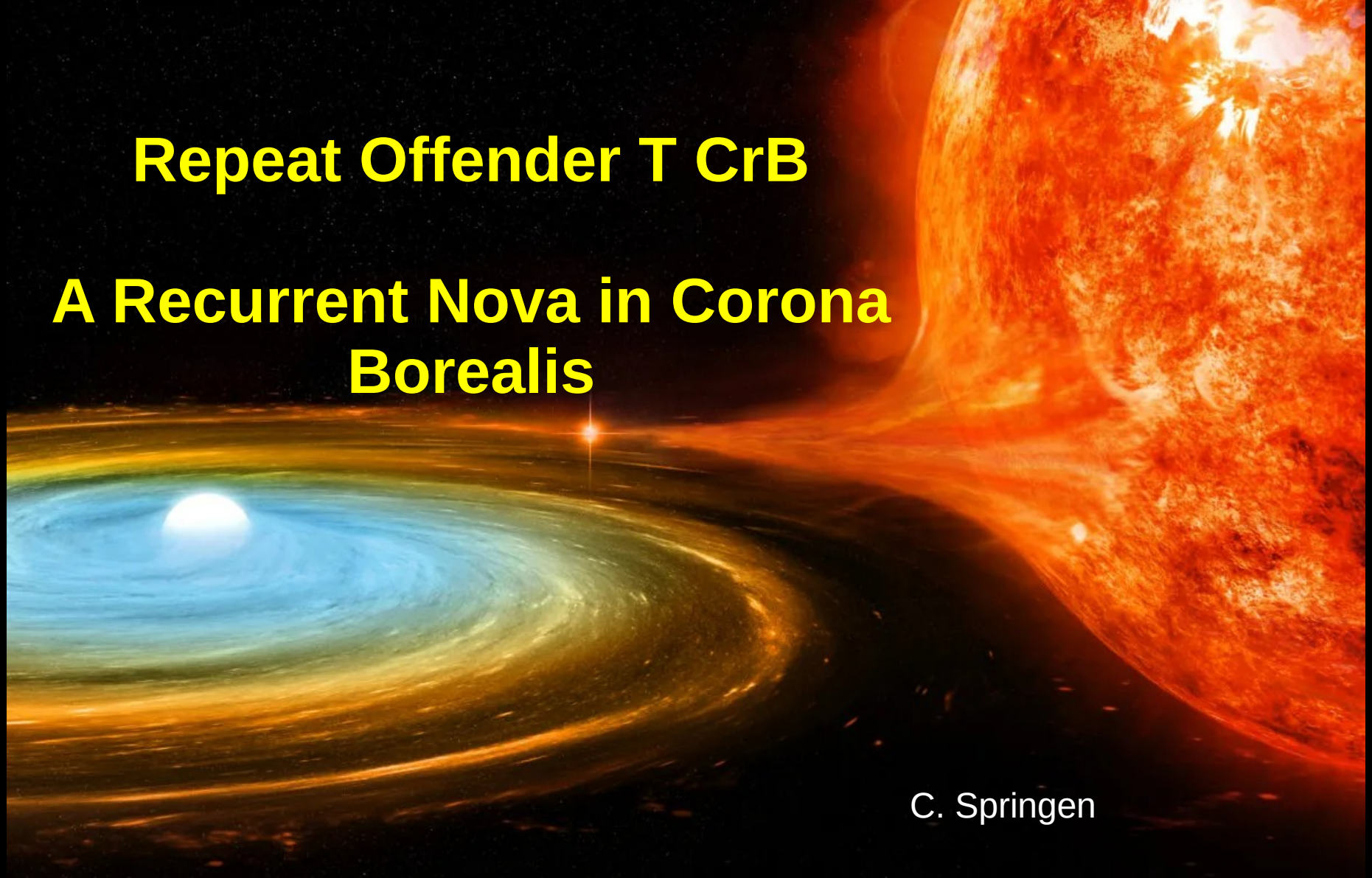

Repeat Offender T CrB
A Recurrent Nova in Corona Borealis
C. Springen

T Corona Borealis

- Preliminaries – Terms & Jargon
- Progenitors – Red Giant & White Dwarf
- Binary Stars acting up - Stellar Bursts
- What am I supposed to do about it? Observing

Come to Terms with Astronomy

- Constellation names are in Latin
  - e.g. Coronae Borealis CrB (Northern Crown)
- Key symbols Earth = ⊕ Sun = ʘ
- pc parsec
  - 1 pc = 3.26 light-years = 206 k AU
- AU Astronomical Unit: mean Earth-Sun distance
  - 1 AU = 149 M km
- π parallax angle in arcseconds [”] or milliarcseconds [mas]
- M absolute & m observed magnitude (brightness)
- Luminosity = total power of EM radiation at all wavelengths (bolometric) emitted by a celestial object in ratio to the Sun $L_{\odot}$ or in Watts

T CrB Description

- T CrB is a Binary system
  - Primary is a White Dwarf (WD)
  - Secondary (donor) is a M3III Red Giant
- T CrB is a Recurrent Nova (RNe)
  - Nova because of its dramatic brightening ***& not*** disintegrating its companion white dwarf (supernova).
  - Brightness expected to go from m = 10 binocular limit up to m = 2.5 naked eye visibility or 8 magnitudes
  - Recurrent with p ≈ 80 years
  - Documented eruptions 1866, 1946 and Possibly 1217, 1787
    - Expected eruption 2025.5 +/- 1.3 yr (Schaefer 2023)
    - Precursor high-state occured in 2015 (same as 1936)

10 Recurrent Novae are Currently Known in the Milky Way Galaxy

1 T Pyx Pryxis

2 IM Nor Norma

3 CI Aql Aquila

4 V2487 Oph Orphiuchus

5 U Sco Scorpius

6 V394 CrA Corona Australis

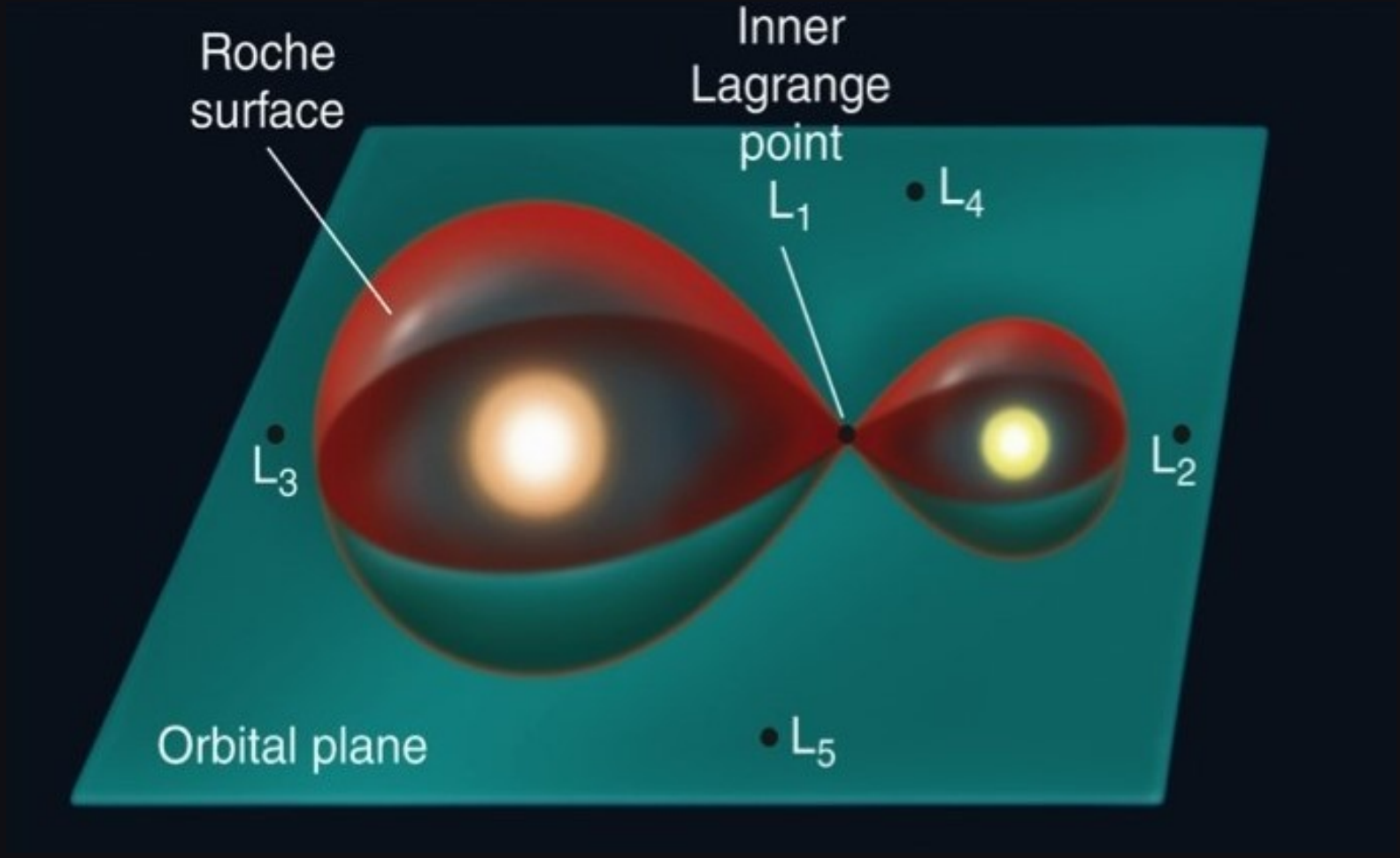
7 T CrB Brightest of RNe m_{qV} = 10.1 m_{peakV} = 2.5

