Science Meeting – Scientific Report

_Proposal Title__: The World of Clusters Workshop, September 2013, Padova_

Application Reference N°: 4720

1) **Summary**

Organizers :

Antonella Vallenari (INAF-Osservatorio Astronomico di Padova, Italy)
Angela Bragaglia (INAF-Osservatorio Astronomico di Bologna, Italy)
Sofia Randich (INAF-Osservatorio Astrofisico di Arcetri, Italy)

Scientific Organizing Committee:
- E. J. Alfaro (Istituto de Astrofisca de Andalucia, CSIS, Spain)
- F. Arenou (Observatoire de Paris Meudon, France)
- F. van Leeuwen (IoA, Cambridge, UK)
- A. Moitinho (SIM, Faculdade de Ciencias da Universidade de Lisboa, Portugal)
- C. Soubiran (CNRS, Bordeaux, France)

All were attending to the meeting, except van Leeuwen and Arenou due to commitments with the Gaia Mission and the University, respectively

Local Organizing Committee:

R. Sordo , T. Cantat- Gaudin and L. Marongiu (INAF- Padova Italy)

Participants
51 Researchers attended the meeting: 7 were part of the SOC, 15 were invited, 29 registered. Participants came mainly from European ESF institutes (26) of 10 countries; 8 participants came from extra-European countries (Australia, Brazil, USA, Chile). 3 speakers from non-ESF countries (Australia, USA) were supported by the ESF grant.

Invited and Contributed talks
We reached a fair balance both for gender (50% of the participants are women) and age/career, with several PhD students and many postdocs (43% of the participants) -most of whom gave talks. We invited 15 astronomers, again maintaining a fair gender and career balance, to cover with general/review talks the main topics. In total we had 17 invited talks of 30 minutes compared to 26 contributed talks of 20 minutes. Several posters were presented. Two sessions were devoted to discussion. The detailed program is at the end of the report

Subjects covered by the talks
The Workshop was divided in four main sessions. 1) Stellar populations in clusters: discussing the properties of the stars in clusters; 2) Clusters and their environment: including the formation and disruption of clusters, as seen by theory and tested by the observations; 3) Clusters as tracers of the Galaxy evolution: exploring the information about the formation of the halo and the evolution of the disk from clusters in ours and in external galaxies. Finally Session 4 was devoted to communication skills for PhD and young post-docs

Webpage
The general Workshop webpage is http://www.oapd.inaf.it/clusters were the Book of the Abstract and the PDF files of all the talks from the speakers can be found

Location
The meeting took place in the magnificent 17th Century Sala Consiliare kindly provided by the Padova Municipality.

External support:
We acknowledge the kind hospitality of the Padova Municipality who supported us with the Conference room, wifi connection, technical support, audio/multimedia devices and finally with material (paper, conference bags).
The GREAT-ITN Project covered the travel expenses for 3 young PhD students of the GREAT network presenting their work at the meeting.

2) **Description of the scientific content of and discussions at the event**

How did our Galaxy form and what was its evolution? Answering to this question will have strong impact in our understanding of open key issues such as the assembly and evolution of the galaxies in general, since the Milky Way is a privileged site to constrain in detail these processes, through the study of the kinematics, age, and chemistry of stars in the field and stellar clusters. In particular, old stellar clusters and their stellar populations hold the key to understand the initial phases of the formation of the halo and of the disks.

In the next few years the cornerstone ESA Gaia mission due to launch at the end of 2013 will revolutionise the domain of Galaxy research. Gaia will be complemented by on-going or proposed large-scale photometric and spectroscopic surveys, both in the visible and in the infrared improving the census of clusters and cluster members at the low mass end and at larger distances from the cluster center, significantly contributing to cluster astrophysics. For the first time, memberships, proper motions, distances from Gaia, metallicity, and ages from ground-based surveys can be homogeneously derived for a large number of clusters. This will provide a wealth of insight into galaxy evolution: their ages, distances, and metallicities will allow us to put well defined probe-points all over the optically visible Galaxy, well beyond the volume where individual stars can be used. These high quality data will allow gathering a better understanding of the formation and evolution of the individual clusters, and of the evolution of the stars in the clusters. When coupled with information about field stars, they will develop a single narrative of the formation of galaxies such as the Milky Way.

