Star clusters 2020
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Abstract book

Aldo Mura-Guzmán
The Australian National University

Fluorine in different stellar populations

The processes involved in the production of Fluorine are still unclear and under debate, since the theoretical models do not well reproduce the observations. The only currently confirmed site of F production, asymptotic giant branch (AGB) stars, is not certain to be responsible for the cosmic abundance. Moreover, an intriguing difference in F abundances has been found between Globular Clusters (GCs) and field stars, where field stars show higher amounts of F by a factor of 10 compared to GCs. This difference could reflect the impact of the environment upon nucleosynthesis, i.e., metallicity dependent yields of fluorine which would help establish the nucleosynthetic origin. This work presents Fluorine abundances corresponding to Carbon Enhanced Metal-Poor stars, field stars from the thin and thick disk, Sagittarius stream stars and 4 Globular Clusters covering a wide range of metallicities ([Fe/H] < -2 for CEMP stars; -1.0 < [Fe/H] < 0.3 for field stars + Sagittarius; -1.0 < [Fe/H] < 0.0 for GCs). Using high-resolution spectra from PHOENIX, CRIRES and IGRINS, Fluorine abundances were measured from the 2.3 μm HF molecular line by spectrum-synthesis method. Observations are here compared with state-of-the-art theoretical predictions which include contributions from the different proposed sites of production (i.e. SNeII, ABG stars, W-R stars, &c.), and previous abundance determinations from literature. All this allows establishing a thorough observational framework in order to better understand the formation sites of Fluorine, its yield dependency and its nucleosynthesis in the Milky Way galaxy.

Alex Alarcón
Universidad de Concepción

Kemochinematical tracers for the formation of dSph - Leo I vs Simulations

Numerical simulations have shown that the Dissolving Star Cluster Model, i.e. many star clusters spreading their stars inside a single dark matter halo, building up the luminous component, is able to explain all dynamical and structural features of dwarf spheroidal galaxies. The main prediction of this model is the presence of stellar streams from stars originating in the same star cluster. We are applying BEACON both to simulations and observational data of 942 stars from Leo I, to find to find chemo-kinematic patterns among stars of different stellar populations using their metallicity and radial velocity. We present the presence of 13 possible streams in the Leo I data with projected angular momentum vectors distributed in random directions.The results are in perfect agreement with the dissolving star cluster model. It is necessary to apply this method to more galaxies with a high quantity of high resolution spectra to have a better understanding of the formation of these objects.

Alexandre Roman Lopes
ULS

Massive Stars in the SDSS-IV/APOGEE2 Survey. New OB and Yellow Supergiant Stars in the Direction of Sagittarius and Perseus Spiral Arms

We have developed a semi-empirical spectral analysis applied in the ongoing massive star survey conducted by the Sloan Digital Sky Survey (SDSS)-IV/ Massive Star Team. A large sample of new O- and B-type stars (among several Yellow supergiants) were identified along the Sagittarius and perseus spiral arms, using the APOGEE2 spectrographs at both, the Las Campanas and Apache Point Observatories. We analyzed the associated spectral features deriving spectral types, as well as the massive star distribution of hundreds of stars along the mentioned lines of sight, finding interesting correlations between the associated heliocentric distances, luminosity classes and spectral types of the newly found massive stellar population.

Alvaro Valenzuela Navarro
PUC / MAS

Verification of star clusters in the direction of the galactic bulge

Star clusters traces the star formation history of the Milky Way (MW) and therefore they are essential to describe how the components of the MW formed. There are abundant open clusters on the disk and globular clusters in the halo, but there are not so many verified cluster inside the MW bulge, because of the crowding and high extinction on visual bands.

We used VVV photometry and KMOS HKs spectra to characterize kinematics of ~20 candidates located on the galactic bulge. We used also proper motions computed with VVV data and RV computed with cross-correlation method to verify new clusters. (Work in progress)

Ana Chies Santos
Universidade Federal do Rio Grande do Sul

Extragalactic globular clusters and massive galaxy formation

TBD

Ana Ennis
Instituto de Astrofísica de La Plata (IALP)

A wide-field look at the field elliptical galaxy NGC 1172 and its globular cluster system

We present results from a wide-field deep photometric study of the globular cluster system (GCS) hosted by NGC 1172. The data are a combination of GMOS (Gemini South) images, and NIR observations obtained with FourStar (LCO). We obtain complete areal coverage of the

GCS, which allows us to examine its full extension, combining optic and NIR data in order to deepen our understanding of the galaxy's properties. Given its location in a very low-dense environment, NGC 1172 proves to be an interesting case since it appears to host a heavily populated GCS, rare for field ellipticals. The results also hint at the potential presence of a third subpopulation, in addition to the conventional "red" and "blue" ones, which is a substantial clue for figuring out its evolutionary history.

