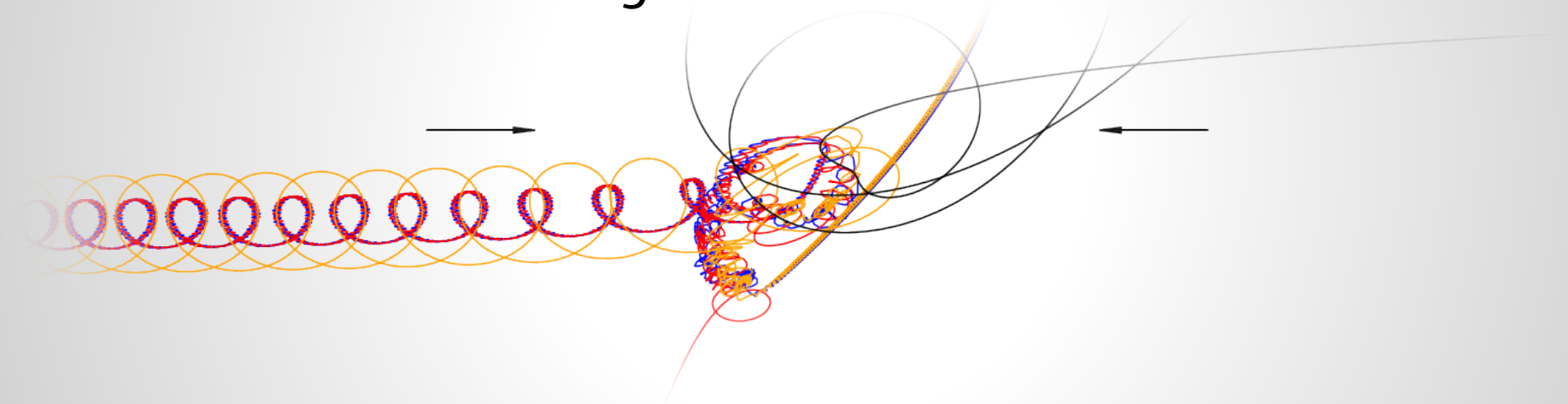


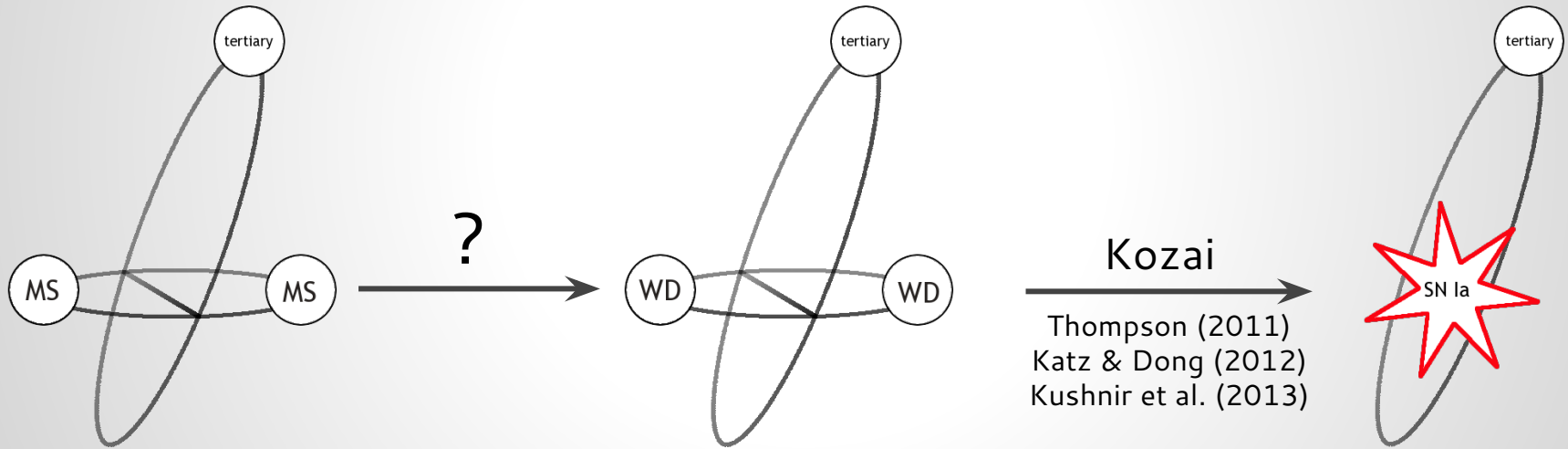
The Trouble with Triples:

Difficulties with the triple scenario and how they might be overcome

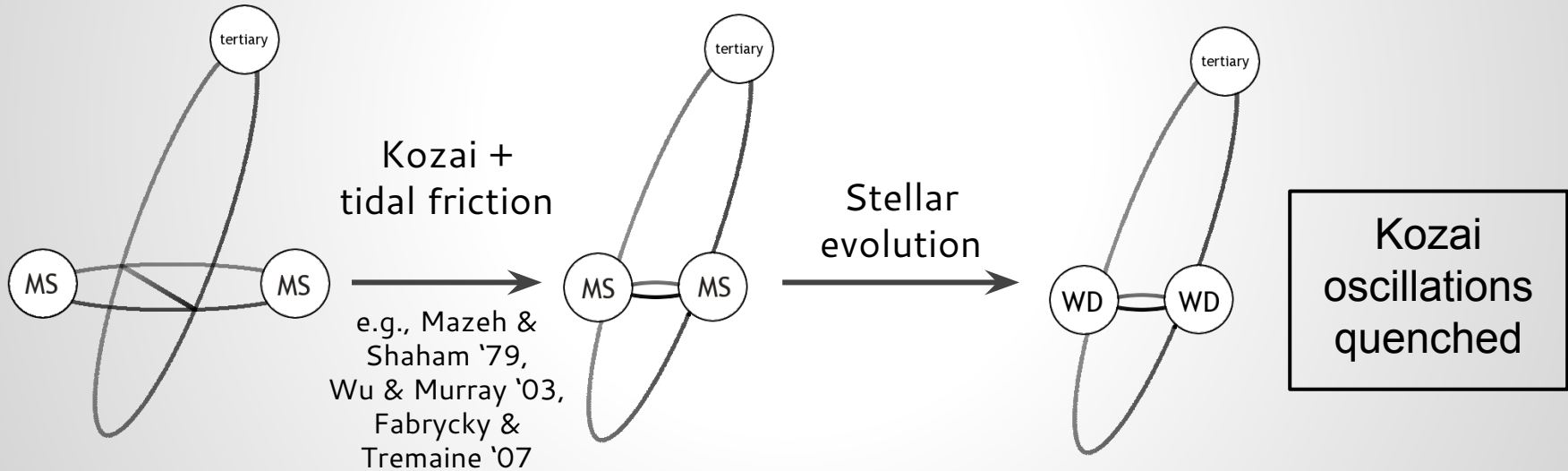


Joseph O'Brien Antognini
August 5, 2015

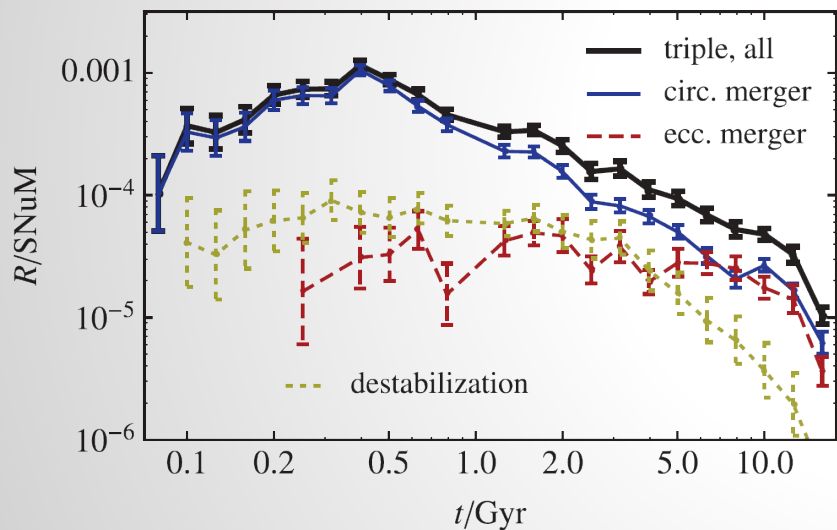
The trouble with triples...