The first session discussed *the stellar population in clusters* . Star clusters provide an unprecedented insight towards stellar structure and stellar evolution, through their very well defined (observational) isochrones. This enormous potential will be enlightened by the Gaia astrometric and photometric data, which combined with the chemical composition and age indicators, will allow a direct comparison with the theoretical stellar isochrones, eventually leading to model calibration. Several talks pointed out the main uncertainties on the theoretical side about convection and in general mixing in the stellar interiors, rotation and mass loss. Cluster observations allow us to constrain the physics and the nucleosynthesis of asymptotic giant branch stars which are among the most important polluters of the interstellar medium. The variation of the chemical composition of these stars is the result of a complex interaction between nuclear processes occurring in the deep interior and macroscopic mixing episodes. The peculiar abundances of two LMC clusters, NGC 1978 and NGC1846 were discussed.
The asteroseismological observations of Kepler and Corot have a great potential to calibrate the stellar models, in synergy with the determination of the global parameters by Gaia. Oscillation frequencies are a unique direct observational probe of stellar interiors since they are less subject to systematic errors than classical cluster fitting, where one usually relies on one particular set of stellar models. In principle, acoustic modes can be used to derive the He abundances and the global parameters, while the mixed modes can give information about the mixing in the core, and the rotation. In particular the transport of the angular momentum in the stars is not well reproduced by the stellar models. Future developments of asteroseismology require improvements in oscillation theory.

The second session, *clusters and the environment* was focused on the formation of the clusters.
The discussion focused on the observational constrains, such as the Initial Mass Function (IMF), the distribution of the stars and pre-stellar cores in young formation regions.
Most stars form in clusters, but the percentage of stars born in dense stellar systems is currently matter of controversy. The morphologies of individual clusters appear to vary significantly from region to

region, suggesting that either star formation in clusters is not universal and may depend on the local environment, or that all clusters form with the same morphology but early dynamical evolution quickly modifies the structure of the phase space distribution.

The IMF in clusters and young association gives hints about the formation process of the clusters, either turbulent fragmentation or quasi static star formation. Data can suggest a possible variation of the IMF slope at the sub-stellar regime, even if the results are hampered by observational uncertainties. This would point in favor of the turbulent fragmentation models, but this result needs to be confirmed. Gaia when complemented by NIR observations can provide important information. Fractal behavior in stellar clustering has been identified in the Magellanic Cloud young clusters, when comparing the properties of pre-main sequence stars and older population. This might be in agreement with turbulent theory of formation that can induce self-similar stellar topology.

Primordial mass segregation has been found also in pre-stellar cores in the Pipe nebula as a result of magnetohydrodynamical processes.

Globular clusters were once thought to be simple stellar populations (i.e. all stars having the same age and chemical abundance) . Now it is well known that they host a variety of anomalies, such as spreads and splits in colour-magnitude diagrams and especially abundance variations in light elements (e.g. C, N, O, Na, Al), and correlations and anti-correlations of elements showing the chemical pattern of the CNO cycle.

Observations can give information about the main polluters, and on the formation time scale. The discussion focused on the main candidate polluters, either intermediate mass AGB stars through slow wind and envelope ejections or massive rotating stars through slow equatorial winds. The situation if far from being clarified, since both models cannot reproduce all the observations. Massive stars cannot produce the Mg-Al and Mg-Si anti-correlations that are observed. In addition they evolutionary time is too close to the SNII lifetime, and differences in [Fe/H] are expected. With AGB stars it is hard to match the highest level of Na enhancement and/or O depletion, unless fine-tuning of input physics, i.e convection treatment and fast mass loss rate, is adopted. The Li abundances can discriminate among the two different scenarios, since Li is only destroyed in massive stars, but can be produced in AGB stars. Recent observations seems to point in favor of AGB stars as main polluters. Open clusters, with the possible but highly controversial case of NGC6791, do not present abundances anomalies. The importance of the cluster mass in the multiple generation problem is still an open question.

