Binary stars ratio in *Gaia* DR2

Blending in gravitational microlensing survey efficiency estimation

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IJCLab

Action Dark Energy, October 2020

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Gravitational microlensing

Microlensing

Gravitational lensing but only the **magnification** is detected. This magnification is **time-dependent**.

Characteristic scales : Einstein angle θ_E (radius R_E); Einstein time $t_E = \theta_E/\mu$.



- Intermediate mass black holes as dark matter ($M \sim 100 M_{\odot}$, $\theta_E \sim 4 mas$, $t_E \sim 700 d$)
- Study deflector population by observing a lot of sources (in LMC) over a long period (years).
- \Rightarrow estimate the number of expected lenses effects, compare to observed.
- ⇒ depends on : deflector characteristics, survey parameters such as search algorithm efficiency, **number of monitored stars**, ... etc

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What is the number of monitored stars : Blending in LMC

A source in the microlensing experiment can be (is) composed of **several** stars.



Figure: Left : image from EROS. Right : image from HST of the same zone. The red circles are identified sources in EROS and have a diameter of 3 arcsec.

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A source in the microlensing experiment can be (is) composed of **several stars**.

Two competing effects on efficiency:

- Greater number of monitored stars.
- Light of amplified star blended with the others \Rightarrow lower relative amplification.

We need to understand what is hidden behind a catalogue source.

• What is hidden behind a source ? Comparison between catalogue and HST.



Figure: Spatial correlation function of HST toward LMC

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• In HST : minimum separation of \sim 0.5 arcsec \rightarrow 25000 AU in LMC.

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Figure: Spatial correlation function of HST toward LMC

- In HST : minimum separation of \sim 0.5 arcsec \rightarrow 25000 AU in LMC.
- Einstein radius projected in LMC $R_E \sim 200 AU$ (for a deflector of $100 M_{\odot}$).
 - 2 sources closer than *R_E* are lensed together

• What is hidden behind a source ? Comparison between catalogue and HST.



Figure: Spatial correlation function of HST toward LMC

- In HST : minimum separation of ~ 0.5 arcsec $\rightarrow 25000$ AU in LMC.
- Einstein radius projected in LMC $R_E \sim 200AU$ (for a deflector of $100M_{\odot}$).
 - 2 sources closer than R_E are lensed together
- R_E < separation < 25000 UA :

uniform or clustered ?

Use of Gaia DR2

 ${\bf Aim}$: quantify the unresolved physical binary population in HST, in the scope of the blending.

We use *Gaia* DR2 to study nearby stellar clustering, and we extrapolate the results to the LMC (50 kpc).

- \bullet between 100 and 600 pc, parallax relative error <20%
- absolute magnitude interval, in Gaia completeness domain
- 30° radius cones along galactic north and south



First remarks

Uniform random distribution : $dP = 2\pi nN \sin \alpha d\alpha \approx 2\pi nN \alpha d\alpha$



- n : stellar density
- N: total number of stars
- α : angular separation
- P : number of pairs

- Overabundance at small scales.
- pairs with separation < 10 arcsec : 99 % of stars appears only once \Rightarrow binary stars largely dominating.

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Minimal separation in Gaia DR2

- $\bullet\,$ Can't resolve stars closer than ~ 0.4 arcsec.
- Density fluctuations (instrumental effects) \Rightarrow discard pairs < 2 arcsec



Figure: Angular separation 2D distribution along ecliptic longitudinal and latitudinal axis, red circle has 2 arcsec radius.

Binary rate estimation

- Divide the sample in distance shells, and for each :
 - Count pairs by physical separation



Binary rate estimation

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 - Subtract random coincidences contribution



Binary rate estimation

- Divide the sample in distance shells, and for each :
 - Count pairs by physical separation
 - Subtract random coincidences contribution
 - Normalize to number of stars in shell



Binarity rate estimation



Binary rate (sep > 200 AU)

 $f_{BS}(200AU) = 1.1\% \pm 0.2$ (stat)

Systematics (WIP):

- Gaia parallax selection : ok
- magnitude range limited to GAIA completeness

Extrapolating toward LMC :

- $\bullet \ \text{neighbourhood} \to \mathsf{LMC}$
- \neq magnitude ranges



separation with maximal probability : $\mathsf{mode} = e^{\mu - \sigma^2}$

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We quantified the binary system rate in unresolved separation domains (HST in LMC).

- Was not studied in the past microlensing experiments.
- Small binary rate in our separation domain : $\lesssim 2\%$ (preliminary) (assuming validity of extrapolation from nearby to LMC)
- \Rightarrow Limited impact on heavy lenses microlensing survey efficiency (\rightarrow on constraints on black holes fraction in dark matter)

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Thanks for your attention.

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Backup

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Binary stars ratio in Gaia DR2

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Parallax relative errors



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Figure: From Raghavan et al. 2010

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