HRMOS science workshop

Monday, 18 October 2021 - Friday, 22 October 2021

INAF Osservatorio Astrofisico di Arcetri (Italy) and online

Programme

Monday, 18 October 2021

Day 1: Day 1 (09:00 - 13:05)

-Conveners: Gayandhi De Silva

Introduction to the project (09:00)

Presenter: RANDICH, Maria Sofia (Istituto Nazionale di Astrofisica (INAF))

The VLT in the 2030's (09:15)

Presenter: Dr MERAND, Antoine (ESO)
By the year 2030, ESO's ELT will be in full operation. The VLT, on the other hand, will remain Europe's workhorse for ground base optical and infrared astronomy. The four 8-m telescopes, offering standalone, incoherent and coherent (i.e. interferometric) foci, is a unique facility now and will remain so for decades to come. I will present the current state of instruments occupying VLT various foci, as well as the planned developments (upgrades or upcoming new instruments). I will also present the developments which followed the June 2019 workshop "The VLT in 2030", as well as the prospects to start future developments.

Probing the origin of globular clusters and their multiple stellar populations: the key role of HRMOS (09:40)

Presenter: D'ORAZI, Valentina (Istituto Nazionale di Astrofisica (INAF))
Despite the tremendous amount of spectroscopic data available for Galactic globular cluster stars, several fundamental questions regarding their complex formation and evolution remain yet unanswered. In the general framework of multiple population (generation?) scenarios, an extensive comprehension of the stellar source of pollutions (and its relationship with global cluster parameters) is still not in hand. Next-coming surveys (already well defined) such as WEAVE, 4MOST, SDSS-V, or MOONS will probably not be providing fundamental clues in this respect, because of their limited resolution, spectral coverage, or a combination of both. In this talk, I will focus on the critical role that will be played by HRMOS, in particular for the combination of light (including lithium) and heavy element abundances (up to lead), which are almost unexplored so far.

HRMOS and metallicity variations in globular clusters (10:05)

Presenter: MARINO, Anna (Istituto Nazionale di Astrofisica (INAF))
The presence of more than one stellar population in globular clusters (GCs) is one of the most intriguing topics in the field of stellar populations. Recently, we have understood that the properties of the different populations are best constrained by precise chemical abundances coupled with the nicknamed "Chromosome Maps" photometric diagram. Reading the "Chromosome Maps" by using the chemical abundances it resulted that, contrary to what commonly believed, a significant fraction of GCs may host stellar populations with different metallicity and heavy element chemical abundances. If all these objects will be confirmed to host stellar populations with different heavy elements abundances, then we have a quite high frequency of Omega Centauri-like GCs. These objects have experienced a more complex star-formation history, and might be associated with former dwarf galaxies. One of the most shocking discoveries is perhaps the apparent metallicity inhomogeneity of even the first stellar population, i.e., that one with elemental ratios similar to that of halo field stars. I will present the latest results on how to read the GC Chromosome Maps in terms of chemical abundances. I will focus on the most intriguing features observed on the maps, namely the features that can be interpreted as proxies of metallicity variations and how future HRMOS observations will provide important steps forwards in this context.

Another brick in the bulge: On the nature of the globular cluster Palomar 6 (10:20)

Presenter: SOUZA, Stefano (Universidade de São Paulo - IAG-USP)
To decipher the history of the Galactic bulge is a tricky task because of the complex stellar populations that live there from other components of the Milky Way. In particular, the globular clusters are fundamental pieces to reconstruct that history since they retain the chemodynamical signatures of the early stages of the Galaxy. In this context, we have the globular cluster Palomar 6 (Pal6), which is in the direction of the Galactic bulge, a region strongly affected by extinction. From high-quality data of Pal6, we found that it has a similar chemical pattern observed for the genuine bulge globular clusters. Also, Pal6 seems to have a second

population of stars making it a Type I globular cluster. The analysis confirms that Pal6 is confined in the inner region of the Galaxy. Moreover, we concluded that Pal6 was probably formed in situ. Therefore, we can say that Pal6 is a genuine Type I bulge globular cluster that has been there since the beginning of our Galaxy.

Black holes in star clusters (11:20)

Presenter: GIELES, Mark (ICREA & ICCUB)
Black holes in star clusters Stellar-mass black hole candidates have been reported in several Milky Way globular clusters, based on either accretion signals or radial velocity variations of companion stars. These individual black holes probably represent much more abundant populations of black holes. Charting the demographics of black holes in clusters helps to understand the contribution of dynamically formed binary black hole mergers to the rapidly growing number of gravitational wave detections. In this talk I will discuss ongoing and future mass modelling efforts to infer the presence of black hole populations in star clusters.

Simulating Globular Cluster Dynamics with HRMOS (11:45)

Presenter: BAUMGARDT, Holger (University of Queensland)
Globular clusters are excellent laboratories to study star formation and the early evolution of galaxies since they contain large samples of equidistant stars with similar ages and chemical abundance patterns. In addition, their high stellar densities make them unique environments for the creation of exotic stars like low-mass X-ray binaries, millisecond pulsars and merging black hole binaries. A full understanding of globular cluster dynamics requires combining the best available photometric information with kinematic data (proper motions, radial velocities) and theoretical models.In my talk I will give examples of what has been learned in recent years about the formation and evolution of globular clusters and discuss how future instruments like HRMOS can enhance our understanding.

