Ages^2: taking stellar ages to the next power

chaired by Scilla Degl'Innocenti (Università di Pisa), David Soderblom (Space Telescope Science Institute)

from Sunday, 17 September 2017 at **17:00** to Friday, 22 September 2017 at **12:30** (Europe/Rome)
at **La Biodola, Isola d'Elba**

organized by:

INFN Istituto Nazionale di Fisica Nucleare

UNIVERSITÀ DI PISA

STScI | SPACE TELESCOPE SCIENCE INSTITUTE

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Monday, 18 September 2017

09:15 - 13:30 Ages of the oldest stars and the connection to the halo and accretion

09:15 **Three questions about the ages of old stars** *15'*

Speakers: Scilla Degl'Innocenti (Università di Pisa/INFN), Santi Cassisi (INAF-Teramo)

09:30 **Local Group dwarfs & the Milky Way: implications on the Galaxy assembly** *30'*

We present an overview of the Local Group dwarfs and specifically, about the satellites of the Milky Way (MW) and the role played on its formation. Although there is observational evidence that the MW has affected the evolution of some dwarf galaxies, the role played by dwarf galaxies on the built of the MW's halo and disk is still on debate. The star formation histories and chemical abundances of the dwarf satellites of the MW may shed some light on this subject.

Speaker: Sebastian L. Hidalgo (Observatoire de la Côte d'Azur), ***invited***

10:00 **Th and U as cosmo-chronometers for old stars** *15'*

We report on the abundance of 31 neutron-capture elements (including Thorium and Uranium) in the highly r-process-enhanced metal-poor giant CS~29497-004 (Hill et al. 2016, arXiv:1608.07463). Combining the various elemental chronometer pairs that are available for this star, and different theoretical yields for the r-process (Waiting-Point approximation, High Entropy Wind models), we derive ages for the star ranging from 12 to 14Gyrs. The U/Th nuclei-chronometer is confirmed to be the most resilient to theoretical production ratio. Beyond the case of CS~29497-004, I will discuss the benefits of using cosmo-chonometers to set the clock at the oldest ages, thanks to the fact that they are largely insensitive to stellar evolution or stellar interior models, and highlight where progress is expected in the coming decade on the observational side (large surveys of metal-poor stars) and on the theoretical side (better understanding of the r-process).

Speaker: Vanessa Hill (Université de la Côte d'Azur)

11:00 **The influence of chemical composition on the evolution of metal-poor stars** *30'*

The early formation history of the Milky Way is preserved in its old, metal-poor stellar populations. The detailed chemical compositions of these stars differ considerably from the solar abundance pattern and, indeed, vary depending on the environment in which the stars formed. I will describe our efforts to understand which chemical elements are most important from the point of view of stellar evolution. In some cases this differs considerably from what can be readily measured from spectroscopy, leading to significant uncertainties. Building on this, I will discuss the importance of being able to match the abundance patterns observed in stars with stellar models in order to facilitate accurate age determinations. Finally, I will highlight the importance of distinguishing between the initial chemical composition of a star and that which is observed at the surface in estimating its age.

Speaker: Aaron Dotter (Harvard-Smithsonian Center for Astrophysics), ***invited***

11:30 **Globular cluster ages: Multiple populations and age-dating implications** *30'*

Speaker: Giampaolo Piotto (Università di Padova), ***invited***

12:00 **Modeling the horizontal branch: unlocking the secrets of ancient star formation** *15'*

I will present a new method that uses the horizontal branch morphology to determine the ancient star formation history of nearby resolved galaxies. Horizontal branch stars are bright and ancient, and their photometric properties depend on age and metallicity. The reason why the horizontal branch is usually neglected in the star formation history determinations of resolved galaxies is the uncertain amount of mass lost on the red giant branch. I will describe a new modeling code that, for the first time, combines classical analysis techniques with synthetic horizontal branch modeling, treating the mass loss as a free parameter and determining star formation histories that are consistent with all the major stellar evolutionary phases. I will show tests of the method and of the code's performance. The analysis of bright color-magnitude features and the advent of next generation telescopes will greatly increase the number of galaxies where accurate star formation histories can be obtained

Speaker: Alessandro Savino (Kapteyn Institute - RUG)

12:15 **Omega Centauri: main sequence's multiple populations galore** *15'*

We take advantage of the exquisite quality of the Hubble Space Telescope to distill the main sequence of omega Cen into its constituent populations. To this end, we restrict ourselves to the five most useful filters: the magic “trio” of F275W, F336W, and F438W, along with F606W and F814W. We develop a strategy for identifying color systems where different populations stand out most distinctly, then we isolate those populations and examine them in other filters where their subpopulations also come to light. In this way, we have identified at least 15 subpopulations, each of which has a distinctive fiducial curve through our 5D photometric space. Our findings show that the stellar populations and star formation history of omega Cen are even more complex than inferred previously.

Speaker: Andrea Bellini (STScI)

12:30 **On the age-dating of old field stars** *30'*

An accurate dating of bulge and halo field populations allows to gauge at which lookback (i.e., at which redshift) one should look for possible analogs of the Milky Way, when their bulge and halo formation process were about to start, well on their way, or even already concluded. However, dating field stellar populations is a very complicated task, generally challenged by the uncertainties in the distance modulus, and the metallicity dispersion. The case of the bulge stellar population is even more difficult due to the stellar crowding, the patchy and highly variable extinction, the distance spread due to the spatial depth of the bar along the line of sight and finally the contamination by foreground disk stars. I will review the commonly used methods to derive the age of field stars, with a particular emphasis on the bulge stellar populations.

Speaker: Elena Valenti (ESO), ***invited***

13:00 **Ages from White Dwarf Cooling Sequences** *30'*

White dwarf cosmochronology has yet to reach its full potential due to recurrent uncertainties associated with the constitutive physics of warm dense matter. For instance, radiative opacities still need to be extrapolated in cool white dwarf models. In addition, cooling ages depend sensitively on the internal chemical stratification which is shaped, over time, by the still uncertain rate of the C12(alpha,gamma)O16 reaction, by convection, semi-convection, overshooting, other mixing processes such as rotational mixing, and by thermal pulses that occur primarily on the Asymptotic Giant Branch. All of these suffer notoriously from major uncertainties, which undermine the reliability of white dwarf cosmochronology. I will review where we stand on these questions, including some very recent seismic results which should lead to an eventual empirical "calibration" of the internal chemical profile of white dwarf stars and, hence, contribute to making white dwarf cooling ages more reliable.

Speaker: Gilles Fontaine (Université de Montréal), ***invited***

16:00 - 16:45 Ages of the oldest stars and the connection to the halo and accretion

16:00 **Sub-Gyr Ages of Globular Cluster using Infrared Photometry: New Breakthroughs and Future Prospects** *15'*

Recently, a new feature has been observed in several HST WFC3-IR color-magnitude diagrams (CMDs) of nearby Globular Clusters (GCs). At low stellar masses, the stellar main sequence in an infrared (IR) CMD exhibits a sharp "kink" (due to opacity effects in M dwarfs), such that lower mass and cooler dwarfs become bluer in the F110W - F160W color baseline and not redder. In this context, I will present the results obtained from the analysis of HST WFC3-IR archival observations of four GCs (47Tuc, M4, NGC2808, and NGC6752) and of new HST/WFC3 IR observations of the old metal-poor GC NGC6397. These works allowed us to estimate the best-fit GC parameters, quantify the correlations among them and derive their individual uncertainties. Our overall results show that observing the near-IR main sequence kink offers a new venue to push the absolute age of GCs to sub-Gyr statistical accuracy. I will discuss the importance of such studies in the context of the next generation near-IR telescopes.

Speaker: Matteo Correnti (STScI)

16:15 **The oldest stars in the galactic halo: not so old** *15'*

We present an updated isochrone age determination of a sub-sample of stars among the halo field stars nearest to the Sun. We use revised parallaxes and reddening estimations based on a detailed study of the local interstellar dust and confirmed by independent diagnostics. The age determination is based on isochrone fitting with a standard technique already used for halo globular clusters. Comparisons with previous investigations on the same sub-sample of stars are performed. We briefly discuss also the main possible shortcomings in the age determination of field stars that could affect the final results.

Speaker: Sergio Ortolani (University of Padova)

16:30 **Improvements in age determinations from isochrone fitting using Gaia parallaxes** *15'*

Age estimates from isochrone fitting of spectroscopic parameters (effective temperature, surface gravity and metallicity) of field stars can be very uncertain (order of 50%). These large uncertainties inhibit the use of stellar ages in for instance galactic archaeology studies. The parallaxes provided by Gaia can significantly improve age estimates from isochrones. Here we present results from isochrone fitting with UniDAM (Unified tool for Distances, Ages and Mass estimation) that incorporate Gaia parallaxes in a consistent way. The use of parallaxes of Gaia DR1 allows us to improve our age and distance estimates substantially - by about 30% in log(age) and about 50% in distance modulus. We also show that further improvements can be expected from future Gaia data releases, bringing log(age) uncertainties to about 0.1 dex and distance modulus uncertainties down to 0.01 mag.

Speaker: Saskia Hekker (Max Planck Institute for Solar system research)

17:15 - 18:45 quick poster presentations

17:15 **CHRONOS plus COSMIC-DANCe: towards an auto-consistent and absolute age scale** *2'*

Different age-dating techniques can produce very different results. The main culprit for this state of affairs is the lack of a universal age scale and the absence of a systematic and robust cross-calibration of the various methods. This situation can change due to the availability of several massive database (Gaia, Cosmic-DANCe, Kepler, Gaia-ESO) and the development of state-of-the-art theoretical models. The CHRONOS project will start with the simplest, least model dependant techniques and will apply them to well known open clusters and associations. It will build up sequentially starting from first principles, observations and simple and well understood physical phenomena, such as Lithium Depletion Boundary and kinematics. These will then be used to bridge the gaps and anchor other precise but relative or model-dependent age scales such as the gyrochronology and asteroseismology to make the ultimate self-consistent universal age scale covering the entire astrophysical time domain.

Speaker: David Barrado (INTA-CSIC)

17:17 **Near-UV Excesses and Variability of 660,000 Sources in the Kepler Field** *2'*

The Kepler field has been entirely observed with the GALEX satellite, as part of the Complete All-Sky UV Survey Extension (CAUSE), in the NUV band (PI James Lloyd). For about 40 days in 2012, GALEX conducted a total of 17 visits, on average, of the whole field. In 2015, we published the GALEX CAUSE Kepler Catalog (GCK) of more than 660,000 NUV point-like sources with NUV≤22.6. We present the comparison of NUV observed fluxes with predictions from classical model atmospheres aimed at identifying objects that display NUV excesses over the expected photospheric flux. The excess, as an activity proxy, will eventually be used to elaborate on the stellar ages and on the impact of the UV flux on exoplanetary atmospheres. Additionally, we computed the NUV light curves of GCK objects. We detected strong NUV variability in several thousand objects and we present selected examples of light-curves of these variable sources.

