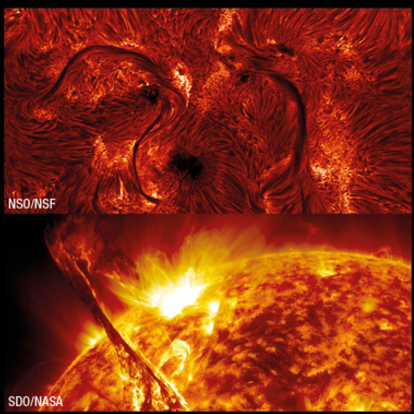
Main goals of the Severo Ochoa Research Program

IAC Postdoctoral Research Excellence Program 2020

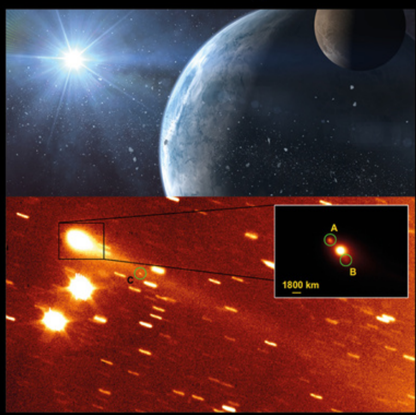
The Instituto de Astrofísica de Canarias (IAC) announces the forthcoming availability of new advanced fellowships as part of its Severo Ochoa Excellence Program. The IAC Research Division is organized in six main research areas, encompassing all the major fields of astrophysics. Each area will offer up two 4-year contract for Advanced Fellows.

The IAC Researchers have access to outstanding state of the art astronomical facilities, including the Observatorios de Canarias and the ESO Observatories, and also to the supercomputing facilities of the RES (Spanish Supercomputing Network) Participation in several ongoing and future space missions is also possible.

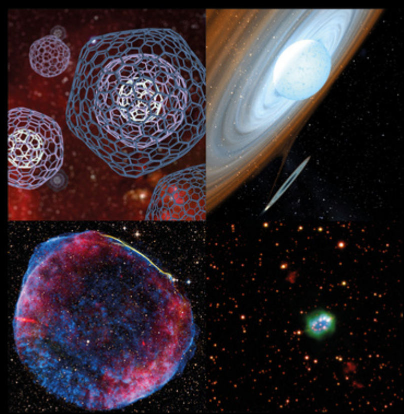
Solar Physics



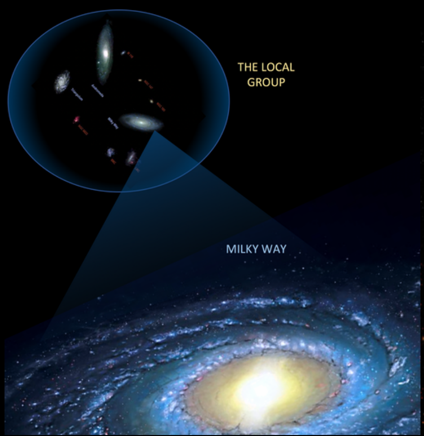
Exoplanetary Systems and Solar System



Stellar and Interstellar Physics

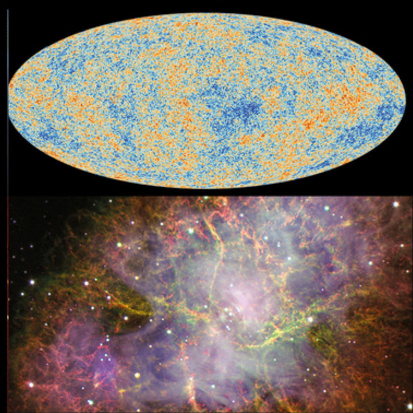


The Milky Way and the Local Group



Formation and Evolution of Galaxies

Cosmology and Astroparticles



Further information:
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EXCELENCIA SEVERO OCHOA

ULL Universidad de La Laguna

MAIN GOALS

Physics of the Sun

To observe the physical structures and processes of the Sun and understand them in terms of the laws of dynamics, magnetism and radiation transfer, including the development of cutting-edge observational and computational techniques to reach those goals.

Specific goals 2020-2023:

• To produce realistic one-, two- and three-dimensional models of key magnetic, dynamic and radiative processes in the solar atmosphere and convection zone using massively parallel computer facilities, in order to understand the physics underlying the solar structures and processes through suitable theoretical models.

