Astrophysical Dynamics, VT 2010

Stellar Winds and Supernova Remnants: Interaction with the ISM

Susanne Höfner

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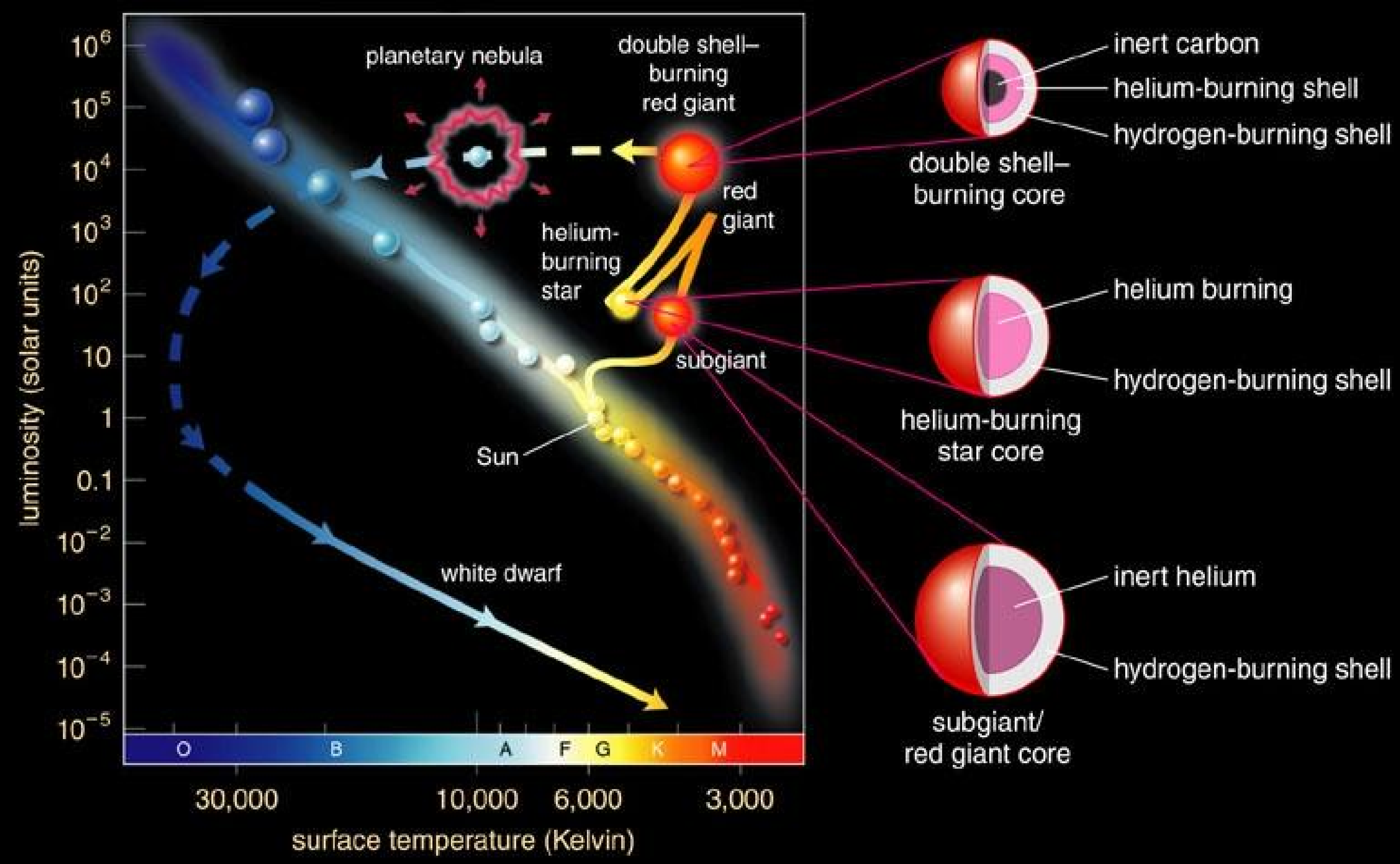
Stellar Evolution: Low Mass Stars



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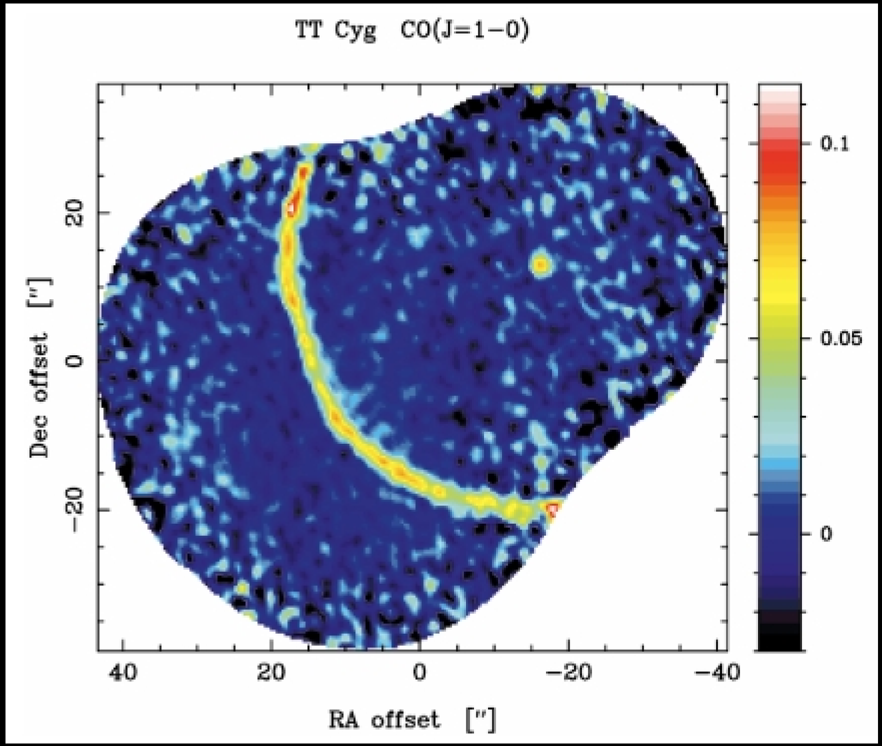
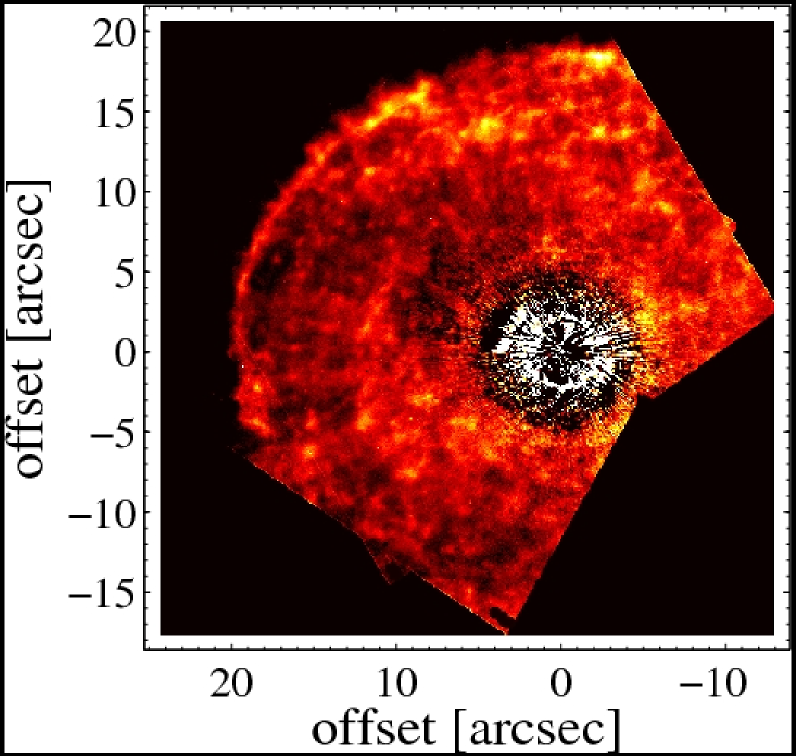
Observations of detached shells

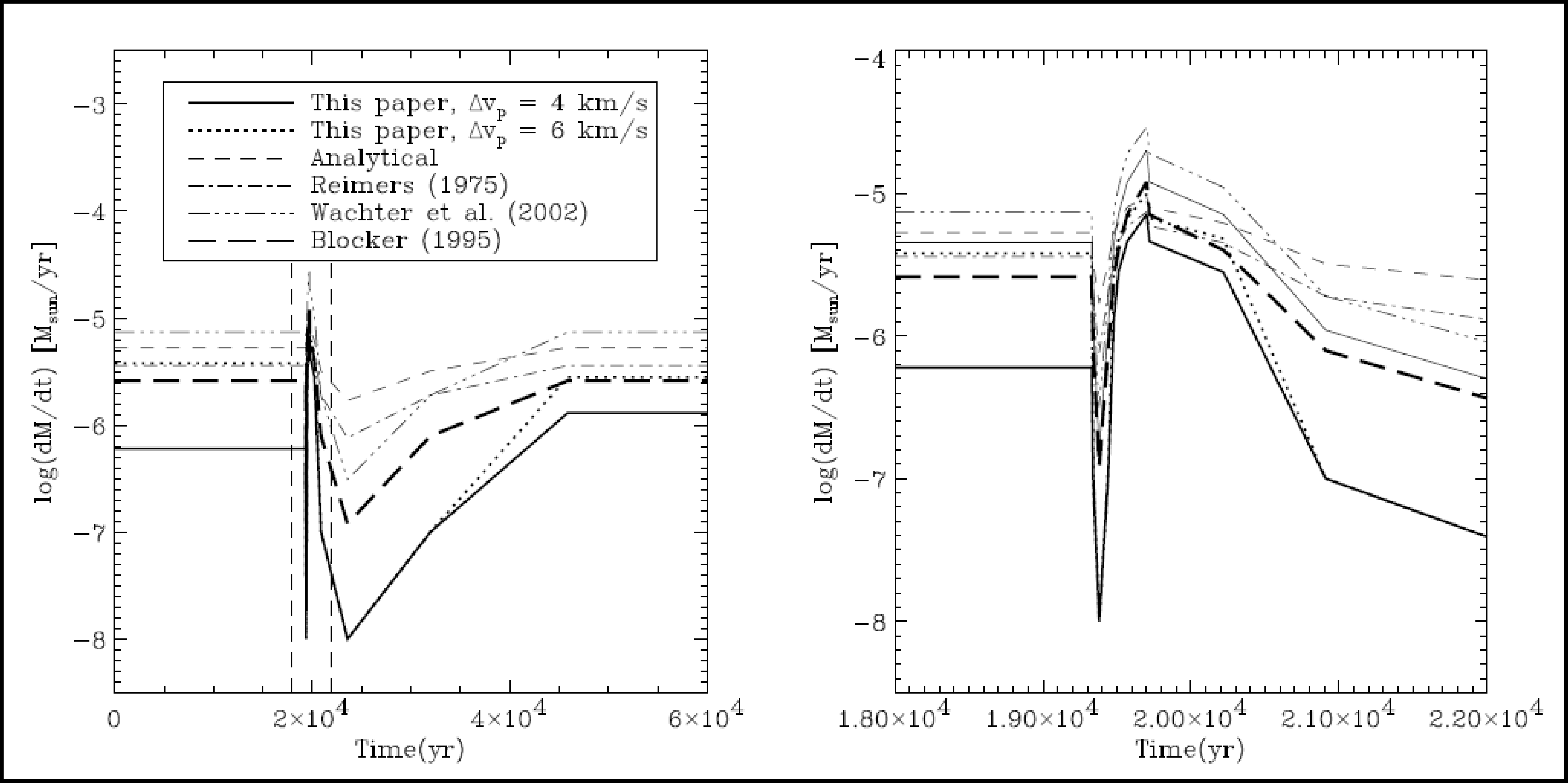


Thin molecular shell around
TT Cyg (Olofsson et al. 1998)



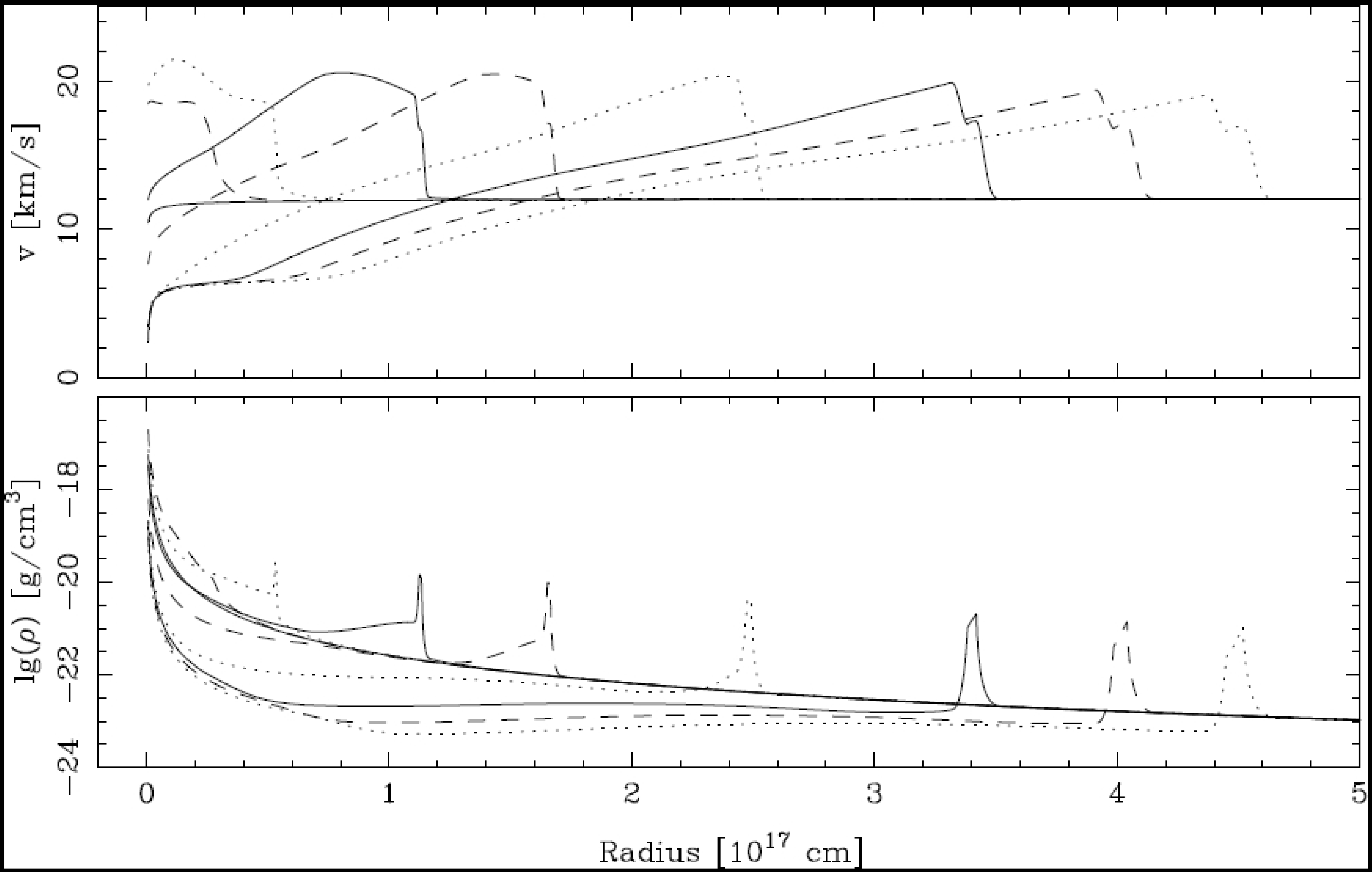
Circumstellar envelope of
R Scl (Olofsson et al. 2010)