Speaker: Emanuele Bertone (INAOE - Puebla)

17:19 **Globular Clusters Towards the Galactic Bulge: Results from Multiwavelength Follow-up Imaging** *2'*

The Galactic globular clusters (GGCs) located towards the bulge of the Milky Way suffer from severe total and differential extinction and high field star densities. They have therefore been systematically excluded from large-scale homogeneous GGC surveys, and will present a challenge for Gaia. Meanwhile, existing observations of bulge GGCs have revealed tantalizing hints they they hold clues to Galactic formation and evolution not found elsewhere. We describe deep, multiwavelength imaging campaigns targeted at poorly studied bulge GGCs, allowing us to place them in the context of their optically well-studied counterparts. We present results including self-consistent cluster ages and structural parameters, while highlighting limitations from spatially variable extinction and extinction law. Lastly, we discuss the complimentary nature of forthcoming facilities, which, together with our observations, will allow us to finally complete our picture of the Milky Way GGC system.

Speaker: Roger Cohen (STScI)

17:21 **Kinematic ages of moving groups - finally viable?** *2'*

Current kinematic age techniques have been demonstrated to be unreliable despite being one of the best means to ascertain ages of young ensembles of stars. Three factors impact the success of traceback ages: (1) imprecise kinematic data introduce significant positional uncertainties when traced back millions of years, (2) incorporating errors in a classical way drives the convergence point to occur at younger ages if at all, and (3) age fitting hinges critically on apriori definitions of known members. Future Gaia data releases along with ground-based RV surveys improve 6-D kinematic data in both quantity and precision, as well as providing abundance information and other age tracers. A Bayesian statistical analysis of the current data tackles the two remaining problems, by rigorously posing the question: given some model for the origin of these stars, how likely are we to observe these data. This method yields kinematic ages of the Beta Pictoris moving group resp. TW Hydrae Association of ~15 Myr resp. ~7 Myr. Modelling the origins of multiple moving groups simultaneously generates probabilistic membership lists from the data and removes membership list dependencies.

Speaker: Timothy Crundall (RSAA - Australian National University)

17:23 **The mass dependence of chromospheric activity evolution** *2'*

We know chromospheric emission decays over time, and yet this empirical relation is still fundamentally an interpolation over 3.5 Gyr from the Hyades to the Sun despite 45 years of progress. Furthermore, its very existence was called into question by Pace et al. (2004, 2009, 2013), who argued that activity plummets and flatlines at 1 Gyr. I will present new HK data for NGC 752 (1.5 Gyr) and Ruprecht 147 (3 Gyr), and ISM-corrected data for M67 (4 Gyr, Curtis 2017), and pair this with the Sun's re-calibrated history (Egeland et al. 2017) and data on field stars from the Keck exoplanet program. I find a mass dependence that supports the van Saders et al. (2016) scenario of weakened magnetic braking to explain the rapid rotation at old ages seen in the Kepler asteroseismology sample. HK emission does rapidly plummet for F stars as proposed by Pace, but continuously declines for G and K dwarfs to approximately 4 and 6 Gyr, respectively, similar to the van Saders magnetic braking timescales.

Speaker: Jason Curtis (Columbia University)

17:25 **Estimating ages, distances, masses and extinction for field stars** *2'*

Detailed studies of the Milky Way's stellar populations usually rely on indirect measurements of stellar distances, ages, masses and extinctions. Thanks to the availability of large stellar surveys, these parameters can be determined with unprecedented precision even for field stars. Using a Bayesian approach that can combine spectroscopic, photometric and astrometric data, we determine distances, masses, ages and extinctions for over about 800,000 stars contained in the RAVE, APOGEE, Gaia-ESO and GALAH surveys. Our code (called StarHorse; Santiago et al. 2016; Queiroz et al., in prep.) has been validated for simulated high-resolution spectroscopic samples and reference samples, yielding a median precision of 8% in distance, 20% in age, 6% in mass, and 0.18 mag in A(V) in the case of highest-quality data. We also present results from the first application of our code to the the combined APOGEE+Gaia dataset.

Speaker: Anna Bárbara de Andrade Queiroz (Universidade Federal do Rio Grande do Sul)

17:27 **Hunting for Brown Dwarfs in the Globular Cluster M4: Second epoch of deep near-IR observations** *2'*

Brown Dwarfs (BDs) present a link between stars and planets, and thus are important for our understanding of both star and planet formation and evolution. Large numbers of BDs have now been detected, but we still do not know much about OLD, METAL-POOR BDs. Globular clusters are the oldest, most metal-poor and most massive stellar aggregated in our Galaxy, and might have produced BDs in large numbers. Our first epoch NIR colour magnitude diagram (CMD) of the old (11.6 Gyr) globular cluster M4 revealed four faint sources that are located in the BD region of the CMD, but had no optical counterpart (i.e. they are not WDs), suggesting that we found four good BD candidates. The second epoch NIR HST data are currently been taken and analysis has already started. We will present the current status of this project and, most importantly, we will determine whether our BD candidates are indeed cluster members, and as such the first confirmed BDs in a globular cluster, or not.

Speaker: Andrea Dieball (University of Bonn)

17:29 **Testing models for stellar angular momentum evolution with K2 observations of Praesepe and the Hyades** *2'*

The oldest open clusters within 250 pc of the Sun, the Hyades and Praesepe, are important benchmarks for calibrating stellar properties such as rotation and magnetic activity. As they have the same age and roughly solar metallicity, these clusters serve as an ideal benchmark for stellar properties at ~600 Myr. We present rotation periods measured with the repurposed Kepler mission, K2, for 48 Hyads and 677 Praesepe members, including the first periods measured for fully convective Hyads. These data have enabled new tests of models describing the evolution of stellar rotation; discrepancies with these models imply that we still do not fully understand how magnetic fields affect stellar spin-down.

Speaker: Stephanie Douglas (Harvard-Smithsonian CfA)

17:31 **Statistical age trends of red giant stars determined through hierarchical modeling** *2'*

While detailed chemical abundances of stars are a very powerful tool for examining the evolutionary history of a galaxy, both simulations and observations are finding that abundances alone are not enough to break degeneracies in the proposed formation scenarios. To break these degeneracies, it is crucial that we also provide ages. By observing red giant stars in the near-IR, APOGEE has obtained the largest spatial spectroscopic coverage of disk stars to date. However, aside from time-consuming asteroseismic methods, ages are very difficult to determine for red giants. We have developed a hierarchical modeling method of determining statistical age trends for APOGEE giants with known distances. This method constrains the mean age and age dispersion of stars in a single abundance bin using the products of Bayesian isochrone matching. In this way, the full non-Gaussian age PDFs of the individual stars are used to determine the most probable properties of the mono-abundance sub-sample.

Speaker: Diane Feuillet (MPIA)

17:33 **The Effect of Combined Magnetic Topologies on Thermally Driven Winds** *2'*

Cool stars with outer convective envelopes are observed to have magnetic fields with a variety of geometries, which on large scales are dominated by a combination of the lowest order fields such as the dipole, quadrupole and octupole modes. Magnetised stellar wind outflows are primarily responsible for the loss of angular momentum from these objects during the main sequence. Previous works have shown the reduced effectiveness of the stellar wind braking mechanism with increasingly complex, but singular, magnetic field geometries. In this paper, we quantify the impact of mixed dipolar and quadrupolar fields on the spin-down torque using mixed field MHD wind simulations. Theses include a wide range of magnetic field strength and reside in the slow-rotator regime. We find that the stellar wind braking torque from our combined geometry cases are well described by a broken power law behaviour, where the torque scaling with field strength can be predicted by the dipole component alone or the quadrupolar scaling utilising the total field strength. The lowest order field component is found to be the most significant and we observe this to continue for higher order mixed field combinations.

Speaker: Adam Finley (University of Exeter)

17:35 **Brown Dwarf Binary Properties as a Function of Age** *2'*

The binary properties of old brown dwarfs are observed to be substantially different than in young clusters, with fewer companions and closer separations seen around older objects. Measuring the initial brown dwarf binary frequency is necessary to allow more realistic modelling for formation theories. Similarly, constraining binary properties at field ages is essential to understand the discrepancies observed and be able to predict the evolution and fate of binaries. In this talk, I will present results from an HST campaign compiled to look at the differences in the binary statistics as a function of age for the extreme low-mass end of the Initial Mass Function. Based on a Bayesian statistical analysis of companion population distributions, I will discuss the implications of observed disparities in substellar binary properties with age for formation and evolution models.

Speaker: Clemence Fontanive (University of Edinburgh)

17:37 **Intracluster Age Gradients And Disk Longevities In Numerous MYStIX And SFiNCs Young Stellar Clusters** *2'*

This study is based on YSO samples from the MYStIX and SFiNCs surveys, and a new estimator of pre-main sequence stellar ages, AgeJX, derived from X-ray and near-infrared photometric data. We present two main results here. First, the discovery of the core-halo age gradients (with younger cores and older halos) in numerous morphologically simple, isolated, and relatively rich stellar clusters. The observed spatio-age gradients can be explained within the framework of the global hierarchical collapse model. Second, the MYStIX+SFiNCs cluster surveys provide the largest cluster dataset to date to study circumstellar disk longevity in young (<=4Myr) clusters. By imposing similar stellar mass sensitivity limits for disky and diskless YSOs and assuming disk fraction of 100% at the zero age we estimate an exponential disk half-life of 2 Myr (based on AgeJX age scale). This value agrees closely with the results of a few previous works.

Speaker: Konstantin Getman (Pennsylvania State University)

17:39 **Age of Pre-Main Sequence stars from lithium: Bayesian analysis of young binary systems** *2'*

In principle the surface lithium abundance (A(Li)) of PMSlate-type stars can be used to derive stellar ages by means of evolutionary models. Unfortunately,the disagreement between predictions and observations does not confirm the method. Note that uncertainty on different input physics (eq.of state, nuclear cross sections.,.) and physics mechanisms (external convection,diffusion,..) lead to different predictions of A(Li). The possibility to date low mass PMS stars from A(Li) was tested on binaries whose common chemistry and age of components constraint the model s. By high-resolution spectroscopy we doubled our sample and derived stellar parameters solving the radiative transfer equation. To compute a suitable grid of models we implemented the Frascati Raphson Newton Evolutionary Code with the accurate Trojan Horse Method rates for Li reactions. Ages were determined by Bayesian analysis. The method, commonly adopted for systems with known masses, was extended to the most common SB2.

