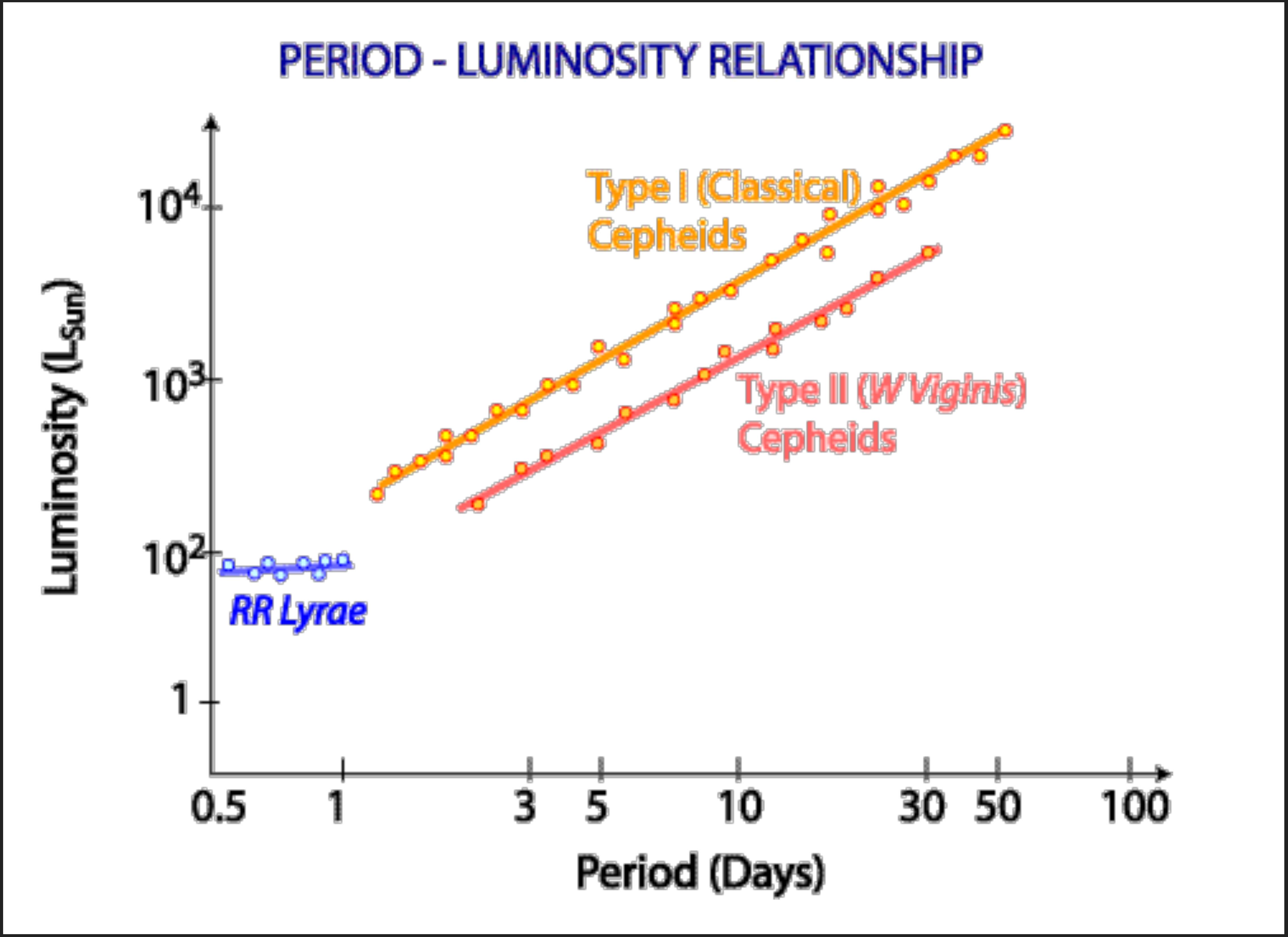
VARIABLE STARS

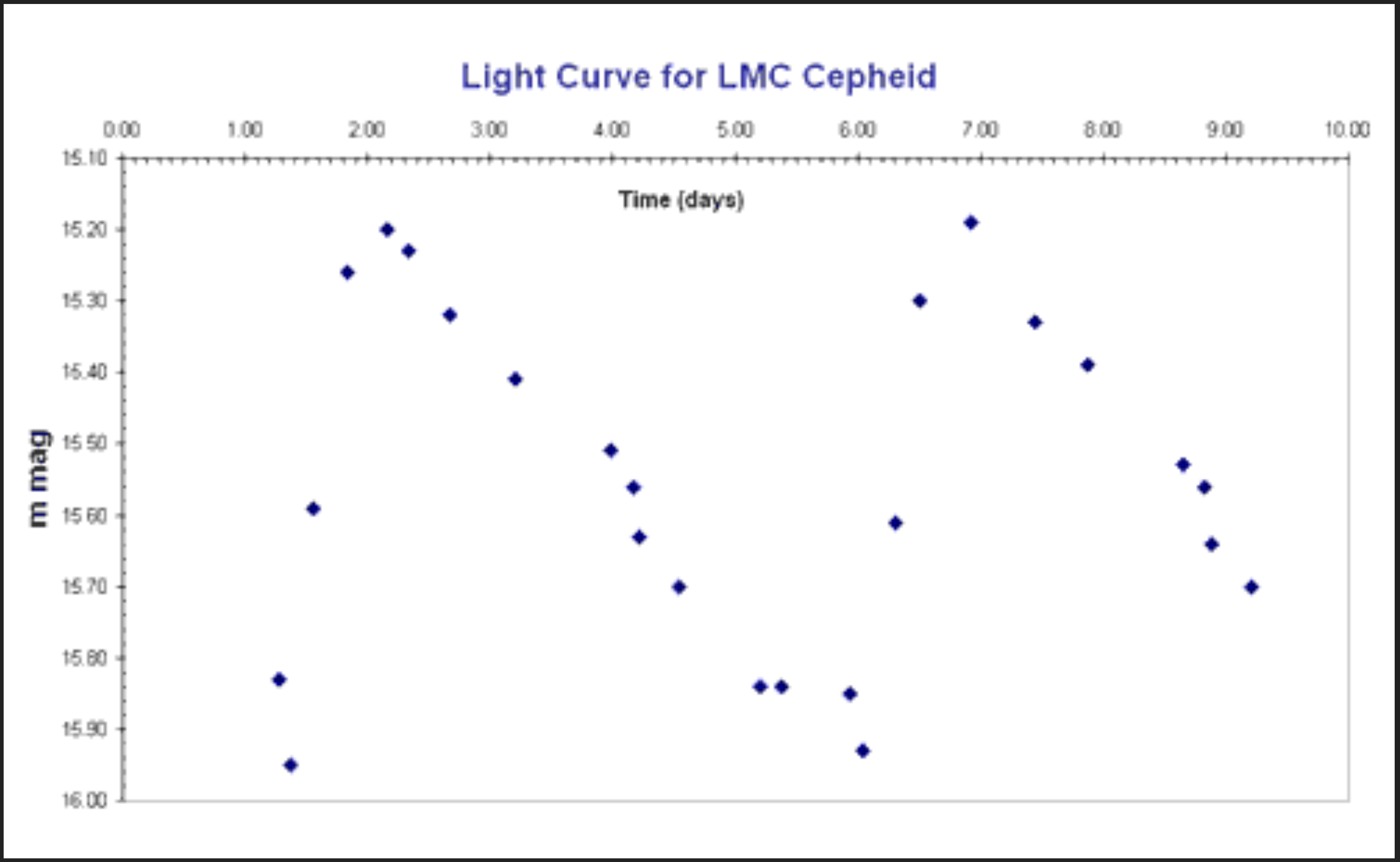
ASTROPHYSICS

Dr H.T.Sener

DISTANCE CALCULATION



DISTANCE CALCULATION



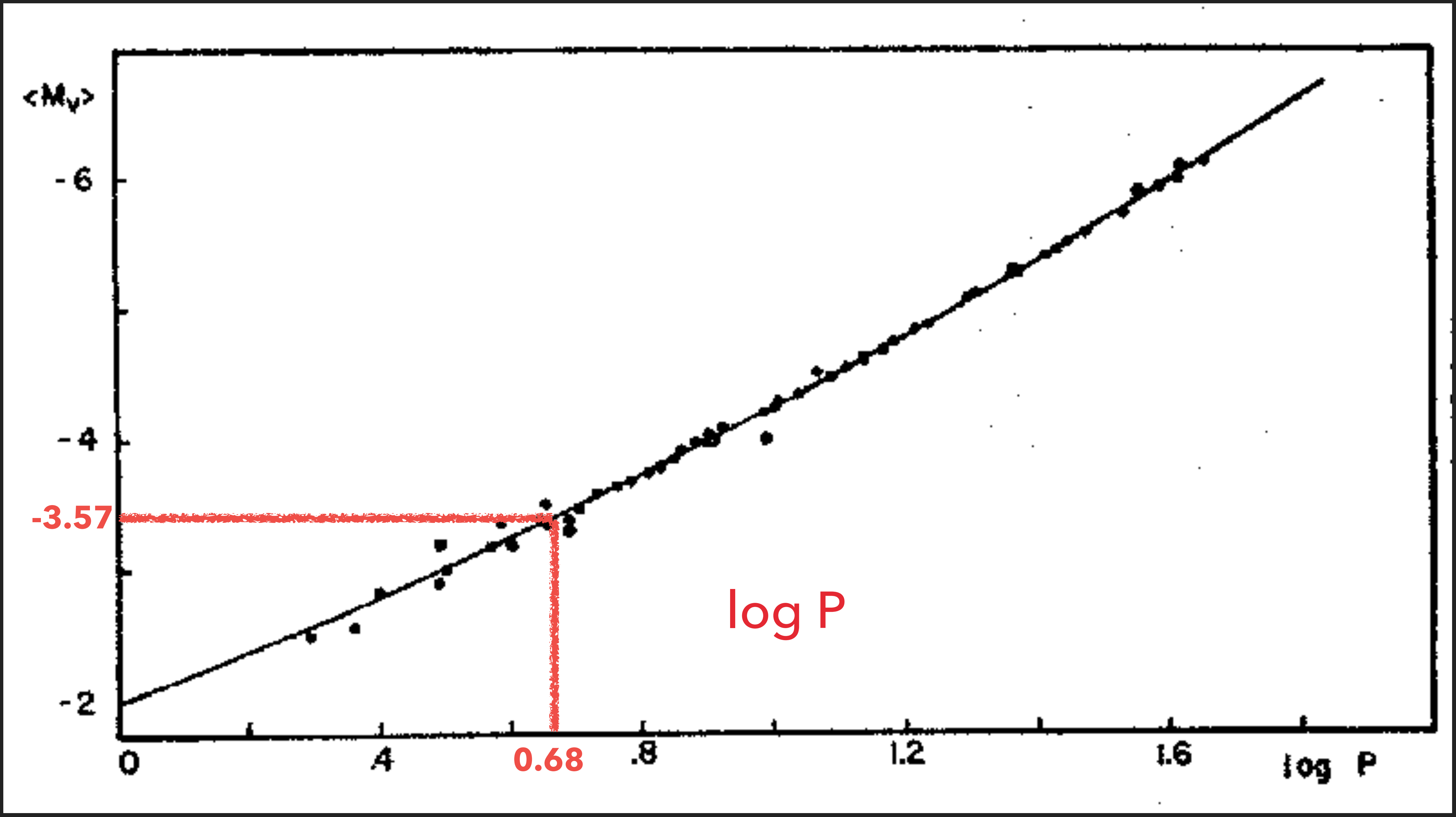
- Light curve ➠ apparent magnitude & Period

