Research Networking Programmes

Short Visit Grant ☐ or 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: Ages of young open clusters using gyro-chronology: preparing for the Gaia data

Application Reference N°: 4988

1) Purpose of the visit

The first goal was to finalise in a paper for a refereed journal ideas on stellar angular momentum (AM) evolution that were developed in collaboration with AIP researchers,. The second was to discuss with AIP researchers, which include world leading expert in the field like Sydney Barnes and Klaus Strassmeier, future developments of this work, particularly those related to the Gaia impact on stellar age estimation and on the description of the evolution of angular momentum.

2) Description of the work carried out during the visit

In the first part of the visit we have developed and implemented a new Two-Zone-Model Monte Carlo Marcov Chain (TZM-MCMC) method for the analysis of rotational periods in open clusters. This method is the result of considerable improvement and extension of a previous work published in MNRAS in 2011. The TZM takes into account the relevant physics regulating the AM evolution of low-mass (less than approximately 1.3 solar masses) stars from the pre-main sequence (PMS) to the late main-sequence. The integration with a MCMC model fitting to the data makes it possible a robust and

accurate derivation of the relevant parameters and associated uncertainties.

This method was then applied to the extensive data on open clusters that is becoming increasingly available, covering ages up to 2.5 Gyr. We focused on the rotational evolution of stars in the slow-rotators sequence, which is partcularly relevant for the foundation of gyro-chronology, exploring the validity of classical wind braking laws with different prescription on the saturation regime as well as new proposal based on MHD simulations.

A new method for identifying stars on the slow-rotators sequence based on a non-parametric fit and on the simmetry of the distribution around this fit has also been elaborated. This constitute a statistically meaningful input for the MCMC model fitting to the data.

In the second part of the visit, after submitting a paper on the results obtained so far with the above method, further work has been carried out on the continuation of the project, which aims at the rotational evolution modelling also outside the slow-rotators sequence and on the consequences of our findings on the depletion of the light elements.

3) Description of the main results obtained

Thanks to the work carried out during the visit, we found that the transport of angular momentum from the radiative core to the convective envelope explains the discrepancies reported in the literature between the gyro-chronology relationships used so far and the observations of clusters with age between 100 and 600 Myr. After most of the core angular momentum has been transferred to the envelope, the subsequent evolution follows the expected Skumanich-type evolution on which the current gyro-chronology relationships are based. We found that, at least in the mass range 0.8-1.1 solar masses, the core-envelope coupling timescale is a well-defined steep function of mass, increasing at decreasing mass. Our results on the core-envelope coupling timescale do not depend on the braking law adopted. The comparison of different wind braking laws, on the other hand, has shown that the mass dependence is best reproduced by assuming that the angular momentum loss is proportional to the convective turnover timescale. Further work has been planned along these lines also in preparation of the Gaia data releases.

4) Future collaboration with host institution (if applicable)

The internal differential rotation resulting from our modelling can be used as an observational constraint for theoretical models of the tachocline, an aspect that will be explored within a collaboration with the MHD group at AIP.

Discussions with members of the stellar group of the AIP have been focused on the possibility of supplementing existing data with new observations. The impact of Gaia and Gaia-ESO data on the rotational evolution of open clusters has been discussed and plans for scientific exploitation have been laid.

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)***

Lanzafame & Spada, 2015, "Rotational evolution of slow-rotators sequence stars", Astronomy and Astrophysics, submitted (http://arxiv.org/abs/1506.05298).

(Other 2 papers on the subject are in preparation, titles and list of authors to be defined).

6) Other comments (if any)

Preliminary results of this work have been presented at the annual SAIT meeting (Catania, 19 May 2015)
The results presented in the paper submitted to Astronomy and Astrophysics have been also presented in a seminar given at the AIP on the 26 June 2015.
In the first part of the visit, a colloquium entitled "Gaia-ESO survey science validation: first results on young open clusters" was given at the AIP (25 February 2015).
Contribution from ESF was acknowledged.