Microlensing of Close Binary Stars

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- Previous work / This work
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Motivation

- What happens when an eclipsing binary is microlensed?
- What happens when a close binary is microlensed?
- ... can we detect source star distension?

Previous work

- What happens when an eclipsing binary is microlensed?
  - See Lukasz' talk later.
- What happens when a close binary is microlensed?
  - For single lens case, see Han & Gould 1997
  - For binary lens (caustic-crossing) case: nothing surprising usually, but fun.
- What happens when binary source fills Roche lobes?
  - Interesting things.

Previous work

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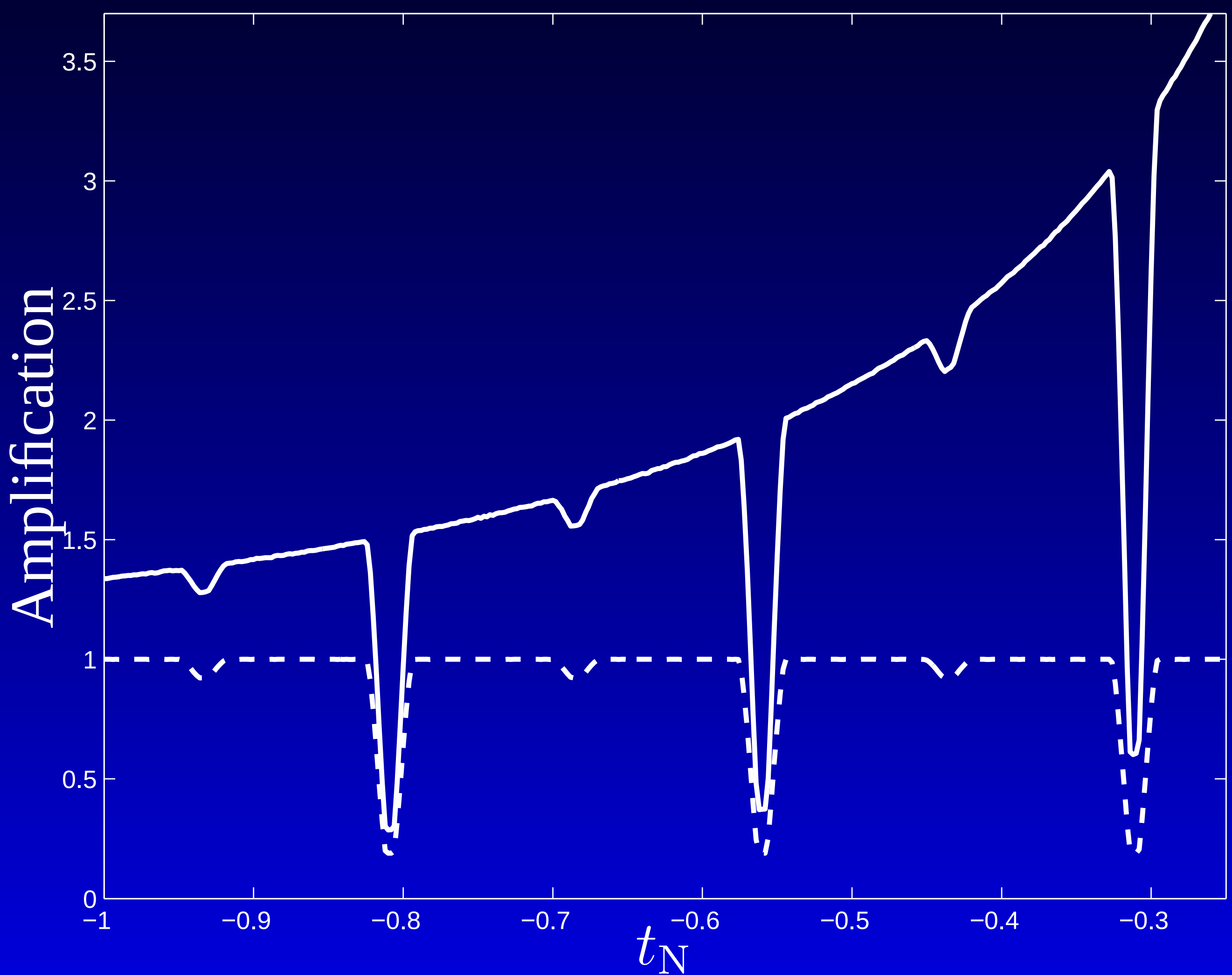
Close binary stars

Used the catalog of eclipsing binary stars of Surkova and Svechnikov (2004).

Name	Period (days)	Sp1+Sp2	$q_{\rm s}$ m_2/m_1	R_1 $(R_\odot)$	R_2 $(R_\odot)$	a $(R_\odot)$	J_1/J_2	i (deg)
TW And	4.12	FV+KIV	0.19	2.05	3.20	13.6	10.4	86.9
HH Car	3.23	8V+BIII	0.82	6.1	10.7	28.9	1.2	81.5
RZ Sct	15.19	B3Ib+F5IV	0.21	15	15.9	62.46	15.3	82.5
V356 Sgr	8.90	B3V+A2II	0.39	7.4	14	46.26	5.2	82.6

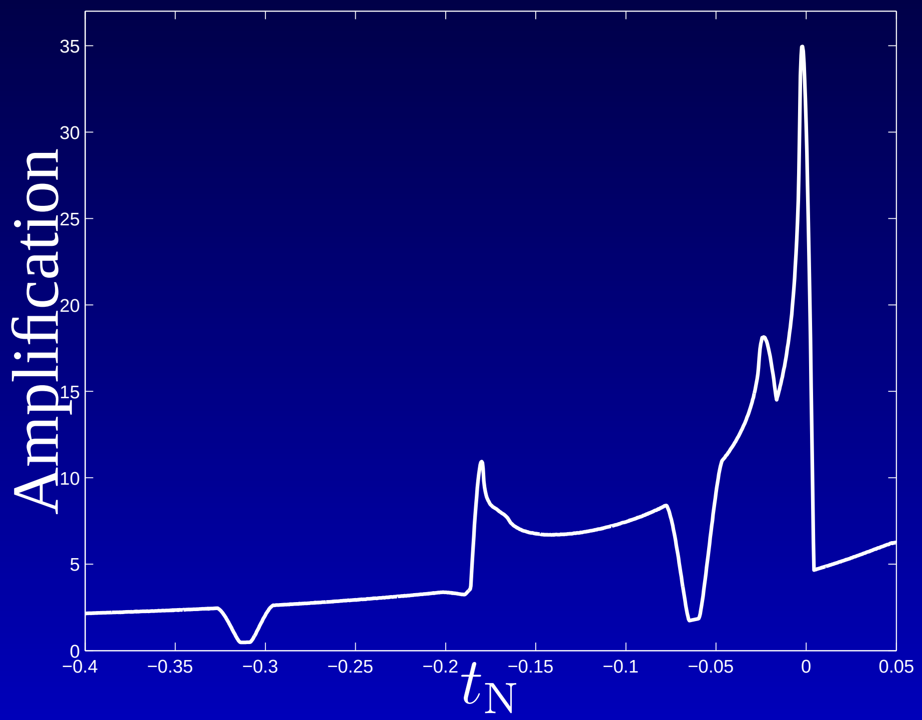
Inverse ray-shooting code (Rattenbury et al, 2002).