$m \cong 15.5$

$P \cong 4.76$

DISTANCE CALCULATION

PERIOD α LUMINOSITY



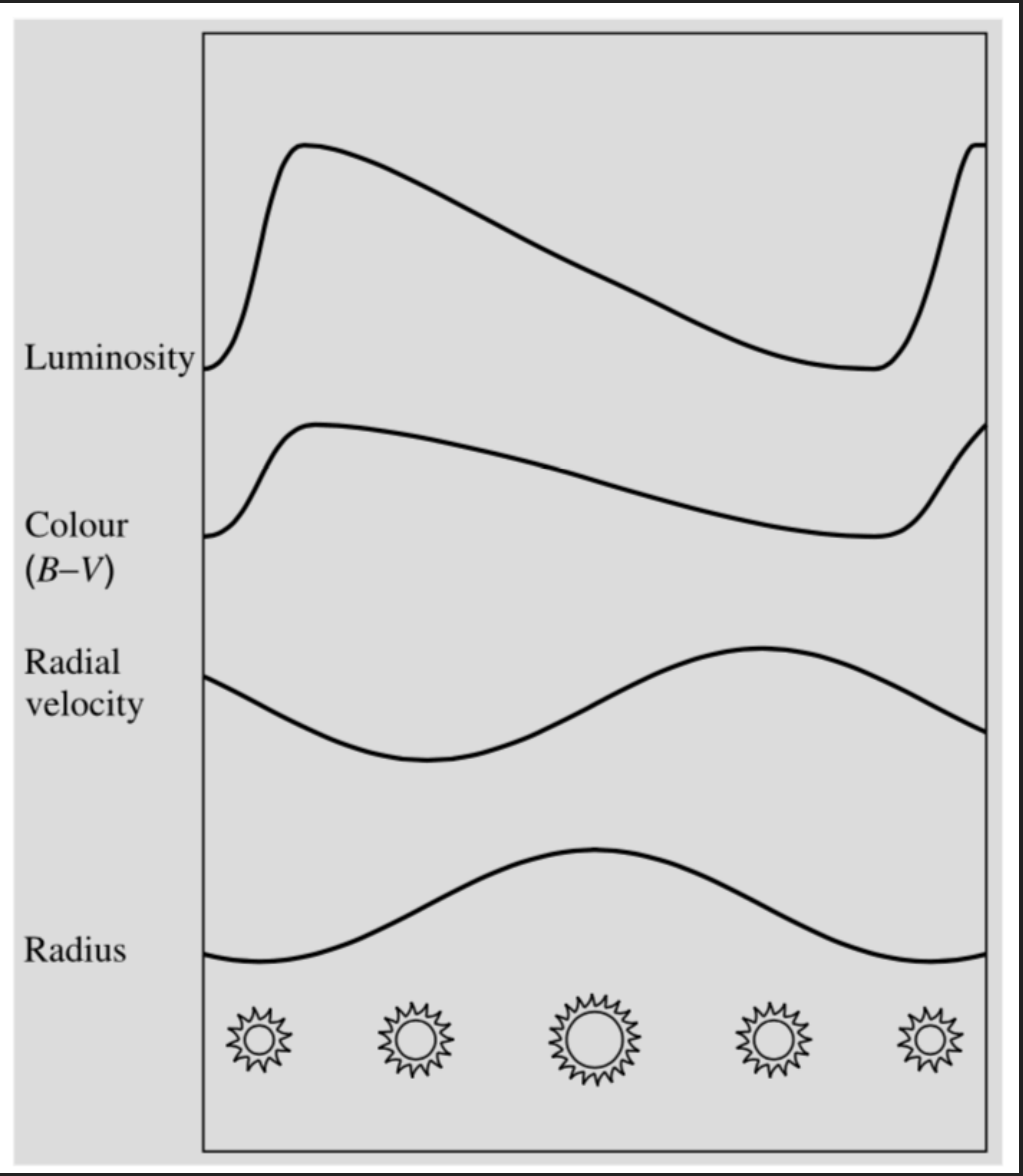
DISTANCE CALCULATION

- P ≅ 4.76 days
- m ≅ 15.56
- M ≅ -3,6

$$m - M = 5log\frac{d}{10}$$

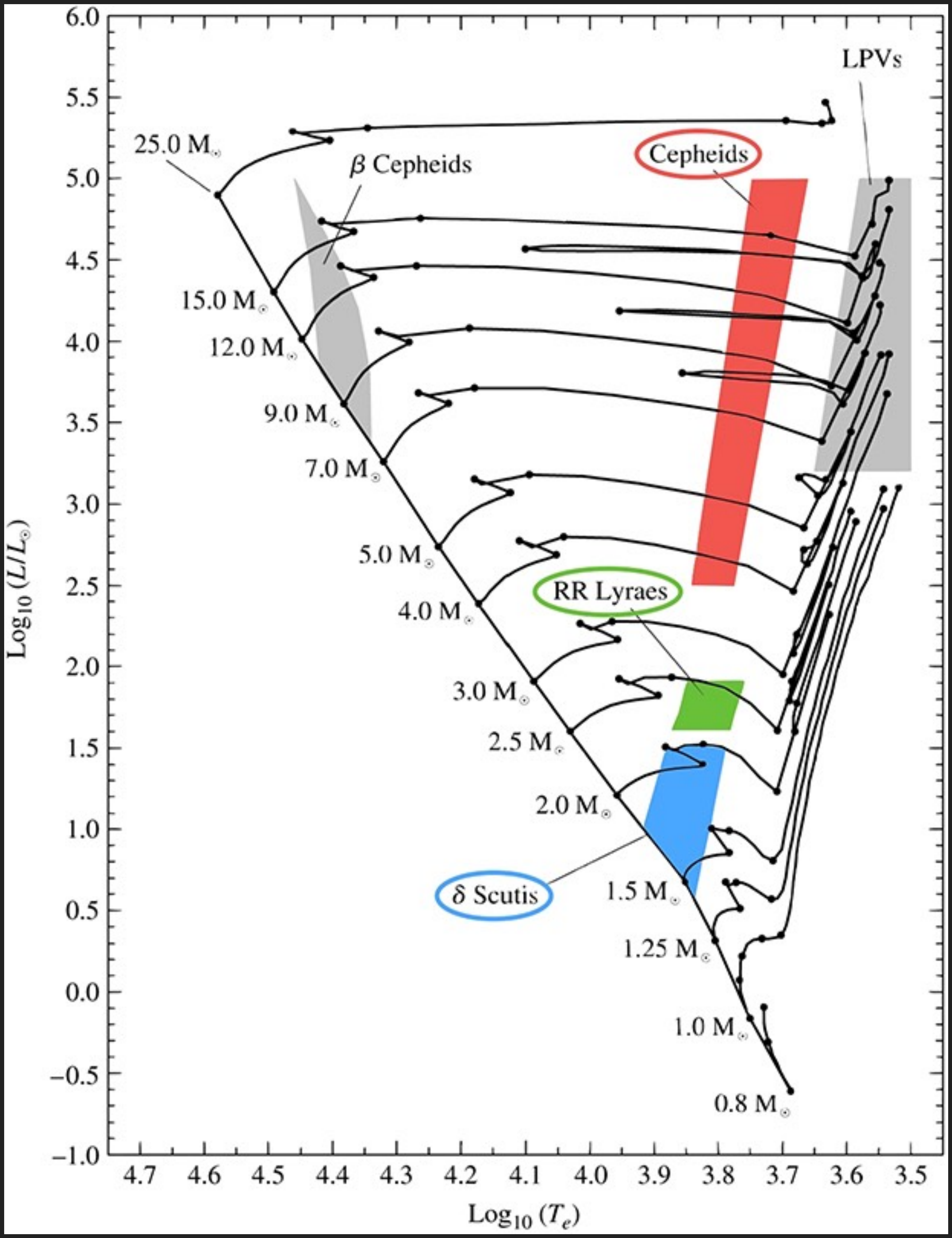
d ≅ 68 kpc

CEPHEID OVERVIEW



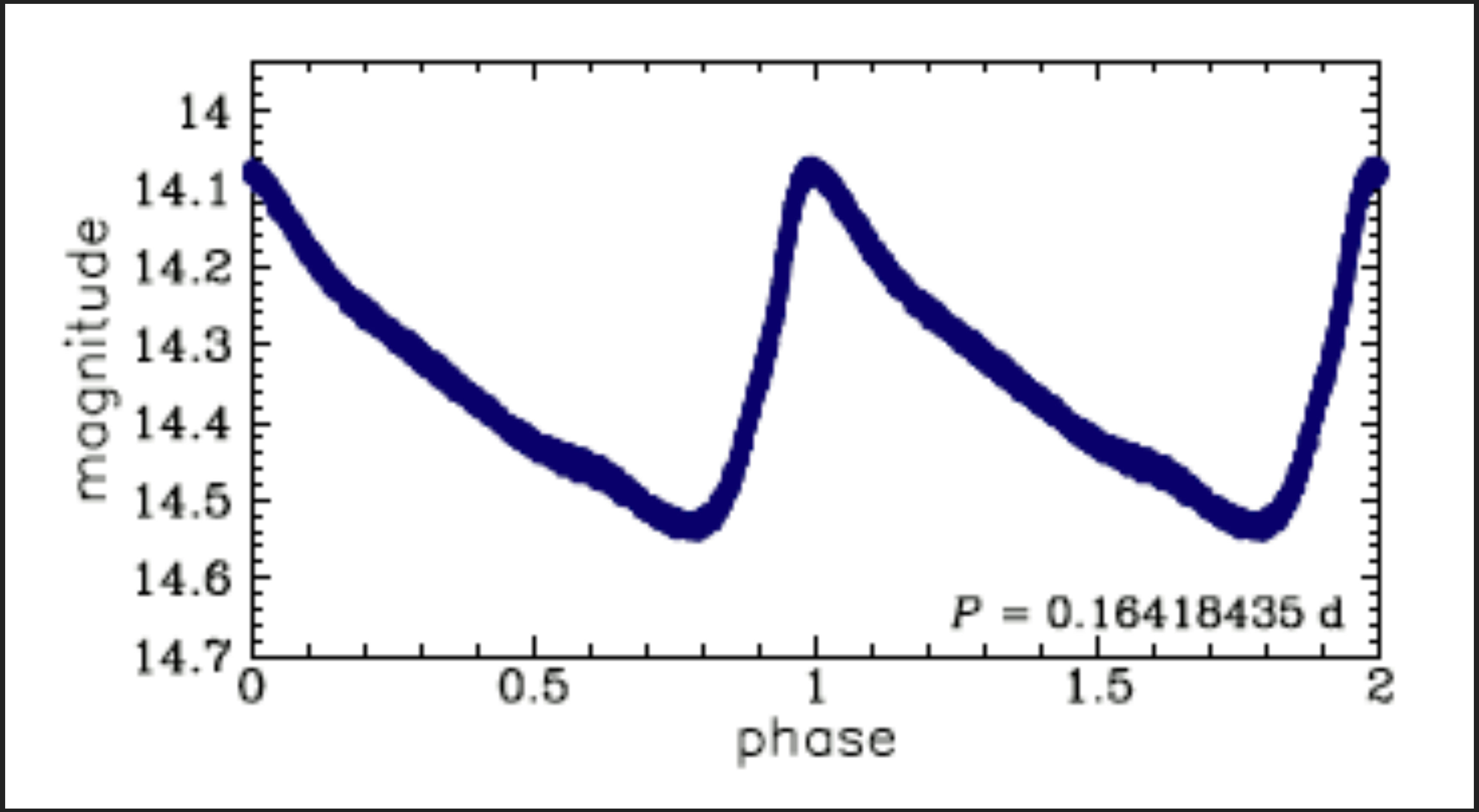
DELTA SCUTI

- @instability strip
- A - F spectral type
- Faint
- Short period
- Small mass
- Pulsate radial & non-radial



DELTA SCUTI

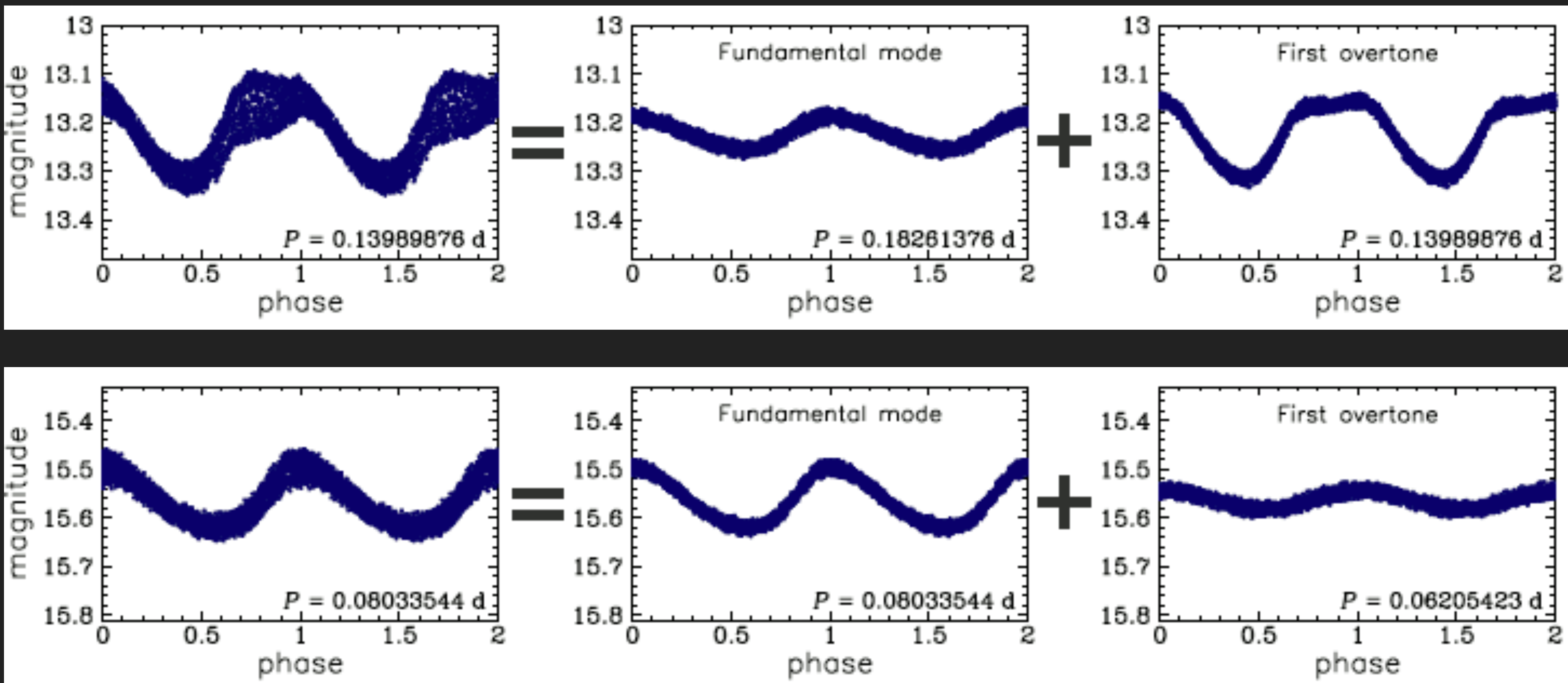
SINGLE MODE PULSATORS



Data: OGLE

DELTA SCUTI

MULTI MODE PULSATORS



Data: OGLE

TIME

- Julian Date (JD): day number + fraction of the day

  since January 1, 4713 BC

  Example: 1 January 2000 = 2 451 545 JD

- Heliocentric Julian Date (HJD): reference is Sun (8.3 min)

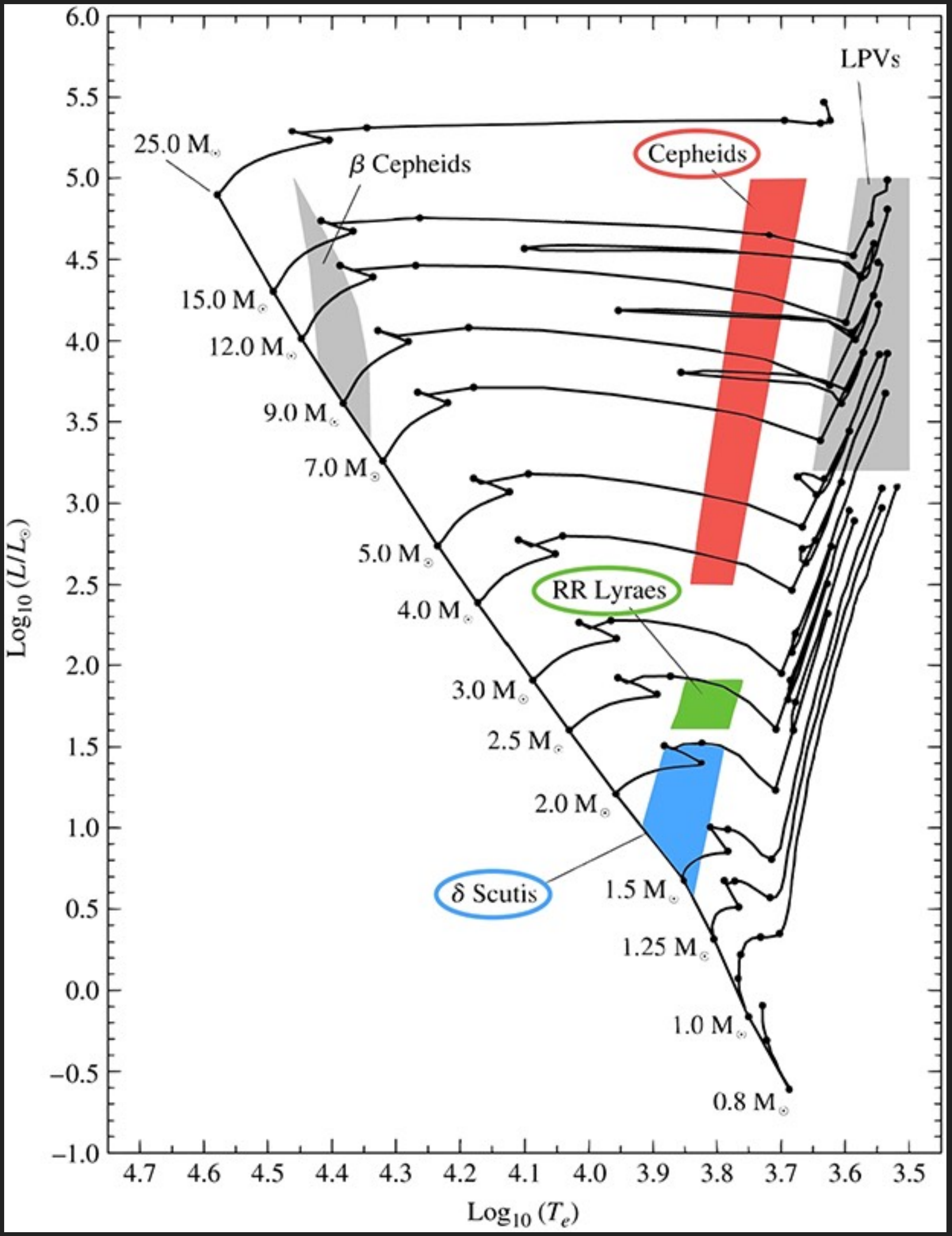
- Barycentric Julian Date (BJD): reference is Solar system

