Planetary Nebulae

David Huijser

Planetary Nebula

- Brief history of spectroscopy
- More details spectroscopy
- PN and their characteristics
- Evolution of PN
- overview and main conclusion

History of Spectroscopy

- “We will never know how to study by any means the chemical composition of the stars”

  Auguste Comte 1835

History of Spectroscopy

- Fraunhofer 1814 → spectrum sun
- Becquerel 1842 → photograph spectrum
- Foucault 1852 → sodium coincide D line's
- Kirchoff 1859 → Kirchoff's Law
- Huggins 1864 → identified H, Fe, Na, Ca in stars
- Secchi 1863 → spectral types

History of Spectroscopy

- The ratio between the powers of emission and the powers of absorption for rays of the same wavelength is constant for all bodies at the same temperature

$$\frac{\varepsilon_\lambda(T)}{k_\lambda(T)} = cons\tan t$$

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- Fraunhofer 1814 → spectrum sun
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History of Spectroscopy

- **O**h, **B**e **A** **F**ine **G**irl, **K**iss **M**e
- Balmer 1885 →
- Thomson 1897 → electron
- Planck 1897 → Black-body energy
- Einstein 1900 → Quanta
- Rutherford 1908 → structure of atoms
- Bohr 1913 → quantized orbits

Introduction to spectroscopy

- chemical composition
- temperature
- abundance of species
- motion
- pressure
- magnetic fields

Introduction to spectroscopy

- 1. It's important spectral lines
- 2. It's energy level structure
- 3. The intrinsic line strength of the transition(s) being observed
- 4. The precise rest, in other words: laboratory wavelengths of any transition observed

What is a Planetary Nebula ?

- “A planetary nebula is an astronomical object consisting of a glowing shell of gas and plasma formed by certain types of stars at the end of their lives. “

http://en.wikipedia.org/wiki/Planetary_nebula

Morphology

- **Classification of Shape**
- Dynamical classification
- I planetoid nebula
- II double envelope
- III ring like
- B bipolarity
- degree of bi-polarity
- a increase of brightness on ends of minor axis
- b “caps”
- c “caps” separated
- d “rectangular” “hour-glass”
- Sp spiral
- D transition objects, diffuse

Morphology

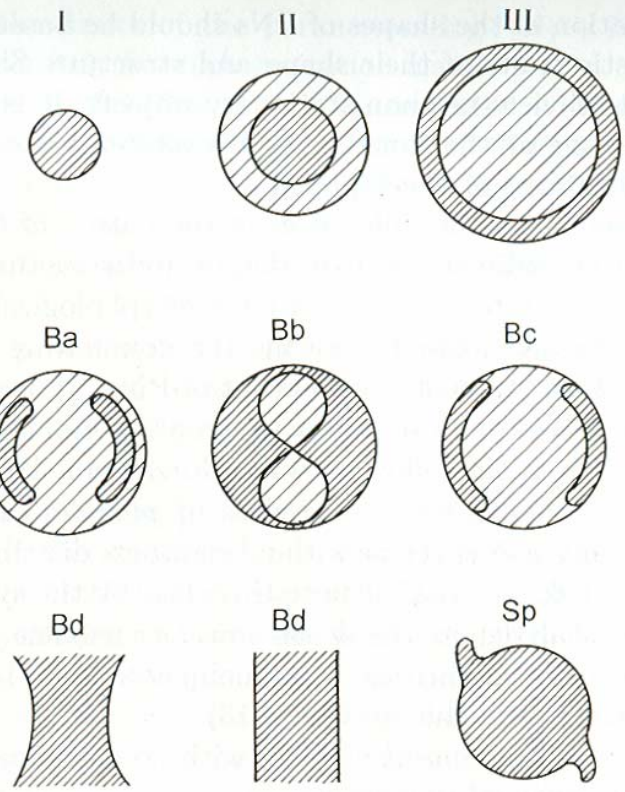


Fig. 1.3. Schematic representation of the shapes of planetary nebulae of various classes