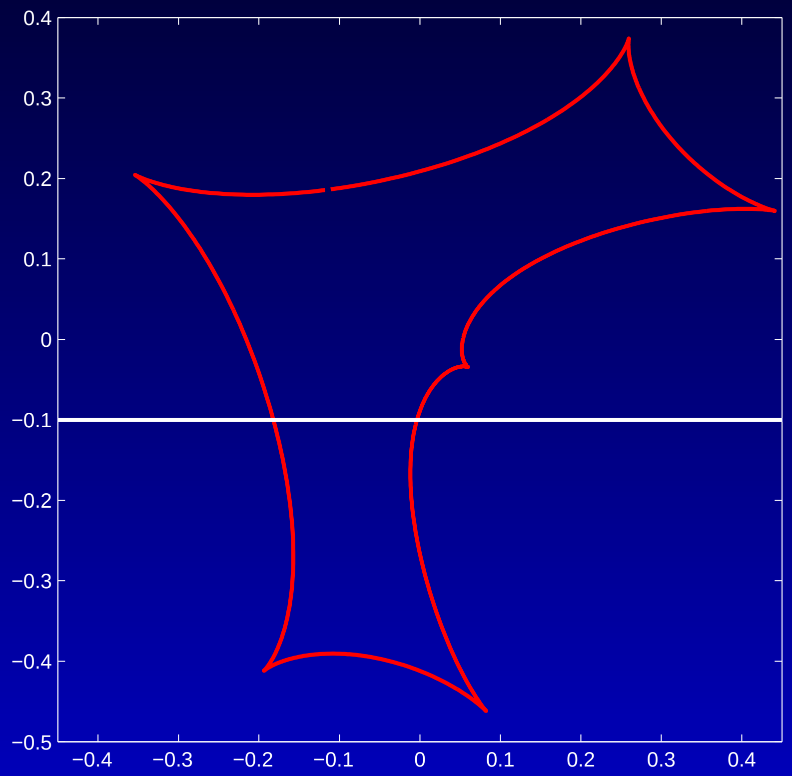
Eclipsing binary + single lens



Source:TW Andromedae. D_{l} = 6 kpc and D_{s} = 8 kpc, t_{E} = 35 days, M_{l} = 0.3$M_{\odot}$ and $u_{\min} = 0.1$.

