XIX IAG/USP Advanced School on Astrophysics

RADIOASTRONOMY

August 31 – September 5, 2025 – Bertioga/SP, Brazil

PROGRAMME

Topic I: "*Radio Telescopes and Fundamentals of observations*"

Alex Kraus (Max-Planck-Institut-für-Radioastronomie, Germany)

Ia) Basic properties of radio telescopes

Ib) Observation methods of "single-dish" radio telescopes

Ic) Observations in the millimeter wavelength range

Topic II: "*An introductory course to the properties of the interstellar medium*"

Maite Beltran (INAF, Italy):

IIa) The composition of the ISM and their properties

IIb) The star formation process of both low- and high-mass stars

IIc) Astrochemistry and molecular astrophysics

Topic III: "*Radio Interferometry: Principles, Practices, and Astrophysical Frontiers*"

Laurent Loinard (UNAM, Mexico):

IIIa) Introduction to radio interferometry

IIIb) Very Long Baseline Interferometry (VLBI)

IIIc) The astrophysics of interferometry

Topic IV: "*Active galactic nuclei at radio wavelengths: properties, life and impact*"

Raffaella Morganti (University of Groningen, The Netherlands):

IVa) Active galactic nuclei (AGN) and radio AGN: and introduction of their properties

IVb) Structure of radio AGN and their life cycle

IVc) Radio jets and their impact in galaxy evolution

Topic V: "*Spectral Line Astrophysics with interferometry: Techniques, Discoveries, and Future Horizons*" **Tom Oosterloo** (University of Groningen, The Netherlands):

Va) Spectral line emission mechanisms and related science

Vb) Spectral line data processing/analysis and future instruments

Invited Talk 1: "*The LLAMA radiotelescope: present status, and perspectives*" - Jacques Lépine (IAG/USP)

Invited Talk 2: "*Solar Chromospheric Flares: A 165-year old mystery*"- Guillermo Giménez de Castro (CRAAM & IAFE)

Invited Talk 3: "*The Radio Observatory Pierre Kaufmann*"- Zulema Abraham (IAG/USP)

Invited Talk 4: "*Recent technical challenges of upgrading the ROPK radio telescope*" - Cesar Straus (INPE/MCTI)

Invited Talk 5: "*Closing the feedback-feeding loop in radio galaxies*"– Tom Oosterloo (University of Groningen)

Invited Talk 6: *"Modeling radio emission from bowshocks of high-velocity massive stars"*- Reinaldo Santos-Lima (IAG/USP)

Invited Talk 7: *The study of young stellar clusters with Gaia and VLBI astrometry"*- Phillip Galli (IAG/USP)

Invited Talk 8: *Astrophysical jets at the highest angular resolutions* - Ciriaco Goddi (IAG/USP)

SCHEDULE

	Sunday Aug 31	Monday Sep 01	Tuesday Sep 02	Wednesday Sep 03	Thursday Sep 04	Friday Sep 05
09:00 - 10:30		Lecture Ia Kraus	Lecture IVa Morganti	Lecture IIb Beltran	Lecture IIIc Loinard	Lecture Vb Oosterloo
10:30 - 11:00		Coffee-Break & Posters				
11:00 - 12:30		Lecture IIa Beltran	Lecture Va Oosterloo	Lecture IIIb Loinard	Lecture IIc Beltran	Lecture IVc Morganti
12:30 - 14:30		Lunch				Closing
14:30 - 16:00		Lecture IIIa Loinard	Lecture Ib Kraus	Lecture Ic Kraus	Lecture IVb Morganti	
16:00 - 17:00	Arrival	Coffee-Break & Posters				
17:00 - 17:30	Registration	Talk 1 Lépine	Talk 3 Abraham	Talk 5 Oosterloo	Talk 7 Galli	
17:30 - 18:00		Talk 2 De Castro	Talk 4 Strauss	Talk 6 Santos-Lima	Talk 8 Goddi	

ABSTRACTS

Lecture I "*Radio Telescopes and Fundamentals of observations"*

Alex Kraus (Max-Planck-Institut-für-Radioastronomie, Germany)

The first lecture will cover the basic properties of radio telescopes. After a brief classification of radio astronomy as a subfield of astronomy, the properties of antennas, with a particular focus on reflector antennas, will be introduced and discussed. Several existing radio telescopes will be presented for illustration.
The second lecture will focus on the observation methods of "single-dish" radio telescopes. Special emphasis will be placed on calibration strategies. Examples of observations in the fields of radio continuum, spectroscopy, as well as pulsars and transients will be presented. Potential difficulties such as those caused by RFI (radio frequency interference) will also be addressed.
The third lecture will focus on observations in the millimeter wavelength range. The specific requirements of such measurements, particularly with respect to telescope location and calibration procedures, will be discussed. Examples of telescopes and their observational results will also be shown.