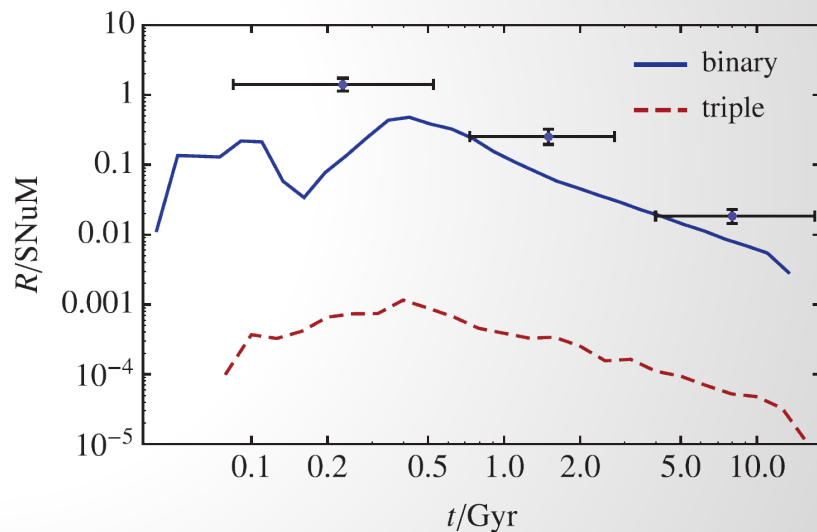
The trouble with triples...



Population synthesis of triples confirms our concerns...