  4 seconds

  since 1991

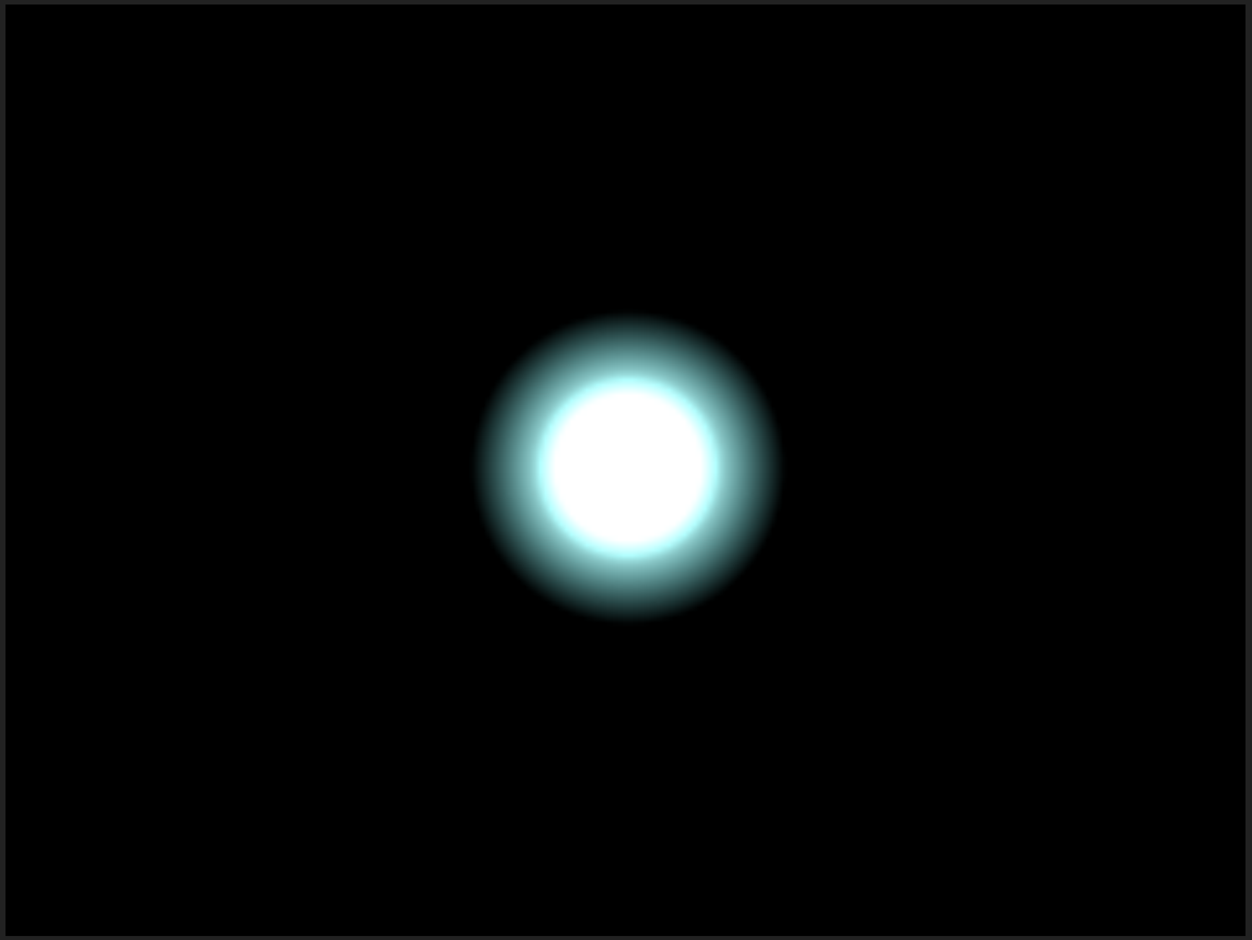
LONG PERIOD VARIABLES

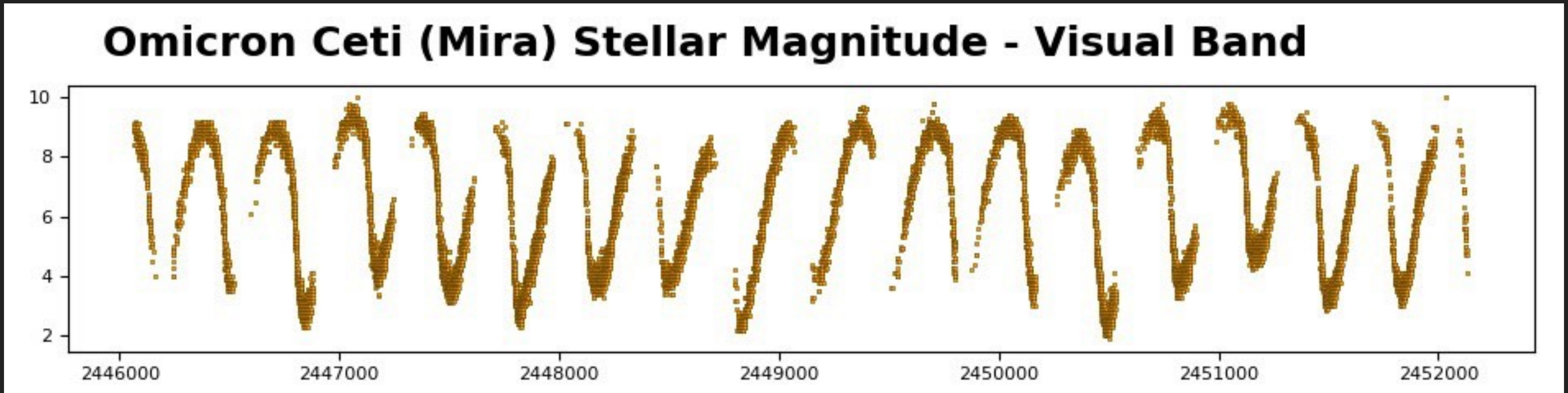
- Mira:
  - Periodic red giant var.
  - 80 days < P < 1000 days
  - $\Delta m > 2.5$ mag
- Semi-Regular Variables:
  - Giant & Supergiants
  - Semi-regular / irregular
  - 30 days < P < 1000 days
  - $\Delta m < 2.5$ mag



MIRA VARIABLES

- First variable
- 80d < P < 1000d
- $\Delta m = 2.5 - 10$ mag
    - Coolest &
    - Largest &
    - Most luminous Red giants





MIRA

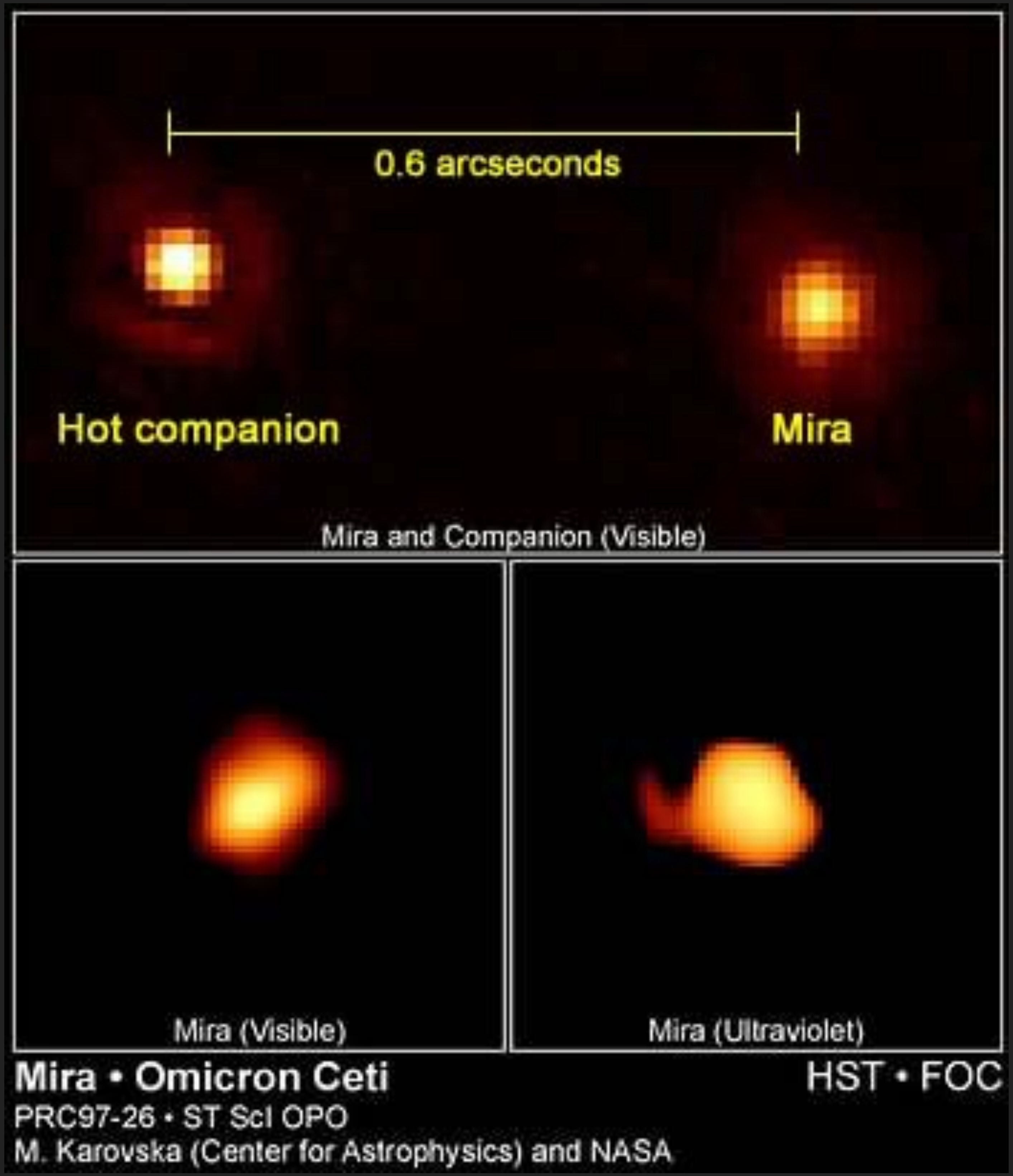
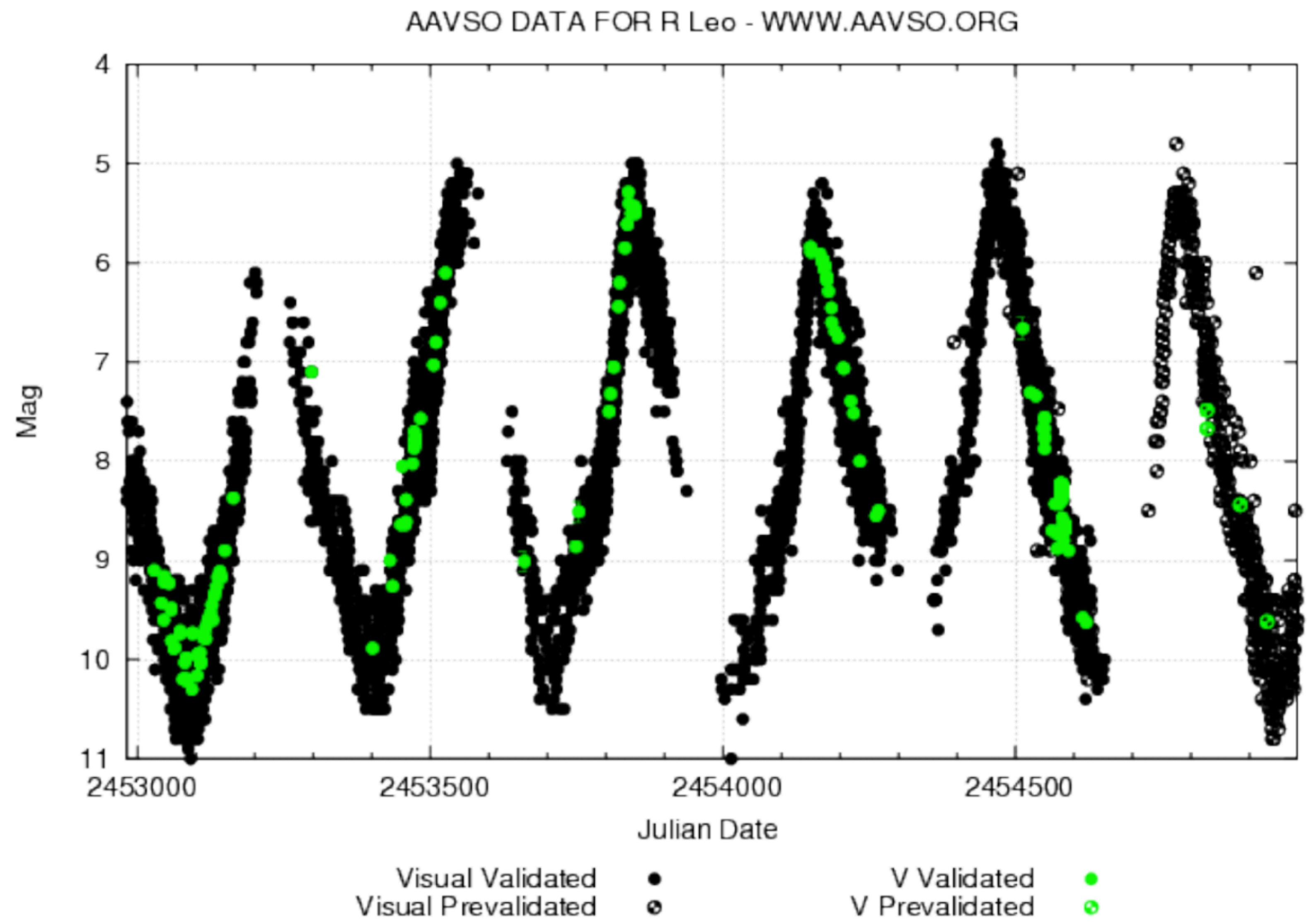