The Physics and Dynamics of Planetary Nebulae
Grigor .A Gurzadyan

Spectra PN

- general structure of Planetary Nebulae are the same!!
- Strong lines: λ = 5007 Å [OIII]
  λ = 4958 Å [OIII]
  λ = 6548 Å [NII]
  λ = 6584 Å [NII]
- Forbidden transition means diffuse gas

Quantitative classification of spectra PN

- Excitation Class, intensities of emission lines
- Low Excitation 0 < p < 4

$$p = \frac{N_1 + N_2}{H_\beta}$$

- Medium Excitation 4 < p < 8

$$p = \log\left(\frac{N_1 + N_2}{4686 HeII}\right)$$

- High Excitation 9 < p < 12+

$$p = \log\left(\frac{N_1 + N_2}{4686 HeII}\right)$$

Nuclei of PN

- among the hottest stars
  * apparent brightness nebula
  * invisibility of nuclei
  * dwarf size and highly ionized elements
    HeII, CIV, NV, NeV, OV
  * powerful radiation → $\lambda < 100$ Å

Spectra of Nuclei of PN

- spectra of nuclei shows great diversity
  1. Wolf-Rayet Type (only WC, no WN)
  2. Of-type
  3. O-type
  4. Continuum type C,

Physical Characteristics

- excitation level → temperature nuclei
- distribution → concentration towards Galactic plane
- expansion 10 tot 30 km/s
- envelope will dissipate into ISM
- condition of thermodynamic equilibrium is not maintained

Physical Characteristics

- In general chemical composition same as sun
- over 1600 known in the Milky Way
- distances, dimensions are hard to determine
- none of the basic physical or geometrical parameters is constant for all PNs

Evolution

- Nebula of material ejected from the central star during the contraction that terminates the red-giant-stage.
- The central ‘remaining’ star is so hot that is emits in ultra-violet

Evolution

- all know forms of ejection of gaseous matter by stars cannot produce PNs

1. impossible reducing such high speeds
2. the small initial velocity of expansion of the envelope is much smaller than the escape velocity of the stellar surface

Process of inflation

- nucleus has ceased to be the generator of nuclear energy
- compression of the nucleus
- compensated by expansion

between Red giants and Planetary Nebulae ?

- OH/IR Masers
- Mirids

Atmosphere are unstable → mass loss.

