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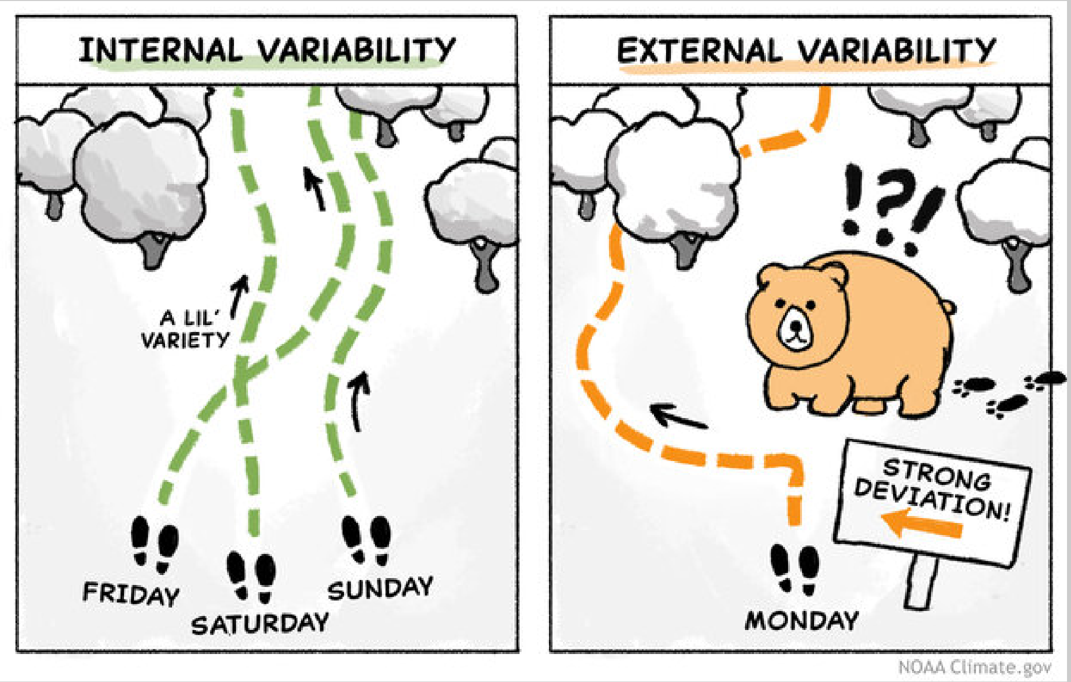

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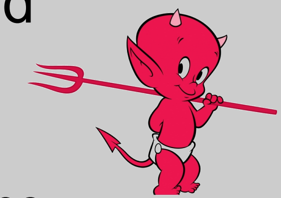
Remember Algol

1. Stellar Variability and the ancient egyptian calender

egypt 3000 years ago:

A calenders was made it contained marks of "lucky" and "unlucky" days.
This draws back to observations and first notes about variability of the star **Algol.**
It was also named Demons Star.

A rather regular periode of 2.85 days was mentioned in the calender.

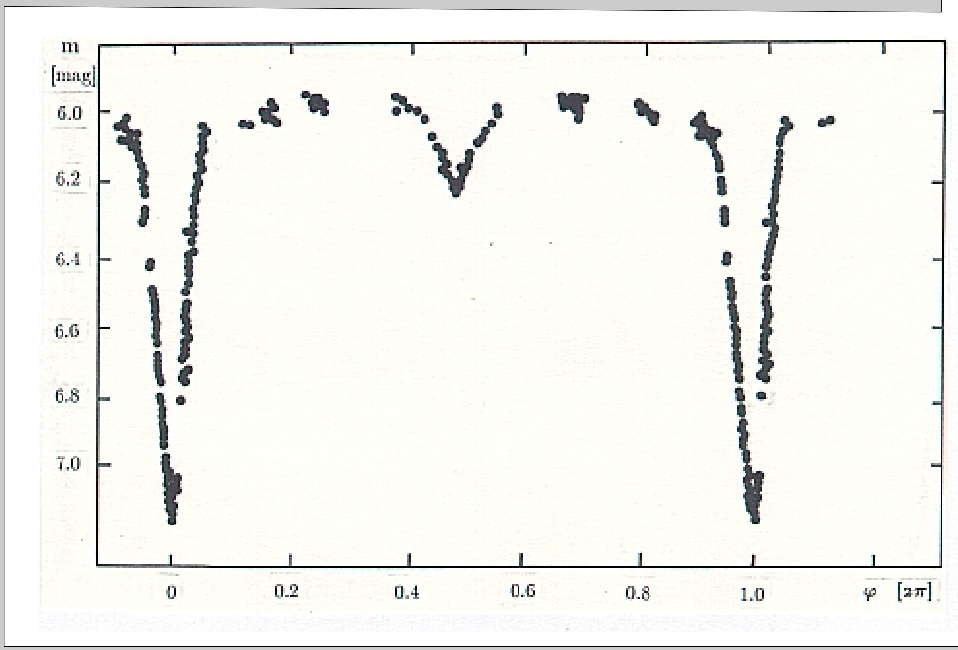


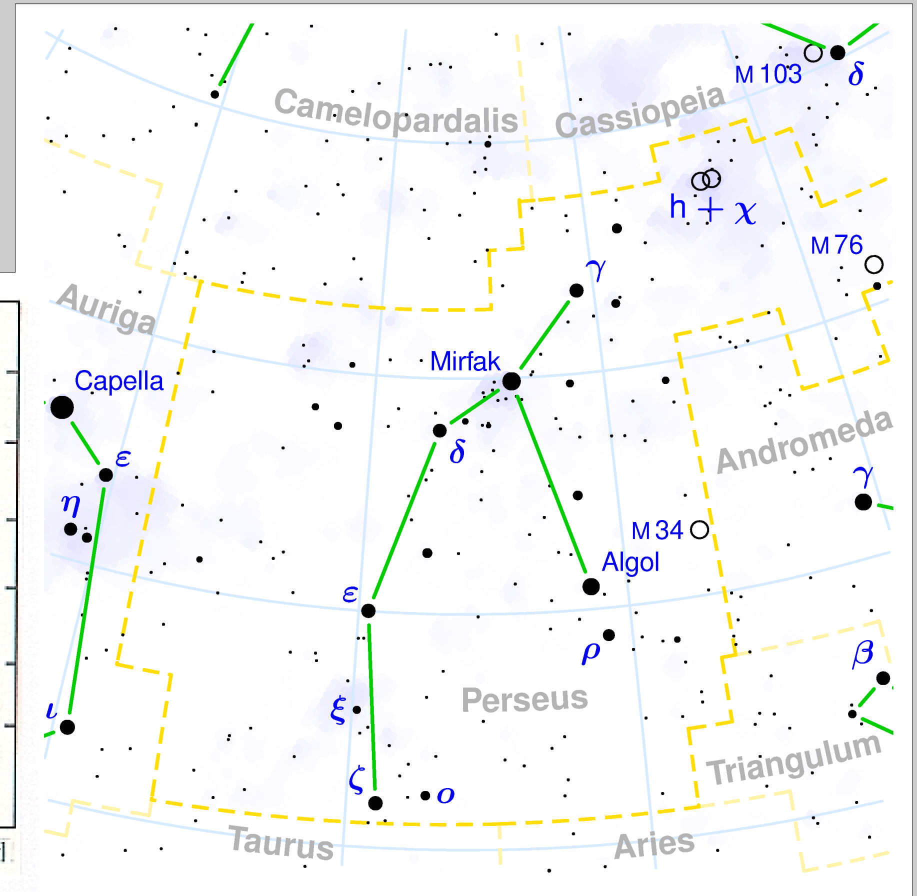
… its supposed to be the
regular angry "steaming" of a demon
→ lucky and unlucky days

historic papyrus calendar
dated 1271-1163 B.C..