8 RS Oph (Erupted Aug 2021)

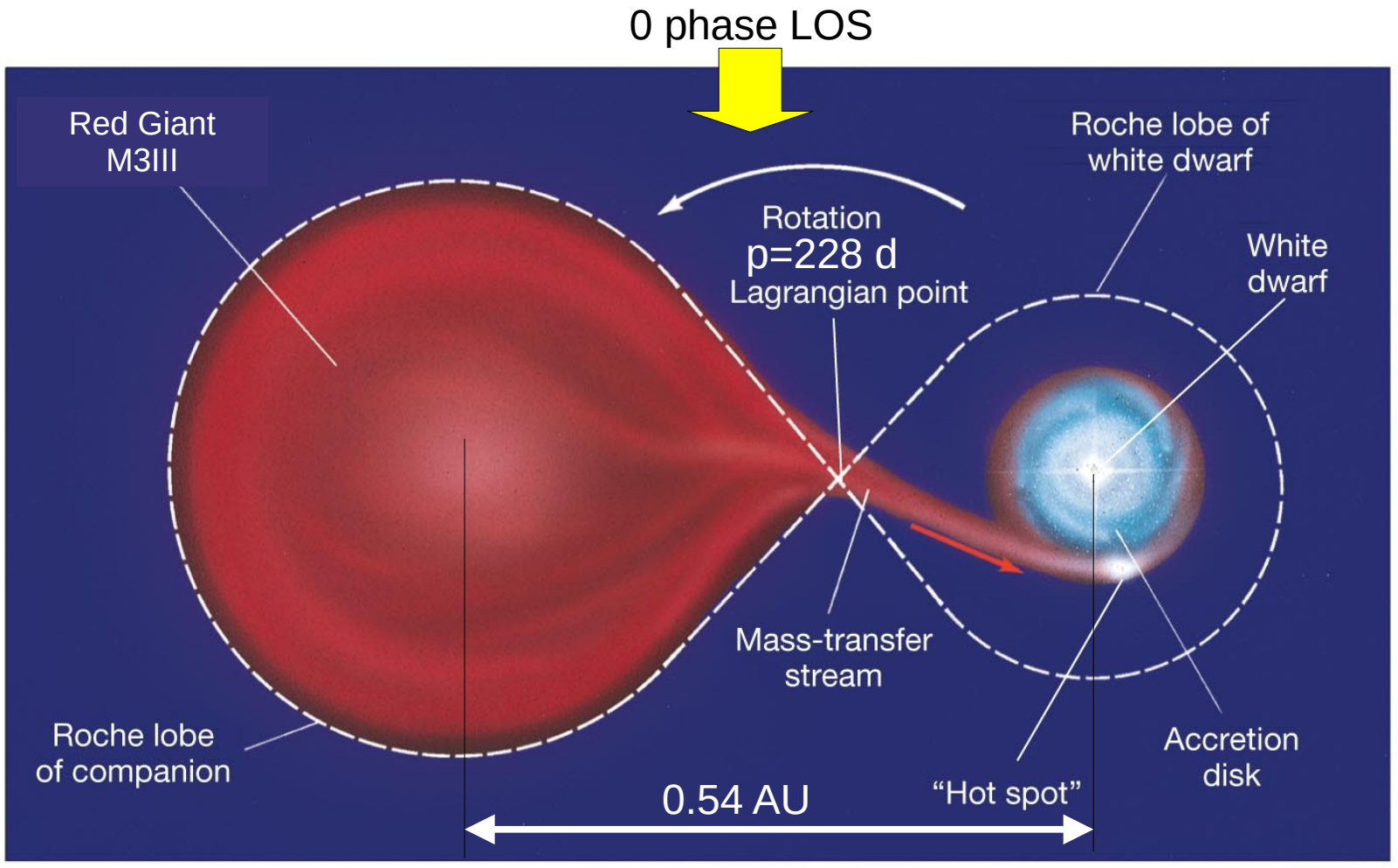
9 V745 Sco Scorpius

10 V3890 Sgr Sagittarius

Teardrops of a Stellar Binary

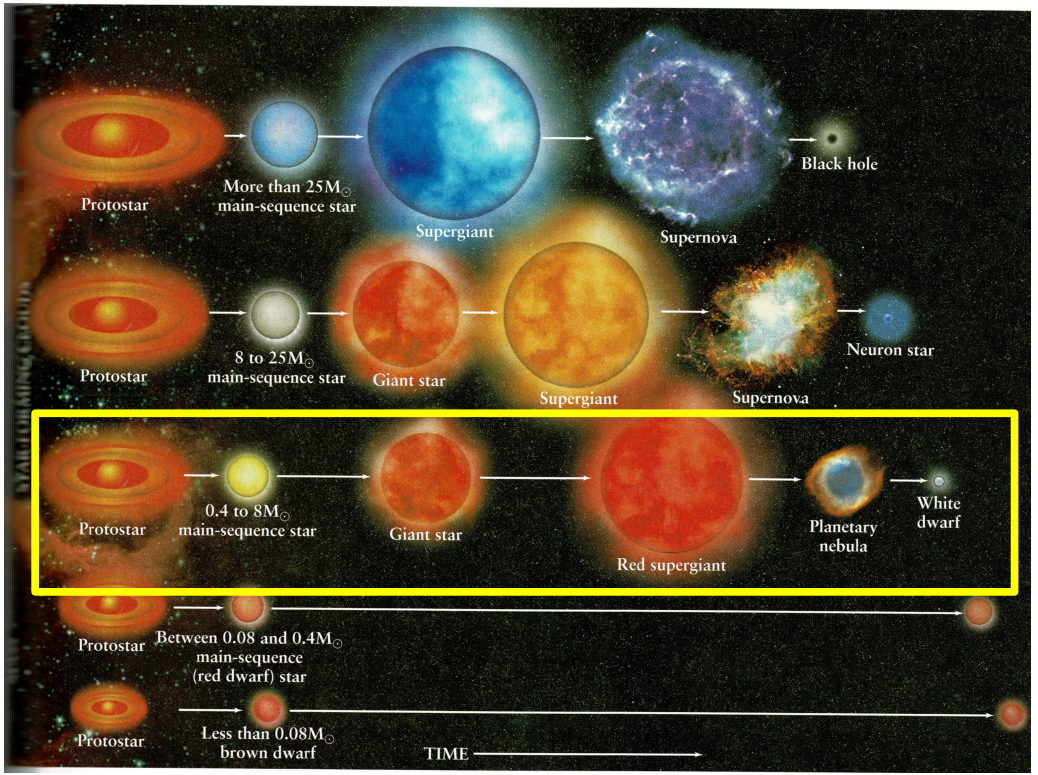


T CrB Nova Binary System



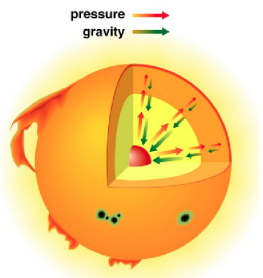
Evolution of Stellar Objects

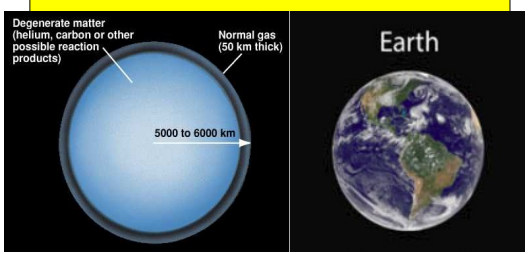
- T CrB - Primary - White dwarf
  - Progenitor is main sequence Sun-like star 0.4 - 8 $M_\odot$
  - End state is electron degenerate WD M = 1.37 $M_\odot$
  - Dense $M_\odot/V_\oplus$
- T CrB - Secondary Red Giant
  - Evolved Sun-like star
  - $M_{RG\text{-}\mathbf{TCrB}}$ = 1.12 $M_\odot$

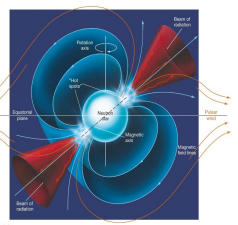


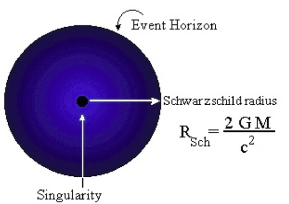
Equilibrium - the Balance of Forces

Ideal Gas Law	Pauli Exclusion Principle		TBD Physics
Hydrostatic Equilibrium	**Electron Degeneracy**	Neutron Degeneracy	Singularity Quark degeneracy?
Main sequence & giant stars	**White Dwarfs**	Neutron Stars	Black Holes
R=.1-1500 $R_\odot$ M≈0.1-200 $M_\odot$ ρ≈10^3 kg/m^3	**R≈6x10^3 km** **M≈1 $M_\odot$** **ρ=10^9 kg/m^3**	R≈10 km 1.4<M<3 $M_\odot$ ρ=10^{17} kg/m^3	R_s=3*M km 3<M<10^9 $M_\odot$ ρ=∞









T CrB System Physical Data

- Binary Star M3III Red Giant + WD
  - M3 Red Giant, cool (3600 K)
    - $M_{TM3} = 1.12\ M_{\odot}$
    - $R_{TM3III} = 75\ R_{\odot}$
  - White Dwarf, hot (10,000 K)?
    - $M_{TWD} = 1.37\ M_{\odot}$ Chandrasekhar limit = $1.4\ M_{\odot}$
    - $L_{TWD} = 100\ L_{\odot}$
- Separation is d = .54 AU
- Orbital Period = 228 d

Implications of Physical Parameters

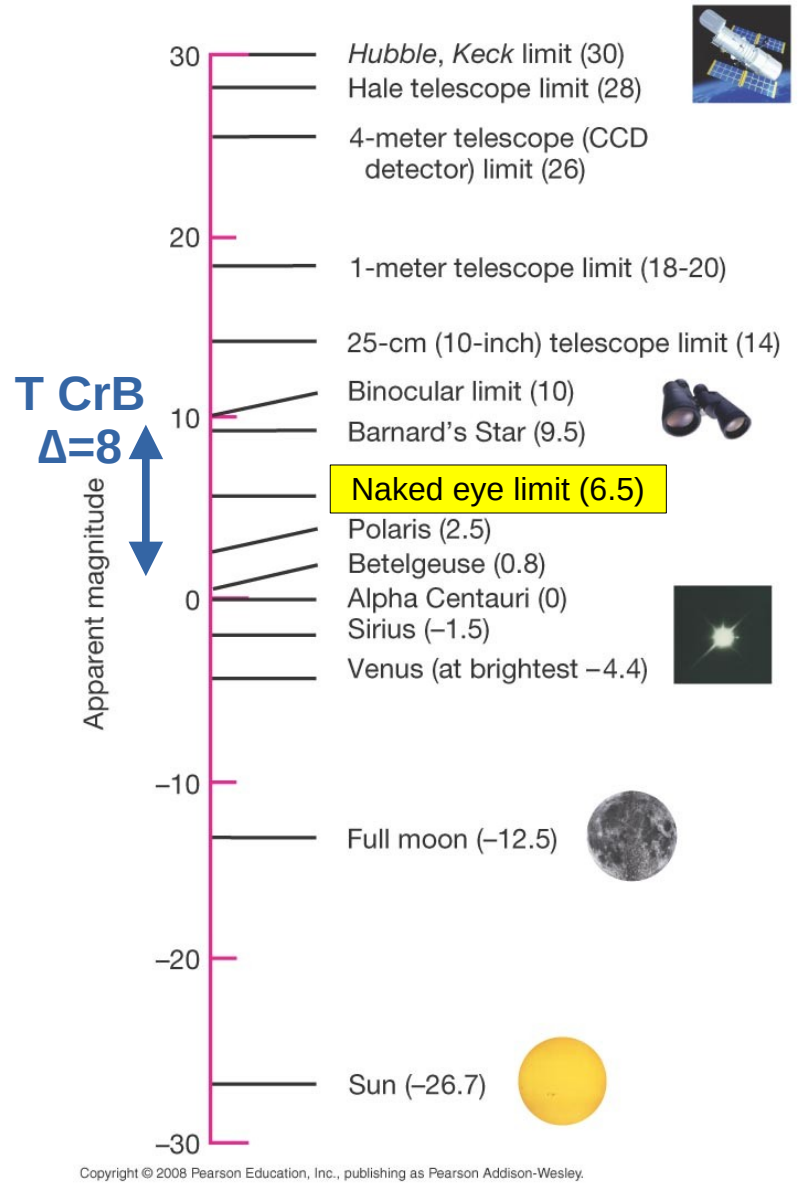
- Recurrance rates vary from 10 - ~100,00 yr
- Fast recurrent RN_e i.e. $\tau_{rec} < 100$ yr imply
  - Mass of primary is close to Chandrasekhar mass $M_{CS} = 1.4\ M_\odot$ $M_{TCrB\text{-}WD} > 1.37\ M_\odot$ √
  - Sufficient mass transfer rate to primary ~$10^{-7}\ M_\odot\ yr^{-1}$
- Mass of evolved secondary Red Giant over fills the Roche Lobe and spills onto the primary White Dwarf
- When sufficient Hydrogen builds up thermo-nuclear fusion initiates and causes major brightening of system

Some Research Results

- Hydrogen is accreting onto surface of the WD
- Base layer of H is electron degenerate so cannot expand thermally
- T CrB WD thermonuclear runaway cycle is imminent (2024-2025) resulting in outburst
- Evidence suggest a net accretion of material
  - Secular evolution of the WD may allow it to reach to the Chandrasekhar limit and explode as either a Type Ia supernova or undergo accretion induced collapse, depending on the composition of the WD.

