

# Luminous Blue Variable Stars

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Luminous Blue Variable Stars = LBV Stars

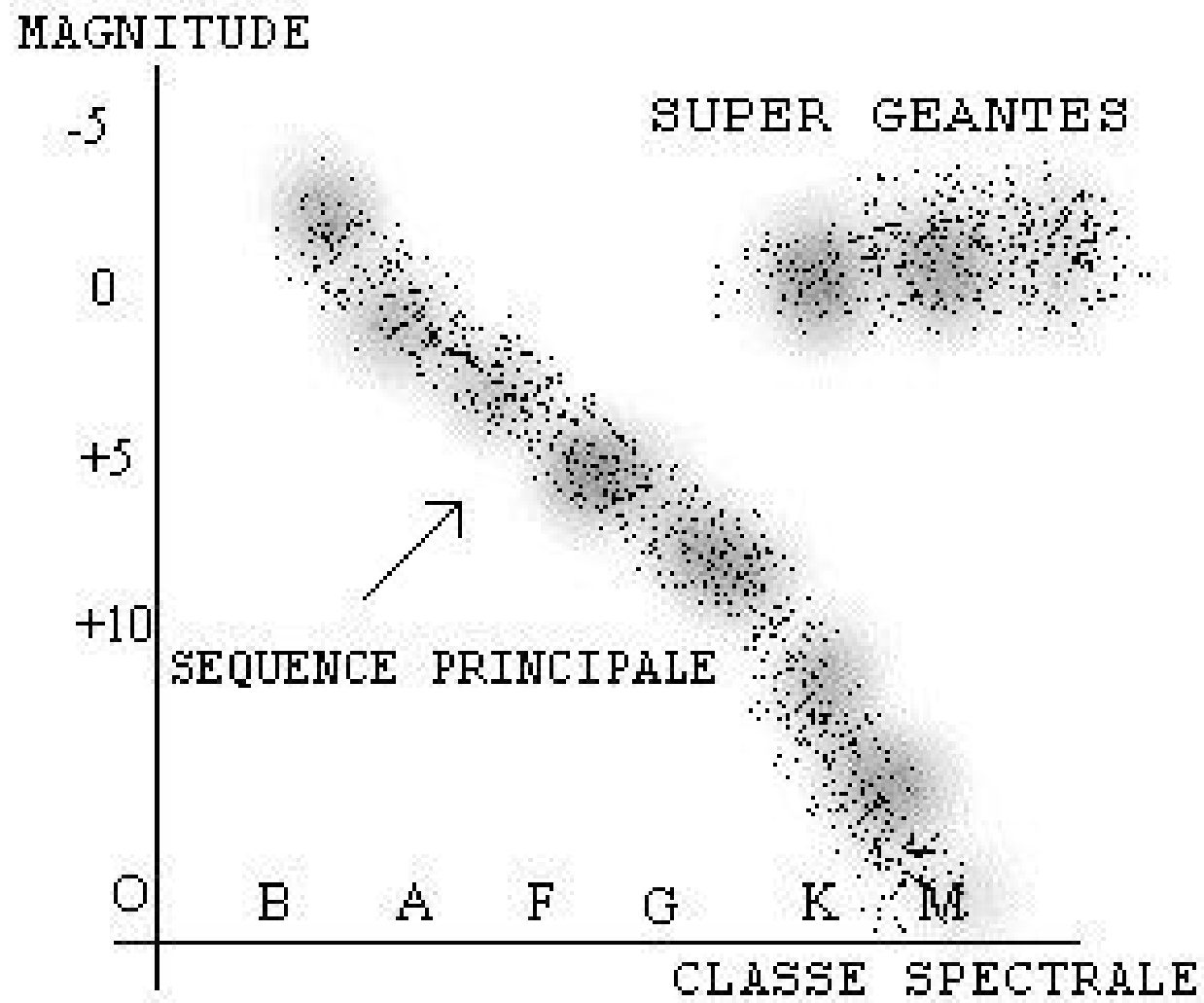
LBV Stars are defined by moderate, irregular variations in brightness with associated spectroscopic changes (...)