Algol Variables

Algol was the first Variable star known …





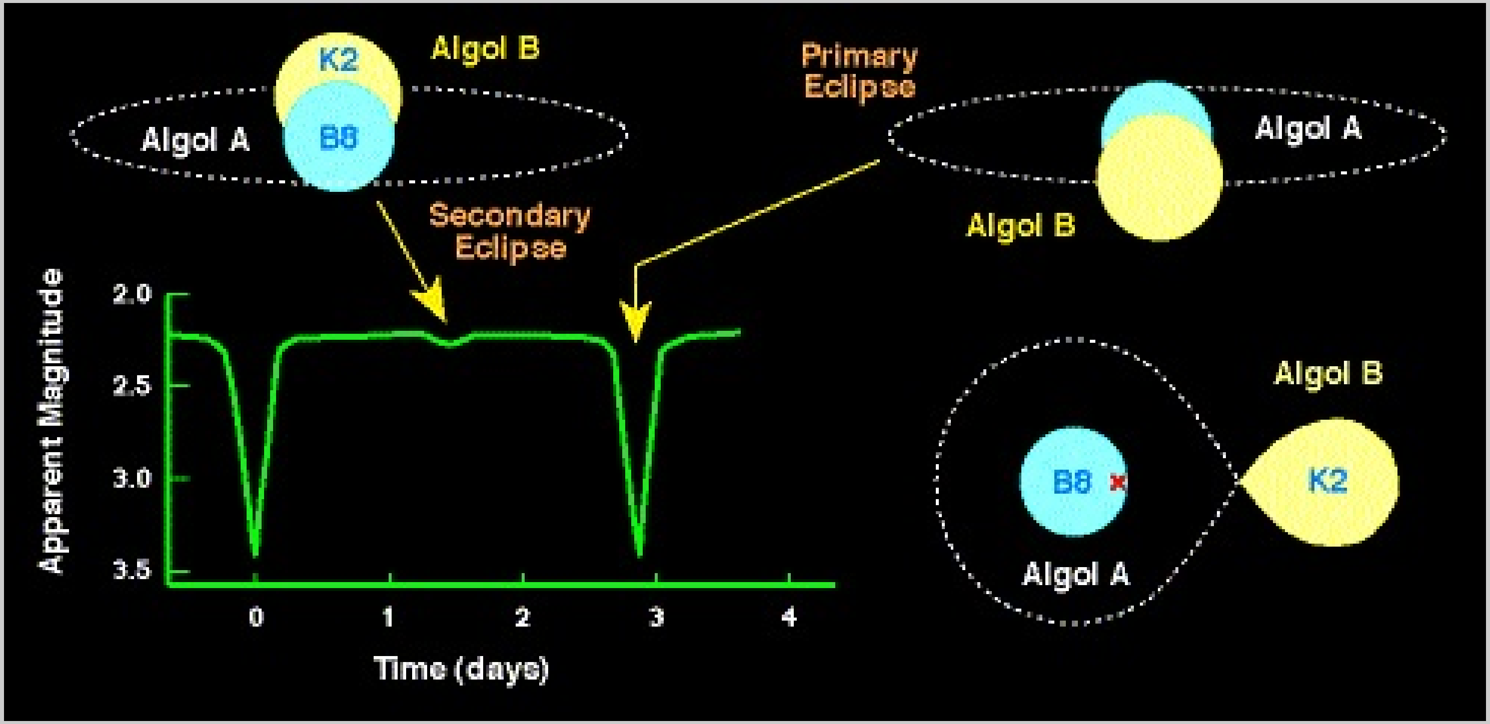
Algol Variable

Algol was the first Variable star known … NO the first CLASS

Algol is an **extrinsic variable**

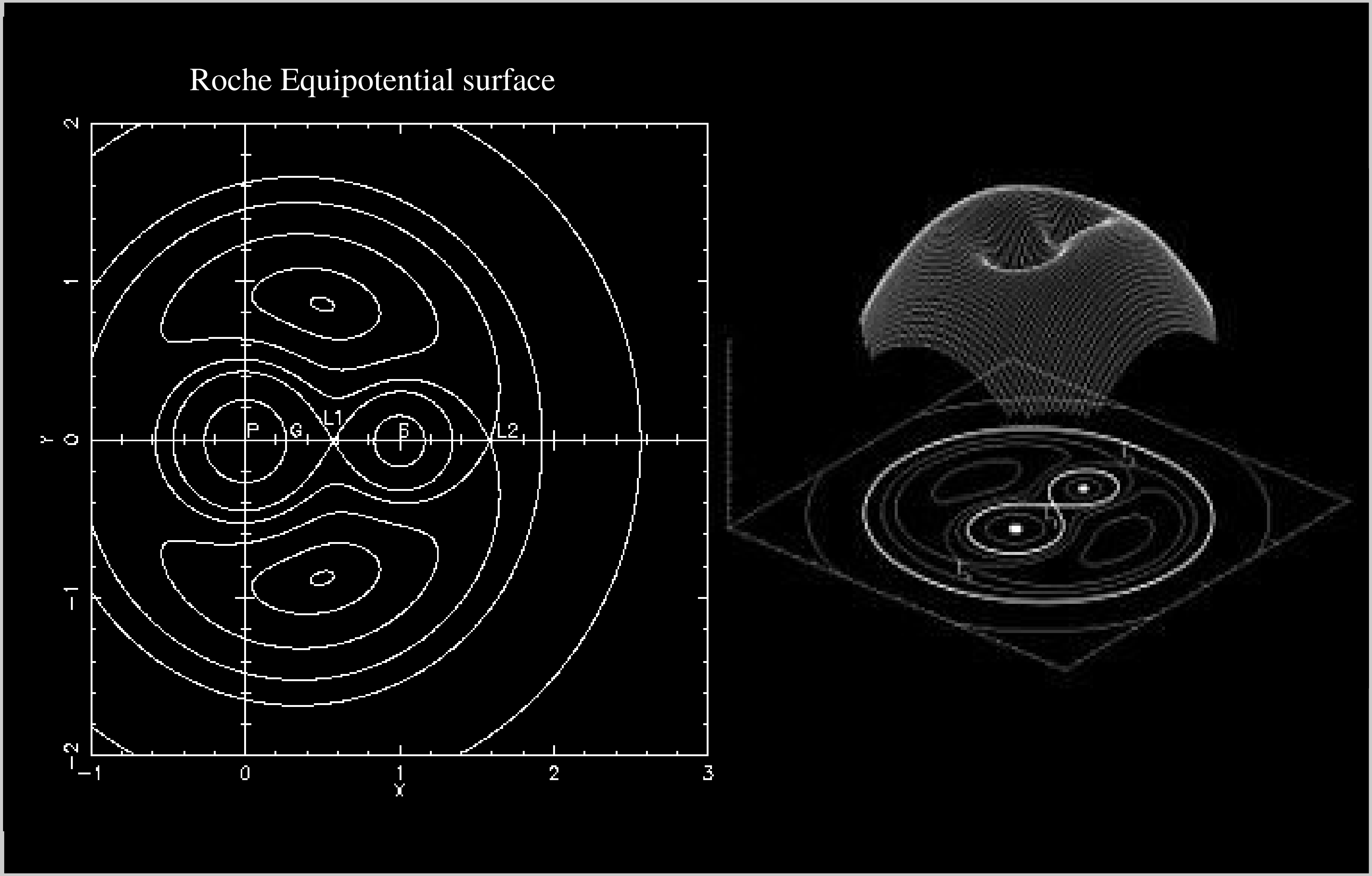
→ in a binary system the stars that revolve around can cover each other
This leads to a drop in brightness, one stronger and one weaker depending on who is covering whom.

Algol variable ↔ eclipsing binary

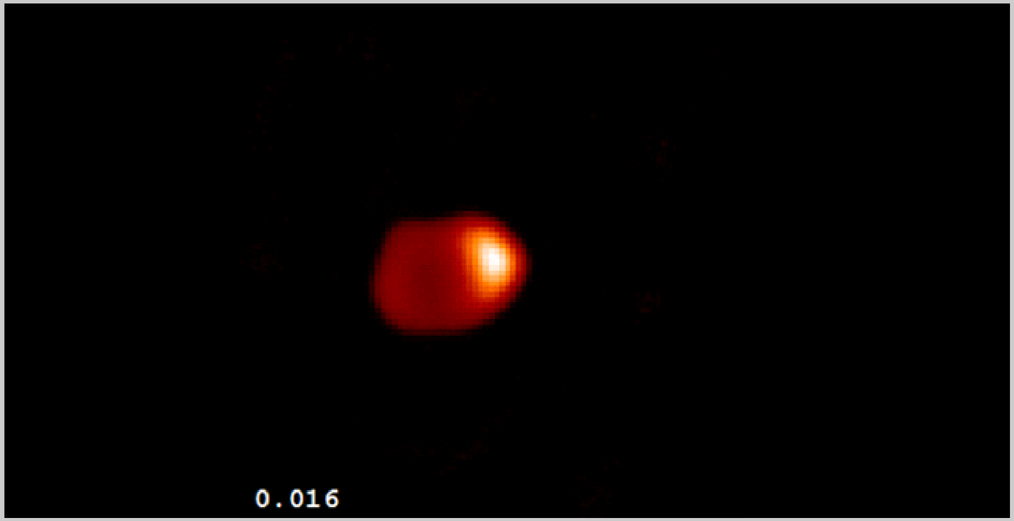


Roche Lobes

Equipotential surfaces in a binary system



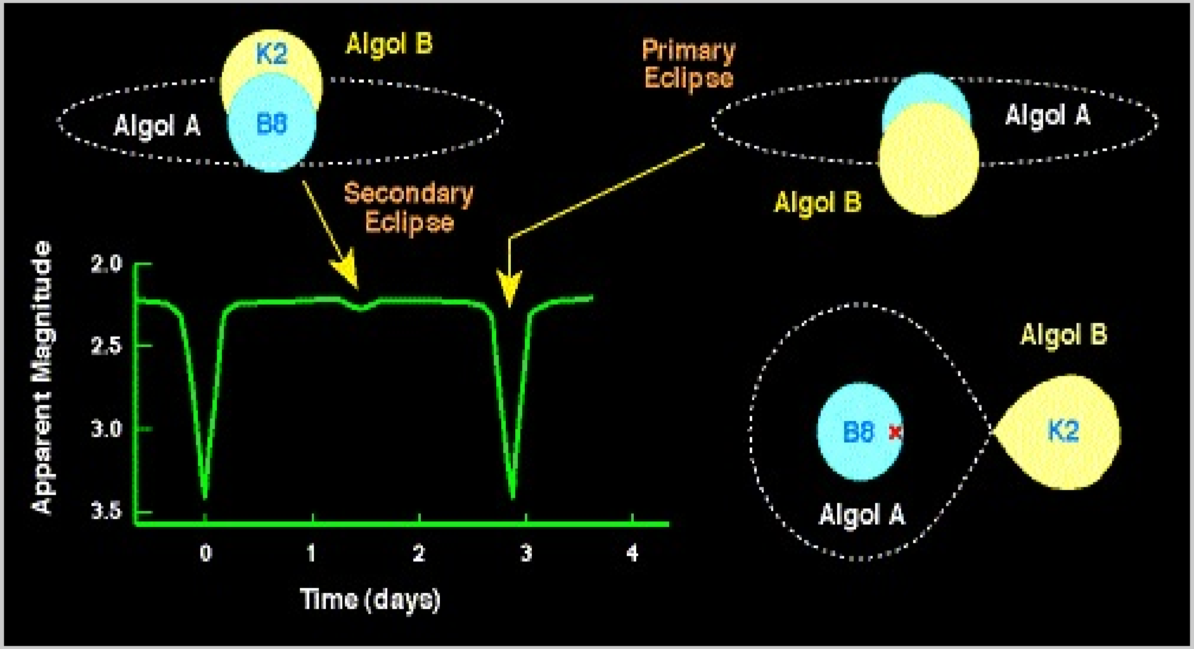
Algol System – in action



Algol System

Near-infrared H-band image
from CHARA interferometry data
August 12 2009

Algol Paradoxon !!



Algol A
is more massive than B

Algol A
is a main sequence star

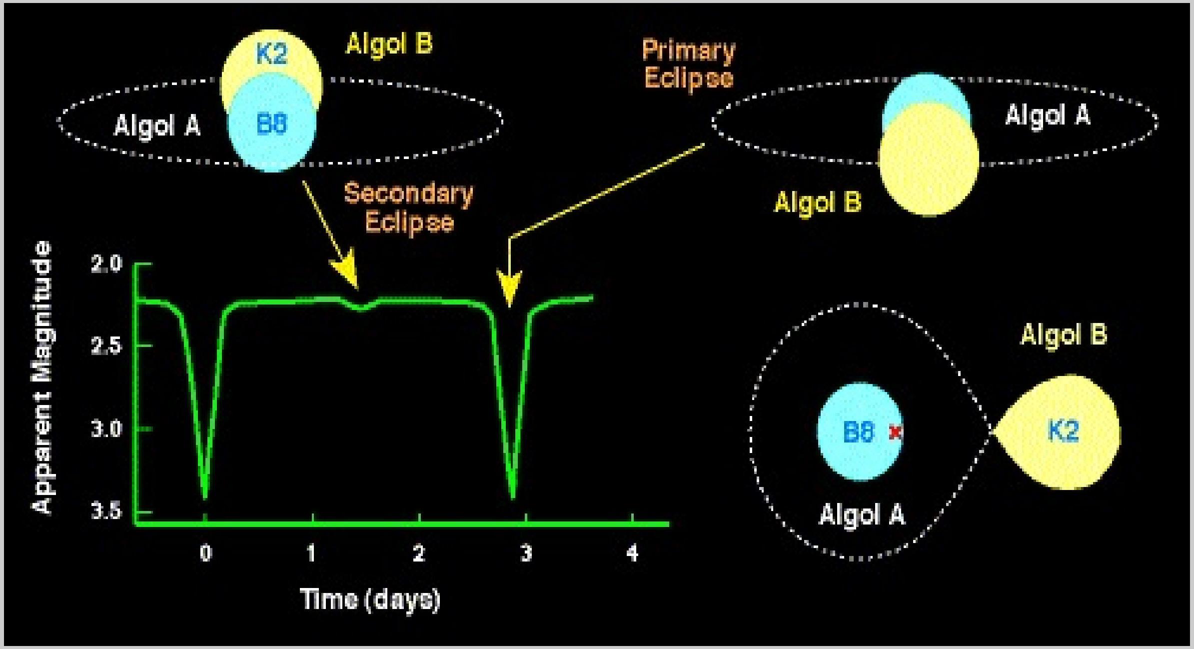
Algol B a subgiant ↔
evolved star

Hey, wait a minute?

