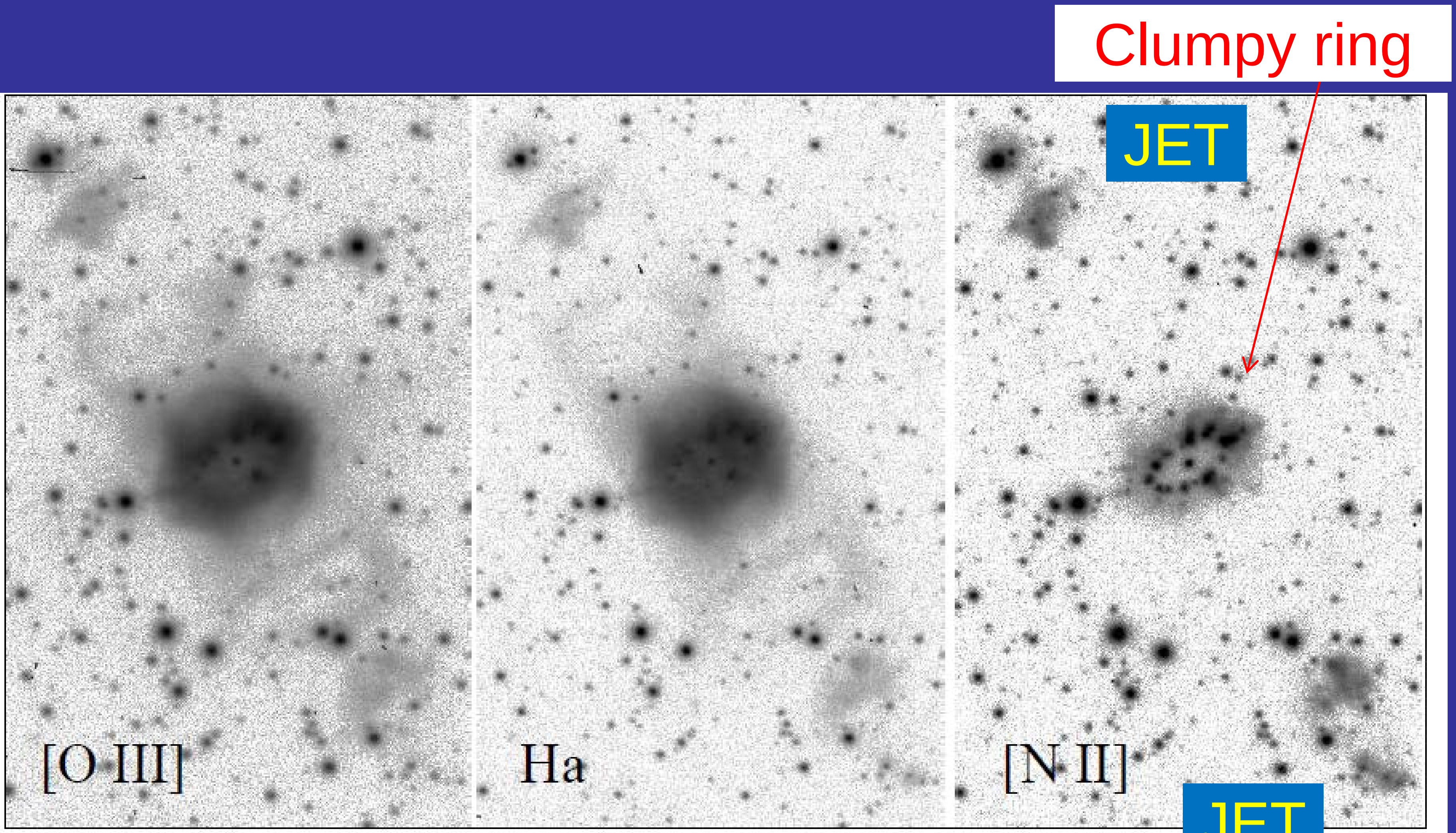


Figure 1. The NOT images of IPHASXJ194359.5+170901 in a log intensity scale. The field of view is 70″×110″ in each frame. North is up and East is left.

An equatorial dense and clumpy ring

Necklace Planetary nebula

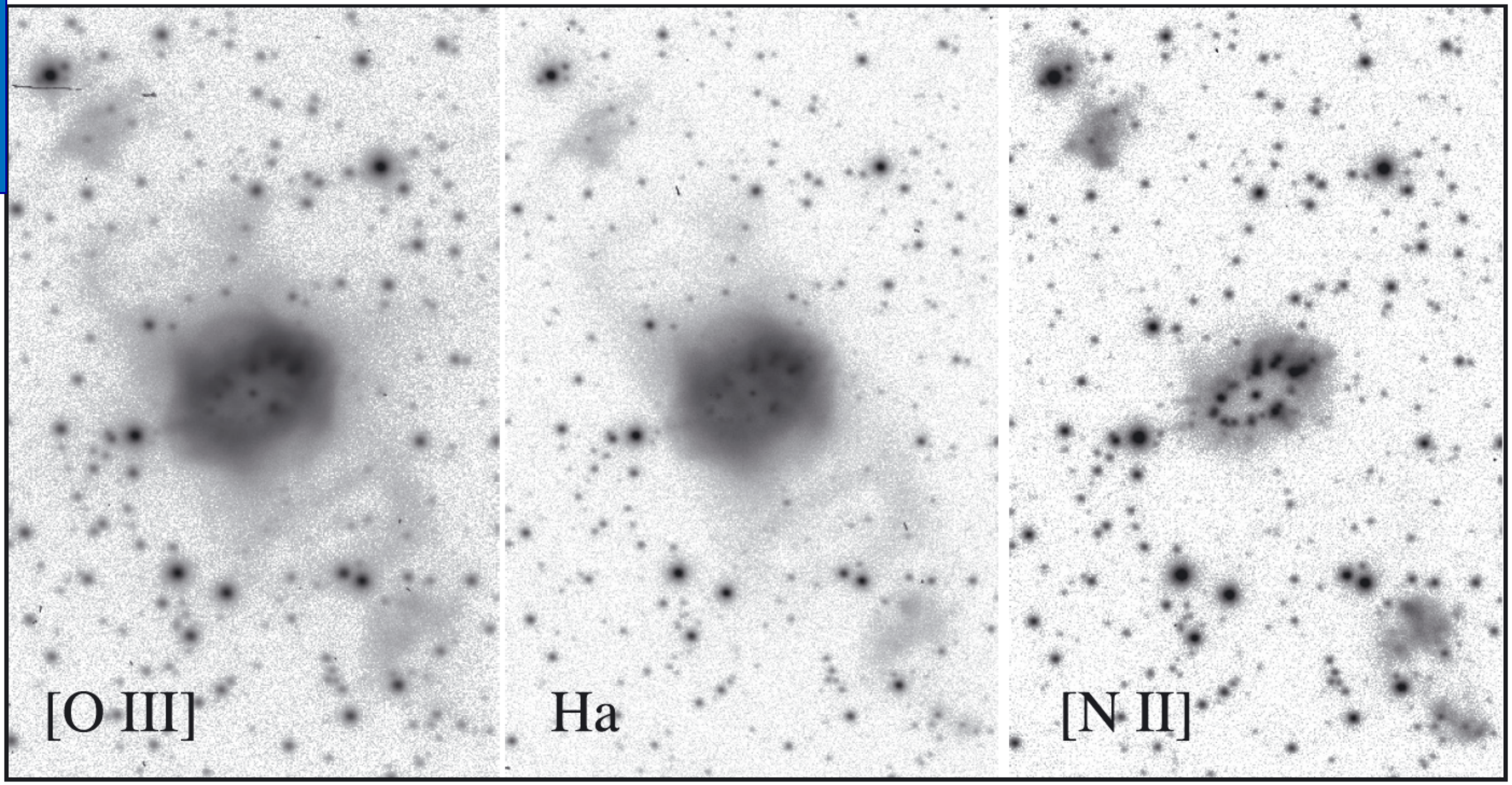
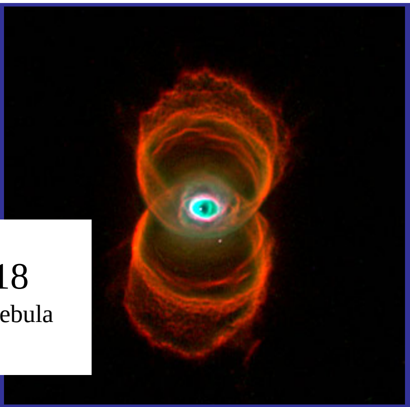