From the theoretical point of view, the formation of globular clusters was discussed.

Several models for the formation of globular clusters and of multiple populations in globulars were presented. The most recent models all have serious shortcomings (e.g. requiring a non-standard initial mass function of stars and GCs to have been initially 10-100 times more massive than observed today). These models also do not seem to agree with observations of massive stellar clusters forming today, which do not display significant age spreads nor have gas/dust within the cluster. A new model was presented where where low-mass pre-main-sequence stars accrete enriched material released from interacting massive binary and rapidly rotating stars on to their circumstellar discs, and ultimately on to the young stars. The proposed model does not require multiple generations of star formation, and would solve the `mass budget problem' without requiring GCs to have been significantly more massive at birth. However, this model is still in its exploratory phase and more tests are required; furthermore, it would not solve the inconsistencies of the massive stars model mentioned above, on which is based.

The third session discussed the importance *of clusters as tracers of the Galactic evolution*. In particular open clusters trace the properties of the disks. Their radial chemical gradient can give important information about the formation process of the disk (inside –out), and it time scale. However from the observational point of view still many uncertainties remain, due to dis-homogeneous determination of properties., such as ages, metal content, distances. It has been pointed out for the first time that clusters are affected by migration as the field stars. The importance of the stellar migration in the disk formation

is not well understood and contrasting results can come out when field stars are taken as proxy. Open clusters instead can be used to constrain the migration models, since their age, distance and chemical properties can be observationally derived with higher accuracy.

GCs can trace the halo formation. They show unique abundance pattern with CN (and Na) strong stars. Tracing GC stars in the field can help to understand what is the fraction of stars formed in GCs and their relation with the field population and finally clarify the scenario of multiple population formation. At least 17% of halo stars formed in globular clusters. CN strong stars have orbits and distances from the plane compatible with the inner halo population indicating that stripped or destroyed globular clusters could be a significant source of inner-halo field stars, and suggesting that both the CN-strong stars and the majority of globular clusters are primarily associated with this population.

Comparing the properties of the clusters in different Galaxies in the Local Group can provide information about the formation mechanism. Only a few galaxies below MV~-13 have GCs, but it is unclear what governs the number of GCs of a galaxy. In addition while M31 and the Galaxy have very similar global properties, their GC systems are completely different. M31 halo GCs preferentially lie on stellar substructures, suggesting this population has been accreted along with their host galaxies.

The third session discussed the coming data *from on-going or future surveys*. In particular, the Gaia-ESO-Survey (GES) will produce high resolution spectroscopy determination of the abundances of about 100 clusters, giving an homogeneous sample, to be compared with the Galaxy evolution models. The first results and the methodology where presented. The GES makes use of several different methods to derive the abundances. As first results, the flattening of the radial chemical gradient of open clusters in the external disk is confirmed. The chemical abundances of three clusters have been analyzed showing an high degree of homogeneity and confirming that OCs of low mass do not show any chemical peculiarity. New data on OCs will come also from the APOGEE survey, that has at the moment derived the chemical abundances of 22 clusters without any previous determination, but is aimed to study up to 1000 OCs. GES and APOGEE have common targets, allowing for an homogeneous metallicity calibration. The first results point in the direction of a flat chemical gradient in the external part of the disk, and no radial alpha element gradient.

IPHAS (INT/WFC photometric Hα survey of the Northern Galactic Plane), UVEX (UV-excess survey, INT. started in 2006) and VPHAS+ can provide important information on the regions affected by interstellar extinction, complementing Gaia.