Speaker: Marina Giarrusso (Università di Catania)

17:41 **Exploring low and intermediate-mass binaries in the young cluster Westerlund 2 using HST** *2'*

We present preliminary results of an HST photometric and astrometric campaign aimed at probing the unexplored population of low and intermediate-mass binaries (P = ~2 days - ~200 years) in the young, massive cluster Westerlund 2 (Wd2). Over the next 3 years, we have a total of 45 orbits using the HST WFC3 instrument. We will be able to measure, for the first time, the separation, flux ratio and the angle of barely resolved short, intermediate and long period binaries in Wd2. We will discuss the properties of binary systems immersed in an environment that resembles the conditions of stellar density and UV radiation found during the early evolution of starburst galaxies and globular clusters and how the main orbital properties of the binary population in Wd2 can be used to constrain models of star and cluster formation and evolution. Our Point Spread Function (PSF) subtraction technique is presented to look for elongation and to compare to the variability uncovered through photometry.

Speaker: Christopher Johnson (Space Telescope Science Institute)

17:43 **The Ages of Rapidly Rotating A-Stars** *2'*

The rapid rotation of A-stars introduces two major difficulties when isochrone dating them. The oblateness and gravity darkening induced by rapid rotation affects the shape and temperature profile of the star. This rotation also changes how the star evolves and must be accounted for when choosing evolution models for comparison. Interferometric observations can address this first concern and modern evolutionary models that account for rotation can address the second concern. When used in conjunction, these yield accurate age estimates for rapidly rotating A-stars. Using observations from the CHARA Array and the MESA evolutionary models, we estimate the ages and masses of seven members of the coeval Ursa Major moving group. We also estimate the age of the directly-imaged planet host star kappa Andromedae with implications for the mass of its companion. Finally, I present new observations and preliminary age estimates for four stars with the lambda Bootis chemical peculiarity.

Speaker: Jeremy Jones (Georgia State University)

17:45 **Towards better understanding of multiple populations in star clusters of the Magellanic Clouds** *2'*

The advent of precision Hubble Space Telescope photometry has fundamentally changed the old concept of massive star clusters as simple stellar populations. It is now proven that essentially all old clusters (older than 9 Gyr) host multiple populations. Our efforts are currently shifted toward younger clusters which show the onset of multiple populations in the Red Giant Branch and other post-main-sequence features. We present the latest findings using a three-filter based pseudo-color index sensitive to multiple populations and also provide possible interpretation.

Speaker: Vera KOZHURINA-PLATAIS (STScI)

17:47 **Searching for Be Stars in the Open Clusters with PTF/iPTF: I. Cluster Sample and Be Star Candidates** *2'*

We conducted a search for Be stars in open clusters using Hα imaging photometry of the Palomar Transient Factory Survey, to investigate the connections between Be star phenomena and ages and environments of clusters. With carefully member identification, we discovered 96 Be star candidates in 32 clusters from 104 open clusters. These selected candidates and those known Be stars show a similar range of mid-infrared colors. The clusters with age 7.5 < log(t(yr)) 8.5 tend to have more Be star candidates; there is about a 40% occurrence rate within this age bin. More than 50% of the 32 clusters have Be fraction Be/(Be+B-type) < 10%, and the clusters with age 8.0 < log(t(yr)) 8.5 have the highest Be fraction. Regarding spatial distribution, Be stars are not centrally concentrated in the clusters and distribute uniformly.

Speaker: CHIEN-DE LEE (National Central University-Taiwan)

17:49 **Evolutionary status of isolated B[e] stars** *2'*

B[e] stars are the hot stars with forbidden lines in their spectra, which can be found in a wide range of stellar ages, from pre-main sequence objects to evolved stars. However, the evolution of most objects with B[e] phenomena are yet to be classified. We study a sample of eight B[e] stars with uncertain evolutionary status to shed light on the origin of their circumstellar dust. We performed a diagnostic analysis on the spectral energy distribution beyond infrared wavelengths, and conducted a census of neighboring region of each target to ascertain its evolutionary status.

Speaker: CHIEN-DE LEE (National Central University-Taiwan)

17:51 **The Solar Twin Planet Search: The age - chromospheric activity relation** *2'*

It is well known that the magnetic activity of solar type stars decreases with age, but it is widely debated in the literature whether there is a smooth decline or if there is an early sharp drop until 1-2 Gyr followed by a relatively inactive and constant phase. We revisited the activity-age (AC) relation through Mount Wilson (MW) Ca II H & K activity indices. We measure the activity indices using HARPS time-series observations of 79 solar twins with precise isochronal ages and physical parameters. New relations between activity and age of solar twins were derived assessing the chromospheric age-dating limits using MW metric. The Ca II H & K AC relation of solar twins evolves until 6 Gyr, in agreement with previous findings using open clusters. This confirms that Ca II H & K lines remain an interesting clock also for stars slightly older than the Sun. We are extending this analysis exploring the flux-flux and AC relations using other optical chromospheric sensitive lines.

Speaker: Diego Lorenzo-Oliveira (Universidade de São Paulo)

17:53 **Time evolution of high-energy emissions of low-mass stars: Fundamental parameters and Halpha & Ca II IRT age-activity relations** *2'*

The age-magnetic activity relations are an efficient alternative way of age-dating low mass dwarfs. Our goal is to establish new age-chromospheric activity relations for KM dwarfs. We secured high-resolution spectra for 100 stars, including a subsample of wide binary stars with well-known ages and members of young kinematic groups. We selected a subsample of M dwarfs with interferometric Teff estimates and related these quantities with spectral features in order to derive the atmospheric parameters for the entire sample. Based on PHOENIX models of stellar atmospheres, we derived a new scale of chromospheric fluxes for Ca II IRT and Halpha indicators. For Halpha and Ca II IRT lines, we found high age-activity correlations. Our method enables estimating chromospheric ages up to 7 Gyr within 0.15 dex of age uncertainty. We also found a promising agreement of our results in comparison to an independent sample of M dwarfs with known ages.

Speaker: Diego Lorenzo-Oliveira (Universidade Federal do Rio de Janeiro)

17:55 **Dating the Hyades cluster with the substellar lithium depletion boundary** *2'*

The lithium depletion boundary (LDB) is a reliable method to obtain ages for open clusters and stellar associations. So far it has been applied to clusters and associations younger than 150 Myr where the LDB takes place among the late-M type population. In older clusters the LDB is expected to move toward fainter luminosities and cooler temperatures, i.e. the realm of the L dwarfs. Using OSIRIS at the Gran Telescopio Canarias we have started a search for the Li~I 670.8~nm~ resonance doublet in L dwarfs with high probability of membership in the Hyades. In this presentation we show our first results which allow us to derive the first estimate of the Hyades age using the LDB method.

Speaker: Eduardo Martin (CSIC-INTA Centro de Astrobiología)

17:57 **Results from the Gaia-ESO and CoRoT collaboration** *2'*

I will present the results concerning the collaboration between the Gaia-ESO spectroscopic survey and the CoRoT mission. This collaboration allow to obtain spectroscopic and seismic parameters for ~1600 Galactic giant stars. I will discuss the procedure we used to derive the parameters with an excellent accuracy.

Speaker: Thomas Masseron (IAC)

17:59 **Ages of Six Bulge Globular Clusters and their Multiple Stellar Populations from the HST Large Legacy Treasury Program** *2'*

The HST Large Legacy Treasury Program (GO-13297, PI Piotto) is a UV-initiative proposal (WFC3/UVIS) to complement the existing optical database of the ACS Globular Cluster (GC) Treasury (GO-10775, PI Sarajedini). This unprecedented photometric database allows accurate and self-consistent determinations of ages, metallicities, distances and reddening values (by the analysis of optical CMDs), as well as a clear characterization of the multiple stellar populations presented in each cluster (using the UV "magic trio", very sensitive to the differences on the CNO abundances). Among the 57 observed GCs we selected six bulge GCs (NGC6304, NGC6624, NGC6637, NGC6652, NGC6717 and NGC6723) in order to study the formation and evolution of the innermost Galactic structural component. In this work we present our preliminar results from the analysis of multiband CMDs. All physical parameters are determined by applying statistical isochrone fits using recent theoretical stellar evolutionary models.

Speaker: Raphael Oliveira (Universidade de São Paulo (IAG/USP))

18:01 **The Lithium Depletion Age of the TW Hya Association** *2'*

The TW Hya Association (TWA) is the youngest of the nearby moving groups. In order to better constrain the age of this benchmark stellar association, we reexamine the Lithium depletion age for TWA. We adopt Lithium equivalent width measurements from the literature along with improved luminosity estimates based on newly available trigonometric distances. We correlate the observed Li depletion in our sample to those of published stellar evolutionary tracks to obtain the Li depletion age for TWA. We compare this Li depletion age to isochronal ages obtained from Hertzsprung-Russell diagram positions. We discuss the implications of an updated age for TWA and its role as the youngest of the nearby moving groups.

Speaker: Mark Pecaut (Rockhurst University)

18:03 **The Power of Combined Infrared and X-ray Data: Probing Stellar Ages in Obscured Massive Galactic Star-Forming Regions** *2'*

I will present two new techniques for constraining the evolutionary ages of intermediate-mass (2-8 Msun), pre-main-sequence stars (IMPS) in obscured, massive Galactic star-forming regions using combined infrared (IR) and X-ray photometry catalogs containing thousands of objects. High-spatial-resolution X-ray images identify IMPS that lack IR excess emission from circumstellar dusk disks. IMPS complete their evolution across the Henyey tracks to reach the ZAMS as AB stars in <10 Myr, hence placing them on the HR diagram by modeling IR SEDs gives a more robust constraint on (model-dependent) evolutionary age than is possible for lower-mass stars on Hayashi tracks. There is also mounting evidence that IMPS with GK spectral types produce intrinsic X-ray emission that rapidly decays with time following the development of a radiative zone, providing a second, independent age constraint. These techniques will be applied to calibrate star formation rates in high-luminosity Galactic regions.