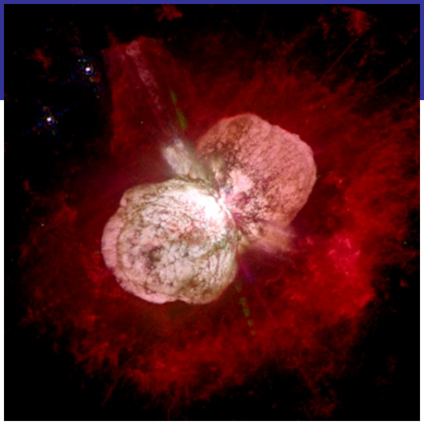
Figure 1. The NOT images of IPHASX J194359.5+170901 in a log intensity scale. The field of view is 70 × 110 arcsec^2 in each frame. North is up and east is left.

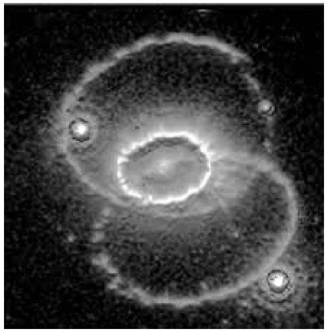
SN 1987A
Supernova remnant

MyCn 18
Planetary nebula



* 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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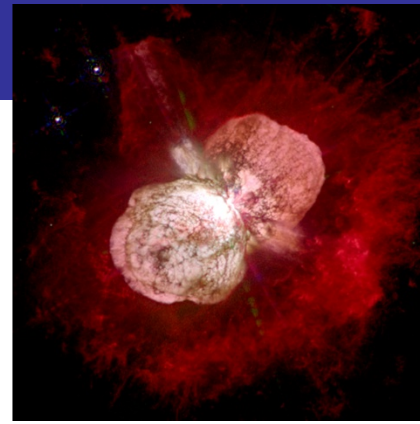
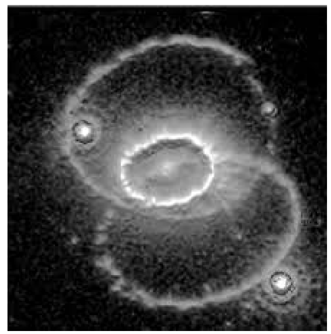
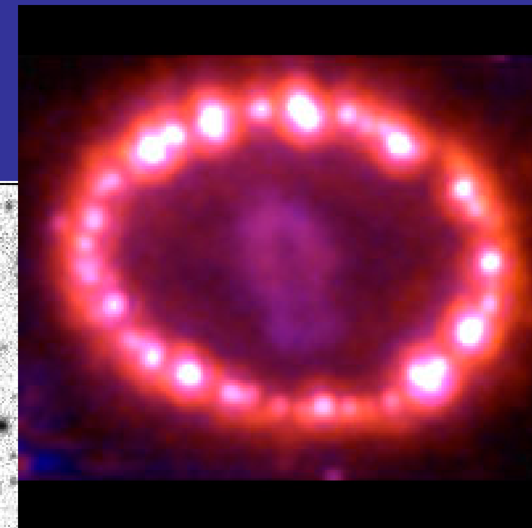


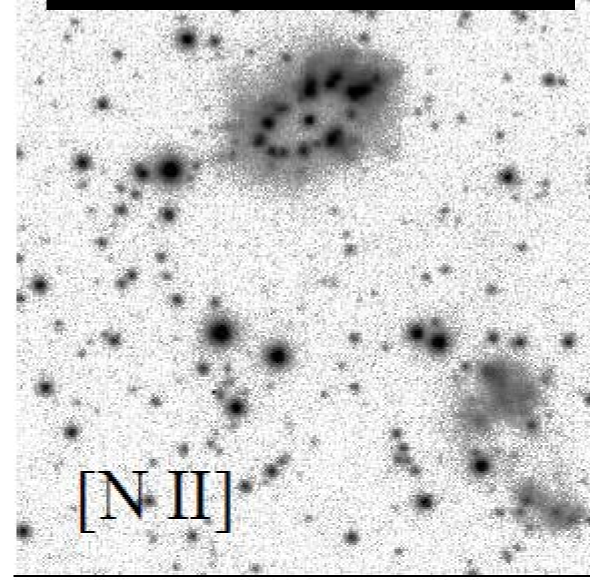


* Inner ring:

<u>Our proposal:</u>

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





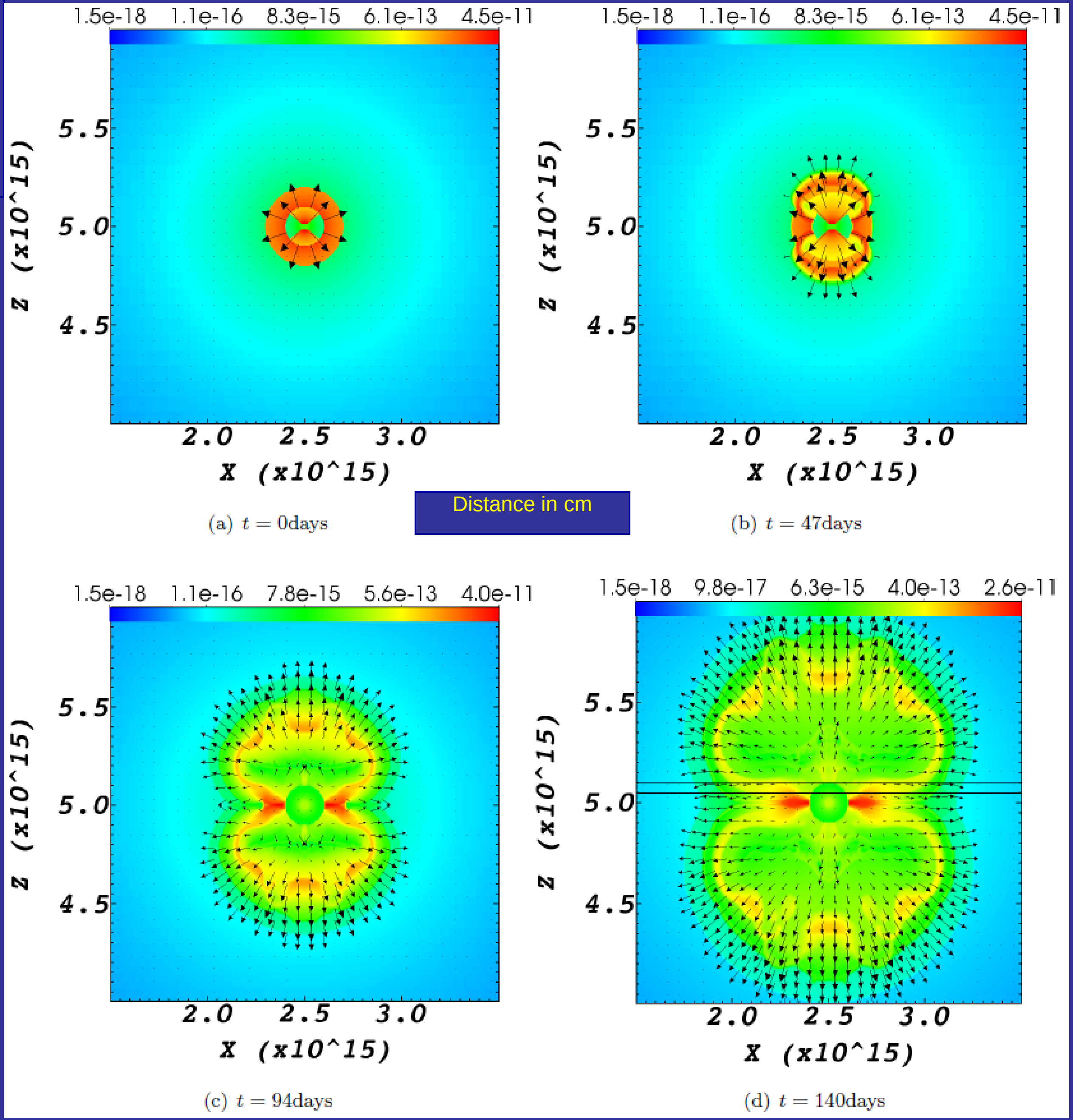
eld of view is $70'' \times 110''$ in each frame. North