Bruno De Bórtoli
UNLP-CONICET

GMOS spectroscopy of SMC clusters

We will give a report on the current status of the analysis of 6 SMC clusters based on GMOS/GEMINI near-infrared spectra in the region of the Ca II Triplet (CaT). We use these strong absorption lines to measure radial velocities and equivalent widths, from which we derive metallicities. Although most clusters of our sample already have photometric metallicity determination, they have not been spectroscopically studied. Consequently, our work provides independent and more reliable information than the photometric studies. Moreover, it provides for the first time information about cluster radial velocity and membership. The radial velocities and metallicities derived by the CaT technique are accurate enough to allow a reliable analysis of their chemical evolution and to explore that of the SMC, adding to our sample other clusters also studied with the CaT technique.

Bruno Dias
UNAB, Chile; MAS, Chile

The VISCACHA survey - deep and resolved photometry of star clusters in the Magellanic Clouds

The VISCACHA (VIsible Soar photometry of star Clusters in tApii and Coxi HuguA) Survey is an ongoing project based on deep and spatially resolved photometric observations of Magellanic Cloud star clusters, collected using the SOuthern Astrophysical Research (SOAR) telescope together with the SOAR Adaptive Module Imager. It complements other large surveys that are not able to resolve stars in the core of these clusters. Since 2015 more than 300 hours of telescope time were used to observe about 150 stellar clusters, most of them with low mass (M < 10^4 Mo) and/or located in the outermost regions of the Large Magellanic Cloud and the Small Magellanic Cloud. With this high-quality data set, we homogeneously determine physical properties from statistical analysis of colour-magnitude diagrams, radial density profiles, luminosity functions and mass functions. Ages, metallicities, reddening, distances, present-day masses, mass function slopes and structural parameters for these clusters are derived and used as a proxy to investigate the interplay between the environment in the Magellanic Clouds and the evolution of such systems, as well as to identify and scrutinize some peculiar clusters. We are also carrying out a spectroscopic follow-up using the Gemini-South Multi-Object

Spectrograph (GMOS-S) to derive radial velocities and metallicities. In this talk some results from the VISCACHA collaboration will be presented.

Bryan Miller
Gemini Observatory

The Extended Globular Cluster System of NGC3923

In the LambdaCMD paradigm of galaxy formation galaxy halos and their globular clusters systems build up over time by the accretion of small satellites. We can learn about this process in detail by observing systems with ongoing accretion events and comparing the data with simulations. Elliptical shell galaxies are systems that are thought to be due to ongoing or recent minor mergers. We present preliminary results of an investigation of the entire globular cluster system of the shell galaxy NGC3923 from DECam g and i-band imaging. We will present the 2D and radial distributions of the globular cluster candidates out to a projected radius of about 120kpc, or 25Re. The color-magnitude diagram will be used to get an initial metallicity distribution. We also will look for associations with the underlying shells and tidal streams.

Camila Navarrete
ESO Chile

Near-IR catalogue of variable stars in omega Centauri

In this contribution, I will present an extensive time-series study of the globular cluster ω Centauri (NGC 5139), obtained in the framework of the VVV Templates project. A total of 42 and 100 epochs of the cluster in J and Ks, respectively, were taken using VIRCAM@VISTA, and PSF photometry was performed to derive light curves for 270 pulsating stars (RRab, RRc, type II Cepheids and SX Phoenicis) and several other variability types in the cluster (e.g., eclipsing binaries, long-term variables, ellipsoidal and spotted stars) with an unprecedented phase coverage in the near-IR. Period-Luminosity (PL) and PL-metallicity relations in both bands were derived for Type II Cepheids and RR Lyrae stars, respectively. For SX Phoenicis stars, PL relations in J and Ks bands for the fundamental mode pulsators were derived for the first time. Amplitudes ratios between optical and near-infrared bands were also derived, which are critical to estimate the mean magnitude of these variable stars when few epochs of the pulsation cycle have been observed.