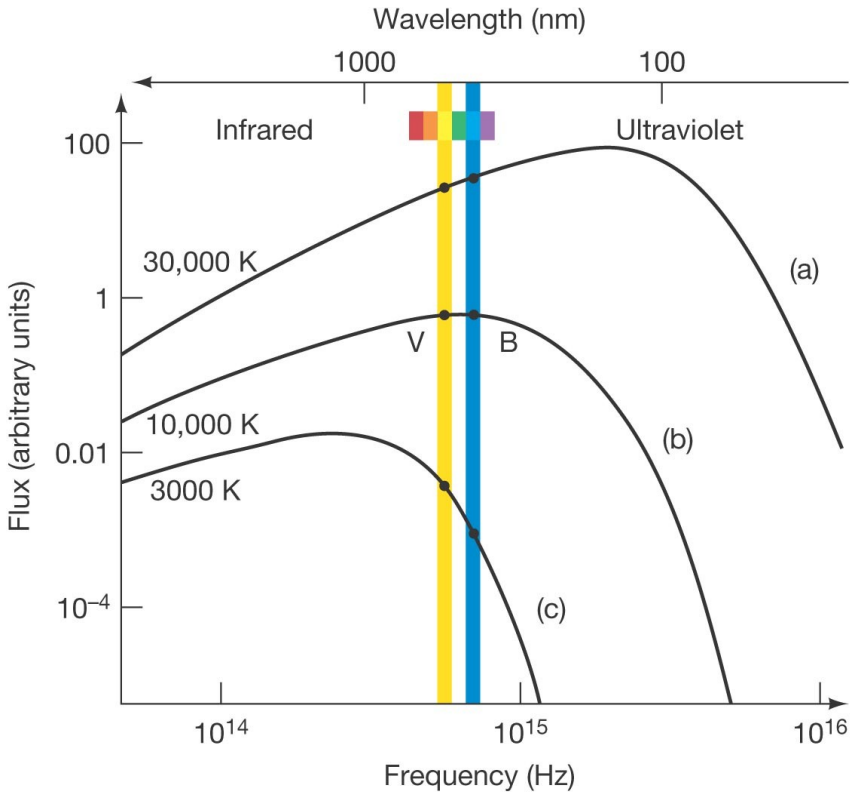
Brightness

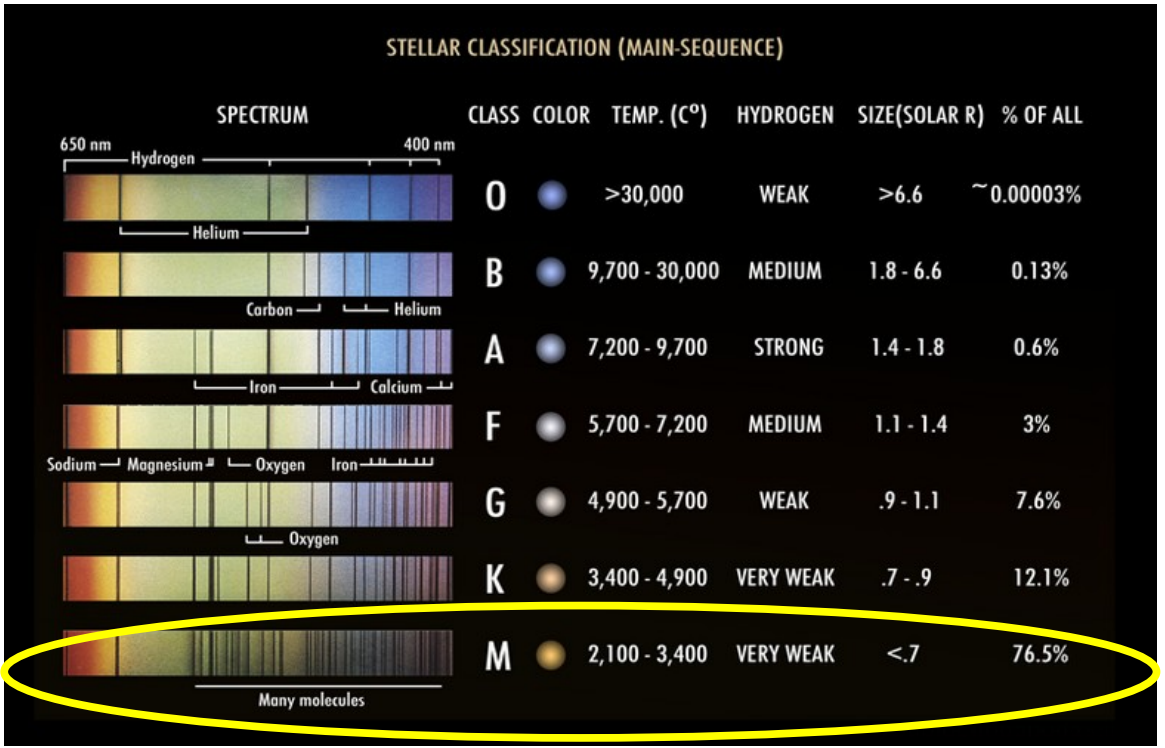
- Measured in Magnitudes
  - Absolute magnitude **M** is @ 10 pc
  - Apparent magnitude **m** is as observed locally
  - Inverted scale – more positive is dimmer
  - Logarithmic scale
    - 5 Magnitudes is 100 x in brightness
    - $m \approx -2.512 \log_{10} (F_x/F_{ref})$ Fref w.r.t Vega
  - Example: Sun m = -26.7 & M = 4.8



M Spectral Type

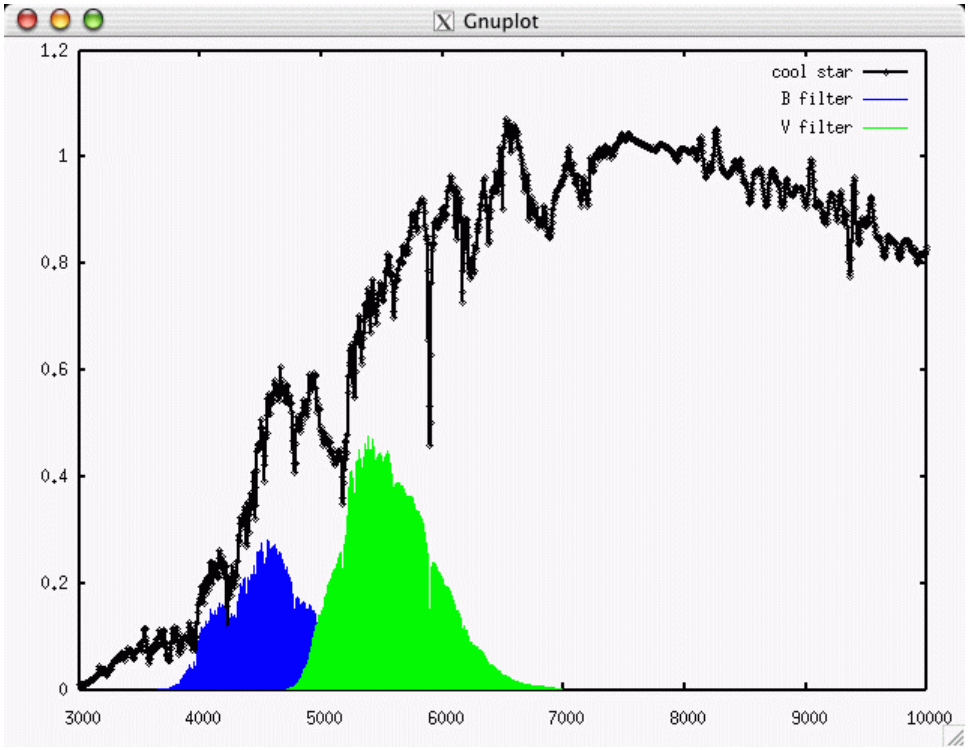
- Cool star M < 3400 K





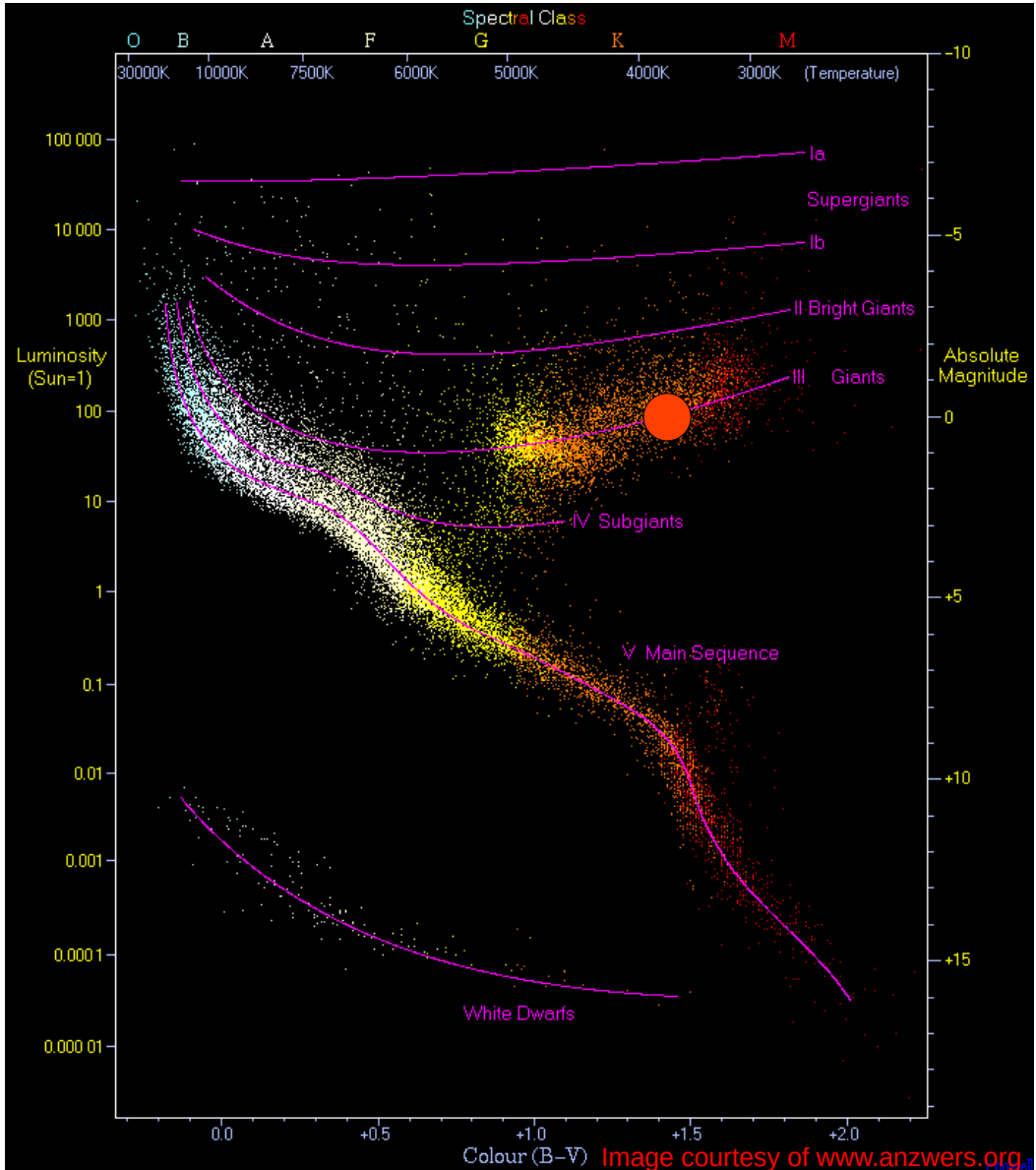
Temperature via Color Index B-V

- T CrB Quiescent color ratio
  - Bq – Vq = 11.6 – 10.1 = 1.5 (very red - cool)
- Peak color ratio (in outburst)
  - Bpk – Vpk = 2.5 – 2.5 = 0 (hotter – like Vega)