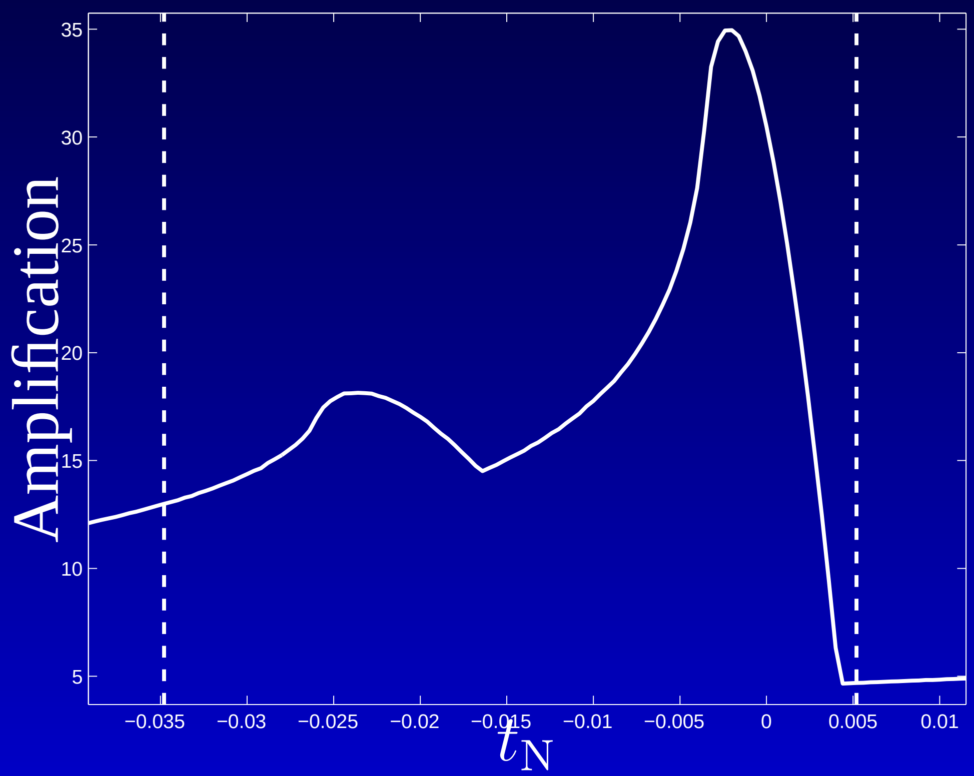
Eclip. binary + caustic crossing

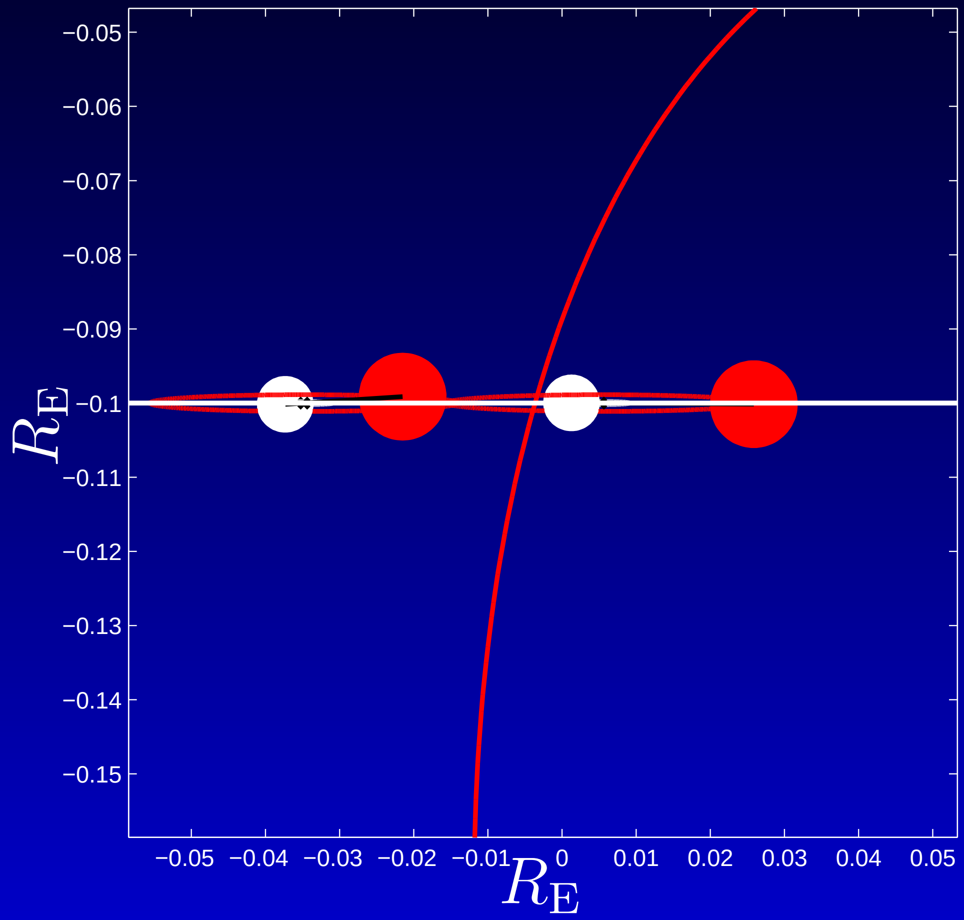




Source: TW And. Binary lens with mass ratio $q_\mathrm{l} = 0.11,\ u_\mathrm{min} = 0.1$, $d = 0.95$, $M_\mathrm{l} = 0.3M_\odot$, $D_\mathrm{l} = 6\,\mathrm{kpc}$, $D_\mathrm{s} = 8\,\mathrm{kpc}$.

Eclip. binary + caustic crossing





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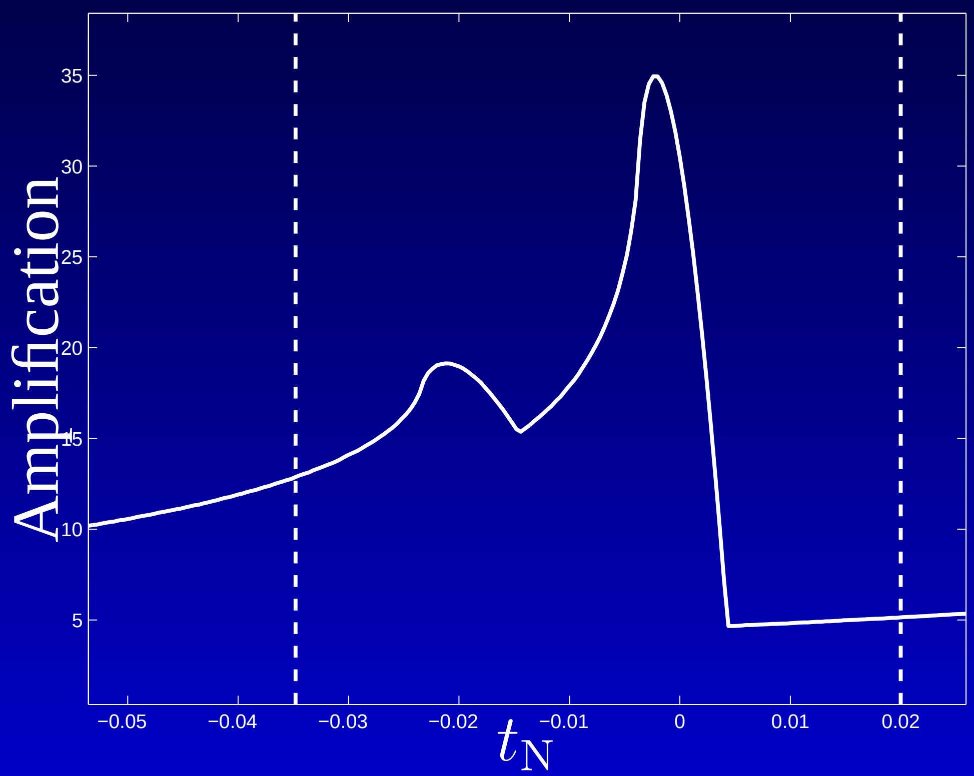