Open clusters science with HRMOS (12:10)

Presenter: SPINA, Lorenzo (Istituto Nazionale di Astrofisica (INAF))
Open star clusters are unique tracers of the Galaxy evolution and excellent laboratories to study stellar physics. The huge volumes of data produced by current (and future) low- and medium-resolution surveys are expected to push these fields forward. However, at the end of this decade there are going to be gaps in knowledge that can be filled through complementary high resolution data. Here I discuss potential 2030s science projects in the field of open clusters for a new high-resolution, multi-object spectrograph with a large observational spectral window.

The chemical composition of young open clusters: is it real or not? (12:35)

Presenter: BARATELLA, Martina (Università degli studi di Padova)
In the last 15 years, several spectroscopic investigations seem to indicate an anomalous chemical composition of young Galactic open clusters and star-forming regions, which include (but is not limited to) sub-solar iron (Fe) abundances of these systems in the solar neighborhood, extreme and unexpected barium (Ba) enhancements (with apparently solar values of lanthanum, La), and super-solar abundances of some atomic species (e.g., ionized chromium). Different independent studies have demonstrated that in such young stars, the higher levels of stellar activity can alter the spectral line formation and, consequently, the derived atmospheric parameters and abundances. These results have drawn attention to the necessity to revise the spectroscopic analysis technique used for very young stars. In this talk, I will present you a new spectroscopic approach (based mainly on Ti lines) developed to overcome the effects of the increased stellar activity that affects the analysis of very young (ages less than 200 Myr) stars. Moreover, I will present to you the outcome of my study on the abundances of the $s-$process elements (Cu, Sr, Y, Zr, Ba, La, and Ce) and their time evolution. I will discuss the results and the scientific implications on stellar properties and Galactic evolution models. I will also address the importance to understand deeply these aspects in light of the data produced on an industrial scale by the concluded, ongoing, and future large spectroscopic surveys.

Kinematic studies of stellar systems with HRMOS (12:50)

Presenter: SACCO, Giuseppe Germano (Istituto Nazionale di Astrofisica (INAF))
Star clusters and dwarf galaxies are powerful astrophysical laboratories to address several open issues in modern astronomy, ranging from stellar evolution to cosmology. Stellar kinematics is a unique tool in this context. In particular, precise and accurate

stellar velocities allow us to measure the mass of a stellar system (including its dark components and their spatial distribution), to determine membership of stars, to detect and characterise binaries, to explore the individual dynamics of different populations within a system, and to study the connection between its present properties and past evolution. Kinematic studies of nearby stellar systems have been recently boosted by astrometric data from the Gaia space mission and radial velocities from multi-object spectrographs (MOSs). However, the precision of the current and next generation of MOSs is limited to 300-500 m/s and Gaia can measure tangential velocities with errors below ~100 m/s only within a 1-2 kpc. HRMOS will allow us to perform kinematic studies with a precision of ~10 m/s in objects located at larger distances. In this talk, we will show how HRMOS can improve our understanding of the properties and the origin of star clusters and dwarf galaxies discussing a few specific science cases.

Tuesday, 19 October 2021

Day 2 (09:00 - 13:00)

-Conveners: Magrini, Laura (Istituto Nazionale di Astrofisica (INAF))

Neutron-Capture elements with HRMOS (09:00)

Presenter: CESCUTTI, Gabriele (Istituto Nazionale di Astrofisica (INAF))
Recently, we have studied barium lines in high-quality spectra of two metal-poor giants in the Galactic halo. The hyperfine splitting effects on the barium lines seem to confirm the theoretical expectation that both r-process events and also s-process contribution by rotating massive stars have polluted the ancient halo of our Galaxy. Nowadays, this kind of result can be achieved only for a tiny fraction of Galactic stars and future surveys cannot tackle this problem due to the low resolution (<30’000) of their spectra. Only HRMOS with its unparalleled capabilities will allow to change this situation and provide the final answers to the origins of the Heavy elements.

CNO isotopes evolution with HRMOS (09:25)

Presenter: ROMANO, Donatella (Istituto Nazionale di Astrofisica (INAF))
The abundances of CNO isotopes provide powerful diagnostics of different physical processes acting in stars and galaxies. In particular, carefully chosen isotopic ratios allow us to set useful constraints to galactic chemical evolution (GCE) models, with special regard to the shape of the integrated galaxy-wide stellar initial mass function. After a brief recap of the significance of the CNO isotopes for GCE studies, I will discuss the possible impact of the HRMOS facility. I will highlight synergies and complementarity with current and planned instrumentations such as, for instance, the iSHELL spectrograph on the NASA Infrared Telescope Facility or the future HIRES spectrograph for the ELT.

Synergy between asteroseismology and high-resolution spectroscopy (09:40)

Presenter: CASALI, Giada (Istituto Nazionale di Astrofisica (INAF))
In the last few years, the synergy between spectroscopy and asteroseismology was key to the improving the precision and accuracy of the inferred stellar properties (surface gravity, effective temperature, chemical composition, radius, mass, age). For instance, given the difficulties associated with measuring log g via spectroscopic analyses, large-scale spectroscopic surveys have now systematically included solar-like oscillating stars among their targets, as key calibrators of surface gravity. A spectroscopic follow-up of targets with asteroseismic constraints by HRMOS (including targets of the ESA M3 mission PLATO) will not only be beneficial to the calibration of spectroscopic analysis procedures but will also allow precise chemical abundance determinations that are key to inferring precise stellar properties (in particular age), to test stellar models, and, notably, for informing models of Galactic chemical evolution and to help identify populations of stars with a common origin.