Camila Ordenes
Pontificia Universidad Católica de Chile

The 3D positions of clouds in the Milky Way's Nuclear Star Cluster

Nuclear star clusters (NSCs) are very common structures. They are in most galactic centres of all Hubble types galaxies. They are composed of millions of stars distributed in just a few parsecs, being more massive and luminous than globular clusters. Our work is focused on the Nuclear Star Cluster and the Nuclear Disc of the Milky Way. Because of their proximity, they can give us unique insight on NSCs in general. More specifically, we consider the clouds of gas and dust that reside in this region and try to determine their 3D positions. Knowing the 3D location of the clouds give us information on two important issues. First, the recent history of Sgr A*: as the clouds reflect the light that it emitted during its more active phases just a few hundred years ago. Second, it can help us understand how star formation proceeds in extreme environmental conditions. The clouds are likely to form stars, a process which may well be regulated by the strong tidal field in the inner Galactic regions. Knowing the 3D position of a cloud is needed to figure out its orbit and the tidal field it feels along it. To determine the clouds' 3D positions we consider that they obscure and redden the emission of the nuclear stars. As a first step in our project, we produce mock 3D distributions of clouds and stars, using as input the observed distributions recently published by several groups, and calculate the expected obscuration. We will discuss the results of recovering the 3D positions from the mock observations, and our plans to apply this method to actual observed data.

Carolina Vargas González
University of Concepción

Looking for heavy metal variations in galactic GC NGC362

By using high resolution spectra of 12 RGB members of NGC362 taken with MIKE spectrograph, I look for the uncommon intrinsic spread on Fe abundances and how this variation, if present, correlates with light and alpha element abundances. In addition, a complete characterization of stellar parameters will be done in order to complement existing literature for the cluster.

Casmir Obasi
Departamento de Fisica, Facultad de Ciencias Exactas, Universidad Andres Bello, Santiago Chile

The Nature Of NewGL FSR-25

NewGL FSR-25 is a newly discovered globular cluster with the Vista Variables in the Via Lactea Extended Survey (VVVX). It is 5 degrees of the milky way bulge, with coordinate of RA: 17: 41: 43.2 and Dec: -19: 34: 16. In this paper we analyze the cluster parameters in detail with the aim of understanding the nature of the cluster. We derive a distance of 6.7Kpc _+1kpc to the cluster , an age of 11Gyrs and metallicity [Fe/H]= -0.5dex. The cluster has a core-radius of 3arcmin which corresponds to 5.8Kpc across with an integrated magnitude of K =-7.2mag, which is at the very faint end of the Globular Clusters Luminosity Function and explains why it was so difficult to detect with other past surveys. By considering many other low luminosity globular

clusters detected by the VVV survey we are now filling the low end of globular clusters luminosity function parameter space. We shall therefore describe the implication of this newly discovered globular-cluster in the light of stellar formation and evolution.

Clara Martínez-Vázquez
Cerro Tololo Inter-American Observatory

What variable stars tell us about the formation and evolution of Local Group dwarf galaxies

There are several kinds of pulsating variable stars that cross the instability strip, which belong to different populations. The most well known are RR Lyrae, low-mass (0.7 Msun) stars, tracers of an old population (>10 Gyr), and classical Cepheids, more massive (> 3 Msun) stars, tracers of a young population (< 500 Myr). Therefore they can be used as tracers of the stellar population of the systems in which they are found. Moreover, both types of stars are considered the best standard candles since they obey well established period luminosity relations and they are used very often to derive accurate and precise distances to their host systems. In particular, RR Lyrae stars are also metallicity tracers so they can provide insight into the chemical evolution of the old population they belong to. Aimed by these fascinating characteristics, I will present in this talk a review about the variable stars - mainly focused on RR Lyrae stars- found in Local Group dwarf galaxies and how they help us to reveal their histories.

Dante Minniti
UNAB/MAS/CATA/VO

The Near_IR View of Globular Clusters in the Milky Way Bulge

The VISTA Variables in the Via Lactea (VVV) Survey and its extension the VVVX Survey are large ESO-Chile Public near-IR surveys of the Southern Milky Way (http://vvvsurvey.org). I will discuss the status of the VVV and VVVX surveys and present the recent results on the globular clusters of the Milky Way bulge and also our latest discoveries.
Among other things, these Surveys have represented a revolution for the study of globular clusters in the Milky Way bulge.
On one hand, the deep near-IR images have enabled the discovery of dozens of new candidate globular clusters in the bulge, that had hitherto remained hidden due to the high crowding and severe differential reddening in the inner regions of the Galaxy.
On the other hand, the near-IR PSF photometry and the multi-epoch observations of variable stars have allowed the accurate measurement of the physical parameters (sizes, reddenings, distances, ages, luminosities, etc.) for several known globular clusters that were poorly studied thus far.