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

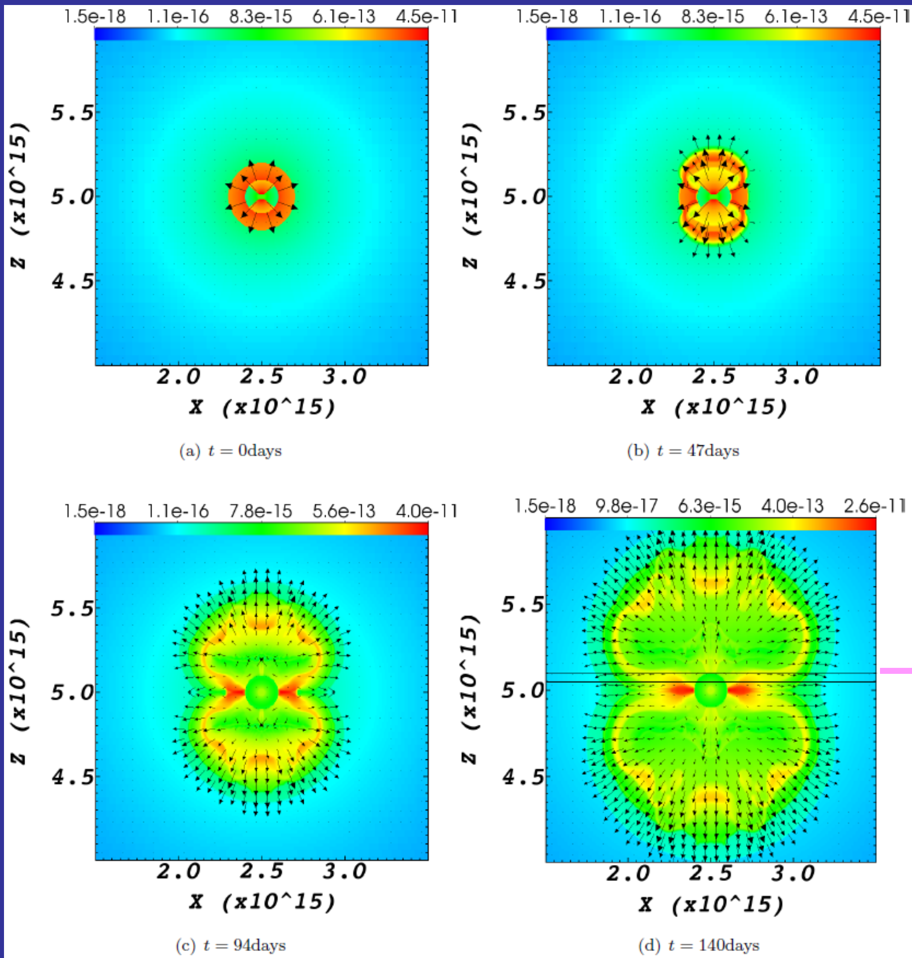
Spherical slow wind + wide jets (half opening angle of 50 degrees). Jet speed 1000 km/s.

