



# GREAT-ESF Workshop “Gaia and Exoplanets: GREAT Synergies on the Horizon” (Torino, Italy – 5,6,7 November 2012) FINAL REPORT

## SCIENTIFIC SUMMARY:

We are at a crucial time for astrophysics research in the field of extrasolar planets. More than 850 planets are now known to orbit main-sequence stars in the neighbourhood of our Sun, discovered using a variety of detection techniques and characterized by means of cunningly devised methods, both from the ground and in space. Seventeen years after the first discovery announcement, the formation and evolution of planetary systems is now emerging as a new, quickly expanding interdisciplinary research field.

The most striking breakthroughs in our understanding of how planetary systems form and evolve, and in our capability to constrain the physics of their interiors and the chemistry of their atmospheres, have benefited from the combination of different observational techniques. The class of transiting, short-period extrasolar planets provides outstanding examples of across-techniques, synergetic efforts in this direction. To-date, 290 planets are known to transit across the disk of their primary star, and for these it is only the combination of photometric transit observations (which reveal a planet's radius) and radial-velocity measurements (which permit to determine a planet's mass) that provides the direct means to determine their densities and hence bulk composition, for meaningful comparison with structural models. The knowledge of very accurate transit ephemerides from photometry is essential to measure the degree of misalignment between the planetary orbital plane and the stellar rotation axis through radial-velocity observations of the Rossiter-McLaughlin effect during transit, for refined understanding of the relative roles of different mechanisms of orbital migration in the formation and early evolution history of exoplanets. The combination of clever, multi-wavelength photometric and spectroscopic techniques to measure planetary emission and absorption at a variety of orbital phases, in and out of primary transit and secondary eclipse, is absolutely necessary for inferring the atmospheric composition and dynamics of exoplanets' atmospheres, for comparison with models of planetary atmospheric chemistry. For non-transiting planets at intermediate separations, the combination of Doppler measurements and space-borne astrometry provides the sole means to derive actual mass estimates and to determine the full three-dimensional orbital architecture of a planetary system. For planetary systems at wider separations, measurements of their emergent fluxes via direct imaging can be most effectively used to infer their atmospheric and other evolutionary (e.g., radius) properties if astrometric measurements are available to dynamically constrain their masses and if



accurate distance estimates can be used to precisely determine the age of the systems. We're ushering in the new era of comparative planetology, in which (even simultaneous) multi-wavelength, multi-technique precision measurements for the characterization of extrasolar planets will allow us to significantly mitigate our inability to send probes to study them up close, as we do in our Solar System.

The era of high-precision astrometry is also approaching. With a launch date now set for October 2013, ESA's global astrometry mission Gaia is due for its first major intermediate catalogue release in five years' time. The Gaia astrometric measurements and data products hold great promise for a wide range of contributions to the field of extrasolar planets astrophysics. The statistical value of a sample of hundreds of thousands of F-G-K-type stars of all ages and metallicities within 200 pc from the Sun screened astrometrically for giant planets is still very high, even in this fast-developing field. The importance of the delivery of direct distance estimates for planet-hosting stars with <1% precision cannot be underestimated. However, while the impact of Gaia data alone in the exoplanet arena will undoubtedly be significant, the farthest-reaching implications of their use and the full exploitation of their scientific potential will only be achieved when combined with data from other ground- and space-based observatories for exoplanets detection and characterization.

The GREAT-ESF Workshop "Gaia and Exoplanets: GREAT Synergies on the Horizon" brought together ~70 scientists involved in observational and theoretical work in the field of extrasolar planets, with the three-fold goal of: a) reviewing the Gaia multi-faceted contribution to the field, within 1 year from launch, b) discussing the synergy potential between Gaia and other ongoing and planned, space-borne and ground-based programs for planet detection and characterization, and ultimately c) providing the seeds for the realization of across-techniques, legacy programs which will fully exploit the scientific impact of Gaia data in exoplanets astrophysics. The topics addressed in this Workshop, whose program and main scientific highlights are outlined below, were very timely indeed, as extrasolar planets are one of the key objective areas of ESF's Gaia REsearch in Astronomy Training (GREAT) Research Network Programme (RNP).