Simulations of stellar atmospheres and spectra of the future (09:55)

Presenter: NORDLANDER, Thomas (Australian National University)
New spectrographs like HRMOS hold great promise to provide high-precision abundance measurements through high-resolution spectra of dozens of stars at a time. However, the chemical composition of stars cannot be directly measured from their spectra, but must be estimated through comparisons to theoretical radiative transfer calculations. At present, shortcomings in this theory are holding back the progress of new instrumentation. Two approximations are common in the study of FGK-type stars: the use of one-dimensional (1D) hydrostatic model atmospheres, and local thermodynamic equilibrium (LTE). Both assumptions can lead to significant inaccuracies, especially at low metallicity and in giant stars. Each approximation can be tackled separately, and grids of 1D non-LTE or 3D LTE spectra have become available in recent years. However, the effects do not "stack", and the combined 3D non-LTE problem is in most cases prohibitively expensive. I will present recent progress and plans for future grids of cutting-edge 3D model atmospheres and 3D non-LTE synthetic spectra for elements of key astrophysical importance including iron.

High resolution spectroscopy, stellar nucleosynthesis, Galactic populations, spectroscopic surveys, exoplanet studies and stellar atmosphere modelling. (10:20)

Presenter: MASSERON, Thomas (Instituto de Astrofísica de Canarias)

High resolution spectroscopy has fundamentally shaped my scientific career and has consequently become my stock in trade. I will present several benchmark examples of my work with high resolution spectroscopy of stellar spectra (a definitely biased point of view but which became relatively extensive overtime), illustrating the needs and requirements for future high resolution spectrographs and in particular for HRMOS. I will notably mention metal-pool stars studies and early stellar nucleosynthesis, Galactic chemical evolution and chemical tagging of Galactic populations, the importance of determining stellar ages via chemical analysis only but also how internal mixing processes in giants can be constrained, globular clusters and the chemistry of their multiple population, chemical outliers and in particular the mystery of the phosphorus-rich stars as well as my recent implication in works with exoplanet studies. Moreover, I will show how all those examples are also tightly intertwined with data coming from large spectroscopic surveys (e.g. APOGEE and Gaia-ESO), but also how the analysis of high resolution spectra is completely determined by our ability to model stellar atmospheres and compile high accuracy atomic and molecular data.

Dynamos, Magnetic Activity and Doppler Tomography: Young stars with HRMOS (11:20)

Presenter: JEFFRIES, Robin (Keele University)

In their youth, low-mass (0.1-1.5 Msun) stars are rapidly rotating, magnetically active and may be accreting gas from a circumstellar disk. As they age, planets form and possibly migrate, disks disperse and stars spin down, becoming less magnetically active. The magnetic field, generated by a rotation-driven dynamo process, plays a key role in all of these events; the stressing and twisting of buoyant magnetic fields by differential rotation and turbulence leads to manifestations such as starspots, chromospheric and coronal heating and prominences; the magnetic field can couple to the stellar wind or surrounding accretion disk to regulate and lose angular momentum, which in turn feeds back into the dynamo. HRMOS offers a unique opportunity to provide long-term monitoring and Doppler imaging of the surface and coronal magnetic activity, prominences and starspot patterns of large samples of stars in open clusters at a variety of well-determined ages. I will describe some of the science goals and the technical requirements of such a project.

Young stars and disk interaction (11:45)

Presenter: NISINI, Brunella (Istituto Nazionale di Astrofisica (INAF))

Young stellar objects are characterised by highly dynamical processes related to the interaction of the still accreting star and its proto-planetary disk. These include accretion of matter, funnelled through magnetic field lines from the disk to the stellar surface, as well as mass ejection in the form of collimated jets and disk winds, responsible for the disk dissipation and removal of angular momentum. The spatial scales of the inner star-disk interaction region (i.e. within 1 au) cannot be directly resolved, however the relevant processes can be individually investigated through high resolution spectroscopy. In particular, spectroscopic surveys of YSOs in young clusters can provide observational foundation to the magnetospheric accretion paradigm and help in the understanding of how the accretion and ejection properties evolve with time and depend on stellar properties (such as mass, luminosity, age, metallicity). In this contribution, I will address the potential of a facility like HRMOS for the above science and which are the needed instrument requirements.

New candidates for chromospherically young, kinematically old objects (12:10)

Presenter: MACHADO PEREIRA, Eduardo (Observatório Nacional do Rio de Janeiro)

One method to estimate stellar ages is based on the so-called chromospheric activity (CA), according to which we can infer that chromospherically active isolated objects must be young. At the same time, stellar orbits in the Galaxy give rise to a statistical relationship according to which anomalous velocities are probably associated with old stars. This work was built in function of objects with high CA (supposedly young) that exhibit high components of space velocities (supposedly old); we call these objects chromospherically young and kinematically old, or CYKOs. We built a sample with 4401 stars with known chromospheric activity and space velocities available through data from the Gaia mission. By applying a formalism proposed in a work that we revisit here, we selected 84 CYKOs objects in order to analyze their amount of lithium, which is sensitive to ages since it is consumed in the stellar interiors over time. Noting the absence of this element in these objects, we tested whether a scenario of smooth coalescence between the components of a short-period binary is feasible to explain their formation. The result of this process would be an isolated star that has already orbited the galactic center enough to present velocities typical of an old object, but still active due to the interaction between the components of the system. Through spectroscopic observations and archive spectra, we found 14 stars whose amount of lithium attests to this scenario, doubling the number previously presented in the literature. In addition, another formation scenario is also preliminarily addressed, and we found 2 CYKOs objects from our sample that are actually companions of white dwarfs. Both hypotheses explore the idea that these stars had their chromospheric activity fueled as they aged.