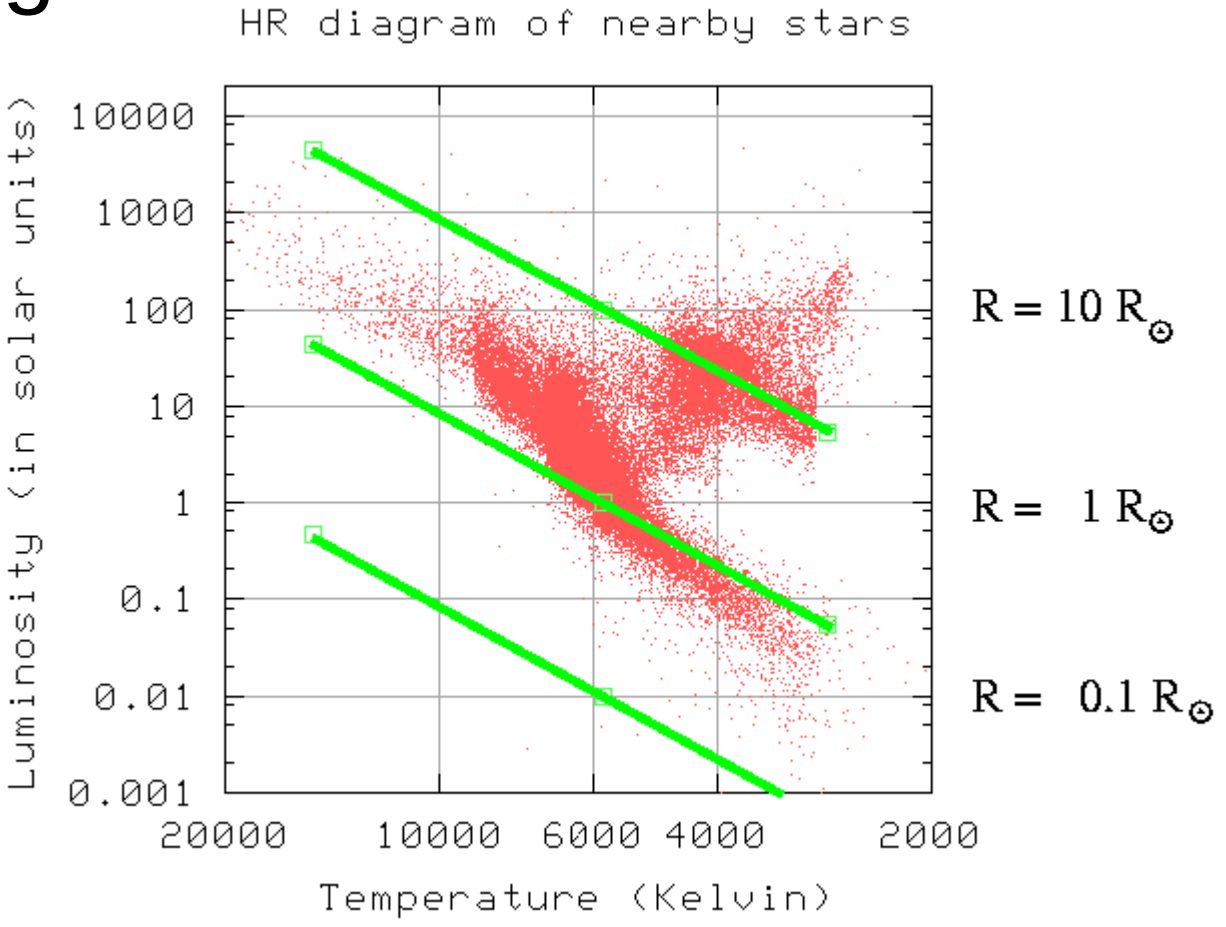
Luminosity Class

- Determined from spectral line widths
- T CrB Primary is a white dwarf
  - Stellar core
  - No fusion → cooling
  - Very small → low luminosity
- T CrB Secondary is a luminosity class III evolved *Red Giant* star
- You only get dwarfs and Giants no *normal* stars :-(



Size on a HR Diagram

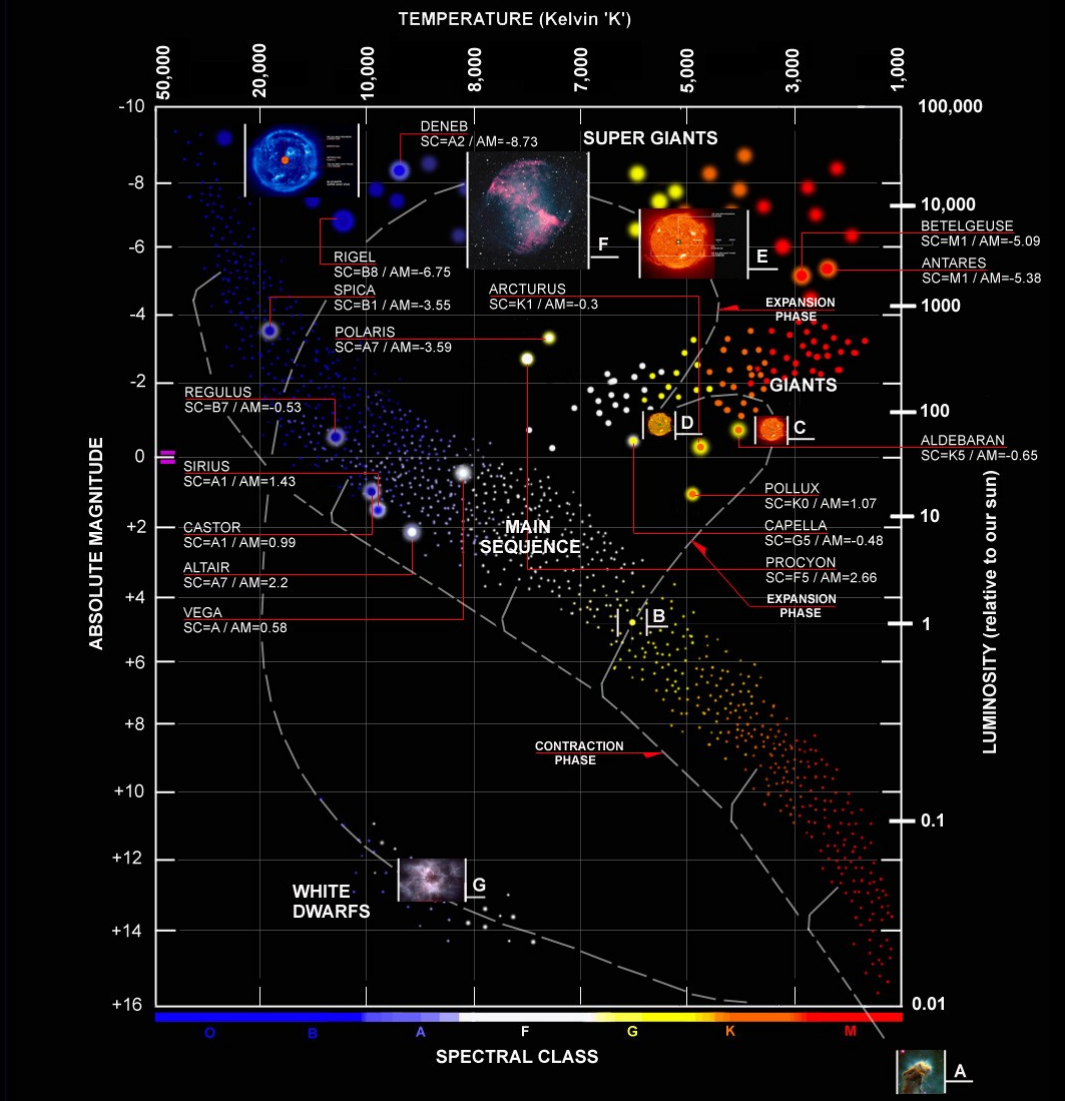
- Diagonal Lines plot constant radii
- Main Sequence stars are about 1 $R_\odot$
  - OB stars a little more
  - M stars a little less
- Note spacing is logrithmic



Hertzsprung-Russel (HR) Diagram

Classification

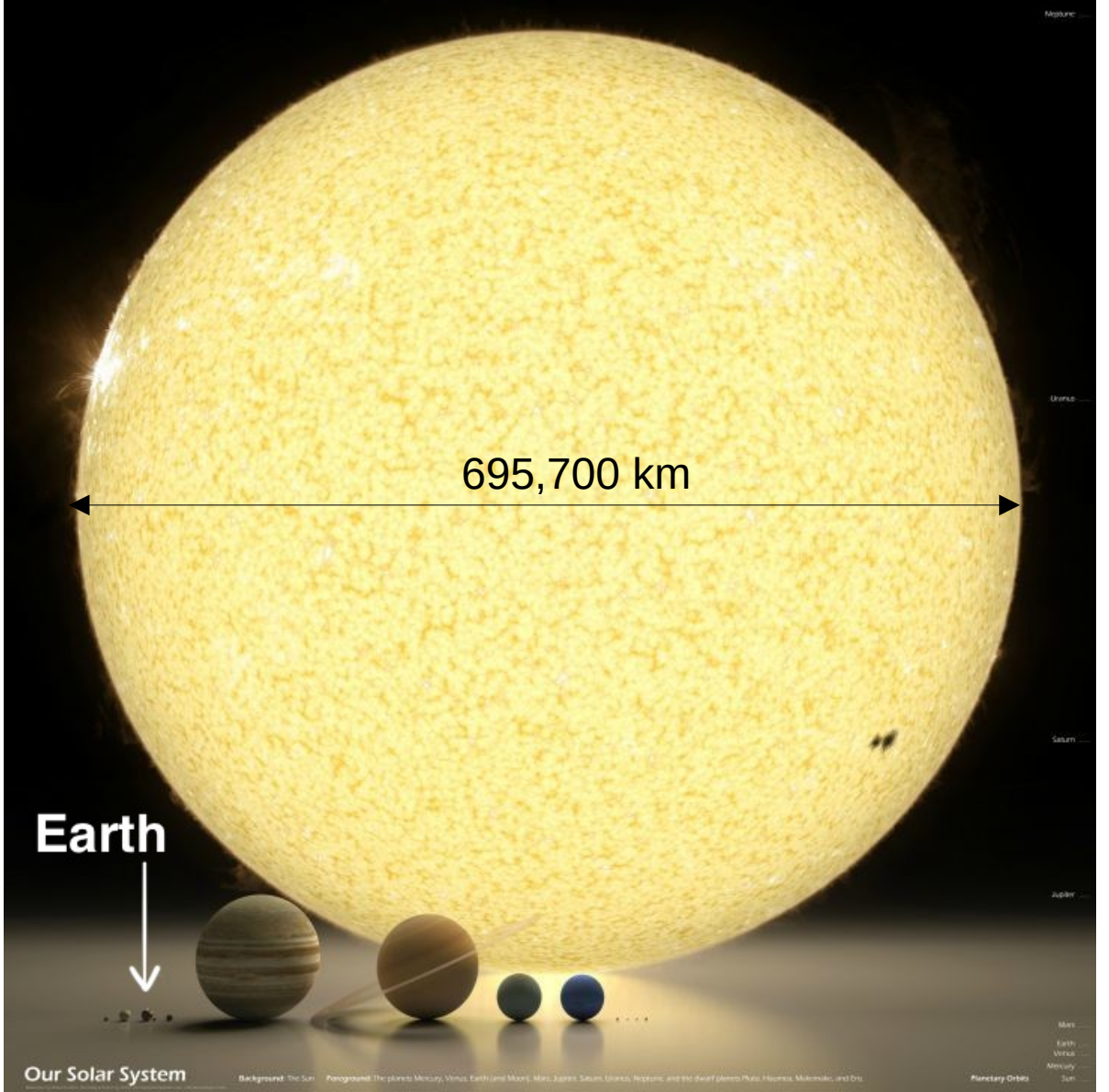
- Evolution
- Size
- Temperature
- Brightness/Luminosity
- Main Seq. Mass



