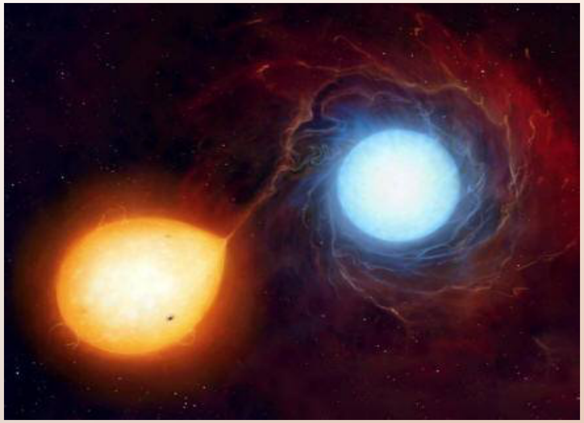
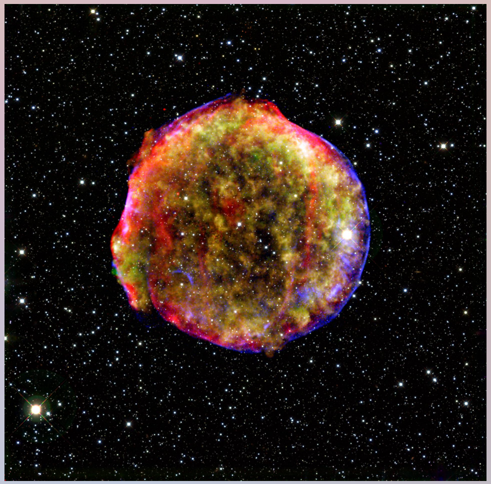


Romain DESCHAMPS
Promoter : Lionel Siess
Collaboration : Philip Davis

Evolution of low- and intermediate-mass binary stars

Why studying binary systems ?

- More than 50 % of stars are in a binary system
- Progenitors of γ-ray bursts, novae, SN1a, …
- Contribute to the ISM enrichment
- Allow determination of stellar properties (masses, ...)

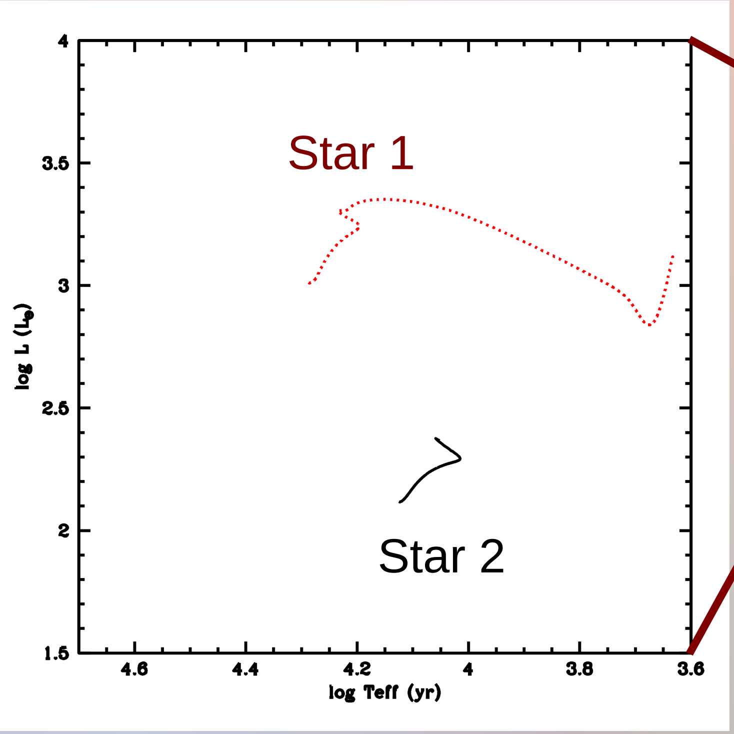


Tycho supernovae
Credit : NASA/CXC/JPL-Caltech/Calar Alto O. Krause et al.

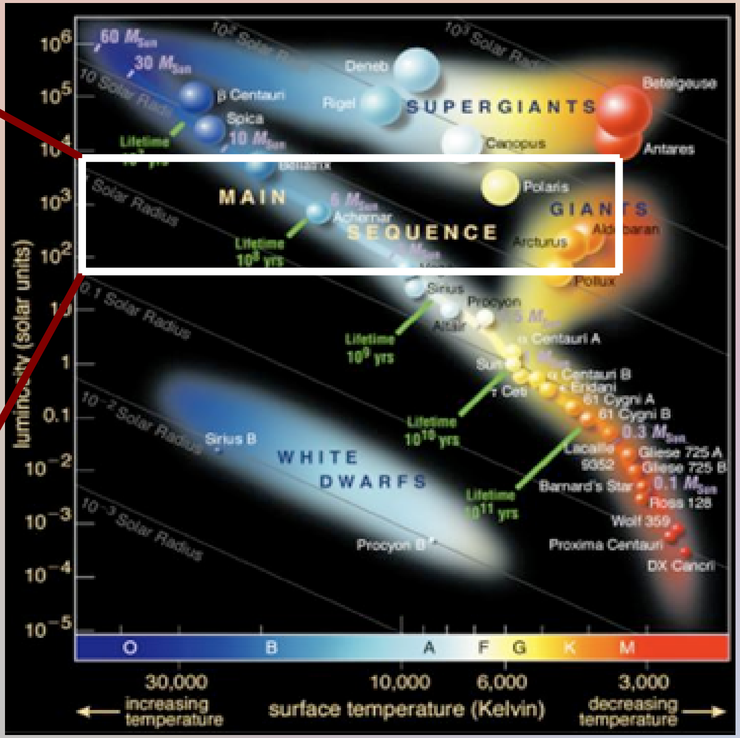
γ-ray (artist view)
Credit : NASA/SkyWorks Digital

Why studying binary systems ?