• To carry out forward modelling from numerical simulations to bridge the gap between observation and theory, taking into account all the physical mechanisms that produce polarization in solar spectral lines.

• To develop novel diagnostic methods and inversion codes. Together with Bayesian inference tools, we will make a significant step forward on the quality of the information extracted from observations.

• To support space projects (e.g., CLASP, Solar Orbiter, Sunrise3) via new developments in observations and theory, including the modeling of the CLASP2 ultraviolet spectropolarimetric observations in order to study the magnetism of the upper solar chromosphere.

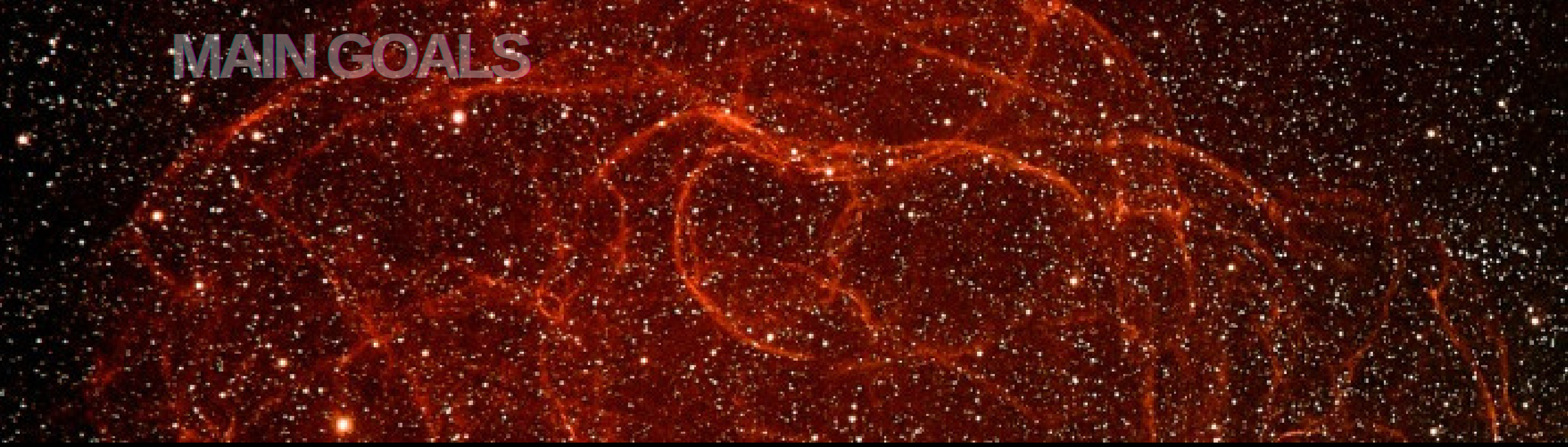
• To expand our understanding of the physics of the Sun by building a bridge between the knowledge gathered from solar observations and modeling, and the diversity of stars.

Exploring the diversity of Planetary Systems

To detect and characterize giant and rocky planets around nearbyvstars, with a focus on planets in the habitable zone and systems around binaryvstars and unusual transiting components. To understand the physical properties of asteroids, comets, transitional and trans-neptunian objects and the origin and evolution of the Solar System.

Specific goals 2020-2023:

- Discovery of exo-Earths via radial velocity searches using the available guaranteed time of the IAC in state of the art high-resolution spectrographs, such as ESPRESSO, CARMENES, NIRPS and HARPS3 (More than 500 observing nights already granted for the period)
- Measuring accurate planetary properties using observations of transiting planets around the closest and brightest host stars from TESS data and ground-based observatories (such as MuSCAT2 and SPECULOOS North), as well as from CHEOPS data for precise radius determination of the smallest exoplanets.
- Characterize exoplanet atmospheres with ESPRESSO, CARMENES and HARPS-N and JWST to push HeI, alkali and molecular detection from Hot Jupiters down to the super-Earth/mini-Neptune regime, and to contribute to the preparation of the ESA PLATO mission (expected launch in 2026).
- Develop an Adaptive Optics system for GTC based on a laser guide star (GTCAO-LGS), which will allow the direct detection and spectroscopic characterization of young giant planets.
- Study the atmospheric parameters and composition of planets' host stars including metal rich white dwarfs to shed light on the composition of the planets / asteroids engulfed during its evolution.
- To study the physical properties and composition of the minor bodies of Solar System, paying special attention to Near Earth Asteroids (NEAs), from the point of view of the planetary defence (Hera and DART missions) and the space exploration (OSIRIS-REx and Hayabusa2 missions), and primitive asteroids (using data from Gaia and JWST). We will also characterize new populations like the extreme trans-neptunian objects (ETNOs) or the interstellar asteroids and comets (e.g. 'Oumuamua and Borisov).
- Astronomy and World Heritage: promoting Earth land- and skyscapes