S-Doradus variables, P Cygni stars,  
Hubble Sandage variables

- characteristics
- examples and discoveries

# Characteristics - progenitors

- Short lived – 40000 years
- Evolutionary phase between H-burning and Wolf Rayet Stars
- $40 M_{\text{sol}}$
- Red LBVs
- Rare: 32 in local group



[http://home.tele2.fr/saultrem/natandmick/soleil/diagramme\\_hertzsprung-russel.jpg](http://home.tele2.fr/saultrem/natandmick/soleil/diagramme_hertzsprung-russel.jpg)

# Characteristics - variability

- Variability
  - Microvariations:
    - $\leq 0,1$  magnitudes
    - Days, weeks
  - Small oscillations:
    - $\sim 0,5$  magnitudes
    - Last for months – few years

# Characteristics - variability

- Moderate eruptions:
  - Unique to LBV Stars
  - 1-2 magnitudes
  - Timescale: 10 – 40 years
  - Atmosphere greatly expands to form optically thick pseudophotosphere
  - Evolve redwards to H-D limit stimulating mass loss

# The Humphreys-Davidson limit

- Upper luminosity limit
- Decreases with decreasing effective temperature
- Boundary:  $T \sim 10^4$  K
- Mass loss must be high
- Not steady but eruptions



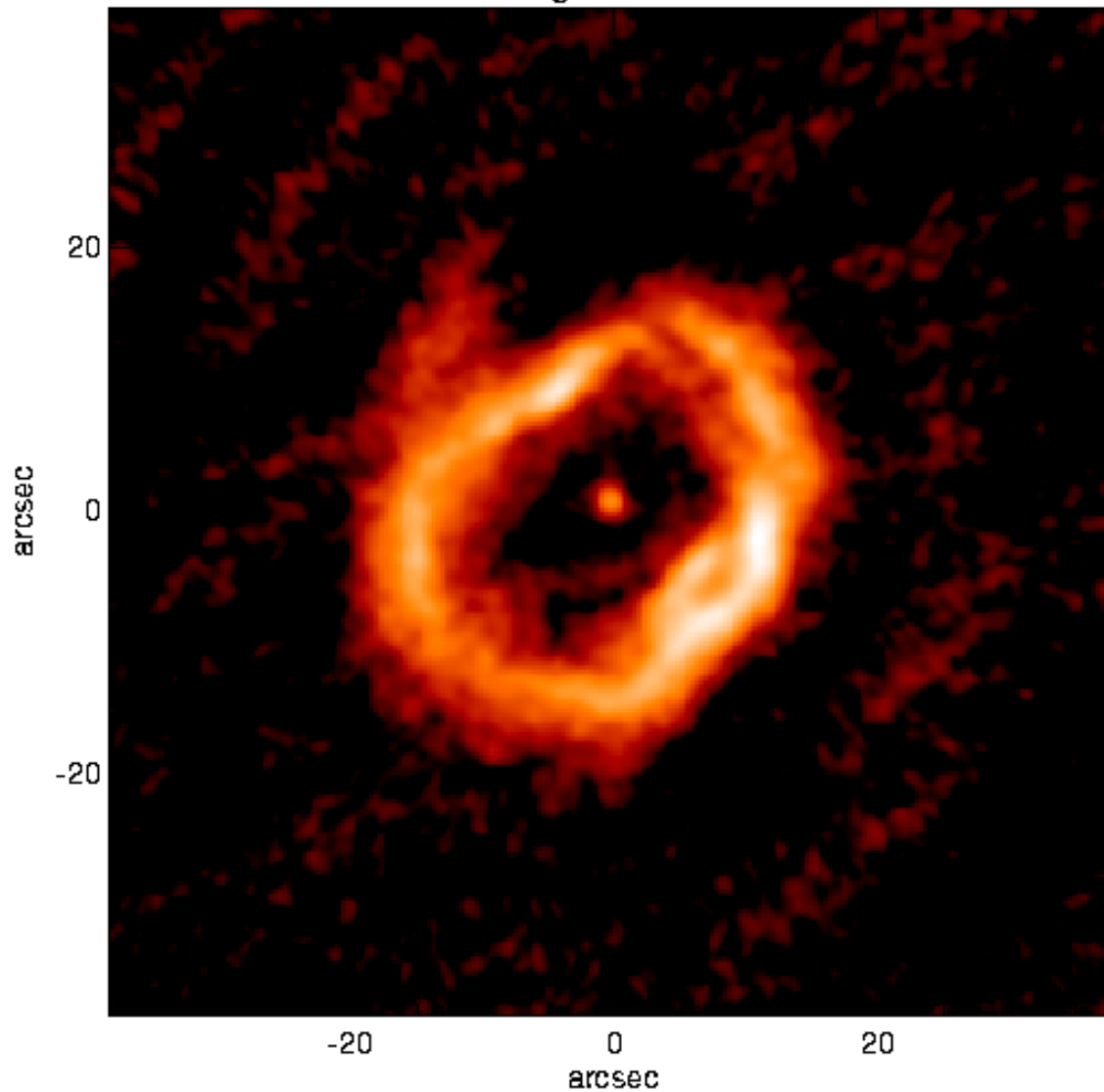
# Characteristics - variability

- Giant eruptions:
  - $\geq 3$  magnitudes
  - May last for decades
  - Frequency: 100 - 1000 years
  - Sudden ejections of mass