These studies contribute to a deeper understanding of the formation and evolution of the Milky Way globular cluster system.

Doug Geisler
Universidades de Concepción y de La Serena

CAPOS: the bulge Cluster APOgee Survey

We present first results from CAPOS, a long-term project to investigate detailed chemical abundances and kinematics in bulge globular clusters using APOGEE-2S.

Evelyn Johnston
Pontificia Universidad Católica de Chile

A MUSE View of the Nuclear Star Clusters in Dwarf Galaxies

Nuclear Star Clusters (NSCs) are compact stellar systems lying at the centres of galaxies with similar sizes to globular clusters but a broader range of masses, typically from 10^5 − 10^8 M⊙. Their formation is still uncertain, with current theories ranging from in-situ star formation fuelled by infalling gas to globular clusters from elsewhere in the galaxy migrating into the core. Due to their relative faintness and the contamination of their light from the host galaxy, spectroscopic studies of these NSCs to derive estimates of their stellar populations is tricky. One approach to combat this issue is BUDDI, a new technique we have developed to model the light profiles of the NSC and host galaxy as a function of wavelength in order to cleanly disentangle their spectra and minimise contamination. In this talk, I will give an overview of BUDDI and present the results from our analysis of a series of NSCs in dwarf galaxies in the Fornax Cluster and what they tell us about how these systems formed.

Francisco Aros
University of Vienna

Searching for intermediate-mass black holes within the complex internal dynamics of globular clusters.

The presence or absence of intermediate-mass black holes (IMBHs) at the centres of dense stellar systems is still an open question. For every suggested IMBH in a Milky Way Globular Clusters (GCs), there is an equally strong non-detection or upper limits. GCs are intrinsically collisional stellar systems, where their dynamical evolution is tied to two-body interactions, which in turn drives the GC towards mass segregation and partial energy equipartition. These effects have a significant impact on our ability to constrain the internal mass profile of GCs and to detect (or rule out) the presence of IMBHs. Simulations of GCs provide the perfect environment to explore the limitations of dynamical models and identify observables which

might help to constrain their mass profiles. Here, we apply dynamical models to simulated GCs to understand how typical assumptions, such as constant mass-to-light ratio and velocity anisotropy, limit our ability to robustly constrain the mass profiles of GCs and the presence or absence of IMBHs in their centres.

Gonzalo Aravena
Universidad de Antofagasta

A VVV near-infrared study of the RR Lyrae variable stars in the globular cluster NGC 6401

Inner Galactic globular clusters are challenging to study. Due to interstellar extinction, our knowledge of many of these clusters remains incomplete. Near-infrared observations of these objects can help us to improve the accuracy in their calculated physical parameters. The tight period-luminosity relation that RR Lyrae variable stars show at these wavelengths can be particularly useful in this endeavor.
In this work, I present a study of the population of RR Lyrae stars in the inner galactic globular cluster NGC 6401 using the near-infrared multi-epoch data from the Vista Variables in the Via Lactea (VVV) survey. My aim is to obtain more precise information about the properties of this globular cluster, such as distance and reddening.

Javier Alonso-García
Universidad de Antofagasta

Pulsating variable stars in the innermost Galactic globular clusters

Galactic globular clusters located in the innermost Galaxy have been historically neglected. Obscuration by clouds of dust and gas in their lines of sight and high stellar densities in their surrounding fields complicate their observation and study. Dealing with the extinction requires near-infrared observations, like the ones provided by Vista Variables in the Via Lactea (VVV) survey and its extension, the VVV-X. More than 50 known Galactic globular clusters located towards the inner Milky Way lie in the region surveyed by the VVV and the VVV-X. Their multi-epoch observations allow us to search and characterize pulsating stars contained in these star clusters. The tight near-infrared period-luminosity relations of these variable stars allow then a better parametrization of the globular clusters. In my talk I will present our current, ongoing analyses of some of these poorly known objects within the framework of the VVV and VVV-X.