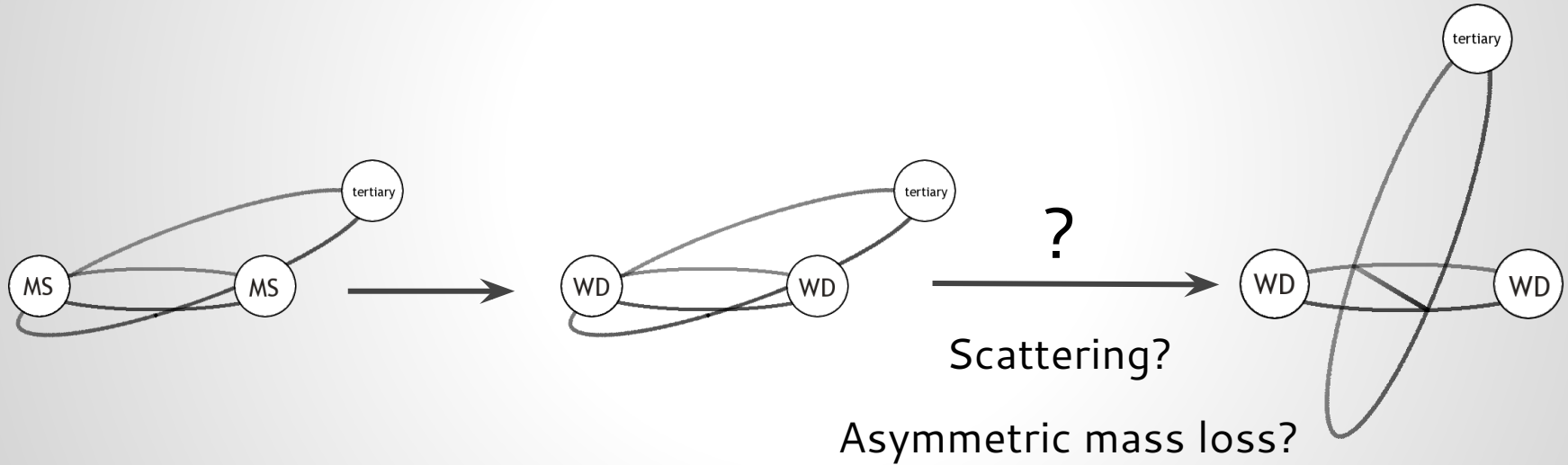


Hamers+ 2013



Hamers+ 2013

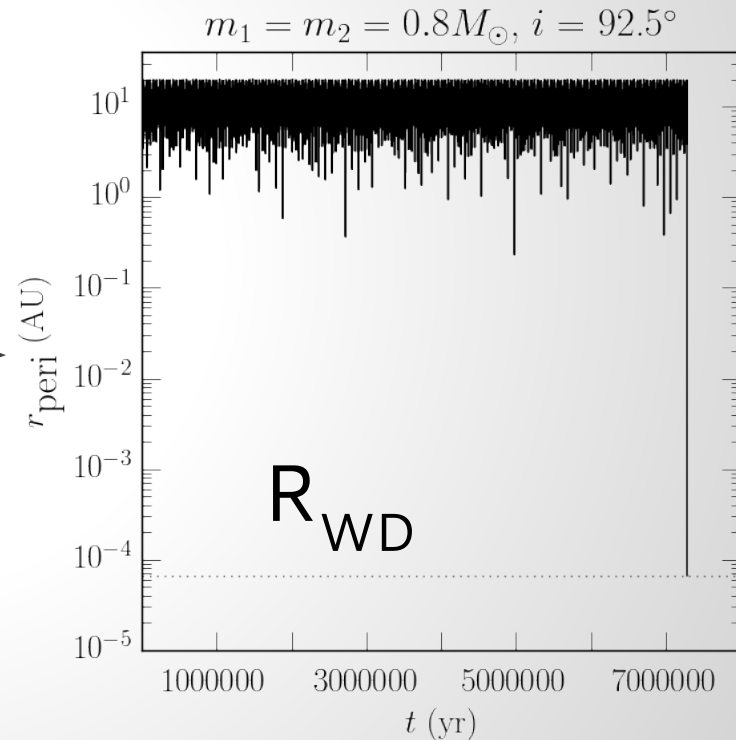
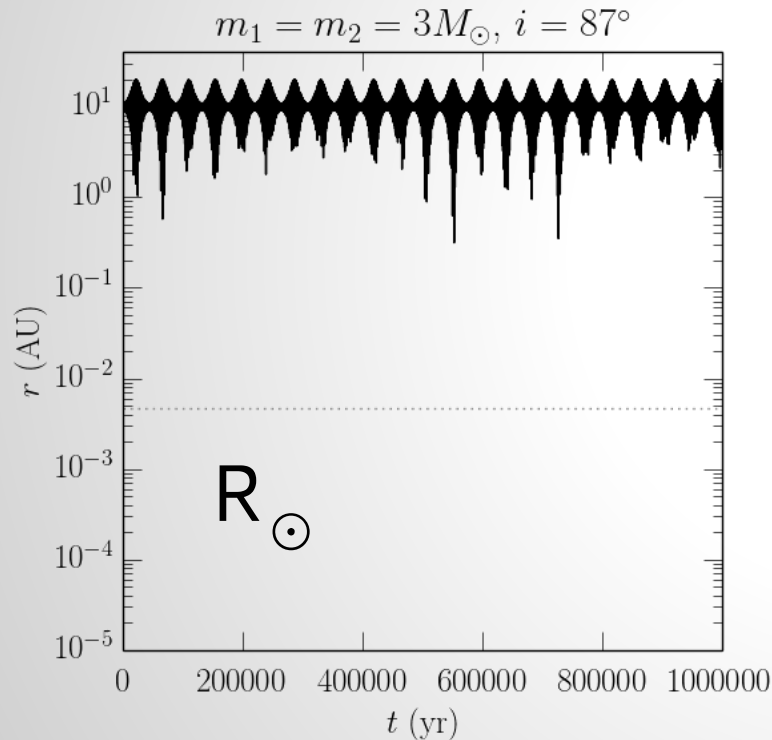
Avoiding the trouble with triples