- The mass determines the evolution of the star massive stars evolve faster.
  → this scenario is not possible if $M_A > M_B$

How can A – the more massive one be on the main sequence and B the less massive a subgiant ?

Algol Paradoxon !!



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Solution: mass transfer possible

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Algol "Dilemma"

Algol System

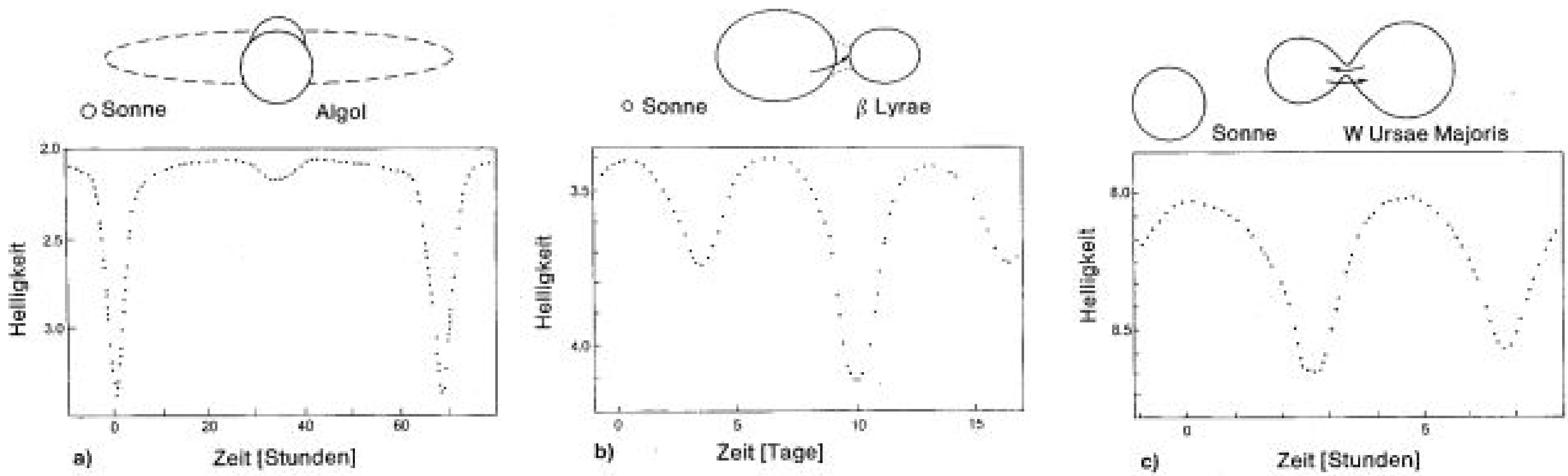
Near-infrared H-band image
from CHARA interferometry data
12 August 2009

→ Algol is not a binary but a

Tripel System

→ around Algol A and B in the center of gravity revolves Algol C

Eclipsing variables



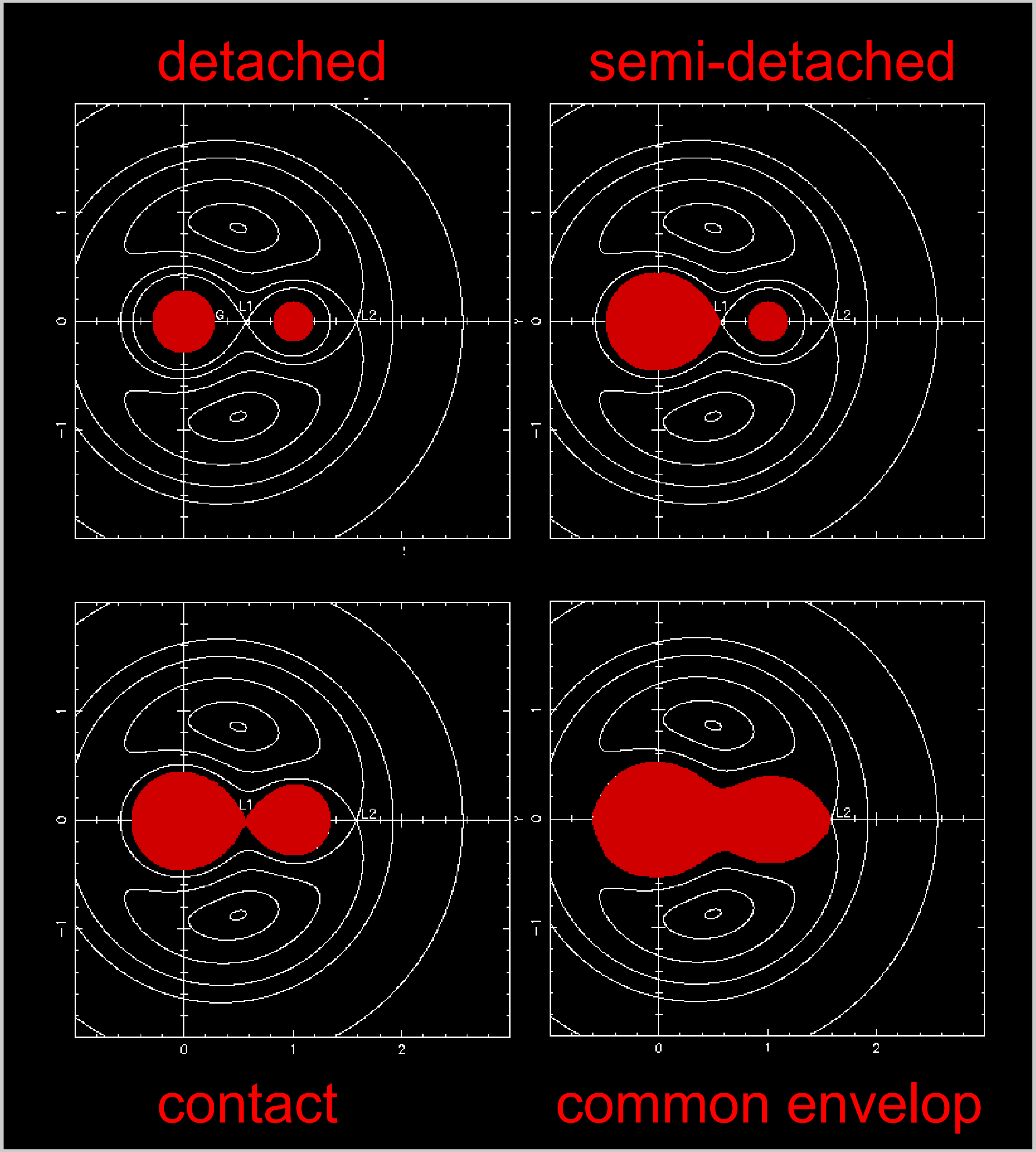
Roche Lobes ↔ different types

Depending on how much of the stars radius filles the equipotential surfaces the System classes are

- detached
- semidetached
- contact
- common envelop

→ determines the degree of interaction between the stars and amount of mass transfere

Different types of eclipsing variables



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Algol Variable ↔ semi-detached

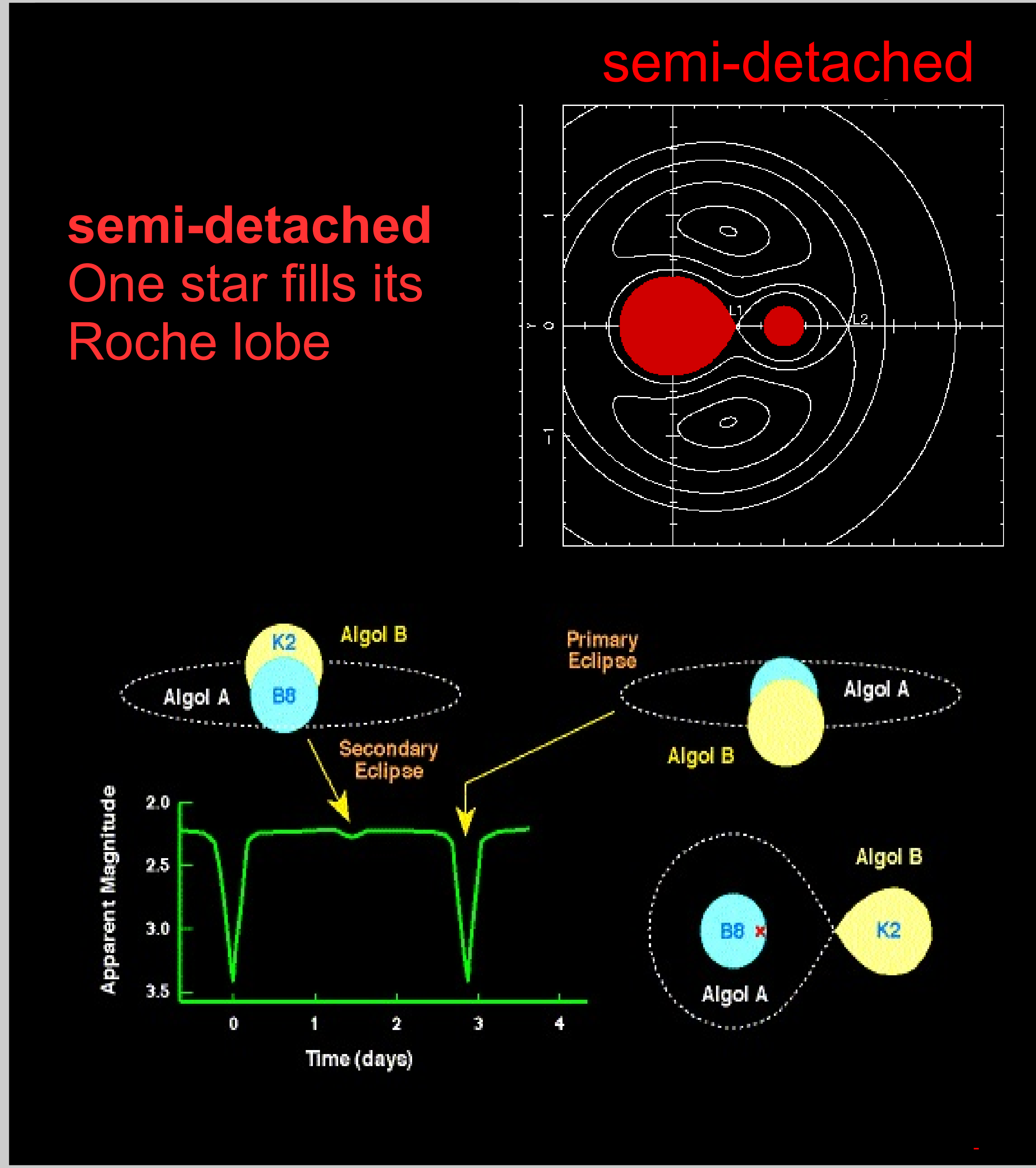
The Algol system is a

semi-detached system

Variability Mechanism:
In one orbit the stars covers each other twice.

because the stars are alined towards the observer "in front of each other". eclipses occur.