Single star evolution



Evolution computed with
BINSTAR

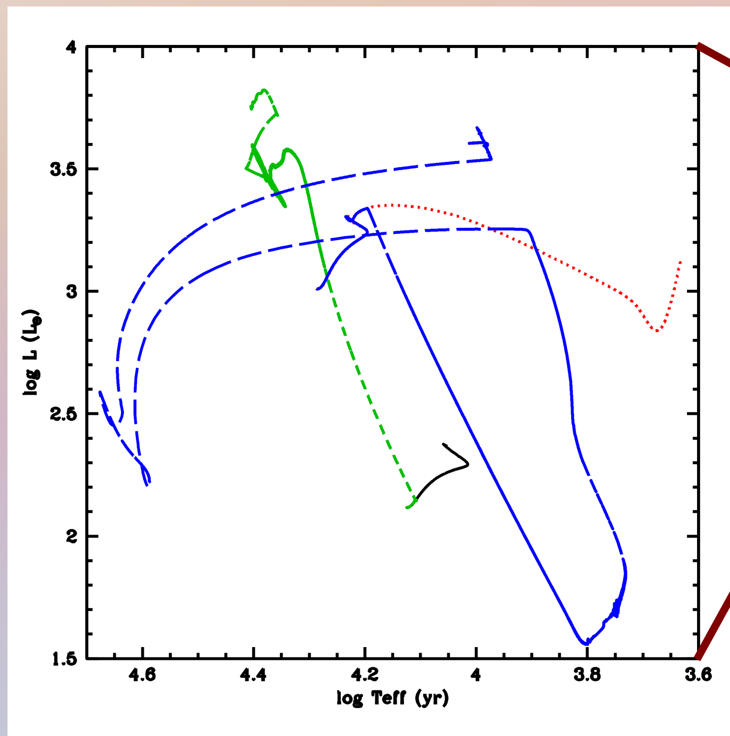


Hertzsprung-Russell diagram

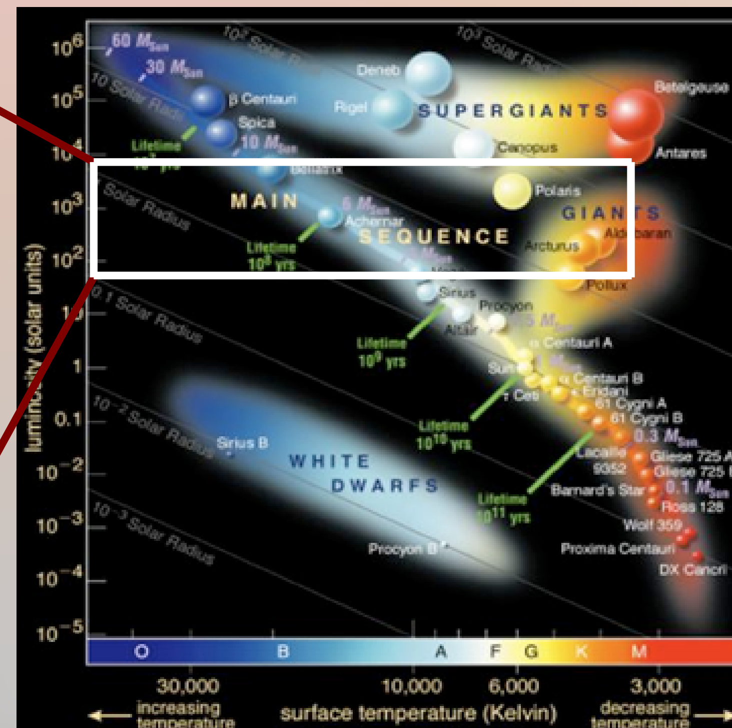
Why studying binary systems ?