Mass loss during a He-shell flash



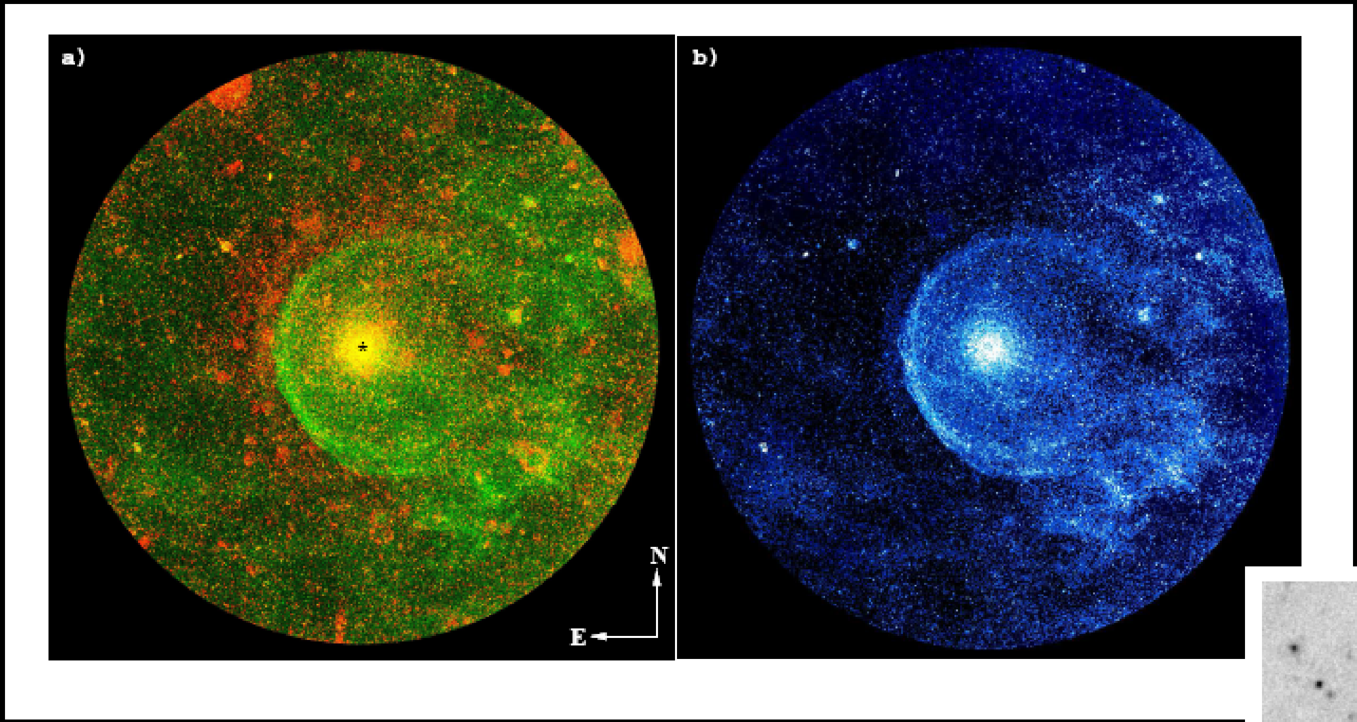
variation of mass loss during a He-shell flash: comparison of models (Mattsson, Höfner & Herwig 2007)

Mass loss during a He-shell flash



variation of wind properties leading to the formation of a detached shell: snapshots of velocity (top) and density (bottom) (Mattsson et al. 2007)

Large-scale structure of the CSE

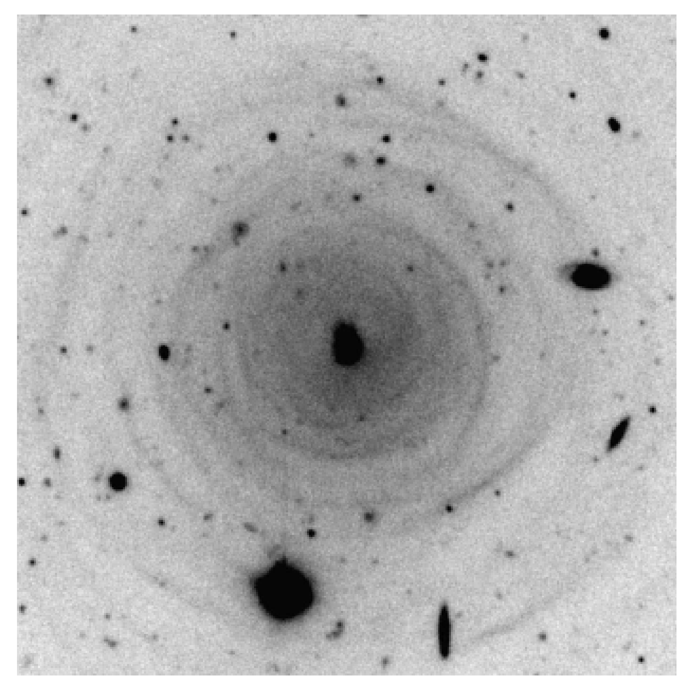


V-band image of IRC+10216 showing shell-like structures in the circumstellar envelope (90"x 90")

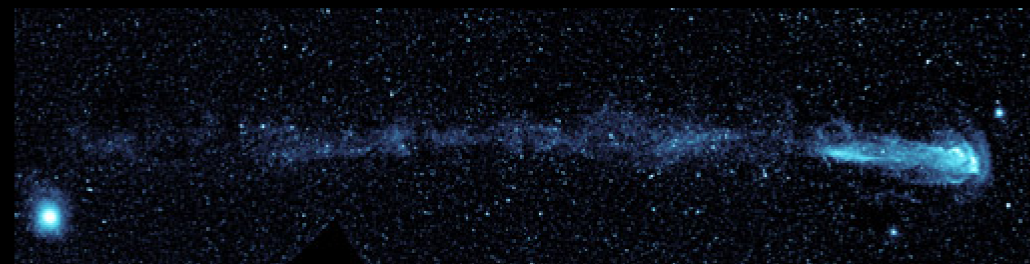
Mauron & Huggins (2010)

GALEX images of IRC+10216 (left: composite NUV+FUV, right: FUV) showing wind - ISM interaction (field of view 62'x 62')

Sahai & Chronopoulos (2010)



Wind of Mira interacting with ISM



NASA's Galaxy Evolution Explorer (GALEX) discovered an exceptionally long (13 light years) tail of material trailing behind the cool giant star Mira (o Ceti). The tail is only visible in ultraviolet light (top left), and does not show up in visible light (bottom left).

www.nasa.gov/mission_pages/galex/20070815/a.html

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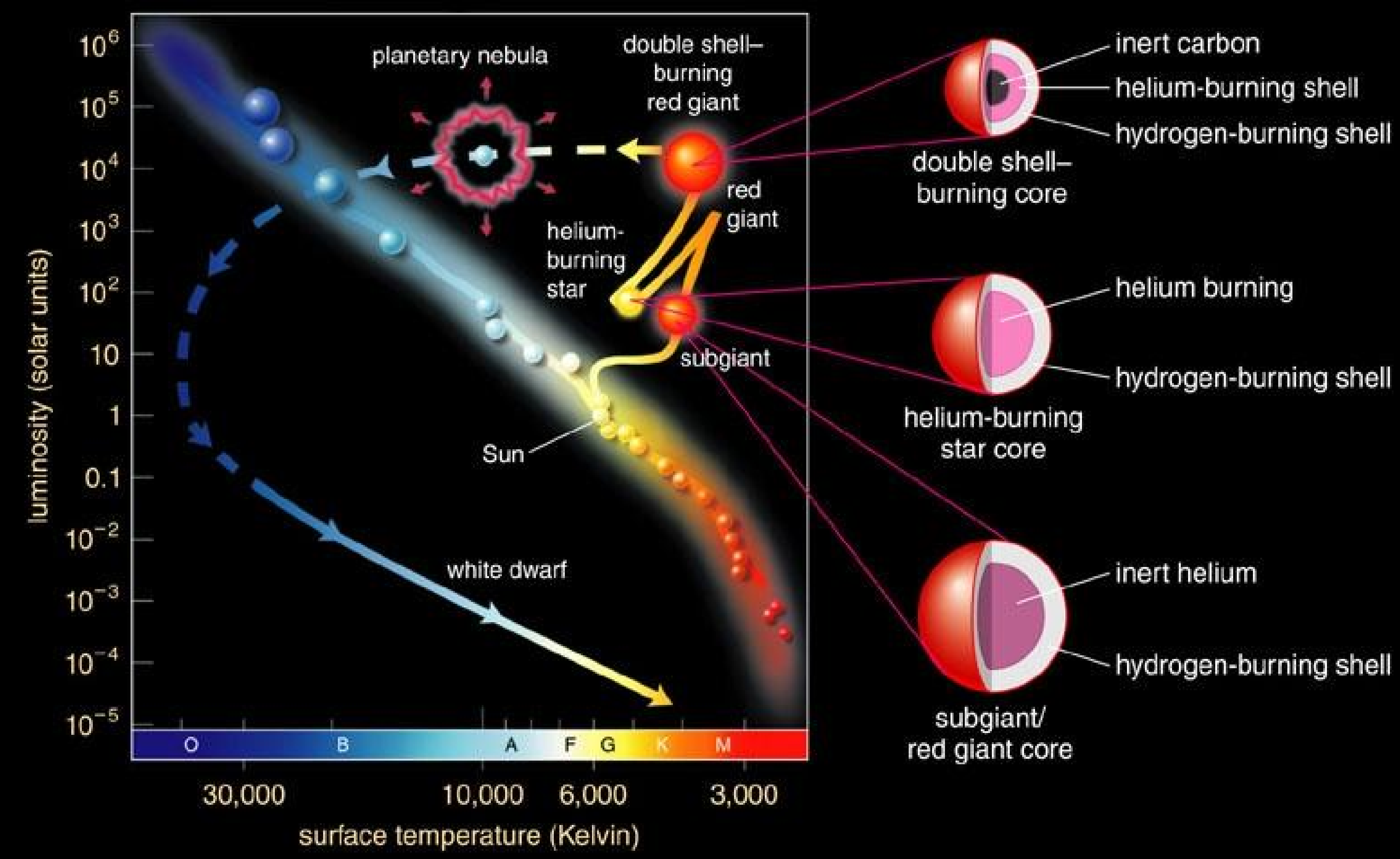