Transiting Planets in Crowded Places (12:25)

Presenter: MONTET, Benjamin (University of New South Wales)

HRMOS will enable radial velocity searches for planets in clusters and towards the Galactic bulge at a scale previously unobtainable with single-object spectrographs. At present, the most comparable cluster planet searches have been for transiting planets with wide-field cameras. We have led a transiting planet search using data from the Kepler telescope towards NGC 6791, an old, metal-rich cluster. I will present the demographics of the planets found in this search and their host stars, highlighting what this search can teach us about similar future surveys with HRMOS and some of the unique benefits HRMOS will provide. I will also discuss the expected yield of transiting planets to be found in the Roman Space Telescope microlensing survey of the Galactic bulge, and how HRMOS will be able to work in concert with data from that mission to fully understand the Galactic distribution of planetary systems.

Testing fundamental physics with HRMOS spectra of solar twin stars (12:40)

Presenter: MURPHY, Michael (Swinburne University)

I will present a new probe of possible variations in the fine-structure constant on Galactic size-scales: solar twins and analogues. This method has been demonstrated on local solar twin spectra from ESO HARPS. We have also recently discovered much more distant solar twins, 4kpc closer to our Galaxy's centre, where the dark matter density is 3 times higher than the local environment. ESPRESSO on the VLT offers the opportunity to observe these distant twins to probe any connection between the dark sector and variations in the constants of nature beyond the Standard Model of particle physics. HRMOS's multiplex advantage over ~25 arcmin scales promises a highly efficient means to gain an order of magnitude in precision, down to the ~20 parts-per-billion level – a truly stringent test of fundamental physics and probe of new physics.

Wednesday, 20 October 2021

Day 3: Day 3 (09:00 - 13:10)

-Conveners: Tolstoy, Eline (Kapteyn, Groningen)

The Gaia-ESO Public Spectroscopic Survey (09:00)

Presenter: Prof. GILMORE, Gerry (Institute of Astronomy Cambridge)
The Gaia-ESO Survey is a very ambitious project to obtain high-quality spectra of 100,000 stars, representing the major stellar populations, from young open star clusters to the oldest field stars, O-stars to M-stars. Gaia-ESO used the VLT GIRAFFE facility, allowing both good signal-noise spectra and also sampling beyond the immediate Solar neighbourhood for unevolved stars. Key features included a focus on star clusters, ensuring the Survey products are consistent with isochrones, and deliberate use of many different spectroscopic analysis pipelines and techniques. Each star was analysed in several different ways, with the single final astrophysical parameter set and elemental abundances resulting from a careful homogenisation. This allows identification of both random and systematic contributions to resulting data products. The Survey proved very successful, thanks to contributions from a large dedicated team. Final data products for all stars observed are currently being released through the ESO and Edinburgh archives. Some lessons learned will be noted.

The Galactic Archaeology with HERMES (GALAH) survey (09:25)

Presenter: Prof. BLAND-HAWTHORN, Jonathan (University of Sydney)
The GALAH survey is a large Australian-led project with a goal to measure radial velocities and ~30 elemental abundances in 1 million stars. Using the HERMES spectrograph at the AAT, GALAH has now observed 750,000 unique stars across three affiliated surveys including the main archaeology program, and associated science arising from the K2GAP and TESS surveys. The advent of Gaia has proved a major boon for the GALAH project, with unique chemical tagging signatures identified in a number of stellar systems, including Gaia-Sausage-Enceladus. GALAH targets stars on the main sequence turn-off to ensure the best possible ages for all stars. In combination with K2GAP and TESS, this has already shown to be an excellent strategy for the many science goals. We briefly mention scientific overlap with the proposed HRMOS instrument.

Synergies between WEAVE and HRMOS (09:50)

Presenter: HILL, Vanessa (UCA, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange)
WEAVE is a new multiobject facility for the William Herschel Telescope that will provide R~5,000 and R~20,000 spectra of millions of stars in the years to come. I will outline the possible synergies between the Galactic Archaeology (GA) and Stellar Circumstellar and Interstellar Physics (SCIP) surveys that will be performed with WEAVE in the years 2022-2029, and HRMOS.

Benchmark stars, benchmark spectrographs! (10:15)

Presenter: ADIBEKYAN, Vardan (Instituto de Astrofísica e Ciências do Espaço (IA))
Gaia benchmark stars are selected to be calibration stars for different spectroscopic surveys. Very high-quality and homogeneous spectroscopic data for these stars are therefore required. We used ultrahigh- and high-resolution spectra obtained with the ESPRESSO, PEPSI, and HARPS spectrographs to measure spectral line characteristics and determined stellar parameters and abundances for these benchmark stars. We show that these outstanding spectrographs can deliver spectroscopic results that are sufficiently consistent for most of the science cases in stellar spectroscopy. However, we demonstrate that there are small but important differences in the performance of these three spectrographs that can be crucial for specific science cases. I propose making an oral presentation about our recent findings, which are published in A&A.