Image: HST

- P = 331 days
- Δm = 6 mag
- Red giant
- 1900K < Teff < 2600K
- Visual binary

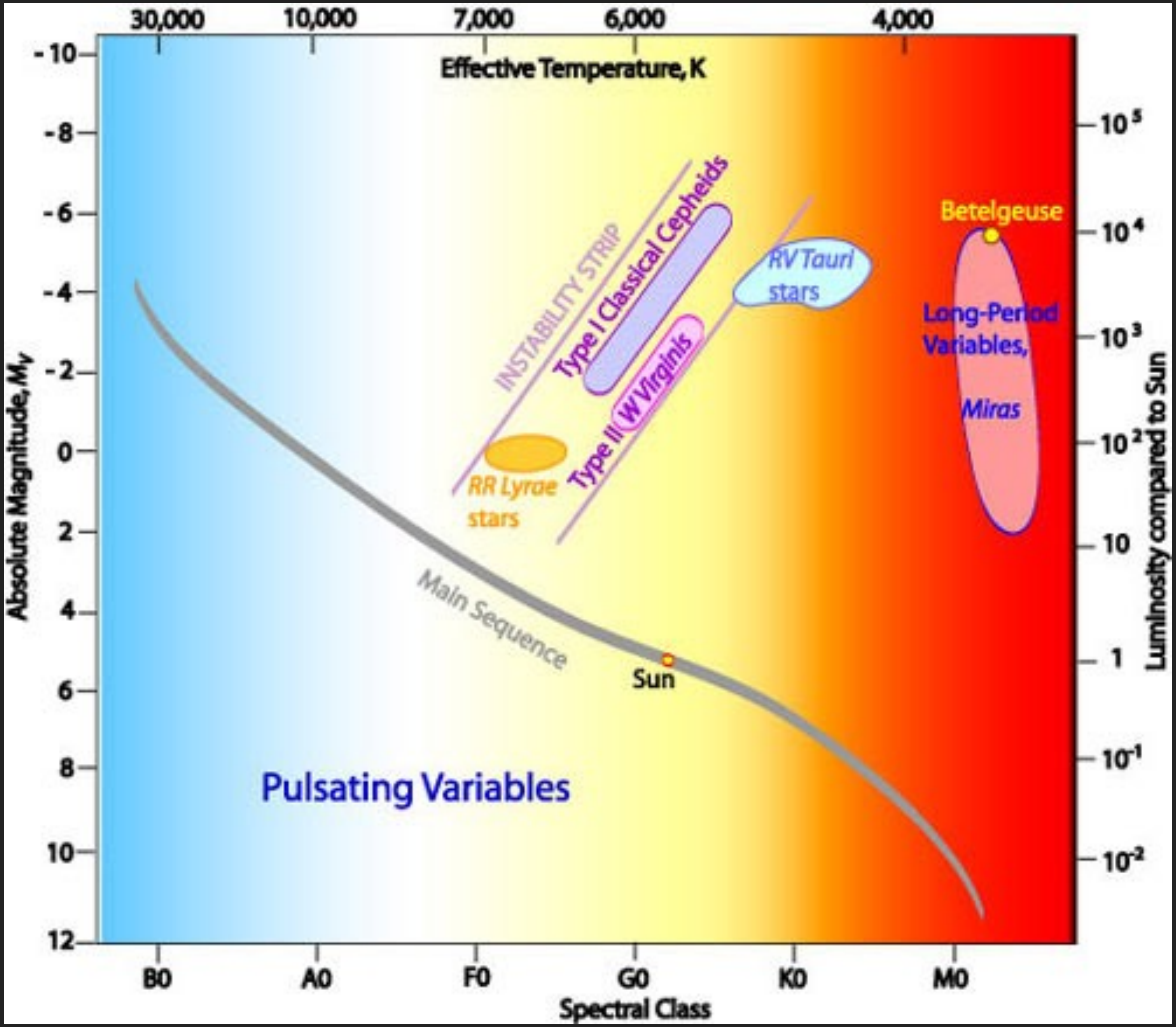
MIRA



1000 day light curve of the Mira, R Leo

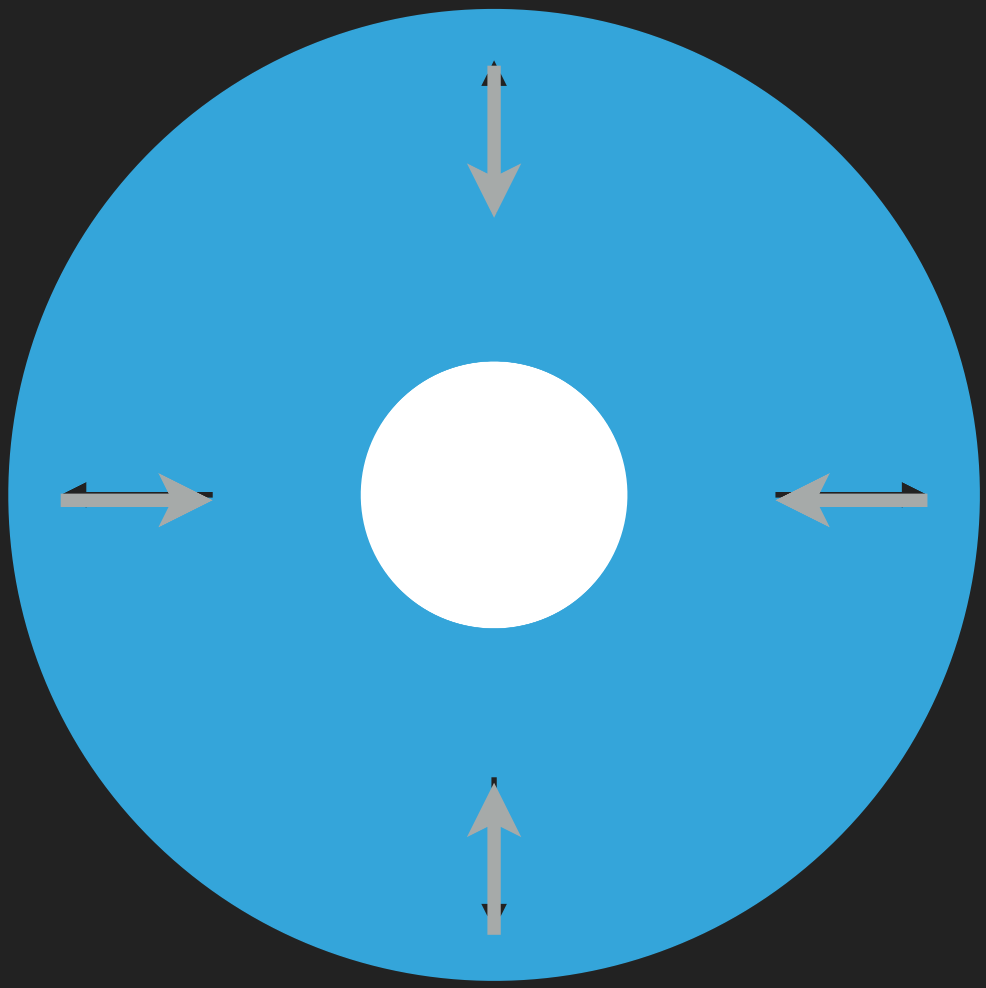
- 80 days < P <1000days
- 2.5 mag < Δm < 10 mag