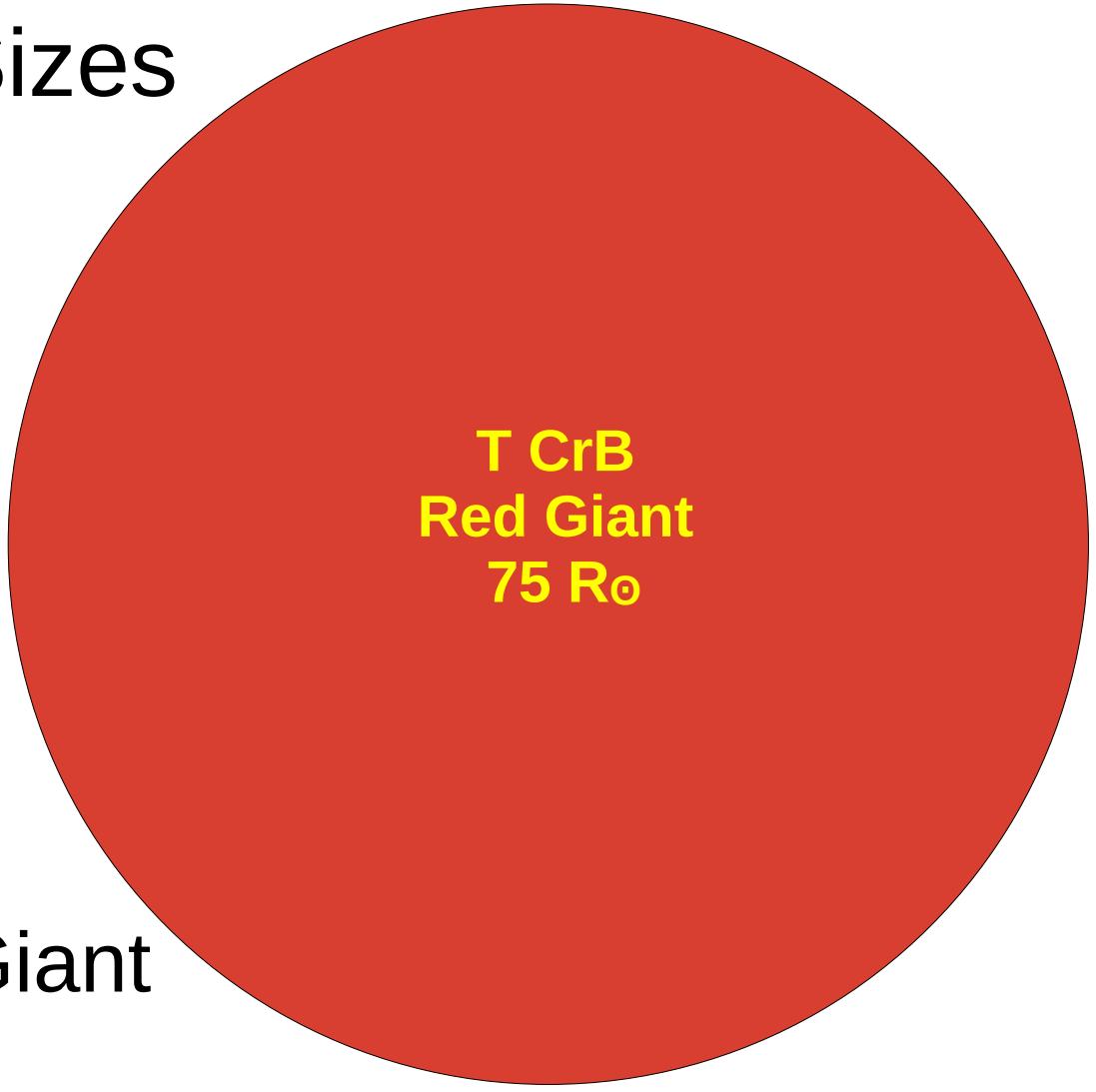
Our Suns Size relative to Earth

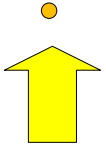
$R_{\odot} = 109\ R_{\oplus}$

T CrB White Dwarf is about the size of Earth.



Sun & M3III Giant Sizes Relative to Sun



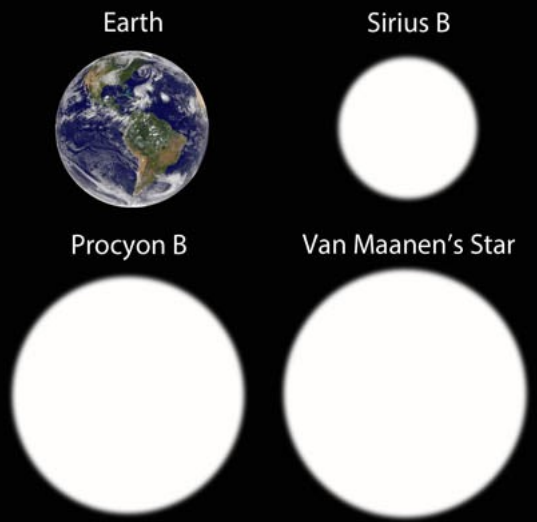


Sun

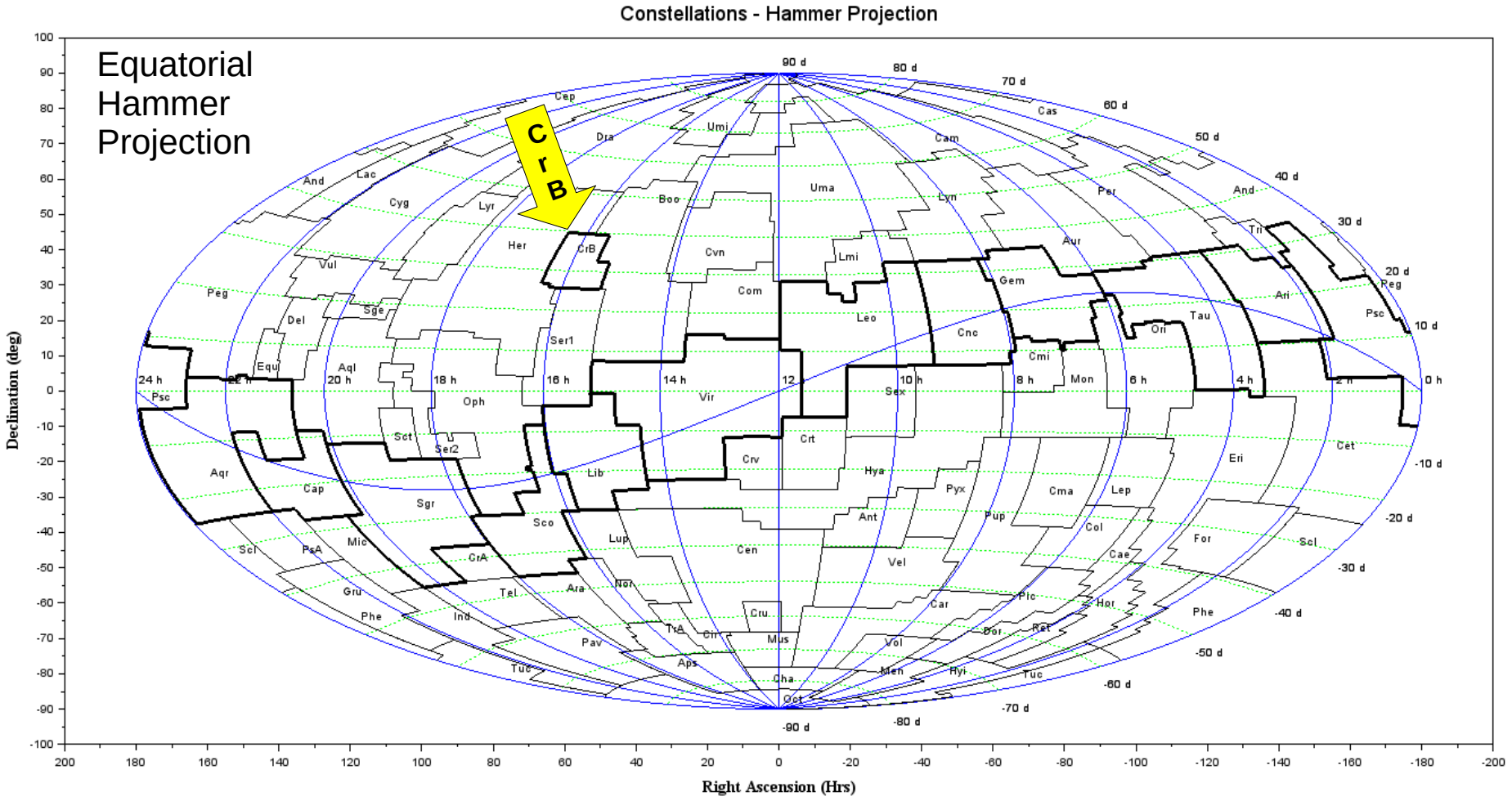
- Companion is a luminosity class III Giant

