Scientific Report on the GREAT ESF International Conference n. 3189: "The Fundamental Cosmic Distance Scale: State of the Art and the Gaia Perspective"

Convenor: Gisella Clementini, INAF Osservatorio Astronomico di Bologna, Italy

1) Summary

One of the most fundamental issues of modern astronomy concerns the ability of measuring distances to galaxies, and to set up the extragalactic distance ladder with the accuracy required for a precise determination of the cosmological parameters, particularly the Hubble constant H_0.

Given the large range of astronomical distances there is no unique indicator able to span them all. Hence, the distance scale is built up from various overlapping indicators and "standard candles", starting from the nearest ones that can be directly calibrated. The last decade has seen dramatic progress in the calibration of different distance indicators. Yet, we still face the frustrating situation that many methods, in particular some of those used to measure the distances to nearby galaxies, are plagued by significant systematic uncertainties, best reflected in the still existing dispersion in the derived distance to the Large Magellanic Cloud.

The Gaia astrometric mission will provide trigonometric parallaxes, hence geometric distances to unprecedented accuracy of most powerful "primary" distance indicators such as Cepheids, Miras and RR Lyrae stars, which will be directly measured in the Milky Way and in some of the nearby Local Group galaxies. The Conference addressed the cosmic distance scale problem starting from the state of the art of current empirical and theoretical efforts of the international community and then focusing on the crucial contribution expected from the Gaia mission to the calibration of both ``primary" and ``secondary" distance indicators.

Particular attention was devoted to a discussion of the systematic uncertainties affecting the various indicators and of their effect on the calibration of the extragalactic distance scale and on the evaluation of the Hubble constant. Primary distance indicators that will be directly calibrated by the Gaia mission, such as Cepheids, RR Lyrae stars, etc., were addressed both from the observational and theoretical point of view, and their role in the calibration of secondary distance indicators was discussed in detail. The meeting also focused on the expected implications of the Gaia results for the understanding of several open problems concerning primary distance indicators, such as the effect of chemical composition on the Cepheid Period Luminosity (PL), PL-Colour (PLC) and Wesenheit relations as well as the existence of a significant metallicity term in the RR Lyrae K band PL relation. Several different secondary indicators were discussed, including Supernovae, Surface Brightness Fluctuations, Planetary Nebulae and Globular Cluster luminosity functions. They were compared with each other, showing the need of accurate inter-calibrations in order to minimize the final error budget on the extragalactic distance scale.

The significant improvement of the cosmic distance scale evaluation expected from Gaia results and the necessary steps to maximize Gaia scientific output in this respect were identified. Particular attention was devoted to identify preparatory work both on theoretical and empirical sides needed to allow the full exploitation of Gaia outcomes, among which the need for accurate spectroscopic follow-ups aimed at reducing systematic effects related for example to the dependence of several indicators on metallicity.

2) Description of the scientific content of and discussion at the event

The GREAT ESF Conference "The Fundamental Cosmic Distance Scale: State of the Art and the Gaia Perspective" took place at INAF Osservatorio Astronomico di Capodimonte, Naples, Italy, over three and a half days, starting on May 3, and ending on May 6, 2011.
With several of the Gaia performance tests completed by April 2012, and the satellite's launch scheduled for spring 2013, this turned out to be a most proper time to bring together major experts in the field of the cosmic distance ladder, and discuss the main shortcomings of current calibrations as well as the role of Gaia measurements for the understanding of the most important open problems, but also for planning fundamental preparatory activities needed for a full and sound exploitation of Gaia results.

Eighty people attended the event. The participants' list (available on the Conference web page, see http://www.na.astro.it/ESFdistance/listaregistrati.php) included the major experts in the field of distance determinations and the measure of the Hubble constant H_0, who reviewed the status of the art of the distance scale "before" Gaia, discussed the extraordinary improvements expected from the mission to the calibration of both primary and secondary distance indicators, and identified preparatory work both on the theoretical and empirical sides needed to allow the full exploitation of Gaia's results. Several young scientists, students and post-docs also attended the Conference and presented their works through oral contributions and poster papers.