Algol is a eclipsing variable



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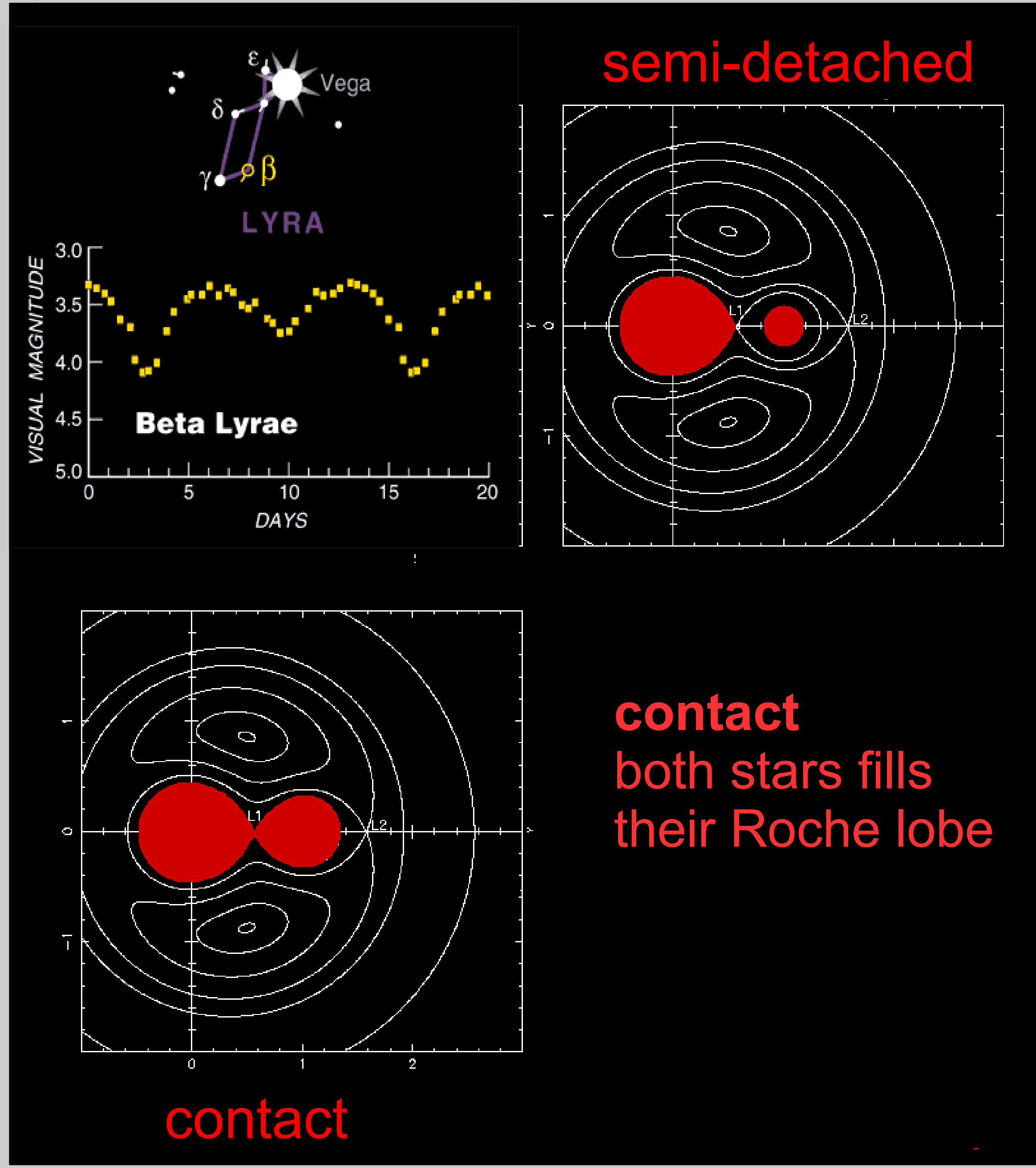
β Lyrae ↔ semi-detached zu contact

Im comparison to Algol is the orbit at β Lyrae very small ↔ **transition** from semi-detached to contact

The distant future can lead stellar merger
→ Example V1309 Sco
→ Red Nova
(see later)

Variability Mechanism:
In one orbit the stars covers each other twice.

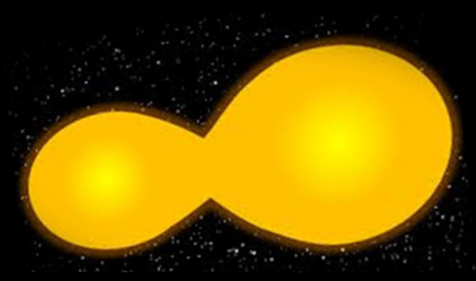


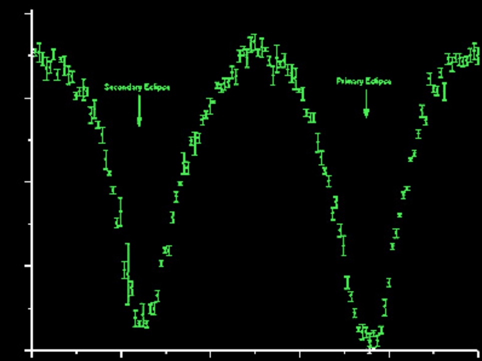
W Ursae Majoris ↔ common envelop

W Ursae Majoris is a common envelope system

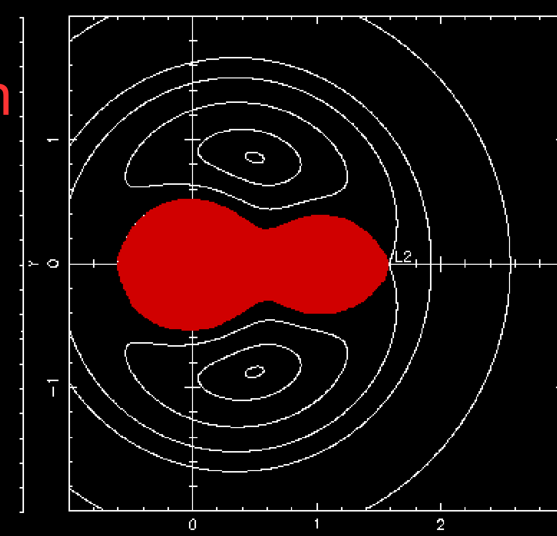
equipotential surface
→ no clear separation anymore
Roche lobe surface forms new envelop and radius

Variability Mechanism:
In one orbit the stars covers each other twice.





- both stars fills their Roche lobe and no clear radius
  Roch lobe surface forms new common envelop and radius



common envelop

eclipsing binaries

binary star systems → shows photometric variability → caused by the stars covers each other twice in one orbit. Due to fixed orbit regular changes
The Roche lobe is filled in to varying degrees what defines subclasses of eclipsing variables:

- **detached** – Roche lobe not filled
- **semi-detached** – one star fills its roche lobe
- **contact** - both stars fill their Roche lobe
- **common envelop** - both stars fill their Roche lobe
  → form common envelope, the roche lobe defines the surface ↔ "radius" of both

→ Evolution from one system to the other are possible

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by planets

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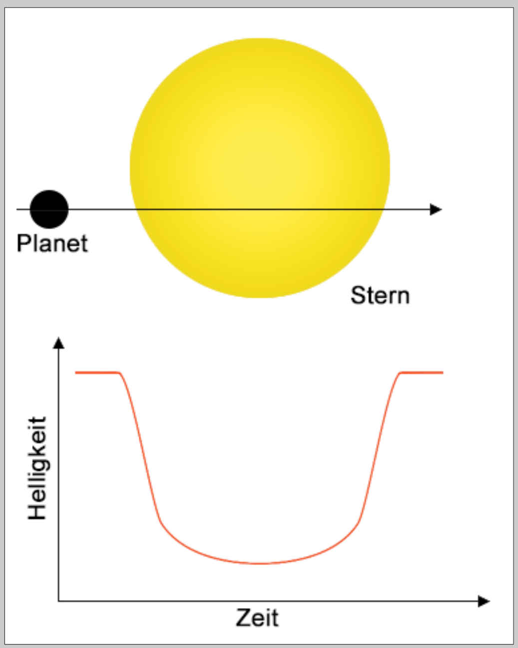
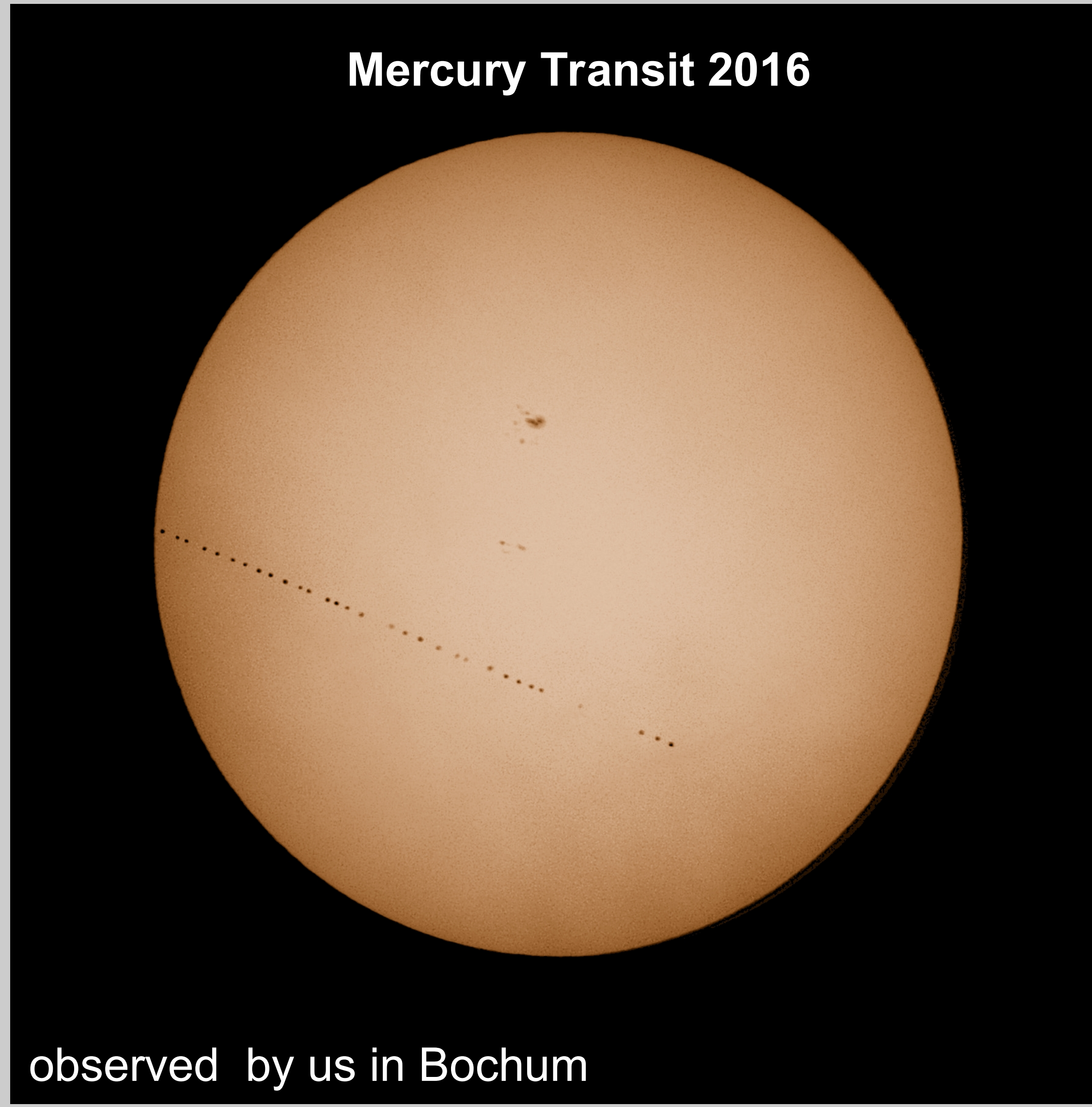
eclipsing variables - Planet Transits