SEMI-REGULAR VARIABLES



OVERVIEW

WHY DO STARS PULSATE

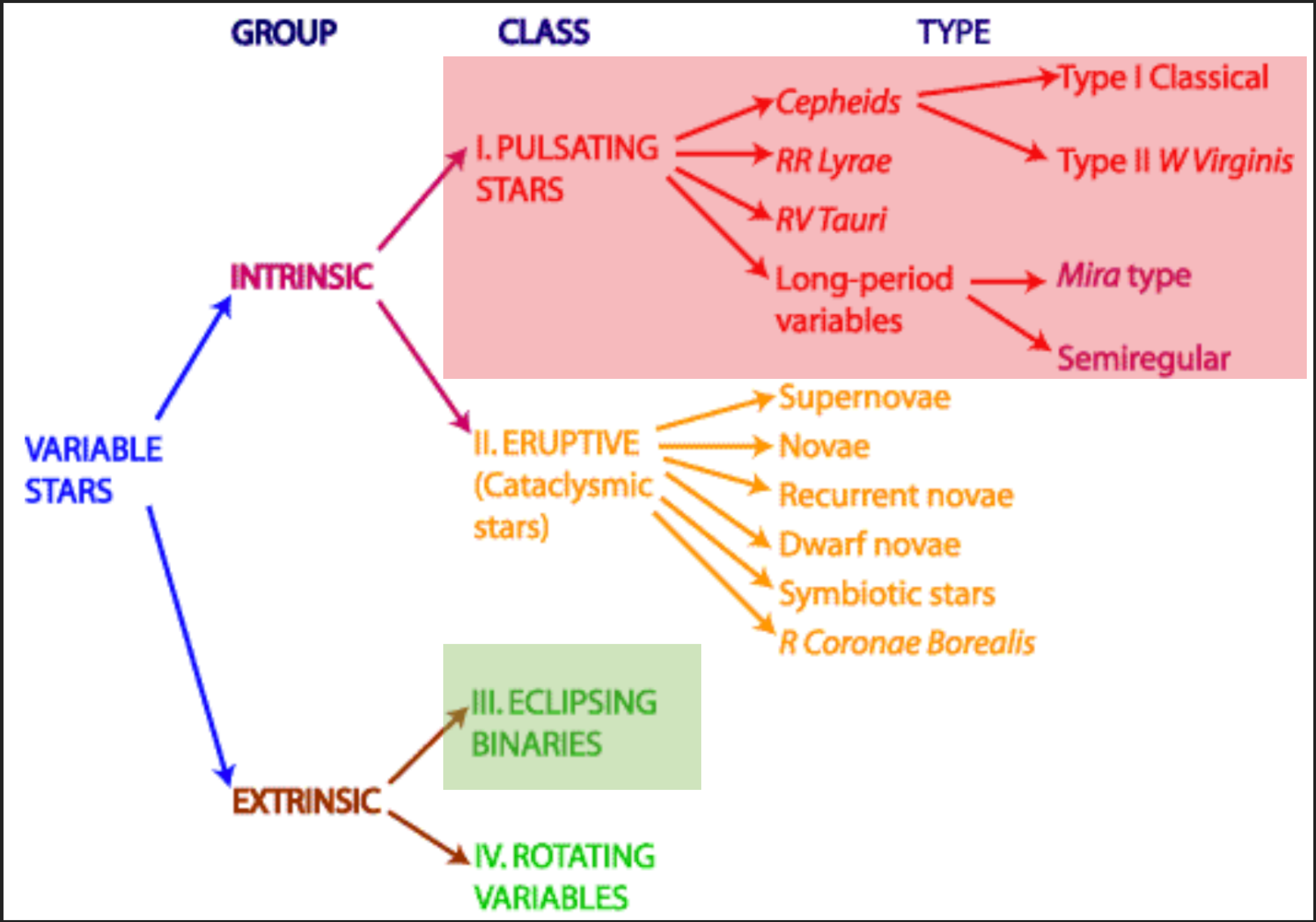


Radiation pressure > gravity

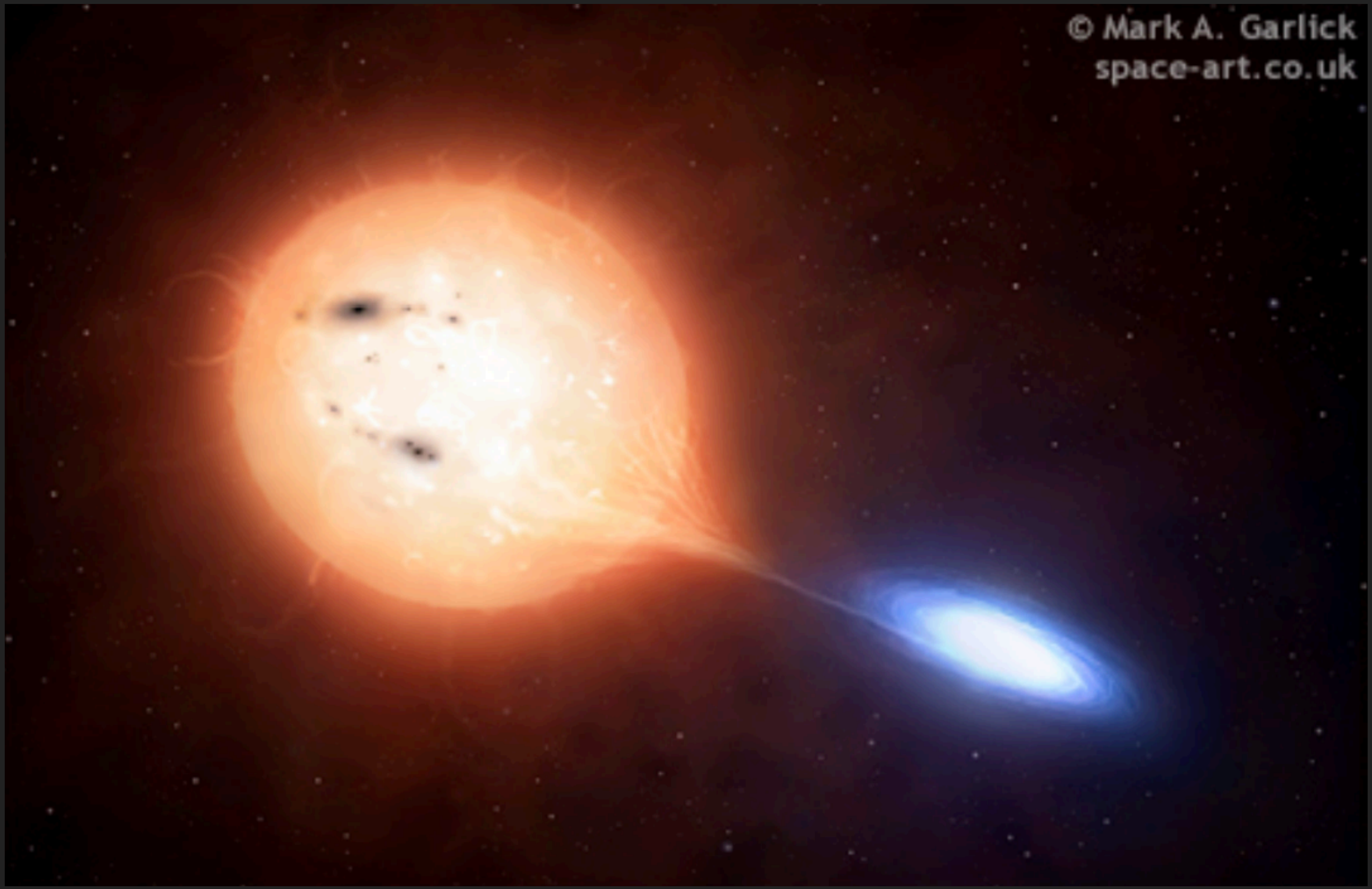
Radiation pressure = gravity

Radiation pressure < gravity

CLASSIFICATION

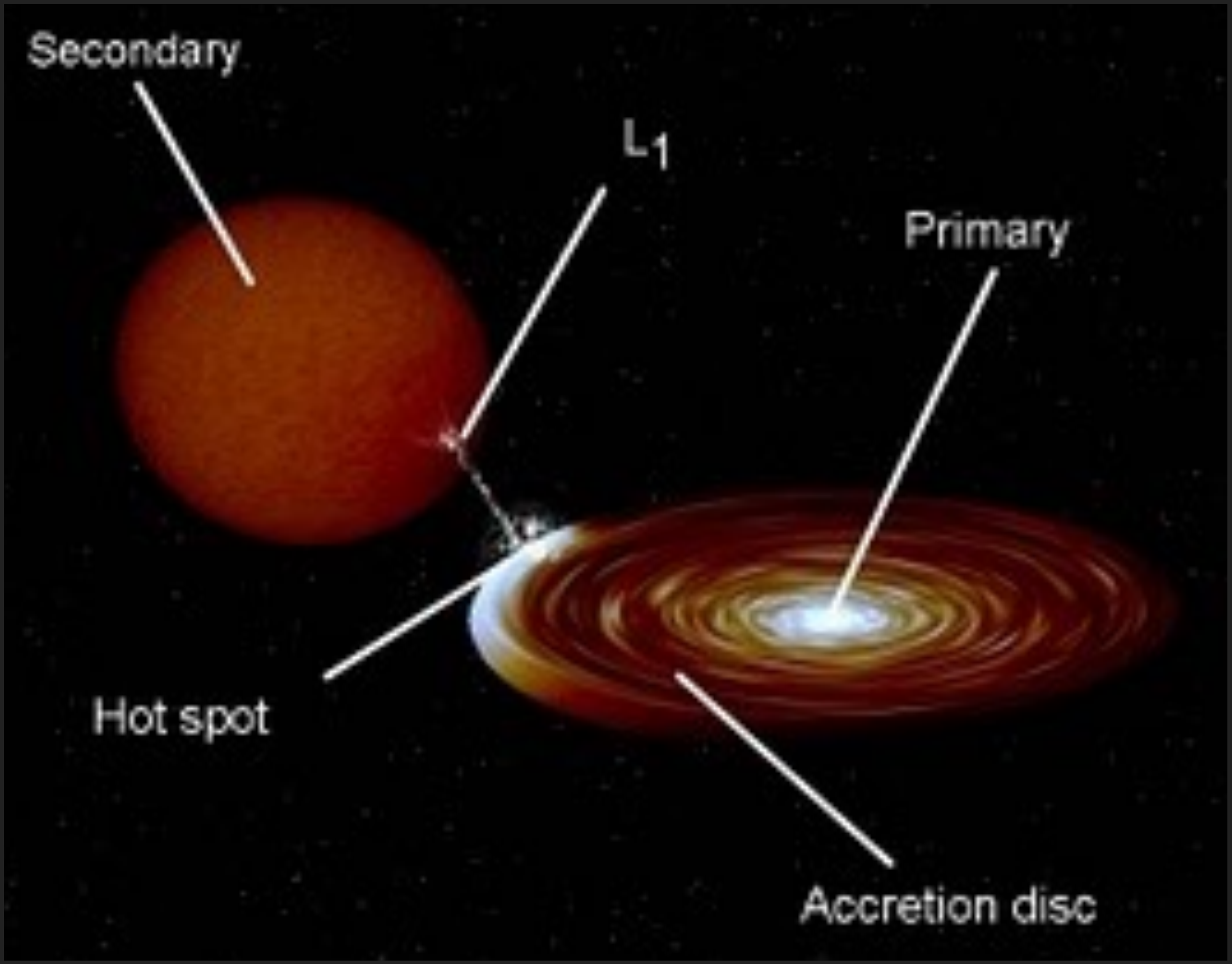


ERUPTIVE (CATACLYSMIC) VARIABLES



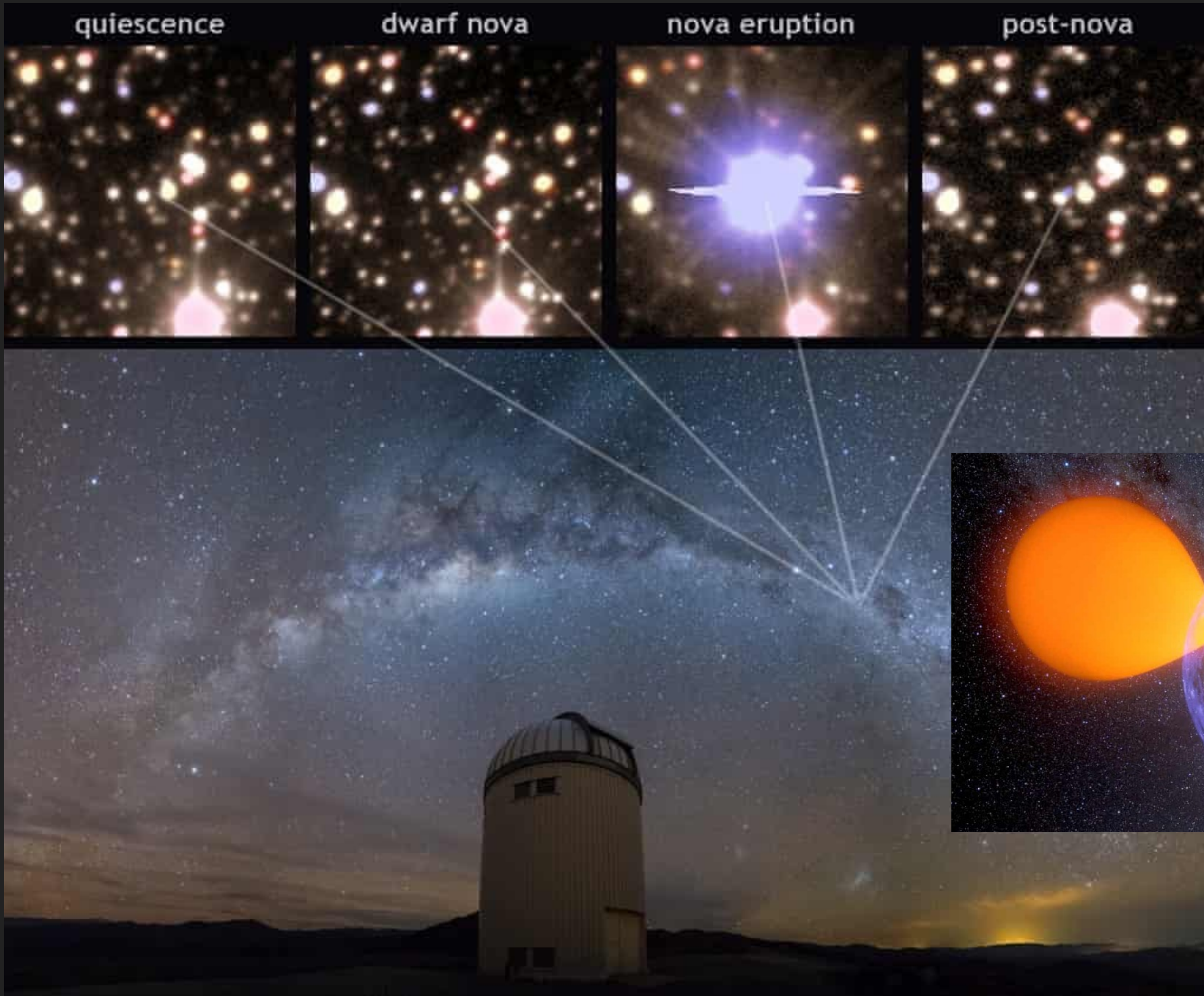
- Primary: White Dwarf
- Secondary: MS Star
- 75 min < P < 6 hrs

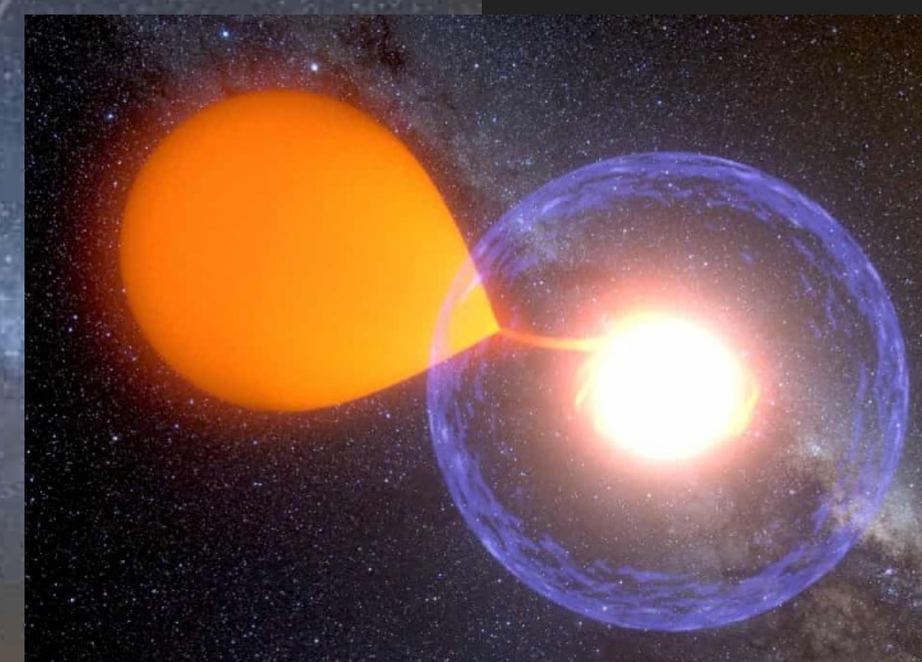
DWARF NOVAE



- Close binary system
- White dwarf accretes matter from its companion
- Instability in the accretion disk