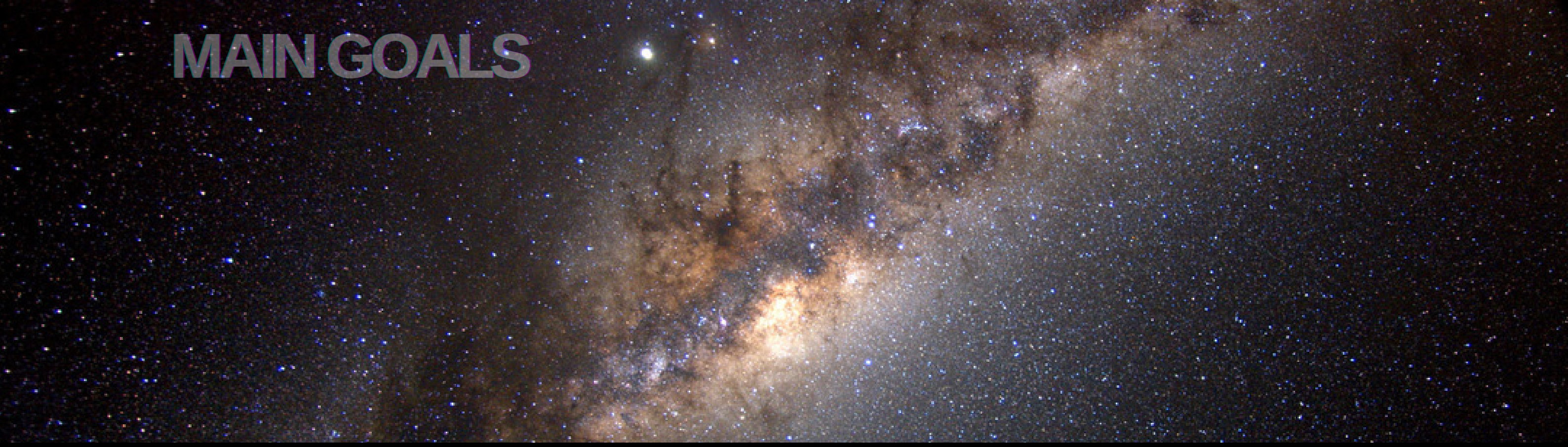


Physics of Stars and the Interstellar Medium

To understand the physics and life cycle of stars, from the most massive and luminous stars to the least luminous brown dwarfs which bridge the gap to the planetary domain, together with the interplay with the interstellar and circumstellar material in different environments and stages of stellar evolution.

Specific goals 2020 - 2023:

- Provide tight observational constraints to compact binary evolution theories, black hole and neutron star formation models, as well as Investigate the physical processes driving accretion/outflow phenomena in interacting compact binaries.
- Provide a model independent empirical description of the properties of massive stars – from protostars to core-collapse supernovae and the progenitors of gravitational wave emitters -- by exploiting the wealth of data provided by the IACOB and WEAVE-SCIP large spectroscopic surveys, as well as the TESS and Gaia space missions.
- Discover and characterize new extremely metal-poor stars formed in the first few hundred million years after the Big Bang. To this end, we will mine large spectroscopic databases, such as SDSS, LAMOST, WEAVE, and DESI.
- Understand the formation routes of complex nanocarbons like fullerenes and graphenes around evolved Sun-like stars, and their survival in molecular clouds and protoplanetary discs. We will follow a highly interdisciplinary approach including astronomy, laboratory astrochemistry, advanced material science and quantum-chemistry, among others.
- Study the connection between the integrated spectra of local HII regions and their resolved internal structure and, in particular, provide new empirical clues to better understand the abundance discrepancy problem in photoionized nebulae. We will drive conclusions from the analysis of a large sample of deep medium to high resolution spectra and/or spatially resolved spectral data of HII regions and planetary nebula.
- Understand the link between planetary nebulae and post common-envelope evolution by gathering and analyzing spectroscopic and photometric time series and 2D spectroscopy.
- Apply asteroseismic techniques to study the internal structure and dynamics along the evolution of solar-like stars from the main sequence to the red-giant branch. High cadence uninterrupted photometric data from the TESS, Kepler and K2 space missions, and ground based time-series spectroscopy obtained with the SONG network of telescopes will be of prime importance for this objective.
- Search and characterize ultracool dwarf stars and substellar objects with complementary techniques such as transits, radial velocity, and direct imaging to constrain models of formation and evolution. To this aim, we will benefit from data from the Euclid and Gaia missions.