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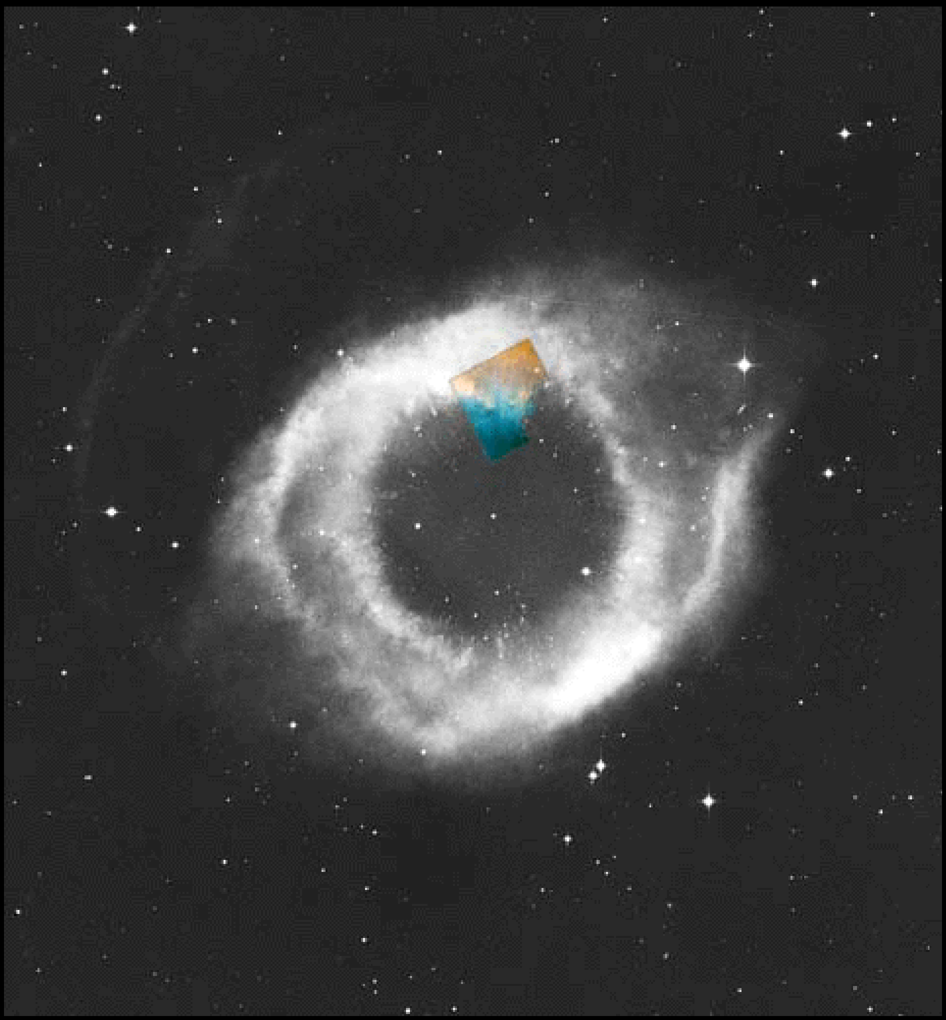
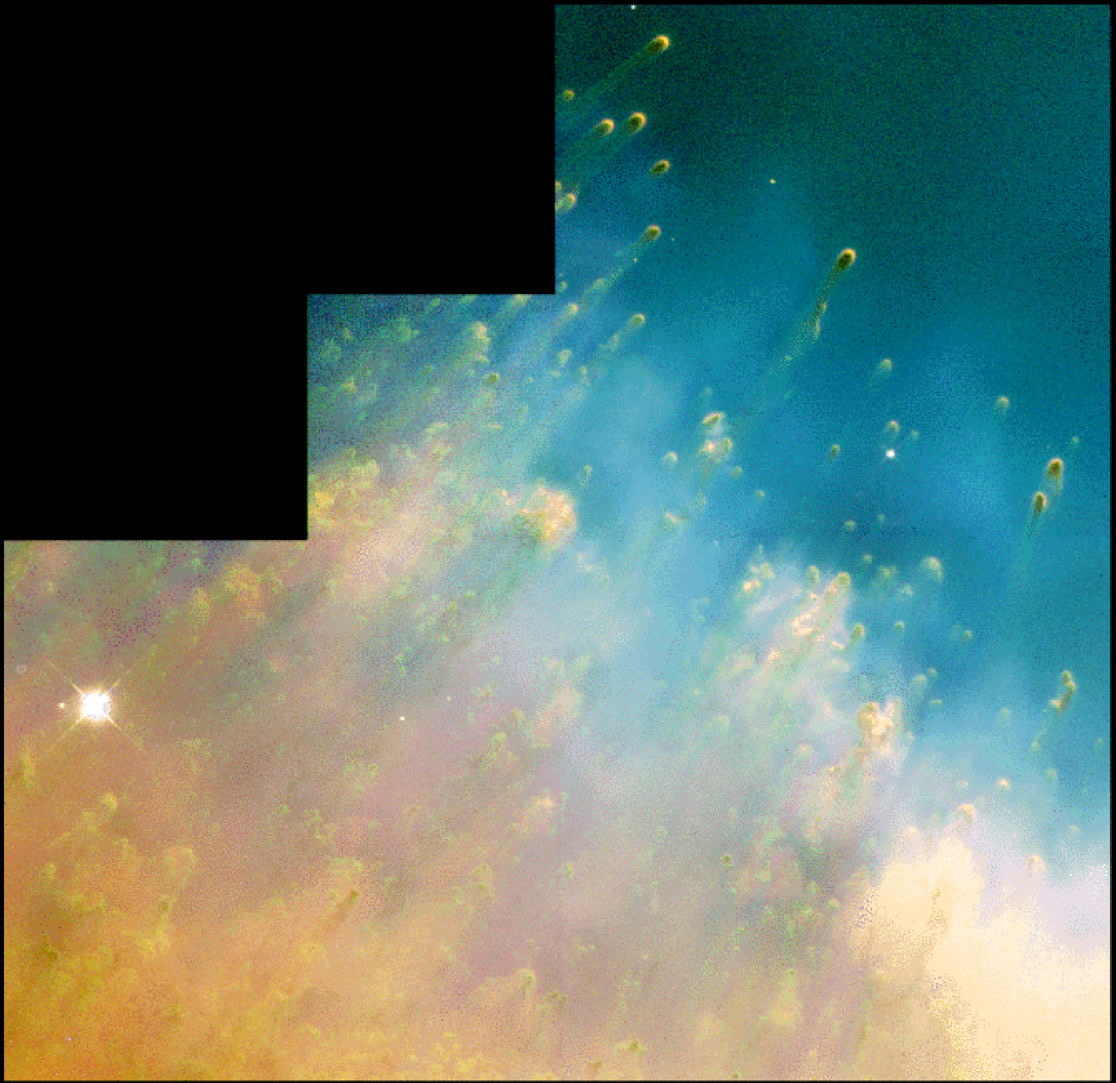
PN: mass loss made visible

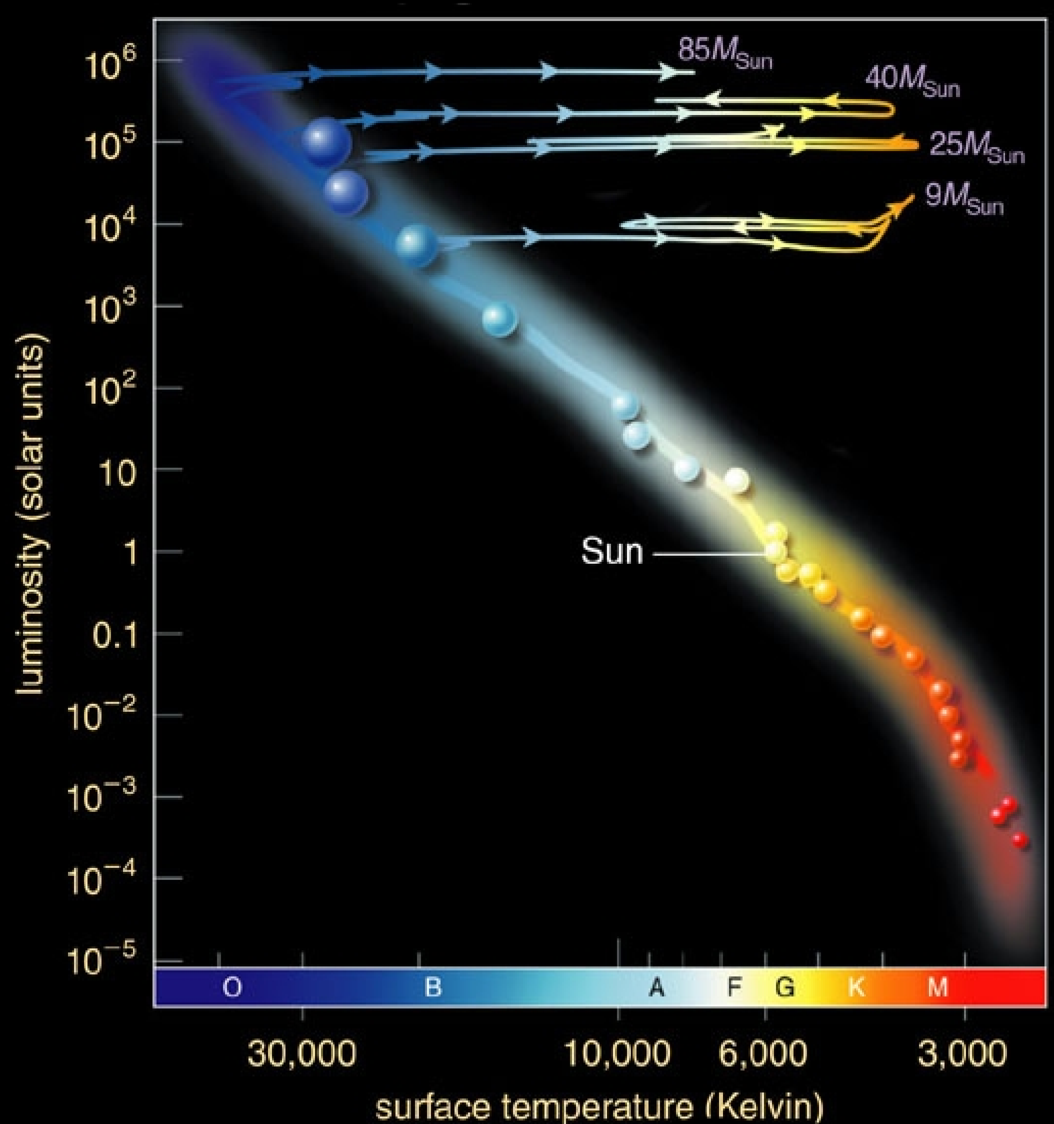


Helix Nebula • NGC 7293 • Las Campanas Observatory and HST
Black & White: J. Bedke (CSC/STScI), Carnegie Institution of Washington
Color Inset: C.R. O'Dell (Rice Univ.), NASA



Helix Nebula • NGC 7293 HST • WFPC2
PRC96-13a • ST ScI OPO • April 15, 1996 • C.R. O'Dell (Rice Univ.), NASA

Stellar Evolution: High Mass Stars



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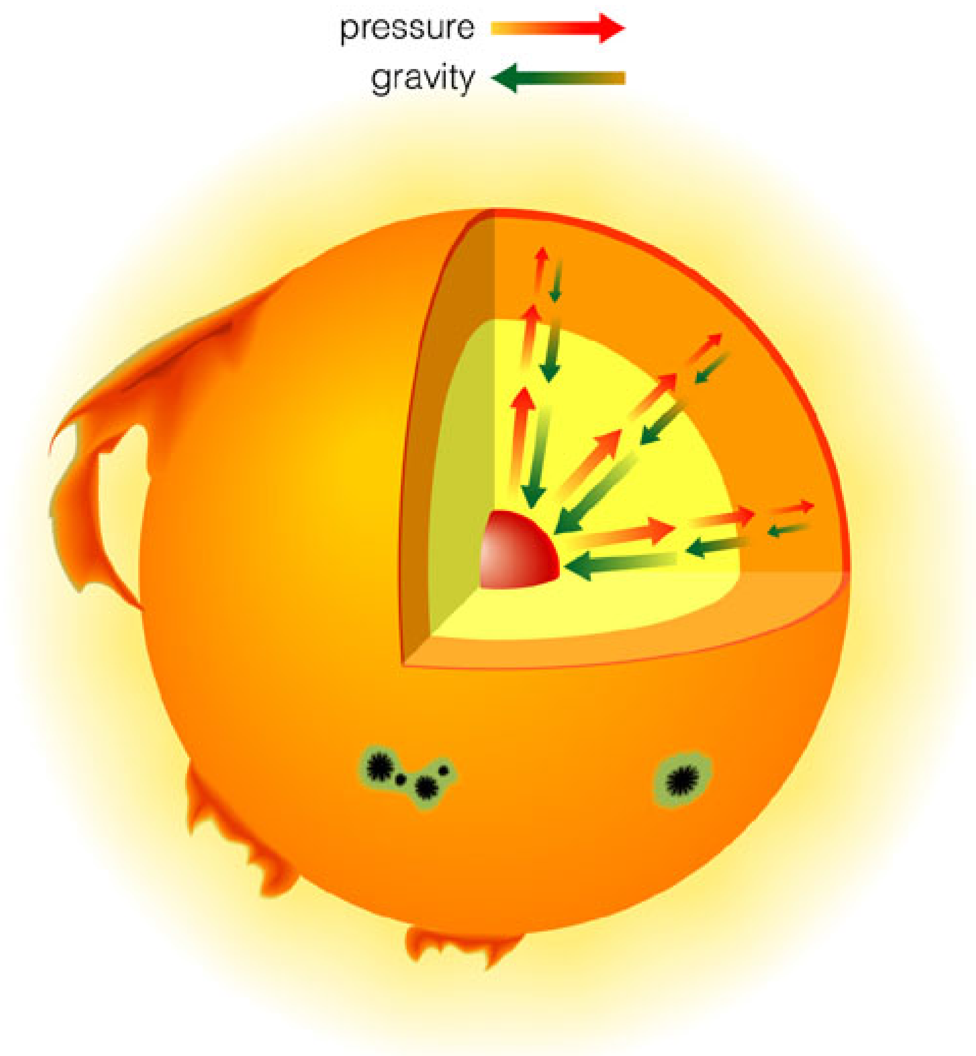
Stellar Structure: Pressure vs. Gravity



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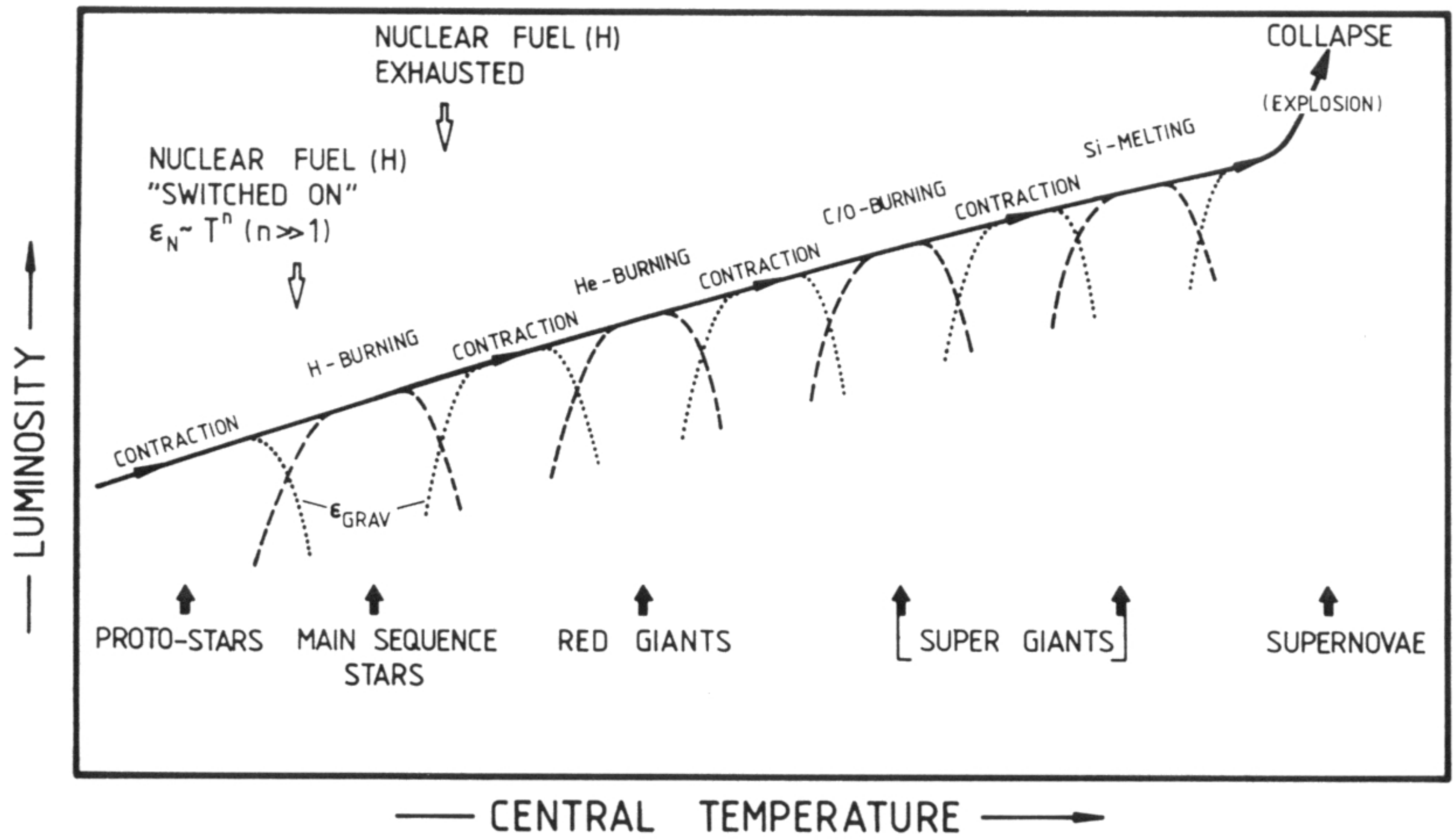
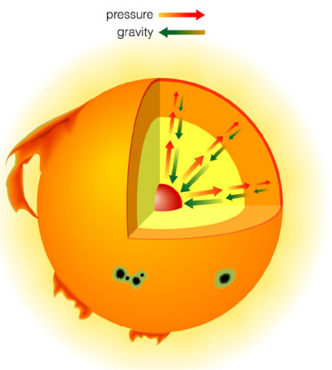
Stellar Evolution: Burning Phases