Speaker: Matthew Povich (California State Polytechnic University, Pomona)

18:05 **The NGC6530 young stellar population in the context of the Lagoon Nebula** *2'*

Accurate knowledge of the amount of interstellar extinction and its properties are crucial to determine stellar masses and ages and to understand the star formation mechanisms. This can be challenging for young clusters such as NGC6530, hosted by the Lagoon Nebula, a very complex HII region illuminated by many O and B-type massive stars of the cluster. A detailed study on the complex dynamics of the gaseous component of this nebula, based on spectroscopic data of the Gaia-ESO Survey, has been very recentely presented by Damiani et al. (2017). We present the analysis of the stellar component observed with GES focusing on the reddening properties of members and non-members. We show that the reddening of the two stellar samples shows a spatial pattern that allows us to trace the nebular tridimensional structure of the dust component. We discuss the connections between the stellar population and the physical properties of the surrounding nebula through its gas and dust components.

Speaker: Loredana Prisinzano (INAF-Osservatorio Astronomico di Palermo)

18:07 **When the present meets the past: the LEGUS perspective on Star Formation of nearby galaxies** *2'*

The synthetic Color-Magnitude Diagram technique is a great tool to explore the detailed star formation history (SFH) of nearby galaxies and refine stellar evolution models by comparing them with the data. Within this framework, I will discuss the results obtained for galaxies of different morphological type which are part of the HST Legacy ExtraGalactic UV Survey (LEGUS), whose aim is to investigate and connect the different scales of star formation, from young stellar clusters to local Universe galaxies. Our targets were studied both in the UV and optical bands, in order to recover their SFH from very recent to older epochs and to understand whether and how the star formation process may depend on the morphological, dynamical and environmental properties of the galaxies.

Speaker: Elena Sacchi (Bologna University / INAF)

18:09 **Towards a relationship between stellar radial differential rotation and age** *2'*

Gyrochronology is an empirical relationship that describes the spin down of a star as it ages.This spin-down may occur through angular momentum loss via the stellar wind. Stellar dynamos drive this wind, and in Sun-like stars the rotational shear at the base of the convection zone is a candidate for the driver of the dynamo. We show that the asteroseismic signatures of rotation and rotation periods from surface variability of five Sun-like stars observed by Kepler agree within the uncertainties. This suggests that in these stars radial differential rotation is weak, similar to the Sun. Using these rotation periods, we also find significant discrepancies between ages from asteroseismology and gyrochronology relations, suggesting that stellar age estimation is problematic even for Sun-like stars. A more physical relationship may exist between the radial differential rotation gradient and the age of the star, however this is difficult to measure for individual Sun-like stars. We explore the prospect of constraining the radial differential rotation gradient using an ensemble of Sun-like stars. We find that with observations from the future PLATO mission we may be able to measure differences in the radial differential rotation gradient in ensembles of stars across the main sequence provided radial differential rotation gradient differ by more than twice that of the Sun.

Speaker: Hannah Schunker (Max Planck Institute for Solar System Research)

18:11 **Solar tests for new opacities** *2'*

Experimental results on radiative opacities (Bailey et al. 2015) suggest that commonly used radiative opacity calculations underestimate the true opacity at conditions similar to the base of the solar convective envelope. This hints at a solution to the solar abundance problem. New calculations of radiative opacities have become available: the new OPLIB opacities (Colgan et al. 2016) for stellar interiors, and OPAS (Mundet et al. 2015) for solar models. We use these new opacities to compute standard solar models and test them against helioseismic and solar neutrino data. While OPAS leads to solar models with low-Z that are globally in reasonable agreement with the data, OPLIB creates serious discrepancies between models and data, especially for the helium abundance and the 8B and 7Be neutrino fluxes. We stress that stellar models and isochrones based on OPLIB opacities should be fully tested if they are to be adopted as a next standard for radiative opacities in stellar models.

Speaker: Aldo Serenelli (Institute of Space Sciences- CSIC IEEC)

18:13 **The Period-Age Relation Derived from Cepheids in LMC Clusters** *2'*

Stellar evolution theory shows that massive stars evolve more rapidly than low mass stars reaching the instability strip at a younger age. The relatively low density of more massive stars also means that they will experience longer pulsation periods. Therefore long period Cepheids are of higher stellar mass than their short period counterparts hence they are younger. This mean that a period-age relation exists for Cepheids. Stellar clusters provide the ideal laboratory for calibrating the period-age relation as the distance, composition and age for each star is the same. Once the period-age relation in calibrated it allows us attribute an age to any Cepheid in the field. We will present an empirical Cepheid period-age relation derived from data we have obtained of young and massive clusters in the LMC using the Faulkes Telescope South at the Siding Spring node of the Las Cumbres Observatory. This will also be cross-calibrated with other available data of LMC clusters.

Speaker: Lawrence Short (Astrophysics Research Institute, Liverpool John Moores University)

18:15 **Substellar companions in the Orion Nebula cluster** *2'*

Young binary stars provide us with perfectly coeval pairs of stars, born in the same environment and with the same metallicity. Comparing their properties may thus provide key information on the early stages of stellar evolution, and constrain theoretical models developed to predict isochrones and evolutionary tracks during the Pre-Main-Sequence. We present new results relative to the population of substellar the binaries in the Orion Nebula Cluster. We studied HST data using a new analysis methods recently developed to detect close companions in the wings of the stellar PSF, in particular the pyKlip library of python modules. Starting from a sample of ~ 1000 individual stars (selected over a range of 11-15 mag), we were able to find ~ 60 candidates in a magnitude range of 16 - 23 mag; we use the presence of the 1.4 micron H2O absorption feature in the atmosphere to discriminate between substellar companions and more massive background objects

Speaker: Giovanni Maria Strampelli (STScI)

18:17 **A Poor Old Giant Singing Away** *2'*

HD122563 is a metal-poor ([M/H] = -2.5) old Population II star. It is one of the few nearby metal-poor stars that can be studied in detail. Such a benchmark star is important for understanding the physics of stellar atmospheres in the not-so-solar metallicity regime, understanding oscillations and stellar interiors in the context of metallicities, and providing a reference point for calibrating large galactic spectroscopic surveys such as Gaia. This star has been well studied using spectroscopic, photometric, and interferometric data. Since just over a year, we have been obtaining radial velocity data from the ground-based SONG Hertzsprung telescope with typically one point per night. We see clear evidence of oscillations and initial analyses point towards the global seismic quantity, numax, in clear disagreement with that predicted from the known radius and mass. We present the current status of HD122563 and our initial asteroseismic results.

Speaker: Frédéric Thévenin (OCA)

18:19 **Ages of field M dwarfs through accurate alpha abundances** *2'*

For M dwarf stars, stellar age is perhaps the most difficult fundamental parameter to measure. With main-sequence lifetimes much greater than the age of the universe, M dwarf ages cannot be derived by matching observables to model grids. M dwarfs can also maintain rapid rotation for several gigayears, complicating efforts to derive ages through gyrochonology. We present a novel approach to measuring ages of field M dwarfs based on the abundances of age-sensitive elements. Detailed chemical analysis of M dwarfs is complicated by the millions of molecular lines that dominate their spectra. We have developed a physically-motivated and empirically-calibrated method to measure the abundances of Fe and Ti in M dwarf from high-resolution NIR spectra. Our method employs M dwarfs with wide FGK companions to calibrate abundances derived from comparison to a grid of synthetic M dwarf spectra. The relative abundance of Ti (an alpha element) to Fe can be used to chemically age-date field M dwarfs.

Speaker: Mark Veyette (Boston University)

18:21 **The FunnelWeb survey: Young stars in the Solar neighbourhood** *2'*

An empirical age-activity relation is one of the most straightforward dating techniques for individual Solar-like and cooler dwarfs. While precise dating is not possible, an age estimate with typical 0.2 dex uncertainty is easily attainable from a single spectral measurement in the range from a few tens of millions of years up to a few gigayears. A model free and data-driven approach has been developed and successfully demonstrated in the RAVE database, using the Ca infrared triplet. I will present the FunnelWeb survey, which is an ambitious new spectroscopic project starting in October this year aiming to observe every Southern Hemisphere star down to magnitude G<12.5, with a focus on young and adolescent stars and M-dwarfs down to G=14.5. Efficient classification algorithms will help to detect all young dwarfs in the Solar neighbourhood, especially when combined with kinematic data. The age-activity relation using the Ca II H&K and Ca II IRT combined with the Lithium 6708A line, in addition to their precisely known orbits (Gaia), will provide not only a huge set of very young candidates for further follow-up studies but also an input catalog for the TESS exoplanet satellite.

Speaker: Marusa Zerjal (Australian National University)

Tuesday, 19 September 2017

09:00 - 12:45 Solar-type and low-mass stars and the connection to exoplanets

09:00 **Three questions about the ages of solar-type and low-mass stars** *15'*

Speaker: Othman BENOMAR (NYUAD)

09:15 **How accurate are asteroseismic ages for solar-type stars?** *30'*

In this talk I focus on the determination of ages of solar-like non evolved stars through asteroseismology. I will discuss the different methods that have been used in the literature for asteroseismic inference along with the assumptions that go into the modelling. I will also focus on the estimation of internal and external errors using the different methods. By comparing results from recent works on similar stars, I aim to highlight the possible origin of systematic errors and a more realistic precision that we can expect on stellar ages from asteroseismology.

Speaker: Orlagh Creevey (Observatoire de la Cote d'Azur), ***invited***

09:45 **Kepler's Eye on stellar spin-down** *30'*

Stellar rotation carries a wealth of information about stellar populations. In particular, the technique of gyro chronology was developed to utilize the spin-down of stars as a function of time as an indicator of stellar age. Gyrochronology has the potential to yield precise ages for large samples of stars, providing unprecedented chronological information for studies of the Milky Way and extrasolar planets. However, the technique is in its adolescence: it has been tested and validated under limited scenarios, but its weaknesses and limitations have hitherto been largely unexplored. With time-domain data from the Kepler mission we can address these gaps: we now have access to datasets of rotation periods for tens of thousands of stars, as well as independent asteroseismic ages and rotation periods for a few hundred old (main sequence) stars. I will discuss my comparisons of theoretical rotation models to these Kepler data, which have yielded unexpected insights into the rotational and magnetic lives of stars (and the Sun!), as well as a better understanding of the power and peril of gyrochronology as a tool.

