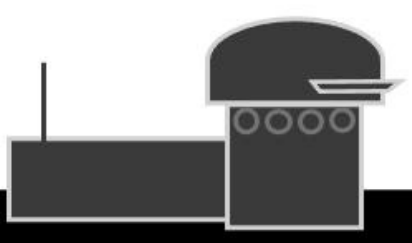
SONG 2024 Science Meeting

10 Years of Science and the Future with SONG

September 18-20, 2024, Tenerife, Spain

Abstract Book



Universidad de La Laguna

INSTITUTO DE ASTROFISICA DE CANARIAS · IAC ·

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- Ana Escorza – Instituto de Astrofisica de Canarias, Spain – *meeting's ombudsperson*
- Diego Godoy-Rivera – Instituto de Astrofisica de Canarias, Spain – *co-chair*
- Desmond Grossmann – Instituto de Astrofisica de Canarias, Spain
- Pere Palle – Instituto de Astrofisica de Canarias, Spain

Confirmed intived speakers

- Mads Fredslund Andersen – Aarhus University, Denmark
- Megan Bedell – Flat Iron Institute, USA
- Juan Antonio Belmonte – Instituto de Astrofisica de Canarias, Spain
- Antonio Eff-Darwich – Universidad de la Laguna, Spain
- Frank Grundahl – Aarhus University, Denmark
- Kelly Hambleton – Villanova University, USA
- May Gade Pedersen – University of Sydney, Australia
- Hans Kjeldsen – Aarhus University, Denmark
- Marian Martinez Gonzalez – Instituto de Astropfísica de Canarias, Spain
- Sergio Simón-Díaz – Instituto de Astrofisica de Canarias, Spain
- Ditte Slumstrup – European Southern Observatory, Chile

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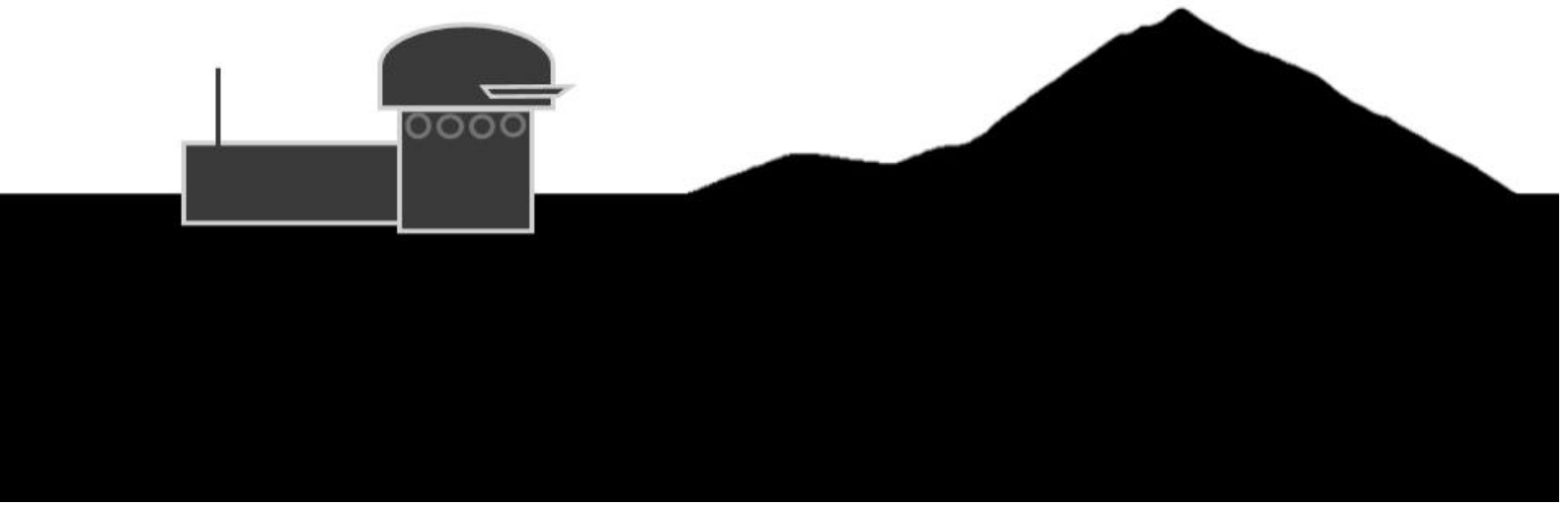
Invited contributions



How does SONG sing - the robotic operations

Mads Fredslund Andersen
Aarhus University

In this talk I will go through the procedures and processes of how SONG is observing as a robotic and automated network of telescopes.
I will highlight the operations of the SONG installation at the Teide Observatory (Tenerife, Spain) and at the Mt Kent Observatory (Australia).
The automatic selection of targets are done by a software package - the Conductor - which will be explained.

Measuring Stellar Radial Velocities at Extreme Precision

M. Bedell (1)
(1) Center for Computational Astrophysics, Flatiron Institute

Many challenges stand in the way of translating an observed stellar spectrum into a precise measurement of the star's center-of-mass radial velocity. These challenges range from instrument calibration to telluric contamination to astrophysically-driven spectral variations. Nevertheless, modern Extreme Precision Radial Velocity (EPRV) projects are beginning to achieve sub-m/s precision regularly. In this talk, I will give an overview of the data analysis tools & techniques that enable RV determination at this level of precision. I will also discuss the synergies between exoplanet-focused EPRV surveys and asteroseismology.