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

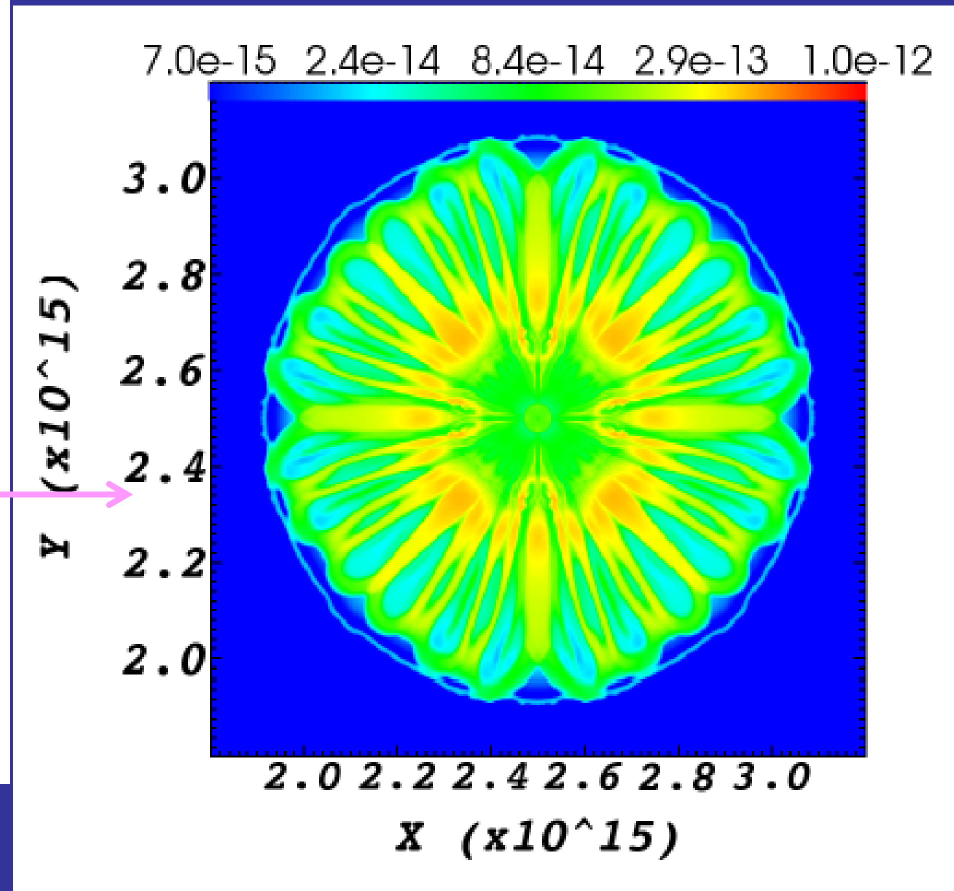


(a) $t = 0$days

(b) $t = 47$days

(c) $t = 94$days

(d) $t = 140$days



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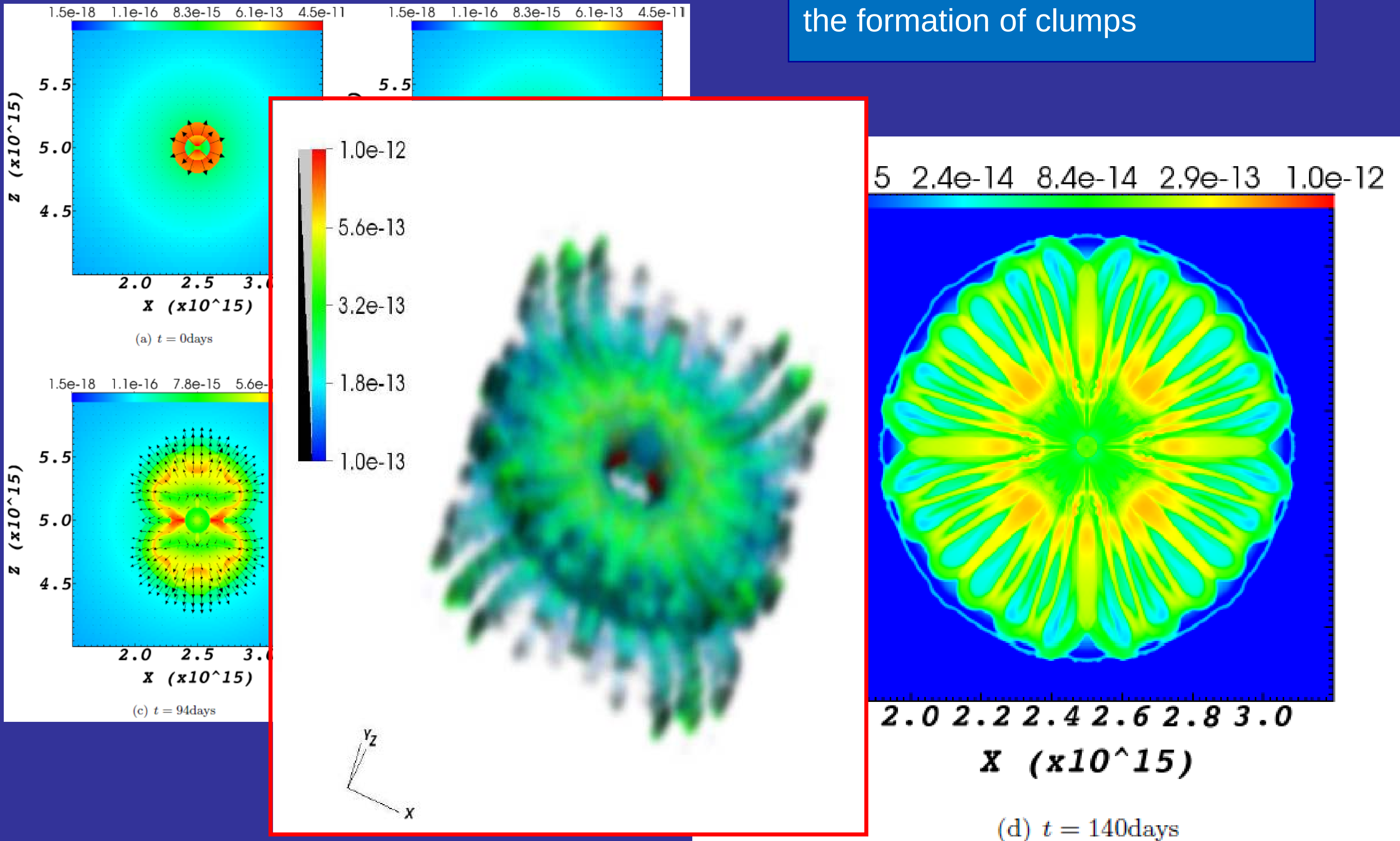

NOTE 1:

The progenitor of SN 1987A was not a post-common envelope system

NOTE 2:

We think the envelopes of exploding massive stars
of SN Ib (no hydrogen envelope)
and SN Ic (no H no He envelope)
are stripped by a binary companion.

Question: Are all core-collapse supernovae require a binary companion?

First we must answer the question:
How do core collapse supernovae explode?

How do core collapse supernovae explode?

One has to account for typical explosion energy of 1e51 erg and up to 1e52 erg.

(a) By neutrino.

(b) By nuclear reactions.

(c) By jets.

All are mentioned in the literature of the last year.

(a) Neutrino mechanisms have failed to reach an explosion energy of E>0.2e51 erg (the PNS limit).

(b) The revived nuclear idea (Kushnir, D.) requires a huge amount of angular momentum; powerful jets must form.

(c) Jets seem to be the most promising mechanism.

So if core collapse supernovae explode by jets, we can go back to the question:

Are all core-collapse supernovae require a binary companion?

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Are all core-collapse supernovae require a binary companion?

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.**

Stochastic angular momentum from pre-collapse convective shells in the core and instability can lead to disks and jets.

No need for a binary companion !!

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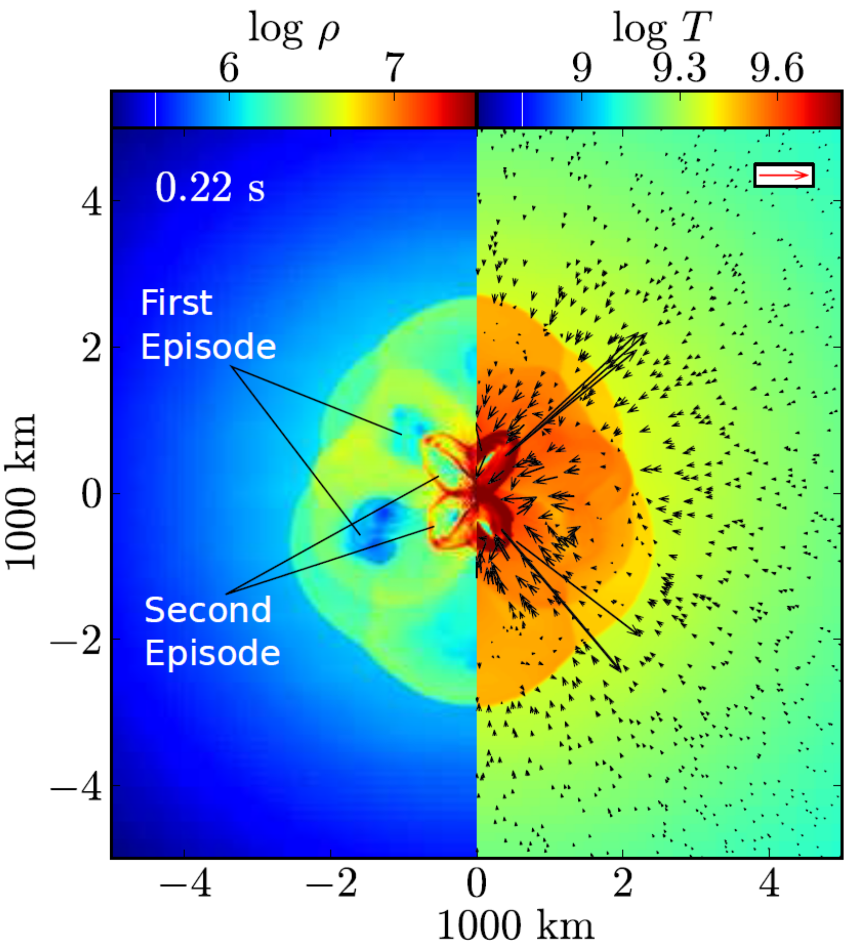
A 2D axi-symmetric simulation with 2 jets-launching episodes.