Lecture II: "*An introductory course to the properties of the interstellar medium"*
Maite Beltran (INAF, Italy):

The first lecture will describe the composition of the ISM and the main properties of dust and gas (atomic, ionized, and molecular hydrogen), focusing on molecular clouds. The second lecture will describe the star formation process of both low- and high-mass stars, with special emphasis on the similarities and differences, the classification of young stellar objects, the properties of outflows, infall, and disks, and will give an overview on how to derive important parameters such as masses, momentum rates, and sizes. The third lecture will introduce astrochemistry in molecular clouds, in which basic aspects of interstellar chemistry and molecular astrophysics will be introduced. This includes detection and formation of molecules, chemistry of important species, deuterium, and complex organic molecules, maser emission, derivation of physical parameters, catalogues and databases, and line identification tools. The course will also present astrochemistry in low- and high-mass star-forming regions.

Lecture III: "*Radio Interferometry: Principles, Practices, and Astrophysical Frontiers"*
Laurent Loinard (UNAM, Mexico):

This lecture series offers a structured exploration of radio interferometry and its application to modern astrophysics, blending theoretical concepts with practical insights and key scientific discoveries.
The first lecture provides an introduction to radio interferometry, beginning with an overview of the electromagnetic spectrum and atmospheric transparency. It covers the fundamental principles of angular resolution, the workings of a 2-element interferometer, and the Van Cittert-Zernike theorem. Participants will learn how the uv-plane and synthesis imaging enable high-resolution observations. The session concludes with a tour of major radio interferometers, showcasing the diversity and capability of current facilities.
The second lecture delves into the principles and practices of Very Long Baseline Interferometry (VLBI). It highlights the differences between connected and VLBI arrays, examining the full VLBI data chain from observation to calibration and imaging. Specific challenges and solutions for VLBI calibration will be discussed, along with advanced topics like VLBI astrometry and millimeter-wavelength VLBI. The lecture will also introduce the major VLBI facilities shaping cutting-edge astrophysical research.
The third lecture shifts focus to the astrophysical phenomena studied with interferometry. It explores emission mechanisms, the physics of active galactic nuclei (AGNs) and superluminal motions, and the role of VLBI in mapping the universe. Topics such as megamasers and their relevance to the Hubble constant tension, as well as groundbreaking results from the Event Horizon Telescope, illustrate the transformative power of interferometric techniques.

Lecture IV: "*Active galactic nuclei at radio wavelengths: properties, life and impact"*
Raffaella Morganti (University of Groningen, The Netherlands):

During the life of a galaxy, the central (super) massive black hole can pass from a "dormant" to an "active" phase. In the latter, huge amount of energy is emitted, originated from the conversion of accreting matter in radiation. The amount of energy can highly

outshine the radiation from the stellar component in the galaxy and can be emitted in different wavebands (from radio to gamma) and, therefore, be observed by different telescopes. The energy emitted by active nuclei is considered to be a key ingredient influencing the evolution of galaxies. This makes AGN extra relevant.
In the lectures I will start by giving an overview of the AGN phenomenon and the variety of the associated manifestations. I will then zoom-in into radio AGN. These are very special and fascinating objects with unique properties. I will describe the properties of the radio emission and how it is characterise by e.g. radio jets and lobes and where the radio plasma can reach up to many hundreds of kiloparsec to mega parsec distances from the host galaxy. The most advanced radio telescopes allow us to explore deep in the heart of these objects where the radio jets are originating as well as follow their expansion up to the intergalactic scales.
I will describe what we have learned about the life-cycle of radio AGN: we can identify just born radio jets as well as dying radio sources. This cycle is key for providing the necessary impact of the AGN on the evolution of the galaxy.
This will be the topic of the last lesson in which I will describe how we think the radio jets can impact their surrounding medium. Cavities in the distribution of the hot, X-ray gas produced by the expansion of the radio plasma are still one of the best evidence of such impact but others (like the presence of jet-driven outflows) are also being found. Finally, I will discuss how these phenomena are included in numerical and cosmological simulations.