### **SCIENTIFIC PROGRAM HIGHLIGHTS:**

The Workshop was organized in three main Sessions.

#### **1) SETTING THE GAIA STAGE:**

The first part of Session 1, which occupied the first day of the Workshop, started with a general overview of the present status of the Gaia mission, now that we are within 1 year from launch (T. Prusti). The chosen approach to the processing of non-single stars and exoplanets within the pipeline of Gaia DPAC was then detailed (D. Pourbaix). The activities carried out at the Torino Data Processing Centre (DPCT, one of the five DPCs within DPAC) were presented (R. Messineo), and its evolution as a centre for science data exploitation discussed.



The second part of Session 1 focused on selected reviews on the status of exoplanets science in terms of statistics based on observational data, modelling, and theory. On the observational side, the state-of-the-art of radial-velocity precision achieved with optical spectrographs (HARPS/HARPS-N) and its possible improvements within upcoming instrumentation (ESPRESSO) was addressed (M. Mayor). In particular, pushing down the planet detection limits has allowed to start addressing the statistical properties of Super-Earths and Neptune-mass planets, revisit the occurrence rates of long-period gaseous giants, and investigated the effects on planet properties and frequencies of varying stellar mass and stellar metal content. New insights on exoplanets interior structure, atmospheres, and orbital migration scenarios were discussed within the realm of the successes of ground-based wide-field transit surveys of bright F-G-K dwarfs (A. Collier Cameron) as well as of space-borne programs exploiting the power of ultra-high photometric precision, such as CoRoT (C. Moutou). Finally, the prospects for significant advancements in our understanding of the architectures and physical properties of wide-separation planetary systems were presented using next-generation direct-imaging facilities (e.g., VLT/SPHERE) as proxies (G. Chauvin). On the theoretical side, the relevant discussions focused on how the combination of several observational techniques can help to constrain theories of planet formation around dynamical evolution both around single stars (C. Mordasini, J. Laskar) and in circumbinary systems (F. Marzari).

### **2/3) WHERE ARE THE OTHERS HEADED TO / ESTABLISHING THE SYNERGIES:**

Sessions 2 and 3, which occupied the second and third day of the Workshop, were introduced by a summary of Gaia capabilities in the exoplanets arena, with a significant discussion of the challenges inherent to the modelling of the astrometric orbits of planetary systems (A. Sozzetti). Then, relevant results on exoplanet science as applications of specific detection and characterization techniques (photometry, spectroscopy, astrometry), both from the ground (e.g., HARPS, HARPS-N, APACHE) and in space (e.g., Kepler, CoRoT), over a broad range of wavelengths, and in different environments (e.g., binary systems), together with the expectations from upcoming and planned ground-based (e.g., ESPRESSO@VLT) and space-borne (e.g., TESS, EChO, PLATO, JWST) observatories were discussed, with an eye at 1) the combination of existing and upcoming datasets with Gaia data in order to fully exploit their scientific potential; 2) the use of Gaia data products as complementary tools for improved characterization of planetary systems (the planets themselves, but also the host stars); and 3) the need for extensive, strategically optimized follow-up programs of both astrometric and photometric Gaia planet detections.