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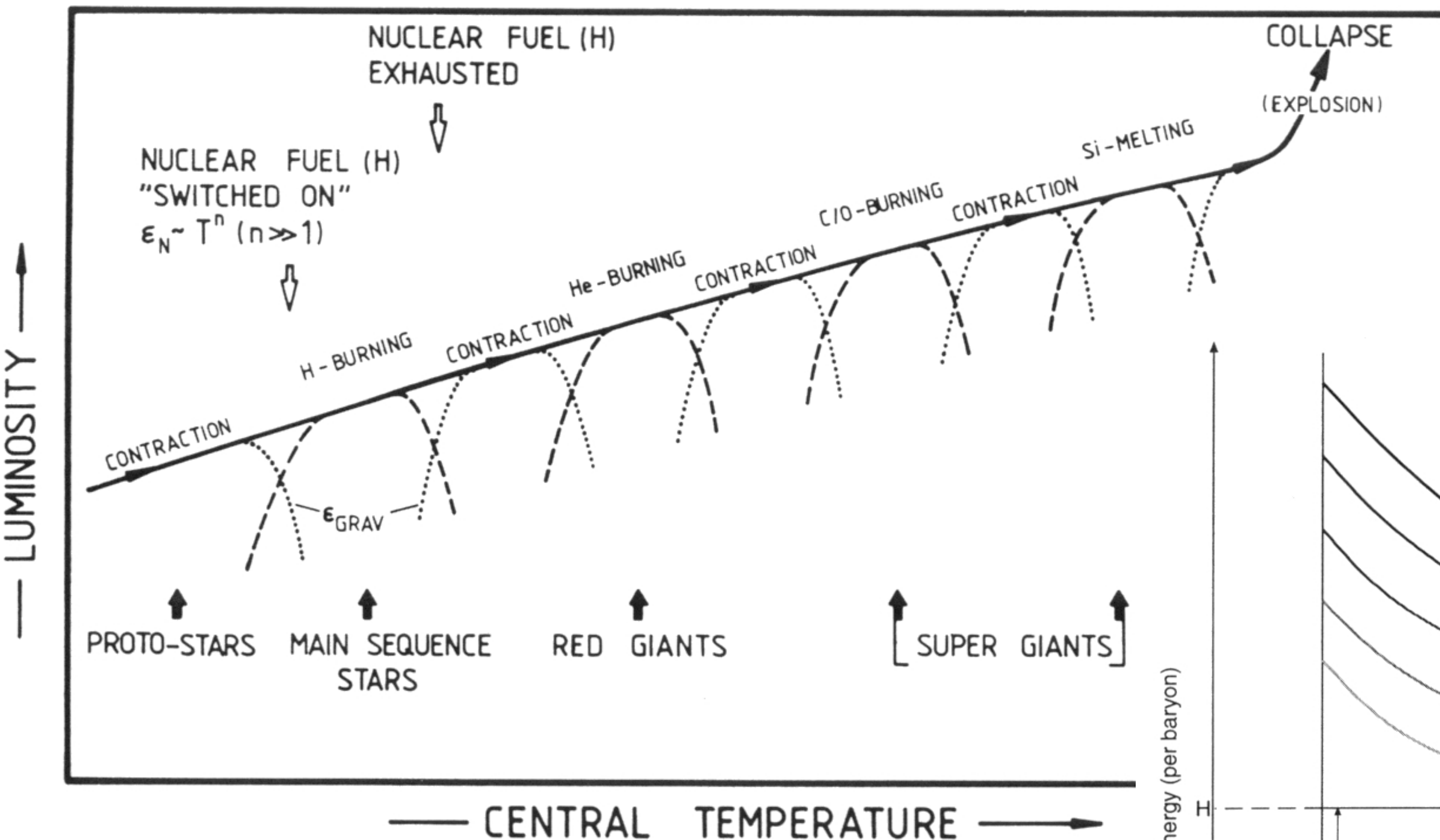

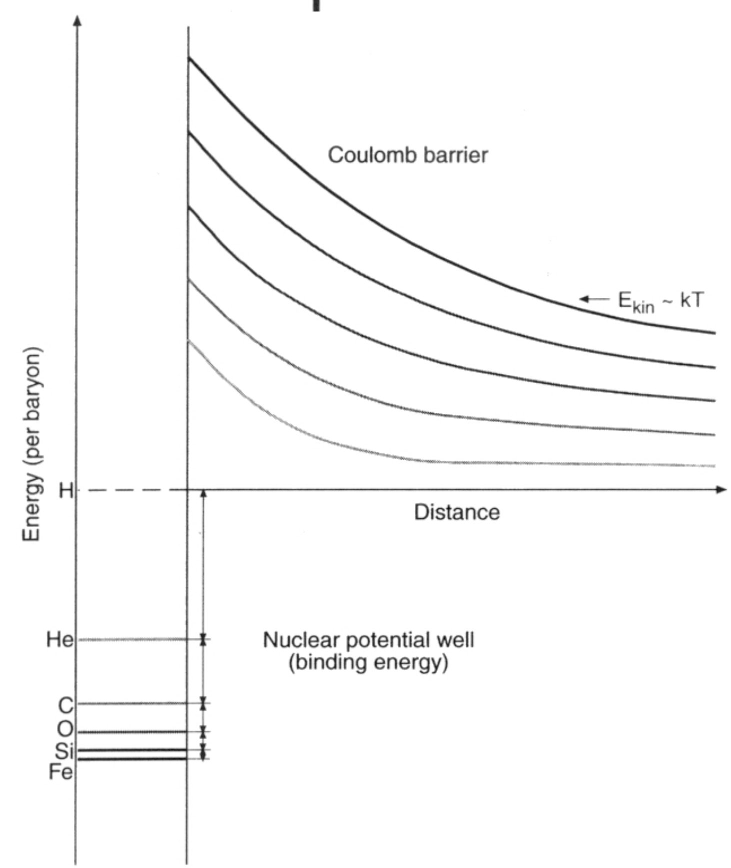

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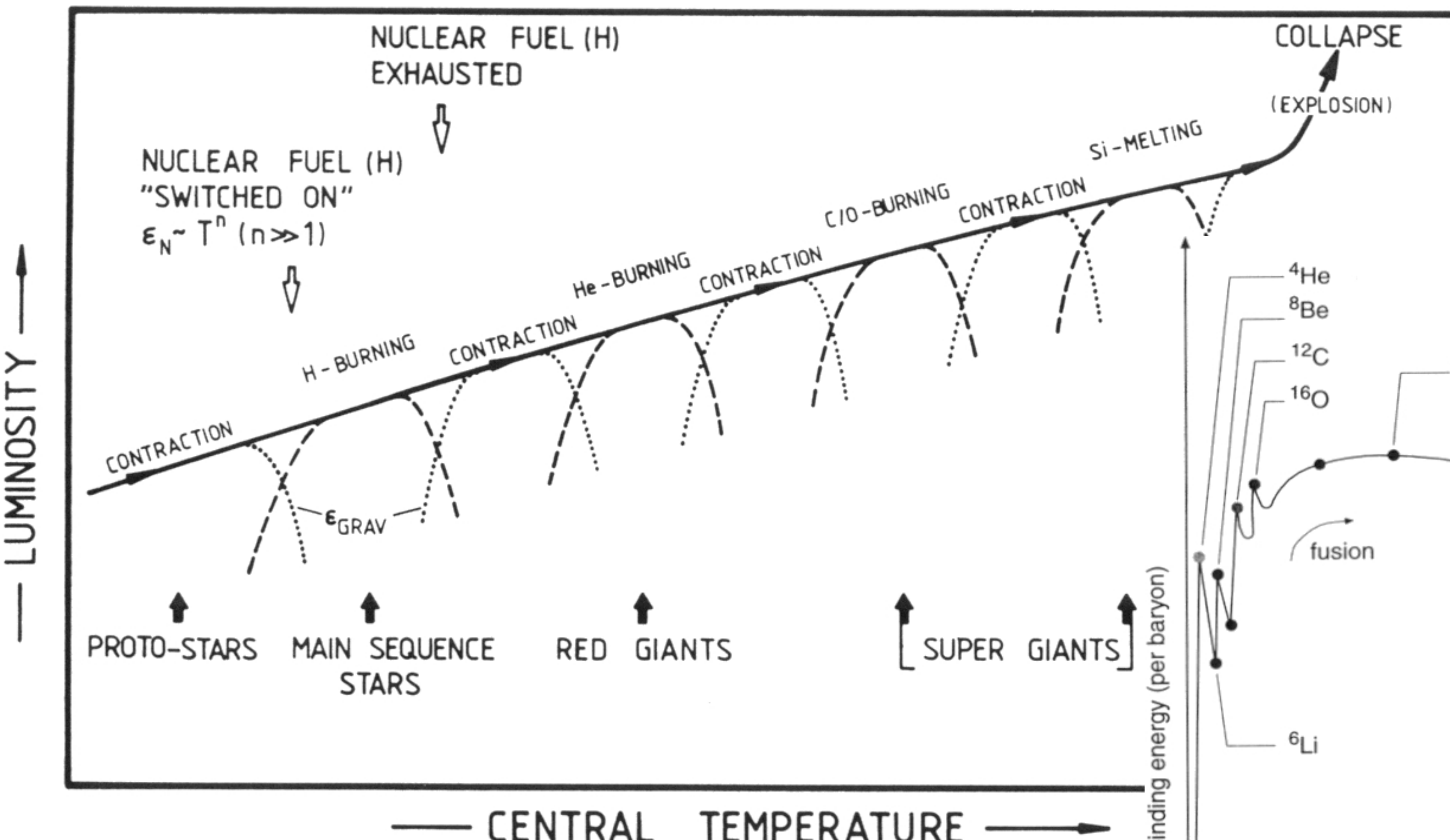