Finally during *the communication skill sessions*, the basic rules of the scientific communication were presented by two experts. Then young researchers had the chance to hold their talks and get comments emphasizing the positive and the critical aspects of the presentations.

3) Assessment of the results and impact of the event on the future directions of the field

The exploitation of the wealth of data that is accumulating requires a large effort from the community, and a global approach taking into account different aspects. The aim of the workshop was to bring together experts of stellar evolution, stellar and cluster dynamics, spectroscopy, numerical modelling of stellar systems, Galaxy modelling in order to promote collaborations between these groups. The meeting promoted the communication between these relatively different communities, to optimize and take maximum advantage of the coming observations in the next years. Theoreticians pointed out topics where theory should be improved, and what constraints can be provided by the Gaia and the coming or on-going surveys. Observers identified critical areas, discussing systematic errors. The interaction between observers and theoretician had as a consequence a deeper understanding of the critical points in the modelling and in the observations, mainly in the field of stellar evolution and cluster formation and evolution. Discussion between people using different

approaches was very lively. New ideas and collaborations were started, new possibilities and perspectives will be considered by many participants. The presentations on the major surveys either already on-going or planned gave an update of the most recent results, opening new perspectives. Finally, the presence of many young astronomers, either PhD or at early postdoc level, was very important. They had the opportunity to present their results, either contributed talks, posters, or invited talks and participate to the discussions after the talks and during the breaks. The session on communication skills was very lively allowing all the participants to get comments on their presentations both by communication experts and young people.

ANNEX 4 a

ESF - Workshop " The World of Clusters"

Final Program

Padova, 23-26 September 2013

MONDAY, 23 Sept - Sala Consiliare

SESSION 1: Stellar Populations in Clusters

chair: R. Blomme				
	9:00:00	9:10:00	L. Littamè	Welcome address of Padova's Assessore alla Cultura
	9:10:00	9:20:00	M. Turatto	Welcome address of the Padova Observatory director
	9:20:00	9:30:00	A. Vallenari	Setting the framework: news from Gaia
	9:30:00	10:00:00	**A. Weiss**	Star clusters - laboratories of stellar structure theory
	10:00:00	10:20:00	O. Straniero	Asymptotic Giant Branch Stars in intermediate age clusters
	10:20:00	10:40:00	A. Lanzafame	Lithium abundance, activity and rotation in Open Clusters and Young Loose Associations
	10:40:00	11:10:00	**Coffee break**	
	11:10:00	11:40:00	**E. Moraux**	The low mass IMF in clusters and the effect of dynamical evolution
	11:40:00	12:10:00	**C. Aerts**	Asteroseismology of stellar clusters
	12:10:00	12:30:00	J. Montalban	Asteroseismology of Red Giants
	12:30:00	12:50:00	E. Corsaro	Asteroseismology of the OCs NGC 6791, 6811, and 6819 from 19 Months of Kepler photometry
	12:50:00	14:30:00	**Lunch**	

chair: S. Randich				
	14:30:00	15:00:00	N. Mowlavi	The Discovery of a new class of variable stars in NGC 3766
	15:00:00	15:30:00	**V. D'Orazi**	Disentangling the complexity of globular clusters: a chemical approach
	15:30:00	15:50:00	H. Lamers/N. Bastian	The origin of multiple stellar populations in clusters
	15:50:00	16:20:00	**Coffee break**	
	16:20:00	16:40:00	W.Chanterau	Uncover the formation of globular clusters
	16:40:00	17:00:00	T. Costado	Study of stellar clusters containing massive stars

Social Event	19:00:00			**Guided tour to the Specola**

TUESDAY, 24 Sept - Sala Consiliare

SESSION 2: Clusters and their Environment

chair: A. Bragaglia				
	9:00:00	9:20:00	A. Moitinho	UPMASK: Unsupervised Photometric Membership Assignment in Stellar Clusters
	9:20:00	9:50:00	**M. Gieles**	Formation & disruption of clusters
	9:50:00	10:20:00	**R. Parker**	The dynamical state of star clusters and the influence of binaries
	10:20:00	10:40:00	H.J.G.L.M. Lamers	The evolution of the stellar mass function of star clusters.