In a binary system, interactions strongly modify and complicate the stellar evolutions

Coupled evolution

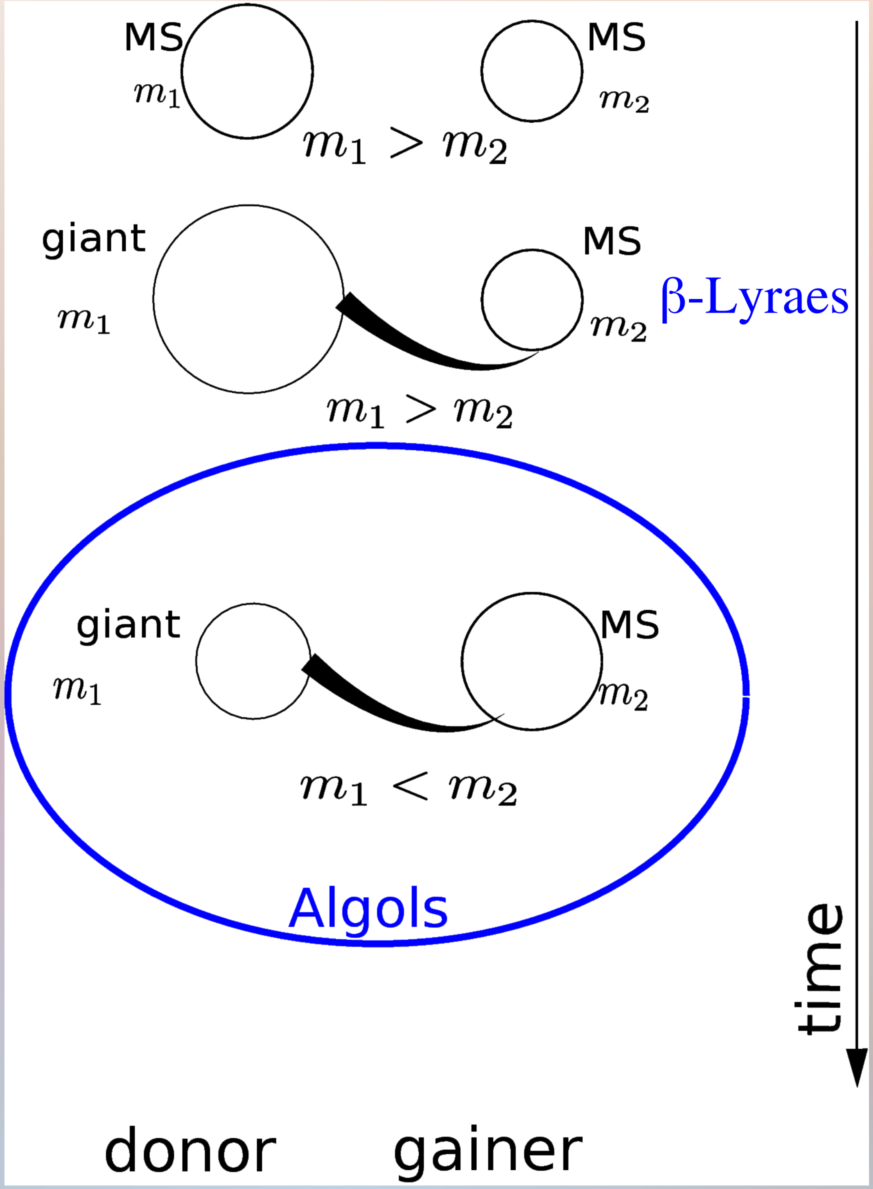


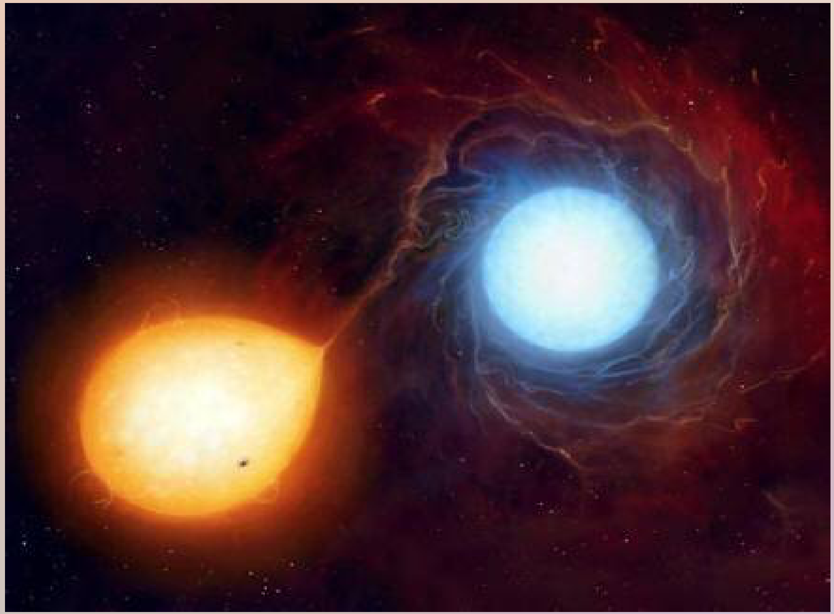
Evolution computed with
BINSTAR



Hertzsprung-Russell diagram

Algols and β-Lyraes problematic



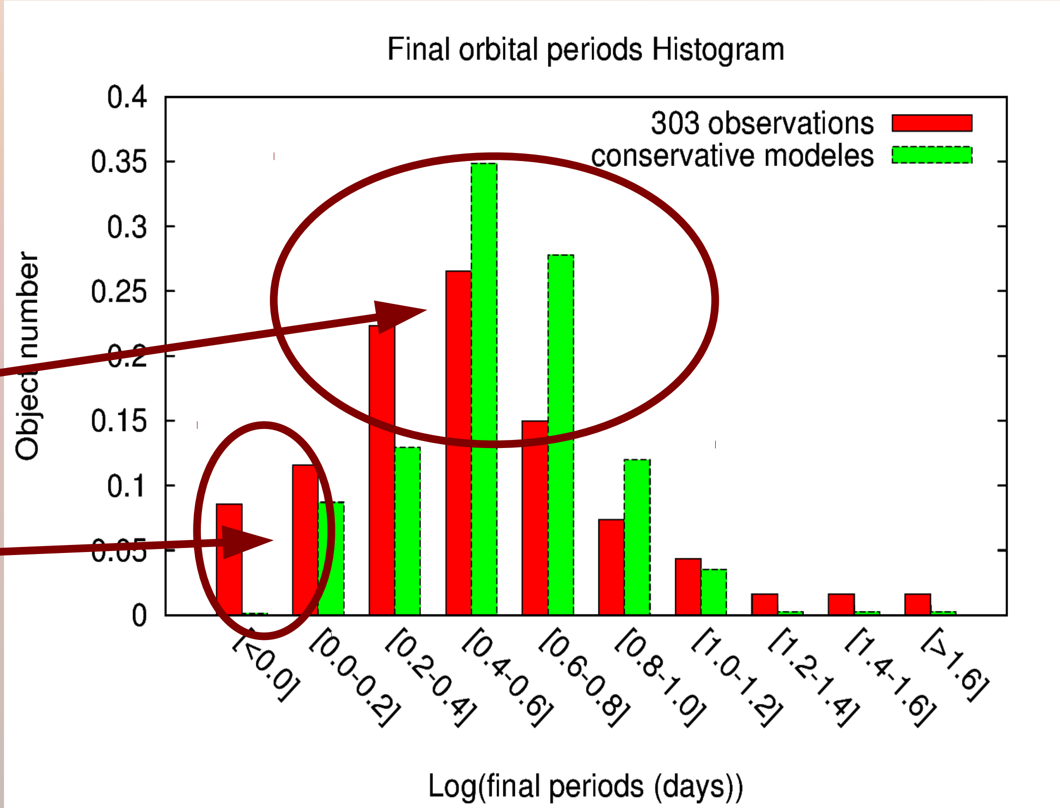


Artist view of an Algol

Algols and β-Lyraes problematic

Period problem :

- **Non conservative evolution**
- **Contact systems** (future investigation with BINSTAR)

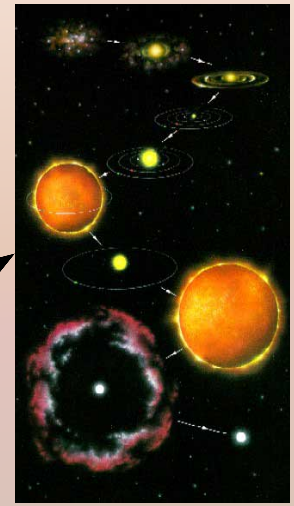


Collaboration VUB – Van Rensbergen et al. 2010

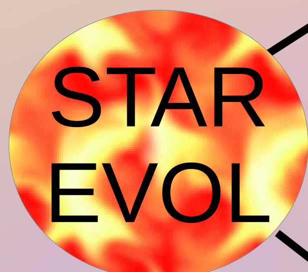
Work in collaboration with the VUB members