Lecture V: "*Spectral Line Astrophysics with interferometry: Techniques, Discoveries, and Future Horizons*"
Tom Oosterloo (University of Groningen, The Netherlands):

This lecture series provides an introduction to the study of spectral lines in astrophysics, focusing on observational techniques, data analysis, and future opportunities in the field. We will examine the mechanisms driving spectral line emissions, such as atomic hydrogen's 21-cm line and molecular gas transitions, observed with leading facilities like MeerKAT, VLA, ALMA, and the upcoming SKA. An overview of the major scientific advancements achieved through spectral line studies will highlight their critical role in understanding the universe.
Technical aspects, including the operation of spectral line correlators and calibration requirements, will be addressed. The lectures will also cover essential data processing techniques such as continuum subtraction for broad and narrow bands, along with methods for visualizing and analyzing spectral line datasets using modern tools. Emphasis will be placed on strategies for source detection, balancing sensitivity with resolution, and employing image weighting techniques tailored to specific scientific goals. Attendees will learn about modeling kinematics from spectral line observations, exploring how data can yield insights into physical conditions and dynamics. Special considerations for absorption-line studies and their unique challenges will also be discussed.
The series concludes with a forward-looking perspective on next-generation facilities like the SKA and DSA-2000, examining their transformative capabilities and the groundbreaking spectral line science they will enable.

Invited Talk 1: “*The LLAMA radiotelescope: present status, and perspectives”* -
Jacques Lépine (IAG/USP)

The LLAMA Observatory, situated in the Argentinian Andes at 4800m altitude, in the Salta province, is a project of Argentina and Brazil, which started in 2014 with an agreement between FAPESP (research foundation of Sao Paulo State), University of São Paulo, and MinCyt (Ministry of Science and technology of Argentina. The expenses will be equally shared. The 12m diameter antenna was constructed by VERTEX Antennentechnik GmbH (Duisburg, Germany). The surface precision of the dish will reach 15 microns r.m.s. deviations from an ideal parabola, after a period of fine adjustments, using holography technique. The antenna will perform observations at mm and sub-mm radio waves, like the international ALMA interferometer. The LLAMA antenna will be equipped with two lateral Nasmyth cabins, similarly to the APEX antenna installed in Chile. Initially, we will work with receivers for band 5, band 6 and band 9 (band names adopted from the ALMA observatory), constructed by NOVA Labs (University of Groningen, Holland). Brazil contributed to the acquisition of those receivers, and to the construction in Brazil of sub-systems, like the optomechanical systems of mirrors to be installed inside the Nasmyth and Cassegrain cabins. Brazil also acquired , from Japan, the cryogenics, and a cryostat, in which the receivers will be installed. An additional receiver for bands 2 +3 is under construction at the Universidad de Chile , and a calibration loads system constructed by the Universidad de Concepcion, Chile. The LLAMA antenna will be very competitive for observations going from Solar Physics, to the interstellar medium, and to extragalactic compact sources, and will participate in International VLBI observations. The rhythm of the construction of the LLAMA observatory and of the mounting of the radiotelescope has suffered variations along the years. It passed a phase of accelerated development, after the MinCyT attributed to the public company INVAP the task of installing the observatory and the radio telescope. Then, recently, the rhythm decreased again due to a decision of the Argentinian government economical to avoid expenses. We believe that the project will reach the situation of “antenna mounted” in 2025.

Invited Talk 2: “*Solar Chromospheric Flares: A 165-year old mystery*”
Guillermo Giménez de Castro (CRAAM & IAFE)

Since Richard Carrington observed a white-light flare through his four-and-a-half-inch telescope in September 1859, the mystery of the origin of chromospheric flares has not been settled. The Solar Chromosphere has historically been studied from spectral lines in the visible and UV, notably Hα, Ca II, Mg II and Lyα. Observations at long UV wavelengths (304, 1600 and 1700 ˚A) from space have been recently added. However, the Chromosphere can also be studied in the infrared, both in the continuum and lines. Studies in this spectral band, which by definition extends from 1 μm to 1 mm, are scarce and recent, and its advantages have been little explored. The Center for Radio Astronomy and Astrophysics Mackenzie, CRAAM, played a leading role in the development of new instrumentation with the Solar Submillimeter Telescope for 1400 & 700 μm (1999), the Solar-T balloon experiment for 100 and 43 μm (2016), the High Altitude THz Solar Photometer (HATS) for 20 μm (2024) and the telescopes for 10 μm (AR30T & SP30T) that are contributing to our understanding of the Solar Chromosphere. This talk reviews what we learned and describes how much can be done with ground-based instruments.