located on the upper part of the HR-diagram

the dispersion velocity of the mirids is the same as the PNs

Macro-structure

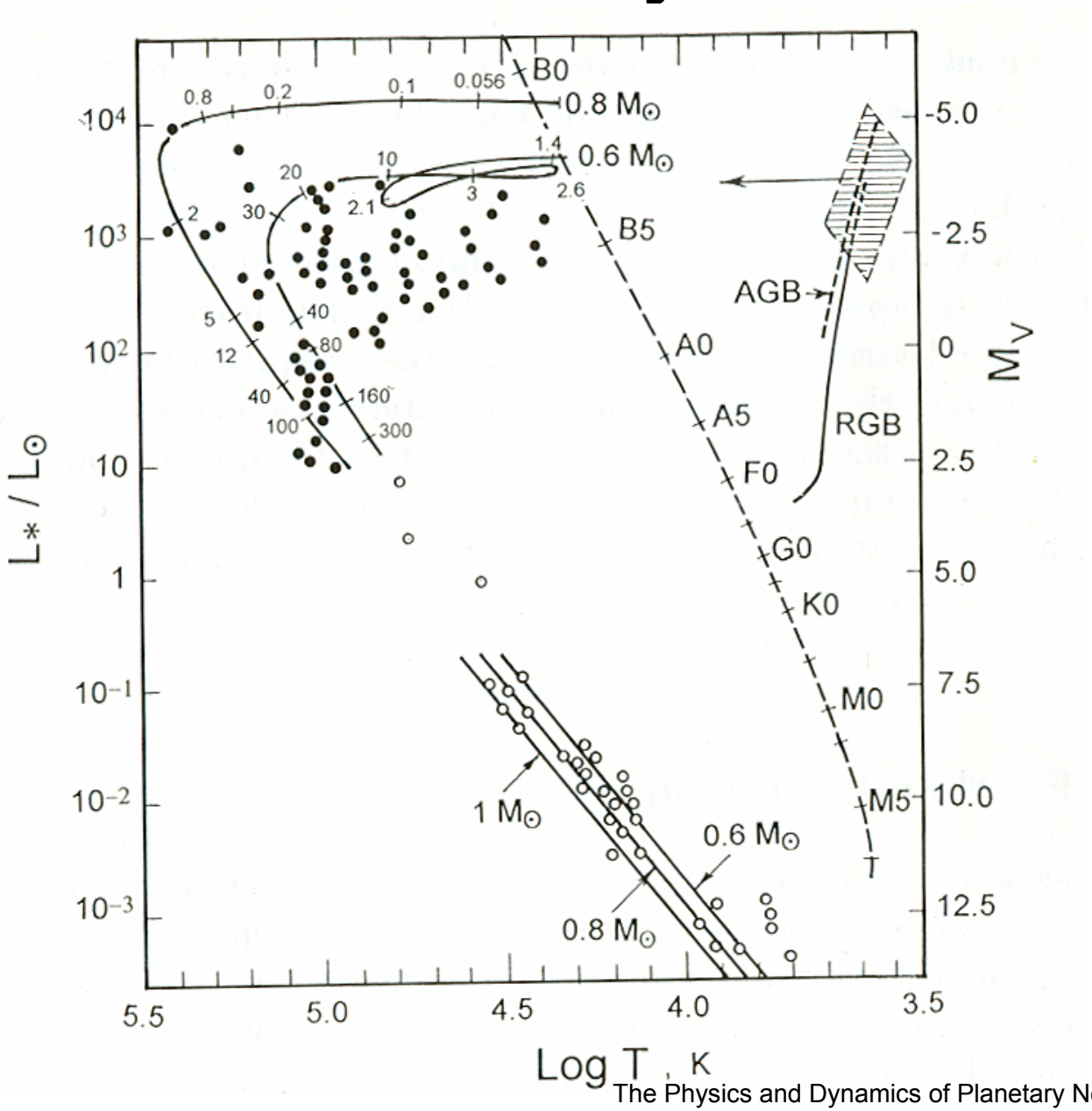
Period I inflation of the outer layers

Period II expansion of separates mass into an envelope.

