An incisive look at the interacting binary SS Leporis
Milli-arcsecond imaging with PIONIER/VLTI

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Interest of interacting binaries

In general: a mass losing giant + a compact star + complex structures

Properties relevant to many astrophysical objects → Excellent laboratories to study numerous physical processes

Evolution dominated by mass transfer processes

Roche lobe overflow (RLOF)

Stellar wind accretion
The breakthrough of interferometry

Spectroscopy or Photometry
→ **Indirect observables**
→ Assumptions required

Numerous unsolved problems, e.g.:
*ellipsoidal variability in detached system?*

**Optical interferometry**
→ **Direct observables**

Constraints on physical sizes, morphology

New model-independent imaging capability

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\( \beta \text{ Lyr (Zhao et al. 2008)} \)

\( \sim 1 \text{ mas} \)

\(< 1 \text{ AU} \)

\( \epsilon \text{ Aurigae (Kloppenborg et al. 2010)} \)

\( \chi^2 = 0.87 \)

\( \chi^2 = 0.69 \)
The case of SS Leporis

M giant + A star + circumbinary envelope
Precursor of post AGB binaries

Algol-type system
Mass ratio $M_A/M_M \sim 2$ to $4$
→ hints for mass transfer

Roche lobe overflow

Distance ~ 270 to 370 pc
Orbit: - $P = 260$ d
  - Quasi circular
  - Inclination estimated to ~ 30°
  - Separation ???

Verhoelst et al. 2007, Welty et al. 1995, Jura et al. 2001
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VLTI observations

4 AMBER archive + 4 PIONIER comissionning

PIONIER images: **SS Lep as a visual binary**

Commissionning data: resolution ~1mas, 2-4h obs each
1st images of an interacting binary @ VLTI
VLTI observations

Parametric modeling: a binary plus circumbinary material

AMBER
H+K bands
R=40

PIONIER
H band
R=40

Envelope (~12mas)
Binary (~5mas)
M giant (~2mas)
The energy balance

M star MARCS model
3200±200K
high metallicity?

A star Rayleigh-Jeans, 9000K
10x oversized (φ~0.6mas)
OR
accretion disk?

Envelope BB @1700K, gaussian?
FWHM ~8mas

Relative flux + 2MASS points →

low resolution spectrum
The orbit and masses

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<tr>
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<th>Before</th>
<th>Now</th>
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<tbody>
<tr>
<td>d [pc]</td>
<td>330±70</td>
<td>280±25 (Hipparcos)</td>
</tr>
<tr>
<td>$M_A$ [M$_\odot$]</td>
<td>2~3</td>
<td>2.7 ± 0.3</td>
</tr>
<tr>
<td>$M_M$ [M$_\odot$]</td>
<td>0.35~1</td>
<td>1.3 ± 0.3</td>
</tr>
<tr>
<td>$M_A/M_M$</td>
<td>4±1</td>
<td>2.2 ± 0.3</td>
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Errors dominated by the distance uncertainty
Mass transfer: stellar wind accretion!

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<tr>
<td>( \varnothing_M ) [mas]</td>
<td>3.1 ± 0.3</td>
<td>2.2 ± 0.01</td>
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<tr>
<td>d [pc]</td>
<td>330±70</td>
<td>280±25</td>
</tr>
<tr>
<td>( \varnothing_M ) [R_\odot]</td>
<td>220±60</td>
<td>130±7</td>
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<td>Roche lobe filling</td>
<td>140±20 %</td>
<td>85±3 %</td>
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Errors dominated by the distance uncertainty

No Roche lobe overflow

Stellar wind accretion

a ~ 1.3 AU
Current vision of SS Lep

Tidal distortion 6-9%

Enhanced mass loss (CRAP)
\[ \sim 10^{-6} \, M_\odot/\text{year} \]
(Tout & Eggleton 1988)

Wind filling the Roche lobe
(Mohamed et al. 2007)

Wind focused in the equatorial plan

Wind accretion efficiency >> 10%
(Nagae et al. 2004)

<1mas
Accretion disk

System history:
- Giant initial mass > 2.2 \( M_\odot \)
- No need for a RLOF
Summary

Results: new vision of the system
Interfero + spectro: - orbit + masses
- important constraints on the mass transfer process

Future work on SS Lep:
- Last PIONIER run: hints for an outburst?
- Circumbinary disk morphology → NaCo/SAM + PIONIER
- Tidal distortion of the M giant? → PIONIER
- Wind morphology + real size of the giant → MR AMBER + VEGA
- Accretion disk or oversized star? → VEGA
+ simultaneous spectro/photometry

Important potential of interferometry for interacting binaries
with model-independent imaging, e.g.:
- Ellipsoidal variability in detached systems?
- Impact of radiation pressure on the Roche lobe geometry?
- Wind focused in the orbital plan?
- ...