White Dwarfs

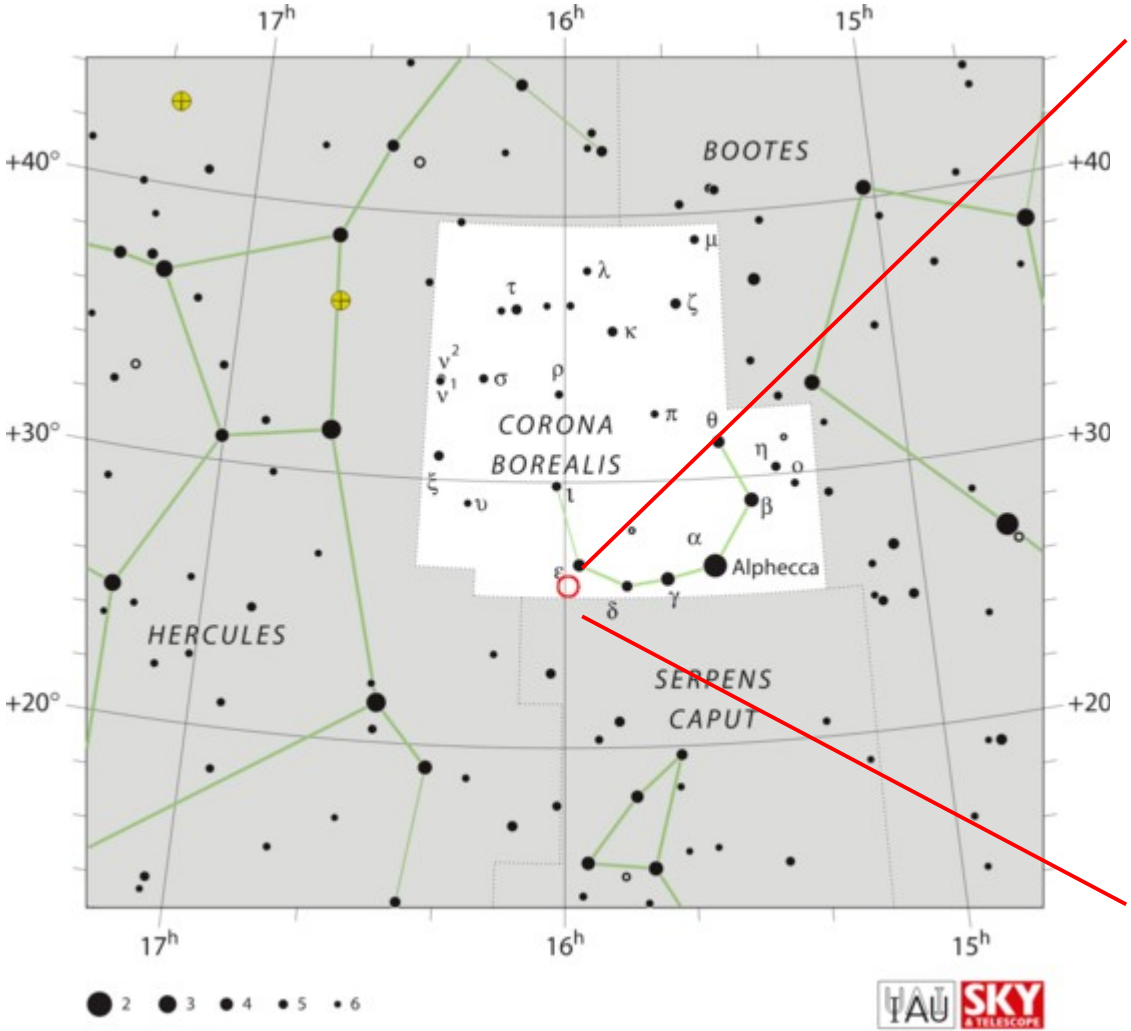
- Small, Earth sized +/-
- Massive ~$M_{\odot}$
- Dense ~10^{9} kg/m^{3}
- Electron degenerate
- No fusion
- Initially hot (white) then cool to Black Dwarf & crystallizes

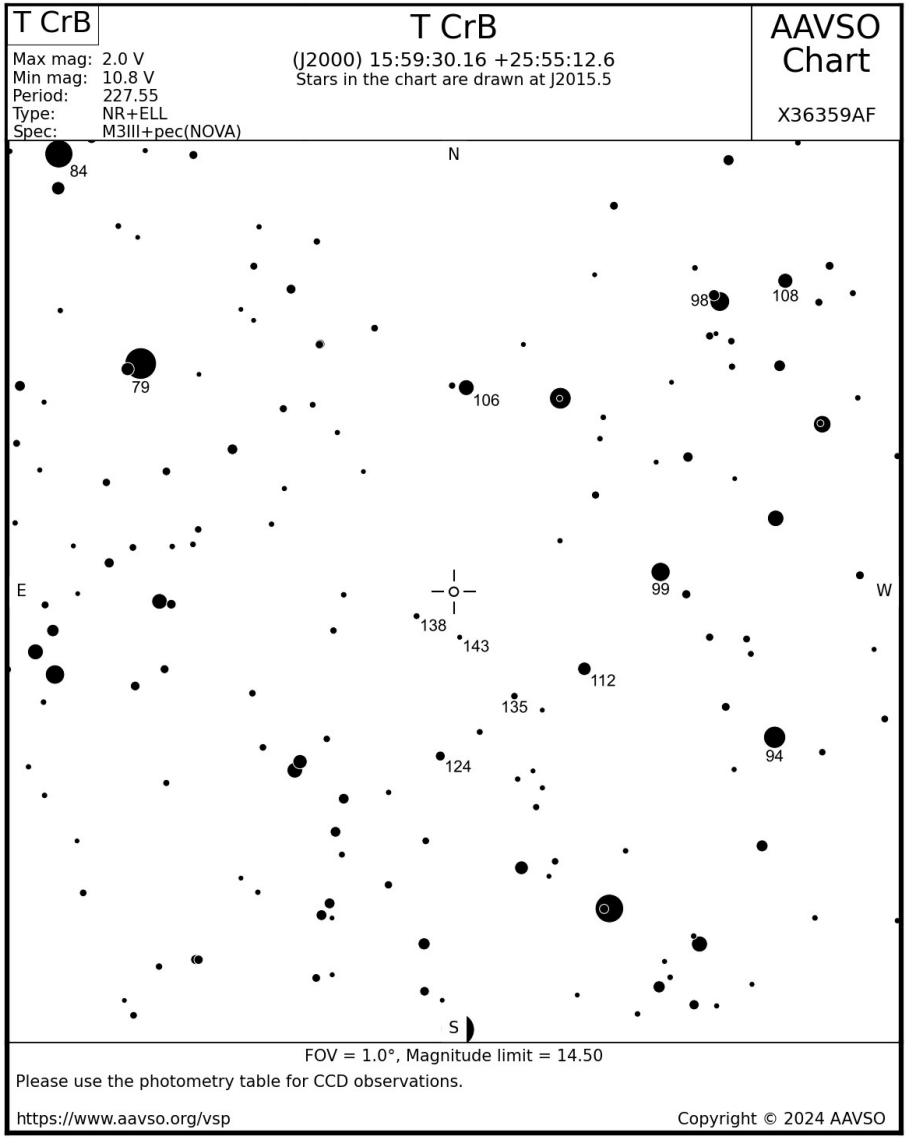


So...Where is Coronae Borealis ?