A precise estimate of Ho, directly from the Hubble law, requires the measurement of accurate distances over cosmologically significant scales (see Freedman et al. 2001, ApJ 553, 47; Saha et al. 2001, ApJ 562, 314 and references therein). To this purpose powerful methods, able to reach distances of the order of 50-100 Mpc and beyond, must be devised. The methods satisfying these requirements are the so called secondary distance indicators, such as the maximum luminosity of Type Ia Supernovae (SNIa), the Globular Cluster Luminosity Function (GCLF), the Surface Brightness Fluctuations (SBF). However, all these indicators need to be calibrated with solid primary methods reaching the range of applicability of the secondary ones.
The last decade has seen dramatic progress in the calibration of different distance indicators (see, e.g. Freedman et al. 2001, ApJ 553, 47; Saha et al. 2001, ApJ 562, 314; Ciardullo 2003, LNP 635, 243; Cantiello et al. 2003, AJ 125, 2783; Altavilla et al. 2004, MNRAS 349, 1344; Di Criscienzo et al. 2004, ApJ, 612, 1092 ;2006, MNRAS 365, 1357; Marconi, Musella & Fiorentino 2005, ApJ, 623, 590; Marconi & Clementini 2005, AJ, 129, 2257; Bono et al. 2008, ApJ, 684, 102; Mould & Sakai 2008, ApJ 686, 75; Bono et al. 2010, ApJ, 715, 277). Yet, we still face the frustrating situation that many methods, in particular some of those used to measure the distances to nearby galaxies, are plagued by significant systematic uncertainties, best reflected in the large dispersion still affecting the distance to the Large Magellanic Cloud (LMC; Walker et al. 2001 ApJ 560, L139; Clementini et al. 2003, AJ 125, 1309; Walker 2003, LNP 635, 265; Salaris et al. 2003 ApJ 588, 801; Marconi & Clementini 2005, AJ 129, 2257; Keller & Wood 2006, ApJ 642, 834; An et al. 2007, ApJ 671, 1640).

The Gaia astrometric satellite will allow for distance determinations out to 20 kpc with accuracies better than 10%, providing direct measurements of the distance to stars throughout our Galaxy and beyond. Specifically, Gaia will obtain trigonometric parallaxes, hence geometric distances to unprecedented accuracy of most powerful ``primary'' distance indicators such as Cepheids, RR Lyrae stars and Miras, thus allowing a reassessment of the entire distance ladder.

The Conference program included 18 invited reviews (each of 25 min plus 5 min for questions) on the main conference topics (see below), 18 contributed talk of 15+5 min, about 20 poster papers, and the conference summary. Each day of the Conference was specifically devoted to the discussion of key topics in the field of the distance ladder, according to the following scheme:
- Day 1: The cosmological distance ladder into context
- Day 2: Stellar pulsation and evolution distance indicators
- Day 3: From Local to Cosmological distances to H_0
- Day 4: Gaia: the "transient" sky and the cosmological distance ladder.
Round tables concluded each full-day meeting by allowing to further discuss the major topics of the day. The Conference was video recorded and all talks are available as pdf files on the meeting web page (see http://www.na.astro.it/ESFdistance/presentations.html).

The first day of the Conference was devoted to putting: "**The cosmological distance ladder into context",** through review talks by: **Gustav Tammann,** who very nicely summarized the pioneering outstanding work done by *Allan Sandage in the field of measuring distances and the cosmic expansion of the Universe;* **Wendy Freedman,** who described the impact of the Hubble Space Telescope on the *Measurements of the Extragalactic Distance Scale.* **Catherine Turon** and **Xavier Luri** then reviewed the contribution of past European Space Agency astrometric missions like *Hipparcos* to the *Building of the cosmic distance* scale and introduced the *Gaia mission,* whose present status was reviewed by **Jos de Bruijne.**
Alistair Walker summarized the significant systematic uncertainties, still affecting the cosmic distance ladder which are best reflected in the still existing dispersion in the derived *Distance to the Large Magellanic Cloud.*
The day was ended going through the first steps of the distance ladder being addressed by **Grzegorz Pietrzynski** who reviewed the *Eclipsing binaries as precise distance indicators,* and a number of contributed talks by*:* **V. Ripepi, D. Graczyk,** and **J. Fliri** and the *Round Table,* led by*:* **Alistair Walker** and **Martin Groenewegen.**