The complementarity between MOONS and HRMOS at the VLT (11:20)

Presenter: GONZALEZ, Oscar (UKATC)
The Multi Object Optical and Near-infrared Spectrograph (MOONS) instrument is the next generation multi-object spectrograph for the VLT. MOONS will combine for the first time the large collecting power of the VLT with a high multiplexing capability offered by 1000 optical fibres moved with individual robotic positioners and a novel, very fast spectrograph able to provide both low- and

high-resolution spectroscopy simultaneously across the wavelength range 0.64μm - 1.8μm. In particular, the near-IR capabilities of MOONS at R~20,000 in its H-band channel are specifically tailored to tackle a variety of key Galactic science cases. In this talk I will provide an overview of the instrument capabilities and science goals to highlight the great complementarity of the parameter space to be covered by having both MOONS and HRMOS facilities at the VLT.

4MOST and future synergies with HRMOS (11:45)

Presenter: BENSBY, Thomas (Lund Observatory)
4MOST is a spectroscopic survey facility that will be placed on the Vista telescope on Paranal in Chile. It will be able to simultaneously obtain spectra for about 2400 objects, 800 at a resolution of about R~20000, and 1600 at a resolution of about R~5000. I will give a brief overview of the 4MOST science cases and give a few possible examples where follow-up observations with a high-resolution multi-fibre spectrograph like HRMOS could be invaluable.

Survey of Surveys: homogeneous radial velocities for 10 million stars (12:10)

Presenter: Dr TSANTAKI, Maria (Istituto Nazionale di Astrofisica (INAF))
In this talk, I will present a comprehensive catalog (Survey of Surveys, SoS) to meaningfully merge the main parameters of the largest ground-based spectroscopic surveys to date (RAVE, APOGEE, GALAH, Gaia-ESO, and LAMOST) using Gaia astrometry as reference. The main steps for the compilation of SoS include i) the cross-match algorithm (XM) between Gaia and the spectroscopic surveys, ii) the cross calibration of the main stellar parameters (radial velocities, effective temperature, surface gravity, and metallicity) to remove biases, and iii) the technical validation of our results in comparison to independent high quality samples. We use the official Gaia XM algorithm (Marrese et al. 2017, 2019) which takes into account the position, proper motion, and parallax in conjunction to their errors, stellar density, epoch, and angular resolution to find the best match. The cross calibration relies on a statistical analysis of the common samples to identify spurious trends and offsets and to perform a reliable error normalization between surveys. The cross calibration arises from data mining techniques to define the 'clean' samples with the most reliable parameters for each survey. As a result, we provide an internally calibrated catalog that is later validated with high quality samples (stellar clusters, asteroseismic and high resolution spectroscopic samples). Additionally, we provide errors on the parameters corresponding to a more realistic representation. SoS guarantees homogeneity and accuracy for several millions of stars, around 10 million with accurate radial velocities and over a million with accurate atmospheric parameters. This pilot study gives insights on how to homogenize the products of large surveys which can be applied to the upcoming 4MOST, WEAVE, and instruments such as HRMOS. Depending on their overlap with SoS and the accuracy of the above samples, they can also be used to revise and update the current SoS reference system.

Galactic Archaeology at High Resolution (12:25)

Presenter: HAWKINS, Keith (University of Texas at Austin)
The holy grail of Galactic Archaeology is the constrain the physical processes responsible for of the formation, evolution and assembly of Milky Way-like galaxies. With current technology, the best way to do this is to use the Milky Way as a laboratory to answer questions of galaxy formation using the detailed spatial, kinematic, and chemical information for its billions of stars. In this context, high resolution spectroscopic surveys, especially those that are multiplexed, will play a critical role in progressing the field forward. In this talk, I will present some areas that the proposed High Resolution Multi-Object Spectrograph instrument could potentially have a high impact.

Searching for planets around evolved massive stars in open clusters: lessons from HARPS (12:50)

Presenter: Dr DELGADO MENA, Elisa (Instituto de Astrofísica e Ciências do Espaço)
Our ability to detect planets around stars with the radial-velocity (RV) method has a strong dependence on our understanding on the stellar jitter of such stars which can reach dozens of m/s in red giants. This intrinsic RV variability can be caused by stellar magnetic activity, pulsations or granulation and it behaves on a different way depending on the spectral type of the stars and on their evolutionary stage. In this work we present the results of a RV survey to search for planets around intermediate-mass stars in 25 open clusters. The long-term observations allowed us to discover new binaries, brown dwarfs and few planet candidates around stars more massive than 2 solar masses and we plan to study the dependence of RV jitter on stellar mass, age and evolutionary status. We present the intriguing RV signals detected in some stars, which mimic long-period planets (P~700 days) and are stable for a period of up to 15 years. In some cases, these RVs are correlated with the FWHM or the BIS (Bisector Inverse Slope) of the CCF although their period seems not to be related to the rotational period of the star, nor they show significant chromospheric activity. We discuss the possibility of whether we might be facing a new kind of stellar pulsations or the RV

variability is caused by long-term stellar activity. Finally, we discuss about possible observing strategies that can help overcome these issues.