Who were the Guanches? The scientific quest for the ancient Canarians

Juan Antonio Belmonte (1)
(1) IAC

For decades helio- and astero-seismology conferences have been held in the Canaries, notably in Tenerife; a few SONG Meetings among them. However, delegates hardly had the opportunity to learn about the people who lived in these islands prior to the Castilian conquest and colonisation along the 15th Century. In the last two decades, different sciences such as archaeology, epigraphy, genetics, astronomy --in its cultural aspects--, and physics thanks to C14 dating, have offered substantial clues as to who these people were, where they came from and when they did it. They apparently ignored navigation during the first European contacts in the late Middle Ages. Hence, the main open question still discussed is how, and exactly from where, they reached this isolated Archipelago in the middle of the Atlantic. In this short review I shall discuss this scientific evidence and will offer the state of the art discussions on this controversial topic thanks to genetics, chronology, and my own archaeoastronomical and, specially, epigraphic studies.

The SONG instrumentation and data reduction

F. Grundahl
Aarhus University

I will describe the basic properties and observing modes for the SONG instruments for the Hertzsprung SONG telescope and the SONG-Australia node. I will provide an account of the recently completed, Python based, spectral extraction pipeline and the pyodine package. Examples of performance and challenges will be given, with emphasis on the status of the new detector at Hertzsprung SONG telescope. Comments on possible future instrumentation upgrades will also be given.

Unlocking Stellar Secrets: The Advantages of Combining Asteroseismology and Binary Star Physics

Kelly Hambleton
Villanova University

Binary star systems are a treasure trove of information for understanding stellar physics. Well-behaved binary systems with wide, detached orbits provide a unique laboratory for studying stellar evolution and determining stellar parameters. These systems allow us to test the asteroseismic scaling relations and offer complementary data that enhance asteroseismic analysis. Conversely, "badly behaved" systems—those experiencing significant tidal forces, angular momentum exchange, or mass transfer—profoundly impact the life cycles of both stars in the binary, leading to phenomena such as tidally excited pulsations, rapid rotation, chemical enrichment, and orbital evolution. In these cases, asteroseismology has emerged as a powerful tool for probing the internal structures of the binary components, offering unprecedented insights into their physical properties and evolutionary states.

In this talk, we will explore the influence of binary star modeling on asteroseismology and highlight the critical role asteroseismology has played in understanding the evolution of complex binary systems. We will demonstrate how the integration of binary star physics with asteroseismology, supported by high-precision observational data from missions like TESS and SONG, is revolutionizing our understanding of stellar structure and evolution.

Viewing stellar structure and evolution through the lens of asteroseismology

M. G. Pedersen
University of Sydney

From the study of exoplanet host stars to supernovae progenitors, a wide range of fields in astronomy rely on predictions from stellar structure and evolution models. Asteroseismology is the study and interpretation of stellar oscillations, which travel deep into the stellar interiors and therefore carry information about the conditions within. This allows us to not only derive fundamental stellar parameters useful for the study of exoplanet and galactic archaeology, but also test our stellar structure and evolution models thereby improving our understanding of stars. With this talk I will provide an overview of how we use photometric and spectroscopic time series to study stellar pulsations, what they can tell us about the stars as well as recent discoveries and advancements made with asteroseismology.

MUSOL. A unique laboratory for the global observations of the Sun.

M. J. Martínez, T. del Pino, P. Pallé, A. Rossemberg
IAC

The Sun's activity cycle was discovered at the end of the XIX century and it has been monitored since then in many different observables. One of the most famous survey is the one at Mount Wilson Observatory, which has been recording the emission at the core of the Ca II H line for more than 50 years. These kind of surveys drive nowadays the study of the activity of other stars. However, though the Sun's cycle is being surveyed and characterised, still we don't know why the Sun even has a cyclic activity. MUSOL (Magnetometry Unit for SOLar-SONG) is an initiative to greatly advance in our knowledge of the Sun's activity and its relationship to the global magnetic field. It is a disc integrated spectropolarimeter that feeds the SONG spectrograph, allowing unique high spectral resolution, high polarimetric accuracy, full Stokes spectropolarimetry of the Sun's integrated disc in the optical range. In this talk, I will review the instrumental concept of MUSOL and I will focus on the expected scientific return. The science comprises the study of the Sun's cycle and global field but also innovative studies on energetic events such as flares. Also, MUSOL serves as a test bench for many stellar analysis techniques.

Chorusing SONGs around the world: the new SONG scientific coordination structure

S. Simón-Díaz (1)
(1) IAC/ULL

In March 2023, and after 9 years of successful operation of Hertzsprung-SONG, we decide to activate a pilot project aiming to improve even further the scientific exploitation of the already available SONG observing facilities (mostly the one in Tenerife, but also the recently incorporated node in Australia) as well as getting ready for an optimal exploitation of the full SONG network (as new facilities will, slowly but surely, be joining the family).