eclipse of the star by planets

In the solar system
visible from earth:
Mercury and Venus transits



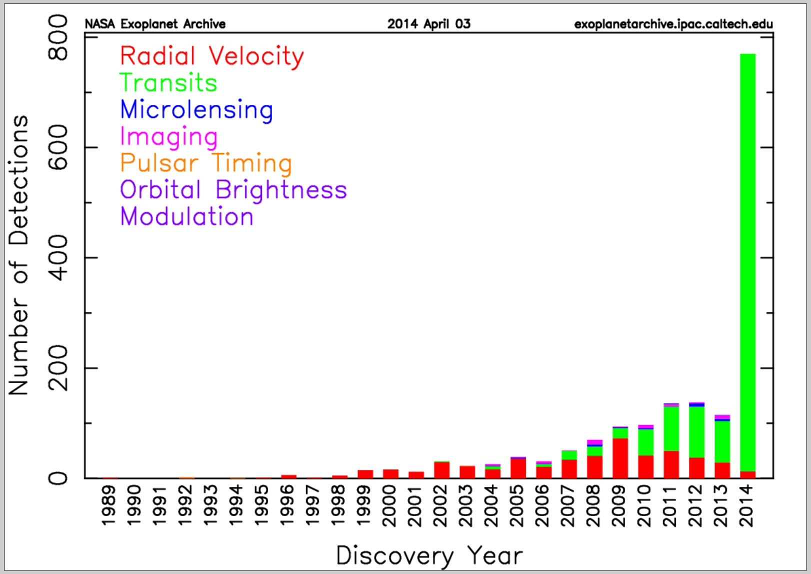


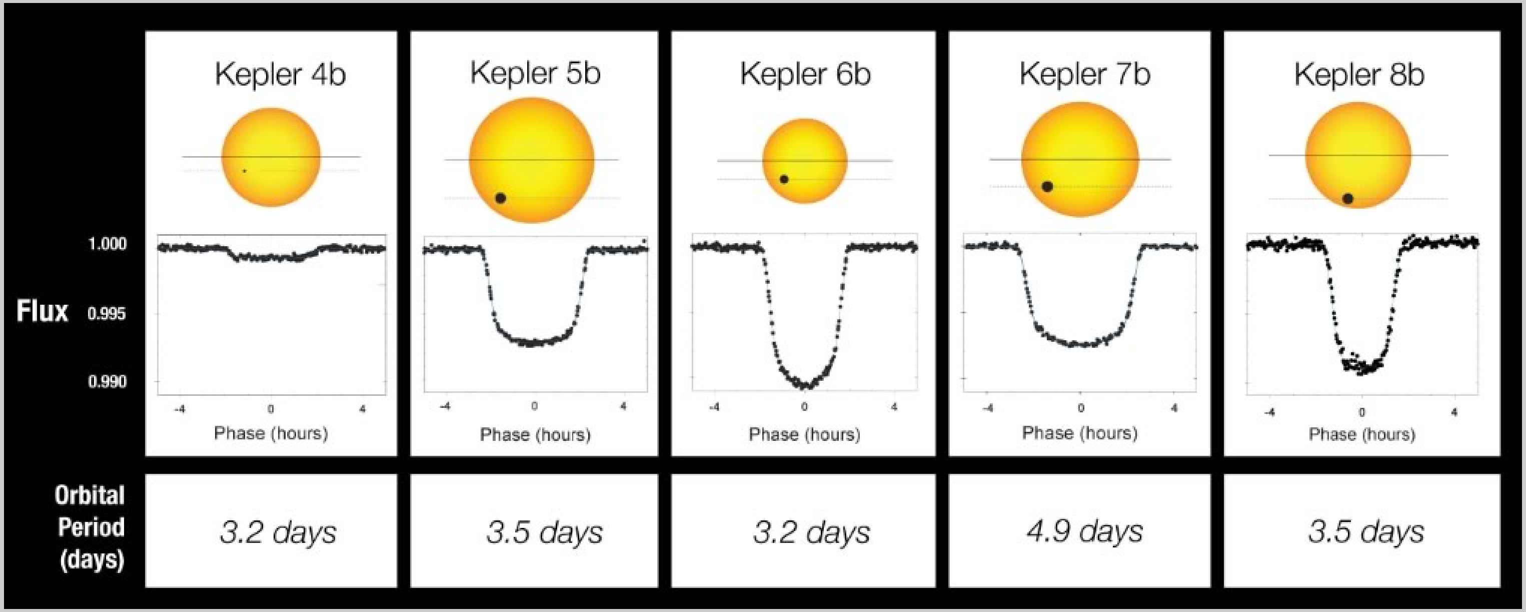
eclipsing variables - Planet Transits

eclipse of the star by planets

In other stars ↔ **exoplanets**
Transit's important **detection** method
for **exoplanets**

The shape of the light curve provides
physical parameters such as inclination of
The orbits ... and even stellar parameters
like the radius





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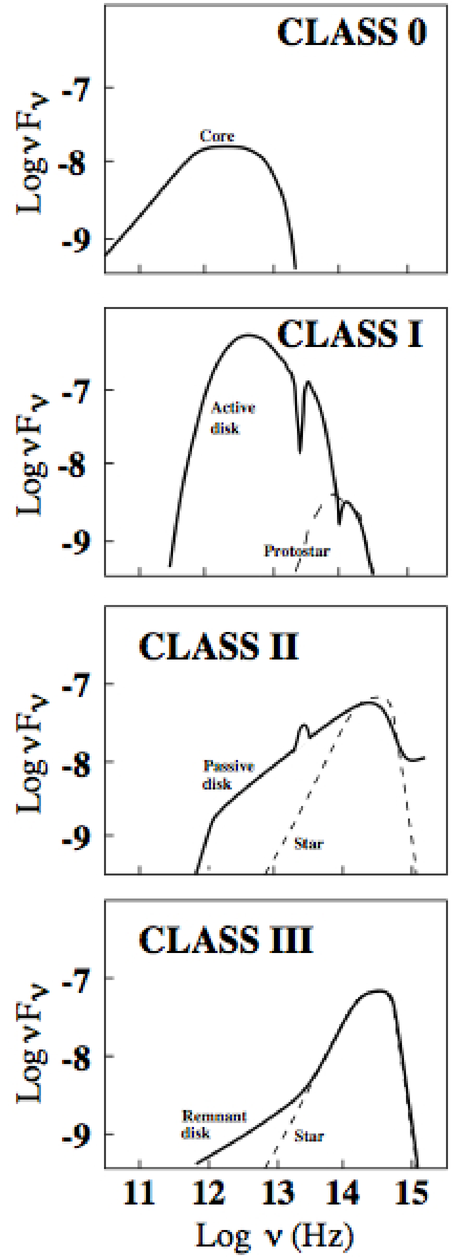
Protostars - accretion disks

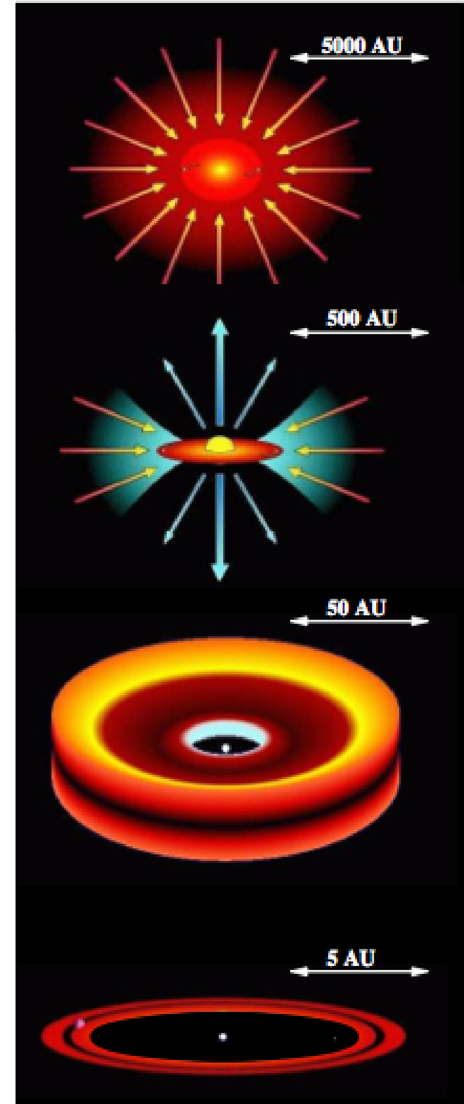
Class 0
protostar embedded cloud (mm) $M_\star \ll M_{shell}$

Class I
protostar growth (MIR), disk (NIR & mm)

Class II
protostar (MIR+NIR), less disk emission
T Tauri stars

Class III
protostar dominates (MIR+NIR) disk remnan
→ Planet formation





Plots by Andrea Isella (Thesis Cal Tec)