Most notable highlights included: a) studies of the Gaia potential to characterize giant planets around stars with extreme evolutionary stages (R. Silvotti), b) analyses of the impact of Gaia on the planet occurrence rate as derived from the space-based transit surveys Kepler and CoRoT (A. Bonomo), c) the identification of synergy elements between Gaia and current and upcoming astrometric planet detection programs both from the ground and in space (J. Sahlmann, S. Reffert, G. Anglada, A. Quirrenbach), d) analyses of the impact of Gaia observations, particularly parallax determinations, on upcoming and planned space-borne observatories with ultra-high precision photometric capabilities for transiting rocky planet detection and atmospheric characterization, such as CHEOPS,



PLATO, TESS, and EChO (D. Queloz, N. Walton, D. Latham, I. Waldmann), e) explorations of the possible synergies of Gaia with next-generation direct imaging instruments (M. Bonavita), and f) significant discussions of the impact of next-generation ground-based infrared spectrograph for precision radial velocities in the Gaia era.

It should also be noted that young scientists participated in large number, were encouraged to present their results through poster presentations, and a number of them were selected for short oral presentations (15 minutes).

### **ASSESSMENT OF THE RESULTS:**

This GREAT-ESF Workshop attracted significant interest, with the launch of Gaia looming close and with the focus on the many connections to establish between high-precision astrometric measurements and other planet detection and characterization techniques. A global figure of 71 participants was reached, a number typically twice that of equivalent events within the GREAT RNP. The success of the event was also measured in terms of the achieved balanced geographical and gender representation (see attached list of participants). An impressive group of experts was enlisted to present invited talks on a well-chosen and balanced selection of topics (see attached final scientific program). The invited talks were uniformly of high quality and they were supplemented by a suite of appropriate contributed talks and posters. The main results mentioned above were of high scientific standards.

High-precision global astrometric measurements with Gaia have the potential to help answering several outstanding questions in the science of planetary systems. Gaia's main strength will be its unbiased and complete magnitude limited census of stars of all ages, spectral types, and metallicity in the solar neighbourhood that will be screened for new planets, which translates into the ability to measure actual masses and orbital parameters for possibly thousands of planetary systems. Furthermore, extrasolar planets are one of the key objective areas of the GREAT ESF RNP, and given the fast-paced development of the field of exoplanets research, the broad scientific focus of this Workshop on exoplanets, Gaia, and its synergies, was commonly noted to be extremely timely, and to entirely fulfil the expectations of GREAT, i.e. creating interdisciplinary exchange and sharing of knowledge and expertise, development and exploitation of new analysis techniques and tools, training of young scientists, and forward looks on the strategic choices to be made for crucial advancements in the field, in light of the contribution that Gaia data will soon start providing to the science of planetary systems. Several clear outcomes of this GREAT Workshop can be identified, the two most relevant ones being 1) a much improved awareness of the synergy potential between Gaia data products and data collected by other ground-based and space-borne observatories devoted to planet detection and characterization, and 2) the identification of specific areas of exoplanet science which will largely benefit from the establishment of concerted follow-up efforts to fully exploit the scientific value of Gaia data on extrasolar planets.

As for point 1), the importance of Gaia exquisitely accurate parallaxes was stressed by many. For example, parallaxes known to a few percent for  $V=15$  dwarfs will translate in



accurate stellar radii with uncertainties  $<5\%$ . As a consequence, it will be possible to refine the planet occurrence rates derived with Kepler data, and to solve the conundrum of the different frequency estimates of Neptune-sized planets as derived from CoRoT and Kepler datasets. Gaia direct distance estimates will also constitute a fundamental input to materialize the contaminants-free target lists of nearby, bright dwarfs for future spaceborne observatories under study by both ESA and NASA, such as PLATO and TESS. Furthermore, the very same data from Gaia will help to improve significantly on spectroscopic determinations of stellar atmospheric (effective temperature, surface gravity, metallicity) and physical (mass, radius) parameters of planet hosting stars, which are today prone to systematic uncertainties that can translate, in the particular case of transiting system, in significant errors in the corresponding physical properties (mass, radius, density) of the hosted planets, thus limiting to a great extent the observational feedback to structural models. Finally, it was recognized how even rough planetary mass estimates derived from Gaia astrometric orbital solutions for wide-separation systems could significantly help in the interpretation of the emergent flux of directly imaged companions, thus resolving at least in part important model degeneracies in predictions of an exoplanet apparent brightness in reflected host star light as functions of orbit geometry, companion mass, system age, orbital phase, cloud cover, scattering mechanisms, and degree of polarization.