Thursday, 21 October 2021

Day 4 (09:00 - 13:00)

-Conveners: Rodolfo Smiljanic

Evolved stars as tracers of the origin of elements in the Universe. (09:00)

Presenter: KAMATH, Devika (Macquarie University)

The chemical evolution of galaxies is governed by the chemical yields from stars, especially from Asymptotic Giant Branch (AGB) stars. Observations from Post-Asymptotic Giant Branch (post-AGB) stars serve as exquisite tools to quantify and understand AGB nucleosynthesis. Our studies have shown that AGB nucleosynthesis is riddled with complexities. In this talk, I will present the invaluable constraints provided by post-AGB stars, the intriguing chemical diversity observed and its implications on element/isotope production in AGB stars and stellar nucleosynthetic yields. I will also present the observed effects of binarity on AGB nucleosynthesis. To cement the gaps in our understanding of AGB nucleosynthesis, we have initiated a strategically designed multi-wavelength spectroscopic study that combines studies of the chemical composition of the photospheres of post-AGB stars covering a wide range of initial masses and metallicity environments (in the MilkyWay and external galaxies) combined with studies of gas and dust in their circumstellar environments. This not only reveals the internal nucleosynthetic processes but also reveals the chemo-dynamical processes that greatly affect the production and evolution of chemical elements and their isotopes. In this talk, I will elaborate on how HRMOS can provide the possibility to optimise our efforts in the optical regime by providing high-spectral resolution and a large spectral coverage coupled with high multiplexing.

Evidences of transport processes in stellar interiors (09:25)

Presenter: Prof. TAUTVAISIENE, Grazina (Vilnius University)

Measurements of elemental abundances and their isotope ratios allow us to perform key tests of mixing mechanisms inside stars and provide powerful diagnostics of chemical enrichment in galaxies across cosmic time. For this purpose we need large samples of stars with precise chemical abundances over a full range of metallicities and other stellar atmospheric parameters, a full range of masses, magnetic activity, as well as of different evolutionary stages. Coupled with information on stellar ages, distances, and kinematics, the elemental abundances can provide a complete fossil record of the history of chemical enrichment for their host galaxies. However, when it comes to the determination of isotopic abundance ratios in stars, very high resolution, high signal-to-noise spectroscopic data are invariably needed, which severely limits current observational studies. In this presentation, we will discuss new possibilities which will be opened with the HRMOS spectrograph in studying abundances of mixing-sensitive chemical elements.

HRMOS for Local group and dwarf galaxies (09:50)

Presenter: Dr SKULADOTTIR, Asa (UniFi)

Dwarf galaxies and larger satellite galaxies are ideal laboratories to study the earliest chemical evolution, different nucleosynthetic channels, dark matter structure, and hierarchical galaxy formation. The Milky Way has dozens of satellites which can be studied in far greater detail than their more distant counterparts. With upcoming large spectroscopic surveys such as 4MOST and WEAVE, these satellites will be targeted for the first time on a large scale – with spectra of hundredths of thousands of stars. This will undoubtedly fuel many new discoveries, that will need high resolution follow-up. Given their dense concentration on the sky, a high resolution, multi-object spectrograph such as HRMOS will be the most efficient way to do this. In this talk, I will go over and discuss the most compelling science cases of Milky Way satellite galaxies in the framework of HRMOS.

Evidence for sub-Chandrasekhar Type Ia supernovae from the last major merger (10:15)

Presenter: SANDERS, Jason (University College London)

We investigate the contribution of sub-Chandrasekhar mass Type Ia supernovae to the chemical enrichment of the Gaia Sausage galaxy, the progenitor of a significant merger event in the early life of the Milky Way. Using a combination of data from Nissen & Schuster (2010), the 3rd GALAH data release (with 1D NLTE abundance corrections) and APOGEE data release 16, we fit analytic chemical evolution models to a 9-dimensional chemical abundance space (Fe, Mg, Si, Ca, Cr, Mn, Ni, Cu, Zn) in particular focusing on the iron-peak elements, Mn and Ni. We find that low [Mn/Fe] $\sim-0.15\,\mathrm{dex}$ and low [Ni/Fe] $\sim-0.3\,\mathrm{dex}$ Type Ia yields are required to explain the observed trends beyond the [α/Fe] knee of the Gaia \emph{Sausage} (approximately at [Fe/H] $=-1.4\,\mathrm{dex}$). Comparison to theoretical yield calculations indicates a

significant contribution from sub-Chandrasekhar mass Type Ia supernovae in this system (from $\sim60\,\%$ to $100\,\%$ depending on the theoretical model with an additional $\pm10\,\%$ systematic from NLTE corrections). We compare to results from other Local Group environments including dwarf spheroidal galaxies, the Magellanic Clouds and the Milky Way's bulge, finding the Type Ia [Mn/Fe] yield must be metallicity-dependent. Our results suggest that sub-Chandrasekhar mass channels are a significant, perhaps even dominant, contribution to Type Ia supernovae in metal-poor systems, whilst more metal-rich systems could be explained by metallicity-dependent sub-Chandrasekhar mass yields, possibly with additional progenitor mass variation related to star formation history, or an increased contribution from Chandrasekhar mass channels at higher metallicity.