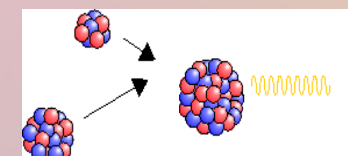
The STAREVOL code

Based on a complete single star evolutionary code: STAREVOL

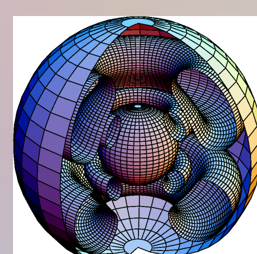


Compute the evolution of star up to the last stages



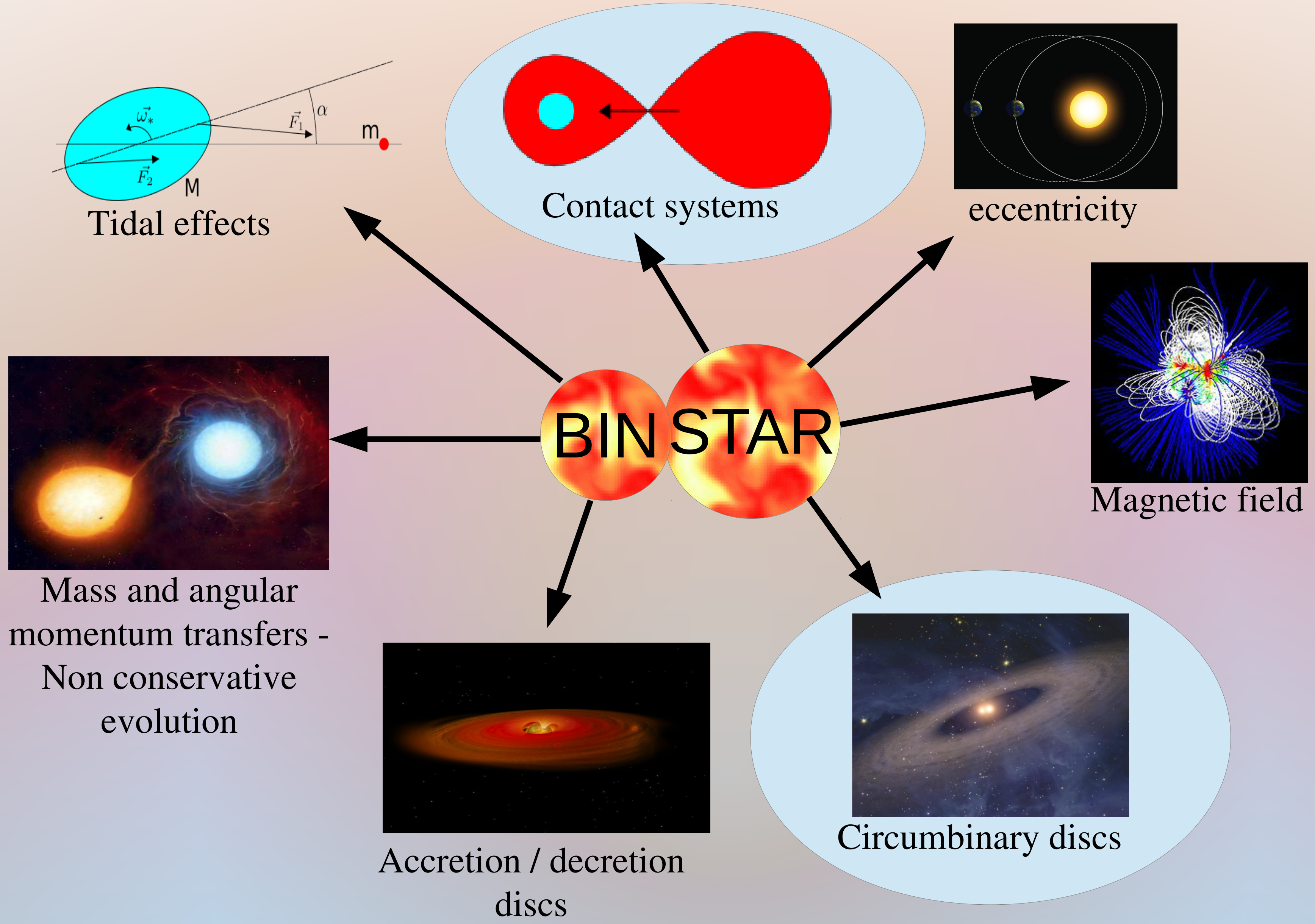


Follow the star nucleosynthesis



Mixing processes
- Rotation

The BINSTAR code



First results

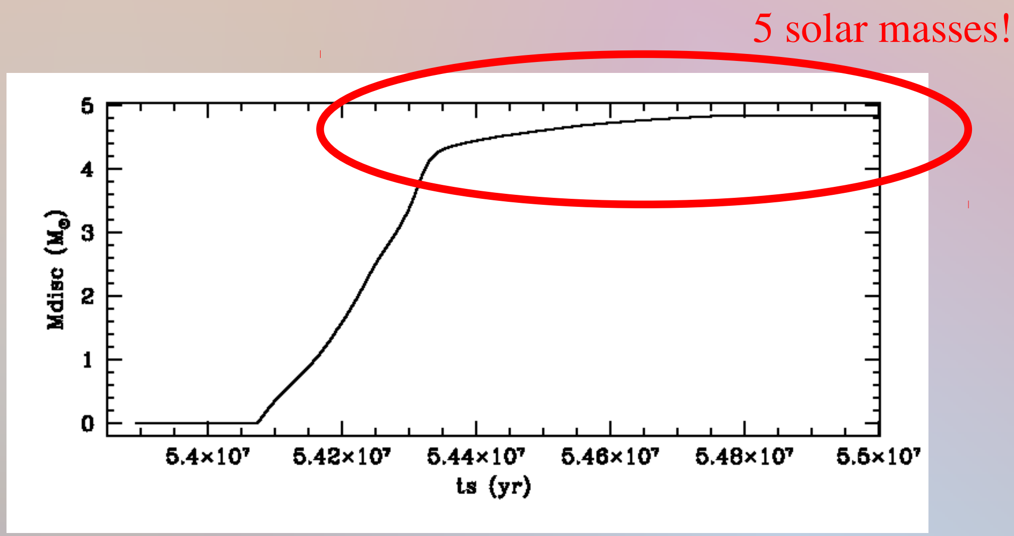
- Accretion on a critically rotating star:

  Mass accretion comes with deposition of angular momentum => the accretor is sped up to its critical velocity (Packet 1981).

Can we spin down the accretor with:

- Magnetic fields?
- Mass ejection?
- Tides?
- Star/disc interactions?

What if the star does not accrete any mass?