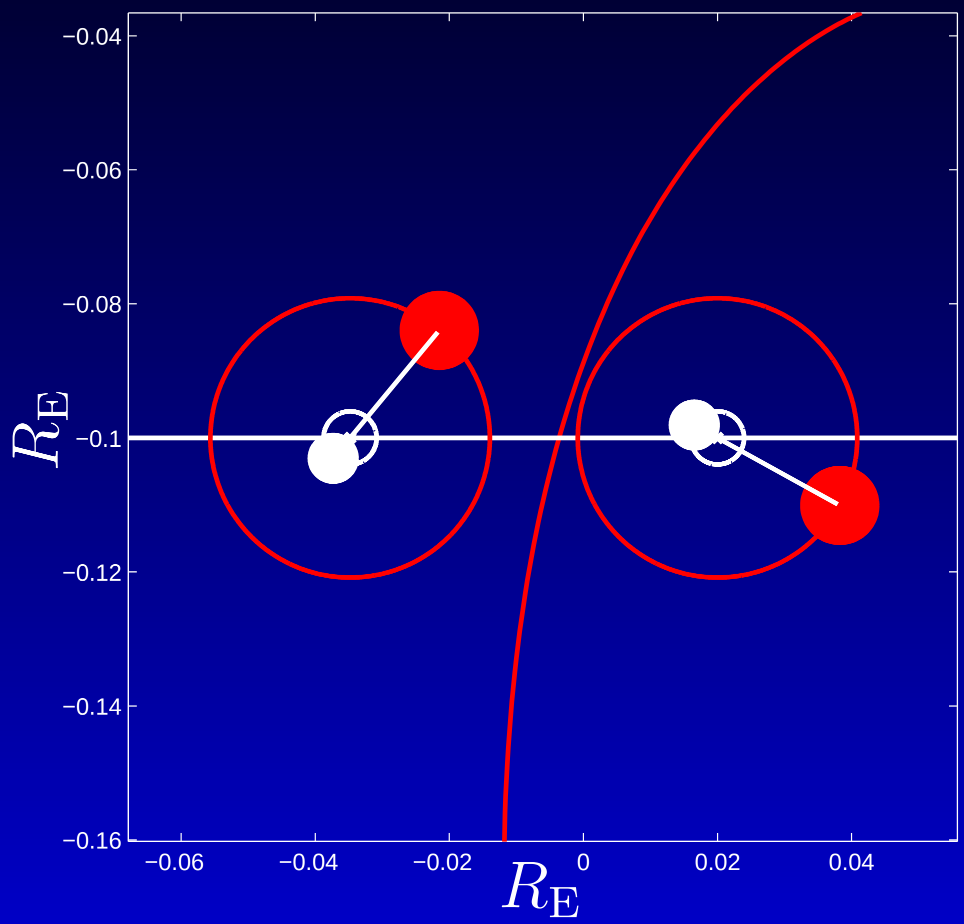

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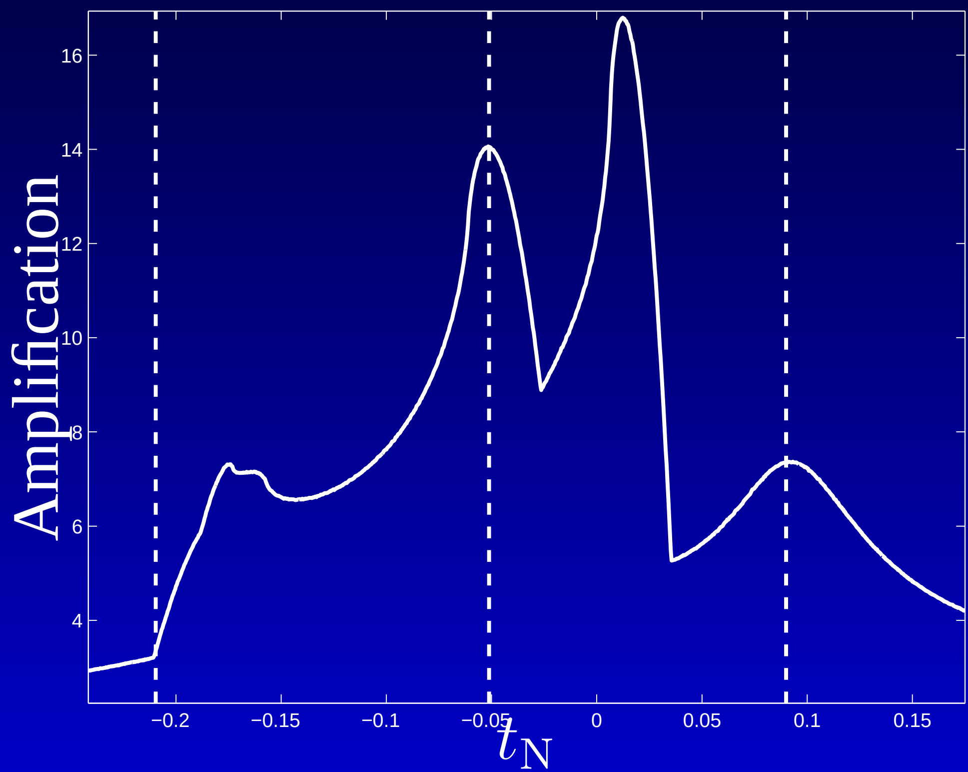
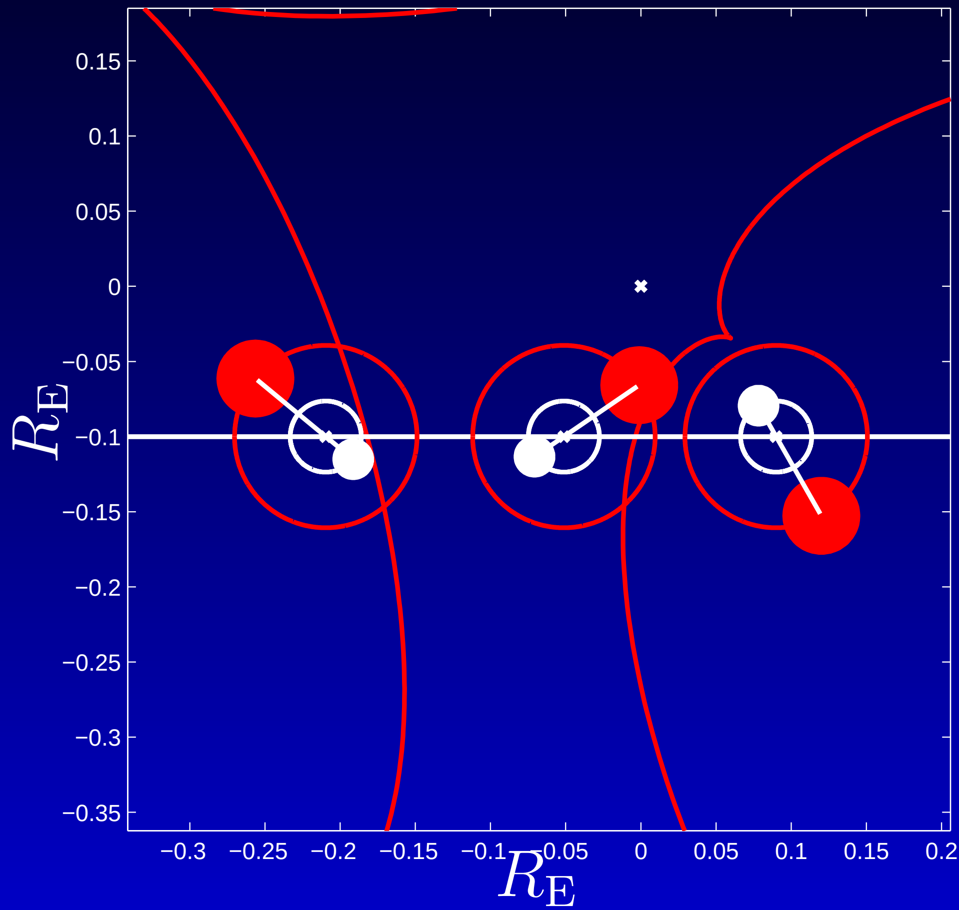
Eclip. binary + caustic crossing

- Other binary source and binary lens systems give similar results.
- Of particular interest is the “repeated caustic” feature ...
- ... and lightcurve plateaus.