The Milky Way and the Local Group

This line of research focuses on the study of Local Group galaxies, including the Milky Way, through resolved stars and nebulae. This field is at the center of important breakthroughs thanks to projects such as the Gaia mission, large follow-up spectroscopic surveys (e.g. WEAVE, SDSS, 4MOST, IACOB, DESI) and other players such as TESS, PLATO and LSST.

Specific goals 2020-2023:

• To study the morphology, structure, chemistry, kinematics, dynamics and assembly history of the different Milky Way components using cutting-edge datasets and interpret these properties through modelling and cosmological hydrodynamical simulations.

• To derive time resolved star formation histories of the different components (thin and thick disk, bulge and halo) of the Milky Way, the Magellanic Clouds and other Local Group galaxies using Gaia, ground based wide field imaging and HST data, and study the stellar populations of the central Galaxy using EMIR and MIRADAS

• To study the internal kinematics and chemistry of dwarf galaxies, and determine their dark matter halo properties, by exploiting Gaia and forthcoming spectroscopic surveys data.• To study the multiple stellar populations phenomenon in globular clusters using colour magnitude diagrams for objects in the Milky Way and its satellites, and high resolution integrated spectroscopy in distant galaxies

• To use Local Group galaxies as a stepping stone to study the distant and early Universe up to the epoch of reionization• To pave the road for the study of resolved stellar populations beyond the Local Group with ELT/HARMONI.

• To develop semi-empirical spectral libraries, stellar evolution model libraries and population synthesis tools, and validate methodologies using local stars, HII regions, planetary nebulae and nearby stellar systems

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MAIN GOALS

Evolution of galaxies across cosmic time

To unveil the physical mechanisms responsible for the most significant transformations in these objects. The team that makes up the research line is strongly involved in the development of forefront instrumentation (FRIDA, GTCAO, HARMONI, WEAVE) and has an important role in the scientific exploitation and development of international projects (SDSS, EUCLID, LSST, WEAVE).

Specific goals 2020 - 2023:

- Identify the sources that reionized the universe one billion years after the Big Bang. Detect and study the first galaxies and quasars. Advance in our understanding of the nature and reality of dark matter. Investigate the low surface brightness universe to test dark matter predictions and galaxy formation theories.
- Study the physics of active galactic nuclei and supernovae feedback and their connection with galaxy evolution from the observational and theoretical point of view. Explore the multi-wavelength nature of feedback and investigate its impact on the host galaxies using data from GTC/EMIR & FRIDA and ALMA. Run the largest hydrodynamical cosmological simulations to date by developing star formation and feedback prescriptions that are designed to work at low resolution.
- Study the physics of star formation and the conditions of the interstellar medium over the history of the Universe and under different physical conditions. Survey the star formation history, and the structural, kinematic and chemical properties of the various components of nearby galaxies to probe models of galaxy formation and evolution in a cosmological context. Get ready for resolved stellar population studies beyond what currently possible, exploiting future instruments on ELTs, JWST and other major facilities.
- Explore different gas accretion mechanisms necessary for galaxies to keep forming stars. Image from the first time Intergalactic Medium gas flows funnelling gas into local galaxies using GTC/MEGARA and WHT/WEAVE. Investigate the role of major/minor mergers and secular processes in galaxy evolution.
- Exploit unsupervised artificial intelligence to go beyond state-of-the-art data analysis techniques and get ready for big-data spectro-photometric surveys such as LSST, EUCLID, J-PAS and WFIRST. Improve the link between observations and theory by extracting and interpreting information from simulations of galaxies in a cosmological context spanning most of the Universes life.