We basically decided to jump from the usual strategy of PI proposals to be submitted and evaluated twice a year, to a more efficient preparation of longer-term proposals discussed and implemented within an optimized working group structure. This structure includes four main working groups (WG), named (WG1) Asteroseismology, (WG2) Exoplanets, (WG3) Binary stars, and (WG4) Spectroscopic variability, plus another one centered on technical/calibration observations. In brief, each one of these WGs, coordinated by one chair (and maybe also a deputy chair), will be in charge of discussing together about observations of interest within the specific topic indicated by the name of each WG. The outcome of the discussion should be a prioritized list of targets to be observed during an specific time-span (which can be longer than the usual 6 months) and with a specific cadence. Everyone in that group will have access to the compiled observations, but how the scientific exploitation will be done should be planned and discussed within each working group. There are also some rules regarding co-authorship of the resulting publications using SONG data.

Each working group will have a more or less fixed percentage of observing time along the year (for example, Astero: 50%, Exoplanets: 20%, Binary stars: 10%, Spectroscopic variability: 20%). While the proposed list of targets which are active should be in coherence with this percentage of time, one important thing to take into account is that this list is not necessarily fixed and can be modified at any time if decided by the corresponding working group. For example, if at some point there are enough epochs for a given targets, the chair of the working work can communicate to the science manager to replace this star by another one and this will be done on the spot.

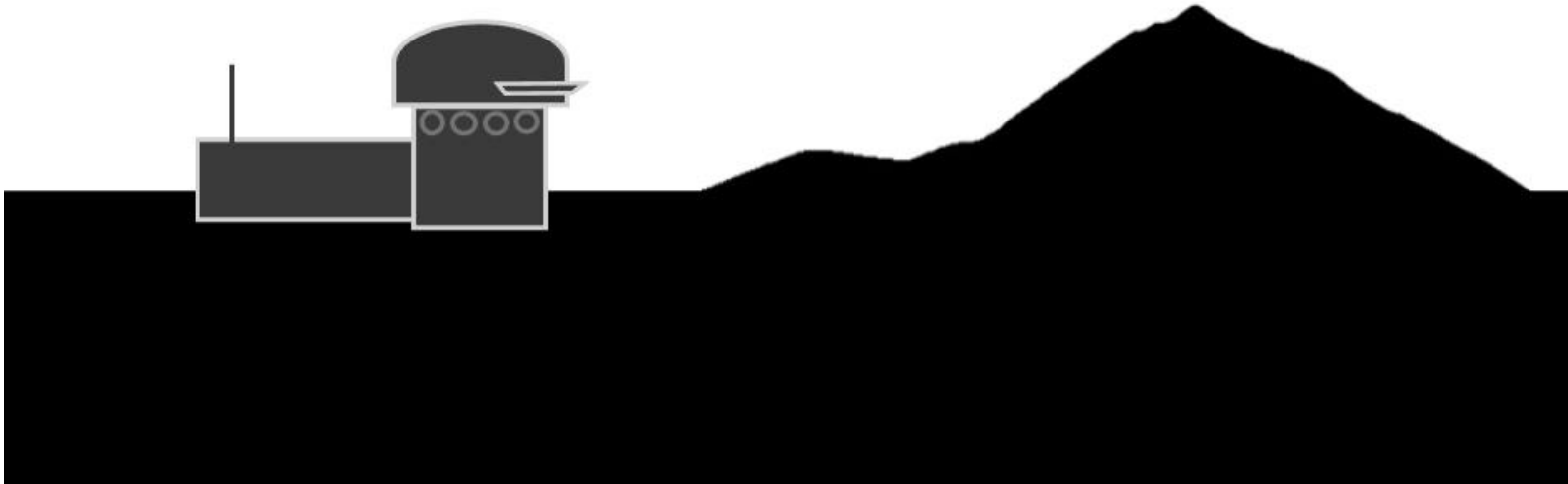
In this talk I will briefly explain to the audience how this new SONG-WG structure has been working during the first year activity, the leassons when learnt, and will present some ideas for further discussion among the SONG community.

Precision stellar spectroscopy in the era of large spectroscopic surveys

D. Slumstrup (1,2), S. Vitali (3,1), P. Jofre (3), H. Korhonen (4)
(1) ESO, Chile (2) Grantecan, Spain (3) Universidad Diego Portales, Chile, (4) MPIA, Germany

With the launch of the Gaia mission Galactic archaeology that uses fossil records to study the evolution of the Milky Way entered a new era. Additional to Gaia, large scale asteroseismic and spectroscopic surveys provide very valuable information, in particular ages and chemical compositions of stars. The massive data sets are treasure troves but come with significantly lower precision than what individual studies can supply and full agreement between different spectroscopic surveys is lacking. This is in part made up for by both internal and external calibrations, which can have the unfortunate side effect of hiding valuable information. To further our understanding, we need to increase the accuracy and precision of stellar parameters and chemical abundances on larger scales by calibrating the surveys on already well-studied benchmark stars, such as the Gaia-ESO benchmark stars (GBS) sample. The GBS cover not only different stellar spectral type but soon also different wavelength ranges because we are collecting high resolution (R~100,000) and high signal-to-noise (>200) infrared spectra in the YJHK bands. This will allow us to homogenously study a large set of benchmark stars in the different wavelength ranges covered by the different surveys. We know that homogeneity, high resolution and high signal-to-noise is crucial to achieve the high precision and accuracy that we are striving for to apply methods such as chemical tagging on larger scales, where our recent results on a homogeneous UVES data set of 75 K2 stars demonstrate well the complications we encounter even with high quality data. I will present this recent work plus our current and future work on the GBS.