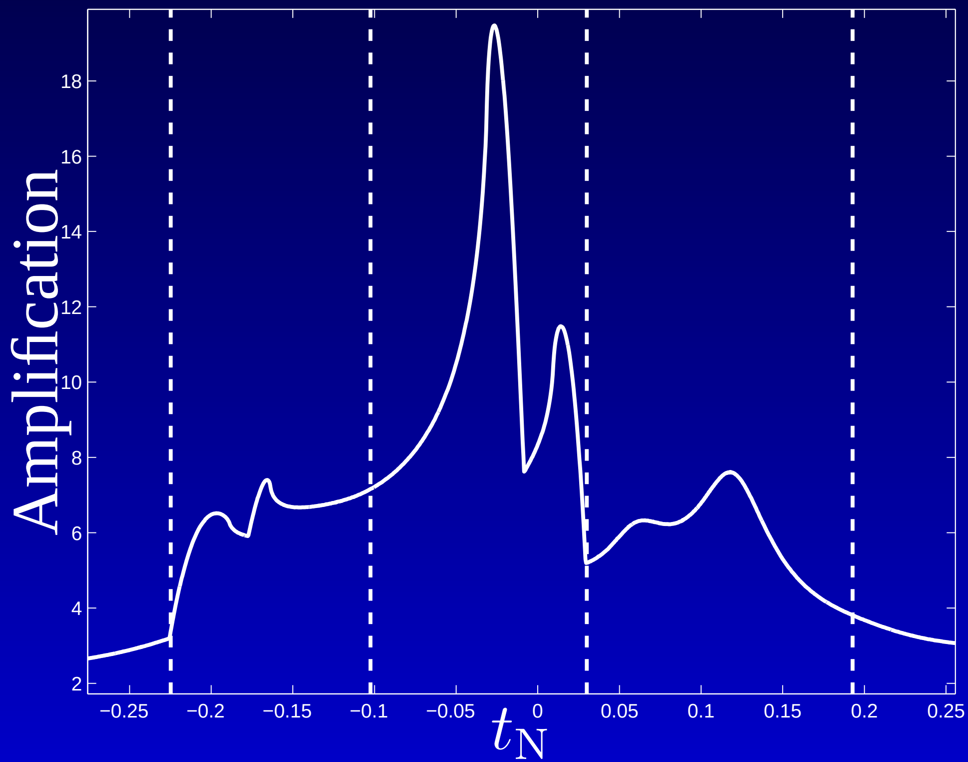
Eclip. binary + caustic crossing

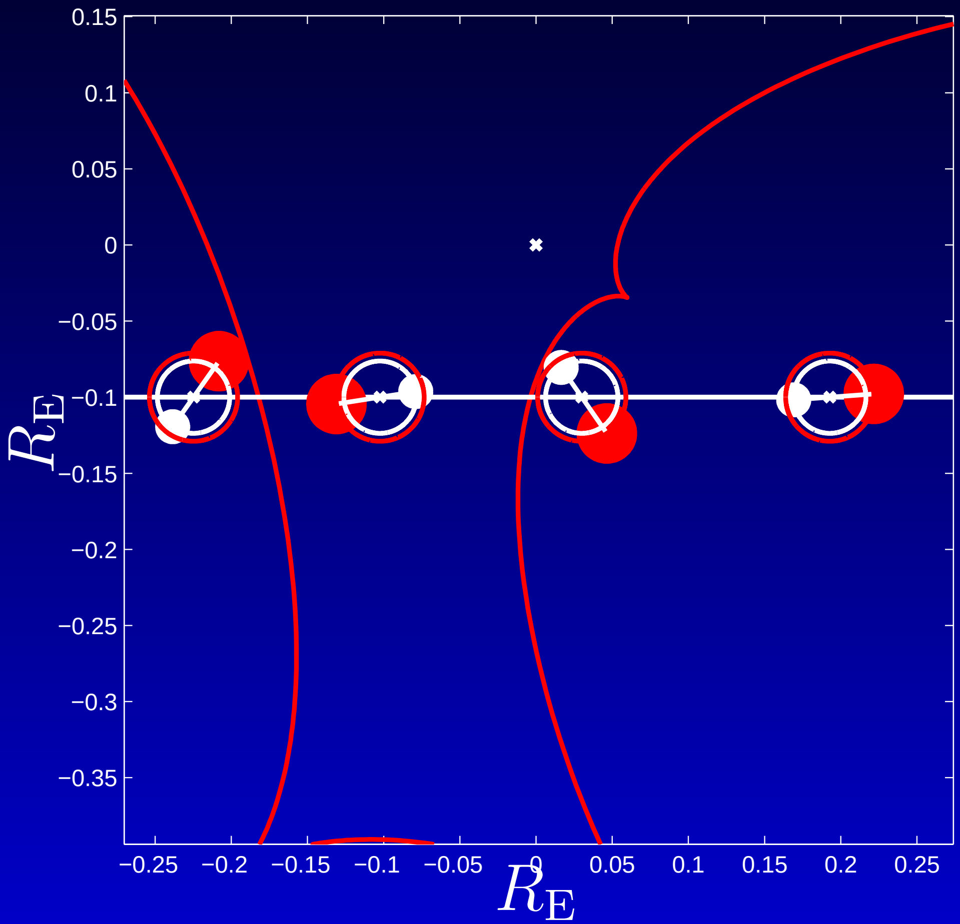




Source: V356 Sgr. Binary lens with mass ratio $q_{\mathrm{l}} = 0.11$, $u_{\mathrm{min}} = 0.1$, $d = 0.95$, $M_{\mathrm{l}} = 0.3 M_{\odot}$, $D_{\mathrm{l}} = 6\,\mathrm{kpc}$, $D_{\mathrm{s}} = 8\,\mathrm{kpc}$.

Eclip. binary + caustic crossing





Source: HH Car. Binary lens with mass ratio $q_{\mathrm{l}} = 0.11,\ u_{\mathrm{min}} = 0.1$, $d = 0.95$, $M_{\mathrm{l}} = 0.3M_{\odot}$, $D_{\mathrm{l}} = 6\,\mathrm{kpc}$, $D_{\mathrm{s}} = 8\,\mathrm{kpc}$.