NOVAE

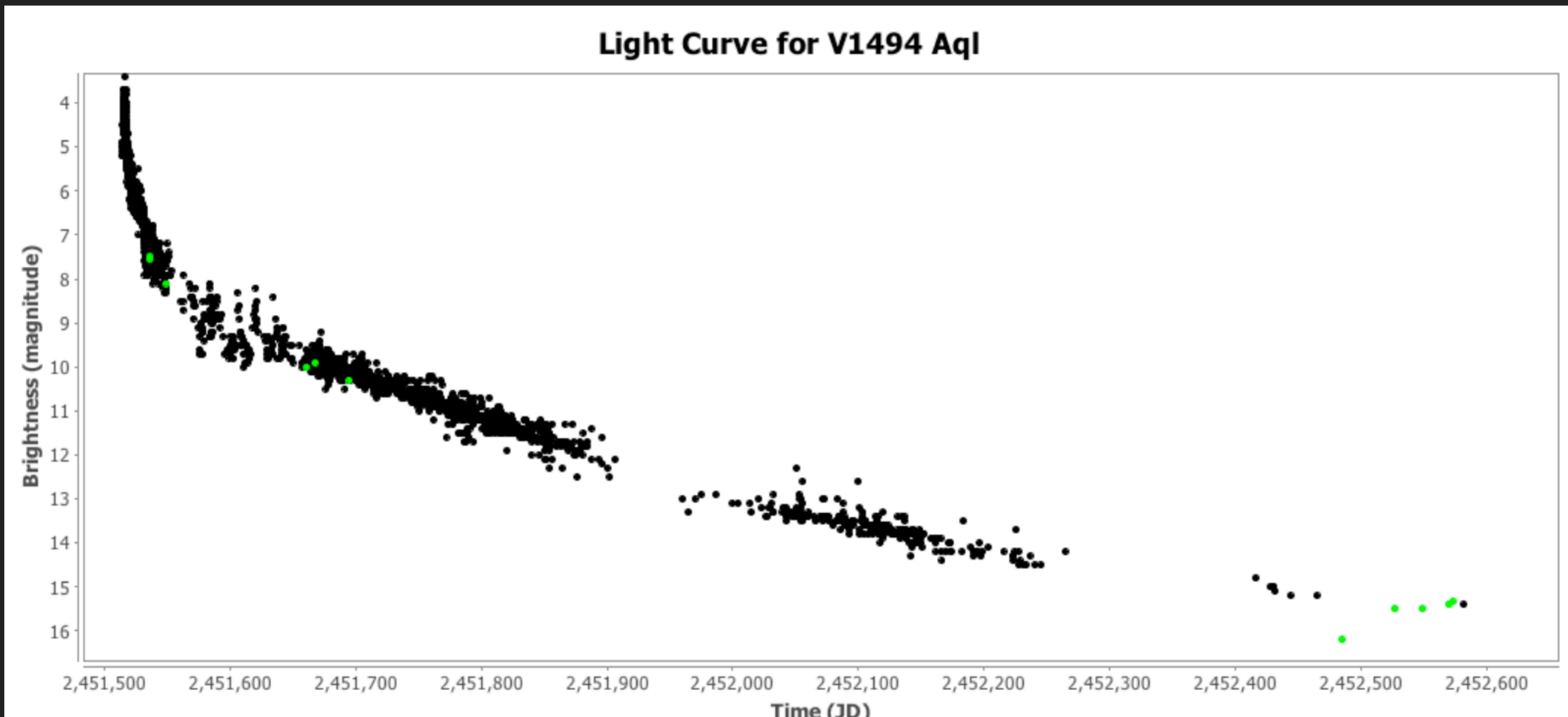




V1213 Cen

See ref. for image credits

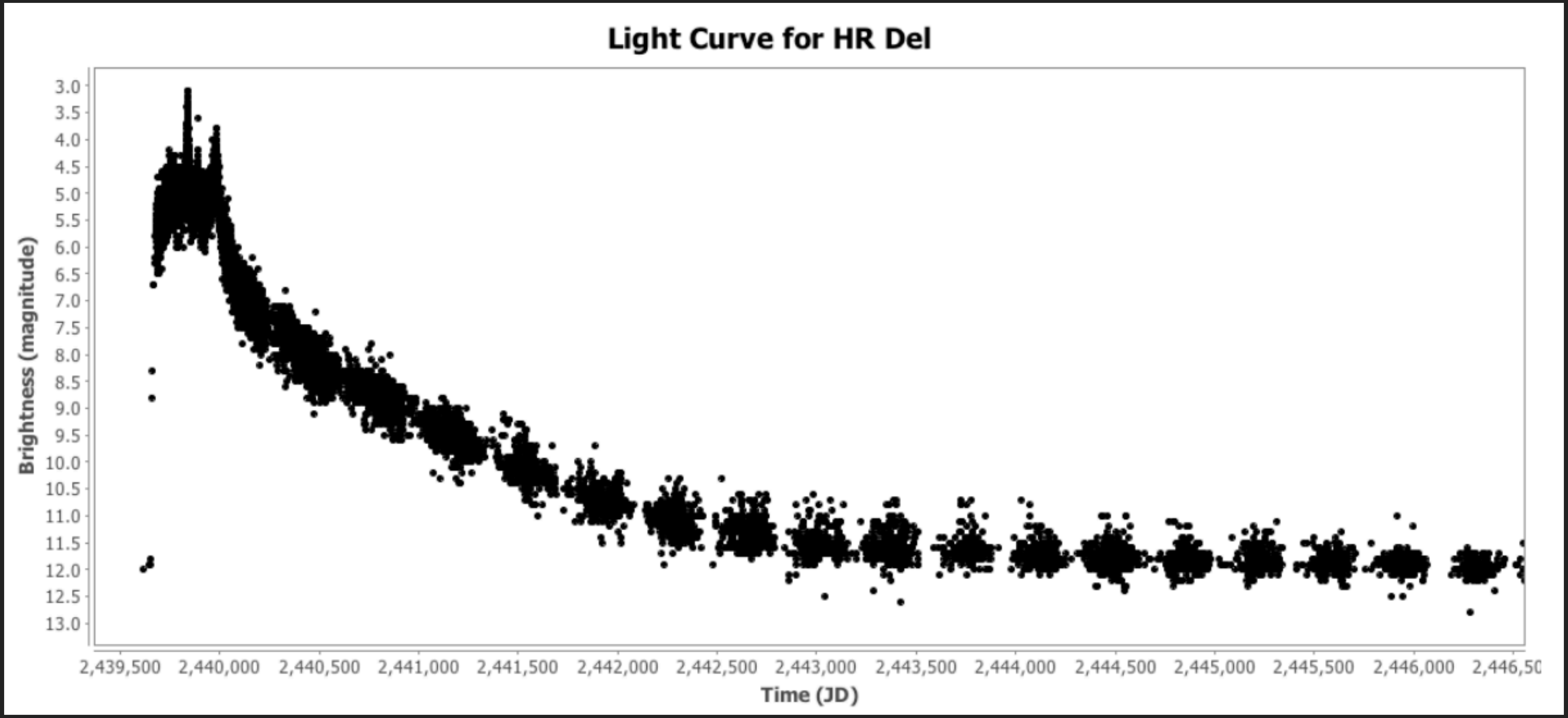
NOVAE



Data: AAVSO

NOVA

- NA: Fast; decline ~100 days
- NB: Slow; decline ~150 days
- NC: Very slow; a decade or more

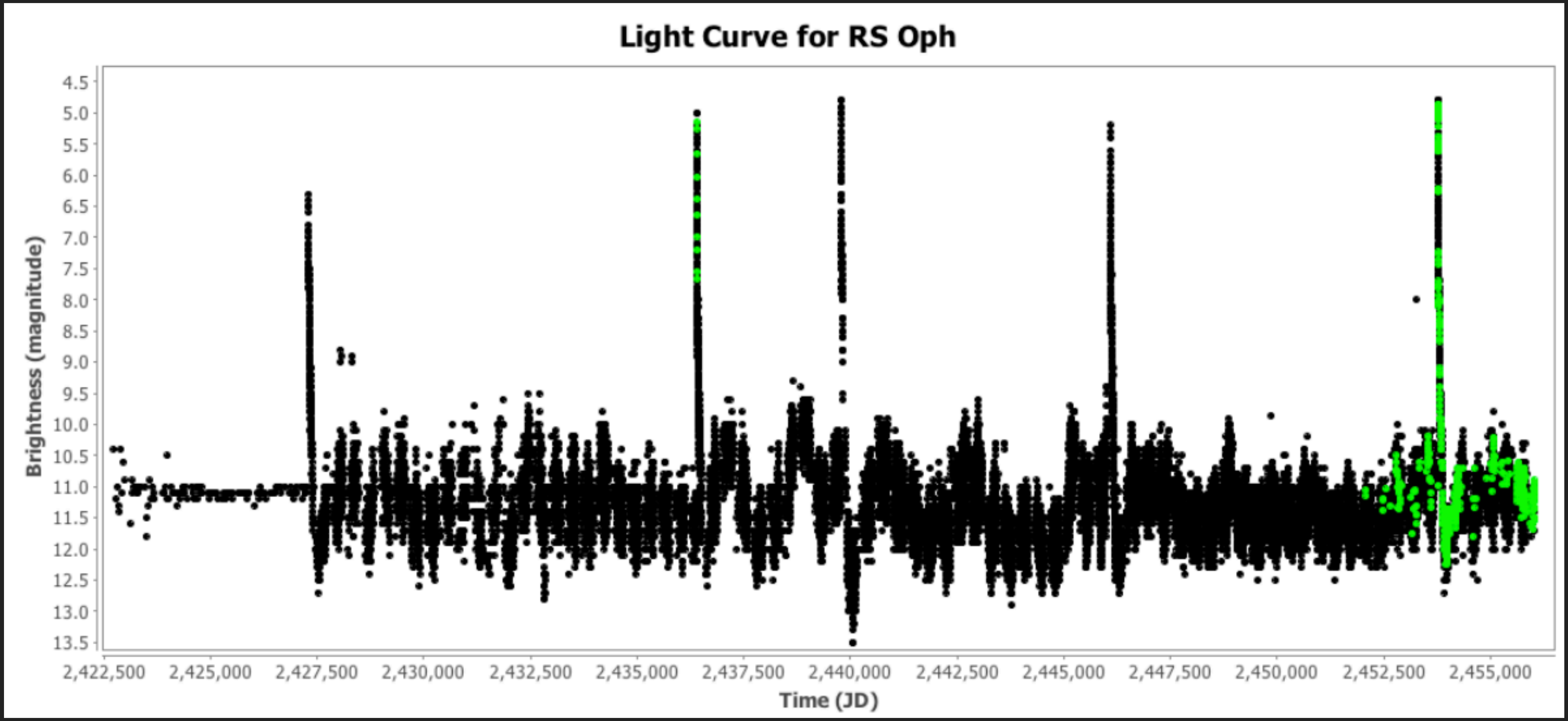


Data: AAVSO

What happened to V838 Mon?

RECURRENT NOVAE

- Repeating @ 10-80 years

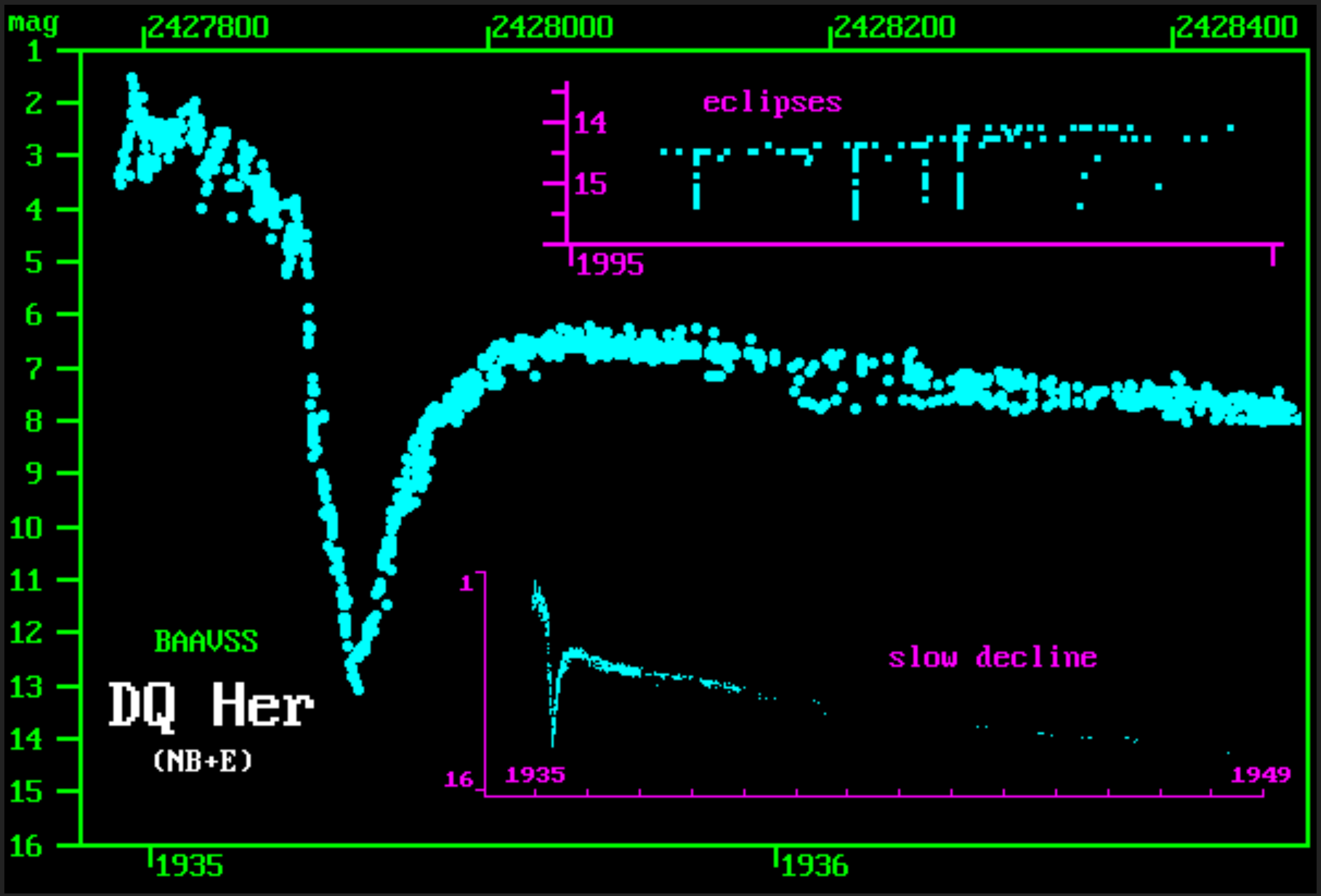


Data: AAVSO

MAGNETIC CV

DQ HER - INTERMEDIATE POLARS

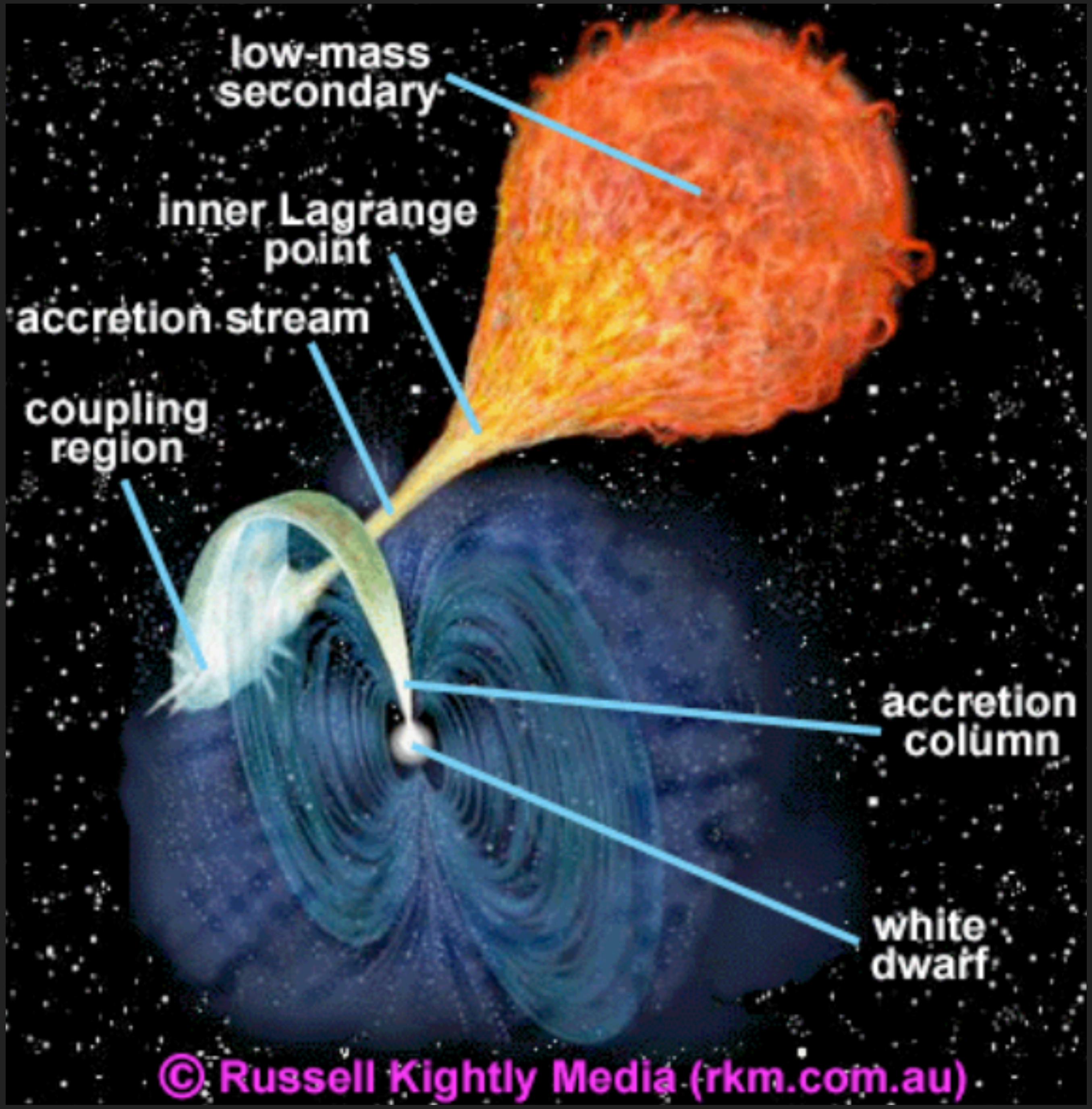
- Red star & fast rotation magnetic white dwarf
- Magnetic Field around white dwarf: 1-10 MegaGauss