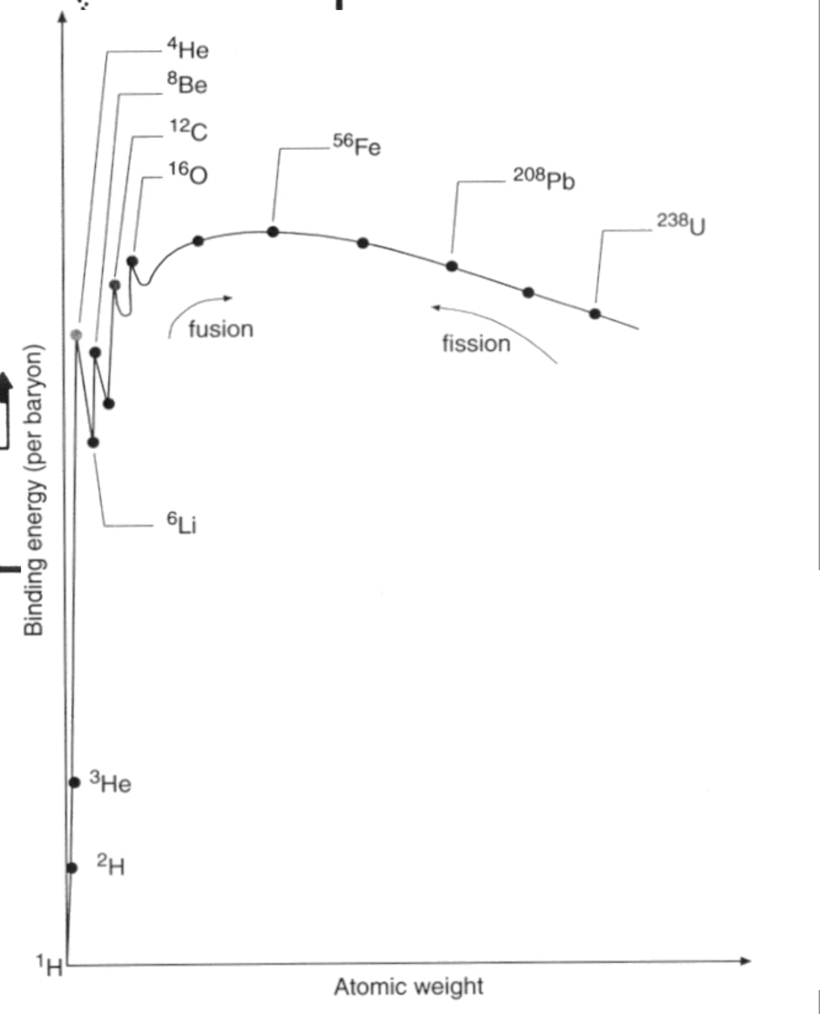

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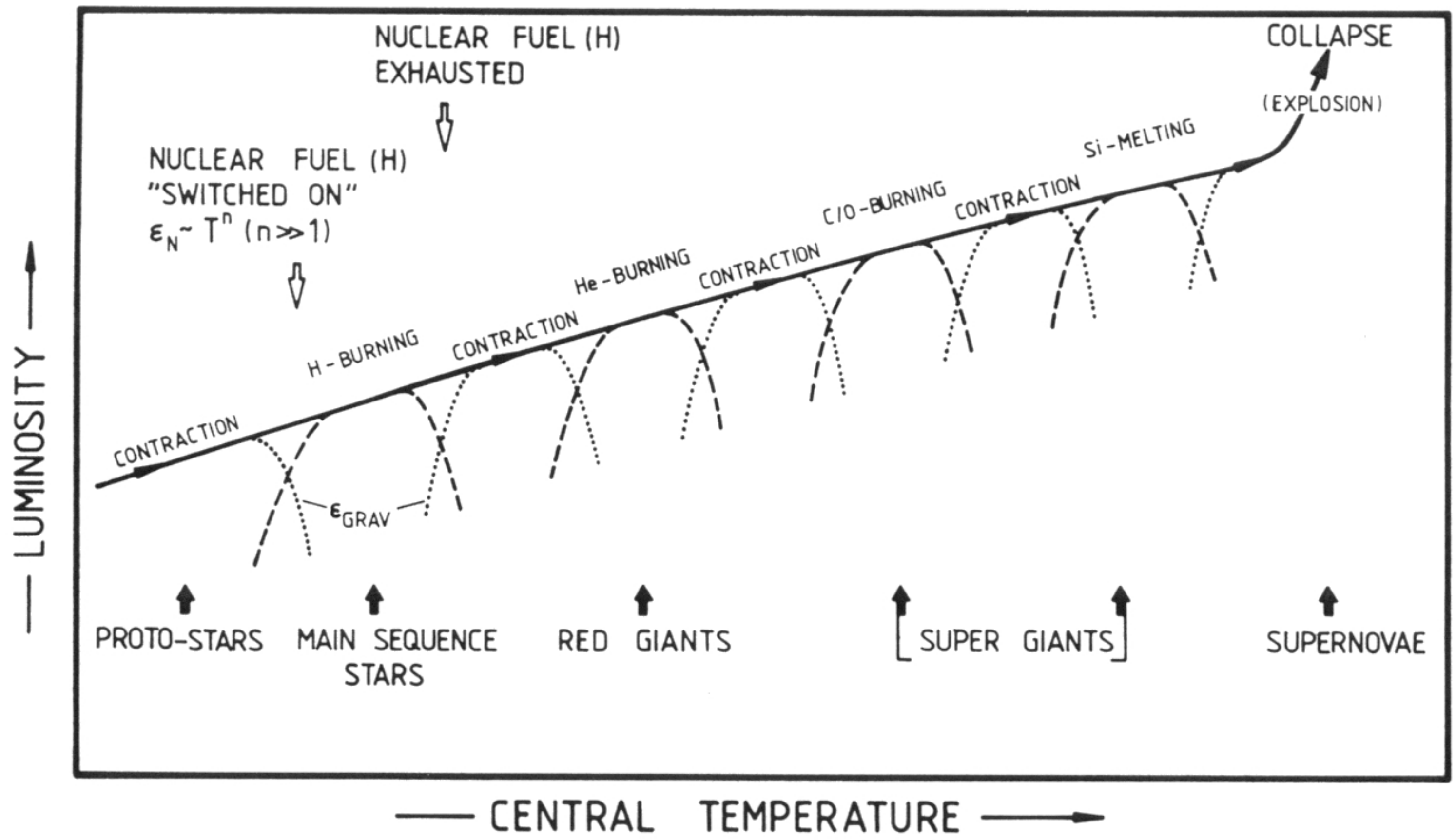

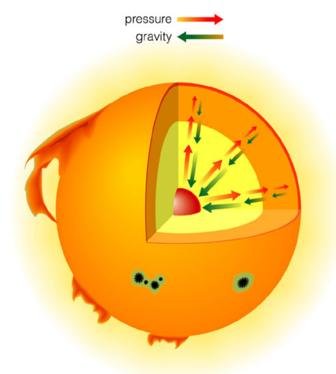

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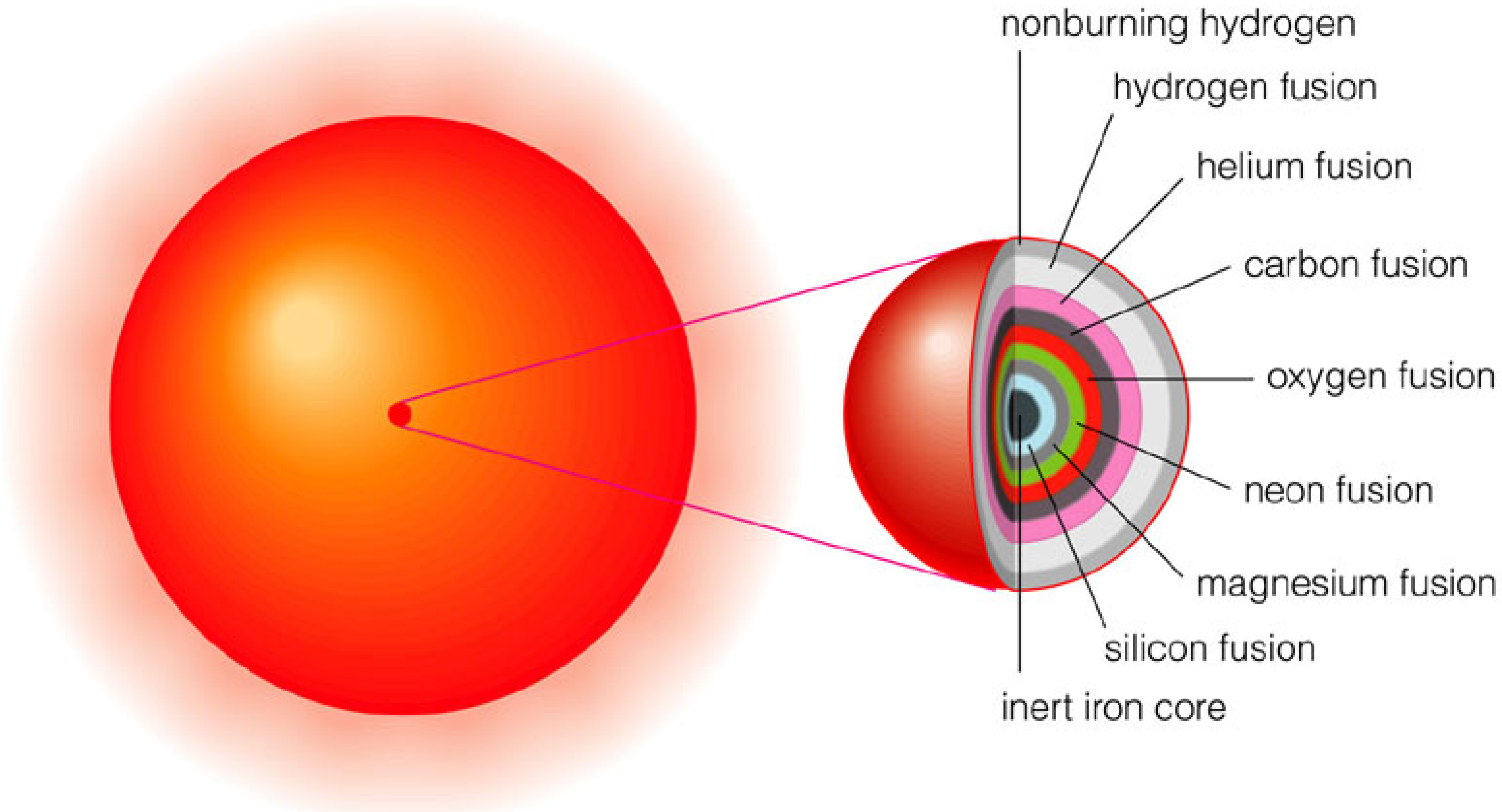
Stellar Evolution: High Mass Stars



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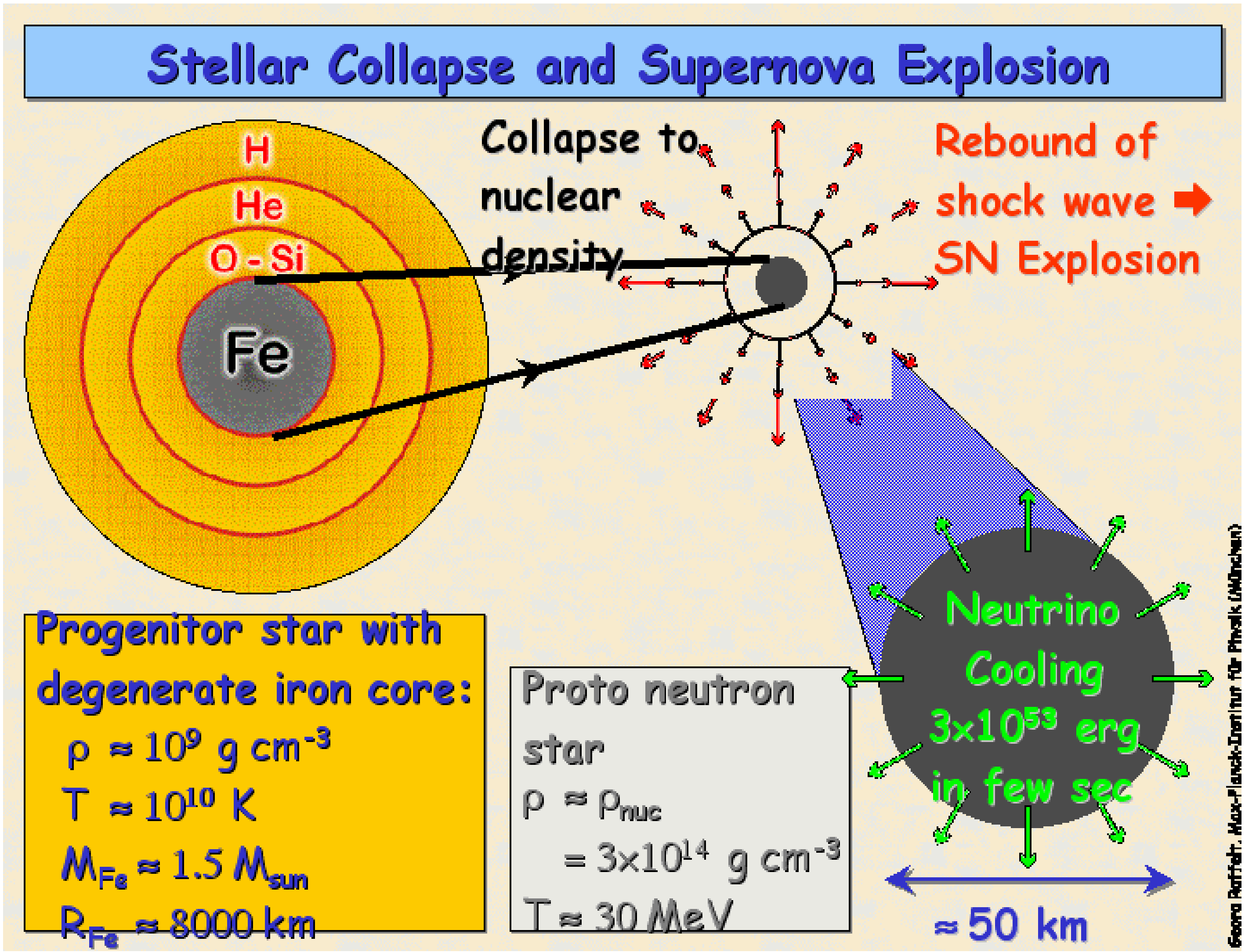
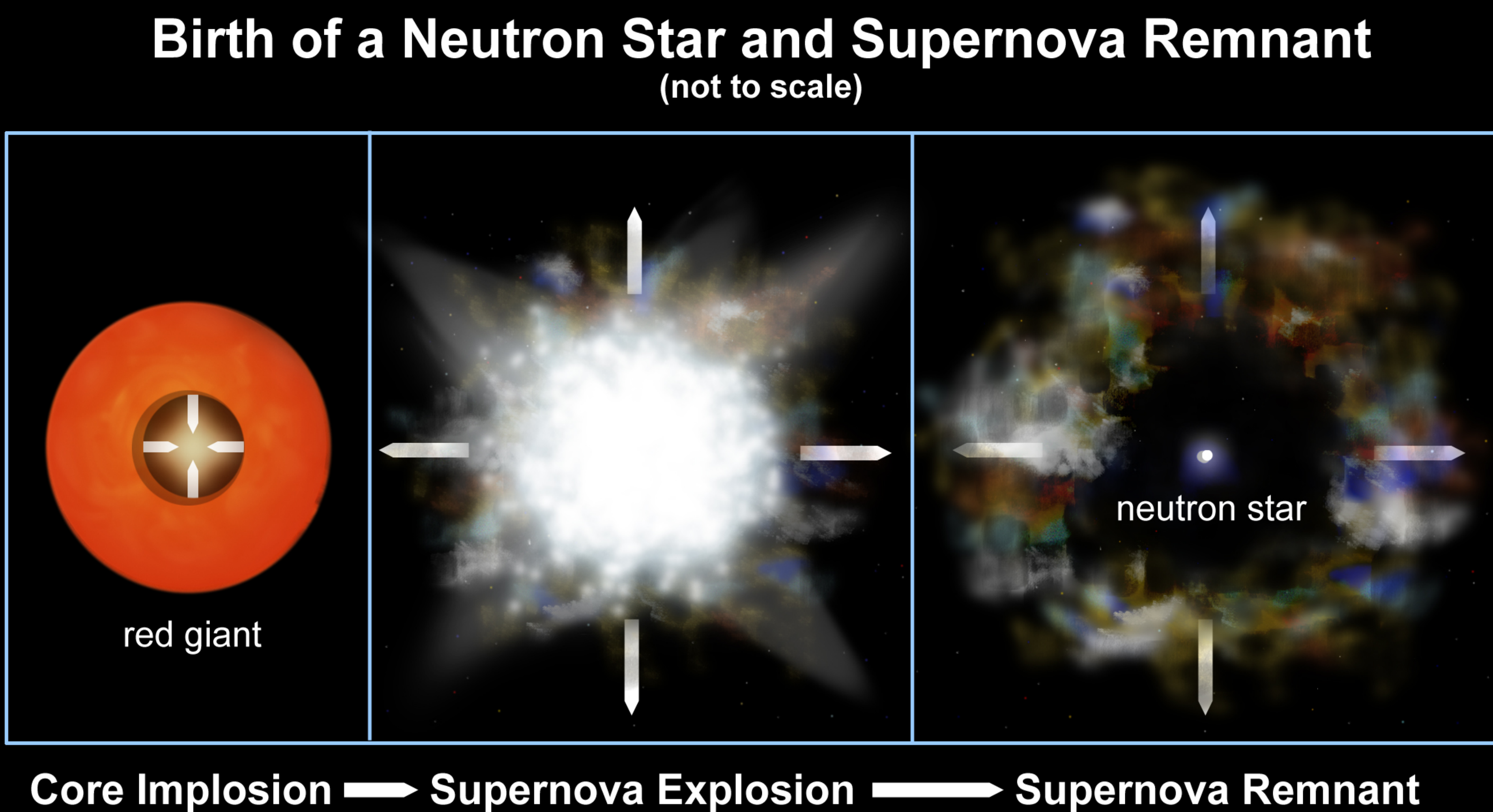
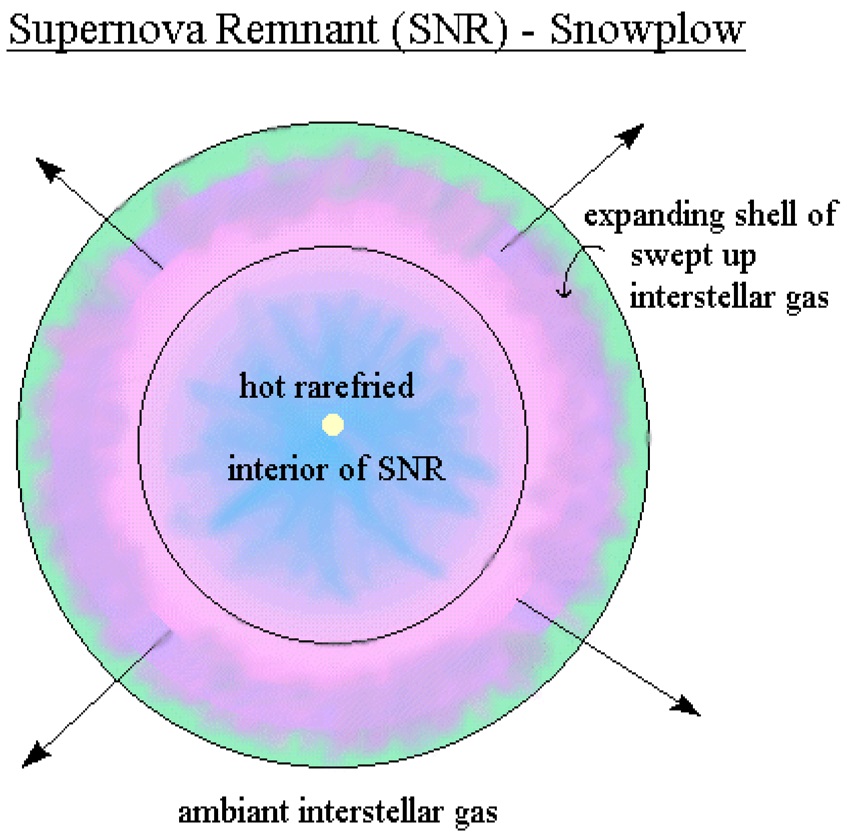
Stellar Evolution: High Mass Stars