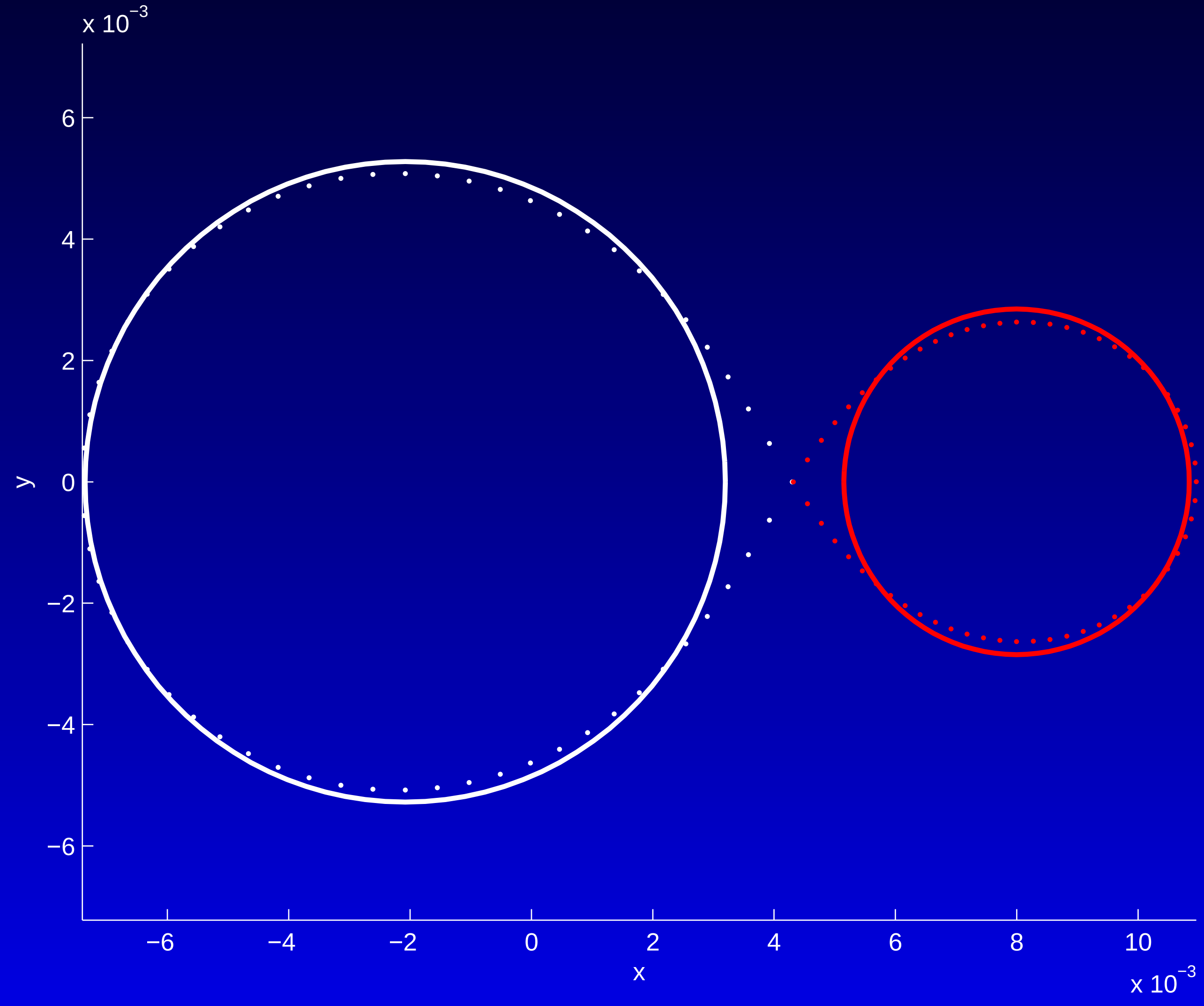
Roche lobes + caustic crossing

- Stars in close systems can become distended.
- Eclipsing close binaries routinely modelled with Roche lobe filling.
- Caustic crossing microlensing events offer high spatial resolution across the source star (size, limb-darkening, shape).
- Can we measure source star distention in typical close binary systems given a caustic crossing microlensing event?