10:40:00	11:10:00		**V. DeBattista**	Radial migration in disk galaxies
11:10:00	11:40:00	**Coffee break**		
11:40:00	12:00:00		E.J.Alfaro	Density or mass, which control the early stages of the star formation process?
12:00:00	12:20:00		H. Bouy	Dynamical analysis of nearby clusters
12:20:00	12:40:00		D. Gouliermis	Exploring the topology of clustered star formation
12:40:00	14:10:00	**Lunch**		

SESSION 3: Clusters as Tracers of Galaxy Evolution

chair: C. Soubiran	14:10:00	14:40:00	**S. Martell**	Globular cluster stars in the Galactic halo
	14:40:00	15:10:00	**A. Ferguson**	Globular clusters throughout the Local Group
	15:10:00	15:50:00	*Discussion: A. Bragaglia*	Discussion on Session 1&2
	15:50:00	16:20:00	**Coffee break**	
	16:20:00	16:40:00	**G. Tautvaisiene**	CNO abundances in clusters
	16:40:00	17:00:00	S. Blanco-Cuaresma	Testing the chemical tagging with old Open Clusters
	17:00:00	17:20:00	B. Rocca-Volmerange	The crucial role of cold stars to model galaxy evolution with Gaia

Social dinner	20:00:00			**Ristorante "Donna Irene"**

SESSION 4: Clusters in the Surveys pre/post Gaia

chair:					
E.J.Alfaro	9:00:00	9:30:00		**A. Bragaglia**	Old clusters of the Milky Way disk
	9:30:00	9:50:00		R. Gratton	Multiple populations in globular clusters: a clue to second parameter problem?
	9:50:00	10:20:00		**P. Frinchaboy**	Chemical abundances of star clusters and the Galaxy with APOGEE
	10:20:00	10:50:00		**J. Drew**	Galactic Plane open clusters in IPHAS, UVEX and VPHAS+
	10:50:00	11:20:00	**Coffee break**		
	11:20:00	11:50:00		**S. Randich**	The promise of the Gaia-ESO Survey for open cluster science
	11:50:00	12:10:00		R. Blomme	Massive-star clusters in the Gaia-ESO Survey
	12:10:00	12:30:00		M. Palmer	A bayesian approach to open cluster distance determination
	12:30:00	12:50:00		L. Magrini	Chemical signature of open clusters: tools to understand the mechanism of disk formation
	12:50:00	13:10:00		T. Cantat-Gaudin	GES open clusters as tracers of the chemical gradient
	13:10:00	14:40:00	**Lunch**		
chair: M. Gieles	14:40:00	15:00:00		P. Donati	Progress in BOCCE survey
	15:00:00	15:20:00		R. Sordo	GES open clusters as stellar evolution probes
	15:20:00	15:40:00		M. Valentini	Corot Red Giants in the GES
	15:40:00	16:00:00		L. Sampedro	Chasing cluster members in GES catalog
	16:00:00	16:20:00		C. Allen	Gaia and the dark matter versus modified gravity controversy

			Discussion	
16:20:00	17:20:00		*Discussion: M. Gieles*	Discussion on Session 3 & 4: are we ready to exploit the scientific potential of Gaia?
17:20:00	17:40:00	**Aperitif**		

THURSDAY, 26 Sept - Sala Rosino

SESSION 5: communication skills

9:30:00	10:00:00		**R. Doran**	Scientific communication I
10:00:00	10:30:00		C. Boccato	Scientific communication II
10:30:00	11:30:00			Selected presentations by young researchers
11:30:00	12:00:00		*Discussion*	Expert comments on the presentations