Period III The evolution of the rarefied gaseous envelope

Mirid → Proto planetary object → PN

Evolutionary Path



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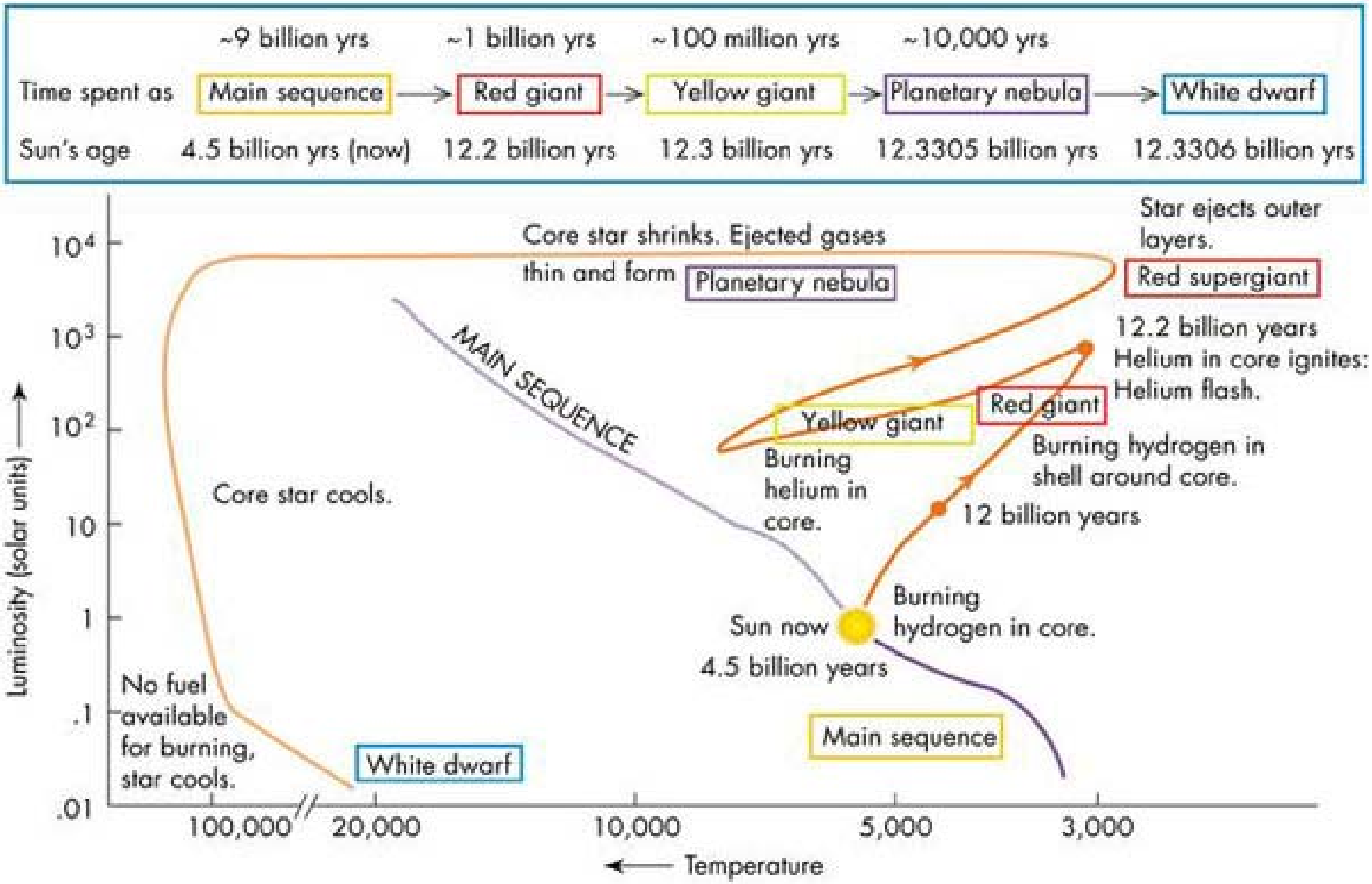
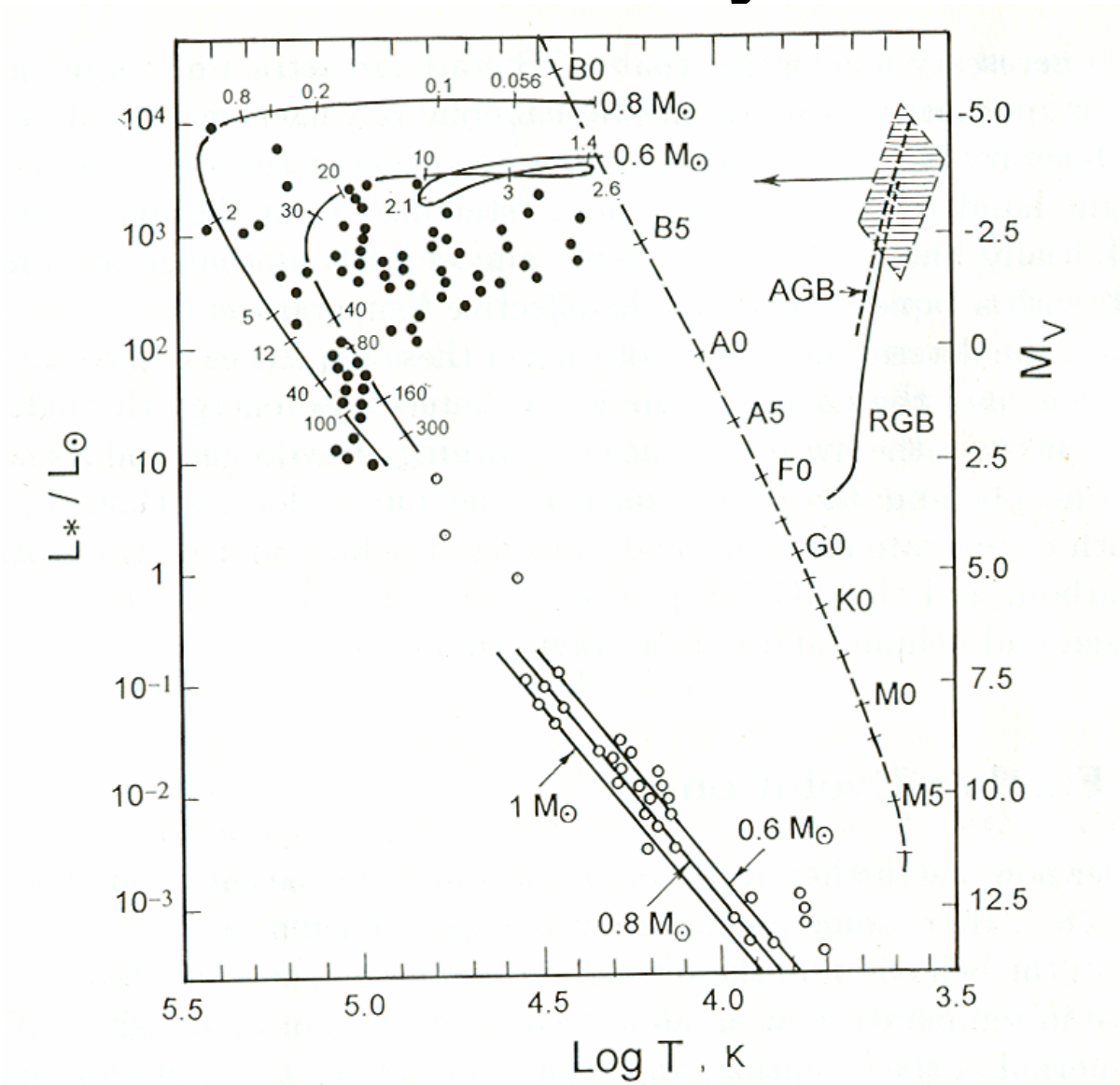
Evolution