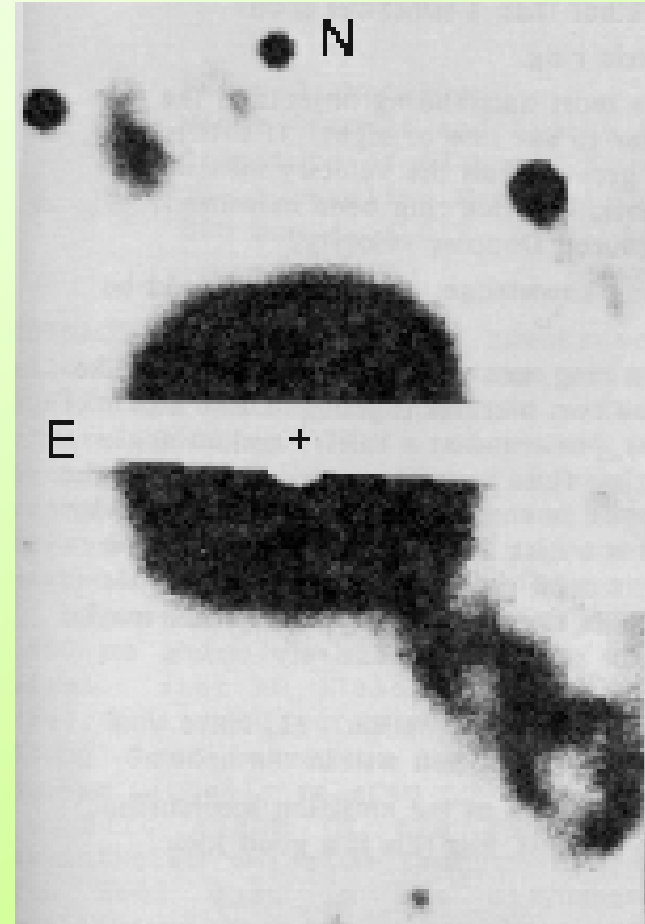
# Characteristics – circumstellar objecta

- Circumstellar nebula
- Produced by mass loss
- N and He rich

ATCA image of AG Carinae



[http://www.astro.umd.edu/~white/images/agcar\\_full.html](http://www.astro.umd.edu/~white/images/agcar_full.html)



## AG Carinae

<http://www.peripatus.gen.nz/Astronomy/LumBluVar.html>

# Characteristics - mass

- High mass-loss rates
- Shell ejection phase/pseudophotosphere phase
- $10^{-5} - 10^{-4} M_{\text{sol}}\text{yr}^{-1}$
- 10 – 100 times mass-loss rate normal supergiant
- At quiescence (visual minimum) star resembles normal supergiant
- Total mass loss  $1 M_{\text{sol}}$  or more

# Characteristics - spectra

- The spectra are variable
- H, HeI, FeII prominent emission lines
- At visual minimum: spectrum resembles that of supergiant H- burning and He- burning stars.
- FeII strongest at visual minimum
- At visual maximum pseudophotosphere resembles much cooler supergiant of type A or type F.
- FeII weaker at visible maximum

# Characteristics – temperature variations

- At quiescence the star is hottest.
  - $T \sim 15000\text{K} - 20000\text{K}$
- At maximum  $T \sim 8000\text{K}$
- Asymptotic minimum value  $7500\text{K}$  no matter how high mass-loss rate
- Apparent cooling due to absorption by surrounding shells