MAGNETIC CV

AM HER - POLARS

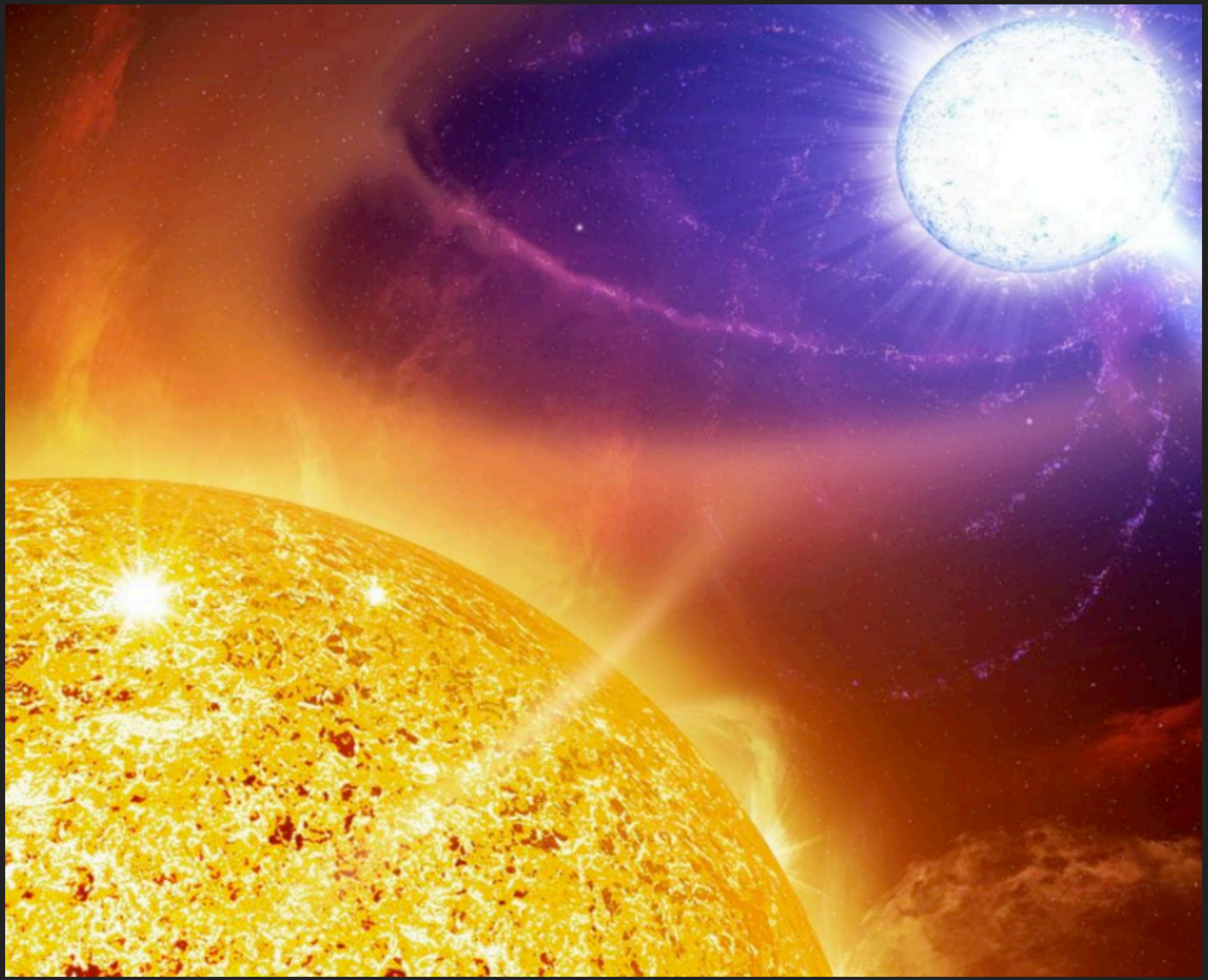
- Magnetic Field: 10-100 MegaGauss
  - Prevents accretion disk
  - Synchronous rotation



MAGNETIC CV

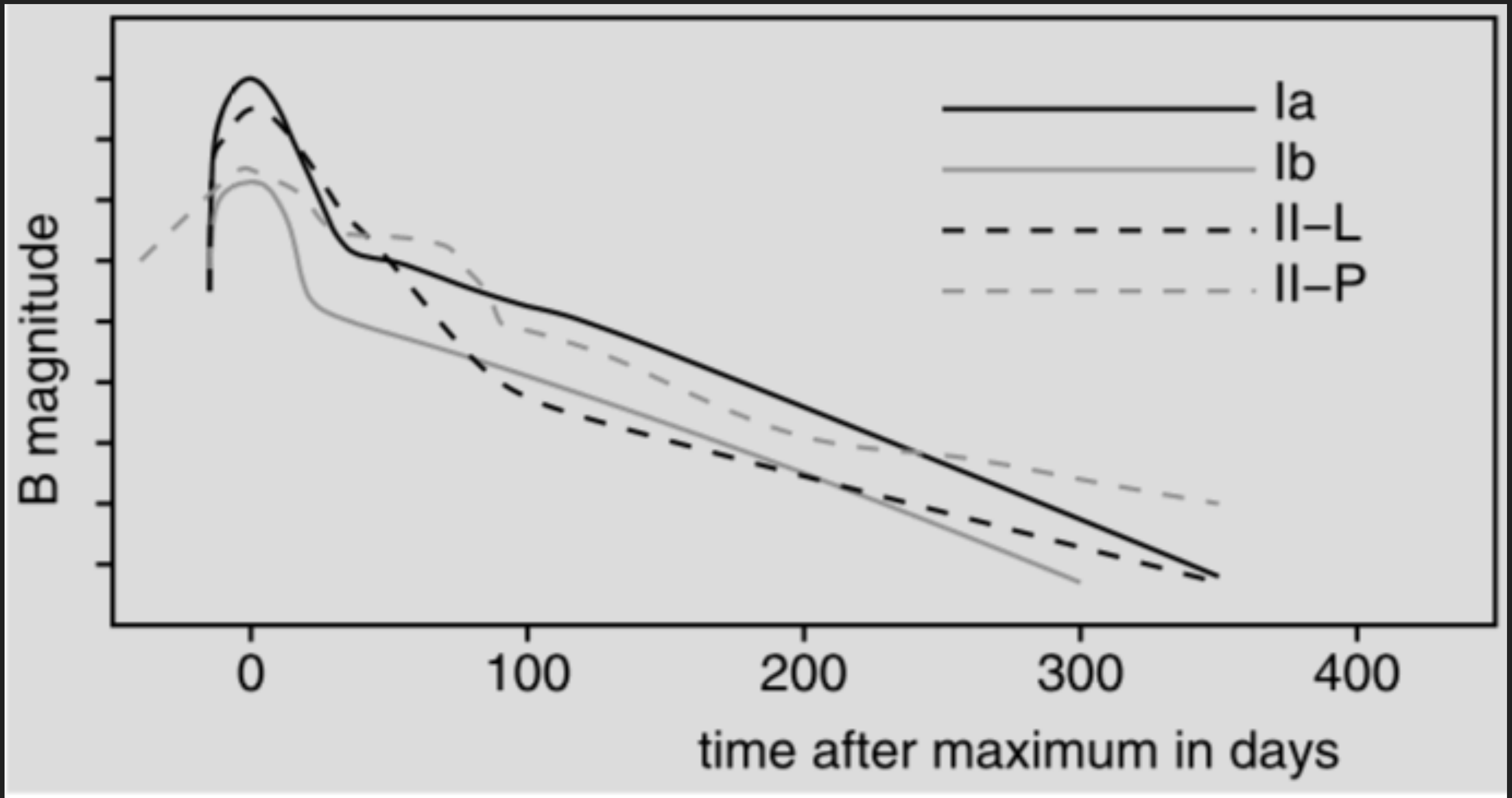
SYMBIOTIC VARIABLES

- Evolved red giant & hot component (MS / wd / ns)
- Nebulosity (common envelope)
- Rare: a few hundred



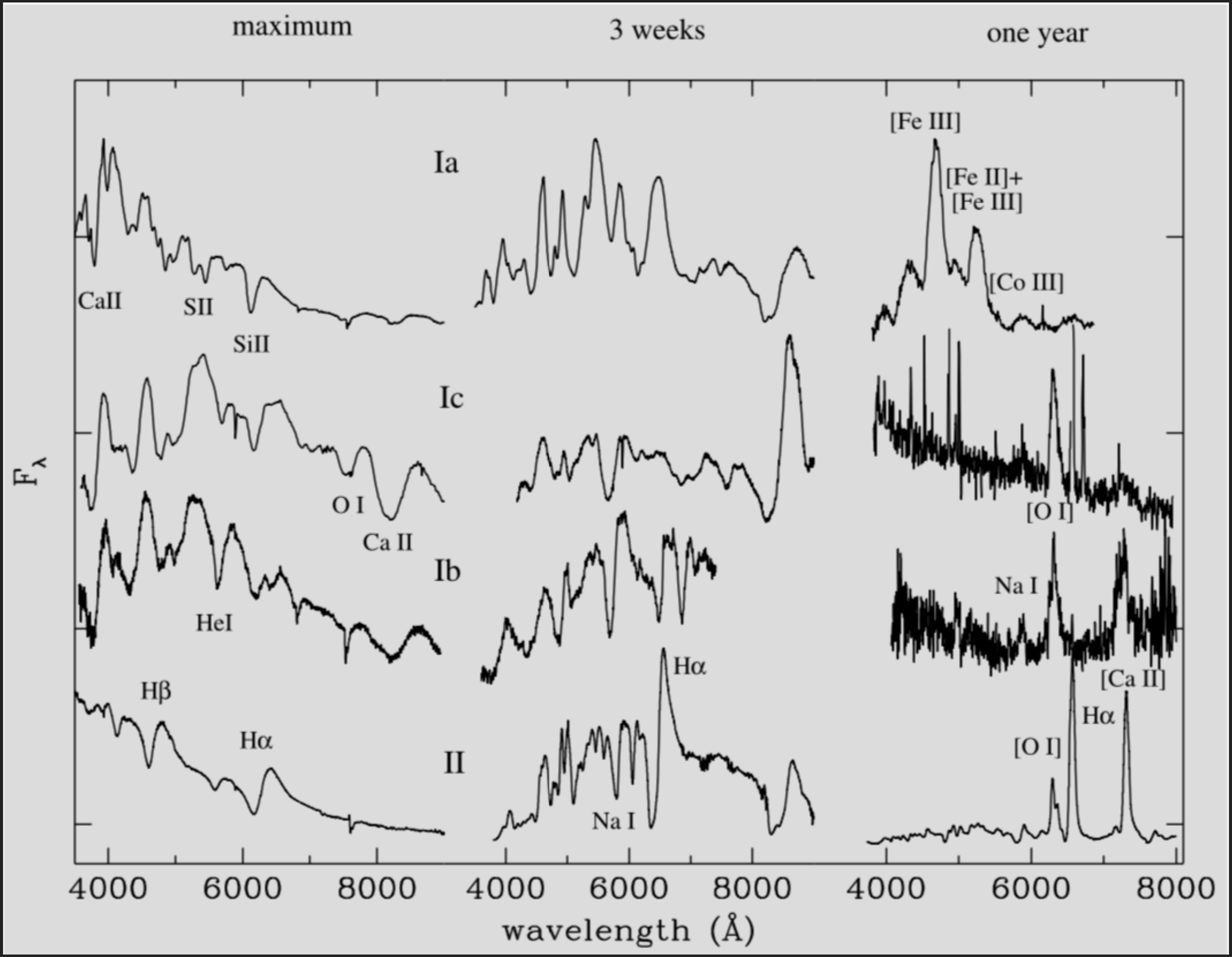
SUPERNOVAE

SUPERNOVA



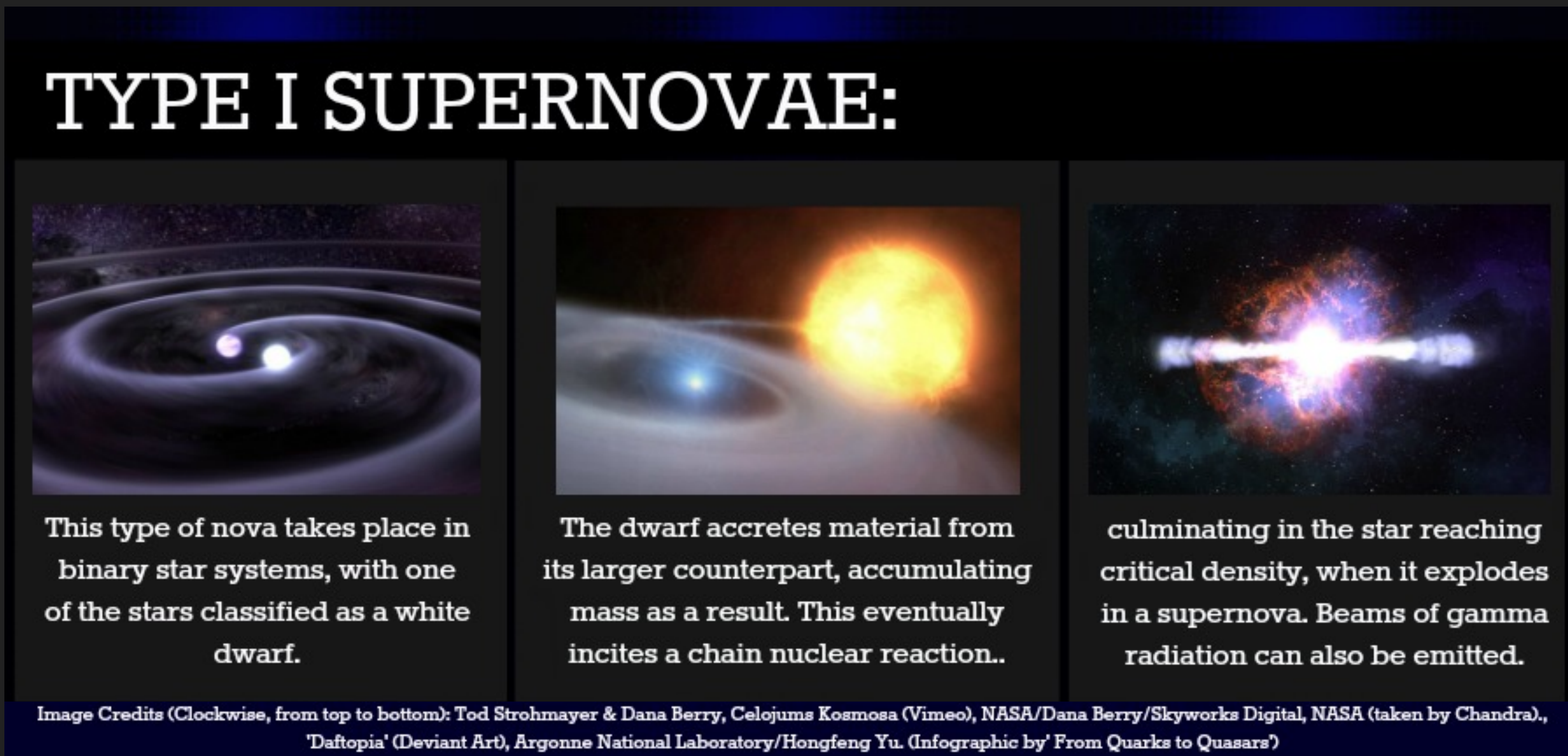
Ia
Ib
II–L
II–P
B magnitude
0
100
200
300
400
time after maximum in days