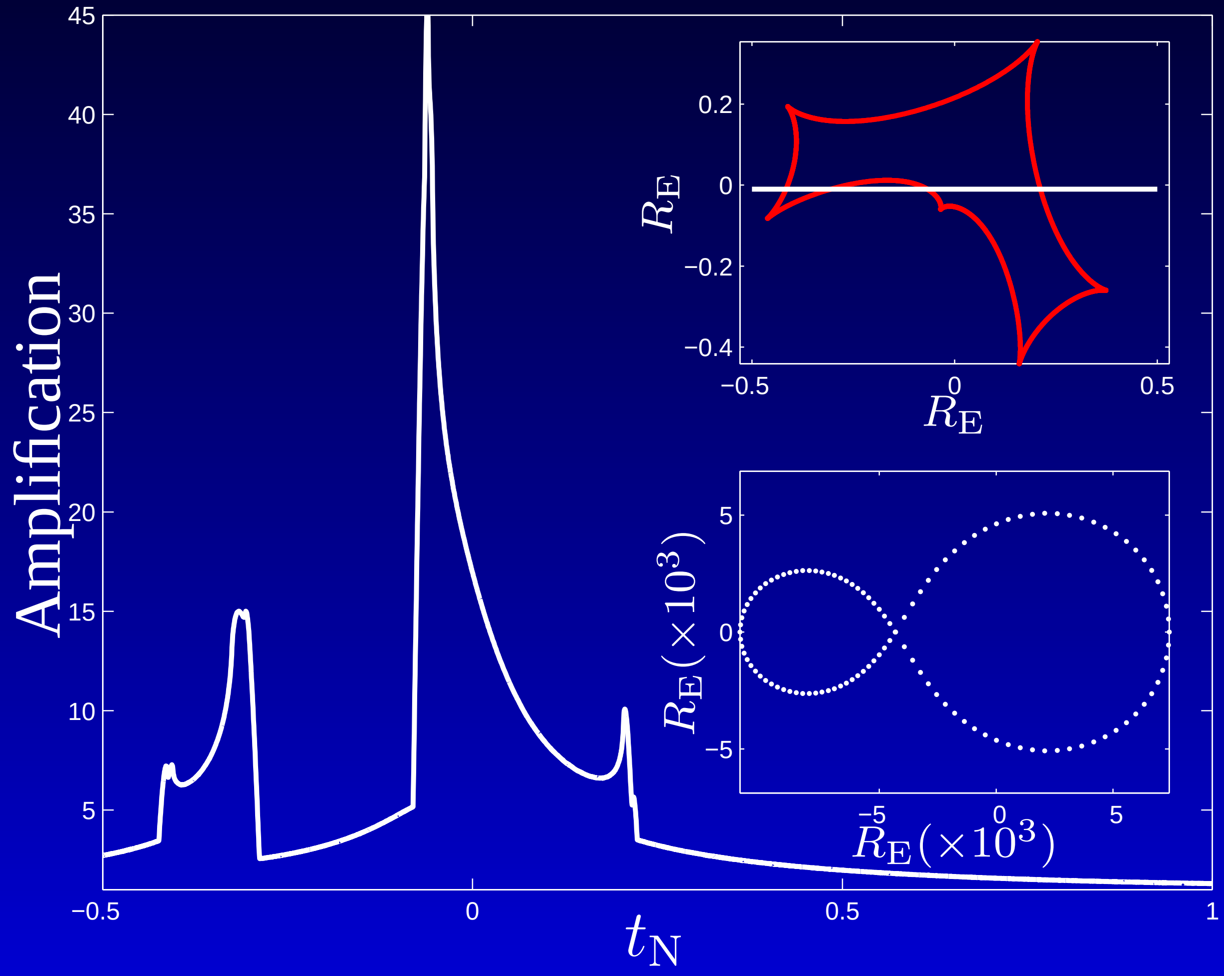
DM Del + caustic crossing

- Compute the 3D shape of the binary star DM Delphini using the Roche model (e.g. Hilditch 2001) and stellar and orbital parameters as given in Gudur, Sezer and Gulmen 1987.
- Assumed $J_1 = J_2$ for simplicity.
- Pass source through caustic crossing.
- Compare lightcurve to that given circular source stars (same area).

DM Del + caustic crossing

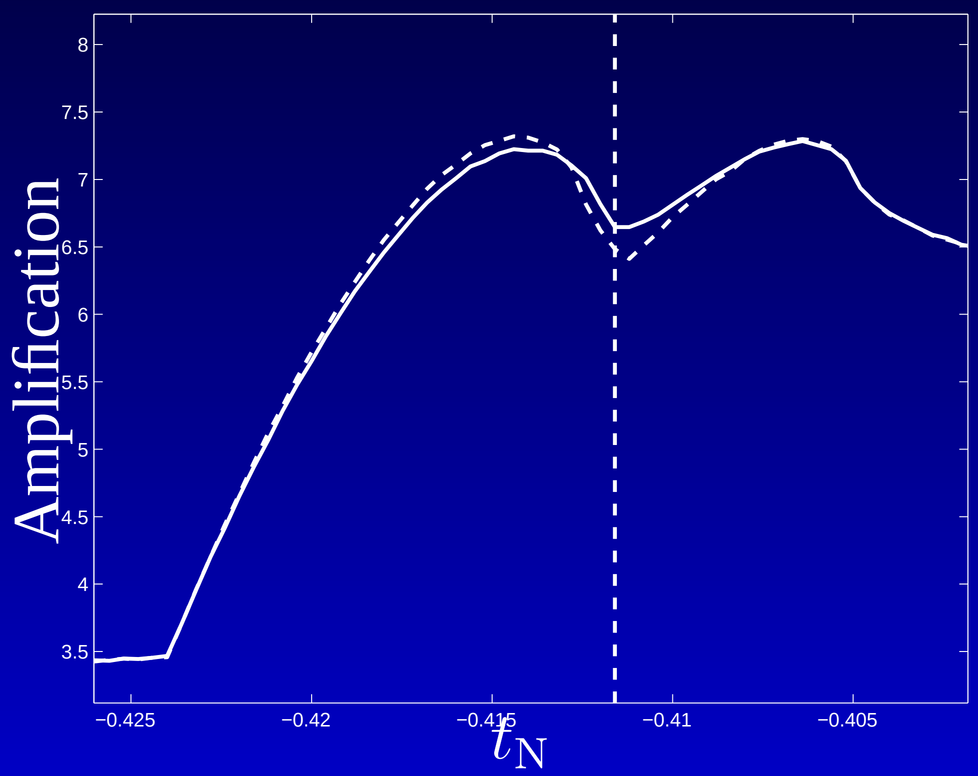


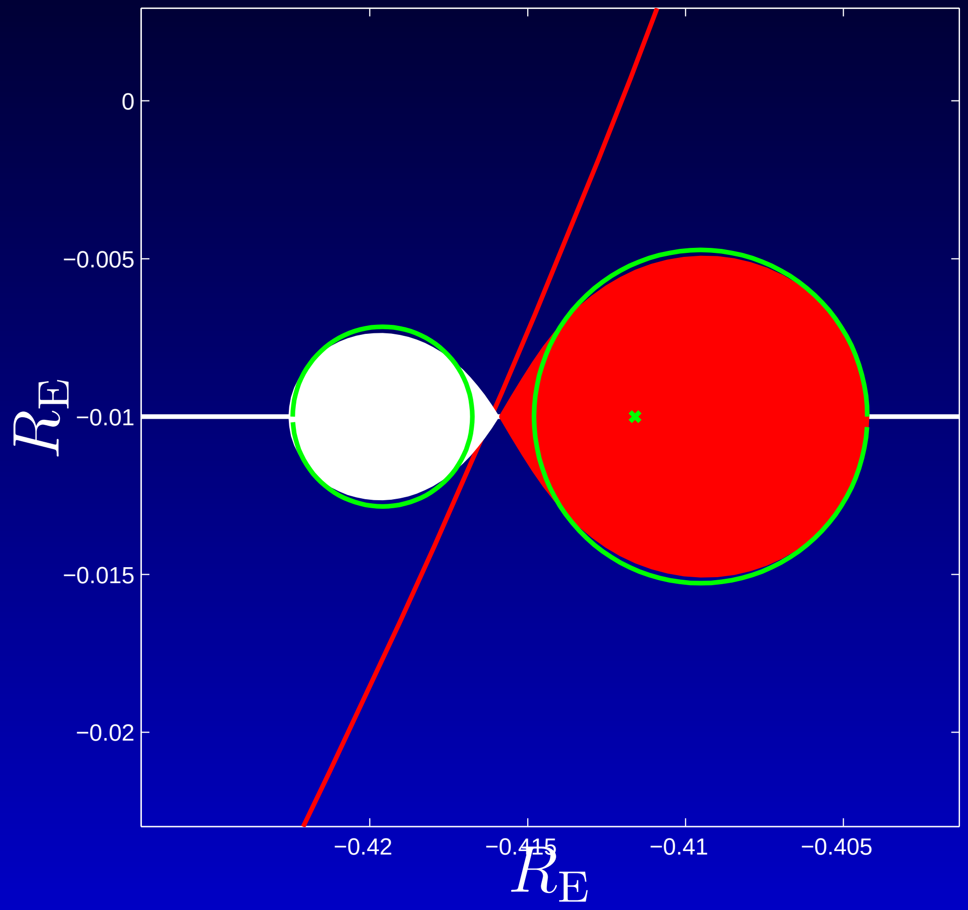
DM Del + caustic crossing



Light curve assuming a binary lens system with $u_{\min} = 0.01$, $q = 0.11$, $d = 0.95$, $\beta = 120°$. $i = 0$.