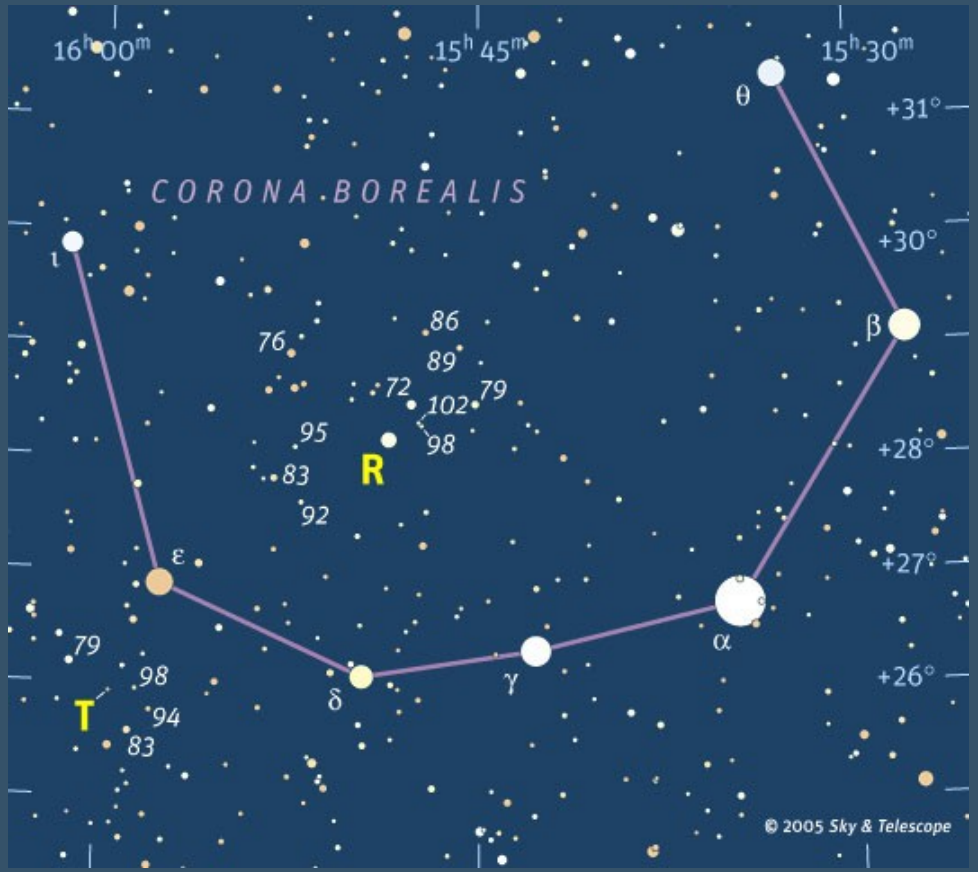


Finder Charts

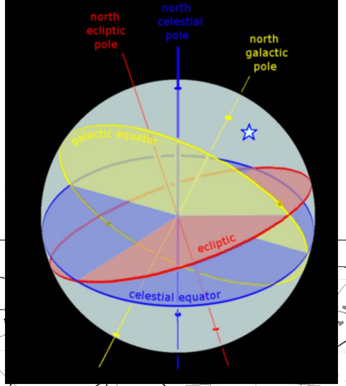


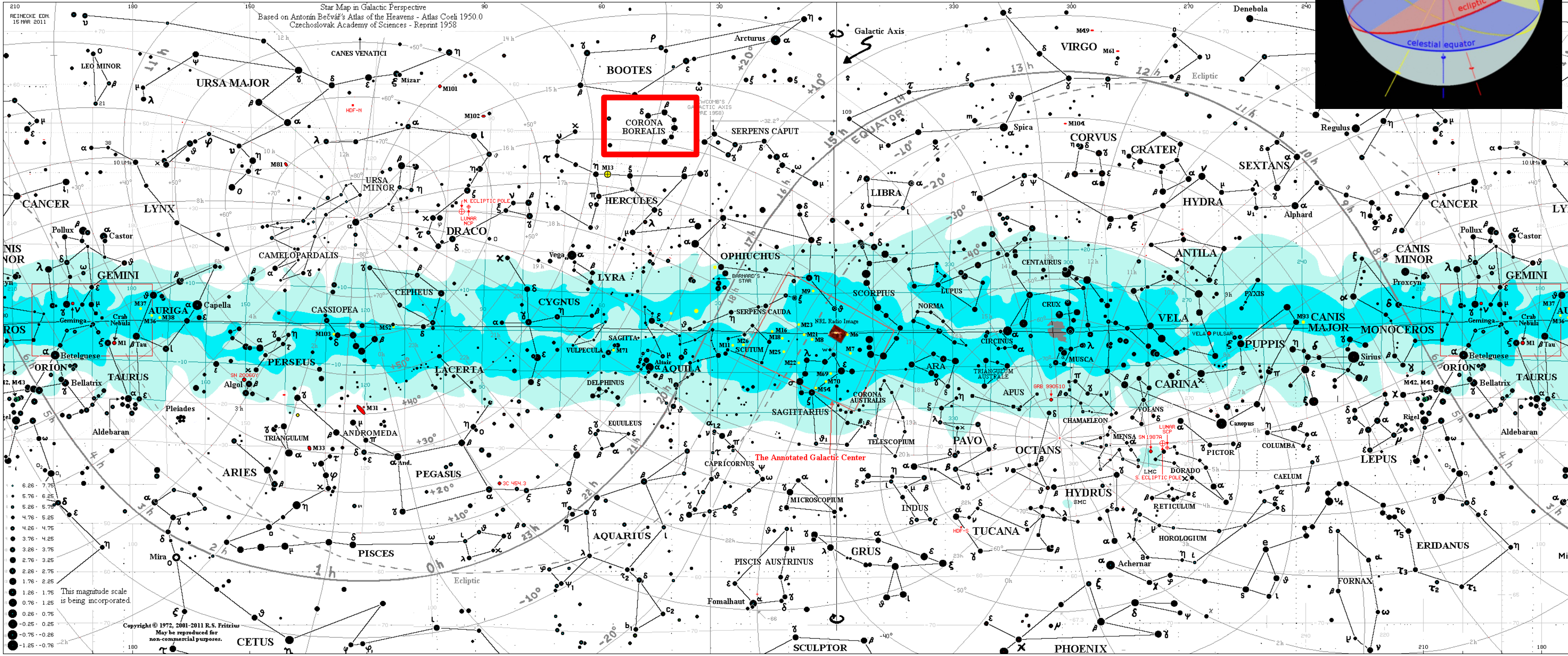


T CrB is Less Than Prominent in Quiescence

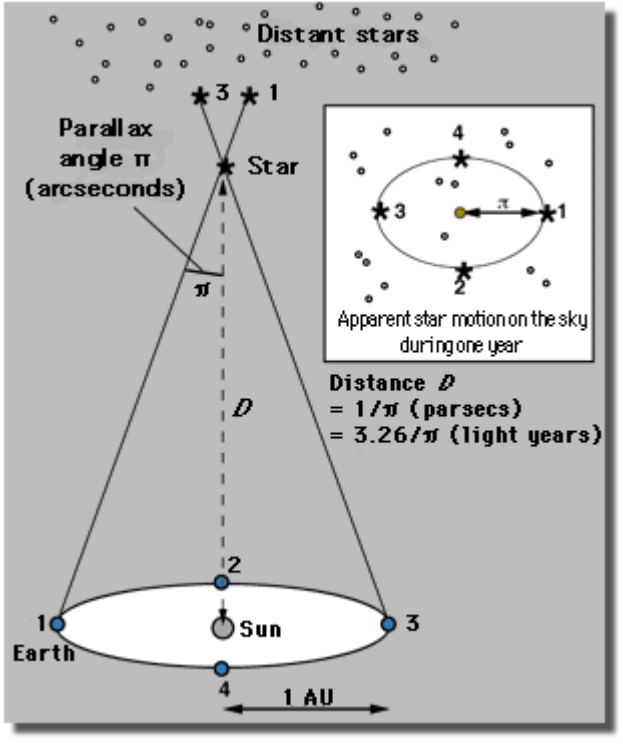


Galactic Projection with T CrB





Parallax Distance of T CrB



- T CrB parallax via Gaia Space Telescope
  - π = 1.1538 mas
  - d = 1/p = 1/(1.1538 x 10^{-3} as) = 866.7 pc
    - +/- 17.7 pc
  - d ≈ 867 pc

Gaia DR3 4111834567779557376

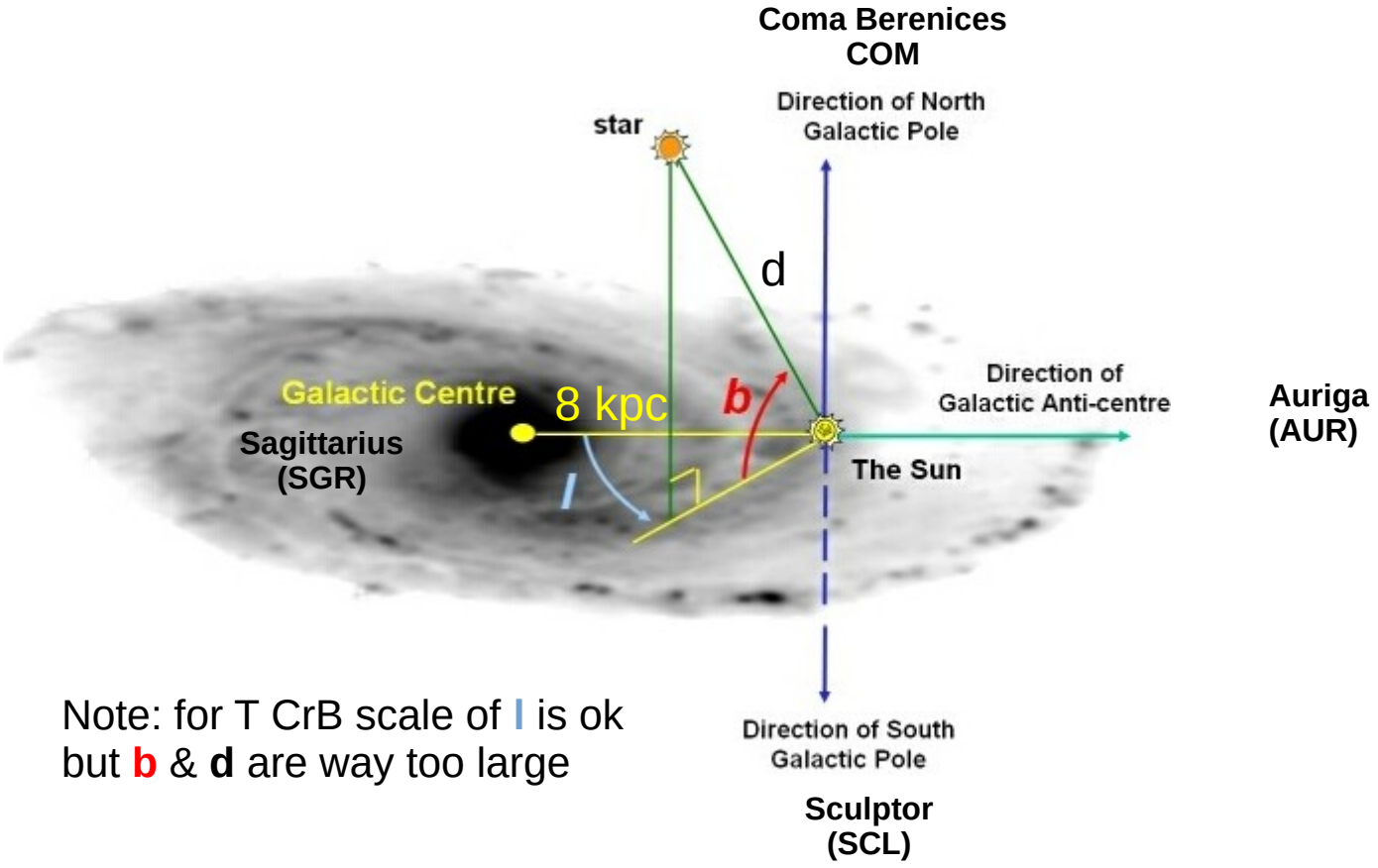
Astrometry | Photometry | Spectroscopy | Astrophysical parameters

Description	Value	Unit
Equatorial ICRS (RA,DEC) at epoch 2016	256.5229102004, -26.5805651308	deg
Galactic (l, b) at epoch 2016	357.0803450631, 8.5731964881	deg
Parallax	1.1538 ± 0.0241	mas
RA proper motion	0.3896 ± 0.0256	mas yr^{-1}
DEC proper motion	-0.2893 ± 0.0165	mas yr^{-1}
Renormalised unit weight error	0.837	