Speaker: Jennifer van Saders (Observatories of the Carnegie), ***invited***

10:45 **Setting Stellar Chronometers: The PTF(+) Open Cluster Survey** *15'*

While we have known for 40 years of the existence of a relation between a solar-mass star's age, rotation, and magnetic activity, observational limitations have hampered the assembly of uniform samples of rotation and activity measurements for stars spanning a wide range of ages and masses. We are still far from being able to describe fully the evolution of either rotation or activity for stars of a given mass, or from being able to use rotation or activity measurements to estimate accurately the ages of isolated field stars. I will describe results from our efforts to assemble a complete sample of rotation and activity measurements for low-mass stars in six open clusters ranging in age from 35 Myr to 2.5 Gyr. Testing our data against theory will allow us to develop a better understanding of the age-rotation-activity relation for these stars from their arrival on the zero-age main sequence to when they are a significant fraction of the age of the Sun.

Speaker: Marcel Agueros (Columbia University)

11:00 **Brown Dwarfs as Clocks: The Age Distribution in the Solar Neighborhood** *15'*

Brown dwarfs cool for their entire lifetimes and, when they are young, overlap in luminosity with low-mass stars. This creates the mass-age-luminosity degeneracy that usually muddles observations of the field population of such cool objects. However, it also presents an opportunity for precise age dating when mass and luminosity are measured. We have recently used Keck and CFHT to measure individual dynamical masses and luminosities for a large sample of brown dwarfs, allowing new tests of substellar evolution and demographics. Our results enable a novel direct determination of the age distribution of field brown dwarfs with masses of 30-70 MJup and spectral types of L4-T5. We determine a median age of 1.3 Gyr that is somewhat younger than previous work but consistent with our population synthesis modeling of a constant star formation history modulated by dynamical heating in the Galactic disk over the past 10 Gyr.

Speaker: Trent Dupuy (Gemini Observatory)

11:15 **An Improved Age-Activity Relationship for Cool Stars older than a Gigayear** *15'*

Magnetic activity is crucial to the understanding of the potential habitability of exoplanets; the strong radiation emitted by a star can cause atmospheric mass loss from the exoplanet. Therefore, it is important to understand magnetic activity and its evolution with time. For solar and late-type stars it is known that they spin down over time due to magnetic braking, which has led to many studies concerning the evolution of stellar rotation and stellar activity with age. The majority of these studies construct a relationship that is only reliable for ages younger than a gigayear due to the difficulty of determining ages for older stars. However, it is now possible to study ages for a larger sample of stars through asteroseismology; opening up the possibility of stellar age investigations for stars older than a gigayear. In this presentation I will present a new and improved age-activity relationship and discuss the possible explanations for the change we see in the relationship.

Speaker: Rachel Booth (Queen's University Belfast)

11:30 **The Ages of the Lowest-Mass Stars and Brown Dwarfs: A Case Study of TRAPPIST-1** *15'*

Age-dating ultracool dwarf stars and brown dwarfs is a critical challenge as these sources are increasingly important for searches of habitable exoplanets. Traditional diagnostics of rotation and magnetic activity are stymied by the decoupling of magnetic field lines from neutral photospheres; spectral diagnostics of surface gravity and lithium depletion are limited to young brown dwarfs (ages < 200 Myr); and binary mass measurements are rare and require accurate evolutionary models. In this talk, I discuss the case study of the planet-host ultracool dwarf TRAPPIST-1, which had contradictory ages reported in the literature. By combining statistical constraints from the color-magnitude diagram, average density, lithium, surface gravity, metallicity, kinematics, rotation, and magnetic activity, we infer a concordance age of 7.6+/-2.2 Gyr. Metallicity and radius effects were significant in this determination. I conclude with ideas for developing age-dating techniques for ultracool dwarfs.

Speaker: Adam Burgasser (UCSD)

11:45 **The Age of Our Nearest Stellar Neighbor** *15'*

The Alpha Centauri triple system (A: G2V; B: K1V; C: dM6) represents an important rung on the stellar age ladder. The two sunlike stars, A and B, have a resolved visual orbit (80 year period), and decades of radial velocity measurements (in part from recent planet hunting, spurred by "Breakthrough StarShot," which aims to send a swarm of laser-propelled nanobots to the system before the end of this century). The accurately known distance, resolved orbit, modern RVs, and asterosiesmology has led to very precise determinations of the stellar parameters, perhaps the best for any star other than the Sun itself. Further, the slightly more massive A component is somewhat evolved, while its lower mass companion is firmly on the Main sequence. This lucky property of the binary allows stellar evolution modeling to pin down the age, as described by Flannery & Ayres in the late 1970's. I summarize the most recent age estimates, and how these fit in with the ultraviolet and X-ray activities.

Speaker: Thomas Ayres (University of Colorado)

12:00 **The ages and evolution of field M dwarfs from rotation, activity and kinematics** *15'*

The ages of M dwarfs in the field of the galaxy are challenging to determine. Consequently, the evolution of rotation and magnetism at field ages is difficult to investigate observationally. Here, we present 200 new rotation period measurements for fully convective M dwarfs in the Southern hemisphere, about half of which are longer than 70 days. We make use of this sample and of our compilation of H-alpha emission for nearby M dwarfs to explore two questions: 1) How does the active lifetime of M dwarfs change with stellar mass? And 2) Do M dwarfs undergo an era of rapid angular momentum evolution? We confirm that the activity lifetime increases with decreasing stellar mass, basing our age estimates on the W component of the space velocity. We show that the lack of M dwarfs with intermediate rotation periods that we previously identified is astrophysical in origin, supporting our hypothesis that M dwarfs rapidly spin down from 10-day to 100-day periods.

Speaker: Elisabeth Newton (MIT)

12:15 **Precise stellar ages as the key to exoplanet evolution** *30'*

The exoplanet field has made huge advances in planet characterization, atmosphere studies, and formation pathways. However, one crucial axis that is particularly hard to access when studying the evolution of exoplanets is the time axis. The physical means to get age information about exoplanet systems is through the age of the host star. A variety of methods has been employed to determine stellar ages, with particular recent progress in asteroseismology. But how precise do stellar ages need to be in order to allow inferences about exoplanet evolution? I will discuss time scales of different processes in exoplanet evolution, and how we can observationally study them. Examples include the properties of the star-planet system upon arrival on the main sequence, tidal shrinking of exoplanet orbits, and the erosion of exoplanet atmospheres.

Speaker: Katja Poppenhaeger (Queen's University Belfast), ***invited***

15:45 - 16:15 Solar-type and low-mass stars and the connection to exoplanets

15:45 **The effect of stellar ages and activity on the habitable zone and habitability of planets** *30'*

Host star has a crucial influence on the habitable zone and the habitability of a planet itself. Within our solar system, the evolution of the Sun over time has greatly affected the surface and atmospheric properties of rocky planets. A significant number of the host stars of exoplanets, particularly low-mass stars, are also active compared to the Sun. Determining accurate stellar ages and activity of host stars is critical in evaluating potential habitability of terrestrial exoplanets, and corresponding atmospheric characterization. In this talk, I will briefly review the current status of star-planet interaction and the effect on habitability, highlighting the needed measurements that could significantly help in advancing the search for habitable worlds.

Speaker: Ravi Kopparapu (NASA Goddard), ***invited***

16:15 - 19:30 Pre-main sequence stars and the connection to the formation and early evolution of stars and planetary systems

16:15 **Three questions about the ages of pre-main sequence stars** *15'*

Speakers: Lynne Hillenbrand, Robin Jeffries, Eric Mamajek (JPL/Caltech, University of Rochester)

16:30 **Testing the accuracy of pre-main sequence stellar models with rotation, inflation, and lithium abundances** *30'*

Accurate ages of young (≤ 100 Myr), solar-type stars are of central importance to many questions in stellar astrophysics. But current methods for dating these objects remain imprecise and mutually contradictory. Perhaps the most reliable method for cluster dating is the lithium depletion boundary technique, however the precision of individual Li-based stellar ages remains limited. An alternative comprises direct comparisons between stellar observables (e.g. Teff, luminosity, radius) and evolutionary models, but such models sometimes under-predict stellar radii by ~10%, thus leading to inaccurate age measurements. In this talk, I review the theoretical justification for treating Li as a sensitive age indicator and highlight recent results of pre-main sequence Li depletion. I also discuss the empirical evidence for radius inflation in active stars young and old, and review theoretical efforts to model this effect though internal magnetic fields and starspots, using Li as a constraint.

Speaker: Garrett Somers (Vanderbilt University), ***invited***

17:30 **Testing the early evolution of pre-main sequence stars** *30'*

Ages of pre-main sequence stars are notoriously uncertain, with implications for measurements of envelope and protoplanetary disk survival times and for quantifying star formation histories. In any given cluster, a spread of apparent ages may be caused by individual differences in stellar evolution, by observational errors, or by a real age spread. The ages of intermediate-mass and low-mass young stars inferred from HR diagrams also differ. In this talk, I will discuss how uncertainties in early accretion histories may affect the location of the stellar birth, how uncertainties in the internal structure affect the subsequent contraction, and how the latest stellar models improve their treatment of these processes. I will then describe how these models are being tested with empirical measurements of stellar masses and estimates of ages from population analyses from HR diagrams and Li depletion boundary.

Speaker: Gregory Herczeg (KIAA/Peking University), ***invited***

18:00 **Ages of pre-main sequence stars with the surveys Gaia/ESO and Gaia** *30'*

Age and masses of pre-main sequence stars are traditionally derived from photometric data using multi-band color-magnitude diagrams and evolutionary models. However, ages derived with this method are affected by several empirical errors not easy to estimate (binary, extinction/reddening, photometric variability, on going accretion, presence of protostellar disks) and depend on the modeling of physical processes not fully understood (opacities, magnetic activity, convection, accretion etc.). High resolution spectroscopy and astrometry can be used to provide alternative observational probes to improve evolutionary models and better understand errors (e.g. Li abundance, rotation, stellar activity, stellar kinematics). In this talk I will discuss recent results and possible future achievements from the high resolution optical spectroscopic survey Gaia-ESO and the Gaia space mission. The former is providing homogeneous astrophysical parameters (e.g. effective temperatures, gravities, Li abundances) for a large sample of star clusters well sampling the full age range between 1 and 100 Myr, while the latter can lead a revolution in stellar astronomy with a catalogue of precise astrometric, photometric and spectroscopic data for more the one billion of Galactic stars.