As for point 2), one of the relevant items of discussion involved a re-assessment of the possible contribution of Gaia photometry to transiting exoplanets science, the merit of defining possible Gaia planetary transit detections as science alerts, and ideas and requirements for the establishment of ground-based follow-up networks of transiting planet candidates identified in Gaia photometric datasets.

The Workshop was a success also in terms of organization, atmosphere, and opportunities for networking. It was common perception that the sessions were well-paced, with ample time for discussion after each oral presentation. Most of the participants considered the scheduled presentations at the 'cutting edge' of science, clearly defining and analysing the most important problems and opportunities in the field in relation to the specific scope of the Workshop. The speakers' presentations were mostly considered as well delivered, often conducive to vibrant discussions. Most of the participants found that formal discussions, often evoking and exploring new research directions, were sufficiently stimulated by the session Chairmen, with enough time devoted to them, although at times they appeared dominated by only a few individuals and did not involve the whole group. The majority also considered the poster session a useful addition, providing significant scientific input to the meeting. According to the participants, the Workshop aims were timely, clearly and efficiently communicated, and in the end fully realised, ultimately making for a very successful event.

As for atmosphere/networking activities, most considered the Workshop more than "just a meeting", or a collection of talks. The welcome aperitif and the social dinner encouraged casual interactions. Coffee breaks in the mornings and afternoons also provided opportunities for informal interactions. Thanks to the remarkable influx of young people drawn to the field of exoplanets by the many opportunities for new ideas and research projects, the median age of the participants was unusually young. The vast majority

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agreed that the organizers succeeded in their efforts to get good participation by experts from both sides of the Atlantic, in making opportunities for young newcomers from Europe to participate, in achieving a representative balance of all national groups, and in reaching an appropriate balance between young and senior participants.

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## GREAT-ESF Workshop

### Gaia and Exoplanets: GREAT Synergies on the Horizon

TORINO, Nov 5-7, 2012

# FINAL SCIENTIFIC PROGRAM

## Monday 5<sup>th</sup> November:

### Session 1: SETTING THE GAIA STAGE

08:30	REGISTRATION OPEN
09:50-10:00	Welcome address
10:00-10:30	T. Prusti – Gaia status
10:30-11:00	D. Pourbaix – DPAC approach to the treatment of Gaia data on non-single stars
11:00-11:30	COFFEE BREAK
11:30-12:00	R. Messineo – The Italian Data Processing Centre in support to the Gaia data processing and its evolution as center for science data exploitation
12:00-12:40	M. Mayor – HARPS search for planets in the southern hemisphere. Results and questions
12:40-13:10	A. Collier Cameron – WASP at the start of the Gaia era
13:10-15:00	LUNCH BREAK
15:00-15:30	C. Moutou – The CoRoT exoplanet program
15:30-16:00	G. Chauvin – A New Era for Exoplanet Imaging
16:00-16:30	COFFEE BREAK
16:30-17:00	C. Mordasini – How the combination of observational techniques constrains planet formation and evolution theory
17:00-17:30	J. Laskar – Dynamical constraints on the determination of extrasolar planets orbits
17:30-18:00	F. Marzari – Planet formation in circumbinary disks
19:00	WELCOME COCKTAIL / APERICENA ( <a href="#">Caffè Roberto, Via Po 5</a> )