Jimena Rodriguez
IALP (CONICET - UNLP)

Hierarchical star formation in nearby galaxies

Star formation proceeds in a hierarchical way, as is revealed by the wide range of length scales of the stellar structures, from large stellar complexes and aggregates to small associations and clusters.
The study of the different structures show that they exhibit self similar and fractal properties. These features are also found for the structures formed by the interstellar medium (ISM). This similarity suggests that the young stellar structures may originate from those of their parental molecular clouds, which are in turn associated with turbulence and self gravity.
We study the hierarchical stellar structure of the young population in some nearby galaxies using multi-band Hubble Space Telescope data. Based in the young upper main sequence stars, we derive some fractal parameters of this population that help us to better understand the possible link between the hierarchical stellar structure and the ISM.

Jose Fernandez
Universidad de Atacama

High-precision abundance analysis of Hidden Fossil Relics that shaped the Halo of the Milky Way

Over the past few decades, it has become clear that the stellar halo of the Milky Way preserves a record of the Galaxy's assembly history. While there is some debate about the formation of the inner halo itself (accretion vs. in situ formations), a consolidated via to reliably identify which stars originated in which stellar clusters, dwarf galaxies, or which stars were accreted, remains to be determined. However, high-resolution near-infrared spectroscopic surveys such as APOGEE with its ability to observe in the H-band and penetrate the dust that obscures significant fractions of the stars in the inner Galaxy provide a way forward. In this contribution talk, we interpret the chemical abundance patterns of unusual metal-poor ([Fe/H] < -0.7 dex) field giants with light-element (e.g., silicon, aluminum, and cyanogen) enhancements as extreme as those observed in globular cluster populations by comparing them to the chemical abundance patterns of the Milky Way. In particular, I discuss the imprints of a new stellar sub-population residing in the inner stellar halo which may have largely originated in early stellar clusters that merged to form the Milky Way halo.

Juan Pablo Caso
Instituto de Astrofísica de La Plata - Facultad de Ciencias Astronómicas y Geofísicas de La Plata, Argentina

Scaling relations for globular cluster systems in early-type galaxies

In the current paradigm globular clusters (GCs) were formed during major starburst episodes, due to galaxy mergers and interactions, or accreted from satellite galaxies. This implies a direct

connection between the GC system and the evolutionary history of the host galaxy, and particularly its mass accretion history.
We analysed the GCs radial distribution for a sample of intermediate luminosity early-type galaxies located in different environments, and supplemented it with literature results. In comparison with previous studies, our compilation expands the sample to fainter luminosities. A change in the scaling relations between the properties of the GC systems and those of the host galaxies might exist at M*~5×10^10 solar masses. We statistically compared our sample with the properties of the halos from a dark matter only simulation. The results point that the extension and effective radii of the GC systems scales with the virial radii and the projected effective radii of the halos.

Julio Chanamé
Universidad Católica de Chile

The dissolution of star clusters and the formation of wide binaries

Wide binaries are ubiquitous in the Galaxy, they are extremely useful for a large variety of astronomical applications, and nowadays we keep learning about their properties and their populations thanks to Gaia's precision astrometry. How exactly they have formed, however, remains as a relatively unexplored question, and no canonical, widely-accepted formation model really exists yet. In this context, N-body simulations have suggested that they could be formed during the dissolution phase of low-mass star clusters and associations. These models, however, make a number of assumptions that are unrealistic and/or arbitrary, especially in their treatment of the process of cluster dissolution. To better understand the formation of wide binaries, we use N-body simulations to carefully follow shells of the cluster as it expands, and we consider escaping stars or binaries only in relation to the mean background density of the environment where the clusters sit. For a suite of simulations with varying initial conditions on cluster mass, size, and virial state, we compare the statistics of the binaries obtained in this way to previous work and to observations of wide binaries in the Galactic field. Our procedure allows us to identify key aspects of the physics of this formation channel that cannot be followed by more simplified models, thus offering observational insight on how to better understand the formation of these intriguing systems. Moreover, we study the possibility of using the observed properties of a population of wide binaries in order to infer the mass and size distribution of the population of extinct star clusters that originated those wide binaries.

Julio Olivares
PUC/MAS

Spectroscopic confirmation of the newly discovered VVV-CL001 cluster with MUSE

We present the first results of MUSE observations of the VVV-CL001 cluster. It is the first cluster discovered by the VVV Survey, and the final goal is to obtain the first kinematics and metallicity study of its stellar content with low resolution. We present here the analysis of cluster

membership of CL001 where we found 28 cluster stars, using both radial velocity and proper motions data for stars in the observed field. Based on the computed cluster's mean velocity RV=-336 +-4.8 km/s, CL001 can be considered among the fastest cluster approaching the Sun. Moreover, we obtain a first estimation of the cluster's metallicity by using a calibration based on the Calcium triplet lines, where we found that it is a metal-poor globular cluster with [Fe/H]=-1.92+-0.18 dex.