PhD project of **Oded Papish**



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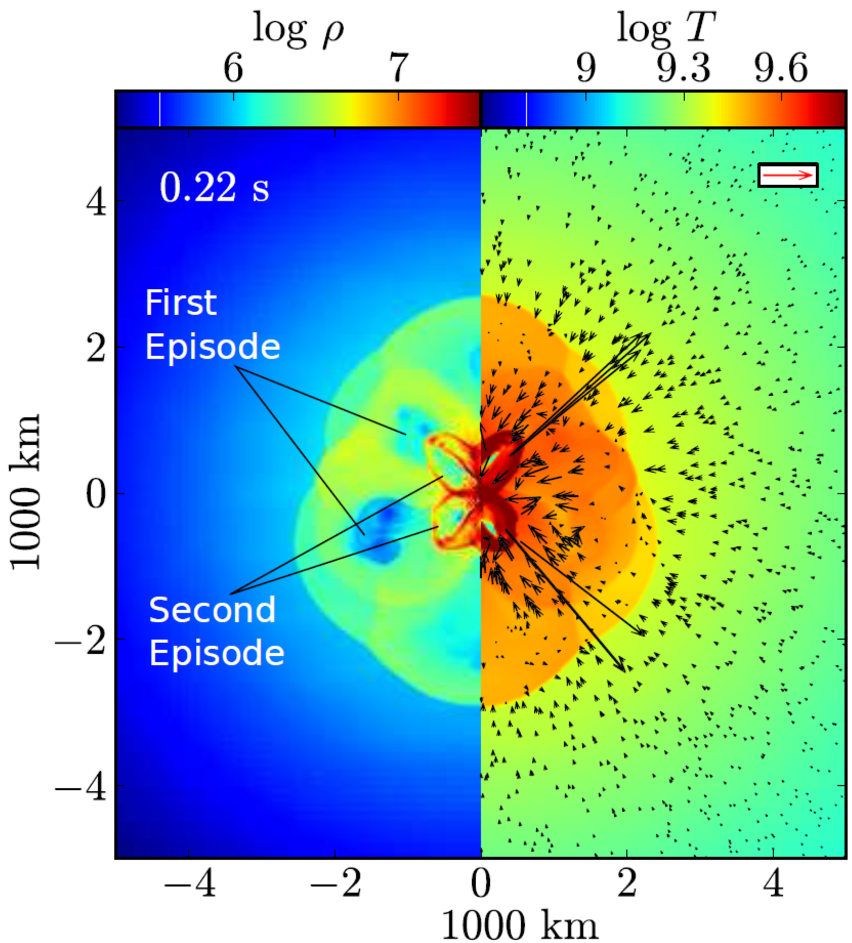
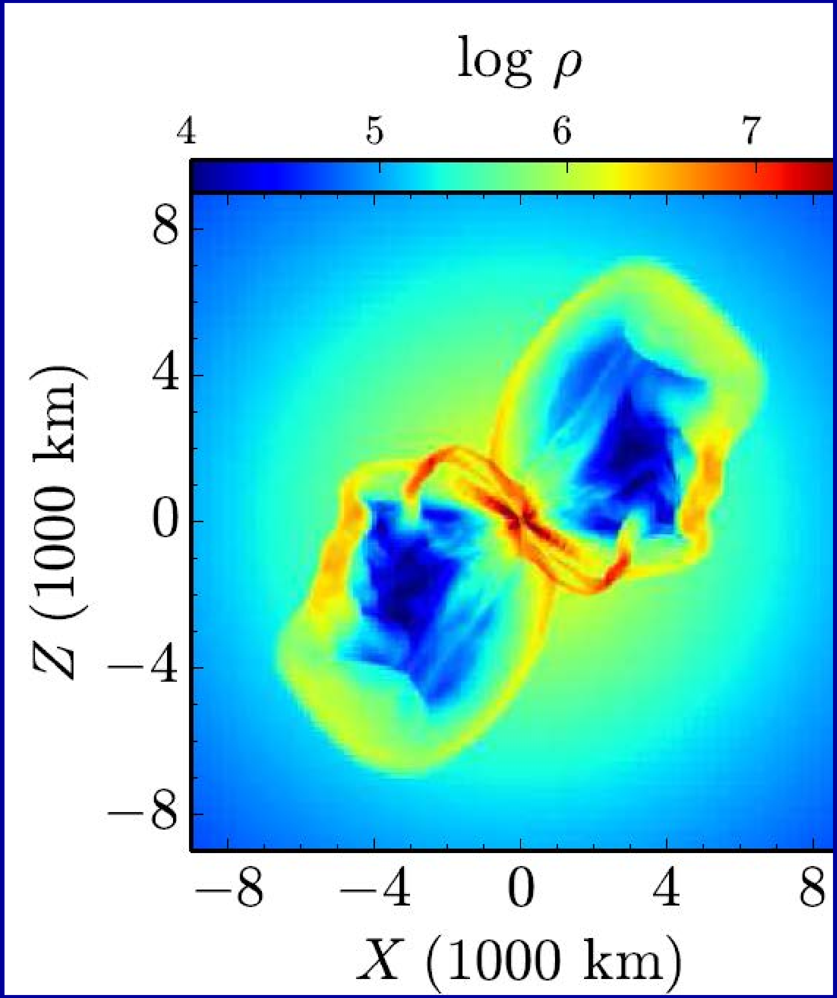


Main challenge:
To supply angular momentum to form accretion disks.

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.

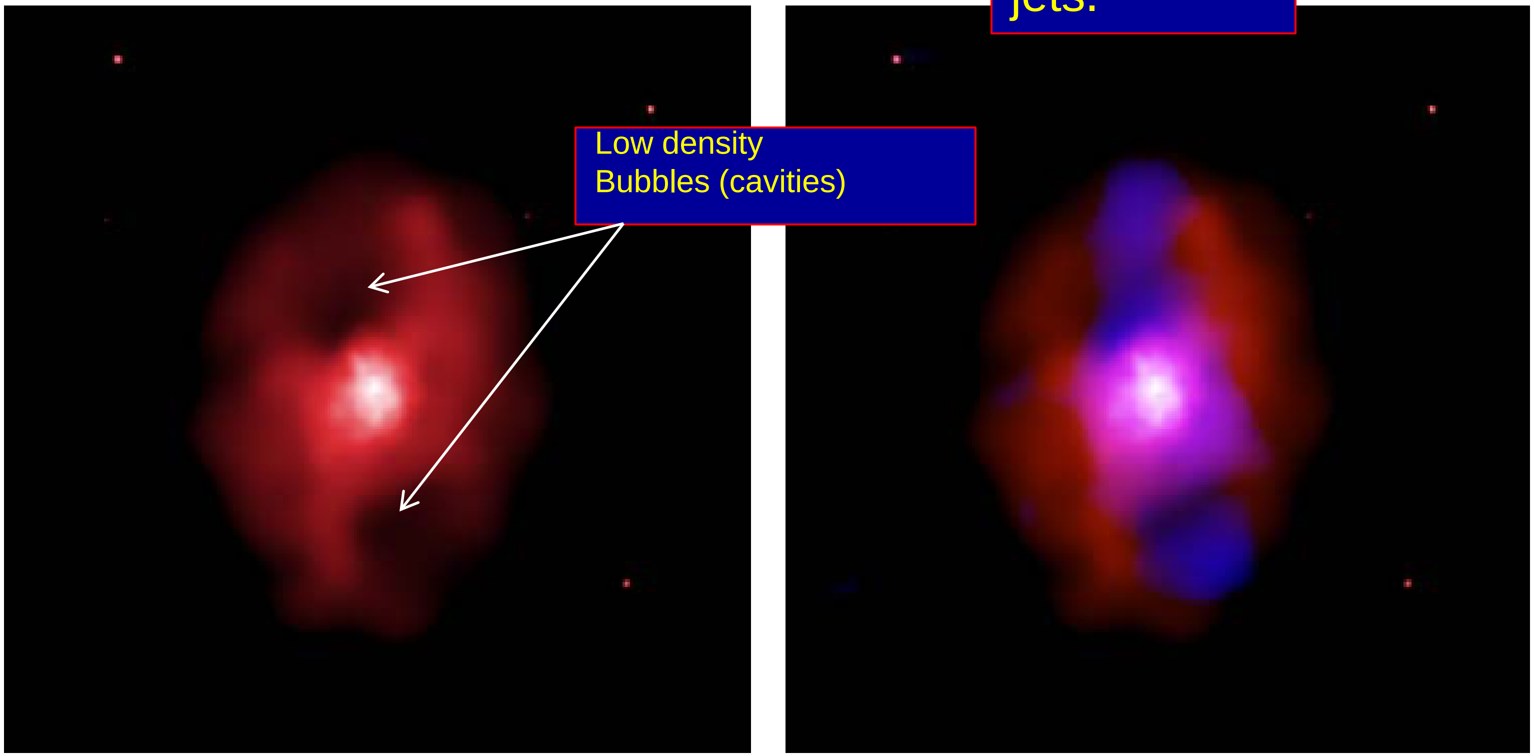
PhD of Oded Papish

NOTE 3:

Bipolar structures are observed in the intra-cluster medium where we see the jets that shape the bubbles (lobes).