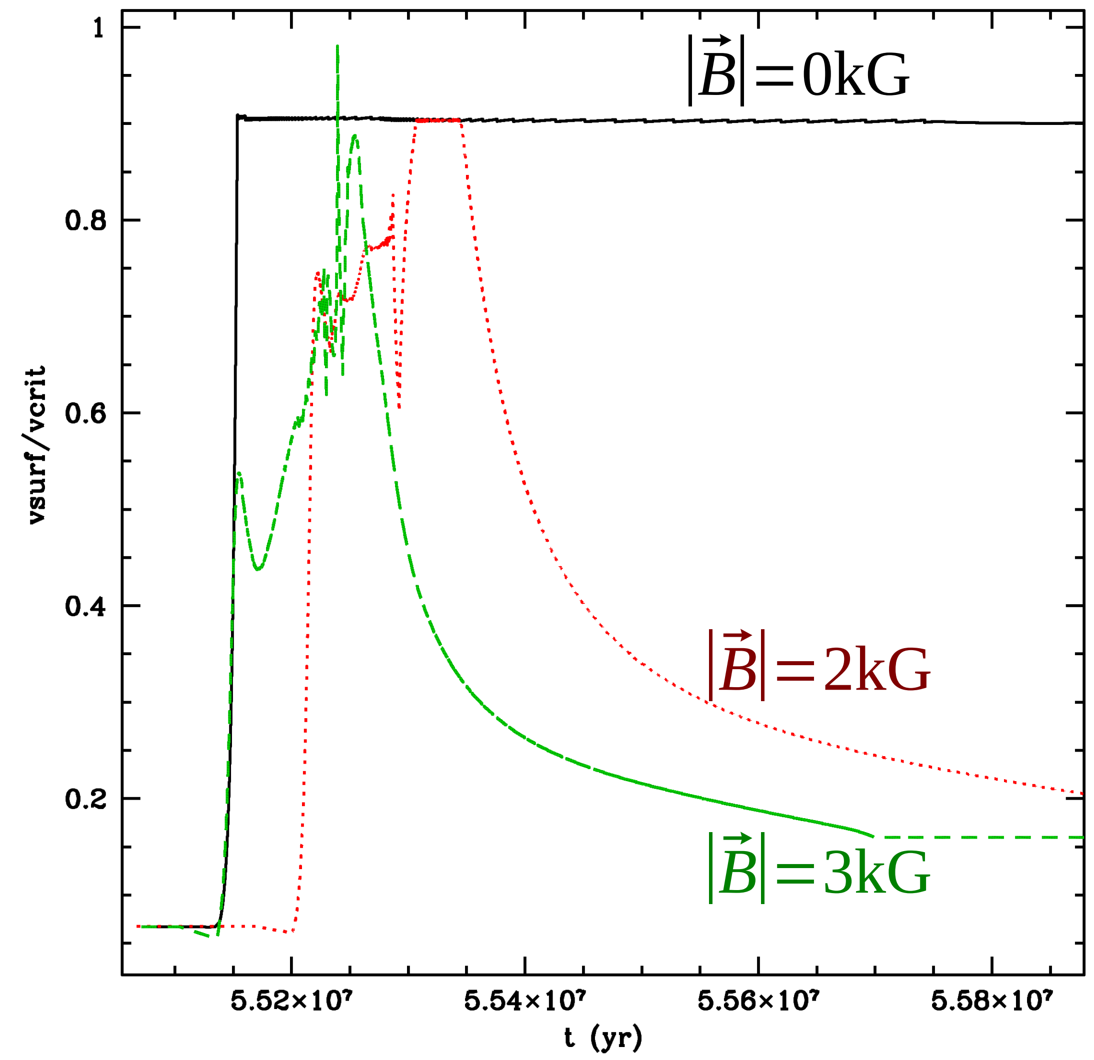


BINSTAR OUTPUT

Effect of magnetic fields

Disk locking and magnetic (wind) braking work but:

- Need magnetic fields of about 3kG (rarely observed in such stars)
- Most of the non accreted matter is expelled (not observed in Algol systems)



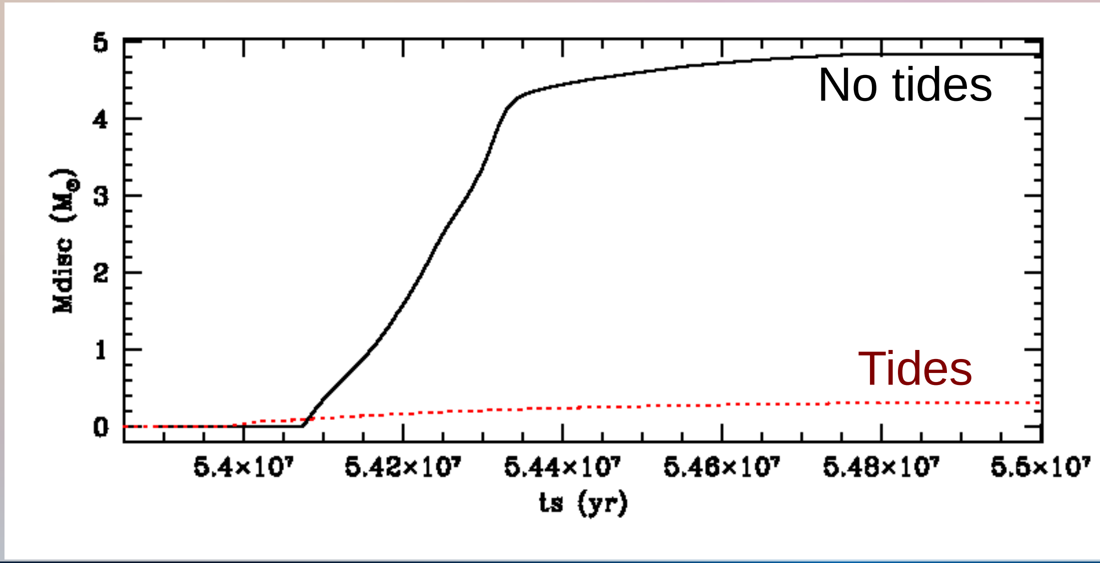
BINSTAR OUTPUT
Based on Dervisoglu et al., 2010