Annex 4b

Participant list

Professor Conny Aerts	**KU Leuven, (BE)**	Speaker
Dr. Emilio J. Alfaro Navarro	**Granada, (ES)**	Speaker
Dr. Christine Allen Armino	**México D.F, (MX)**	Speaker
Dr. Sergi Blanco Cuaresma	**FLOIRAC , (FR)**	Speaker
Dr. Ronny Blomme	**Brussel, (BE)**	Speaker
Dr. Caterina Boccato	**Padova, (IT)**	Speaker
Dr. Hervé Bouy	**Villanueva de la Cañada, MADRID, (ES)**	Speaker
Dr. Angela Bragaglia	**Bologna, (IT)**	Speaker
Dr. Tristan Cantat-Gaudin	**Padova, (IT)**	Speaker
Dr. William Chantereau	**Versoix, (CH)**	Speaker
Dr. Enrico Corsaro	**KU Leuven, (BE)**	Speaker
Dr. Valentina D'Orazi	**Sydney , (AU)**	Speaker
Professor Victor Debattista	**Preston, (UK)**	Speaker
Dr. Paolo Donati	**Bologna, (IT)**	Speaker
Dr. Rosa Doran	**Sao Domingos de Rana, (PT)**	Speaker
Dr. Janet Drew	**Hatfield, (UK)**	Speaker
Professor Annette Ferguson	**Edinburgh, (UK)**	Speaker
Dr. Peter Frinchaboy	**Fort Worth, (US)**	Speaker
Professor Mark Gieles	**Guildford , (UK)**	Speaker
Dr. Dimitrios Gouliermis	**Heidelberg, (DE)**	Speaker
Dr. Raffaele Gratton	**Padova, (IT)**	Speaker
Professor Henny J.G.L.M Lamers	**Amsterdam, (NL)**	Speaker
Dr. Alessandro Lanzafame	**Catania, (IT)**	Speaker
Dr. Laura Magrini	**Firenze, (IT)**	Speaker
Dr. Sarah Martell	**North Ryde , (AU)**	Speaker
Dr. Andre Moitinho de Almeida	**Lisboa, (PT)**	Speaker
Dr. Josefina Montalban	**Liège, (BE)**	Speaker
Dr. Estelle Moraux	**Grenoble, (FR)**	Speaker
Dr. Nami Mowlavi	**Versoix,, (CH)**	Speaker
Dr. Max Palmer	**Barcelona, (ES)**	Speaker
Dr. Richard Parker	**Zürich, (CH)**	Speaker
Dr. Sofia Randich	**Firenze, (IT)**	Speaker
Professor Brigitte Rocca-Volmerange	**Paris, (FR)**	Speaker

Dr. Laura María Sampedro Hernández	**Granada, (ES)**	Speaker
Dr. Rosanna Sordo	**Padova, (IT)**	Speaker
Dr. Oscar Straniero	**Teramo, (IT)**	Speaker
Dr. Grazina Tautvaisiene	**Vilnius, (LT)**	Speaker
Dr. Marica Valentini	**Liège, (BE)**	Speaker
Professor Antonella Vallenari	**Padova, (IT)**	Speaker
Professor Achim Weiss	**Garching, (DE)**	Speaker
Dr. Katia Biazzo	**Catania, (IT)**	Participant
Dr. Diego Bossini	**Birmingham, (UK)**	Participant
Dr. Teresa Costado Dios	**Granada, (ES)**	Participant
Dr. Thais dos Santos Silva	**São Paulo, (BR)**	Participant
Dr. Beatriz Fernandes Soares	**Paris, (FR)**	Participant
Dr. Vincent Henault-Brunet	**Guildford, (UK)**	Participant
Dr. Carme Adriana Martinez Barbosa	**Leiden, (NL)**	Participant
Dr. César Muñoz	**Concepción, (CL)**	Participant
Dr. Tjibaria Pijloo	**Nijmegen, (NL)**	Participant
Dr. Alex Ruelas	**México, D.F, (MX)**	Participant
Dr. Caroline Soubiran	**FLOIRAC , (FR)**	Participant