The second day of the Conference was devoted to the: **"Stellar pulsation and evolution distance indicators",** with reviews by **Maurizio Salaris** on the *"Evolutionary" distance indicators* (e.g. the MS fitting and the Red Giant Branch Tip)*;* **Filippina Caputo**, on *Distances from RR Lyrae stars;* **Lucas Macri** who reviewed the status of the art of *Cepheids as distance indicators and Anchors to SN hosts; and* **Patricia Whitelock** who reviewed the *AGB variables and the Distance Scale.*
Contributed talks on the subjects of the day were presented by: **C. Klein, G. Wallerstein, N. Matsunaga, N. Nardetto, L. Szabados, C. Ngeow, S. Kanbur, M. Romaniello, J. Storm.**
The Round Table of the day was led by **G. Bono & W. Gieren.**

The third day of the Conference was devoted to moving : **"From Local to Cosmological Distances to H0"**, with reviews by **Rolf Kudritzki** on *"Distances to Galaxies from the Brightest Stars in the Universe";* **Robin Ciardullo** on **"***The Planetary Nebula Luminosity Function in the Era of Gaia";* **Adam Riess** on *"Supernovae: from Calibration to Cosmology";* **John Blakeslee** *on "Surface Brightness Fluctuations as Primary and Secondary Distance Indicators";* and **Marina Rejkuba** on the *"Globular Cluster Luminosity Function as distance indicator in comparison with other distance determination methods."* Contributed talks on the topics of the day were given by*:* **G. Fiorentino, G. Altavilla, M.T. Botticella, G. Raimondo and M. Cantiello,** whereas the Round Table was led by **A. Saha & B. Leibundgut.**

The fourth and last day of the conference focused on **"Gaia: the *"transient"* sky and the cosmological distance ladder"**, with reviews by **Laurent Eyer** on the topic *"Standard Candles in the Gaia Perspective";* **Gerry Gilmore** on *"Real-time science with Gaia – delivering distance tracers through Gaia Alerts;* and **Massimo Della Valle** on *"Novae as distance indicators in the Gaia era".* A final *c*ontributed talk was given by*:* **E. Masana**, whereas the *Conference Summary* was delivered by: **Carla Cacciari** and **Abhijit Saha.**

The Conference set the status of the art of the cosmic distance scale "before" Gaia, thus providing a reference point of the cosmic distance scale for several years to come, until the completion of the Gaia mission and the full exploitation of the Gaia catalogue.
All presentations were video-recorded, their pdfs made available for download from the Conference website: http://www.na.astro.it/ESFdistance/presentations.html, and a special issue of Astrophysics and Space Science will collect the most important results discussed at the Conference. It will be organized in comprehensive reviews (up to 12 pages each) resulting from the contributions of different authors working on the same subjects and summarizing different key topics of the Distance Ladder and its connection to Gaia, discussed during the meeting. The volume, to be published by the end of 2011 is expected to allow higher scientific impact and citation rate to the publication of the Conference results and to become a reference text on the Distance Scale subject.

A number of social events took place during the Conference, they included the Conference Reception on May 2, 2011; a visit to the Capodimonte Museum on May 3, 2011; visits to Naples Observatory Historic Library which hosts a collection of precious ancient books, among which one original manuscript by Copernicus; the Social Dinner on May 4, 2011; a Classic Music Concert and Wine Tasting on May 5, 2011; and a visit to the Roman town of Pompei, on May 6, 2011.