Kathy Vivas
Cerro Tololo Inter-American Observatory

RR Lyrae stars as Reddening Probes: Calibration in the DECam Optical Bandpasses using Globular Clusters

RR Lyrae variable stars are not only a well established standard candle of old stellar populations, but also, they are extremely good standard colors. These properties make RR Lyrae stars valuable tools in high extinction regions, such as the Galactic Bulge, since it is possible to obtain the line-of-sight reddening if multi-band photometry is available. We present preliminary results of an ongoing project that aims to derive calibrated Color-Period relationships in the optical filters (ugrizY) used by the Dark Energy Camera (DECam) on the Blanco Telescope at CTIO. We obtained multi-band, multi-epoch observations of 12 galactic globular clusters with known populations of RR Lyrae stars, spanning a range of metallicities, location in the Galaxy and Oosterhoff type.

Mario Soto
Universidad de Atacama

The extinction of the southern Galactic disk in VVV

We report on an extinction map derived from the VVV survey data in the Southern Galactic disk. This map, obtained with the Rayleigh-Jeans Color Excess method, supersedes previous versions which relied on older pipelines and thus it allows a more robust determination of extinction values in the stellar populations close to the Galactic plane.

Mike Beasley
Instituto de Astrofisica de Canarias

Deconstructing the mass accretion histories of Red Nugget “relic” galaxies via their globular cluster systems

Massive, compact “relic” galaxies are extremely old, metal-rich and high-density systems. They are thought to be the local counterparts of the Red Nuggets seen at high redshift which are believed to go on to form the cores of nearby early-type galaxies. The study of these systems

offers the opportunity of understanding the earliest phases of massive galaxy formation in the Local Universe. In this contribution I will discuss the key role that globular clusters play in identifying true relic galaxies, and in constraining their formation histories. More generally, I will show that hierarchical merger models can be used to constrain the accreted mass fractions of massive galaxies using only the number and colour distributions of their globular cluster systems as input. Our approach makes predictions for the mass distribution of the dark matter haloes of massive galaxies — which in the case of relics turn out to be quite unusual — and is something that can be directly tested via GC kinematics with JWST.

Morten Andersen
Gemini Observatory

The importance of high spatial resolution -- Multiconjugate Adaptive Optics observations of you massive star clusters

The low-mass content of massive star clusters and how massive star clusters form are still open and important questions in astrophysics. One of the main obstacles to tackle these questions is large degree of crowding. Here we present recent results from multiconjugate adaptive optics observations of young massive star clusters in the Milky Way and the Large Magellanic Cloud. We will discuss the low-mass stellar content and the spatial distribution of the stars which provides information on the formation path of the clusters.

Nathan Leigh
Universidad de Concepción

The Chaotic Three-Body Problem in Newtonian Gravity

This paper derives a general statistical solution to what is arguably the oldest open question in both physics and astrophysics: the three-body problem. The three-body problem has resisted a general analytic solution for centuries. Various implementations of perturbation theory provide solutions in portions of parameter space, but only where hierarchies of masses or separations exist. Numerical integrations show that bound, non-hierarchical triples of Newtonian point particles will almost always disintegrate into a single escaping star and a stable, bound binary, but the chaotic nature of the three-body problem prevents the derivation of tractable analytic formulae deterministically mapping initial conditions to final outcomes. However, chaos also motivates the assumption of thermodynamic ergodicity. Using this assumption, we derive a complete statistical solution to the non-hierarchical three-body problem, one which provides closed-form distributions of outcomes (e.g. binary orbital elements) given the conserved integrals of motion. We compare our outcome distributions to large ensembles of numerical three-body integrations, and find good agreement, so long as we restrict ourselves to “resonant” encounters (the ~ 50% of scatterings that undergo chaotic evolution). In analyzing our scattering experiments, we identify “scrambles” (periods in time where no pairwise binaries exist) as the

key dynamical state that ergodicizes a three- body system. The generally super-thermal distributions of survivor binary eccentricity that we predict have notable applications to many astrophysical scenarios, such as the formation of gravitational wave sources in globular clusters.

Paula Jofre
UDP

Accuracy and precision of industrial stellar abundances

TBD

Sebastian Ramirez Alegria
Universidad de Antofagasta

High-mass stars in VVV Clusters

TBD