Speaker: Giuseppe Sacco (INAF - Osservatorio di Arcetri), ***invited***

18:30 **Constraints for the ages of pre-MS stars from asteroseismology** *15'*

Age is a fundamental tool to understand different phenomena in stellar astrophysics. But in the pre-main sequence (pre-MS) stages, the errors in age can be up to 100% as for example the ages of young clusters are typically given as 5 +/- 5 Myr. Asteroseismology of pre-MS stars can be used as a novel age indicator because the pulsations provide an observable that is changing sensitively and smoothly with age and is independent of distance. The analysis of the pre-MS stars' pulsation properties provides important constraints for the pre-MS lifetimes. Furthermore, measuring the evolutionary changes of the pulsation periods enables us to investigate the speed of early stellar evolution and test our current theoretical models. I will present the first measurements of evolutionary period rate changes for stars in the young cluster NGC 2264 and latest results illustrating how asteroseismology can constrain the ages of pre-MS stars.

Speaker: Konstanze Zwintz (University of Innsbruck)

18:45 **Stellar radius inflation in the Pleiades and consequences for the ages of low-mass PMS stars.** *15'*

The radius of a star is a critical output of stellar models. It sets the effective temperature at a given luminosity and hence the age of PMS stars inferred from their positions in the HR diagram. Observations of low mass binaries show that standard models under-estimate stellar radii; the suggested cause being magnetic activity inhibiting convection and/or blocking surface flux due to star spots. We have measured radius inflation of single, magnetically active low mass stars in the Pleiades by combining rotation periods from the K2 mission with new vsini measurements of ~200 low mass stars to determine average radii as a function of luminosity. Comparison with model isochrones at Pleiades age shows an over-radius 12+/-2% compared to standard models. If such radius inflation is also present in younger active low-mass PMS stars then current estimates of their ages and masses are underestimated and the ages of young clusters inferred from low mass isochrones should be up two times older.

Speaker: Richard Jackson (Keele University)

19:00 **Planet ingestion on a pre-main sequence star: the case of 2MASS J08095427−4721419 in the Gamma Velorum cluster.** *15'*

We performed a theoretical study of the effects of planet ingestion on the characteristics of a pre-MS star. We applied our analysis to the case of the Gamma Velorum cluster member 2MASS J08095427−4721419, which shows a peculiar over-abundance of metals with respect to the other cluster members. We analyzed the effects on the star of changing the characteristic of the accretion episode, namely the age at which the planet is ingested (t0), the planet mass and its chemical composition. We showed that the mass of the ingested planet required to explain the metals over-abundance increases by decreasing the age t0 and by decreasing the iron content of the planet. We also discussed the systematic errors in the inferred stellar mass and age when a grid of non-accreting models is used to recover the characteristic of a star that undergoes to a planet ingestion episode. Effects on the star are still visible long after the planet ingestion episode.

Speaker: Emanuele Tognelli (Università di Pisa/INFN)

19:15 **Assessing the ages of young moving group binaries** *15'*

Young moving groups (YMGs) are fundamentally important for constraining ages and evolutionary processes of young stars. As a consequence, constraining the ages of the groups themselves is of high priority. M-type stars offer an interesting path for this, since they remain in the pre-MS phase for ~100 Myr, comparable to the ages of YMGs, and thus are suitable for isochronal analysis. Dynamical mass in combination with bolometric luminosity offers particularly good isochronal prospects. Close binaries provide the possibility to constrain both of these properties, and are thus the most valuable targets available. Here I report on a campaign to monitor binaries in YMGs that have been spatially resolved in the AstraLux M-dwarf multiplicity campaign. The binaries are followed up both with AstraLux imaging for additional astrometry, and with a radial velocity campaign. I will present results on the most promising, most peculiar, and most devious cases in the sample.

Speaker: Markus Janson (Stockholm University)

Wednesday, 20 September 2017

09:00 - 12:45 **High- and intermediate-mass stars and the connection to clusters**

09:00 **Three questions about the ages of massive stars and of clusters** *15'*

Speakers: Conny Aerts, Selma de Mink, Elena Sabbi (Space Telescope Science Institute)

09:15 **Challenges for age-dating young stellar clusters** *30'*

Young massive clusters (YMCs) offer an exceptional opportunity to test our understanding of stellar evolution, due to the large numbers of stars in all phases of evolution. High precision CMDs of YMCs have shown unexpected features (e.g., extended main sequence turnoffs and dual main sequences), that originally were thought to suggest that large (100s of Myr) age spreads were present within the clusters. However, subsequent work has shown that stellar rotation is the most probably explanation. YMCs also offer our best hope in understanding the origin of the multiple populations phenomenon that is observed in (nearly) all ancient globular clusters. By using a ~2 Gyr YMC that displays multiple populations, we can test scenarios for their origin. By age dating both populations, an upper limit to any age difference of ~10 Myr can be placed. This calls into question models that invoke multiple generations of star formation within massive clusters as the origin of multiple populations.

Speaker: Nate Bastian (Liverpool John Moores University), ***invited***

10:15 **The mass discrepancy in massive eclipsing binaries and its effect on ages** *30'*

The mass discrepancy in binaries stands for the difference between the stellar component masses inferred from binary dynamics (dynamical masses), and those obtained from spectral characteristics of stars and evolutionary models (evolutionary masses). The discrepancy is a strong indication of our theories/models to contain shortcomings as the dynamical masses are strictly observational and model-independent. The problem is closely related to the problem of internal mixing in evolutionary models, where the overall mixing is typically mimicked by the substantially increased values of the core overshoot parameter, which has a large impact on the inferred ages of the stars. In this talk, we will present an overview of the current status of the research field and will propose a valid recipe of resolving the mass discrepancy problem.

Speaker: Andrew Tkachenko (Institute of Astronomy, KU Leuven), ***invited***

10:45 **The Initial-Final Mass Relation as an Input to Deriving Accurate Stellar Ages** *15'*

Modern studies of individual stellar populations are increasingly uncovering stars that reside in a wide range of evolutionary states and mass ranges. Soon to execute programs with the James Webb Space Telescope will link brown dwarfs to white dwarfs in the same color-magnitude diagrams! Over the past 15 years, our group has led a global study of the initial-final mass relation of stars to connect the properties of stars burning hydrogen today to their eventual end state. Our latest observations have significantly reduced the scatter on the relation at low and intermediate masses, and have provided new discoveries of >1 Msun white dwarf remnants in young star clusters to understand stellar mass loss and evolutionary timescales for massive stars. In this presentation, I'll describe how our latest initial-final mass relation is improving the derivation of ages for the most interesting local stellar populations.

Speaker: Jason Kalirai (STScI)

11:00 **Stellar Evolution with Open Clusters** *15'*

Accurate inference of stellar parameters and well-calibrated models are paramount to many fields in astronomy, including galactic archaeology and exoplanets. We use the framework developed as part of the MESA Isochrones and Stellar Tracks (MIST) project to compute a series of evolutionary models and assess the utility of various observational data sets for the task of constraining uncertain stellar physics parameters and inferring the properties of stars in open clusters. Using three well-studied open clusters as case studies, we demonstrate that a combination of well-calibrated models, high-quality data, and robust fitting tools are required for this task. We expect to be able to disentangle the subtle differences induced by the uncertain model parameters with a combination of exquisite photometry, distances, and membership identification for these nearby open clusters from Gaia in the next few years. With this approach, we hope to deliver sub-Gyr absolute age precision.

Speaker: Jieun Choi (Harvard University)

11:15 **First Spectroscopic Detection of Fast Rotating Stars in a Young LMC Cluster** *15'*

Young globular clusters in the Large Magellanic Clouds could provide insight into the problem of multiple populations found in Milky Way clusters. Photometric studies of young clusters have discovered an extended (broadened) main sequence turnoff (eMSTO) and a bifurcated main sequence. Isochrone fitting and broad and narrow-band photometry have suggested several explanations to account for these features: a range of ages, different rotation rates, or different metallicities. Our high-resolution spectra of eMSTO stars in NGC 1866 (200 Myr) mark the first direct detection of a population of rapidly rotating stars in a young globular cluster. Details of the population fraction, spatial distribution, and the presence of a non-rotating population will be discussed, as well as implications for a formation scenario.

Speaker: Andrea Dupree (Harvard-Smithsonian Center for Astrophysics)

11:30 **Ages of massive (B) stars: Effects of rotation and apparent age spreads** *30'*

In this talk, I will review how rotation affects stellar evolution. Particularly, I will discuss the effects of rotation on the internal structure of star and the uncertainties linked to its modelling. I will also discuss how rotation affects the stellar surface, and how this affects the stellar characteristics (Teff and L). Finally, I will put all of these effects together, and discuss the implications on stellar clusters, showing how a classical isochrone is modified due to rotation.

Speaker: Cyril Georgy (University of Geneva), ***invited***

12:00 **Ages of massive (O) stars: effects of mergers and rejuvenated binary products** *30'*

Except for the Sun, ages of individual stars can only be estimated from models or calibrations and are never of fundamental nature. Depending on the stellar type, stellar environment and method of the age inference process, age estimates are subject to various biases and uncertainties. In massive (O) stars, ages are usually estimated by comparing observables of stars such as luminosity, effective temperature and surface gravity to stellar models of single stars. The precision and accuracy of the inferred stellar ages are then thought to be dominated by intrinsic uncertainties of the applied stellar models and the statistical techniques used to match the observations to the models. Such age estimates are made under the fundamental assumption that stars have lived their lives as single stars. However, more than 70% of all O stars are members of close binary star systems and will exchange mass with a companion during their life, sometimes even leading to a merger of both stars. Binary products are rejuvenated and can appear as blue straggler stars. The apparent ages inferred for binary products from single star models are younger than their true ages and can therefore significantly bias inferences made from such objects. I will describe the rejuvenation process, discuss the impact of binary products on age estimates and highlight potential consequences for our understanding of stars and stellar populations.

Speaker: Fabian Schneider (University of Oxford), ***invited***

12:30 **CMD modelling with LEGUS: recent SFH of dwarf galaxies between 3 and 12 Mpc** *15'*

I will present the detailed recent star formation history (SFH) of dwarf galaxies between 3 and 12 Mpc from the Legacy ExtraGalactic UV Survey (LEGUS). This sample includes a variety of morphologies and densities, such as the diffuse and low density Holmberg II, the Magellanic irregular NGC4449 and the Blue Compact NGC1705. The SFHs are derived by comparing deep UV color-magnitude diagrams (CMDs) with state-of-the-art synthetic CMDs generated with the latest stellar evolution isochrones. I will discuss how these SFHs relate to previous optical studies and I will provide new insights into the evolution of two independent stellar chronometers, massive main-sequence and helium-burning stars. Systematics are evaluated using two independent sets of models: the MESA-MIST and PADOVA-PARSEC.