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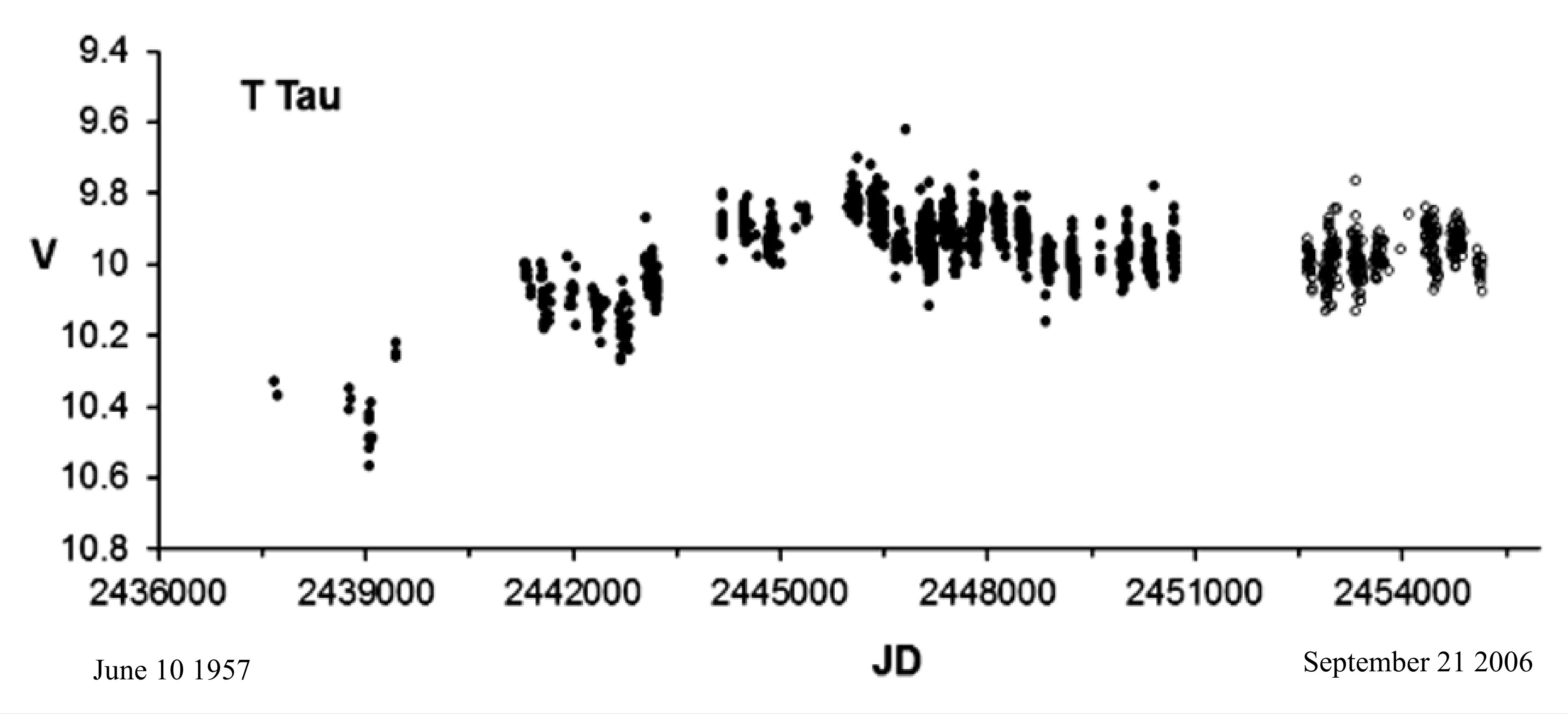
Protostar – T Tauri class

Protostar – T Tauri class

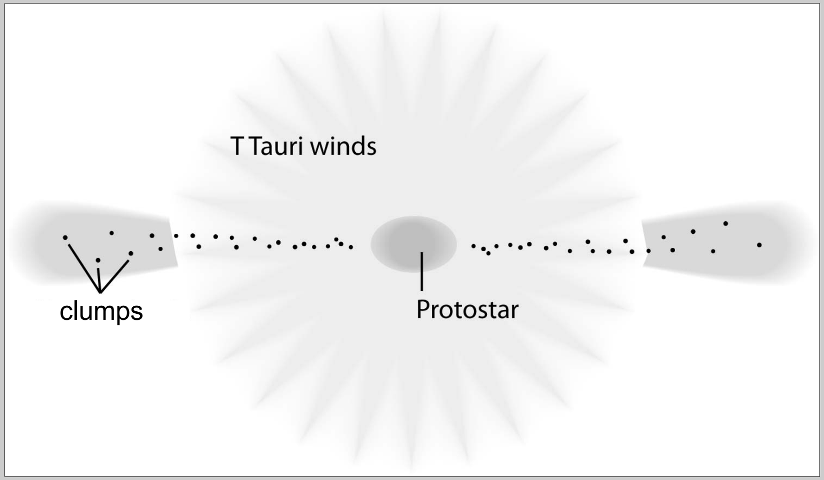
T Tauri star **lightcurve → shows <u>variability</u> !!**



Protostar – T Tauri class

- **T Tauri stars - regular variability**

Clumps around the protostar or in the disk
→ the star is eclipsed



T Tauri Stars – irregular variability

Luminosity of the system dominated by the accretion disk, so besides stellar parameters the luminosity depends on the accretion rate in the disk

$$L = \frac{G M_\star \dot{M}}{R_\star}$$

accretion increases/decreases
↕
luminosity increase/decrease

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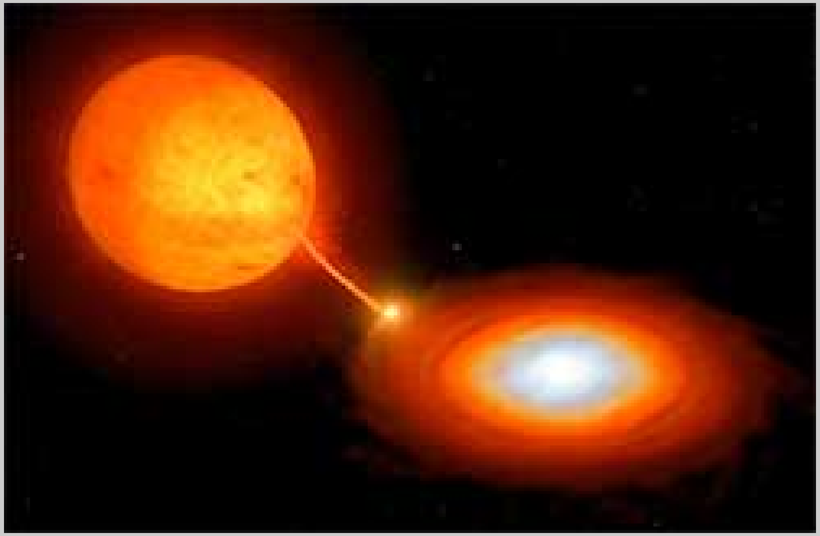
Cataclysmic variable or short CV

cataclysmic ↔ greek
κατακλυσμόζ = flooding

Cataclysmic variables

Binary of a **white dwarf** plus **main sequence star** or **red giant**

Roche lobe from the companion star is filled
→ generates mass transfer to the white dwarf
↔ the flood



White dwarf does not accrete material directly onto the star but via an **accretion disk**

Combines the **two variability mechanisms** – we already know

- **Eclipsing variable**
- **Variability from an accretion disk**

Cataclysmic variables

Cataclysmic variable, can have

spontaneous outbreaks = novae

these are divided into subclasses

- **nova**
- **symbiotic Nova**
- **dwarf Nova**

novae™

Inspiration • Education • Opportunity

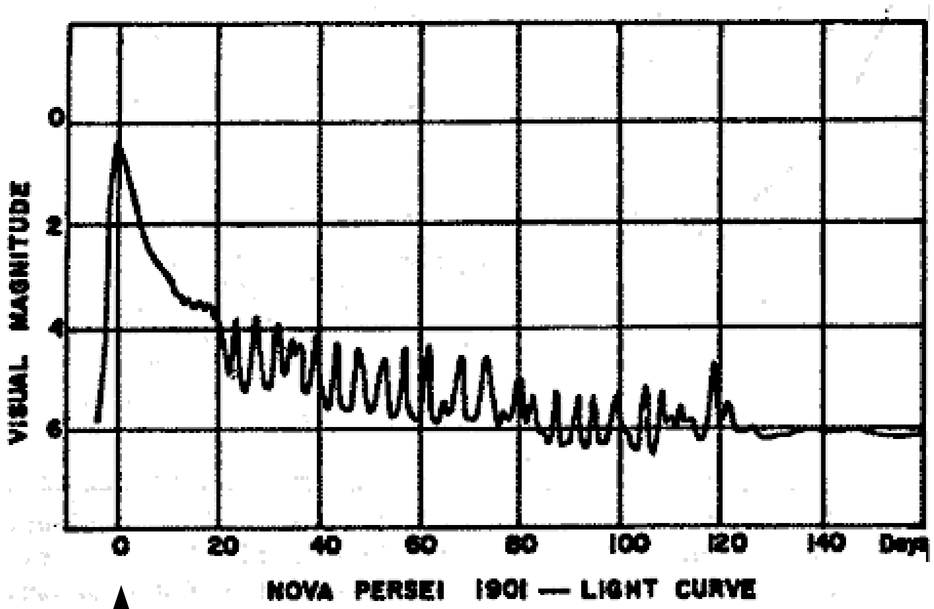
Cataclysmic variables – Novae

observations

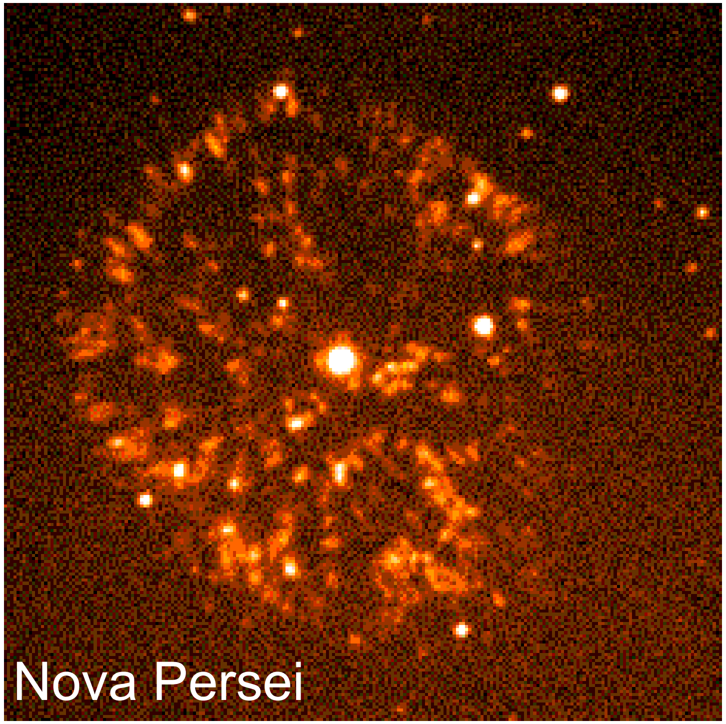
- spontaneous increase in brightness within a few days of **$7\text{-}20^{mag}$**

  $M_V \sim +4^{mag}$ to $M_V \sim -8^{mag}$ translates to **$L_{max} = 10^5 L_\odot$**

  fast type 1-2 weeks, slow type ~ 100 days to fall 2^{mag}
- **mass loss rate ~ 10^{-5} – 10^{-3} $M_\odot$ v_{exp} ~ 1000-2000 km/s**



eruption



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Cataclysmic variables – Novae

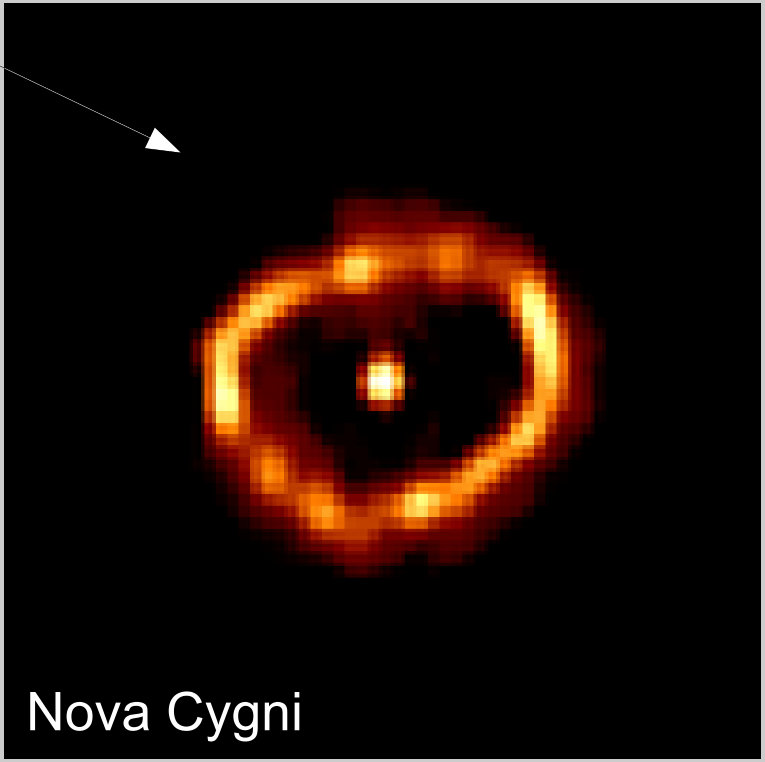
Theory - Mechanism

- Accretion (**~10^{-8} $M_{\odot}a^{-1}$**) of material onto the surface of the WD

  are about **10^{-4} $M_{\odot}$** accreted (mostly H) → hot enough
  ↔ ignites hydrogen burning on the surface of the white dwarf
  ↔ degenerate material ↔ H-flash