Contributed & requested talks



The eccentric progeny of AGB binaries: the 15-year Mercator monitoring program and its synergy with SONG

A. Escorza (1) & H. Van Winckel (2)
(1) Instituto de Astrofísica de Canarias, (2) Institute of Astronomy, KU Leuven

A rich collection of peculiar objects forms when Red or Asymptotic Giant Branch stars undergo gravitational interactions in binary systems. Some of these binary interaction products seem to have avoided common envelope (CE) evolution and have something important in common: their orbital properties cannot be fully explained by standard binary evolution models. Their orbital periods are too long to be the outcome of CE evolution, but too short to have hosted an RGB or an AGB star. Additionally, their non-zero eccentricities are at odds with the predictions of tidal interaction. These systems are excellent tracers of the interaction processes involved in their formation and can be used to constrain significant uncertainties that remain in binary evolution and interaction models. However, their periods are very long, and the observational efforts needed to constrain each orbit are almost unaffordable.

In this context, the HERMES spectrograph, mounted on the Mercator Telescope, in La Palma, has been game changing. Soon after the telescope commissioning, a long-term monitoring program started observing evolved stars, focusing on detecting and/or characterizing binaries with an evolved component. 15 years later, I will review the unique datasets obtained for different families of evolved binaries. I will highlight the most important scientific results of this monitoring program, putting special emphasis on the breakthroughs that would not have been possible without Mercator's dedication. Additionally, I will describe the biases of the dataset and discuss how SONG can complement it and become an integral piece in the evolved binary puzzle over the next years.

The Paranal solar ESPRESSO telescope: PoET

A. R. G. Santos (1), N. C. Santos (1), R. Gafeira (2), A. Cabral (3), A. Silva (1), A. Oliveira (3), B. Wehbe (3), D. Alves (3), I. Leite (3), J. Martins (1), M. Abreu (3), M. Monteiro (1), P. Moreno (1)
(1) Instituto de Astrofísica e Ciências do Espaço - U. Porto, (2) Instituto de Astrofísica e Ciências do Espaço - U. Coimbra, (3) Instituto de Astrofísica e Ciências do Espaço - U. Lisbon

The Paranal solar ESPRESSO telescope (PoET) is a new daytime instrument to be linked to the night-time spectrograph ESPRESSO (ESO-VLT). PoET aims to observe the Sun during the day, taking advantage of ESPRESSO's wide spectral range and high resolution of R~200000. Currently being built, PoET is expected to see its first light in the second quarter of 2025. By collecting simultaneous disk-resolved, up to a resolution of 1”, and Sun-as-a-star observations, the primary goal of PoET is to advance our understanding of solar phenomena, particularly magnetic activity, and their signature in disk-integrated observations. Originally conceived to mitigate stellar signals for improved planet detection and characterization—especially for Earth-like planets around Sun-like stars—PoET will also promote a more complete understanding of the physical processes taking place in the Sun. With its unparalleled combination of spectral resolution and range, PoET will monitor the Sun for several hours per day, providing valuable data across the solar disk, from active regions to the quiet Sun, among other solar scenarios. Such data will be a valuable asset to radiative transfer modelling, MHD wave propagation, atomic model tuning, and long-term monitoring of the solar atmosphere. Furthermore, the knowledge acquired through PoET will complement ESPRESSO’s night-time observations and boost the solar-stellar connection. PoET exemplifies the synergy between night-time spectrographs and solar observations.

Sequential neural posterior estimation for inversion of the rotation profile of solar-like stars

C. Verret (1), A. Eff-Darwich (2,3), R. García (4), M. Huertas (2,3), S. Korzennik (5), S. Mathur (2,3)
(1) CentraleSupélec, (2) ULL, (3) IAC, (4) CEA Saclay, (5) CfA

Retrieving the internal rotational profile of solar-like stars from seismic observations is key to understanding the angular momentum transport in those stars, which impacts the ages derived from stellar modeling. For solar-like stars, inversions with classical techniques (regularized least square, RLS, and optimally localized average, OLA) has been very challenging due to the small number of observed rotational frequency splittings.
We present initial results from a novel machine learning (ML) technique that uses sequential neural posterior estimation (SNPE). This is a simulation-based inference algorithm based on automatic posterior transformation, which includes a statistical analysis that allows us to estimate uncertainties.
To train this ML technique, we simulated 10,000 rotation profiles, that are a combination of several piecewise constants and slopes. These profiles are easy to parametrize as they only depend on a set of rates and positions. Thanks to rotational kernels derived using a standard solar model, we computed the corresponding rotational splittings for the 48 modes that are typically measured with a high signal-to-noise ratio for the solar-like stars observed by the Nasa Kepler mission. The training data is therefore a pair of the parameters of the rotation profile (output of the SNPE) and the corresponding splittings (input of the SNPE).
We find that the rotation rate inferred both at the surface and in the interior from the posteriors are correctly retrieved within the uncertainties, while the precise location of the change of the profile recovered is less reliable, but still in agreement within the error bars.
Finally, we test the SNPE algorithm on solar rotational splittings acquired by observing the Sun as a star and compare the ML results to those obtained with a traditional RLS technique. The ML technique recovers the rotation profile better than the RLS technique, suggesting that the SNPE is a very promising algorithm for retrieval of stellar internal rotation profile.

