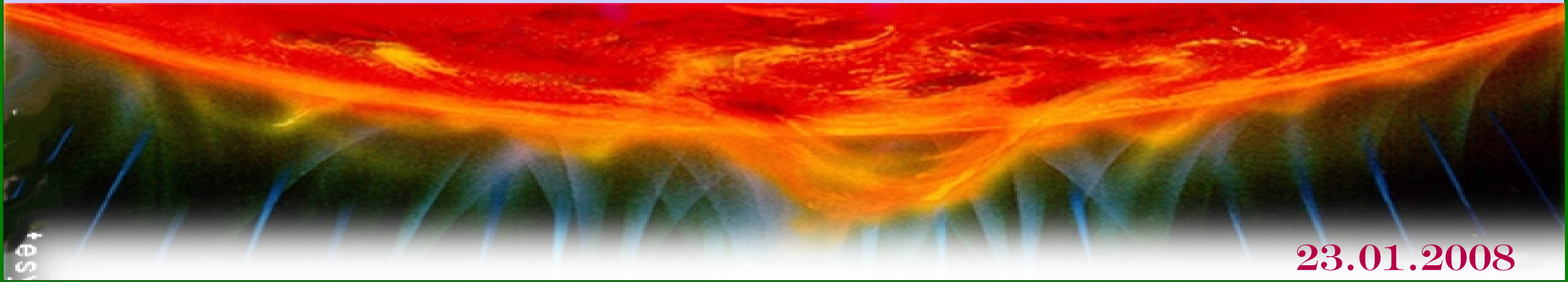
STELLAR WINDS



23.01.2008

CONTENT

- STELLAR WINDS: INTRODUCTION
- DEPENDANCY ON TEMPERATURE AND MASS
- STELLAR WIND OF THE SUN
- SOLAR-LIKE STELLAR WINDS
- WINDS IN CLOSE BINARIES

Stellar Winds: Introduction

- The emission of particles is called the stellar wind

- The particles comprising the wind are accelerated differently, depending on the nature of the star

- Most important parameters derived from observations:

  - Mass loss rate $\dot{M}$: amount of mass lost by the star per unit time
  - Terminal velocity v_{∞}: velocity of the stellar wind at a large distance from the star

- Mass loss rates for different stars vary greatly

DEPENDANCY ON TEMPERATURE AND MASS

COOL , LOW-MASS STARS

- stars like our sun lose 10^{-14} $M_{\odot}$/yr from winds from: - the surface $(200-300\frac{km}{s})$

  - coronal holes $(700\frac{km}{s})$

- Red Giants show lower wind velocities $(20-60\frac{km}{s})$
- But mass losses are higher (10^{-8}–10^{-5} $M_{\odot}$/yr) because radii are 100 $R_{\odot}$ or more
- Driving Mechanism: wind arises from pressure expansion in a hot corona, which is heated by the mechanical energy generated from convection in the subsurface layers

Dependancy on temperature and mass

Hot, high-mass stars

- much stronger winds: speeds up to $2000 \frac{km}{s}$
- → experience mass loss rates of up to $\dot{M} \approx 10^{-4} M_{\odot}/yr$
- Driving Mechanism: - lack the strong convection zone
  - therefore no heating of circumstellar corona
  - stellar winds remain at temperatures comparable to star´s surface
  - so lack high gas-pressure needed to drive an outward expansion against the stellar gravity
  - but: quite high radiative flux
  - pressure of this radiation drives the wind expansion
  - primarily by means of line scattering (electron is shuffled between two descrete, bound energy levels of an atom)

Dependancy on Temperature and Mass

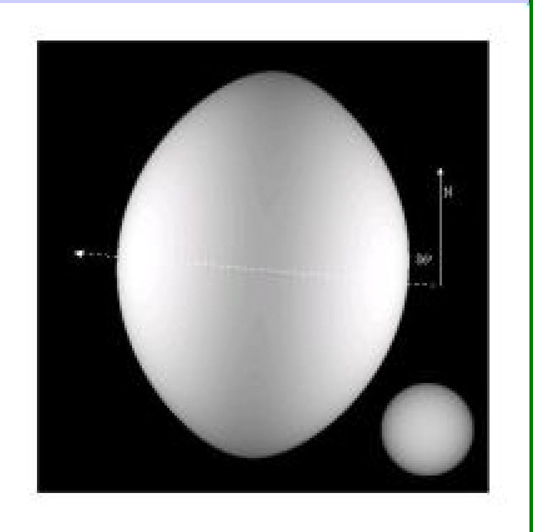
Very Massive Stars

- losing mass at rates in the order of $10^{-5} M_{\odot}$/yr

- lifespans in the order of a few million (10^6) yr

- may end their lives as Wolf-Rayet objects: stars which have completely shed their hydrogen envelope