DM Del + caustic crossing





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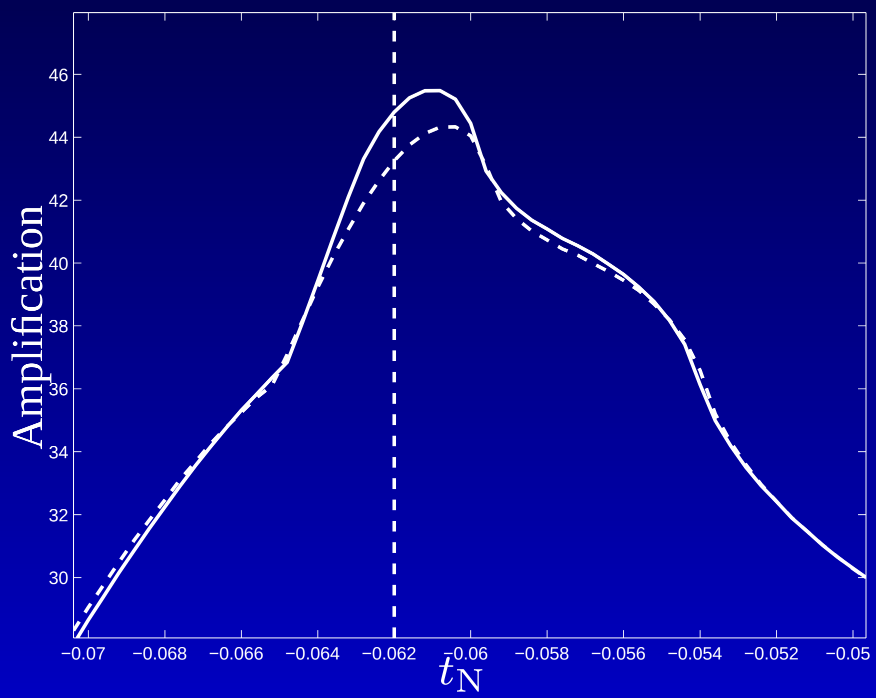

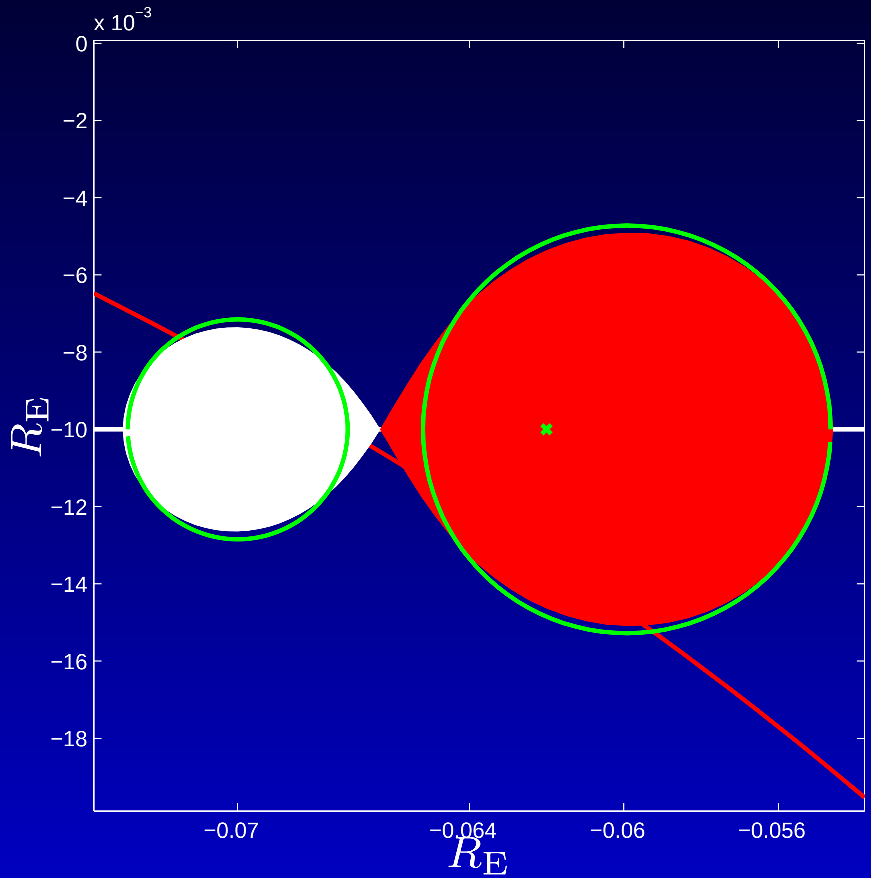

What are the chances?

$$N = N_{\mu\mathrm{l}} \cdot P_{\mathrm{cb}} \cdot P_{\mathrm{bl}} \cdot P_{\mathrm{cc}} \cdot P_{\mathrm{gv}}$$

- $N_{\mu\mathrm{l}}$: number of microlensing events per year
- P_{cb}: probability of a close binary star as source
- P_{bl}: probability of a binary lens
- P_{cc}: probability of a caustic crossing
- P_{gv}: probability of being able to see the effects of distended stellar atmospheres during the caustic crossing.

Given current surveys, and assuming adequate sampling, and assuming all close binaries have extended sources (!), the expected rate is only ~ 2 over 5 years. But: Earth Hunter?

Conclusions

- Extended source atmospheres can produce appreciable differences wrt spherical source star in caustic crossing events.
- Effect is most marked when the caustic line crossing is close to perpendicular to the line between source stars.
- Untested: Whether modelling extended source stars would be successful, given current data properties.
- “Repeated caustic crossings”: a clue to close binary systems.
- Another consideration for modellers?
- See Rattenbury, MNRAS, 392, 2009.