Relocating SONG-China to the Lenghu site

Chunguang Zhang(1), Licai Deng(1), Qili Liu(2), Fan Yang(1), Xiaodian Chen(1)
(1)National Astronomical Observatories, Chinese Academy of Sciences

In July 2012, the Delingha site was chosen to construct the Chinese node of SONG after evaluating available choices. We started regular manual operations after the first-light in August 2015. However, observing conditions deteriorated over the following years with rapidly increasing light pollution and less observing nights as a result of urbanization and climate change, respectively. We started monitoring the Lenghu site in March 2018, and confirmed it to be a high-quality site for optical astronomy based on 3 years of continuous data. Since November 2021 we have been working on moving SONG-China to the Lenghu site, and the whole process is nearly finished. We hope the Chinese SONG node can start working again in Lenghu this winter.

Multiple Melodies: Probing Binary Coevality with SONG Asteroseismology

D. Godoy-Rivera (1)
(1) Instituto de Astrofísica de Canarias

Binary stars play a crucial role in astrophysics, offering essential insights into star formation and stellar evolution. A key element of their diagnostic power is the so-called “coevality assumption”, which posits that the components of a given binary system share the same age. While the use of the coevality assumption is widespread (e.g., determination of stellar properties, age-dating benchmarks), it has been scarcely tested in the literature. In this work, I will discuss the prospects for novel constraints to the binary coevality assumption from asteroseismic analyses. New samples of binary systems with wide separations (a > 100 AU) have been identified in recent years thanks to the Gaia astrometry. Some of these binaries feature bright and cool components (apparent G < 8 mag and Teff < 5500 K) and could therefore exhibit asteroseismic oscillations detectable by SONG. By integrating constraints from asteroseismic analyses with classical characterization methods, precise ages can be obtained for the binary components, paving the way for novel studies into the coevality assumption

Discovery of high-degree nonradial pulsations in Zeta Virginis

D. Mkrtichian
NARIT

I will report on an ongoing high- and medium-resolution spectroscopic survey, which has resulted in the detection of 44 new bright (V = 2-6 mag) rapidly rotating A-type (vsini > 100 km/s) high-degree nonradial pulsators. Most of these stars exhibit prograde nonradial pulsations with frequencies reaching up to 80-110 c/d. These new Delta Scuti-type pulsators are ideal targets for detailed investigation of their pulsation spectrum using multisite SONG campaigns.

High-degree nonradial pulsations in the rapidly rotating A3 V star Zeta Virginis (vsini = 227 km/s) were discovered in 2023 during this survey. Eight nights of new high-resolution single-site SONG observations of Zeta Virginis were carried out at OT on May 9-16, 2024. The two-dimensional Discrete Fourier Transform analysis of line-profile variations revealed the excitation of a rich spectrum of high-frequency (f = 5-112 c/d) and high-degree (l, m = 4-20) nonradial modes. The low-degree mode spectrum was revealed through the analysis of TESS light curves. I will discuss the discovered frequency spectrum and the reasons for the apparent extension of the frequency spectrum to high frequencies.

Planets Orbiting Evolved Stars - Lessons from the 25-Year Lick-SONG-CARMENES Monitoring Campaign

D. Spaeth (1), S. Reffert (1)
(1) Landessternwarte, Zentrum für Astronomie der Universität Heidelberg

To capture a comprehensive picture of the diversity of exoplanets, it is necessary to detect planets in various environments. By focusing on planets orbiting evolved stars, we can explore a higher stellar mass regime than typical planet searches around main-sequence stars and provide a glimpse into the influence of the host star's evolution on planetary systems. So far, around 150 planets orbiting evolved stars have been confirmed, of which the planets around lower-luminosity giants are well-established. However, detecting planets around very luminous giant stars presents unique challenges. Namely, several of these giants, previously thought to host planets, were recently revealed as false positives. For one such false-positive host, a dipole non-radial oscillation model provides the so-far best alternative explanation for the variations of the radial velocities and the associated activity indicators. Nonetheless, the overall picture remains elusive.
In this talk, I present intermediate results from a 25-year radial velocity monitoring campaign combining data from Lick, CARMENES, and SONG for evolved planet candidate stars. I demonstrate that the activity indicators available from the CARMENES spectrograph can sometimes decisively argue against the planetary nature of the radial velocity variations. Nevertheless, a long baseline of RV measurements remains the most crucial diagnostic for identifying discrepancies from a Keplerian signal and confirming planetary companions. I outline our plans to combine SONG data with the upcoming Waltz radial velocity survey at Landessternwarte, Heidelberg, and discuss how the effect of the Waltz CCD's charge transfer inefficiency offers a new approach to investigate spurious periodicity in SONG radial velocities.