Public outreach activities were also organized. These consisted of a competition with prizes for children of elementary schools, who were invited to submit art works illustrating their ideas on how astronomers measure the distances to stars. The artworks were shown in the Conference Hall and the conference participants voted their favorites. Prizes were awarded to the winners on May 11, 2011.

A full report on the Conference was provided by G. Clementini during the GREAT Plenary Meeting held in Bruxelles on June, 21-23, 2011. The presentation can be retrieved from the following web page: http://great.ast.cam.ac.uk/Greatwiki/GreatMeet-20110621?action=AttachFile&do=view&target=great-pm4-jun11-clementini.pdf

Gaia will have a major impact across all areas of astronomy and astrophysics, and the distance scale is one of these areas. The distance scale is one of the "Grand Challenge" themes of the GREAT ESF RPN. The Conference is one of the major international meetings to be held during the ESF RNP.

The Conference main results can be summarized as follows:

- measuring accurate astronomical distances still owes a crucial, central role in Astrophysics, as demonstrated by the large participation of people covering basically all different steps of the Cosmic Ladder, as well as major experts in the measure of H_0;

- several different groups working in the field of "primary" distance indicators such as Cepheids and RR Lyrae stars, and on "secondary" indicators such as SNe and SFB attended the Meeting, which thus strongly fostered exchanges and collaborations

- the great expectations from Gaia are in the satellite contribution to setting the zero points of the "primary" distance indicators (e.g. Cepheids and RR Lyrae stars)

- it was widely acknowledged that:
 i) an accurate evaluation of the metal abundance of the "primary" indicators
 ii) a very robust inter-calibration of the different indicators
iii) the most accurate treatment of systematic errors
iv) the exploitations of new standard candles bridging "primary" and "secondary" indicators, such as the Ultra Long Period Cepheids are needed ingredients to reach the goal of setting H_0 to the 1-2% accuracy, a goal now becoming achievable thanks to Gaia.

The presentations and discussions during the Conference provided a very important launch and introduction to the International PhD school on the Distance Scale planned to take place in Teramo (Italy) in spring 2012 within the framework of the recently approved FP7 EU GREAT ITN (see http://great.ast.cam.ac.uk/great-itn).

The Naples conference was a GREAT success, also for the very friendly and collaborative atmosphere. Several of the participants dropped us a note after the meeting. Here is one of these messages we received from one of the invited speakers, Prof. Gustav Tammann:

"Dear Gisella, dear Organizers,
I still have not thanked you for the wonderful and most interesting days in Naples. Your organization was outstanding, and with your kindness and diplomacy you brought the Conference to a pleasant and memorable success.

With kindest regards

Gustav"

The Conference final program is attached below and also available in pdf format along with the Abstract booklet for download from the Conference web side (see http://www.na.astro.it/ESFdistance/program.html) .

CONFERENCE PROGRAM

Day 0 – May 2, 2011

Buses leave at 18/18:15 from Hotel Villa Capodimonte to OACn

18:30 – 20:00 ♦ Welcome reception & registration (INAF - Osservatorio Astronomico di Capodimonte)

Buses leave at 20:30 from Capodimonte Museum stop (100 m from OACn) to Hotels downtown and at 20:15 /20:30 from OACn to Hotel Villa Capodimonte

Day 1 - May 3, 2011 Tuesday

Buses leave at 8:00 from the Via Medina meeting point (close to Hotels downtown), at 8:30 from Grand Hotel Capodimonte and at 8:30/8:45 from Hotel Villa Capodimonte

8:30 ♦ Registration. The registration desk will remain constantly open till lunch time.