Other mechanisms

- Mass ejection:
  - Stellar winds not efficient enough
  - No observational counterpart of mass loss in algols, but β-Lyraes show evidences of mass ejection (bipolar outflows)
- Tides:
  - Too weak

BINSTAR OUTPUT

Tidal prescription: Zahn 1977



Star-disc boundary layer

Does accretion stop when the gainer reaches the critical rotational velocity?

- Star-disc boundary layer effects
  - Accretion of mass with outwards transport of AM
  - Is a disc always present?
  - Is some matter lost through this mechanism?
  - Where is the AM excess redistributed?

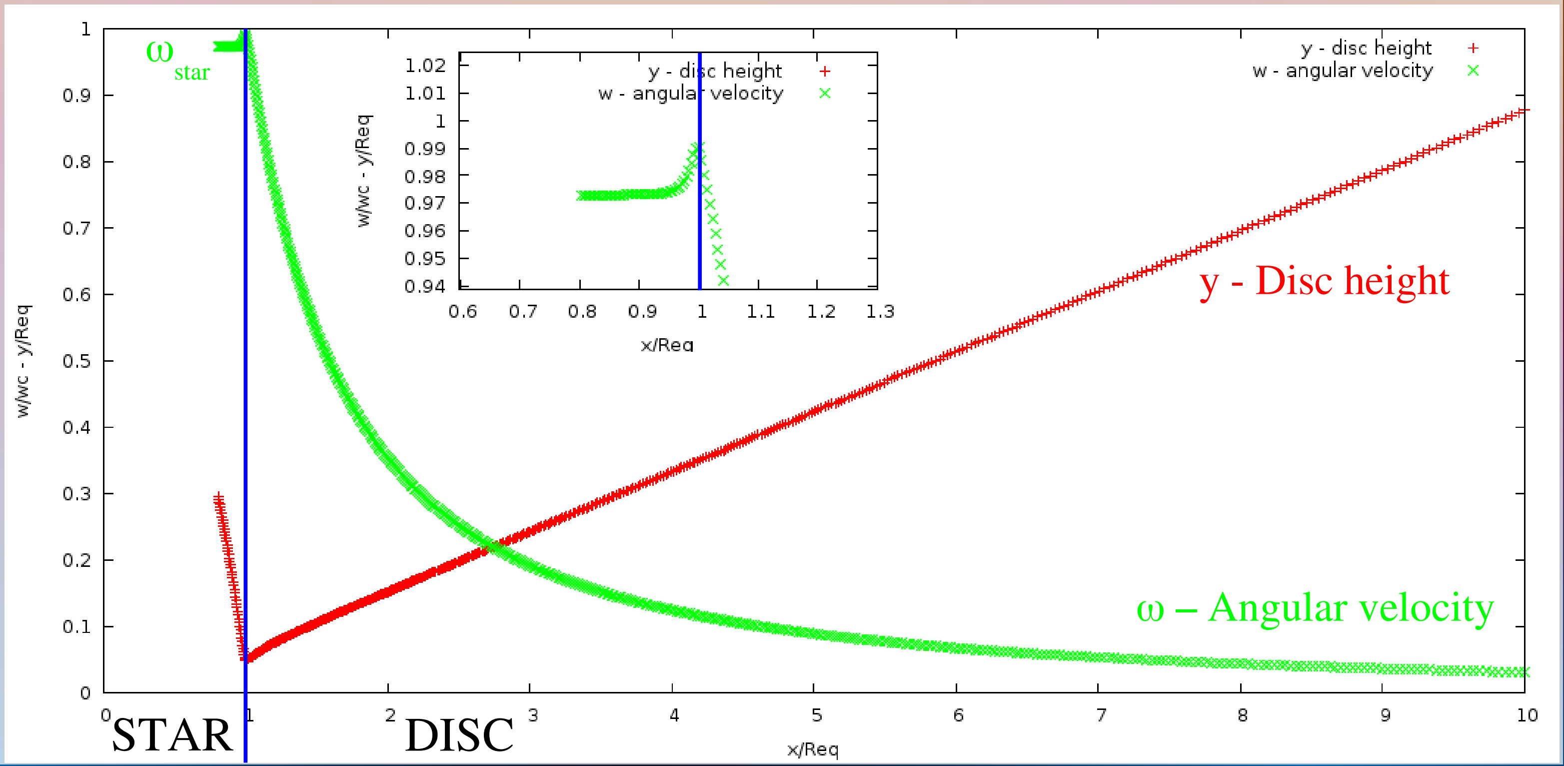
Star-disc boundary layer

Star-disc Boundary layer formation

- Hydro treatment of the disc structure *coupled* with `BINSTAR`
- Star accretes mass but not AM

`BINSTAR` output

Based on Paczinsky 1991



The need for hydrodynamical simulations

What is the degree of conservatism if the gainer is spinning very fast?