Speaker: Michele Cignoni (Università di Pisa/INFN)

21:30 - 23:00 Special talk

21:30 **The dawn of gravitational wave astronomy and the multimessenger Universe**

The detection of gravitational waves from the coalescence of binary black hole systems marked the birth of gravitational wave astronomy and opened a new chapter in the multimessenger investigation of the Universe. Among gravitational wave sources, mergers of compact objects with at least one neutron star are thought to be associated with electromagnetic transient phenomena (e.g. short Gamma Ray Bursts). Simultaneous observations of gravitational interferometers and ground-based or space telescopes will thus provide an unique opportunity to find the electromagnetic counterparts of these gravitational wave sources. The talk will discuss the latest results on gravitational wave searches, describe the electromagnetic follow-up campaigns, and highlight prospects and challenges of multimessenger observations.

Speaker: Massimiliano Razzano (Università di Pisa/INFN)

Thursday, 21 September 2017

09:00 - 13:30 Evolved stars and the connection to Galactic archaeology

09:00 **Three questions about the ages of evolved stars** *15'*

Speaker: Saskia Hekker (Max Planck Institute for Solar system research)

09:15 **How well can we determine ages from asteroseismology for giants?** *30'*

Asteroseismology is now delivering ages for red giants stars on a massive scale, and promises to set the standard for dating stellar populations as required to set up the chronology of the Milky Way disk formation. In this talk I will review the different observables and techniques involved in asteroseismic age determination for giants, focusing in the intrinsic precision and accuracy that can be achieved as well as the importance of setting the zero point of the asteroseismic age scale. I will discuss the main sources of uncertainty and the ongoing efforts for achieving an age precision as required for studies of our Galaxy.

Speaker: Victor Silva Aguirre (Stellar Astrophysics Centre, Aarhus University), ***invited***

09:45 **How old are the different components of the Galaxy and over what timespan did they form?** *30'*

Several all the processes at play in the formation of our Galaxy, such as gas accretion, internal secular evolution, and mergers. New data are unveiling the complexity and the interplay of the several stellar populations in each of the galactic components. A fully self-consistent model of the MW is still missing, but parallel efforts using different techniques have shown to be extremely useful in, at least, pointing out which would the best observational constraints to these models be. It is a consensus that the knowledge of ages for large samples of stars in our Galaxy is probably the most precious information in order to strongly constraint the different evolutionary paths of the different galactic components. In this talk I will discuss how current data for which age information is available have already contributed to our views of how the galaxy has formed. I will illustrate with examples for the Bulge, the thick and thin disks and the halo. I hope to convince our picture of how the MW formed its components is now getting much more clear. Still, a community effort to obtain ages for larger samples of stars, especially at old ages, is necessary. In this respect the Plato mission combined with ground-based spectroscopic surveys could play an important role, depending on the details on the targets and observational strategies made.

Speaker: Cristina Chiappini (Leibniz-Institut für Astrophysik Potsdam), ***invited***

10:45 **Can we really use chemical properties of red-giant stars as age indicators ?** *15'*

The cornerstone mission, Gaia, together with complementary surveys (CoRoT, Kepler, APOGEE, Gaia-ESO) will revolutionize our understanding of the formation and history of our Galaxy, providing accurate stellar masses, radii, ages, distances, as well as chemical properties for very large samples of stars across different Galactic stellar populations.To exploit all potential of the combination between spectroscopic and seismic observations, the population synthesis approach will be a very crucial and efficient tool. We develop the Besançon Galactic model (Lagarde et al 2017) for which stellar evolution predictions are included, providing the global asteroseismic properties and the surface chemical abundances of low- and intermediate-mass stars. For the first time, the BGM can explore the effects of an extra-mixing occurring in giant stars. Using this new version of the BGM, we attempt to evaluate the possibility of deriving ages and masses of clump stars from their chemical properties.

Speaker: Nadège Lagarde (Institut UTINAM)

11:00 **Testing asteroseismic ages of red giants in open clusters with isochrones** *15'*

Oscillating red giants in open clusters provide tight constraints for testing theories of stellar structure and evolution. Through their oscillation spectra it is possible to deduce their stellar parameters (asteroseismology), while at the same time the stellar properties can also be determined independently through isochrones. We aim to verify the asteroseismic ages, computed using the same set of isochrones (PARSEC) as used for the isochrone fitting, with the optimal isochrone. Additionally, we investigate the impact of the known ages and metallicities on the derived stellar masses. For this work, we use public data from Stetson (NGC 6791) and Hole (NGC 6819) for the isochrone fitting as well as high-precision long-term photometry obtained by the NASA Kepler space mission for the asteroseismic analysis.

Speaker: Nathalie Themessl (Max Planck Institute for Solar System Research)

11:15 **Stellar ages for galactic archaeology with K2 and TESS** *15'*

In this talk I will present the recent data analysis of the K2 Galactic Archaeology Program. I will include seismic inference of the stellar populations using spectroscopic data from the K2-HERMES survey. Finally, I will give prospects for what we can achieve for TESS in the frame-work of the TESS-HERMES survey, which has already observed about 30K stars in TESS' southern continuing viewing zone.

Speaker: Dennis Stello (UNSW Sydney)

11:30 **Star formation histories of dwarf galaxies in the local Universe** *30'*

One of the main applications of stellar evolution models and galactic archeology is the derivation of the star formation histories (SFHs) of nearby galaxies from the Color-Magnitude Diagrams (CMDs) of their resolved stellar populations. SFHs are a key ingredient to understand galaxy evolution in general. This research field has made a tremendous step forward with the advent of HST, and is likely to experience another quantum leap with JWST. I will review the current knowledge of SFHs in dwarf galaxies in the local Universe (i.e. within 20 Mpc) as derived by various groups with the synthetic CMD techniques. The impact of various sources of uncertainties (e.g. photometric depth and errors, reddening, binary stars, stellar evolution uncertainties, different SFH codes) will be discussed.

Speaker: Monica Tosi (INAF - Osservatorio Astronomico di Bologna), ***invited***

12:00 **Ages and the Assembly of the Milky Way** *30'*

In this talk I will discuss the unique insights provided by stellar ages on the build-up of the stellar halo and the disk of the Milky Way. I will present current ideas regarding the formation of these Galactic components and the progress that can be enabled by combining ages, abundances, and phase space information.

Speaker: Charlie Conroy (Department of Astronomy, Harvard University), ***invited***

12:30 **Rediscovering the Milky Way formation history with Gaia white dwarfs** *30'*

The vast majority of stars will become white dwarfs at the end of the stellar life cycle. These remnants are precise cosmic clocks owing to their well constrained cooling rates. Gaia Data Release 2 will detect up to 300,000 new white dwarfs, which will then be observed spectroscopically with WEAVE and 4MOST. By employing spectroscopically derived atmospheric parameters combined with Gaia parallaxes and the initial-to-final mass relation, white dwarfs can constrain the local stellar formation history in a rather direct way. In particular, by using only remnants more massive than about 0.7 solar mass, which come from progenitors with negligible main sequence lifetimes, we will obtain an exquisitely precise formation history for the last 12 Gyr. Alternatively, we will acquire very direct constraints on the ages of first disk/halo stars by looking at the coolest Gaia white dwarfs. One challenge will be to connect these results (within 50-500 pc) with larger scale Galactic evolution.

Speaker: Pier-Emmanuel Tremblay (University of Warwick), ***invited***

13:00 **Terzan 5: a site of recent star formation in the Galactic Bulge** *15'*

Two distinct populations with very different iron abundances, spanning a huge metallicity range (~1 dex) have been discovered in Terzan 5 (a globular cluster-like stellar system in the Galactic bulge). Thanks to the combination of AO-corrected ground-based observations and ultra-deep HST images, we have finally distinguished two MS-TO points, thus providing the age of the two populations: 12 Gyr for the most metal-poor component, and just 4.5 Gyr for the most metal rich one. Altogether these pieces of evidence demonstrate that Terzan5 is (1)the remnant of a massive system that was able to retain the iron-enriched gas ejected by violent supernova explosions and (2)a site in the Galactic bulge where recent star formation occurred. The striking chemical similarity between Terzan5 and the bulge stars opens the fascinating possibility it is the fossil remnant of one of the pristine massive structures that generated the bulge via repeated interactions and mergers.

Speaker: Emanuele Dalessandro (Università di Bologna)

16:00 - 19:30 Evolved stars and the connection to Galactic archaeology

16:00 **Temporal evolution of the elements in the context of GALAH: method description and preliminary results** *15'*

The field of Galactic archaeology is currently undergoing a revolution largely thanks to a new generation of ambitious spectroscopic surveys of >10e5 stars, such as APOGEE, GALAH and Gaia-ESO, producing copious amounts of high quality, high resolution observations. Galactic chemical evolution plays an important role in the interpretation and understanding of this expanding body of data, with the ultimate goal of probing the mechanisms of galaxy formation. I will present an overview of my work involving age/mass determination using a full Bayesian framework of isochrones fitting. Using this method, I derived ages and masses for a sample of 200000 stars using a combination of GALAH derived stellar parameters/abundances and Gaia-TGAS parallaxes (when available). I will present the reconstructed temporal evolution of elements such as Na,Mg,Al,Si,K,Ca,Sc,Ti,Cr,Fe,Ni,Cu,Ba and many more, and the implication of these trends in the context of chemical evolution and Galactic formation.

Speaker: Jane Lin (Research School of astronomy and astrophysics, ANU)

16:15 **Determining ages of asteroseismic targets: going beyond the use of scaling relations** *15'*

Asteroseismology allows us to measure the basic stellar properties of field giants observed far across the Galaxy. Most of such determinations are, up to now, based on simple scaling relations, involving the average large frequency separation (Dnu) and the frequency of maximum power (numax). In our work, we implement Dnu and the period spacing computed along detailed grids of stellar evolutionary tracks, into isochrones and hence in a Bayesian method of parameter estimation. Tests with synthetic data reveal that masses and ages can be determined with typical precision of 5 and 19 per cent, respectively, down to 3 and 10 per cent when we add independent information on the stellar luminosity. We also test this method to NGC6819 giants, found that the mean age, in agreement with other derivations, does not presents systematic differences between RGB and RC stars, but its dispersion is larger than expected, with the spread partially ascribable to stars that underwent mass-transfer events.