9:00 – 9:20	Welcome (Director of the Naples Observatory)
9:20 – 9:30	Communications (SOC + LOC)

⇥ **The cosmological distance ladder into context**

Note: **_Invited Reviews_** (30 min. each, including 5 minutes for questions/discussion, orange background)
  Contributed talks (20 min. each, including 5 minutes for questions/discussion)

Chairperson: **G. Clementini**

9:30 – 10:00	**G. Tammann**	*Allan Sandage and the cosmic expansion*
10:00 – 10:30	**W. Freedman**	*Measurements of the Extragalactic Distance Scale*
10:30 – 11:00	**C. Turon / X. Luri**	*Building the cosmic distance scale: from Hipparcos to Gaia*

11:00 – 11:30   Coffee break + Poster viewing

11:30 – 12:00	**J. de Bruijne**	*Status of the Gaia project*
12:00 – 12:30	**A. Walker**	*The Large Magellanic Cloud and the Distance Scale*
12:30 – 12:50	V. Ripepi	*The distance to the LMC from first results of the VISTA Magellanic Cloud (VMC) Survey*

12:50-14:30   Lunch break: Buffet lunch + Visit to the Observatory historical library, with books by Copernico etc., group of 20-30 persons.

Chairperson: **M. Groenewegen**

14:30 – 15:00	**G. Pietrzynski**	*Eclipsing binaries as precise distance indicators*
15:00 – 15:20	**D. Graczyk**	*The early type eclipsing binaries as a distance indicator*
15:20 – 15:40	**J. Fliri**	*First results from the POMME survey of M31*

15:40 – 16:10   Coffee break + Poster viewing

16:10 – 16:40	Round Table on the topic of the day (including posters) **A.Walker /M. Groenewegen**

17:15 – 19:45 ♦ Visit to the Capodimonte Museum (http://en.museo-capodimonte.it)

Buses leave at 20:00 from the Capodimonte Museum to Grand Hotel Capodimonte and Hotels downtown, at 20:00/20:15 to Hotel Villa Capodimonte

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Day 2 - May 4, 2011 Wednesday

Buses leave at 8:00 from the Via Medina meeting point (close to Hotels downtown), at 8:30 from Grand Hotel Capodimonte and at 8:30/8:45 from Hotel Villa Capodimonte

⇶ **Stellar pulsation and evolution distance indicators**

Chairperson: **M. Marconi**

9:00 – 9:30	**M. Salaris**	*'Evolutionary' distance indicators*
9:30 – 10:00	**F. Caputo**	*Distances from RR Lyrae stars*
10:00 – 10:20	**C. Klein**	*Mid-infrared Period–Luminosity Relations of RR Lyrae Stars Derived from the WISE Preliminary Data Release*
10:20 – 10:40	**G. Wallerstein**	*Calibrating the Metallicity of RR Lyrae Stars by Measurement of the CaII Triplet Lines*

10:40 – 11:10 Coffee break + Poster viewing

11:10 – 11:40	**L. Macri**	*SHOES Cepheids: from Anchors to SN hosts*
11:40 – 12:00	**N. Matsunaga**	*Classical Cepheids found in an IRSF near-IR survey and their impacts*
12:00 – 12:20	**N. Nardetto**	*The projection factor of Cepheids*
12:20 – 12:40	**L. Szabados**	*Problems and possibilities in fine-tuning of the Cepheid P-L relationship*

12:40-14:30 Lunch break: Buffet lunch + Visit to the Observatory historical library (group of 20-30)

Chairperson: **W. Gieren**

14:30 – 14:50	**C. Ngeow**	*The Mid-Infrared Period-Luminosity Relations for Classical Cepheids*
14:50 – 15:10	**S. Kanbur**	*The Possible NonLinearity of the mean light and multiphase Cepheid Wesenheit functions in the Magellanic Clouds*
15:10 – 15:30	**M. Romaniello**	*The influence of chemical composition on the pulsation properties of Cepheids: theory vs. observations*
15:30 – 15:50	**J. Storm**	*Calibrating the Cepheid Period-Luminosity relation from the infrared surface brightness technique*

15:50-16:20   Coffee Break + Poster viewing

16:20 – 16:50	**P. Whitelock**	*AGB Variables and the Distance Scale*

16:50 – 17:20	*Round table* on the topic of the day: **G. Bono / W. Gieren**

Buses leave at 17:30/17:45 from OACn to Hotel Villa Capodimonte and at 17:45 from the Capodimonte Museum stop to Grand Hotel Capodimonte and Hotels downtown

Bus transportations to the social dinner leave from different hotels at 19:30 (downtown), 19:50 (Grand Hotel Capodimonte) and at 20 from Villa Capodimonte

20:30 ♦   **Conference Dinner**   + Speech by **M. Capaccioli**

Bus transportations to Hotels leave at the end of the social dinner.