SUPERNOVA

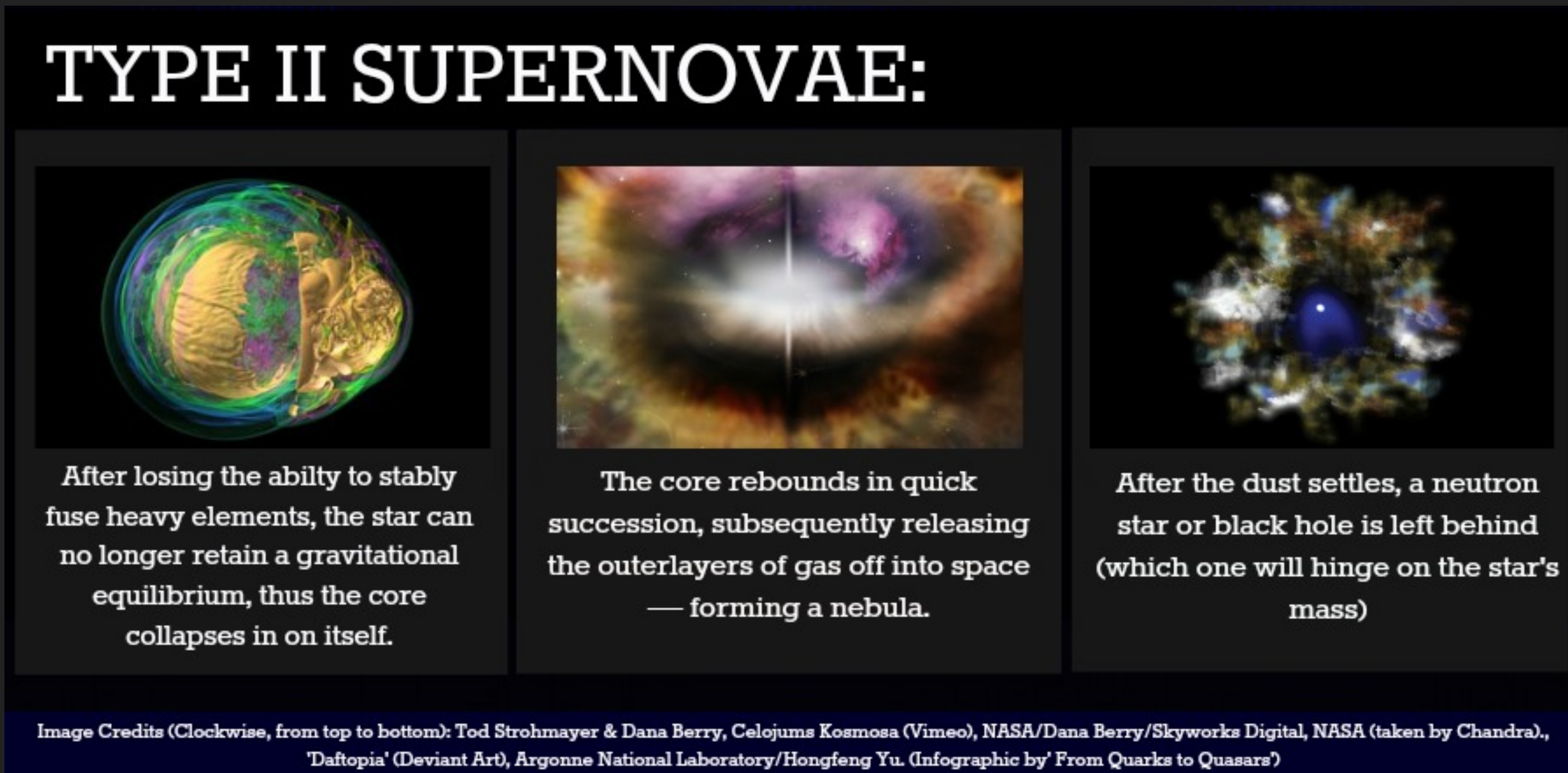


(Supernovae and Gamma-Ray Bursters, ed. K. Weiler, Lecture Notes in Physics, vol. 598, pp. 21–36)

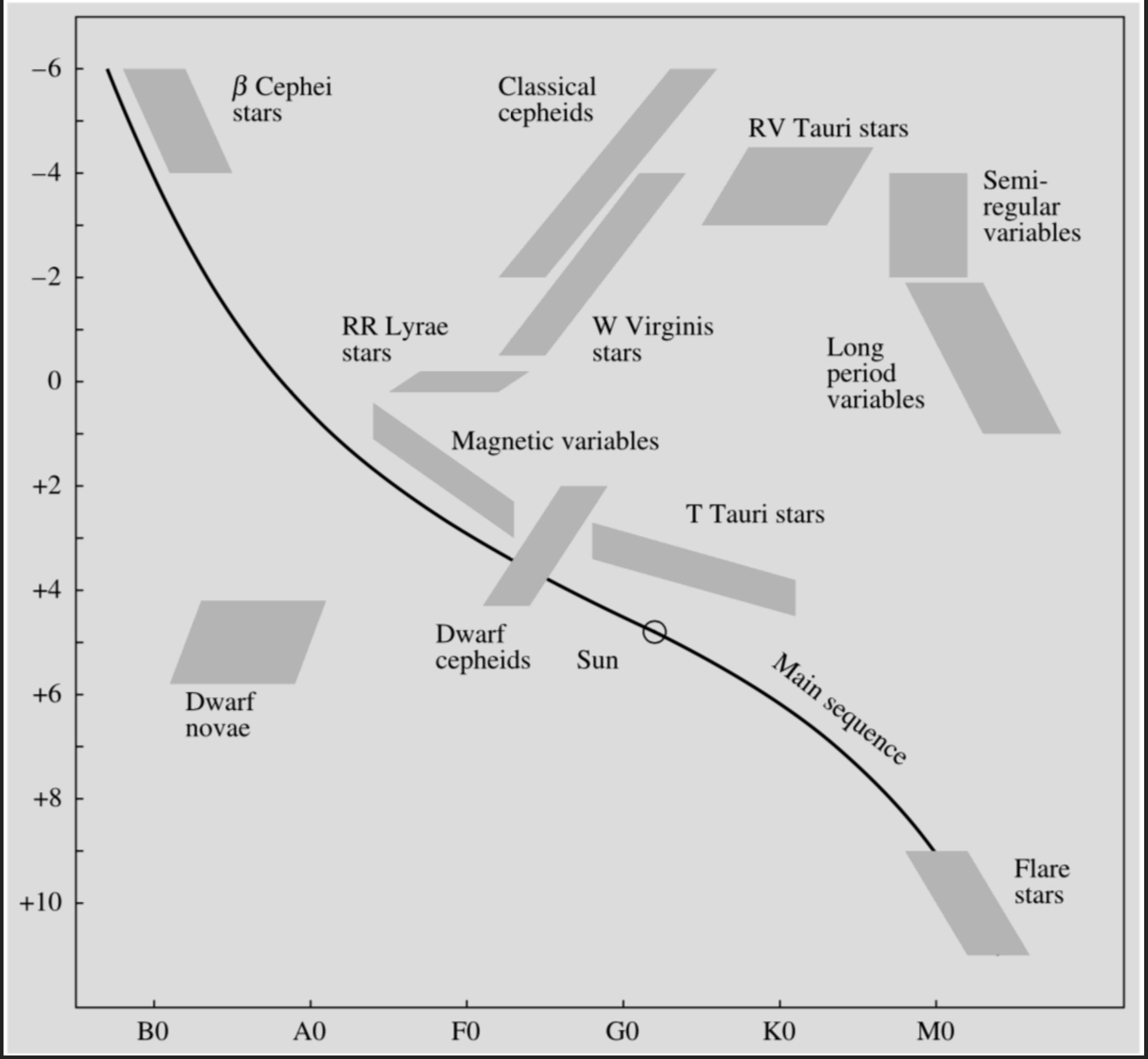
SUPERNOVA


TYPE I SUPERNOVAE:
This type of nova takes place in binary star systems, with one of the stars classified as a white dwarf.
The dwarf accretes material from its larger counterpart, accumulating mass as a result. This eventually incites a chain nuclear reaction..
culminating in the star reaching critical density, when it explodes in a supernova. Beams of gamma radiation can also be emitted.
Image Credits (Clockwise, from top to bottom): Tod Strohmayer & Dana Berry, Celojums Kosmosa (Vimeo), NASA/Dana Berry/Skyworks Digital, NASA (taken by Chandra)., 'Daftopia' (Deviant Art), Argonne National Laboratory/Hongfeng Yu. (Infographic by' From Quarks to Quasars')

SUPERNOVA


TYPE II SUPERNOVAE:
After losing the abilty to stably fuse heavy elements, the star can no longer retain a gravitational equilibrium, thus the core collapses in on itself.
The core rebounds in quick succession, subsequently releasing the outerlayers of gas off into space — forming a nebula.
After the dust settles, a neutron star or black hole is left behind (which one will hinge on the star's mass)
Image Credits (Clockwise, from top to bottom): Tod Strohmayer & Dana Berry, Celojums Kosmosa (Vimeo), NASA/Dana Berry/Skyworks Digital, NASA (taken by Chandra)., 'Daftopia' (Deviant Art), Argonne National Laboratory/Hongfeng Yu. (Infographic by' From Quarks to Quasars')

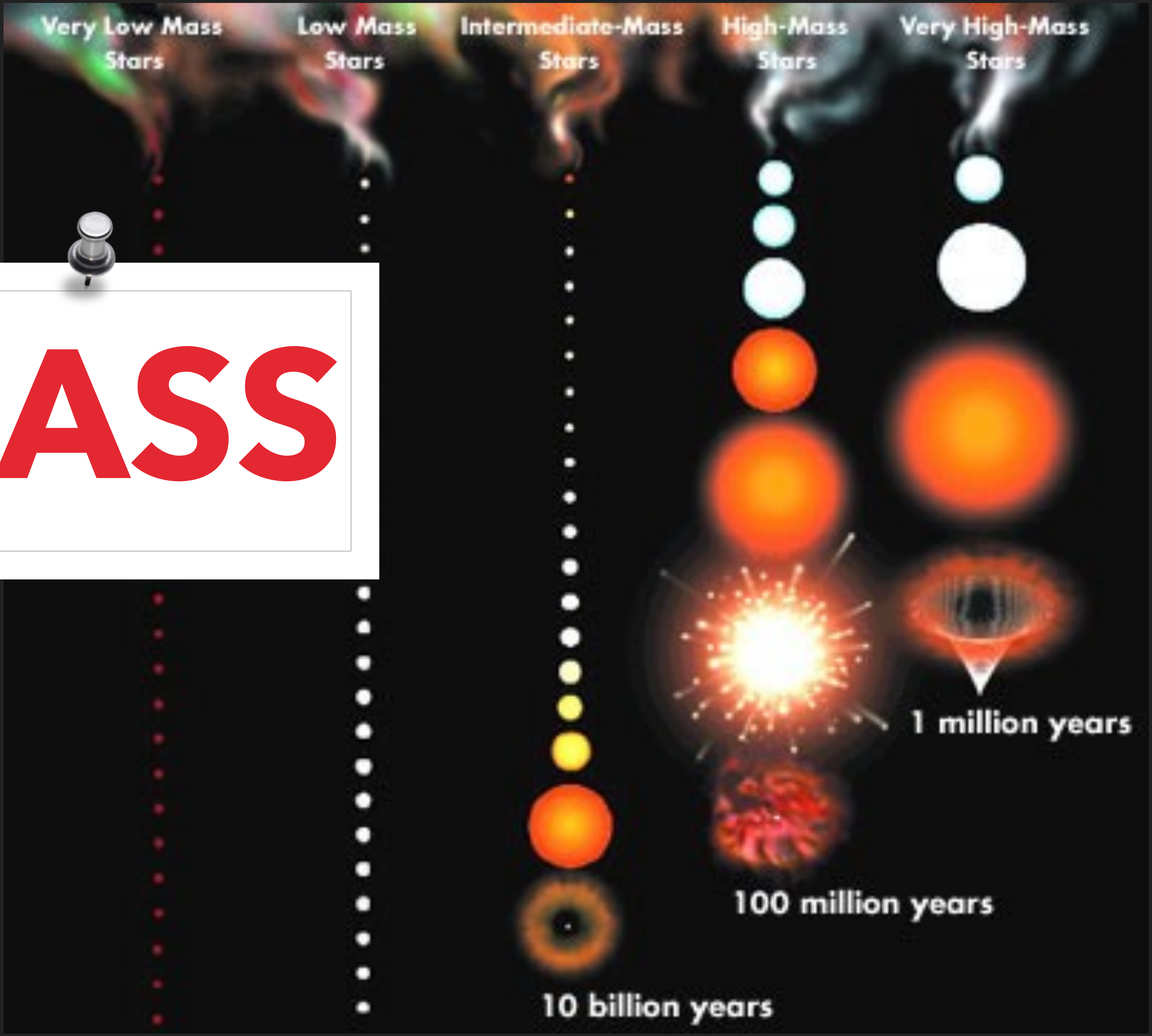
HR DIAGRAM FOR VARIABLES



Variable	N	P	Spectrum	Δm
Classical cepheids (δ Cep, W Vir)	800	1–135	F–K I	$\lesssim 2$
RR Lyrae	6100	<1	A–F8	$\lesssim 2$
Dwarf cepheids (δ Scuti)	200	0.05–7	A–F	$\lesssim 1$
β Cephei	90	0.1–0.6	B1–B3 III	$\gtrsim 0.3$
Mira variables	5800	80–1000	M–C	$\gtrsim 2.5$
RV Tauri	120	30–150	G–M	$\lesssim 4$
Semiregular	3400	30–1000	K–C	$\lesssim 4.5$
Irregular	2300	–	K–M	$\lesssim 2$

EVOLUTION OF STARS

MASS



EVOLUTIONARY TIME SCALES

Stellar lifetimes (unit 10^6 years)

Mass [$M_\odot$]	Spectral type on the main sequence	Contraction to main sequence	Main sequence	Main sequence to red giant	Red giant
30	O5	0.02	4.9	0.55	0.3
15	B0	0.06	10	1.7	2
9	B2	0.2	22	0.2	5
5	B5	0.6	68	2	20
3	A0	3	240	9	80
1.5	F2	20	2000	280	
1.0	G2	50	10,000	680	
0.5	M0	200	30,000		
0.1	M7	500	10^7		

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