Research Networking Programmes

Short Visit Grant ☒ or Exchange Visit Grant □

(please tick the relevant box)

Scientific Report

Proposal Title: A search for candidate astrometric microlensing events observable by Gaia.

Application Reference N°: 6867

Purpose of the visit

The purpose of my visit to the Osservatorio Astrofisica di Torino was to work with Dr Richard Smart and the Astrometry group in attempting to predict future astrometric microlensing events which could be observable by Gaia. My intention was to use a list of high proper motion objects identified in the UKIDSS Galactic Plane Survey (GPS, [1]) and other catalogues as candidate lens objects, and the Initial Gaia Source List (IGSL, [2]) as a catalogue of background sources. The ability to empirically measure accurate masses of singular objects is a rare. Mass estimates of singular field objects currently rely on models which have been shown to be problematic [3]. However, masses of singular objects are measurable if they pass in front of a background source, causing a small shift in its apparent position. Typically centroid shifts are smaller than a few mas, until Gaia the astrometric precision required for such a detection was impossible to achieve [4].

Description of the work carried out during the visit

Belokurov and Evans [4] showed that the bulk of the astrometric microlensing events which will be observed by Gaia will occur in the Galactic bulge and plane due to the higher relative source density. This was therefore the most attractive target for my own search. At the time of application for this grant our search for high proper motion objects in the GPS at $l > 60°$ was our most promising data set in terms of event probability. In the interval between application and the start of the visit I produced a proper motion catalogue of the Vista Variables in the Via Lactea (VVV) survey. This catalogue covers a smaller area, 560 deg^2 compared to 900 deg^2 for the GPS at $l > 60°$, despite this it contains approximately 30% more sources since it covers

the Galactic bulge and southern Galactic plane. Furthermore, since the VVV survey observes each source between 50 and 150 times in the Ks band, compared to twice for the GPS in the K band, the astrometric precision is higher and the false detection rate much lower.
To take advantage of the new VVV proper motions, the astrometric microlensing search was split into two parts: The first, a search completely internal to the VVV, using high proper motion sources as the lens candidates and low proper motion sources from the same array as the background source candidates. The second, the originally proposed search with the GPS and other proper motion catalogues providing the lens candidates and the IGSL providing the background source candidates.
The differences in the methods applied to the two searches essentially comes down to the selection of initial nearby background sources. For the VVV these are simply any source within the same array as the lens candidate within 15 years of lens motion. For the GPS and literature search they are any IGSL source within 1 arcminute of the lens candidate, matched using the CDS XMatch service[1]. The literature lens candidates are high proper motion objects drawn from the GPS, the UKIDSS Large Area Survey (LAS, [5]), the revised NLTT [6], the LSPM North catalogue [7], and a list of ultracool dwarfs compiled by J. Gagné[2] retrieved on 23/9/2014. We also included the VVV lens candidates in the list compiled from the literature in order to potentially identify lensing of background objects that are heavily saturated in the VVV data. On production of the list of lens-background source pairs, we calculated the time to the expected minimum separation (relative to the epoch of the lens and background source positions) and the minimum expected separation. We rejected any candidates with epoch of minimum separations outside of the Gaia observation window of 2015 to 2022. We also rejected any candidates from the literature search with minimum expected separations greater than 1 arcsecond. For the VVV we tightened this requirement to 0.5 arcseconds, since the astrometry is more precise.
From here we estimated the expected deflection in the position of each background source. This is a particularly uncertain measurement since it is in turn dependent on three particularly uncertain variables, the minimum expected separation, the lens mass, and the lens distance.

Description of the main results obtained

We have identified eighteen high proper motion objects in the VVV field which will pass within 0.5 arcseconds of a background source. Some are low mass stars and some are white dwarfs. Estimates of the expected background source positional deflection suggest one or two may be large enough to be detectable by Gaia, although there are large uncertainties in these values. Although none appear to be brown dwarfs, the current VVV proper motion code suffers from high incompleteness for the highest proper motion sources, and is therefore likely to have missed some of the nearest and candidates. Once the proper motion code is optimised for very high proper motion source detection I intend to re-run the astrometric microlensing code and it is possible this will generate more candidates. One important point that needs to be considered is the issue of extinction. This should not be of too much concern for the lenses, however the background sources may suffer from extinction in the Gaia G band compared to the VVV Ks band. This may mean that their astrometric accuracy is degraded to the point that any deflection in position cannot be measured to a useful certainty.

[1] http://cdsxmatch.u-strasbg.fr/xmatch
[2] http://jgagneastro.wordpress.com/list-of-ultracool-dwarfs/

For the literature search we found 26 unique candidates (ie. not duplicated between the LSPM and rNLTT) with estimated deflections up to a few mas during Gaia operations. Among these candidates there is considerable variation in the contrast between the lens and background source, which provide some interesting test cases. Again, there are considerable uncertainties in the estimated deflections. For the VVV search consideration for systematic uncertainties was not warranted, since any should effect both the lens and background source equally. In the case of the literature search, where astrometry for the background source and lens come from different sources, the systematic uncertainties will come into play. More work is warranted to understand the extent and attempt to correct these issues.

Future collaboration with host institution (if applicable)

The extent of future collaboration with the host institute will depend on whether the predicted events are observed by Gaia.

Projected publications / articles resulting or to result from the grant *(ESF must be acknowledged in publications resulting from the grantee's work in relation with the grant)*

I am currently producing sections of a Gaia Data Processing and Analysis Consortium document (DPAC, Gaia-C3-TN-OATO-RLS-008) which is a request for cutout observations of the sources involved in the predicted events. This work may form the basis of a publication at a later date, or be included in a paper detailing the VVV proper motion catalogue. I also intend for this work to form a chapter of my thesis. If any of the lensing predictions are indeed measured by Gaia then they will most certainly be published, though this will not be for some time.

References

[1] Smith et al. 2014 MNRAS 443, High proper motion objects from the UKIDSS Galactic plane survey
[2] Smart 2013 CDS I/324, The Initial Gaia Source List (IGSL)
[3] Dupuy, Liu & Ireland 2014 ApJ 790, New Evidence for a Substellar Luminosity Problem: Dynamical Mass for the Brown Dwarf Binary Gl 417BC
[4] Belokurov & Evans 2002 MNRAS 331, Astrometric Microlensing with the GAIA satellite
[5] Smith et al. 2014 MNRAS 437, A 1500 deg^2 near infrared proper motion catalogue from the UKIDSS Large Area Survey
[6] Salim & Gould 2003 ApJ 582, Improved Astrometry and Photometry for the Luyten Catalog. II. Faint Stars and the Revised Catalog
[7] Lepine & Shara 2005 AJ 129, A Catalog of Northern Stars with Annual Proper Motions Larger than 0.15" (LSPM-NORTH Catalog)