Formation of a SNR



SNR: Expansion & Interaction with ISM



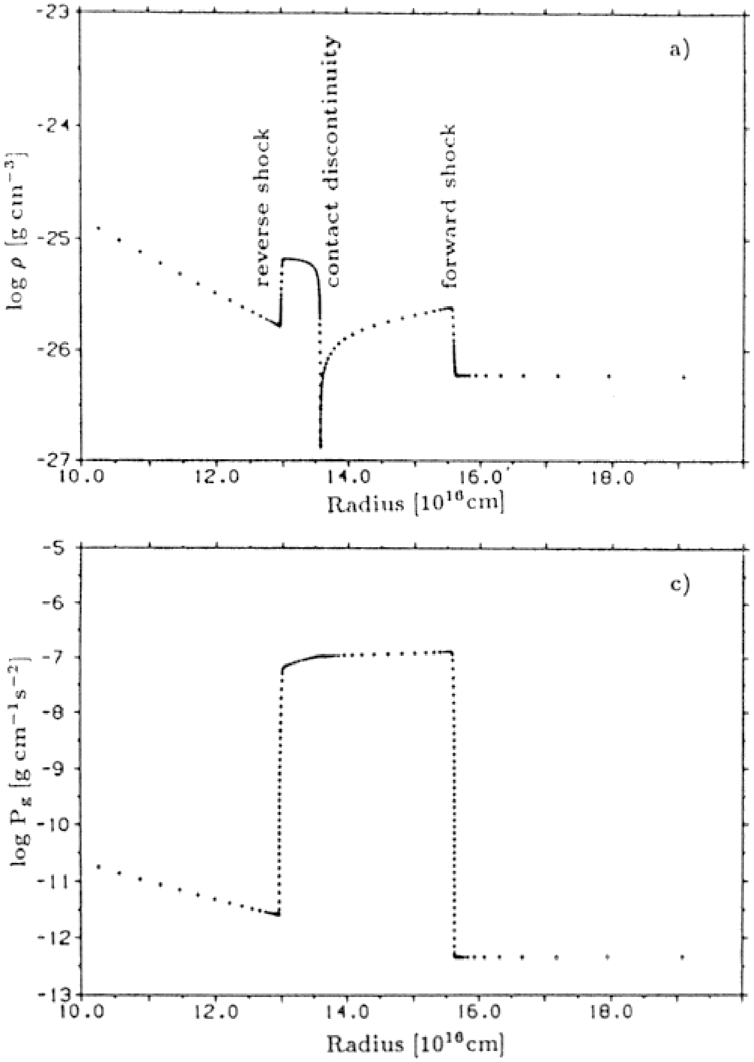
- How fast will the SNR expand, and on which typical timescales ?

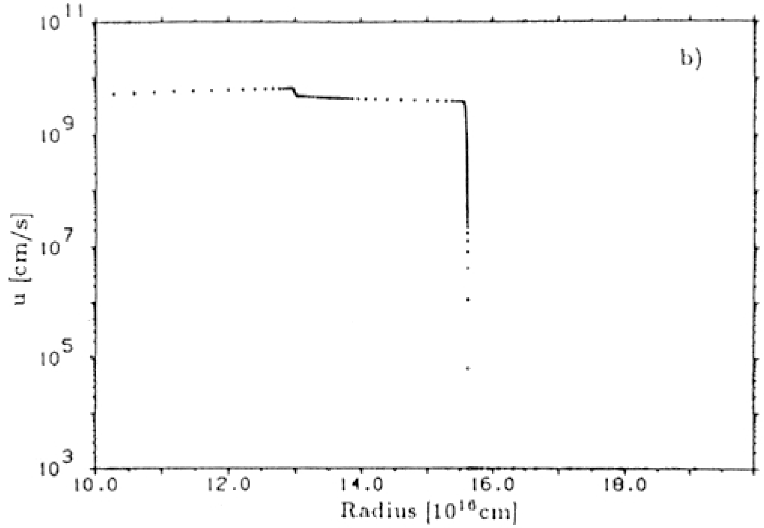
- What are the dominant physical processes ?

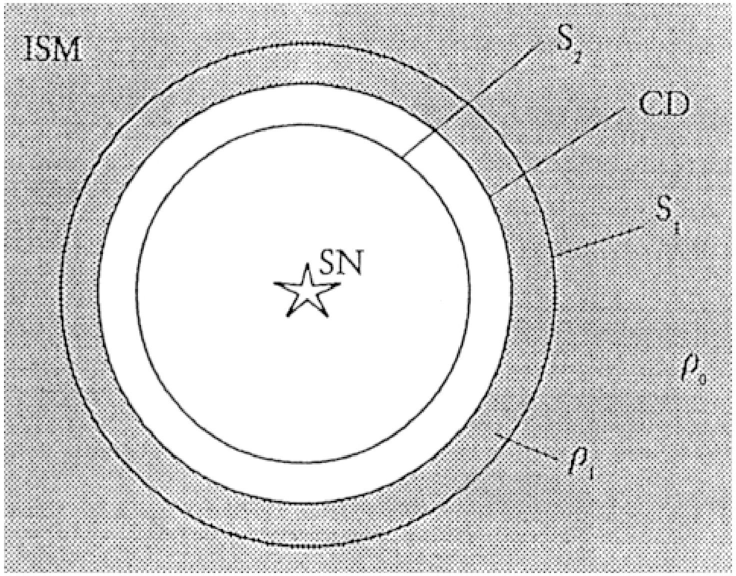
- What are typical temperatures and densities ?

- How will the SNR interact with the surrounding ISM ?

