Research Networking Programmes

Exchange Visit Grant ■

(please tick the relevant box)

Scientific Report

The scientific report (WORD or PDF file – maximum of eight A4 pages) should be submitted online within one month of the event. It will be published on the ESF website.

Proposal Title: Exploiting Kinematics from the Gaia-ESO Survey

Application Reference N°: 4994

1) Purpose of the visit

The purpose of the visit was for Dr Richard Parker, a Royal Astronomical Society (RAS) fellow at Liverpool John Moores University (LJMU), UK to visit Prof. Michael Meyer and his group at ETH Zurich, Switzerland. Dr Parker was formerly a post-doc in Prof. Meyer's group, and whilst still in Zurich he had initiated a long-term project to study the spatial distribution of star-forming regions, and to couple this with information on the radial (line of sight) velocity distributions. In order to do this, he has developed an extensive suite of N-body simulations which follow the dynamical evolution of star forming regions over Myr timescales. These simulations can then be used to place constraints on the initial conditions of observed star forming regions by analysing both in a self-consistent way. Presently, the information available to observers from a star forming region consists of the two-dimensional position for each star, the stellar mass, and in some cases the radial velocity of stars. Usually, however, only information on the spatial distribution and the mass are comprehensive enough to perform a detailed analysis.

In a pioneering paper, Parker et al (2014, MNRAS, 438, 620) showed that it is possible to distinguish differences in the initial conditions of star-forming regions based on their present-day spatial distribution, and the arrangement of the most massive stars with respect to the average stellar positions in the region. This method has enabled observers to distinguish between 'bound' and 'unbound' initial conditions for star formation – which ultimately tells us how likely a star-forming region is to dissolve into the disc of our Galaxy, or whether the region will remain a bound star cluster. It also

enables us to place constraints on the initial density of a star-forming region (Wright et al, 2014, MNRAS, 438, 639; Parker 2014, MNRAS, 445, 4037).

However, the above results were derived using N-body simulations in which the mass and position of every star (and indeed the probability of membership in the region) was known to 100% accuracy. This is an idealised situation and observed star-forming regions are not characterised to the same degree of certainty. For this reason, Dr Parker and collaborators are exploring techniques and methods to improve our constraints on the initial conditions of star-forming regions. The next stage in this process is to incorporate information on the velocities of stars in their analysis of regions.

It is envisaged that the extra information on radial velocities provided by the Gaia-ESO survey will in turn complement proper-motion (movement across the sky) measurements provided by Gaia. However, framing the questions we need to ask of the simulations of star-forming regions so that we can best exploit the Gaia data is a challenging task. For this reason, we proposed an exchange visit for Dr Parker to visit Zurich to discuss the latest observational data with both Prof. Meyer and his post-doc, Dr Elisabetta Rigliaco, who is also involved in the Gaia-ESO survey. Dr Parker also scheduled a visit to the group at Arcetri observatory, Italy, where Drs Germano Sacco, Sofia Randich and Francesco Palla are all heavily involved in the Gaia-ESO survey. The purpose of this visit was to facilitate knowledge transfer between LJMU, ETH Zurich and Arcetri and to update the groups in Arcetri and ETH on the simulation effort.

The goal of the visit was to foster further collaboration between Dr Parker and Prof. Meyer. In particular, they wanted to compare the velocity dispersion data from N-body simulations to the observational results for particular star-forming regions from the Gaia-ESO survey. Finally, they wanted to discuss the potential to exploit the full kinematical data from Gaia (radial velocity plus proper motion) using the simulations as a test-bed.

2) Description of the work carried out during the visit

Dr Parker presented the latest results from his simulation work to the star and planet formation group at ETH, as well as partaking in discussions with Prof. Meyer and Dr Rigliaco on how to compare the simulation data to the observational data on ρ Oph from the Gaia-ESO survey.

Dr Parker & Prof. Meyer discussed the early dynamical evolution of star-forming regions, in the context of the most recent observational and theoretical work. Based on these discussions, Dr Parker began writing up a paper on the kinematical information available in the N-body simulations. This first paper (Parker & Wright, in prep.) uses the 1D radial velcoity dispersions and compares the same range of initial conditions in Parker et al 2014. The extra information provided by the velocity dispersions places further constraints on the initial conditions of star-forming regions.

During Dr. Parker's visit to Arcetri, he and Drs Sacco and Randich discussed the latest observational data on Chamaeleon I, which is a spatially substructured star-forming region and is thus ideally suited for the analysis techniques pioneered by Dr Parker and collaborators. Furthermore, they discussed the possibility of determining the initial conditions of old Open Clusters, using Gaia.

Between proposing the exchange visit and Dr Parker's three weeks in Zurich, he has been working in collaboration with Dr James Dale (USM, Munich, Germany) on analysing the output of hydrodynamical simulations of star formation to link the early phases of star formation with the later dynamical evolution, which is modelled using N-body techniques. This research is vital if we are to refine the initial conditions of the N-body simulations and make meaningful comparisons with observations. During the exchange visit, Dr Parker wrote up a paper which analyses the spatial distribution of gas, and stars, in the hydrodynamical simulations in a self-consistent manner. This paper has been submitted to the MNRAS journal.

3) Description of the main results obtained

Dr Parker and Dr Rigliaco compared the observed velocity dispersion of the ρ Oph star-forming region. Based on this and other spatial information, they concluded that the region is consistent with being bound. Whether or not a star forming region is bound has important implications for the population of the disc of the Milky Way galaxy; bound regions are expected to contribute few stars to the disc, whereas unbound regions will contribute all of their stars. This interpretation will be included in the analysis section of a future paper led by Dr Rigliaco.

Dr Parker and Prof. Meyer discussed the latest results from analysis of the velocity dispersions in pure N-body simulations. Based on these discussions, Dr Parker began work on the write-up of the second paper in the series 'Dynamical evolution of star-forming regions', in collaboration with Dr Nick Wright (University of Hertfordshire, UK). They then discussed other ancilliary projects, such as the analysis of gas distributions and how they compare to the distributions of stars in young regions.

4) Future collaboration with host institution (if applicable)

Dr Parker and Prof. Meyer will continue to collaborate on predictive simulations and observational analysis for the Gaia data. They plan to work on a paper directly comparing the spatial and velocity information in observed regions targetted by the Gaia-ESO survey. Dr Parker will also remain in contact with the researchers at Arcetri to work on follow-up analysis.

5) 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)*

1. 'Dynamical evolution of star forming regions: II Basic kinematics', R.J. Parker & N.J. Wright, MNRAS, in prep.

2. 'Kinematics in nearby star-forming regions: observations meet simulations', R.J. Parker, M.R. Meyer, E. Rigliaco, MNRAS, in prep.

3. 'On the spatial distribution of stars and gas in numerical simulations', R.J. Parker & J.E. Dale, MNRAS, submitted.

6) Other comments (if any)