- Massive blue stars typically rotate at high speeds
  - → some flatten at the poles and bulge at the equator
  - → gravity darkening
  - → outflow of radiation unevenly distorted over the surface (polar regions brighter, equatorial regions dimmer)
  - → bright poles drive a denser wind than dimmer equator



Stellar Wind of the Sun

- Expected lifespan of sun: 10^{10} yr

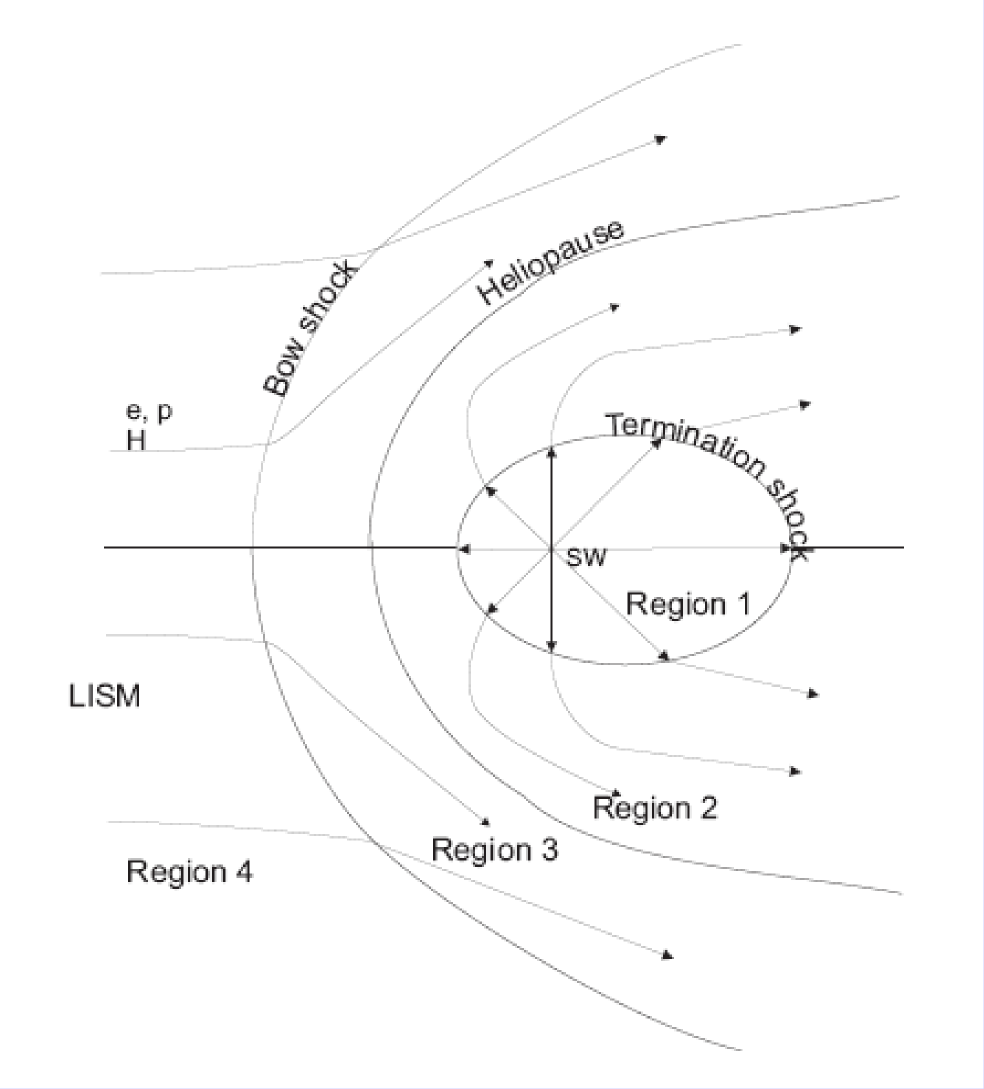
- stars like our sun lose 10^{-14} $M_{\odot}$/yr from winds from: the surface $(200-300\frac{km}{s})$