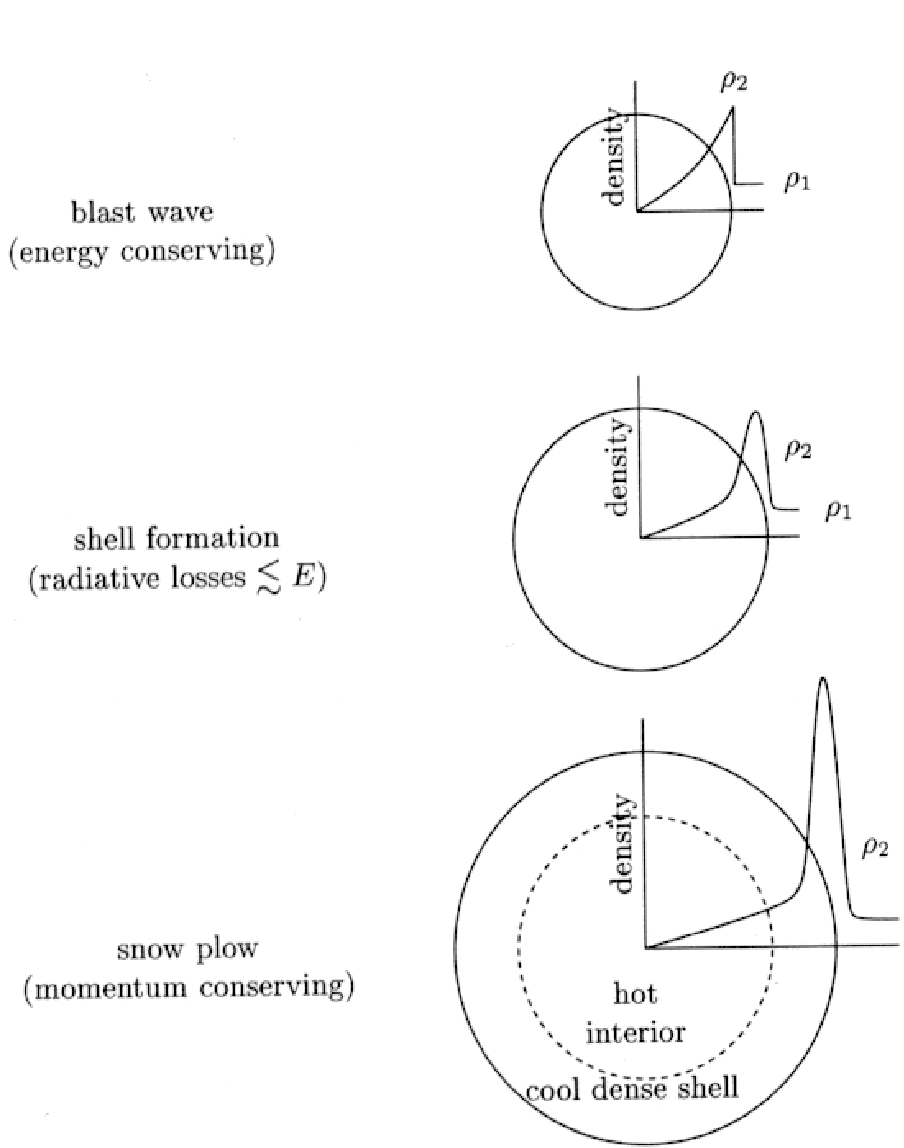
SNR: Free Expansion Phase

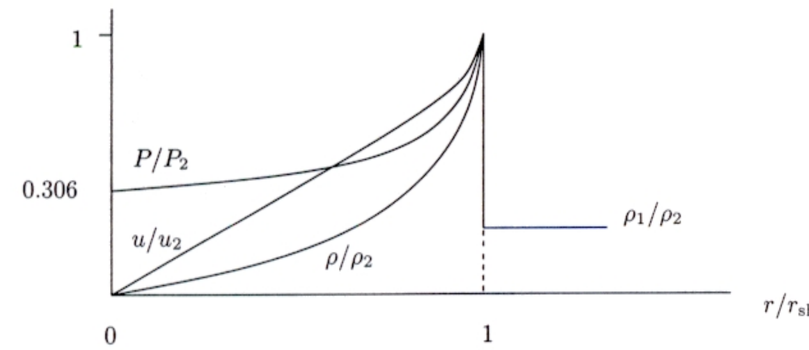


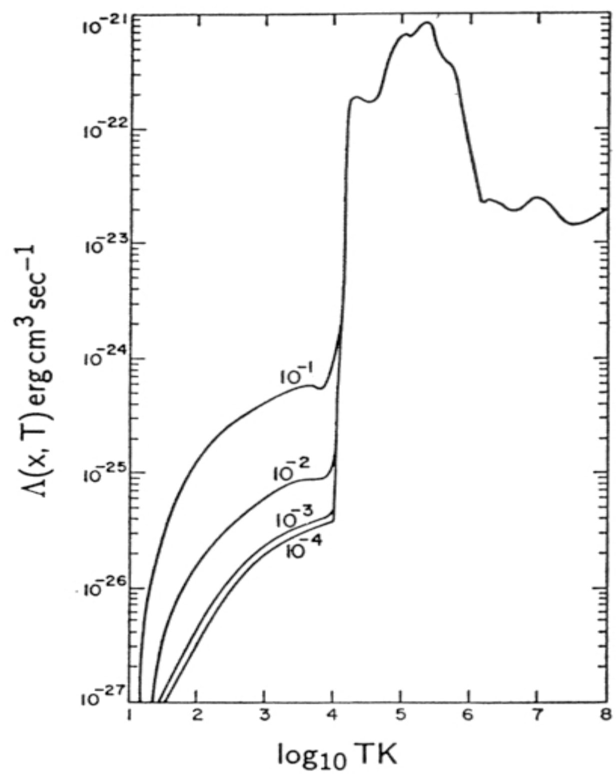




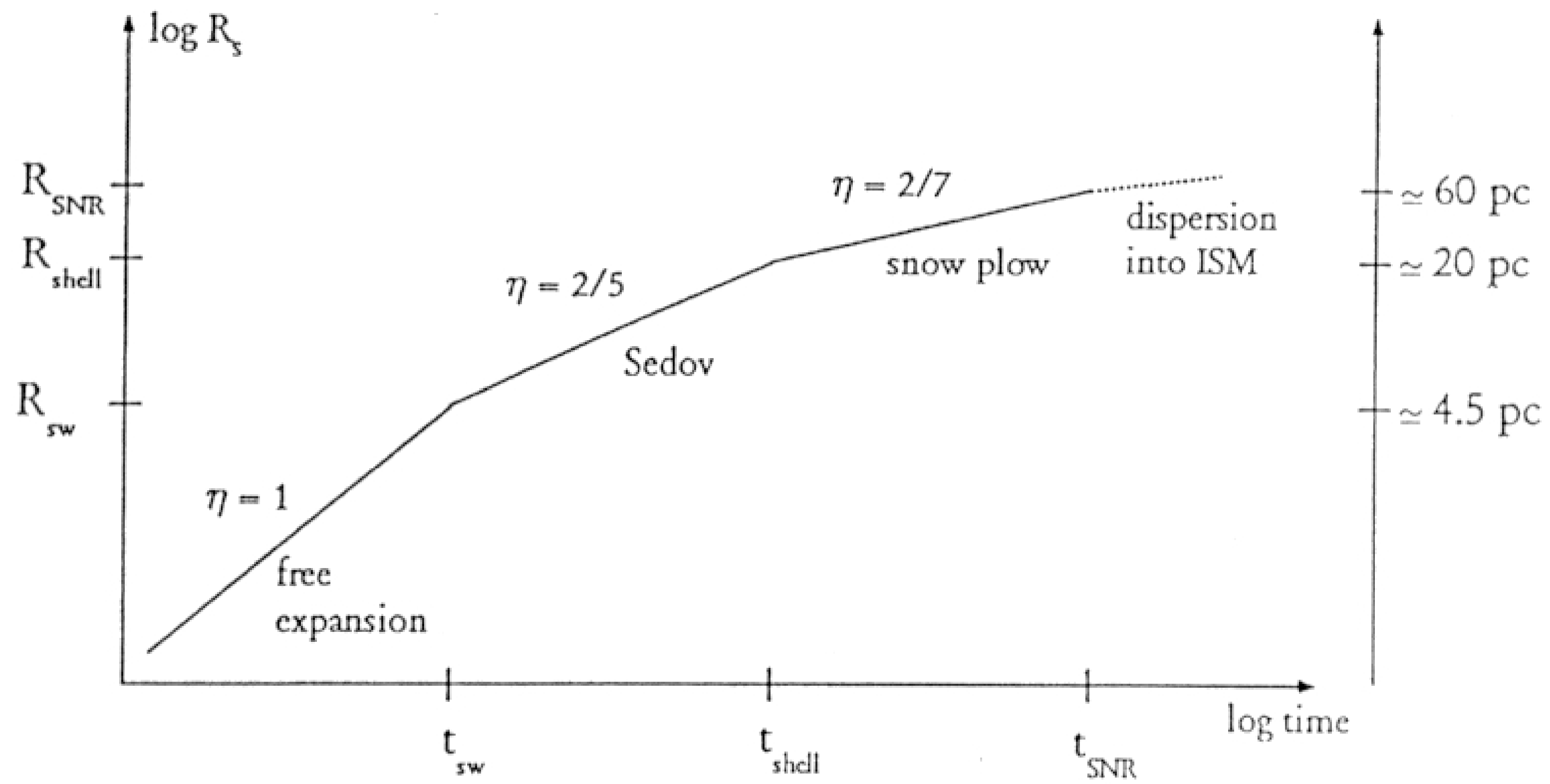
SNR: Expansion & Interaction with ISM



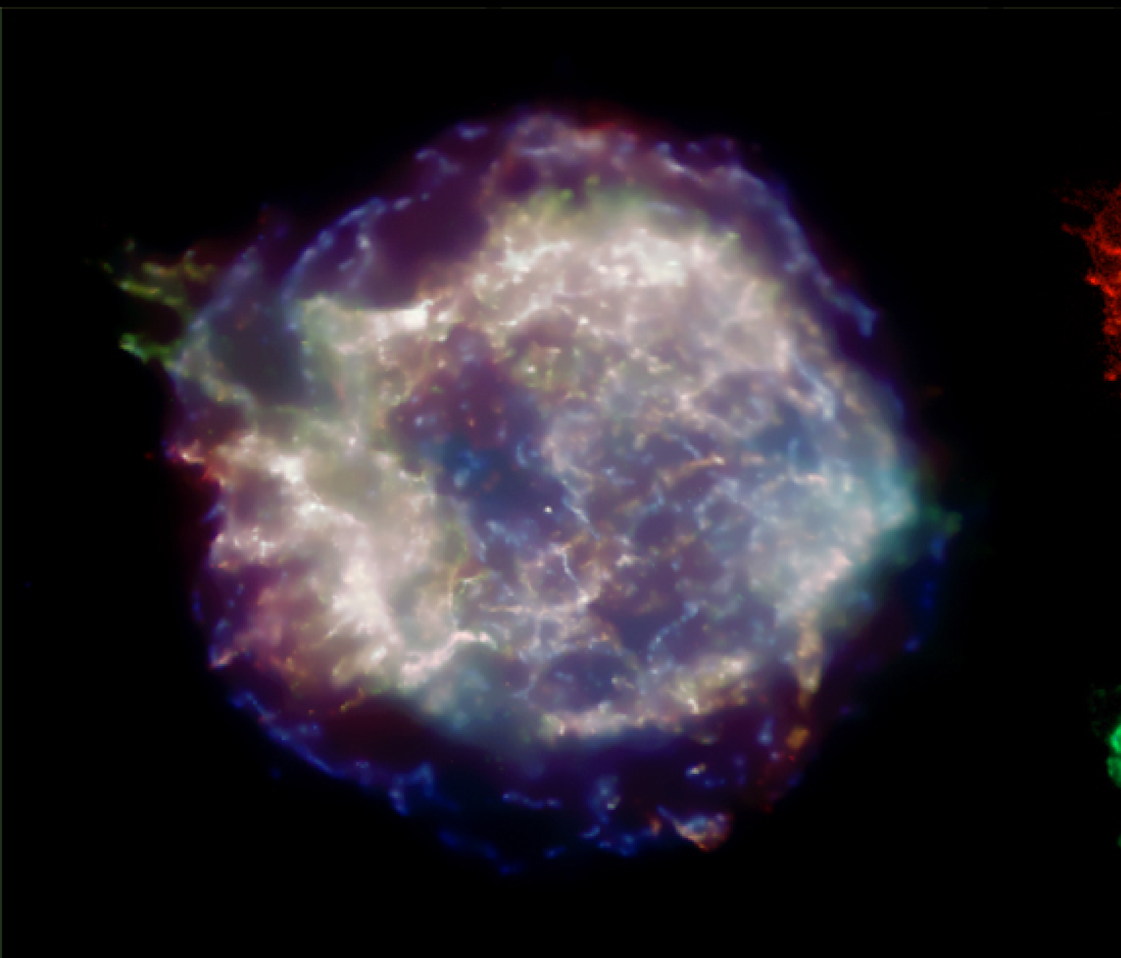




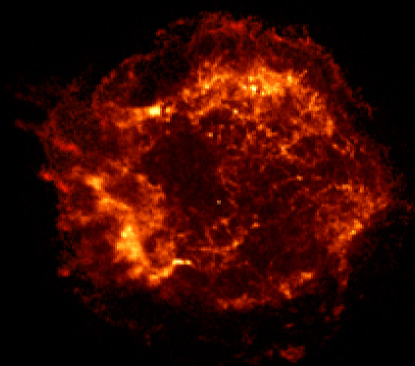
SNR: Expansion & Interaction with ISM



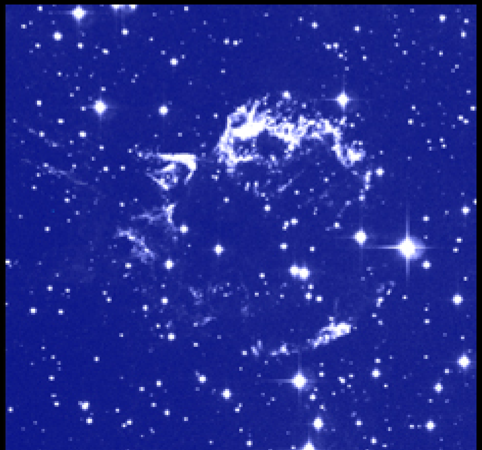
Example: Cas A SNR



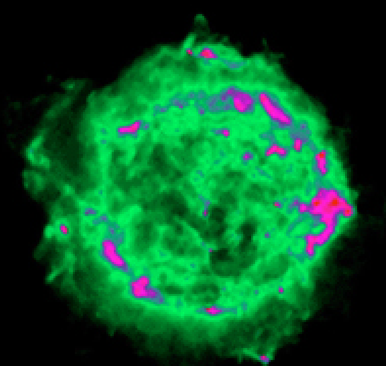
Chandra image (X-rays)



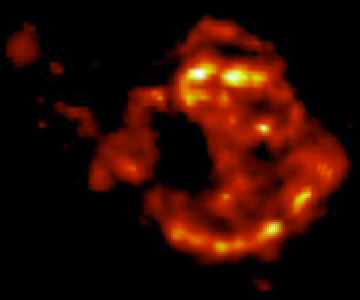
X-Ray (NASA/CXC/SAO)



Optical (MDM Obs.)

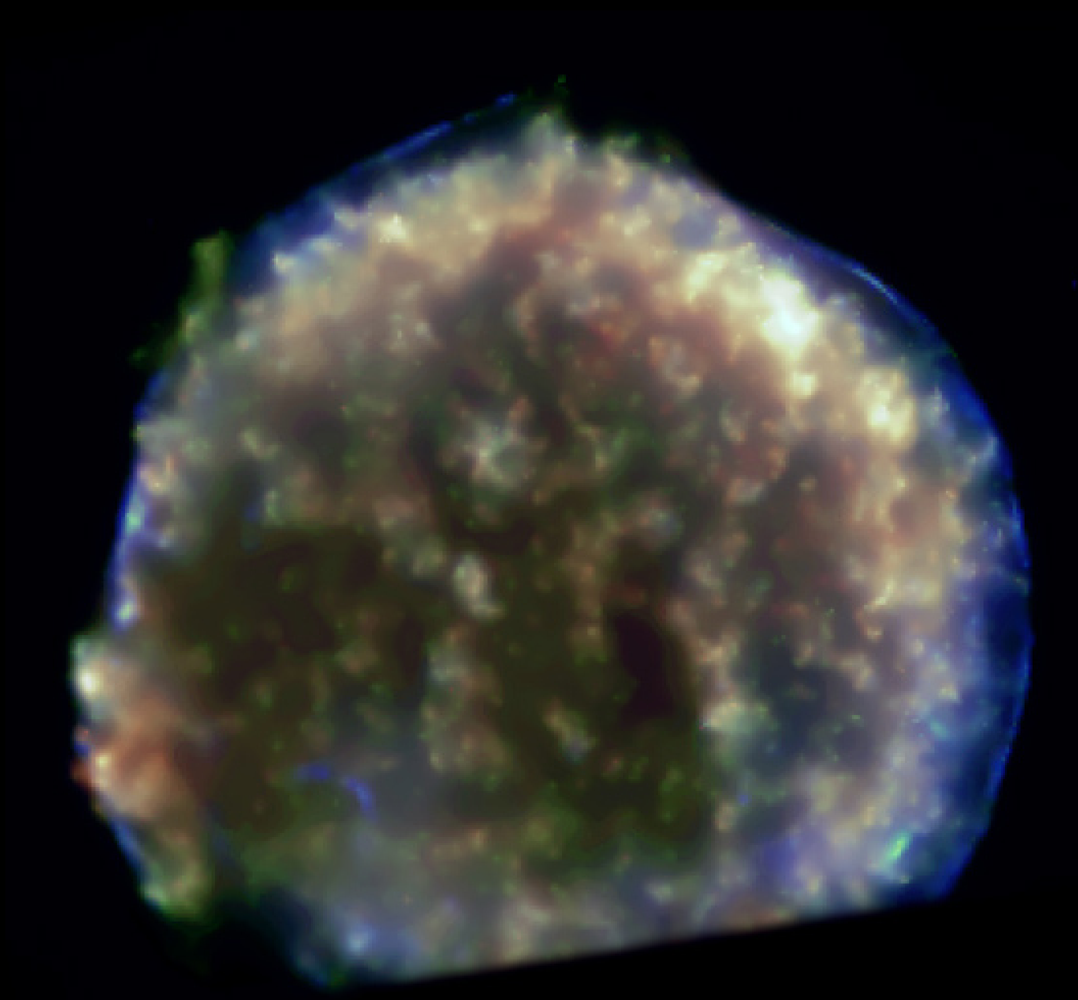


Radio (VLA)



Infrared (ISO)