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Day 3 - May 5, 2011 Thursday

Buses leave at 8:40 from the Via Medina meeting point (close to Hotels downtown), at 9:00 from Grand Hotel Capodimonte and at 9:00/9:15 from Hotel Villa Capodimonte

⏩ **From Local to Cosmological Distances to Ho**

Chairperson: **E. Brocato**

9:30 – 10:00	**R. Kudritzki**	*Distances to Galaxies from the Brightest Stars in the Universe*
10:00 – 10:20	**G. Fiorentino**	*Ultra Long Period Cepheids: a primary standard candle up to the Hubble flow.*
10:20 – 10:50	**R. Ciardullo**	*The Planetary Nebula Luminosity Function in the Era of Gaia*

10:50 – 11:00   Conference Picture

11:00 – 11:30   Coffee Break + Poster viewing

11:30 – 12:00	**A. Riess**	*Supernovae: from Calibration to Cosmology*
12:00 –12:20	**G. Altavilla**	*Gaia and the discovery of Supernovae.*
12:20 – 12:40	**M.T. Botticella**	*Supernova search and rates with Gaia*

Lunch break   12:40-14:30   Buffet lunch + Visit to the Observatory historical library (group of 20-30)

Chairperson: **B. Leibundgut**

14:30 – 15:00	**J.P. Blakeslee**	*Surface Brightness Fluctuations as Primary and Secondary Distance Indicators*
15:00 – 15:20	**G. Raimondo**	*SBF and Distances: a Theoretical View*
15:20 – 15:40	**M. Cantiello**	*Improving the cosmological distance scale: SBF and SNeIa inter-calibration*
15:40 – 16:10	**M. Rejkuba**	*Globular cluster luminosity function as distance indicator and comparison with other distance determination methods*

16:10 – 16:40   Coffee Break

16:40 – 17:10	Round table on the topic of the day: **A.Saha/B.Leibundgut**

17:10 – 18:40   Poster viewing + visit to the ancient instruments of the OACn

17:10 – 18:40   GREAT–ITN WP6 meeting / The LOC counts the ballots and awards the school's exhibition prizes

18: 40 – 20:30   Classic Music Concert + Wine Tasting

Buses leave at 20:45/21:00 from OACn to Hotel Villa Capodimonte and at 21:00 from the Capodimonte Museum stop to Grand Hotel Capodimonte and Hotels downtown

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Day 4 - May 6, 2011 Friday

Buses leave at 8:00 from the Via Medina meeting point (close to Hotels downtown), at 8:30 from Grand Hotel Capodimonte and at 8:30/8:45 from Hotel Villa Capodimonte

⯈ **Gaia: the "transient" sky and the cosmic distance ladder**

Chairperson: **X. Luri**

9:00 – 9:30	**L. Eyer**	*Standard candles in the Gaia Perspective*
9:30 – 10:00	**G. Gilmore**	*Real-time science with Gaia – delivering distance tracers through Gaia Alerts*

10:00 – 10:30   Coffee break

10:30 – 11:00	**M. Della Valle**	*Novae as distance indicators in the GAIA era*
11:00 – 11:20	**E. Masana**	*Simulation of the Gaia final catalogue: expectation of the distance*

	estimation

11:20 – 11:50	*Conference Summary* **A.Saha / C. Cacciari**

11:50 – 12:10   Results from the scholar's exibition award
12:10 – 12:15   Thanks from SOC – LOC

12:15 – 14:00   Lunch break   Buffet lunch

Tour to Pompei   14:00 – 20:00/20:30

End of conference