  coronal holes $(700\frac{km}{s})$

- sun is expected to lose only ~0.01% of its mass

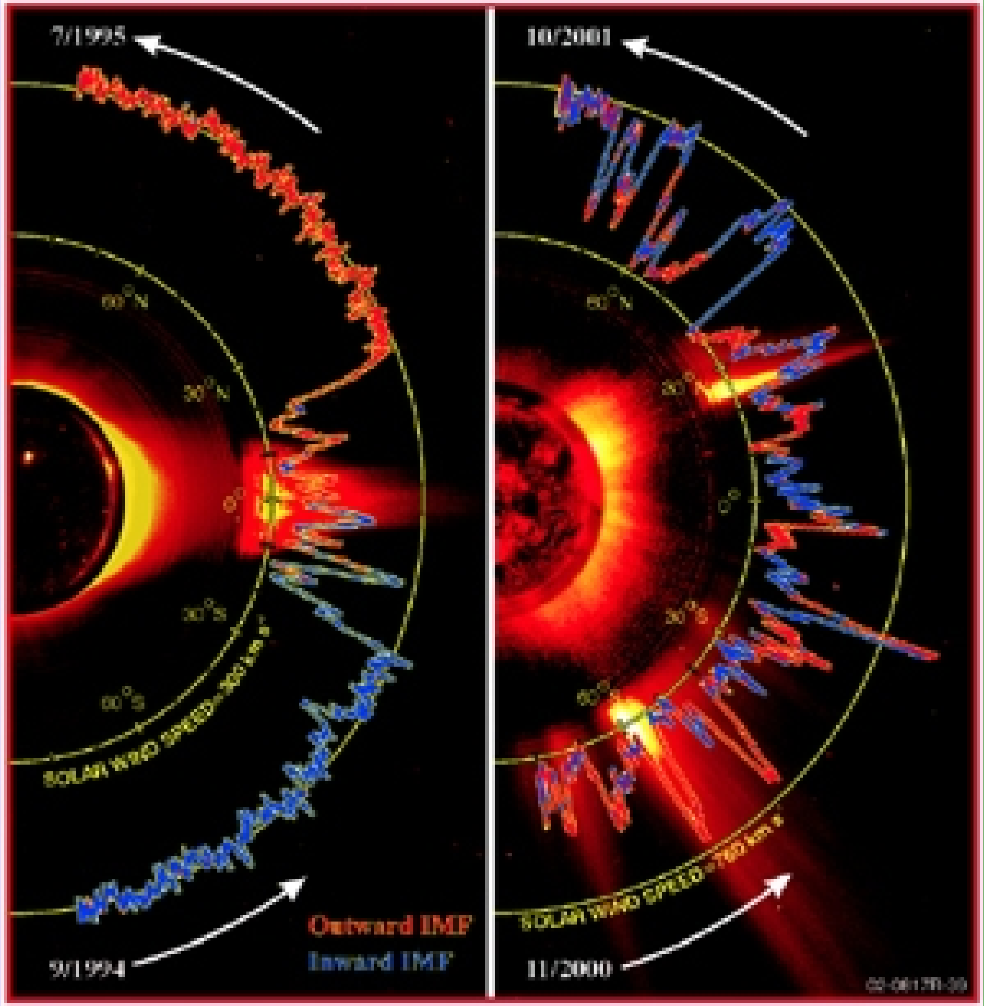
STELLAR WIND OF THE SUN

- Basic structure of heliosphere
- Solar wind is highly supersonic
- Termination shock → radial wind is shocked to subsonic speeds
- Bow shock: ISM flow is shocked to subsonic speeds
- Heliopause: contact surface separating plasma flows of the solar and interstellar winds
- Neutrals in the LISM can penetrate into the solar system through HP and TS



STELLAR WIND OF THE SUN

- Solar wind observations collected by the Ulysses spacecraft during two separate polar orbits of the Sun
- six years apart
- at nearly opposite times in the solar cycle
- Near solar minimum (left):
  → activity is focused at low altitudes
  → high-speed solar wind prevails
  → magnetic fields are dipolar
- Near solar maximum (right):
  → solar winds are slower and more chaotic
  → fluctuating magnetic fields.