Using cluster stars observed by K2 to interpret single stars observed by SONG

D. Stello, C. Reyes et al.
UNSW-Sydney

Performing asteroseismic analysis to probe the physics in the deep interior of open cluster stars has been a long-sought goal. The common properties among cluster stars reduces intrinsic star-to-star variation among an ensemble, leading to clear stellar sequences in fundamental astronomical diagrams, such as the colour-magnitude diagram. Such sequences provide insight into stellar evolution and can serve as diagnostic tools to inform stellar properties of field stars. Hence, using clusters stars to make asteroseismic diagrams could provide a way to probe yet undiscovered stellar physical processes and to inform interior properties of single stars.
In this talk I will present new seismic results on the subgiants and red giants in M67 from three campaigns of K2 data. The cluster stars reveal beautifully clear sequences – like pearls on a string – in the small-versus-large frequency separations – known as the CD diagram, and in the epsilon-versus-large frequency separation diagram. These sequences show new features that reveal the location of the bottom of the convective envelope as it moves deep into the stellar interior in the very early red giant branch phase. The result shows that the CD diagram has the potential to study overshoot at the bottom of the convection zone and that it holds diagnostic power to estimate mass and hence age in late evolutionary phases. I will demonstrate how these results can be used to inform target selection and our interpretation of single-star observations made by SONG.

A new catalog of magnetically active solar-like oscillators

E. Corsaro (1), A. Bonanno (1), C. Kayhan (2), M. P. Di Mauro (3), R. Reda (3), and L. Giovannelli (3)
(1) INAF OACT, (2) Erciyes University, (3) INAF IAPS

In this talk I will present a recently published new catalog of stars for which detected solar-like oscillations and magnetic activity measurements from chromospheric spectroscopic observations are both available. These results were obtained by exploiting NASA TESS mission light curves for active stars observed within the Mount Wilson Observatory HK project and the HK survey of the Hamburg Robotic Telescope TIGRE. Light curves for a total of 191 stars were analyzed by adopting recent techniques based on Bayesian analysis and model comparison to assess the presence of a power excess originating from solar-like oscillations. Solar-like oscillations could be characterized in a total of 34 targets, for which estimates for the global asteroseismic parameters nu_max (the frequency of maximum oscillation power), Delta_nu (the large frequency separation), and the amplitude of the solar-like oscillation envelope A_max are available.
This catalog opens the possibility of shedding light on the interplay between magnetic fields and oscillations.
Importantly, because of their relatively high brightness, several of these targets are suitable for observations with SONG. This would offer the unique opportunity to study how oscillation amplitudes of active stars compare between photometry and

spectroscopy, and to possibly confirm oscillations in some of the targets for which the detection outcome from photometry was unclear.

Introduction of the Optical Observation Environment of the New SONG Site

Fan YANG
NAOC

Lenghu site is located in the Saishiteng Mountain near Lenghu Town in Qinghai Province whose altitude is about 4200m. It has replaced Delingha as the new SONG site of China. I will introduce the general information about Lenghu site. Detailed site parameters, site monitoring instruments, and site conditions will be presented. I will also talk about the measures have been and/or will be taken to preserve the dark sky of Lenghu site.

SONG at Apache Point Observatory: Status update

Jason Jackiewicz (1), Jon Holtzman (1), Chas Miller (1)
(1) New Mexico State University

The National Science Foundation in the U.S. is supporting the installation of a new SONG node at Apache Point Observatory in southern New Mexico. The project is finishing up its second year and lot of progress has been made. The goal is to be science ready in September 2025. Much more work needs to be done, and this talk will report on the milestones reached and the challenges ahead.

Determining the stellar properties of χ Dra A using radial velocities from SONG and asteroseismology from TESS photometry

Jonatan Rudrasingam (1), Frank Grundahl (2), Mikkel Lund (3), Poul Erik Nissen (4)
(1) AU, (2) AU, (3) AU, (4) AU

The mass of χ Dra A is determined using 622 radial velocities from the SONG telescope on Tenerife and 53 previous astrometric measurements. The mass is around 1 $M_\odot$. Furthermore, using 27 TESS sectors, we determined the average asteroseismic parameters and 18 oscillation frequencies, which we used to determine the stellar properties. We compared the asteroseismic mass with the dynamical mass, and they are in agreement.

The NLTE effects of important elements based on high-resolution spectra

Junbo Zhang(1,2), Jianrong Shi(1), Carlos Allende Prieto(2), Hong Wu(1)
(1)NAOC, (2)IAC

Stellar element abundances, when combined with kinematic characteristics and age, can effectively depict the properties of the Milky Way and various stellar populations. This is crucial for advancing our understanding of the formation and evolution of stars and galaxies. However, deriving precise stellar abundances is challenging. The low particle density in the atmospheres of certain stars, along with the fact that some spectral lines originate from high energy levels, can lead to deviations from Local Thermodynamic Equilibrium (LTE). In such cases, it becomes essential to consider Non-Local Thermodynamic Equilibrium (NLTE) to accurately determine stellar parameters and element abundances. We have performed NLTE abundance analyses for several key elements in both optical and infrared bands of selected stars based on high-resolution spectra. Moving forward, we plan to simultaneously calculate the NLTE populations of Mg, Ca, and potentially other elements, to explore the NLTE effects on individual and multiple elements.