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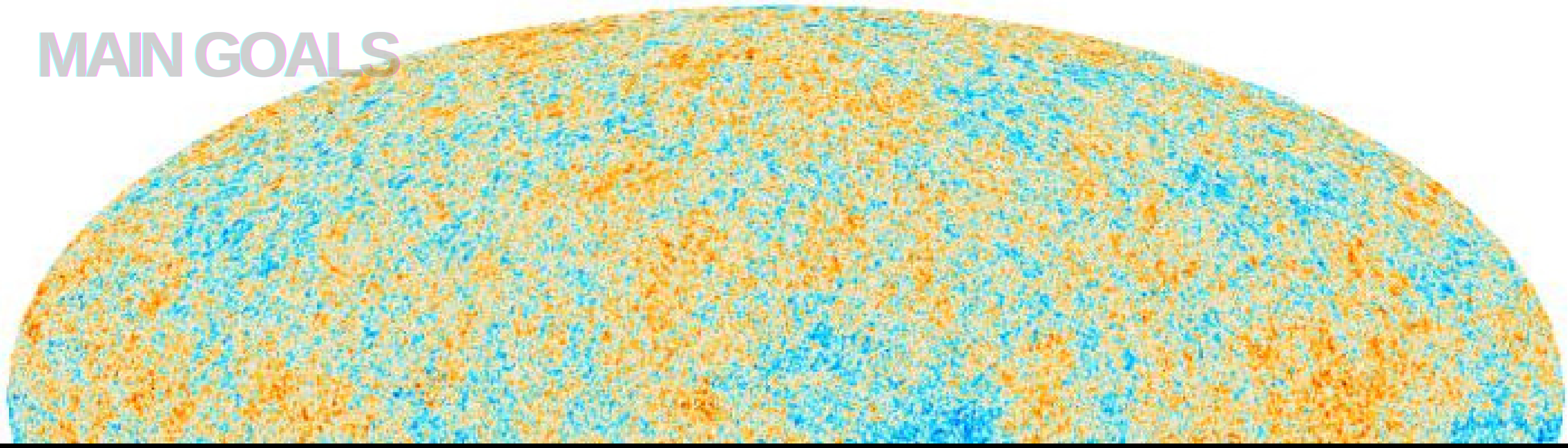
MAIN GOALS



Cosmology & Astroparticles

Aim to study cosmic- and gamma-rays sources, exploring the Early Universe, the dark ages and the nature of dark matter and dark energy.

Specific goals 2020-2023:

- Astroparticle physics: study of cosmic-rays and gamma-ray sources with AMS, MAGIC and CTA. Understanding the origin, propagation mechanismsand chemical composition of cosmic rays. First science with the Large Size Telescope of the Cherenkov Telescope Array. Contribute to multimessenger astronomy with follow-up of transient events. Searches for annihilation of dark matter with the MAGIC telescopes and preparation for TeV science with CTA.

- Cosmic Microwave Background studies on the Physics of the Early Universe, Primordial Gravitational Waves and Dark Ages. Obtain primordial Bmodes constraints combining the CMB polarization experiments at Teide Observatory (QUIJOTE, STRIP, Groundbird, KISS) with Planck. Improving detectability of B-modes by future experiments like Litebird (JAXA) via new maps of polarized radio emission in the northern hemisphere and models ofVthe radio foregrounds. Epoch of reionization constraints from spectral measurements of the CMB using newly developed instrumentation (TMS). Scientific preparation of future instruments to measure spectral distortions (SKA, space missions).

- Constraints on dark energy, dark matter, neutrino masses and time variation of fundamental constants with massive spectroscopic surveys (eBOSS, DESI, WEAVE, EUCLID, eROSITA, JPAS) and other. Cosmological parameters constraints from measurements of the low redshift large-scale structure at $0.4<z<1.6$ with DESI and EUCLID, leading the determination of accurate error bars to BAO and Redshift Spectral Distortion measurements Dark energy equation of state constraints and dynamical behavior determination using the new DESI Lyman alpha data. BAO reconstruction combined with cosmic voids to provide best BAO measurements. Study cosmic web around galaxy clusters using eROSITA data and JPAS data. Constraints onneutrino masses with Planck, galaxy clustering, Lyman alpha forest and galaxy clusters with DESI, EUCLID and WEAVE. LCDM model tests using the Integrated Sachs-Wolfe effect. Searches of ultra-light bosonic particles: axions and dark photon emission from stellar evolution considerations (eg. Tip of the Red Giant Branch), and improved constraints from microwave polarimetry.

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