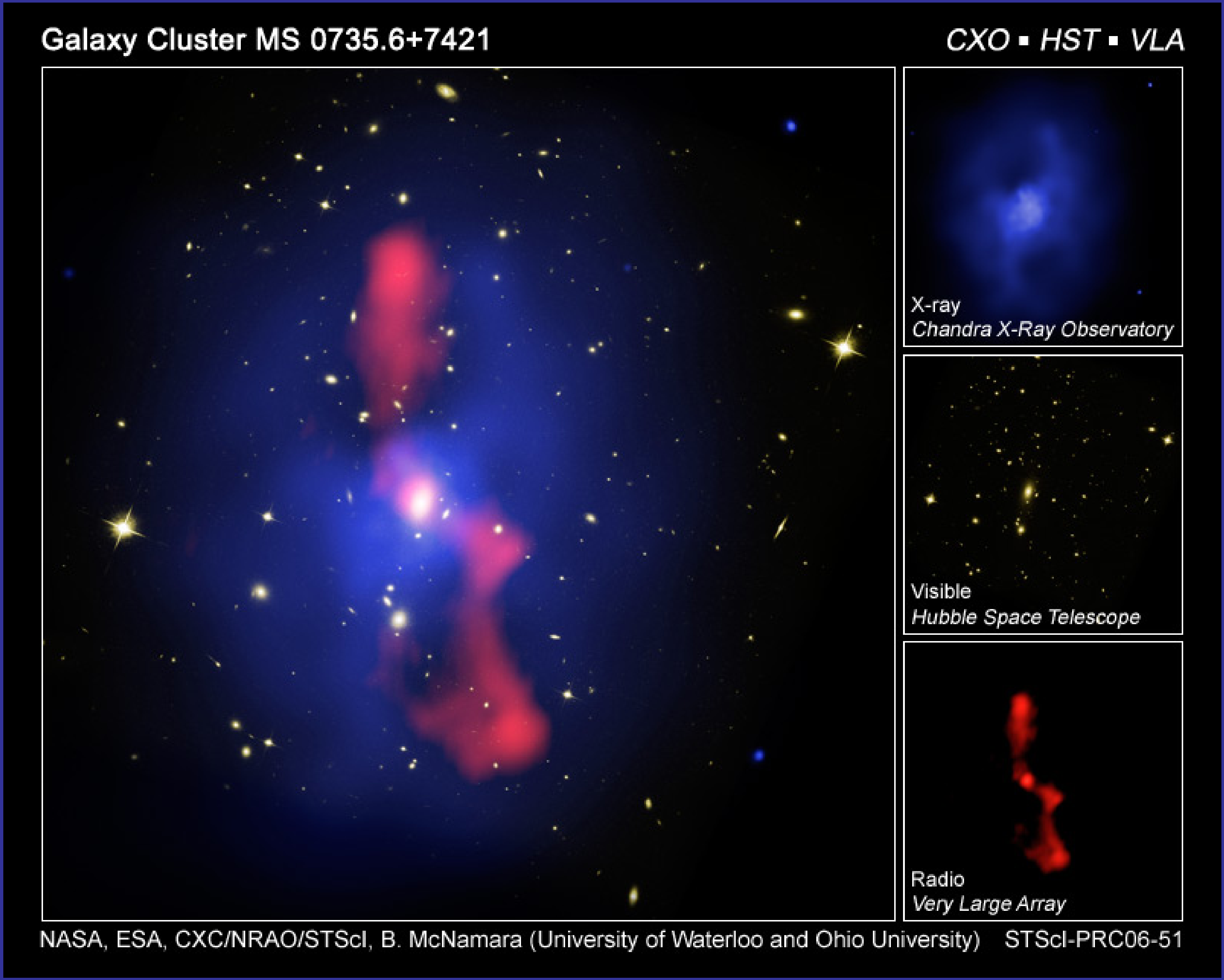
Red: X-ray

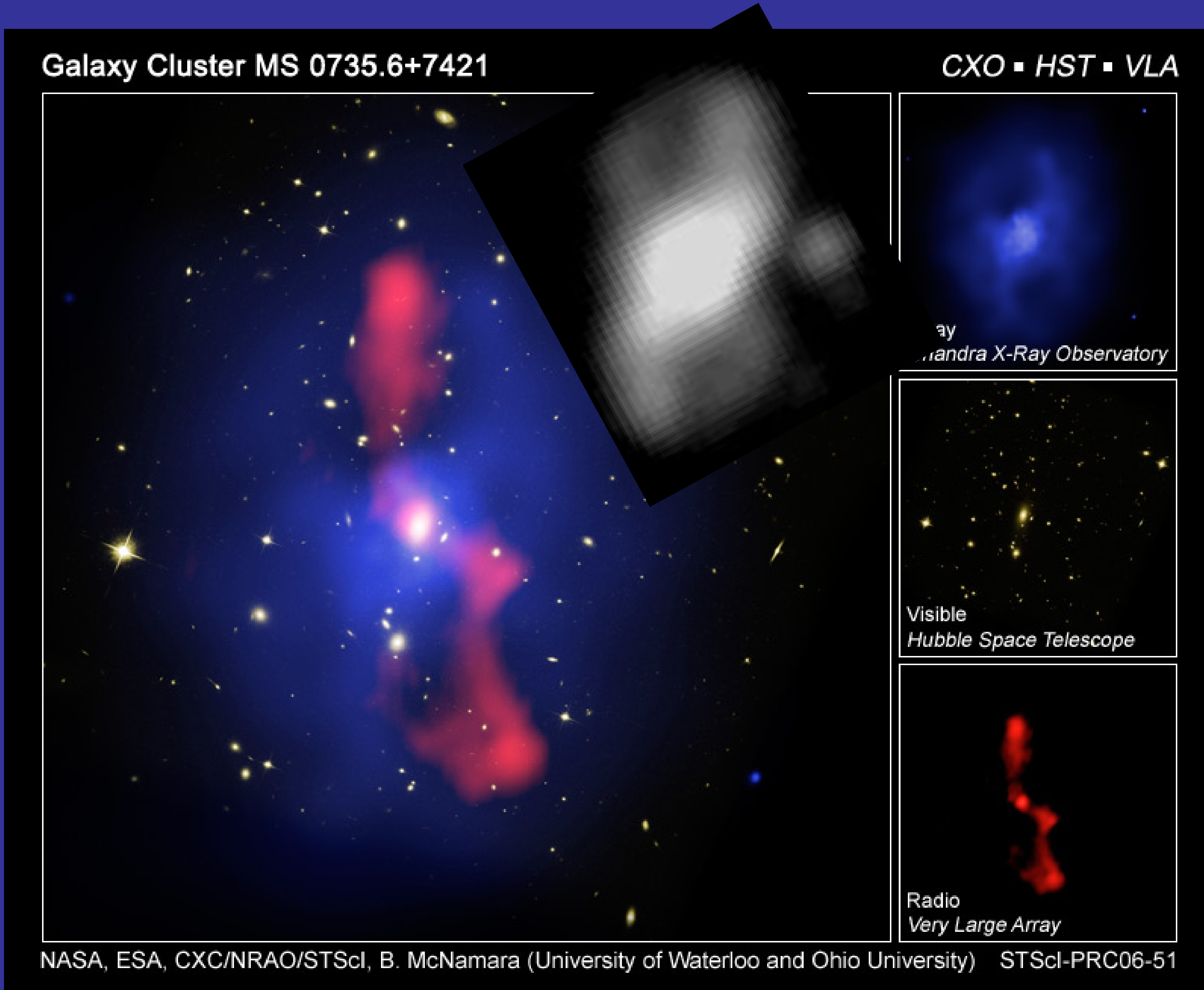
Blue: radio implying jets.