SOLAR-LIKE STELLAR WINDS

- difficult to detect directly
- no successful direct methods
- but can be studied indirectly (observing interaction regions carved out by collisions between these winds and the ISM)
  → called astrospheres (analog for heliosphere)
  → do not exist in the absence of a stellar wind
- Hydrogen heated by charge exchange processes produce enough HI Lyα absorption to be detectable in UV spectra of nearby stars
- ISM cannot account for all of the observed absorption
  → partly due to HI gas within the astrospheres
- amount of astrospheric absorption
  → diagnostic for strenght of SW

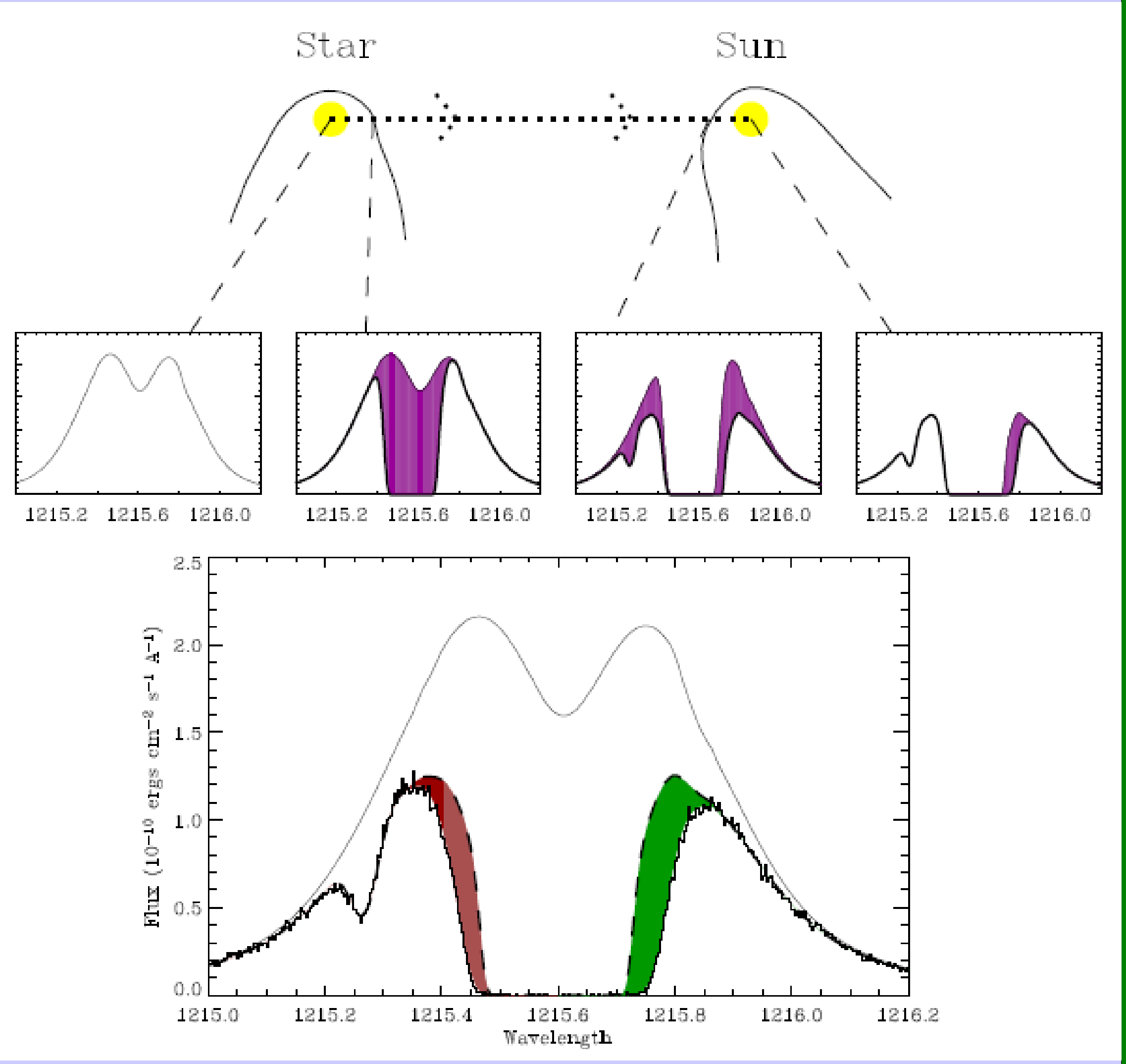
SOLAR-LIKE STELLAR WINDS

- Middle panels:

• Lyα-profile-changes of αCenB from initial appearance at the star and through various regions that absorb parts of the profile
• Astrospheric absorption blueshifted relative to the ISM absorption
• Heliospheric absorption redshifted relative to the interstellar absorption

- Lower panel:

• in some cases evidence for excess HI-absorption
→ astrospheric absorption
• actual observed Lyα-profile of αCenB



SOLAR-LIKE STELLAR WINDS

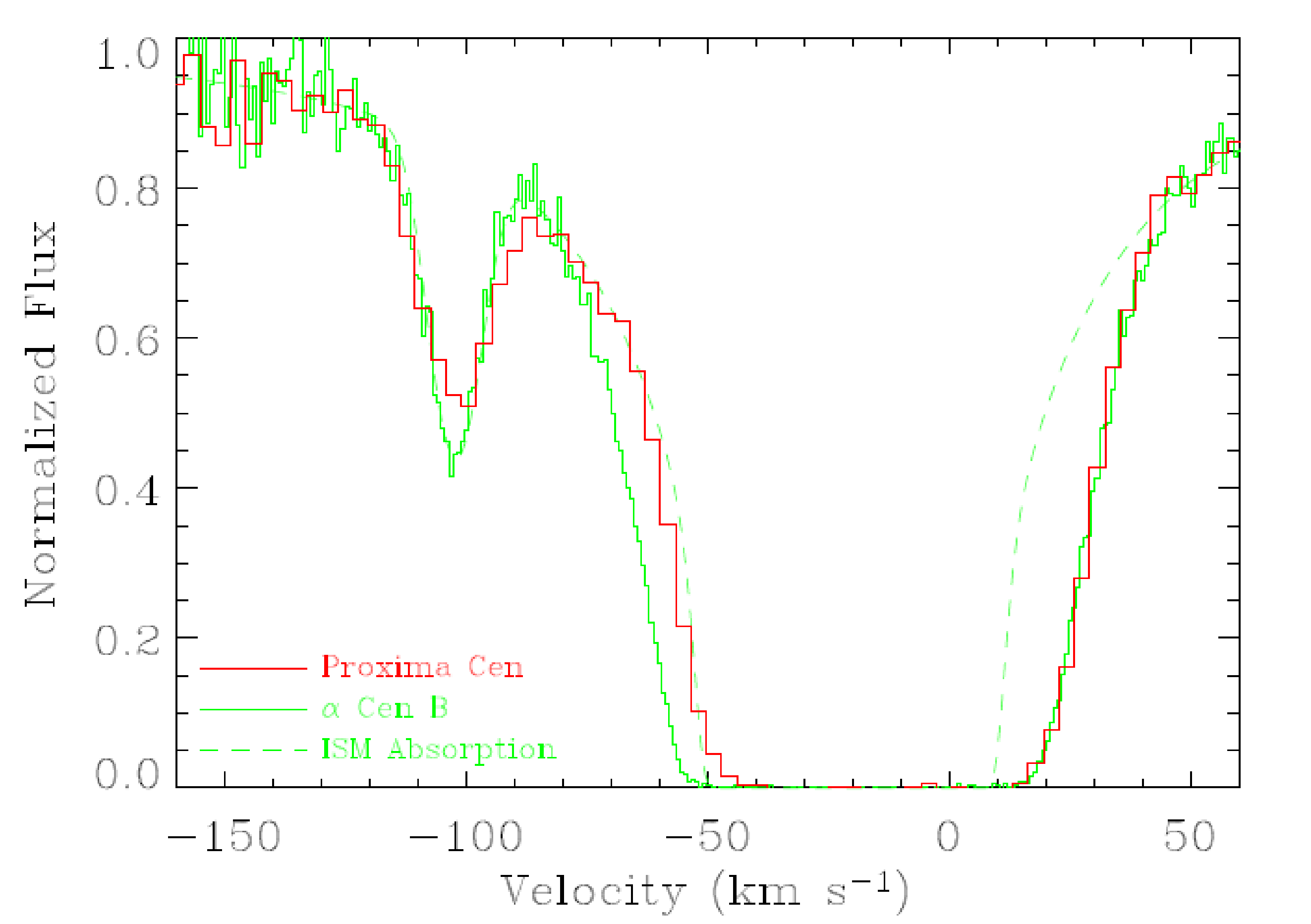
• Comparison of Lyα spectra of αCenB and Proxima Cen