~9 billion yrs
~1 billion yrs
~100 million yrs
~10,000 yrs
Time spent as
Main sequence
Red giant
Yellow giant
Planetary nebula
White dwarf
Sun's age
4.5 billion yrs (now)
12.2 billion yrs
12.3 billion yrs
12.3305 billion yrs
12.3306 billion yrs
Luminosity (solar units)
10^4
10^3
10^2
10
1
.1
.01
Core star shrinks. Ejected gases thin and form Planetary nebula
Star ejects outer layers.
Red supergiant
12.2 billion years
Helium in core ignites: Helium flash.
MAIN SEQUENCE
Yellow giant
Red giant
Burning helium in core.
Burning hydrogen in shell around core.
12 billion years
Core star cools.
Sun now
4.5 billion years
Burning hydrogen in core.
Main sequence
No fuel available for burning, star cools.
White dwarf
100,000
20,000
10,000
5,000
3,000
Temperature

White dwarf ?

- the real nuclei of PN form an isolated group
- the nuclei are quite far from the white dwarfs
- takes of millions of years to reach the ordinary white dwarfs

Evolutionary Path



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Overview

- PN got unique spectra
- Planetary nebula’s are the final phases star’s life
- Not all red giants become a PN
- Most of the PN are formed from MIRIDS or OH/IR masers

Literature

- Modern Astrophysics (Caroll/Ostlie)
- Introduction to Astronomy & Astrophysics (Zeilik /Gregory)
- Astronomical Spectroscopy (Tennyson)
- Optical Astronomical Spectroscopy (Kitchin)
- Planetary Nebulae (Gurzadyan)
- The physic and dynamics of Planetary Nebulae (Gurzadyan)
- www.wikipedia.com