Example: Tycho's SNR



SN event observed by
T.Brahe in 1572

no stellar remnant:
SN type Ia

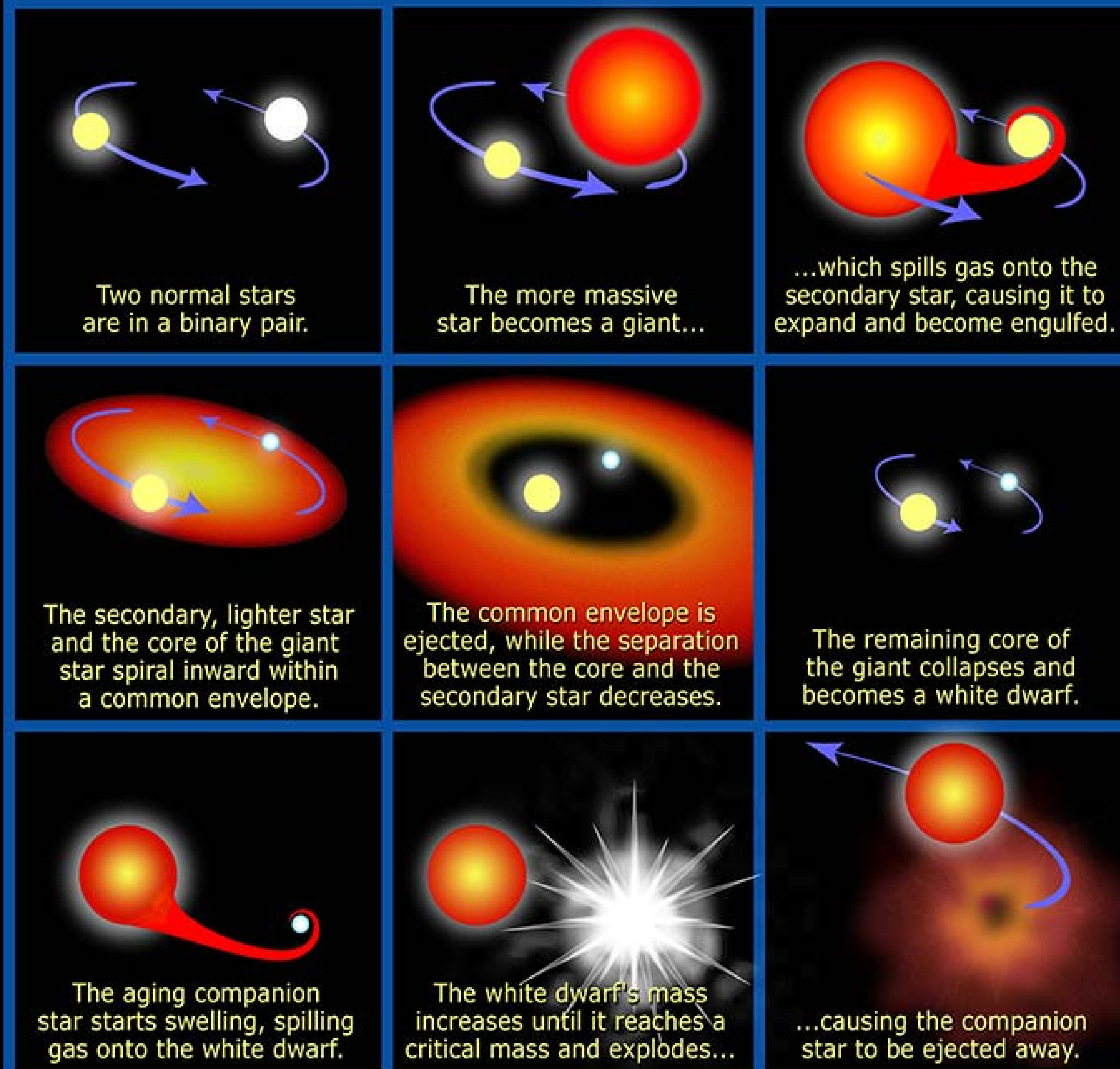
Chandra image:
- X-rays
- colours: diff. energies
- blue rim:
  shock, 20 million K
- fingers: stellar debris,
  10 million K

Classification of Supernovae

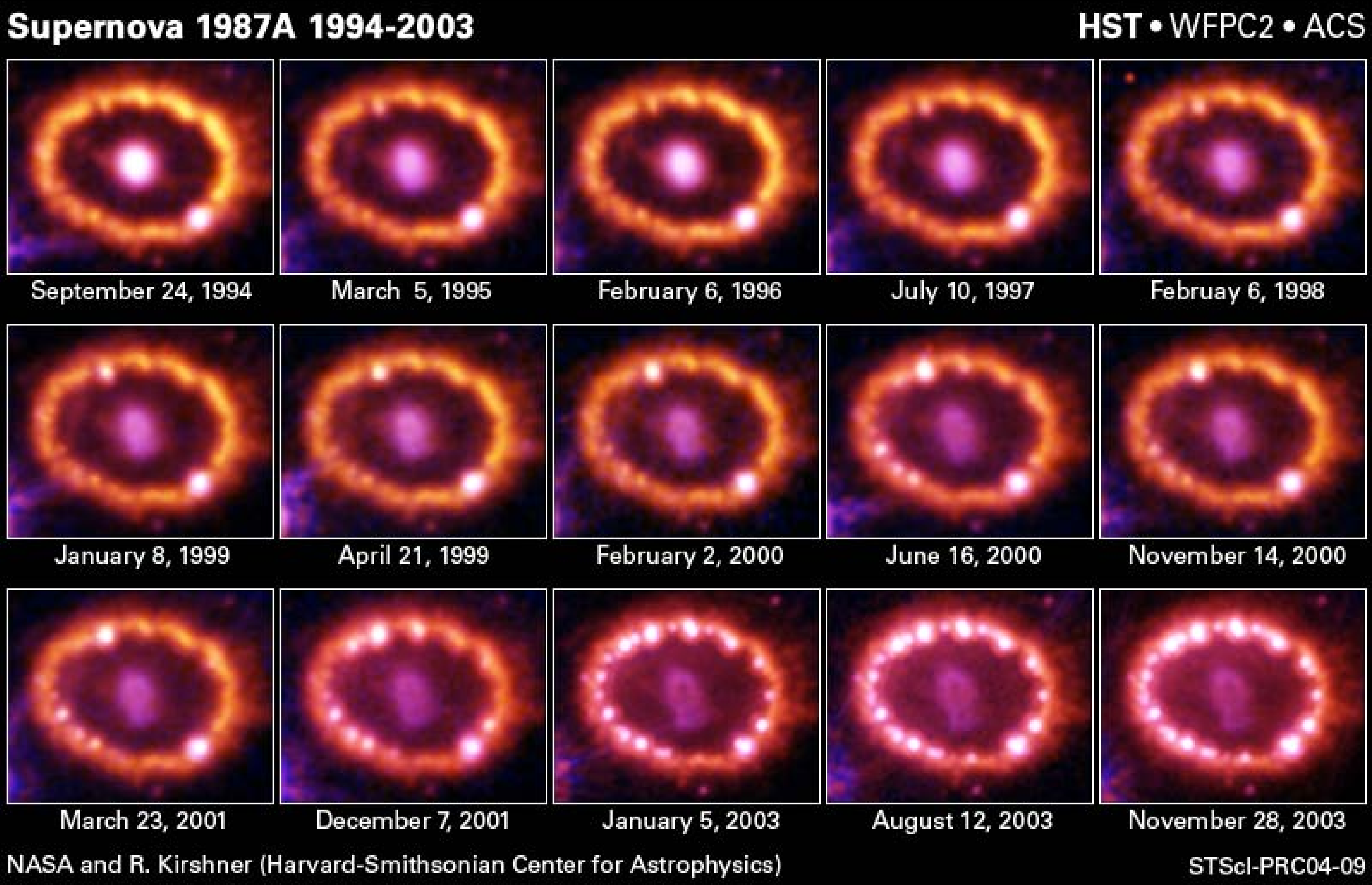
Type	Ia	Ib	Ic	II
Spectrum	No Hydrogen			Hydrogen
	Silicon	No Silicon		
		Helium	No Helium	
Physical mechanism	Nuclear explosion of low mass star	Core collapse of evolved massive star (may have lost its hydrogen or even helium envelope during red-giant evolution)		
Light curve	Reproducible	Large Variations		
Neutrinos	Insignificant	~ 100 x Visible energy		
Compact Remnant	None	Neutron star (typically appears as pulsar) Sometimes black hole ?		
Rate/h^2SNu	0.36 ± 0.11	0.14 ± 0.07		0.71 ± 0.34
Observed	Total ~ 2000 as of today (nowadays ~200/year)			

Georg Raffelt, Max-Planck-Institut für Physik (München)

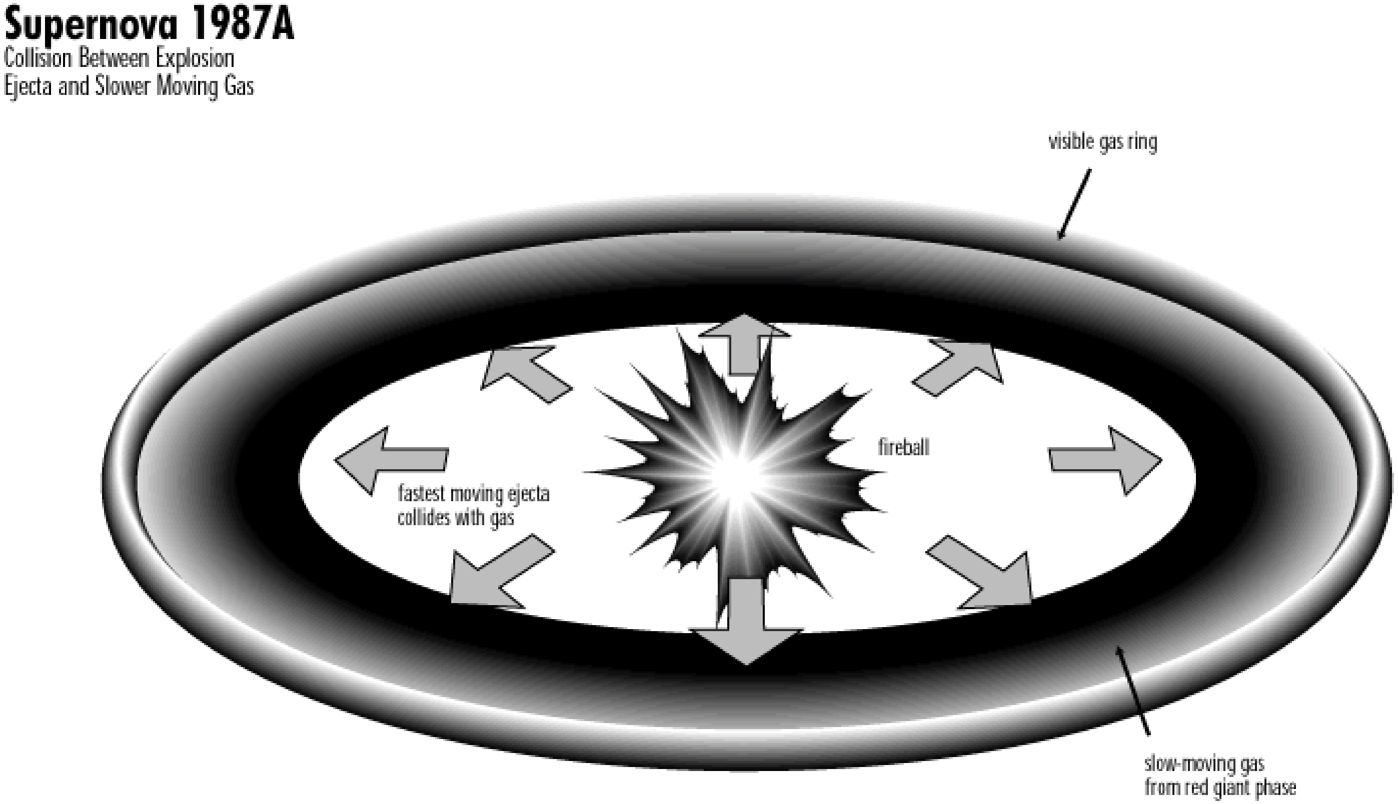
The progenitor of a Type Ia supernova



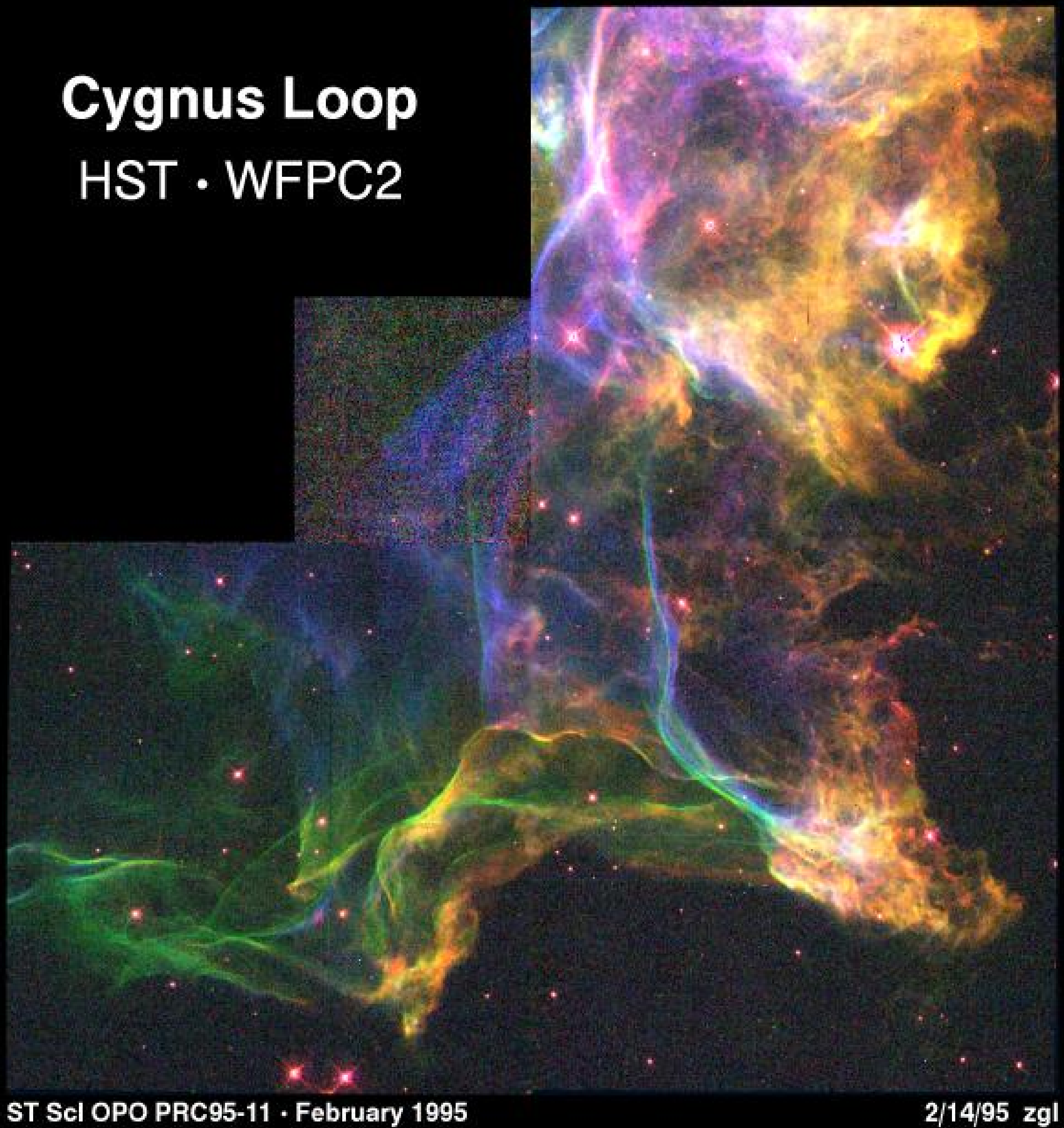
Example: SN 1987A



Example: SN 1987A



Example: Cygnus Loop



SN explosion took place about 15 000 years ago

HST picture shows only a small part of the SNR

the shock wave (moving left to right) is hitting denser IS gas

blue: O (doubly ionized)
hot gas behind shock
red: S (singly ionized)
cooler gas
green: H
directly behind shock