- Stellar winds and Hot-spots lead to mass loss from the system.
- Does the disc also loose mass?
  - Tidal disc truncature
  - Disc winds
  - Jets
  - ...

} hydrodynamical simulations required

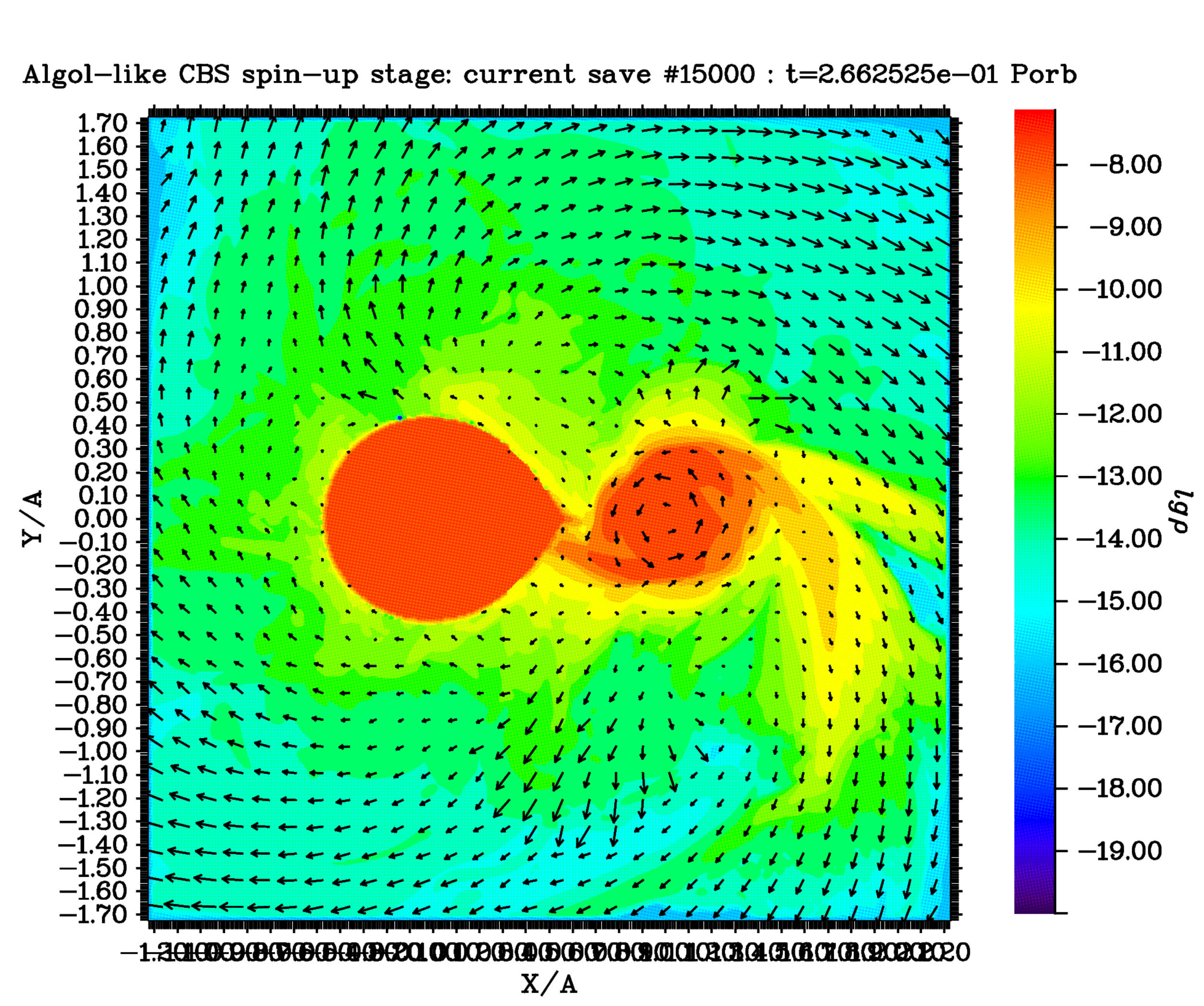
The MIRA code

Alexey Sytov and Dmitry Bisikalo

- 3D Eulerian hydrodynamical code MIRA

- Starting from BINSTAR outputs

- Accretion on a critically rotating star



MIRA output of an Algol system: 3.6 + 6M_o, P=2.5d

Collaboration with Alexey Sytov and Dmitry Bisikalo

What is next?

- Algols are just an appetizer for `BINSTAR`
  - Barium star evolution (implies evolved stars)
  - Chemical composition of the accretor is modified

Synthesis population for canonical model
IAA collaboration – Dermine 2011

Problematics

•Models not able to reproduce eccentricities for objects having $500 < P < 5000$ j

•Barium star nucleosynthesis more complex => heavy element production