Chemical abundance inventory in phosphorus-rich stars

M. Brauner (1), (2), T. Masseron (1), (2), D. A. García-Hernández (1), (2)
(1) Instituto de Astrofísica de Canarias, (2) Departamento de Astrofísica, Universidad de La Laguna

Chemically peculiar stars, such as the recently discovered metal-poor phosphorus-rich ([P/Fe] $\gtrsim$ 1.2 dex) stars, call current theories on stellar nucleosynthesis and galactic chemical evolution into question. Given that the P-rich low-mass and low-metallicity giants are not expected to produce their high phosphorus contents themselves, we aim at finding clues on the progenitor that polluted the interstellar medium out of which these stars were born. On the search for the progenitor, we first achieved a remarkable enlargement of the P-rich stars sample, from originally 16 to 78 stars. We performed a detailed chemical abundance calculation on this new sample, using the high resolution near-IR (H-band) spectra from the APOGEE-2 survey (DR17). Among other things, we report enhancements in several elements, such as Al, Si and Ce, as well as strong correlations. In a second step, we analyzed optical UVES spectra of four P-rich stars, successfully obtaining the abundances and upper limits of 21 light ($Z \leq 30$) and 27 heavy ($Z > 30$) elements, including key elements characteristic for different nucleosynthetic processes, such as the s- and i-process.
In this talk, I will give an overview on the current knowledge on these chemically peculiar stars, in particular, about the chemical inventory that we obtained as well as its implications on the nature of nucleosynthetic process of the P-rich stars progenitor. By uncovering the origin of the P-rich stars we may gain insights on the still unknown nucleosynthetic formation pathways of phosphorus in our Galaxy.

Interferometric observations of solar-like pulsators: a survey to constrain scaling relations

M. Vrard (1), D. Mourard (1), O. Creevey (1), S. Deheuvels (2)
(1) Observatoire de la Côte d'Azur, (2) Institut de Recherche en Astrophysique et Planétologie

The asteroseismic scaling relations allowing to estimate the masses and radii of solar-like pulsators have now been vastly used to investigate a great number of physical problems in the local universe. However, recent results on luminous red giants and binaries show that the scaling relations appear to be inconsistent with dynamical measurements and Gaia data in these specific regimes. It is therefore necessary to obtain precise and accurate independent measurements to evaluate and understand the limits of seismic scaling relations. It is the program that is proposed by the ERC ISSP (Interferometric Survey of Stellar Parameters) which has the objective of obtaining direct interferometric constraints on nearby stars with an angular diameter larger than 0.2 mas. The use of the SPICA instrument in the visible with the 300m bases of the CHARA interferometer indeed allows us to reach a precision of 1% on the radius. Thus, the realization of a survey of hundreds of asteroseismic targets with interferometric observations becomes possible. That is what the ERC ISSP is proposing and has started to perform in 2023. In this talk we will present the first results of this interferometric survey on several solar-like pulsators, finding a coherence between the interferometric and asteroseismic radii. We will also discuss what can SONG data bring to the survey and the importance of it for benchmark PLATO stars.

Introducing an automated pipeline for the estimation of the period spacing and other seismic parameters of solar like oscillators

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Due to missions like KEPLER and TESS, large datasets with promising seismic data are now readily available. While the estimation of some parameters can be automated, yielding satisfactory results, the automatic estimation of the period spacing proves to be problematic. We present a pipeline that can be used on datasets containing a large number of targets. The aforementioned pipeline automatically estimates key seismic parameters, the position of the central five l=0 and l=2 modes, and the position of safely detectable l=1 mixed modes. Our pipeline produces values for DeltaPi which lie >80% of the time in an interval of 10% around the literature value for a sample (N=450,M=2-3 solar masses). Furthermore, we achieved a result of >70% for another sample (N=3600,M=0.8-3 solar masses). We achieve this by identifying the frequency position of the five central l=0 peaks, eliminating them from the PSD and performing a peak search with differing prominences. We then assign a quality grade to each assumed dipole mode, by performing an R-value correlation test, which allows for the detection and rejection of likely misidentified modes. We furthermore assign additional quality grades to the found modes which depend on their overall properties (Prominence, R-value, position). This enables us to group the modes into batches, which allows for a spectrum of solutions, associated to the different quality grades. Using this grading method, we achieve at least one correct value per target 92% of the time for the N=450 sample and 88% of the time for the N=3600 sample. We make use of the asymptotic relation for the calculation of DeltaPi, using an optimized version of the grid-search algorithm, resulting in a reasonable calculation time on the scale of seconds to minutes per target. While not as exact as the hands-on approach, our pipeline will prove useful if used on a large number of targets as an initial analysis.