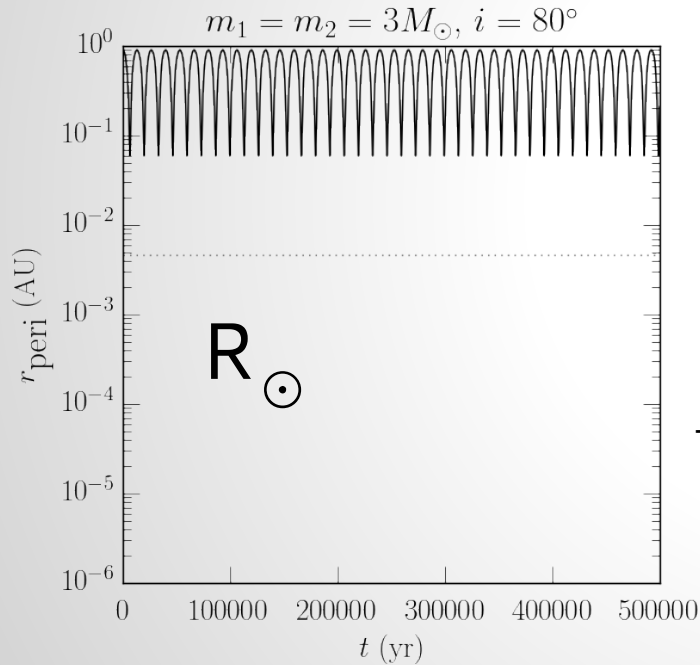
WD kick uncertainties

- How does an adiabatic force change the orbital inclination?
- Are the kicks actually adiabatic?
- Are the kicks in one direction, or is there a random walk?
- What, me worry?

How much do WD kicks have to change the inclination?



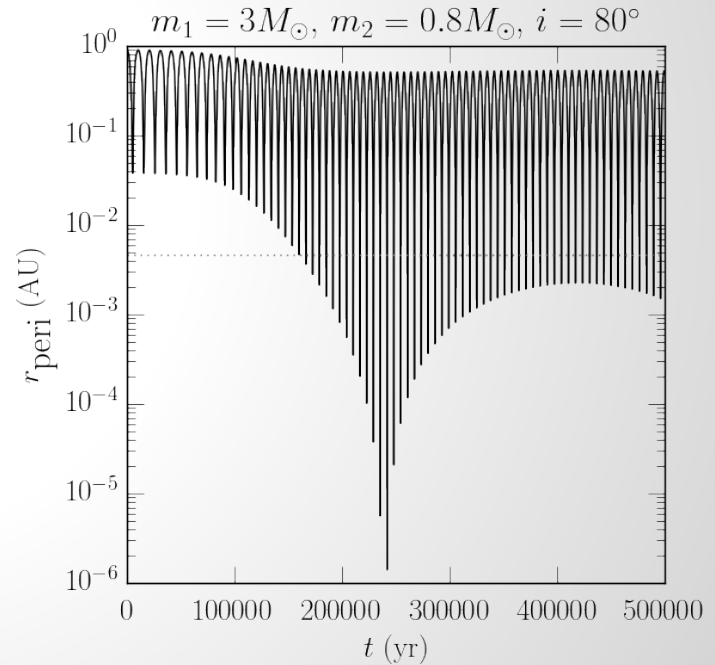
How much do WD kicks have to change the inclination?