HRMOS can illuminate globular cluster contributions to halo assembly (11:20)

Presenter: MARTELL, Sarah (University of New South Wales)

I will discuss the potential for HRMOS in studying the stars that are escaping from globular clusters into the halo field through streams or extratidal structures. These stars allow us to address questions of globular cluster origins, abundance anomalies, and chemical tagging, as well as dynamics, mass loss, and dark matter. The large-scale spectroscopic surveys planned for the 2020s will collect R~20,000 spectra for some of these stars, but there will be room to expand on the information they will gather. In addition, future Gaia data releases and LSST imaging will reveal new candidate extratidal structures. HRMOS will make it possible to investigate these candidates thoroughly, and to directly compare across a wider range of environment by observing near globular clusters and nuclear star clusters in Local Group dwarf galaxies. I will discuss the science gains to be had in observing these stars with higher resolution, higher RV precision, a multiplex of 50-100, and an 8m telescope.

The Scars of Galaxy Formation: Studying stellar streams in our halo with HRMOS (11:35)

Presenter: SIMPSON, Jeffrey (UNSW Sydney)

The halo of our Milky Way is scarred by galaxy formation in the form of stellar streams. These streams are a uniquely powerful tool for understanding the building blocks of the Milky Way’s stellar halo, the mass and shape of the Milky Way’s halo, and ultimately the nature of dark matter. Each stream is the remnant of a dwarf galaxy or globular cluster; the former are especially interesting as each stream reveals stars identifiably from a single dwarf galaxy within our own halo. In this talk I will present results from the ongoing Southern Stellar Stream Spectroscopic Survey (S5), which has been using the Anglo-Australian Telescope, Magellan/HIRES, and VLT/UVES to characterise and study stellar streams identified in the Dark Energy Survey and Gaia. I will discuss the requirements for HRMOS for studying streams and the advantages HRMOS could have over other future survey instruments.

A new tool for chemical tagging based on iron-peak elements (11:50)

Presenter: MINELLI, Alice (UniBO - Istituto Nazionale di Astrofisica (INAF))

The homogeneous comparison between the chemical composition of the Milky Way (MW) and its more massive satellites (Large Magellanic Cloud - LMC and Sagittarius - Sgr) reveals that the latter galaxies have different chemical abundances with respect to the MW stars for almost all the species. In particular the largest difference is measured for [V/Fe] and [Zn/Fe], reaching up to 0.5/0.7 dex for stars with [Fe/H] > -0.5 dex. We interpret these low abundance ratios in LMC/Sgr stars in terms of a lower contribution from massive stars to the chemical enrichment, compared to that experienced by the MW, since these elements are mainly produced by hypernovae, Type II supernovae or electron-capture supernovae with high-mass stellar progenitors. We propose to use the chemical abundance ratios of iron-peak elements (in particular Sc, V and Zn) as tools to identify possible extra-galactic stars. Here we present the homogeneous analysis of high-resolution spectra of RGB stars belonging to four metal-rich GCs, namely NGC 5927, NGC 6496, NGC 6388 and NGC 6441. According to their dynamical properties, the first two have been clearly identified as in-situ clusters, while the other two seem to share an accreted origin, but their orbital properties make their classification more uncertain. We found that the α-elements Si, Ca and Ti and the slow (La and Ba) and rapid (Eu) neutron-capture elements show similar abundance ratios in all the four GCs. Instead, Sc, V and Zn display a stark difference, where NGC 6388 and NGC 6441 have abundance ratios for these iron-peak elements similar to those of LMC/Sgr stars, and significantly lower to the ones measured in NGC 5927 and NGC 6496, in agreement to those of MW stars. Therefore, our analysis provides an independent confirmation that NGC 5927 and NGC 6496 formed in-situ, as already suggested by the kinematics. Also, it allows identify NGC 6388 and NGC 6441 as likely formed in an external environment with a low star formation efficiency and where the gas has been poorly enriched by massive stars.

Oxygen-enhanced extremely metal-poor DLAs: A signpost of the first stars? (12:05)

Presenter: WELSH, Louise (University of Milano Bicocca)

The properties of the first stars remain unknown. The chemistry of relic environments, enriched only by the supernovae of the first (Pop III) stars, may offer the best opportunity to uncover their properties (e.g. mass distribution and explosion energies). In this talk, I will present the analysis of two of the most chemically near-pristine gas reservoirs at a redshift z~3 observed using a high resolution spectrograph (R~40,000). The primary aim is to assess the nature of the [O/Fe] ratio in the extremely metal-poor (i.e. <1/1000 of the solar metallicity) regime. Prior observations indicate that the [O/Fe] ratio of metal-poor ([Fe/H]<-2) DLAs is consistent with a constant value, [O/Fe]~+0.4, but this ratio may increase when [Fe/H] < -3. I report [O/Fe] =+0.51 +/- 0.10 and [O/Fe]=+0.62 +/- 0.05 for two near-pristine gas reservoirs. These new, high-precision measurements strengthen the idea that the [O/Fe] abundances of the most metal-poor DLAs are elevated compared to DLAs with [Fe/H]>-3. This elevated [O/Fe] ratio may be a sign of enrichment from a generation of metal-free stars. I compare the observed abundance pattern of the latter system to the nucleosynthetic yields of Pop III supernovae using a stochastic chemical enrichment model. Future high-precision measurements in new systems will contribute to a firm detection of the relationship between [O/Fe] and [Fe/H], and allow us to rule out potential contamination from Pop II stars. This effort will be aided with the advent of the WEAVE survey. I suggest that the combined study of near-pristine gas reservoirs along with stars in halo of the Milky Way and surrounding dwarf galaxies may draw out evolutionary relationships and help reveal the properties of the first stars.