**Tuesday 6<sup>th</sup> November:**

**Session 2/3: WHERE ARE THE OTHERS HEADED TO / ESTABLISHING THE SYNERGIES**

09:30-10:10	<b>A. Sozzetti</b> – The Gaia Exoplanet Discovery Potential
10:10-10:30	<b>R. Silvotti</b> – White Dwarf Planets with Gaia
10:30-10:50	<b>D. Segransan</b> – Uncovering low-mass multiplanetary systems in high-precision radial velocity surveys
10:50-11:30	COFFEE BREAK
11:30-11:50	<b>R. Claudi</b> – Global Architecture of Planetary Systems: GAPS
11:50-12:10	<b>D. Queloz</b> – CHEOPS and NGTS in the Gaia era
12:10-12:30	<b>N. Santos</b> – Planet frequency and stellar metallicity
12:30-14:30	LUNCH BREAK
14:30-14:50	<b>L. Buchhave</b> – Small planets do not require a metal-rich environment
14:50-15:10	<b>A.S. Bonomo</b> – The impact of GAIA on the planet occurrence rate as derived from the space-based transit surveys Kepler and CoRoT
15:10-15:30	<b>G. Torres/A. Sozzetti</b> – Improving Physical Parameters of Planet Hosts
15:30-15:50	<b>R. Haywood</b> – Analysis of simultaneous photometric and spectroscopic data of the CoRoT-7 system
15:50-16:10	<b>S. Reffert</b> – The Astrometric Search for Extrasolar Planets with PRIMA in the light of Gaia
16:10-16:40	COFFEE BREAK
16:40-17:00	<b>J. Sahlmann</b> – Search for planets around ultra-cool dwarfs with astrometry
17:00-17:20	<b>G. Anglada-Escudé</b> – CAPS Project and the role of ground based astrometric programs in the pre-Gaia era
17:20-17:40	<b>A. Quirrenbach</b> – Very high precision astrometry to detect nearby planetary systems down to the Earth mass
17:40-18:00	<b>M. Gai</b> – Building on NEAT concept
18:00-18:20	<b>I. Waldmann</b> – EChO
18:20-18:40	<b>G. Vladilo</b> – Exploring Planetary Habitability with Energy Balance Climate Models
20:00	SOCIAL DINNER ( <b>Pautasso Restaurant</b> )



**Wednesday 7<sup>th</sup> November:**

**Session 2/3: WHERE ARE THE OTHERS HEADED TO / ESTABLISHING THE SYNERGIES**

09:30-09:50	<b>C. Bender</b> – The Habitable-zone Planet Finder Spectrograph
09:50-10:10	<b>S. Jeffers</b> – CARMENES
10:10-10:30	<b>M. Bonavita</b> – Exploring the possible synergies of Gaia with the next generation direct imaging instruments
10:30-10:50	<b>E. Covino</b> – Results of HARPS-N observations of the transiting system Qatar-1 in GAPS
10:50-11:20	COFFEE BREAK
11:20-11:40	<b>S. Zucker</b> – Directed Follow-Up of Gaia Photometry in Search of Transiting Planets
11:40-12:00	<b>L. Mancini</b> – HAT-South: a global network of automated telescopes to detect transiting exoplanets
12:00-12:20	<b>M. Damasso</b> – The APACHE Project: searching for transiting planets around cool stars
12:20-12:40	<b>N. Walton</b> – PLATO: PLANetary Transits and Oscillations of stars - revealing extra-solar Earths in the era of Gaia.
12:40-14:30	LUNCH BREAK
14:30-14:50	<b>D. Latham</b> – Gaia and TESS Synergies
14:50-15:10	<b>V. Nascimbeni</b> – The TASTE project at LBT: unveiling GJ1214b
15:10-15:30	<b>R. Church</b> – How stellar dynamics shapes the population of Gaia-observable exoplanets
15:30-15:50	<b>K. Gozdziewski</b> – On the dynamics of planetary systems around evolved, compact binaries
15:50-16:10	<b>M. Molinaro</b> – The Virtual Observatory: exploiting data potential in progress and in an interoperable way
16:10-16:40	COFFEE BREAK
17:00	END OF WORKSHOP



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