MIEK

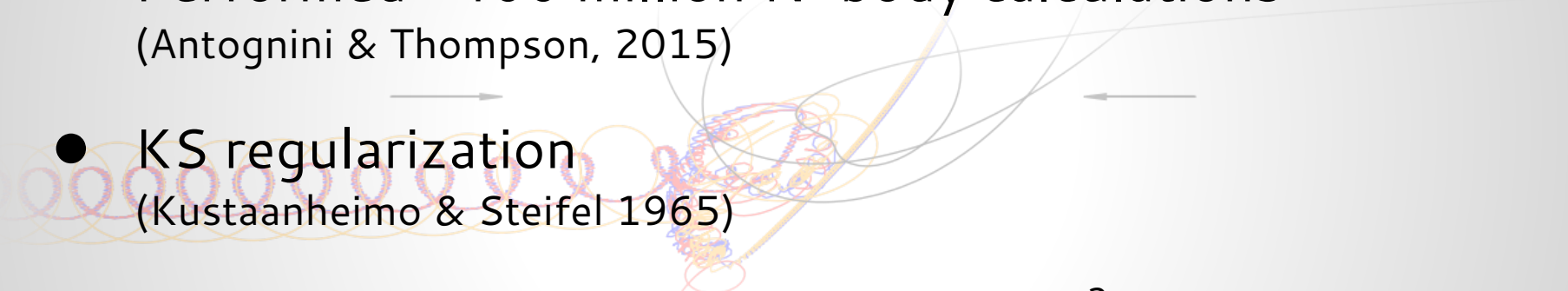
(Shappee & Thompson 2013)

Detailed description: A large black arrow points from the left plot to the right plot. Above the arrow is the text 'MIEK' and below it is '(Shappee & Thompson 2013)'.



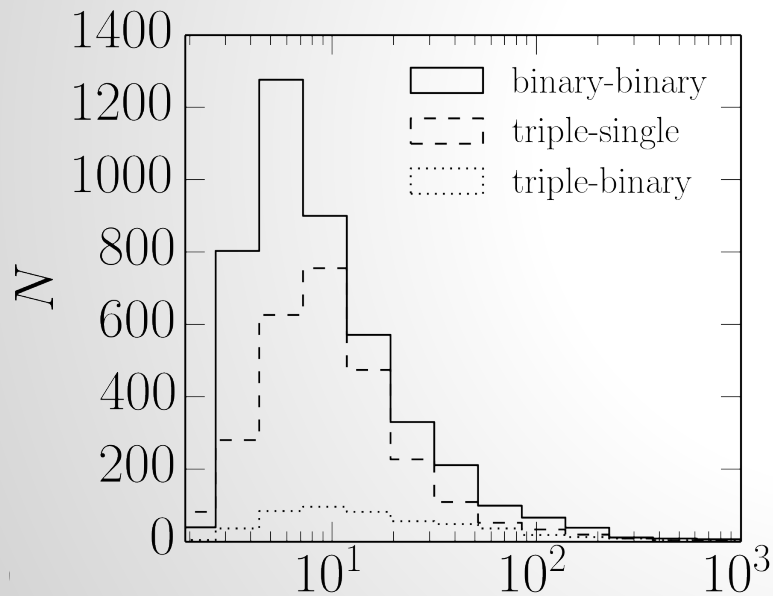
Scattering with Fewbody

(Fregeau et al. 2004)

- Performed ~400 million N-body calculations
(Antognini & Thompson, 2015)
 - KS regularization
(Kustaanheimo & Steifel 1965)
 - Energy conservation tolerance of 10^{-3}
(Portegies Zwart & Boekholt 2014; Boekholt & Portegies Zwart 2014)
 - Check for convergence in max impact parameter
- 

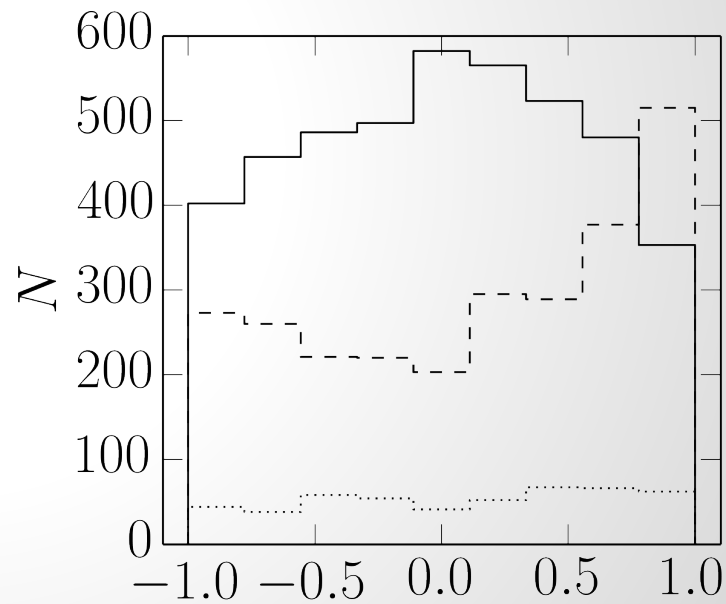
Dynamically formed triples are...