  → about 10% of the material ejected
  → degeneracy lifted
  → normal burning until H exhausted

- Nova as a "skin disease" by WZ


Nova Cygni

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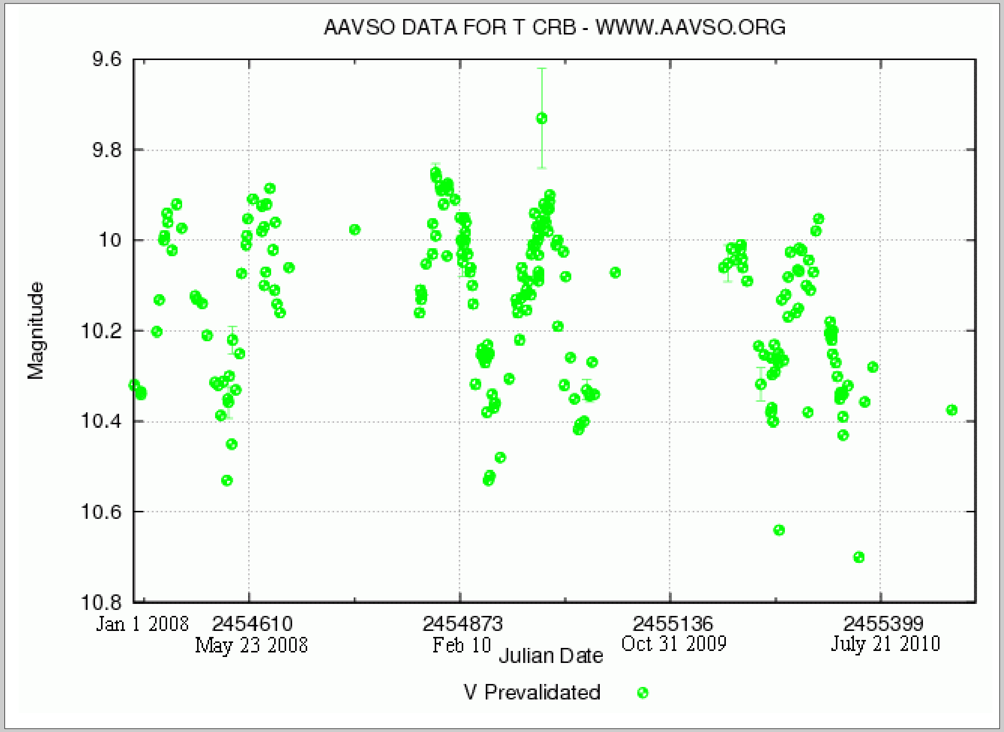
Cataclysmic variables – reccurent Novae

→ degeneracy lifted
→ normal burning until H exhausted

→ possibly after 10-100 years its repeated = **recurrent novae**

↔ **T Corona Borealis variable**



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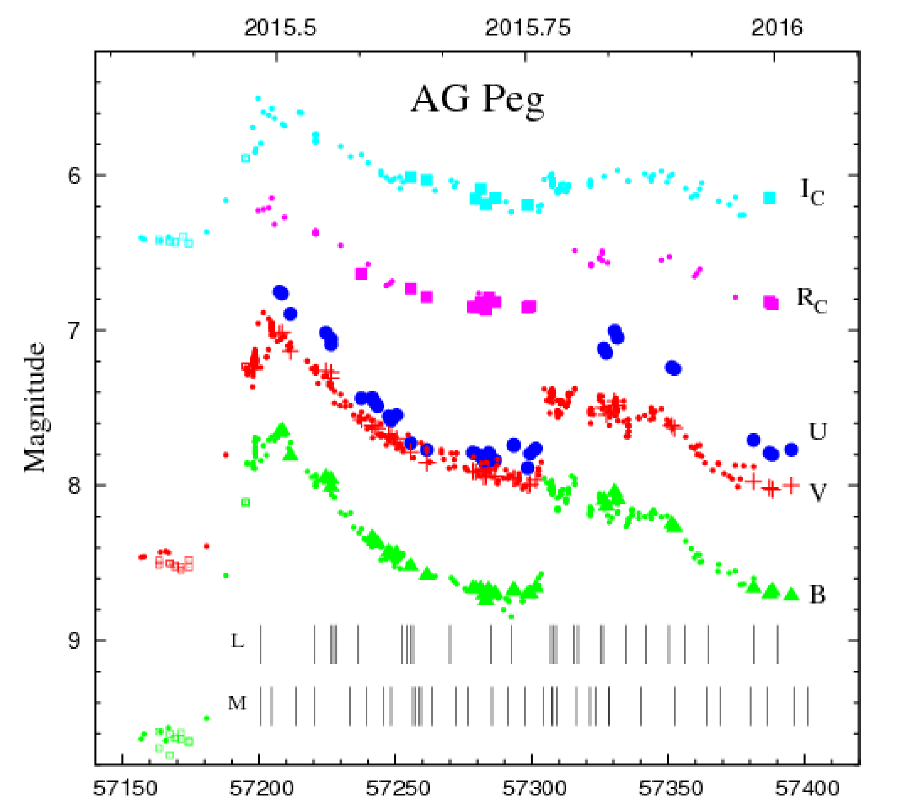
Cataclysmic variables – symbiotic Novae

- **Binary** of a **white dwarf** plus **main sequence star** or **red giant**
  but Roche lobe not filled (≠Nova) ↔ detached system

- companion star has a high mass loss rate due to slow winds
  ↔ **Accretion of the wind !**
  → same **like** in **Nova** = **enough mass** accreted **H-Flash ignites**
  hydrogen burning…etc.

symbiotic nova



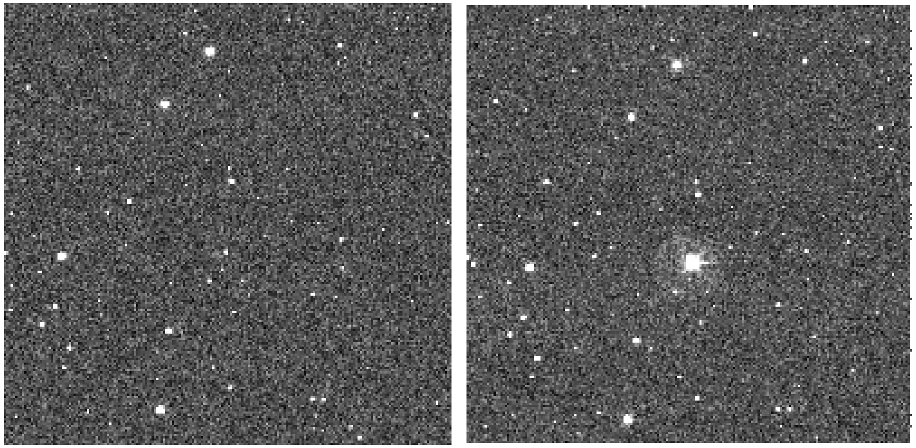
Skopal et al. 2017

Cataclysmic variables – dwarf novae

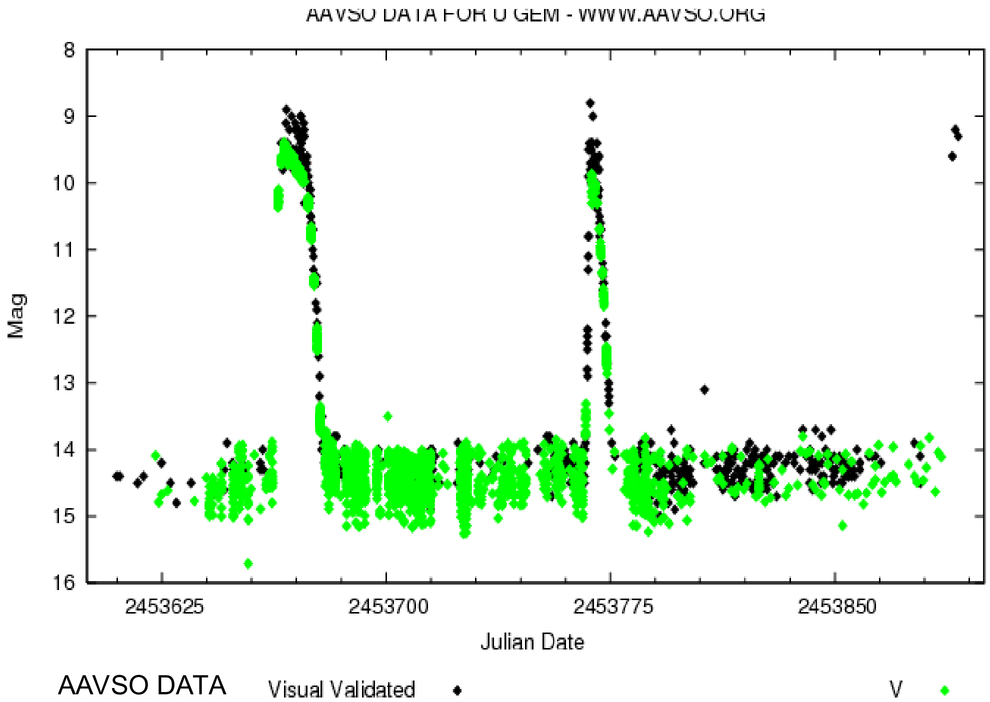
obserevation

- **Multiple spontaneous increases in brightness of** of **2-6^{mag}** at **intervals** from **~ 10 days** to a **few months**