Reimagining large spectroscopic data with unsupervised machine learning generative models (12:20)

Presenter: TING, Yuan-Sen (Australian National University)

Modern-day machine learning generative models allow us to directly model the distribution of the observed spectroscopic data, even when the stellar labels are absent. In recent years, we have seen the explosion of studies in terms of supervised machine learning. However, the exploration of unsupervised generative models in stellar spectroscopy is, unfortunately, lagging behind. In this talk, I will discuss various unsupervised machine learning methods, including generative models and normalizing flows and their pros and cons. I will demonstrate how unsupervised generative models can uncover missing atomic features, auto-calibrate imperfect models, and detect outlier spectra without needing a predefined training set with stellar labels.

Functional Data Analysis for Extracting the Intrinsic Dimensionality of Spectra: Prospects for Chemical Tagging (12:45)

Presenter: PATIL, Aarya (University of Toronto)

High-resolution spectroscopic surveys of the Milky Way have entered the *Big Data* regime, and have opened avenues for solving outstanding questions in Galactic Archaeology. However, exploiting their full potential is limited by complex systematics, whose characterization has not received much attention in modern spectroscopic analyses. We present a novel method to disentangle the component of spectral data space intrinsic to the stars from that due to systematics. Using Functional Principal Component Analysis (FPCA) on a large sample of giant spectra from the Apache Point Observatory Galactic Evolution Experiment (APOGEE), we find that the intrinsic structure above the level of observational uncertainties requires ≈10 Functional Principal Components (FPCs). Our FPCs can reduce the dimensionality of spectra, remove systematics, and impute masked wavelengths, thereby enabling accurate studies of stellar populations. To demonstrate the applicability of our FPCs, we use them to infer stellar parameters and abundances of giants in the open cluster M67. We employ Sequential Neural Likelihood, a simulation-based Bayesian inference method that learns likelihood functions using neural density estimators, to incorporate non-Gaussian effects in spectral likelihoods. By hierarchically combining the inferred abundances, we put stringent constraints on the chemical homogeneity in M67. In this talk, I will discuss spectral dimensionality reduction using FPCA and its application to M67. I will also discuss the promising implications of our results for the future of *chemical tagging* in the Milky Way.

Friday, 22 October 2021

Day 5: Day 5 (09:00 - 13:00)

-Conveners: Tozzi, Andrea (Istituto Nazionale di Astrofisica (INAF))

High-Resolution Multi Object Spectrograph for the VLT: an overview (09:00)

Presenter: BRUCALASSI , Anna (Istituto Nazionale di Astrofisica (INAF))
In this talk I will give a general overview of the HRMOS spectrograph concept design for the VLT . Different approaches and optical solutions will be also discussed in order to be compliant with the scientific requirements.

Options for the HRMOS fibre positioner (09:25)

Presenter: Dr LAWRENCE, Jon
HRMOS is envisaged as a high-resolution fibre-fed spectrograph with a moderate degree of multiplex capability, installed on one of the 8m Unit Telescopes on the VLT. Here we consider options for the fibre positioning system for HRMOS. One option is to refurbish the existing OzPoz positioner that is part of the FLAMES facility. OzPoz is a pick and place robotic fibre positioner commissioned in 2003. We also consider other potential types of fibre positioner that may offer advantages.

A new fibre positioner solution for the HRMOS front-end (09:50)

Presenter: GONZALEZ, Oscar (UKATC)
In this talk I will present a new concept for a telescopic fibre positioner in a theta-r or theta-phi-r configuration as a potential solution for the High-Resolution Multi Object Spectrograph for the VLT. The positioner concept, being developed at the UKATC, builds up from the technology of MOONS and KMOS instruments to provide a fast field reconfiguration, close packing for high-density targeting, and reliable fibre allocation, aimed to maximise the observing efficiency of HRMOS.

The Data Management Advantage of MOS (10:15)

Presenter: Dr WORLEY, C.Clare (University of Cambridge)
The proposed HRMOS is the next step in pursuing, on a large scale, precise chemical characterisation of stellar populations. A number of new medium-to-low resolution spectroscopic survey instruments, in operation or under development, provide a wealth of data on a very large scale from which key subsets can extracted as input to higher resolution spectroscopic surveys (e.g. with HRMOS). While the potential data volume for HRMOS is only 50-100 fibres per observation block, compared with 1000-4000 fibres per observation block for the medium resolution projects such as 4MOST, WEAVE, MOONS and MSE, it is still advantageous for the HRMOS project to leverage the data management systems, spectral reduction pipelines and quality control processes developed for these very large scale projects. CASU has led or is leading the data analysis system development for Gaia-ESO, WEAVE and 4MOST with future prospects for MOONS and MSE. In this talk we present the development undertaken to meet the data management challenges of these projects and the synergies they present for the proposed HRMOS.

Holistic spectroscopy: complete reconstruction of a wide-field, multiobject spectroscopic image using a photonic comb (11:20)

Presenter: Dr KOS, Janez

Discussion session (11:35)