extremely compact



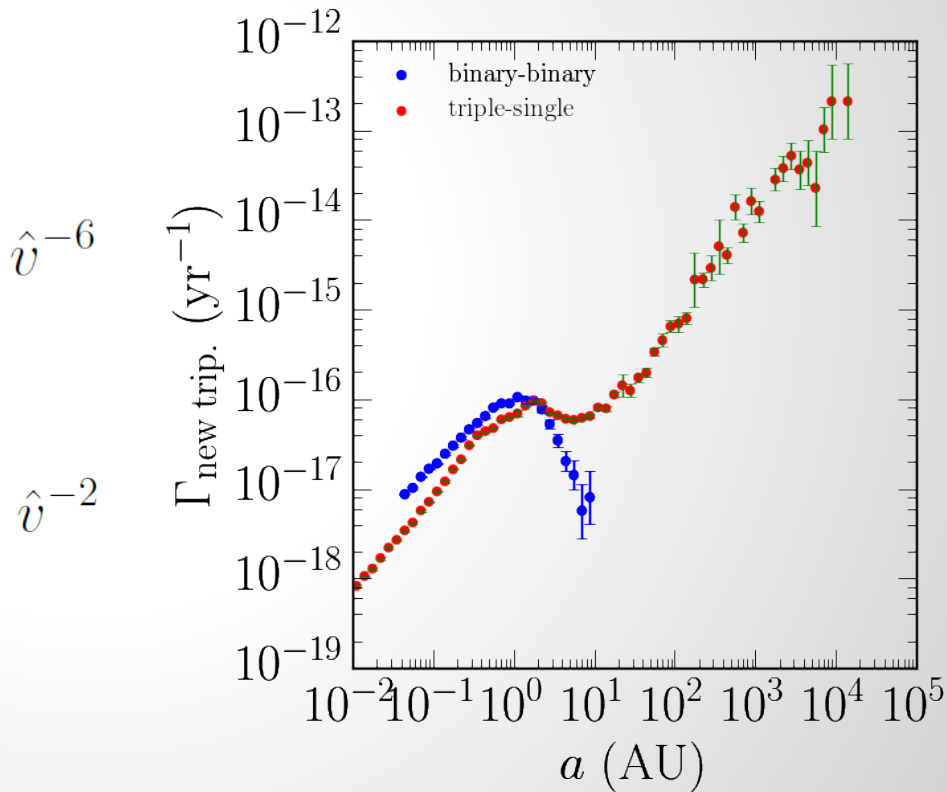
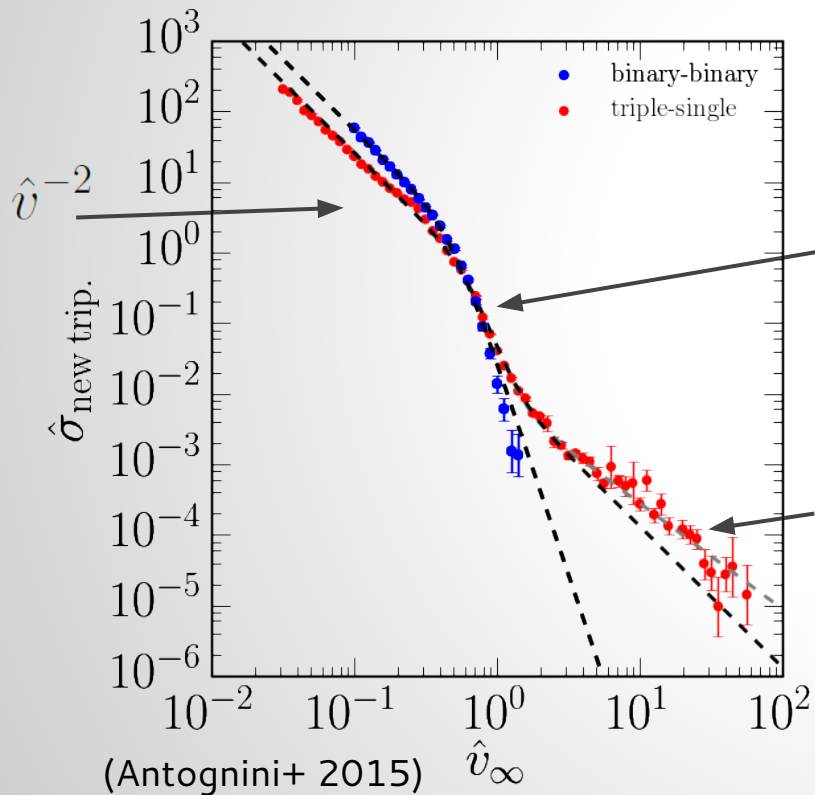
(Antognini+ 2015) $r_{\text{peri, out}}/a_{\text{in}}$