- mass loss ~ **10^{-9} – 10^{-8} $M_\odot$**



U Geminorum



Kataklysmische Veränderliche – Zwergnovae

Theory – Mechnism

- **Akkretion** of masse on the **WZ via an accretions disk**

$$L = \frac{G\ M_\star\ \dot{M}}{R_\star}$$

normal rate is $\dot{M} = 10^{-11}\text{-}10^{-10}\ M_\odot\ yr^{-1}$

at $10^{-9}\text{-}10^{-8}\ M_\odot\ yr^{-1}$ → **Disk-Instability**

Material transport in accretion disk occurs via viscosity

- Viscosity changes with opacity

between 3000-5000 K the degree of ionization changes ↔ Opacity

→ - between 3000-5000 K the degree of ionization changes

hot ↔ high viscosity ↔ large amounts accreted → high L

cold ↔ low viscosity ↔ not much accreted → low L

- **high viscosity** ↔ star cannot accrete fast enough

→ T erhöht → Expansion → **Zwergnova**

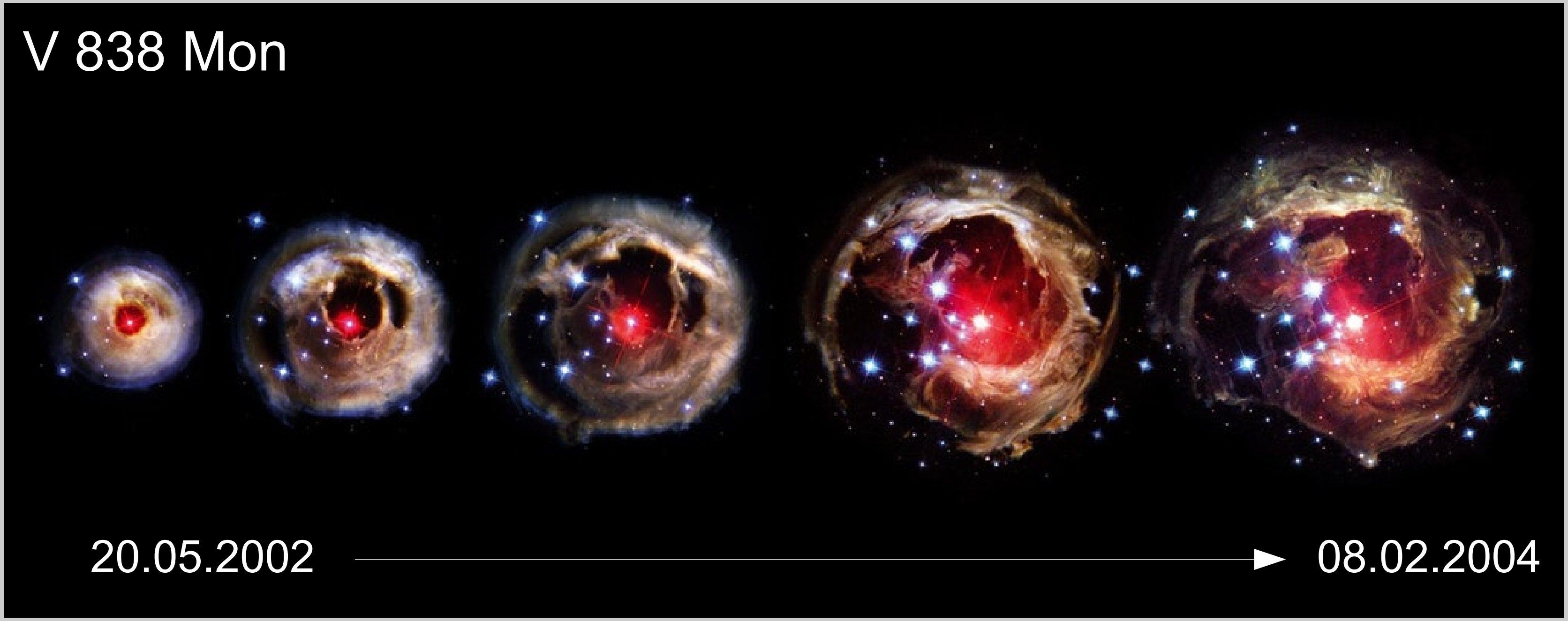
↔ Dwarf nova as “hiccup” of the accretion disk around WZ

(Luminous) Red Nova

observation

compared to Nova

- **similar light curves**
- considerably **redder**
- SED shows **IR excess**
- **different spectrum** (e.g. lower ionized lines)
- Prototype is V 838 Mon ↔ rather new class among the variables



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(Luminous) Red Nova

Theory – Mechanism

Merging of 2 stars (not necessarya white dwarf)
Brightness rise/burst, with the possibility of a shell ejection

Alternative proposals exist, e.g. an atypical SN with strong extinction

More events, more observations needed.

Nova et al.

Nova:
H-Flash on a WZ generated by
Mass accretion from companion

Symbiotic Nova:
H-Flash on a WZ generated by
Mass accretion of the companions wind

dwarf novae:
Disc instability generated by
increased mass accretion

Luminous Red Nova:
Fusion of 2 stars / atypical SN

...there was another nova

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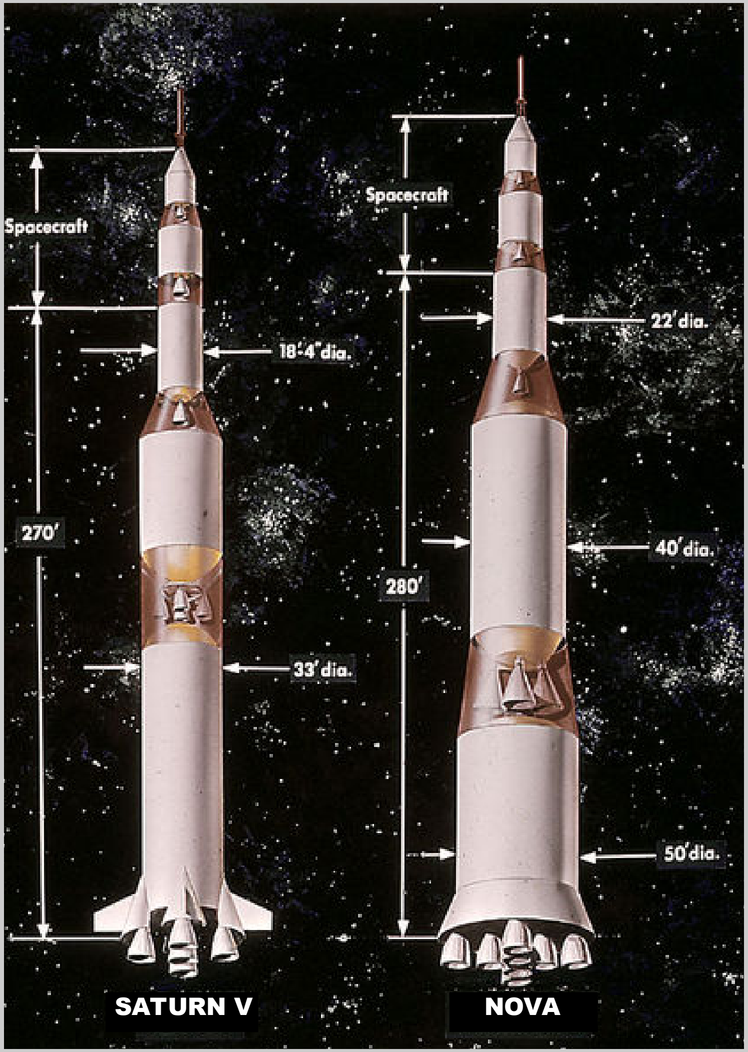
...there was another nova
which was supposed to be the big
brother of the Saturn V rocket
(with up to twice the payload)



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Types of Variability

I. Intrinsic Variability ✔

Star variable "by itself" → variability caused by physical changes of star

- **pulsation variable ✔**
- **Eruptive ✔**
- **Rotationally induced variables ✔**

II. Extrinsic variability

Star not variable by "itself"→ variability generated by external influences

- **Binary stars ↔ eclipsing variables ✔**
- **Accretion disks ↔ like T Tauri ✔**
- **binary+accretion disk ↔ cataclysmic variables, novae ✔**

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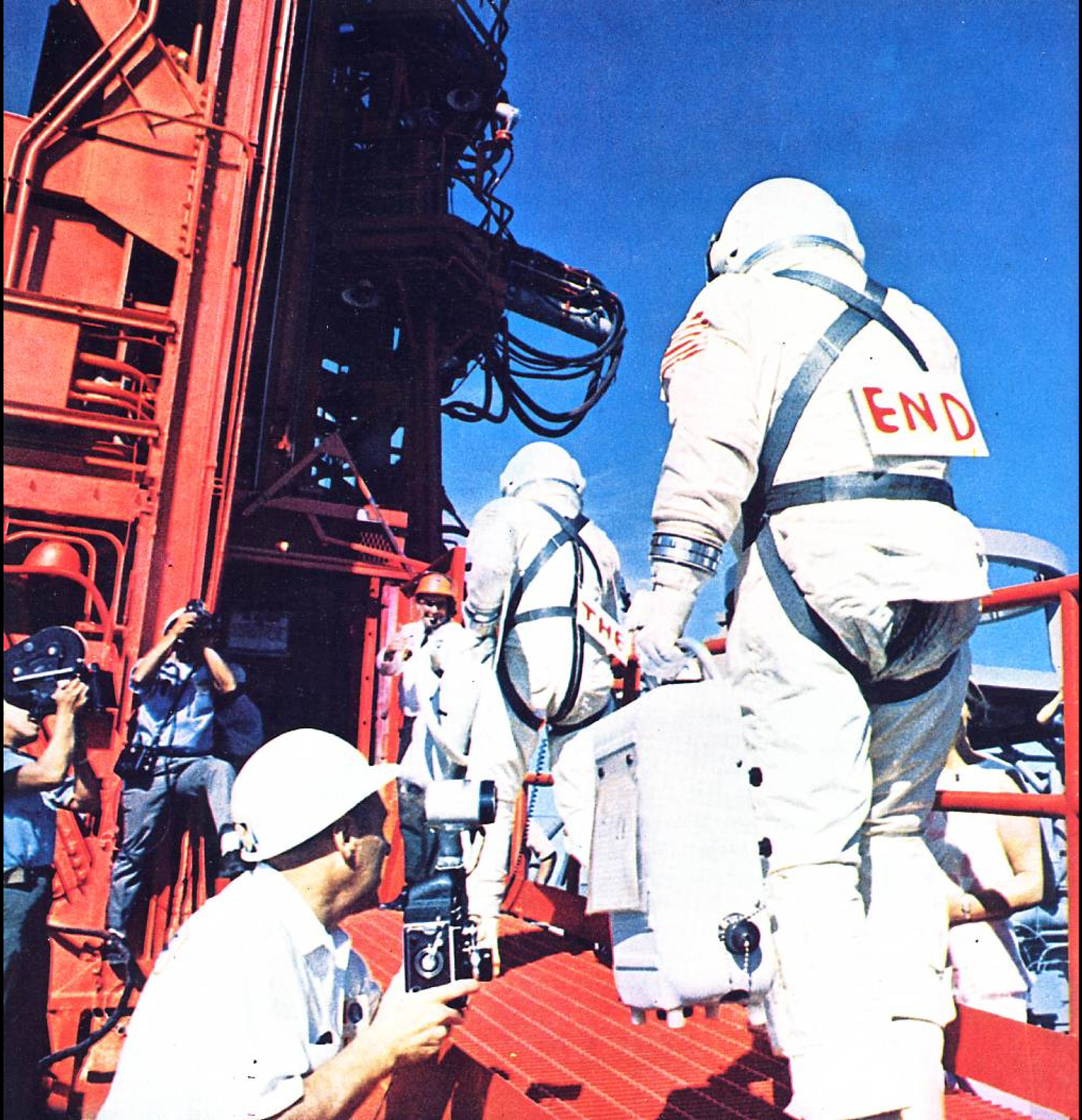

END
THE