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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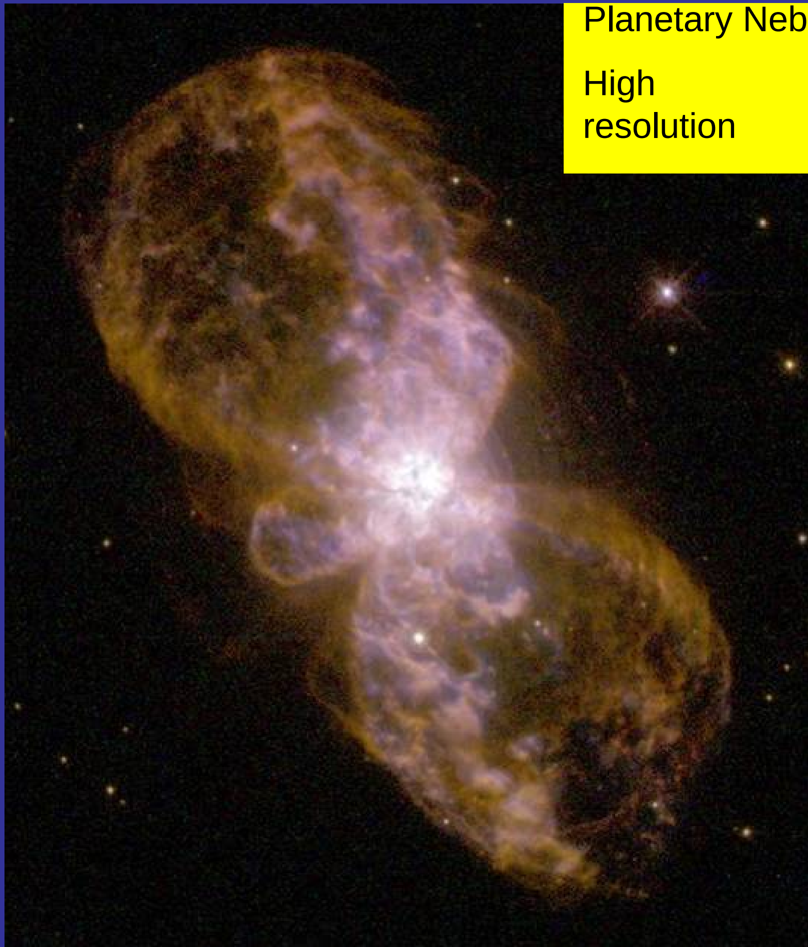
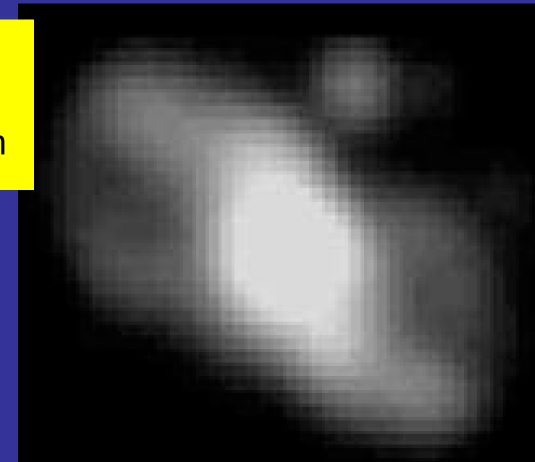
STScI-PRC06-51

Planetary Nebula Hb 5:

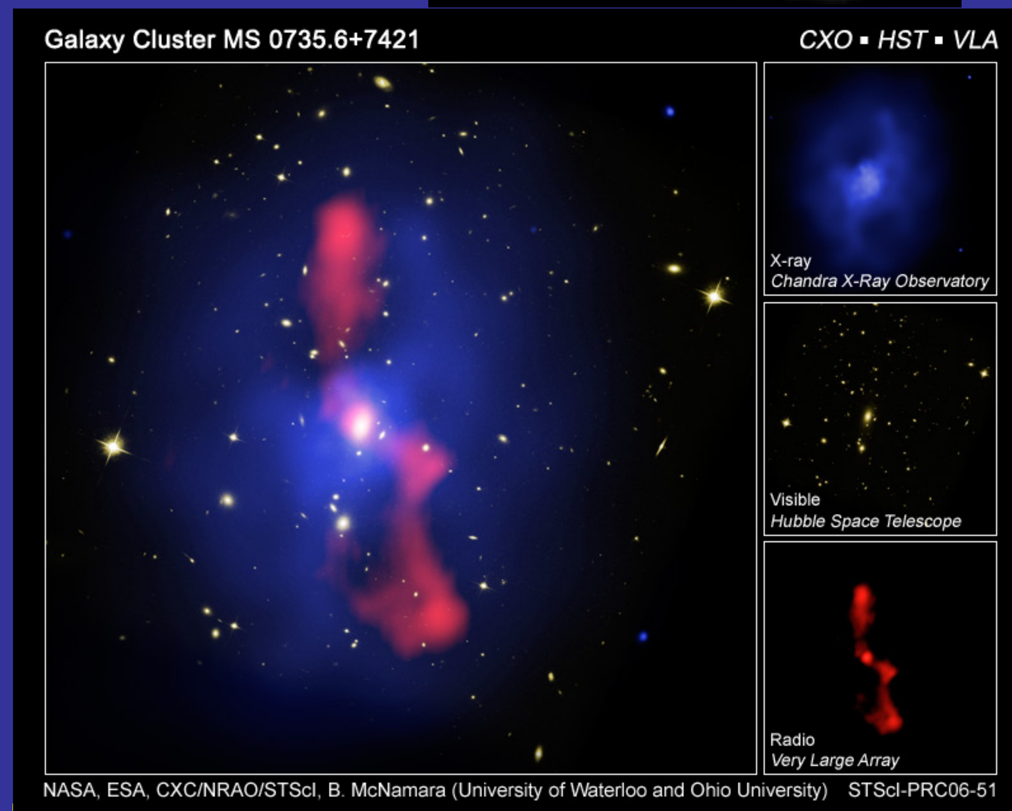
High resolution



Low resolution



Shaping by jets



MS 0735.6+7421

A cluster of galaxies

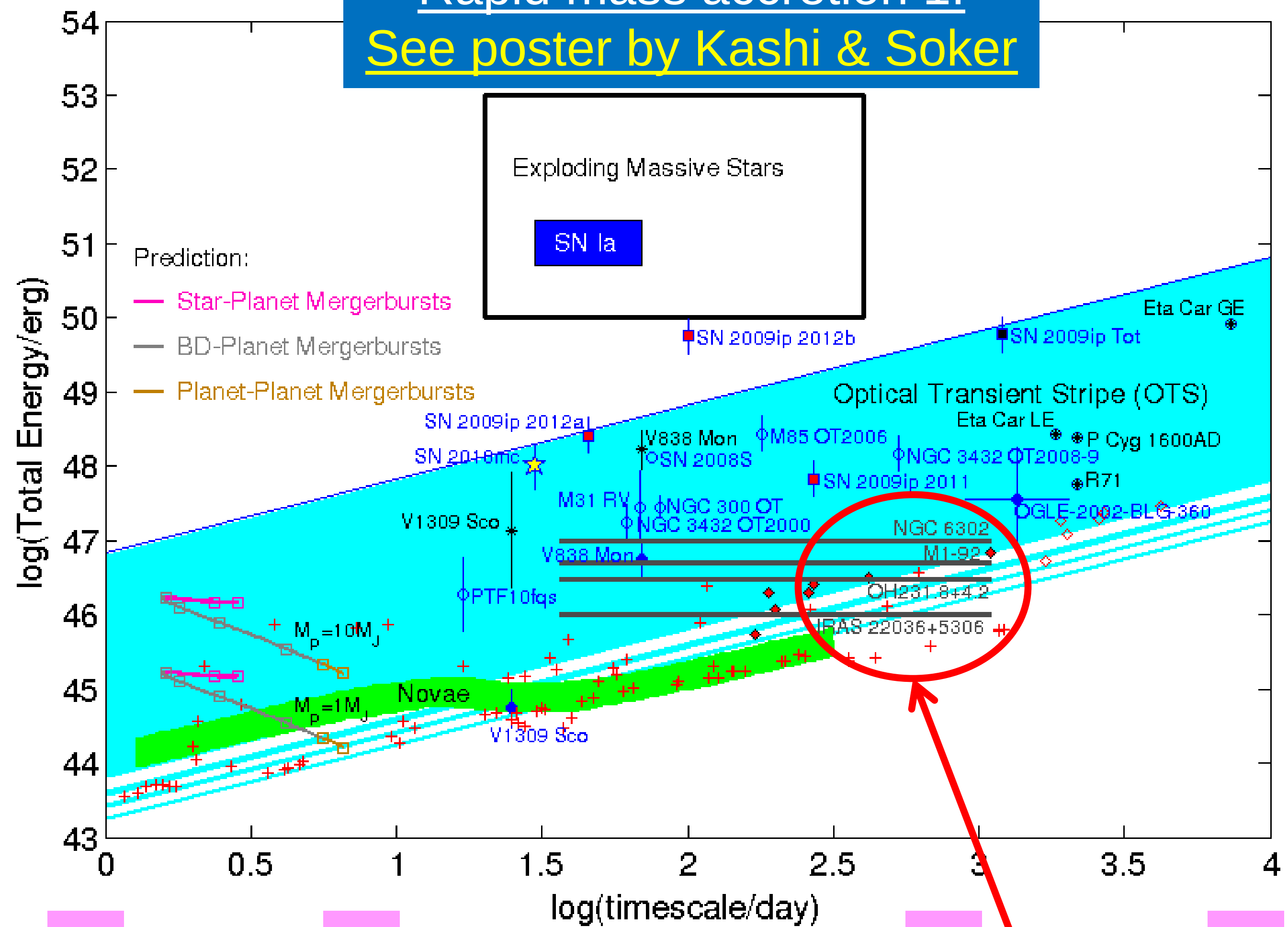
NOTE 4:

In some systems very high mass accretion rate on to a main sequence star takes place: 0.01-1 Mo/year.

Such are ILOTs, the 1837-1856 Great Eruption of Eta Carinae, common envelope, grazing envelope evolution (GEE), and more.

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, . . "

NOTE 5:

Type Ia supernovae can also take place inside a nebula (Danny Tsebrenko PhD thesis). This is actually a planetary nebula (SNIP: SN Inside a Planetary nebulae).

Planetary nebulae hold the key to solve the puzzle of the progenitor of SN Ia.

Other Objects shaped by jets. Note Type Ia Supernova Remnants

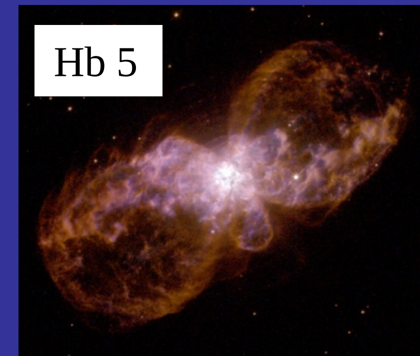
MyCn 18

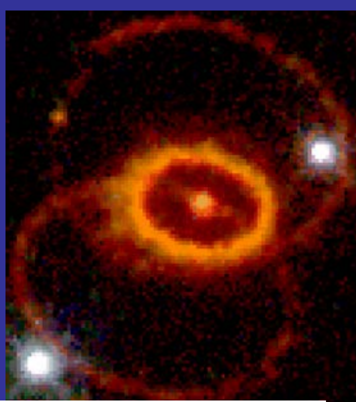
IC 418

NGC 6302

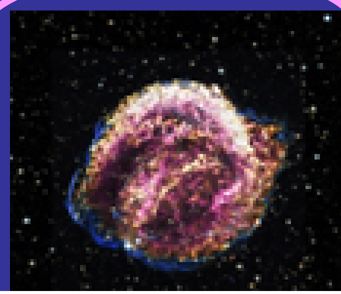
$\dot{M}_{MS} \approx 0.01 M_{\odot}\ \mathrm{yr}^{-1}$

Hb 5





SN 1987A



Kepler SN remnant (Type Ia)

Young star S106 IR in star forming region

Eta Carinae

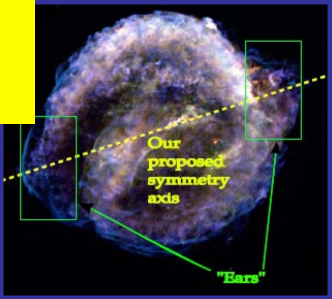
Accretion rate onto a main sequence companion (via a disk with jets)

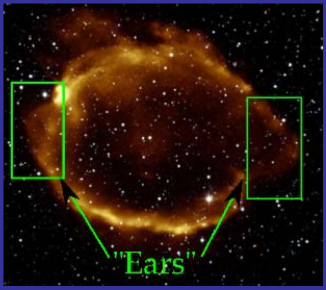
$\dot{M}_{MS} \approx 1 M_{\odot}\ \mathrm{yr}^{-1}$

G299-2.9 SN remnant

Planetary nebulae

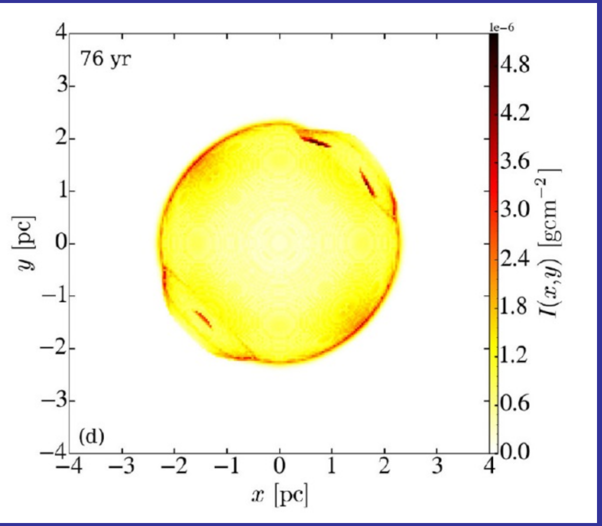
Remnants of supernovae Ia





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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Summary from the Nice meeting:

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