Galactic Coordinates

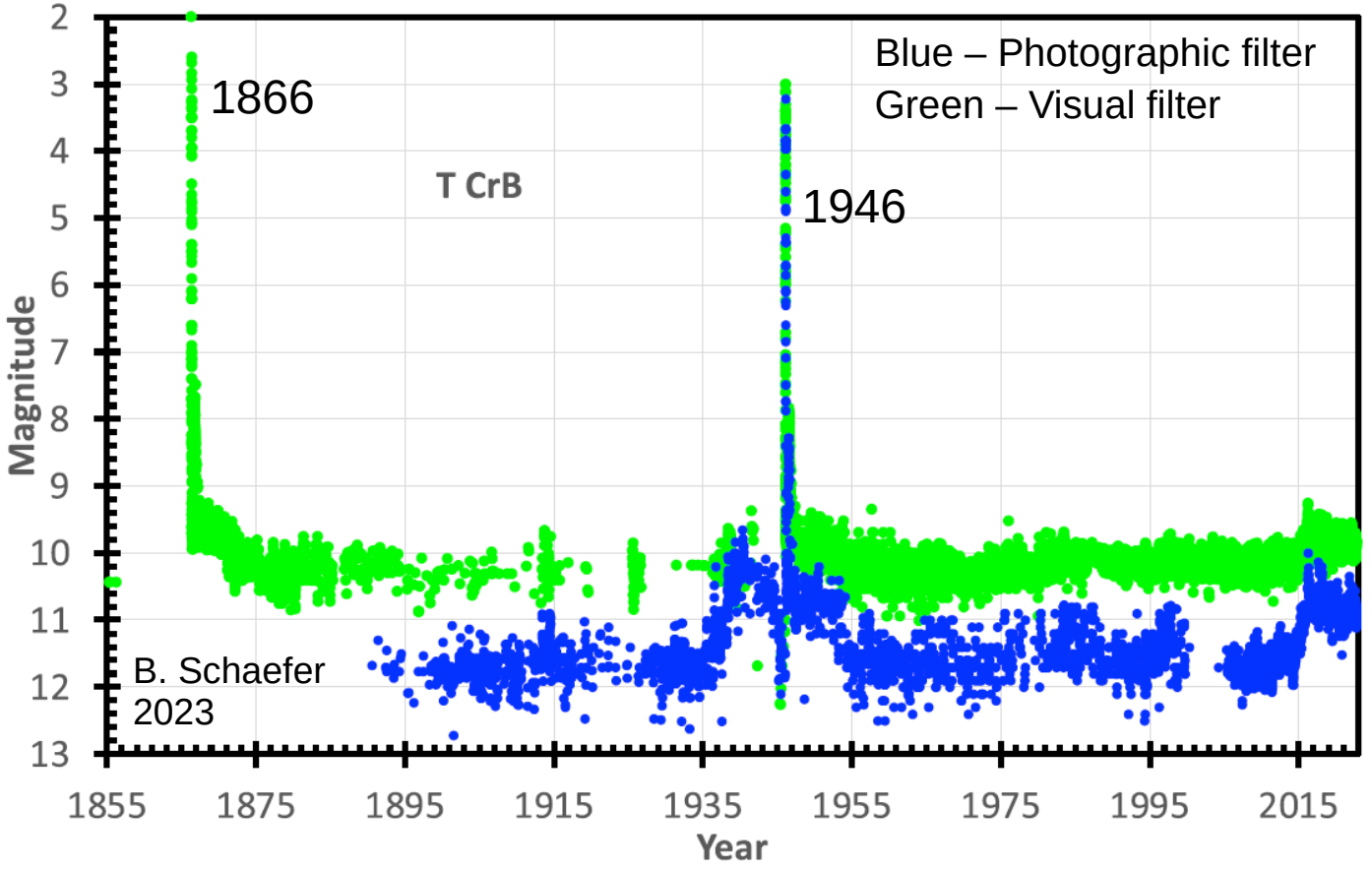
T CrB

- **b** = 48.1648º
- **l** = 42.3738º
- d = 0.9 kpc

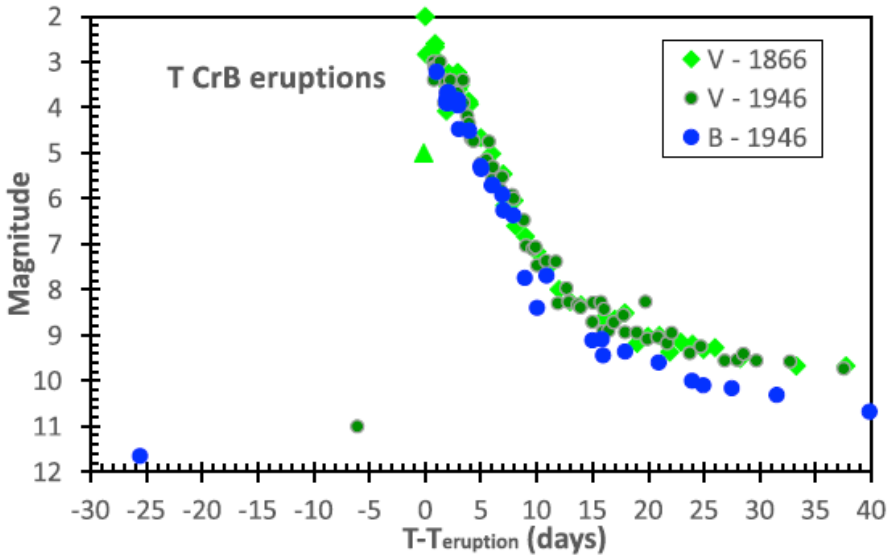


Note: for T CrB scale of **l** is ok
but **b** & **d** are way too large

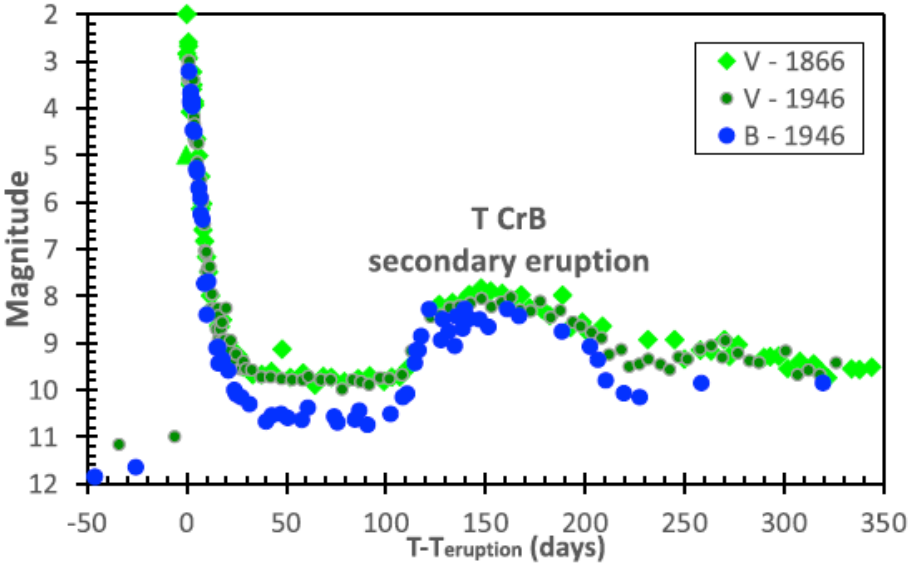
Observed Outbursts of T CrB



B & V Band Light Curves

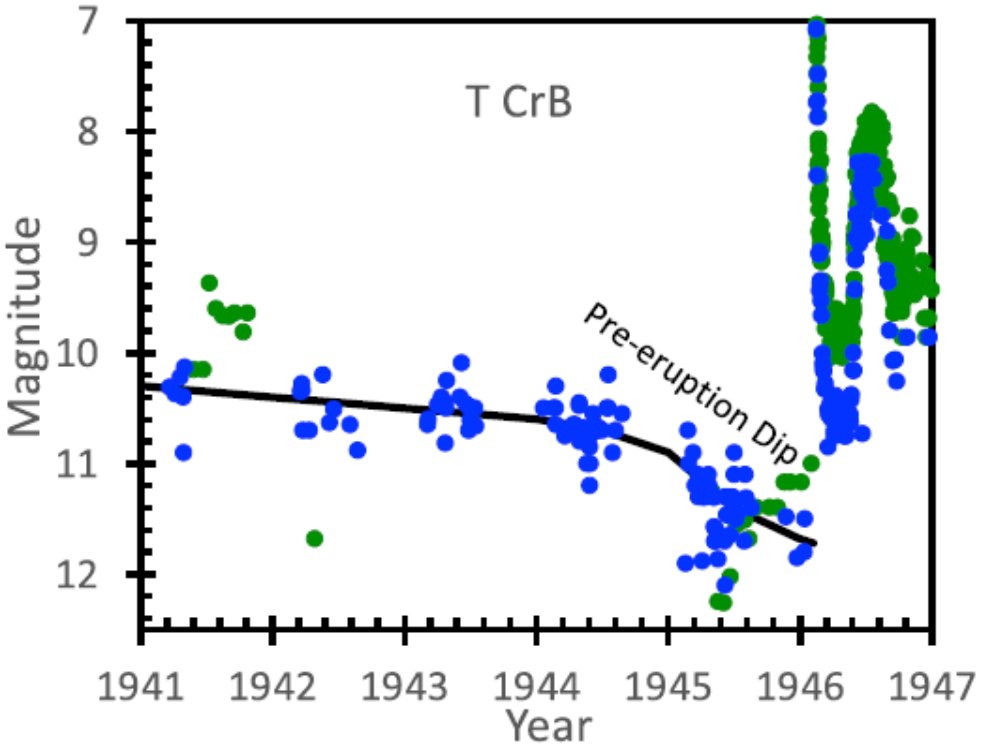


- Rise time ~1 Mag hr^{-1}
- Fall 3 Mag 5 days



- Unusual for a Nova - secondary eruption
  - Explanation TBD

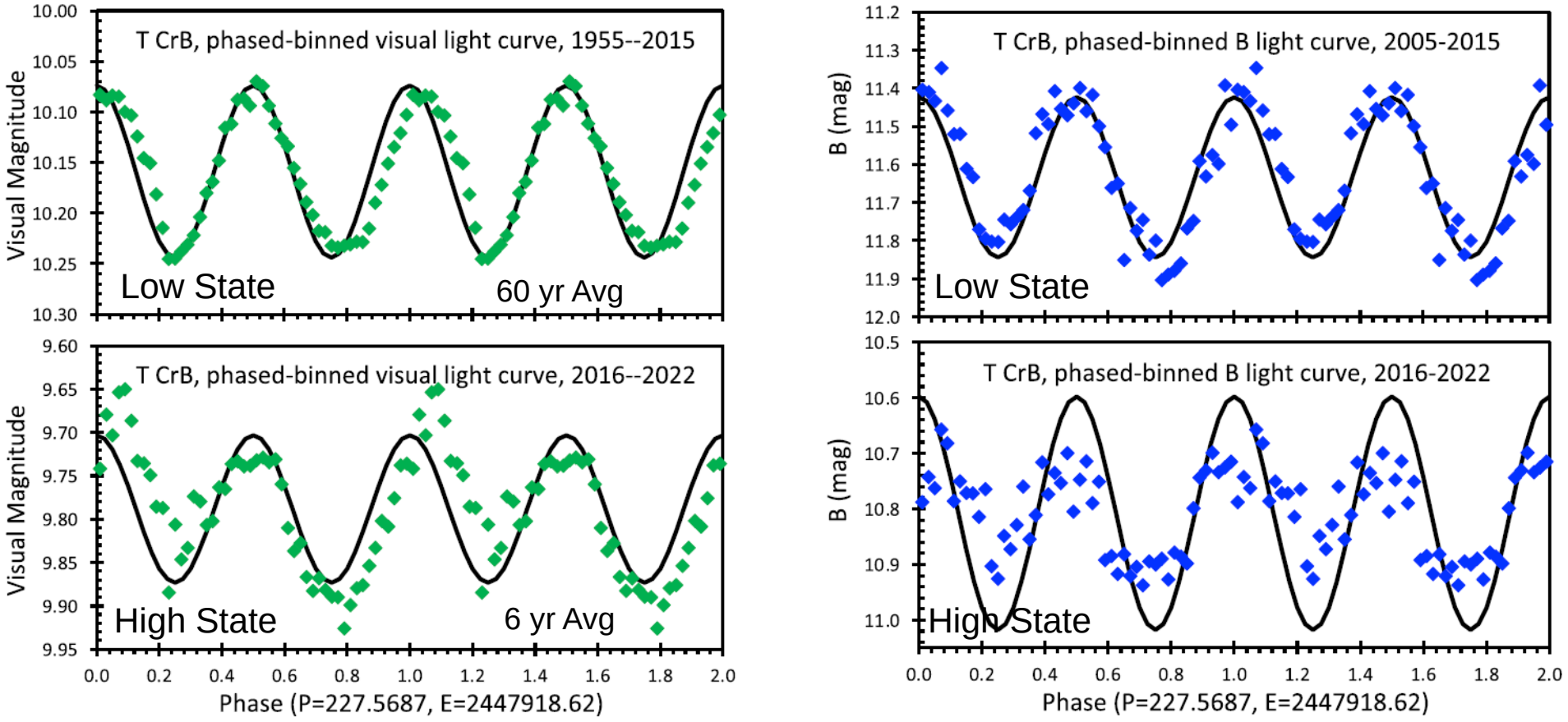
Pre-eruption Dip in B & V Apparent Magnitudes



Recent pre-eruption dip observed in 2015

B – Blue filter
V – Visual (green) filter

Orbit Phase Aligned Variability



How to see T CrB, the 'brightest nova of the generation'

- **Typically, T CrB is not visible to the naked eye at a magnitude of 10. When it reaches peak brightness, T CrB will be comparable to Polaris, the North Star, which has a magnitude of 2. (The smaller the number, the brighter it is.) It should remain this bright for a few days to a week before vanishing again. Astronomy.com**
- **Bootes and and Hercules are relatively easy to find constellations – Corona Boralais is mid-way between them.**
- **No other stars except for the “crown” are bright enough to notice so T should stand out in dark area around constellation.**


The End
Until Next Cycle
HARDY
RS Oph
Illustration

Some References

- **Astronomical League - Binocular Observation Guide** https://nightsky.jpl.nasa.gov/docs/TCrB.pdf
- **“The B&V light curves for recurrent nova T CrB from 1842-2022…”**, Schaefer, Bradley E., Dept Phy. & Astron., LSU 2023 Mar 5.
- How to see T CrB, the 'brightest nova of the generation', Elisabeth Gamillo, Astronomy.com, March 18, 2024.