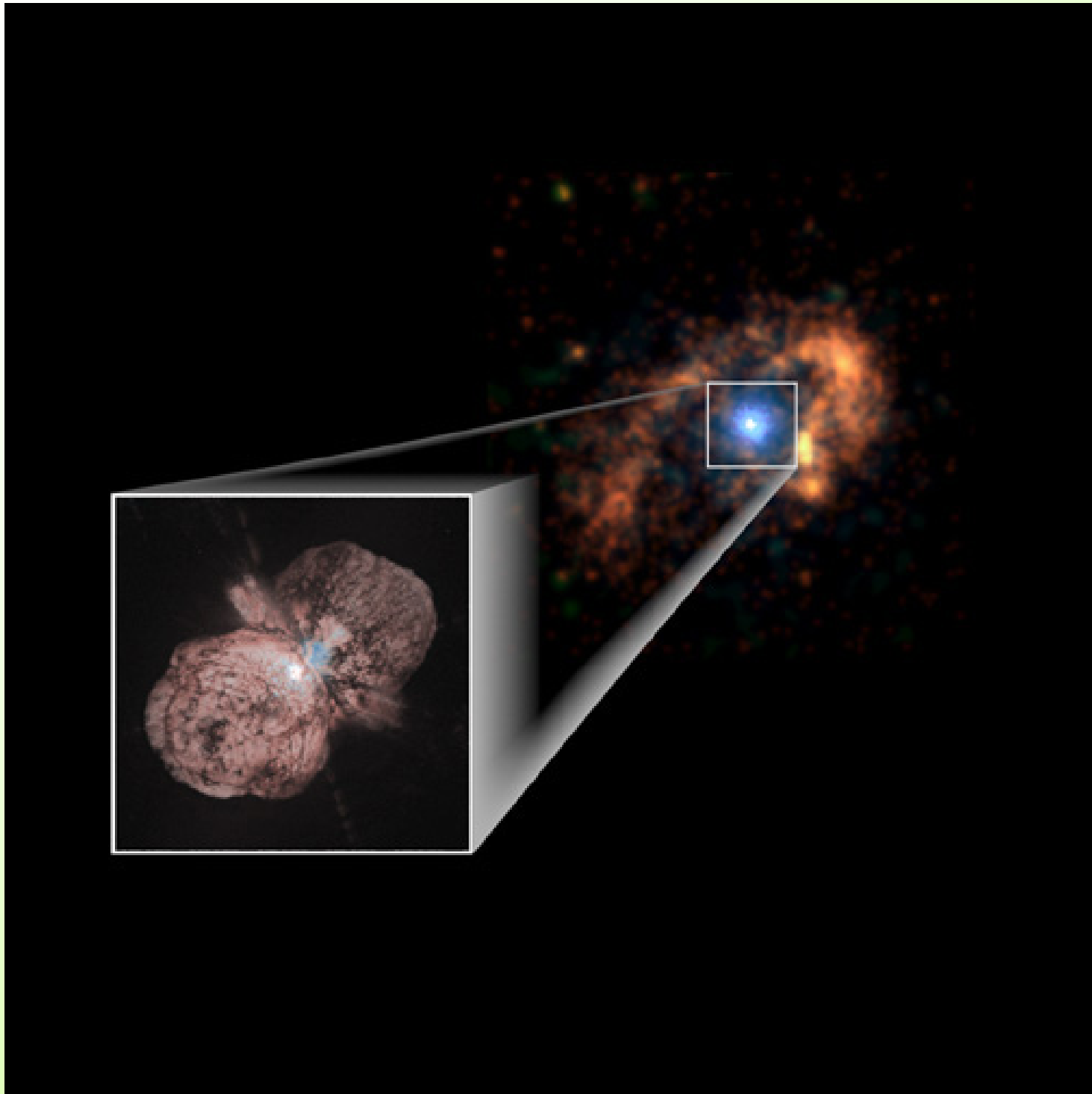
# Characteristics - luminosity

- Bolometric magnitudes remain roughly constant
- $M_{\text{bol}} \sim -10$
- $10^6 L_{\text{sol}}$
- 3 luminosity types:
  - $\eta$  Carinae
  - $-11 < M_{\text{bol}} < -9$
  - below the Humphreys-Davidson limit



# $\eta$ Carinae

- 1837 – 1860
- Suddenly appeared in the sky
- $120 M_{\text{sol}}$
- $5 * 10^6 L_{\text{sol}}$
- Homunculus Nebula, 1843



[http://chandra.harvard.edu/photo/0099/0099\\_xray\\_optical\\_lg.jpg](http://chandra.harvard.edu/photo/0099/0099_xray_optical_lg.jpg)



<http://www.astro.princeton.edu/~mbrown/astropic/ecar.jpg>

# P Cygni

- 1600
- Since 18th century slowly increasing brightness
- Only small shell (8'') at H $\alpha$  wavelengths





- NGC 2363
- 30-60  $M_{\text{sol}}$
- Discovered in Hubblepictures in 1996
- From 21,5 to 17,8 magnitude in 3 years  $\rightarrow$  40 times as bright