Speaker: Diego Bossini (University of Birmingham)

16:30 **Using asteroseismology to calibrate spectroscopic ages for giants** *15'*

Asteroseismology permits us to infer masses for large samples of evolved red giant stars, which have also been the subject of comprehensive spectroscopic surveys. There is a strong correlation between the C/N ratio, mass and metallicity; this permits us to assign spectroscopic ages linked to a physical mechanism (the first dredge-up), as opposed to being a correlation. In this talk I critically analyze the strengths and weaknesses of this approach. I demonstrate the importance of an absolute asteroseismic mass calibration for reliable ages. Independent chemical evolution checks on C/N in unevolved stars are important for constraining the mass dependence of the first dredge up. Mixing on the RGB is an important confounding factor in metal-poor giants, and I discuss its impact for solar abundance stars. Finally, I discuss the prospects for using C/N as an age diagnostic in core He burning stars, where the current mass need not reflect the initial one.

Speaker: Marc Pinsonneault (Ohio State University, Dept. of Astronomy)

16:45 **Constraints on models from the combined Gaia/ESO and Gaia surveys** *30'*

I will review the Gaia-ESO Spectroscopic Survey, focusing on its potential to deliver, in combination with Gaia data, a major advance in stellar age calibration.

Speaker: Sofia Randich (INAF - Osservatorio di Arcetri), ***invited***

17:15 **Alternative Stellar Evolutionary Paths in Open Star Clusters: Stars Whose Ages Aren't What They Seem** *30'*

Open star clusters long have been fundamental benchmarks for stellar age determinations. And yet roughly 25% of the evolved stars in older open clusters do not fall on single-star isochrones, and age determinations for them in isolation would fail. I will review the status of observations, and consequent understanding, of blue stragglers, yellow giants, sub-subgiants and other stars of interest in open clusters with ages greater than 1 Gyr, including recent results from the K2 campaign on M67. Their stories will begin with the well-identified binary populations among solar-type stars in these clusters, very similar to the field binary population in frequency and period distribution less than 10,000 days. It is inevitable that the evolution of the stars in many of these binaries will be affected by the presence of their companions, and follow alternative stellar evolutionary paths.

Speaker: Robert Mathieu (Department of Astronomy, University of Wisconsin–Madison), ***invited***

18:15 **Improved white dwarf cooling ages using asteroseismology and eclipsing binaries** *15'*

With relatively simple evolution dominated by cooling, white dwarfs are excellent chronometers. Soon, Gaia will uncover hundreds of thousands of new white dwarfs, allowing us to date distinct components of the Milky Way with unprecedented precision. In order to maximize our results we need a more complete understanding of the interior structure of white dwarfs, especially their range of envelope layer masses and core mass fractions. We can empirically address these questions with high-precision photometry, using both space-based asteroseismology and high-speed imaging of eclipsing binaries. I will present some of the most recent observational constraints from both techniques on the core composition and envelope masses of white dwarfs, the two most important parameters controlling the cooling rate of these stellar fossils.

Speaker: JJ Hermes (University of North Carolina at Chapel Hill)

18:30 **Refining stellar evolution with the time-implicit hydrodynamic code MUSIC** *15'*

We present the latest developments and scientific results from the compressible, hydrodynamic, time-implicit code MUSIC. MUSIC uses a preconditioned Jacobian-free Newton-Krylov method to efficiently model stellar interiors in 3D without being hindered by high memory requirements. MUSIC has realistic opacity and equations of state and is suited to low- to moderate-Mach number flows (1e-6 < M < 1). This makes it a versatile tool for investigating a range of phenomena in stellar astrophysics. After summarizing recent code development and benchmarking, I will present results of our first studies: accretion on young objects, which affects their age and evolution in the HR diagram; and convection in various types of stars. A major motivation for our MUSIC work is to derive new prescriptions for stellar evolution codes and therefore improve models which are widely used in stellar and galactic astrophysics. Our first applications show successful developments in this direction.

Speaker: Thomas Constantino (University of Exeter)

18:45 **Improving stellar models with 3D atmospheres** *15'*

One of the key ingredients when determining the ages of stars is one-dimensional numerical models of stellar structure and evolution. However, many of today's stellar models share common shortcomings. To address this, we have consistently implemented results from 3D simulations of stellar atmospheres into the stellar evolution codes: GARSTEC, ASTEC, and MESA. Our implementation substitutes the non-physical atmosphere with a more appropriate T-tau-relation -- which depends on the physical properties of the star -- to set up more realistic outer boundary conditions. Furthermore, to refine the treatment of convection, the mixing-length parameter is calibrated from the 3D simulations and changes as the star moves in the HR-diagram. We investigate the impact of our implementation on low-mass stars by examining their evolution, structure, and stellar oscillation characteristics. Furthermore, we analyse the impact on the temperature during evolution on the red giant branch.

Speaker: Jakob Mosumgaard (Stellar Astrophysics Centre, Aarhus University)

19:00 **Convective Core Overshooting and Ages: Probabilistic Constraints from Color–Magnitude Diagrams of LMC Clusters** *15'*

We present a framework to simultaneously constrain the values and uncertainties of the strength of convective core overshooting, metallicity, extinction, distance, and age in stellar populations. We then apply the framework to archival Hubble Space Telescope observations of six stellar clusters in the Large Magellanic Cloud that have reported ages between 1 and 2.5 Gyr. Assuming a canonical value of the strength of core convective overshooting, we recover the well-known age–metallicity correlation, and additional correlations between metallicity and extinction and metallicity and distance. If we allow the strength of core overshooting to vary, we find that for intermediate-aged stellar clusters, the measured values of distance and extinction are negligibly effected by uncertainties of core overshooting strength. However, cluster age and metallicity may have disconcertingly large systematic shifts when the overshooting extent is allowed to vary by more than 0.05 Hp. Using the six stellar clusters, we combine their posterior distribution functions to obtain the most probable core overshooting value, 0.500-0.134+0.016Hp, which is in line with canonical values.

Speaker: Leo Girardi (Osservatorio Astronomico di Padova)

19:15 **High-precision binary parameters for calibrating stellar evolutionary models.** *15'*

Detached eclipsing binary systems are often used to calibrate stellar evolutionary models, but require high precision to constrain free parameters such as convective overshooting and helium abundance. While overshooting can be constrained using asteroseismology, it is not currently possible to detect pulsations in all types of stars. Helium abundance can only be directly measured in hot stars. We present the results of two newly discovered binary systems, with masses determined to better 1% precision. These systems both contain a sub-giant component, which allows the age of the systems to be pinned-down. Together with high-precision stellar parameters, this can help constrain the free parameters, as was shown for the systems AI Phe and LL Aqr. In addition, one system appears to show delta Scuti pulsations, which would allow the internal structure of the pulsating star to be probed.

Speaker: Jessica Kirkby-Kent (Keele University)

Friday, 22 September 2017

09:00 - 12:30 Stellar models and their limitations

09:00 **Three questions about stellar models** *15'*

Speakers: Yveline Lebreton (Paris Observatory), Marc Pinsonneault (Ohio State University)

09:15 **From micro- to macrophyisics: the status of stellar models for solar-like stars** *30'*

Recent years have seen new developments of microphysics inputs such as radiative opacities and nuclear reaction rates, as well as qualitative advancement in modeling of macroscopic processes such as radiation hydrodynamics simulations of near surface convection. Moreover, new tools such as asteroseismology open up the possibility of obtaining empirical measurements to poorly constrained physics such as (convective core overshooting) or even chemical composition (helium in particular) of low mass stars. In this talk, I will try to present a comprehensive overview of all theoretical and observational developements and how they impact the modelling of low-mass solar-like stars, focusing mainly, but not only, on the main sequence phase.

Speaker: Aldo Serenelli (Institute of Space Sciences (CSIC-IEEC)), ***invited***

09:45 **Stellar models and their limitations: the abundance scale** *30'*

In order to derive the chemical composition of a star, observed spectra are compared to theoretical synthesis and to compute theoretical spectra the stellar atmosphere needs to be modelled. Several grids of stellar models are available as also several codes to compute them. The use of different models can imply differences in the abundances derived. We will discuss the limitations and differences in the stellar models and also the limitations due to observations.

Speaker: Elisabetta Caffau (OBSPM), ***invited***

10:45 **Opacity data for stellar models and its uncertainties** *30'*

Laboratory experiments have found iron opacity predictions are notably different from measurements performed at conditions similar to the boundary between the solar radiation and convection zone [Bailey et al., Nature (2015)]. The measurements help resolve discrepancies between helioseismology and solar models. However, it is essential to understand the difference between opacity predictions and measurements. New measurements with chromium, iron, and nickel are providing a systematic study of how opacity changes with temperature, density, and atomic number. This helps further evaluate experiment error possibilities and constrain hypotheses for opacity model refinements. ++ Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Speaker: James Bailey (Sandia National Laboratories), ***invited***

11:15 **Nuclear reaction rates in stellar conditions as input for stellar models** *30'*

Nuclear reaction rates in stellar conditions, or close to, are among the key parameters for stellar models. In the last 2-3 decades, huge efforts have been dedicated to their experimental determination with the least feasible uncertainty. In particular, Hydrogen burning key reactions belonging to pp chain and CNO or successive cycles (NeNa, MgAl) have been measured. In this talk, after a general introduction on the main challenges of nuclear astrophysics, the present status of the art for the knowledge of reaction rates will be reviewed, with some specific examples. Moreover, the future possibilities of investigating Helium and Carbon burning reaction rates will be described.

Speaker: Alessandra Guglielmetti (Università degli Studi di Milano and INFN Milano), ***invited***

11:45 **Ages and age spreads in young and old massive clusters** *30'*

In this talk I will touch the connection between two different problems: 1) the presence of `multiple stellar populations' in Galactic Globular Clusters, testified by the presence of stars with important differences in the abundances of light elements in these systems, but not among the halo field stars, requires the formation of "second generation stars". How long is the time span required to produce the chemical anomalies? This depends on the different scenarios proposed. 2) Young Massive Clusters (YMC) in the Magellanic Clouds display extended turnoff regions: are these the signature of an extended period of star formation, and which is the age spread required? And is this the same phenomenon of which we see the signature in old GCs? Recently, the youngest among YMC were shown to host not only extended turnoffs, but also a "split" main sequence (MS), which is not compatible with an interpretation in terms of age differences, but is well understood in terms of different rotation of the component stars, being the blue MS stars slowly rotating and the red MS highly rotating. This has gained also observational support. In addition, the presence of possibly "younger" blue MS stars can be interpreted in terms of coeval stars whose initially rapid rotation has been braked. Therefore, prolonged star formation in young massive clusters is not the solution for the multiple population problem in old GCs.

Speaker: Francesca D'Antona (INAF - Osservatorio Astronomico di Roma), ***invited***

12:15 **conference close and farewall** *15'*