~uniform in inclination



$\cos i$ (Antognini+ 2015)

Scattering processes are strongly velocity dependent



Rate estimate

$$5 \times 10^{-3} \text{ yr}^{-1} \sim \Gamma_{\text{SN Ia}} \stackrel{?}{=} \Gamma_{\text{new triple}}$$

$$\Gamma = N n v \sigma$$

Diagram illustrating the components of the rate equation $\Gamma = N n v \sigma$:

- N : ???
- n : ?
- v : ?
- σ : pretty well known now

Assumptions about N in the field

- 10^{10} white dwarfs in the Galaxy
(Napiwotzki 2009)
 - 10% of WDs are in WD–WD binaries
(Holberg 2009)
 - 20% of WD–WD binaries have tertiaries
- ⇒ 2×10^8 WD–WD binaries with tertiaries

Rate estimate in the field

$$\Gamma \sim 5 \times 10^{-9} \text{ yr}^{-1} \left(\frac{N}{2 \times 10^8} \right) \left(\frac{n}{.25 \text{ pc}^{-3}} \right) \left(\frac{v}{40 \text{ km s}^{-1}} \right)^{-1} \left(\frac{a_{\text{max}}}{10^4 \text{ AU}} \right)$$

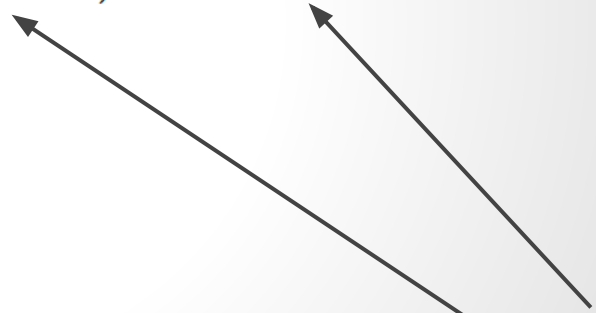
Hopeless.



Ellipticals??



Even more
hopeless.



Assumptions about N in open clusters

- 10^5 open clusters in the Galaxy
(Piskunov et al. 2006)
 - The typical system is in an open cluster with 300 members
(Porrás et al. 2003)
- ⇒ 3×10^6 triples in open clusters

Rate estimate for open clusters

$$\Gamma \sim 5 \times 10^{-4} \text{ yr}^{-1} \left(\frac{N}{3 \times 10^6} \right) \left(\frac{n}{10 \text{ pc}^{-3}} \right) \left(\frac{v}{.3 \text{ km s}^{-1}} \right) \left(\frac{a_{\text{crit}}}{10^4 \text{ AU}} \right)^2$$

Within a
factor of ~ 10

Too low?

Too high?

Summary

- Still unclear how to avoid coalescence on the main sequence
- Scattering does not work in the field. Open clusters are complicated.
- WD kicks need to change the inclination by $>15^\circ$

A survey for the community:

By show of hands, what fraction of SNe Ia happen in triples?

None of them

$\ll 10\%$

$\sim 10\%$

All of them