• Alpha/Proxima Cen data agree well on the red side of the HI-absorption

• on the blue side the Proxima Cen data do not show the excess Lyα absorption seen toward αCen (i.e. astrospheric absorption)

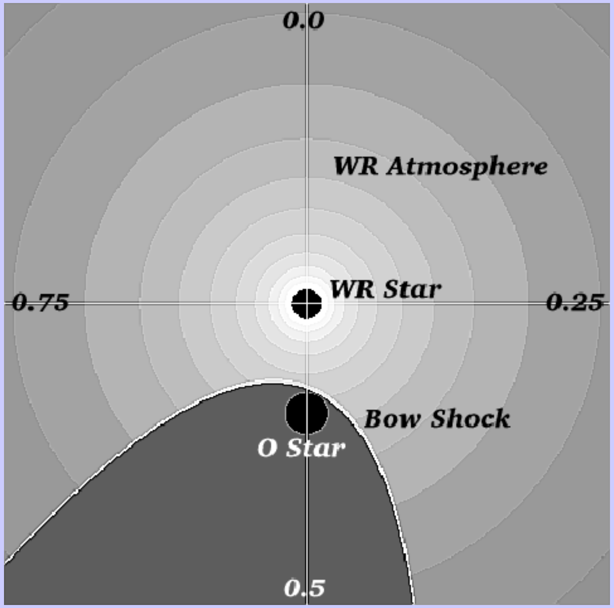
• Proxima Cen weaker wind
→ less absorption

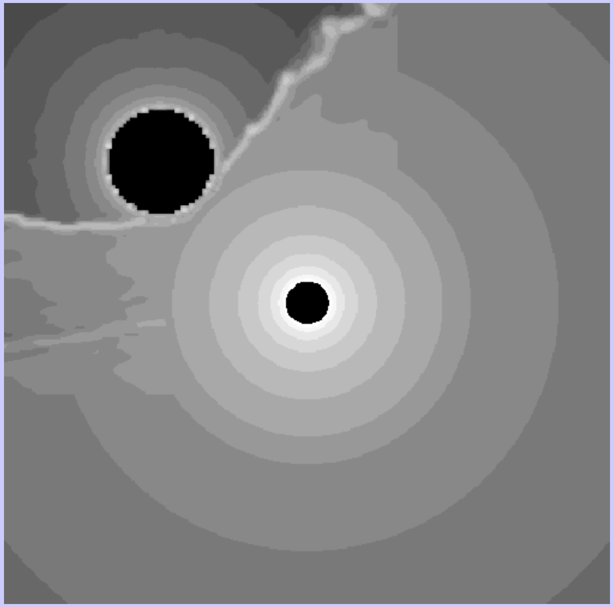
• suggests how the astrospheric absorption might be used as a diagnostic for the mass loss rates of solar-like stars



WINDS IN CLOSE BINARIES

- Hot, massive stars (e.g. Wolf-Rayet) often occure in close binary systems
- WR-stars have particularly massive winds
- much stronger than those of less-evolved companion star
- collision of the two winds can be complex and violent





V444 Cygni: WN5 & O6III-V

- WR-wind overpowers wind of companion star
- stopping only at shock front near surface of O-star