The SONG network for PLATO Benchmark Stars

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PLATO is an ESA mission designed to detect Earth-like planets in Sun-like systems, and to use asteroseismology to characterise the host star. As part of the preparation of the mission, a workpackage called "Benchmark Stars" has been set up to (1) help prepare PLATO by providing critical test data of the stellar pipelines, and (2) to help validate the mission's scientific data, once science operations begin.
A team of scientists work together within the framework of this workpackage to better define and better characterise these targets. As most of the benchmark stars are bright, the SONG telescopes are ideal for new observations of these stars. In my talk, I will summarise the current state of the benchmark stars, including showing an overview of the selected targets. I will then present some science cases for which SONG observations are and/or would be ideal.

SONG node at Observatorio del Teide

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The “Herzsprung SONG Telescope” was the prototype and also the first node to became fully and continuously operational since more than 10 years ago (solar observations in 2012 and also stellar since 2014). In this contribution we describe its characteristics, operational scheme and the many experiences acquired since then. Furthermore, the important challenges ahead to maintain and even to improve its effectiveness will be also discussed.

SONGs of distant Earths: Exoplanetary science from the SONG network

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The stars that the SONG telescopes observe so intently are sometimes orbited by planets. This is their story. I give an update on the status and performance of the Australian SONG node which has recently begun science operations. I also present some results of exoplanet characterisation done by SONG, and discuss possible scientific aims that can be well-addressed by the network's unique capabilities.

Tracing the magnetic activity evolution of solar-like stars with long photometric observations

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The magnetic and rotational properties of solar-like stars are strongly coupled due to the interaction of rotation and convection in their outer envelopes, which fuels their magnetic dynamos and as a consequence their magnetic activity cycles.
Thanks to the large number of the Kepler targets with measured rotation periods and photometric magnetic activity index, Sph, we investigate how magnetic activity evolves in solar-like stars. We compute the stellar Rossby number, Ro, the ratio between the rotation period, and the convective overturn timescale, using the Yale Rotating Evolution Code. We divide our sample of main-sequence single stars by spectral type, revealing distinct patterns in their magnetic activity index relative to their Rossby number.
In this talk, we will present the results of such analysis. Notably, G and K dwarfs exhibit a pronounced decline in Sph around Ro/Ro_Sun,of 0.3, indicative of a transitional phase that coincides with the location of the intermediate-rotation period gap. In contrast, F dwarfs, characterized by shallower convective zones, does not show any trend of Sph versus Ro, particularly as the effective temperature rises. These deviations likely stem from the faster evolutionary pace of F dwarfs. Our analysis indicates that the Sun shares a comparable magnetic activity level with other Sun-like stars selected with similar effective temperature and metallicity. We will discuss our findings in the context of current dynamo models.

Double-mode RR Lyrae stars as robust distance and metallicity indicators

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RR Lyrae stars are one of the primary distance indicators for old stellar populations such as globular clusters, dwarf galaxies and galaxies. Typically, fundamental-mode RR Lyr stars are used for distance measurements, and their accuracy is strongly limited by the dependence of absolute magnitudes on metallicity, in both the optical and infrared bands. Here, we report the discovery of a period-(period ratio)-metallicity relation for double-mode RR Lyr stars, which can predict metallicity as accurately as the low-resolution spectra. With theoretical and observational evidence, we propose that the period-luminosity relation of double-mode RR Lyr stars is not affected by the metallicity. Combining the Large Magellanic Cloud distance and Gaia parallaxes, we calibrate the zero point of the period-luminosity relation to an error of 0.022 mag, which means that in the best case double-mode RR Lyr stars can anchor galaxy distances to an accuracy of 1.0%. For four globular clusters and two dwarf galaxies, we obtain distances using double-mode RR Lyr stars with a distance accuracy of 2-3% and 1-2%, respectively. With SONG high-accurate estimate of metallicity, double-mode RR Lyr stars will be established as an independent distance ladder in the near-field universe.

Rossby waves, stellar activity and asteroseismology

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Recent progress in the theory and observations of Rossby waves in the Sun prompts immediate application to stellar physics. The Rossby waves may lead to observed short term cycles in stellar activity. The waves can be also detected in stellar light curves, which opens the possibility to their use in asteroseismology. I will discuss recent development in the theory of Rossby waves and future applications to probe stellar interiors.

First follow-up observation for searching metal-poor candidates using Gaia XP spectra

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The 220 million low-resolution Gaia XP spectra present us great potential to search for extremely metal-poor (EMP) stars. Although machine learning is very popular for dealing with such low-resolution spectra, we use FERRE to fit these spectra with model spectra to obtain a catalog of atmospheric parameters. In this short presentation, we aim to illustrate the efficiency and potential of our catalog in searching for metal-poor stars. We selected 15 EMP candidates for the first follow-up observation with INT/IDS over two nights in February this year. The reduced spectra were then fitted with model spectra in FERRE to obtain the parameters. Six of these stars have [M/H] below -3.0.

Periodic variable stars in ZTF and TESS.

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In the last five years, the number of periodic variable stars has increased by three million. We used the ZTF DR2 data to find and build a catalog that includes 780,000 periodic variable stars. These periodic variable stars were classified into 11 types, which greatly complemented the variable stars in Galactic disk. Based on the latest ZTF DR16 data, we found 2 million periodic variable candidates. We also found 0.3 million periodic variable candidates from TESS. In this presentation, we describe methods for identifying and classifying periodic variable stars. We focus on the science of multi-period variable stars and discuss how SONG can help in the study of these variable stars.