Invited Talk 3: "*The Radio Observatory Pierre Kaufmann"*
Zulema Abraham (IAG/USP)

In this presentation I will discuss the evolution of the ROPK radio telescope instrumentation over the last 50 years and its association with scientific objectives, in the context of Brazilian and global reality. I will also discuss the current status and future prospects of the observatory.

Invited Talk 4: "*Recent technical challenges of upgrading the ROPK radio telescope*"
Cesar Straus (INPE/MCTI)

I will describe the recent and ongoing upgrades of the 13.7 m antenna of the Radio Observatory Pierre Kaufmann, which replace old and failing components with a more modern implementation. This includes the tracking system, spectrometer, receivers, data acquisition and lab facilities.

Invited Talk 5: "*Closing the feedback-feeding loop in radio galaxies*"
Tom Oosterloo (University of Groningen)

Invited Talk 6: *"Modeling radio emission from bowshocks of high-velocity massive stars"*
Reinaldo Santos-Lima (IAG/USP)

Massive stars modify their surroundings through their intense ultraviolet radiation field, violent mass-ejection episodes, or the continuous injection of mechanical energy from their powerful winds. These wind-interstellar medium (ISM) interactions produce shocks, the perfect scenarios for energizing cosmic rays via the diffusive shock acceleration mechanism. A particular case of stellar wind collision with the ISM comes from runaway massive stars, which move through the interstellar medium with V > 30 km/s. The outer shock, called the bow shock, propagates through the ambient medium cooling efficiently and compressing the gas. The bow shocks of a few massive runaway stars were detected at radio wavelengths with a high level of non-thermal emission, most probably synchrotron radiation. These systems are also interesting because they provide a laboratory for studying many aspects of cosmic ray transport and acceleration around shocks. In this talk, I will present our modeling of the bow shock structure of massive runaway stars using plasma simulations (MHD), the distribution of cosmic ray electrons obtained from solving the transport equation for locally accelerated particles and those from the galactic background, and the production of synthetic maps of radio emission and polarization from these systems at frequencies of ~GHz, which can help interpret current and future observations.

Invited Talk 7: *The study of young stellar clusters with Gaia and VLBI astrometry"-*
Phillip Galli (IAG/USP)

Significant progress has been made in recent years to discover and characterise young clusters thanks to the state-of-the-art astrometry provided by the Gaia satellite. Ground-based Very Long Baseline Interferometry (VLBI) surveys in the radio domain also played an important role to complement the Gaia catalogue in regions of high extinction which are ubiquitous to young clusters and dramatically affect optical observations. These projects combined together delivered proper motions and parallaxes for a large number of young stellar objects making it possible, for the first time, to construct a 3D map of the nurseries to which they belong. In this talk I will review important results on the study of young stellar clusters and individual stars obtained from Gaia and VLBI astrometry.

Invited Talk 8: *Astrophysical jets at the highest angular resolutions*
Ciriaco Goddi (IAG/USP)

Astrophysical jets are a ubiquitous and powerful phenomenon in astronomy, ranging from young stellar objects (YSO) to super-massive black holes (SMBH) and Active Galactic Nucleii (AGN). Jets are believed to play a central role in regulating protostellar and black hole mass-accretion as well galaxy growth via AGN feedback. Despite their significance, their driving mechanisms remain elusive, primarily due to the observational challenges of probing the inner regions where jets are launched and collimated. Achieving the required resolution to test theoretical models demands cutting-edge techniques like Very Long Baseline Interferometry (VLBI) at (sub)millimeter wavelengths, which provide the highest angular resolution available in ground-based astronomy. In this talk, I will highlight key findings from ALMA, the EHT, and global VLBI networks, emphasizing their impact on our understanding of mass-accretion and mass-loss processes in Galactic star formation, the role of magnetic fields in launching relativistic jets, and black hole physics. I will also discuss future prospects, including planned expansions and technological innovations, poised to unlock transformative discoveries in jet astrophysics and SMBH science over the coming decade.

Poster presentations

Summary

1. Arthur S. Magalhães (IAG - Universidade de São Paulo), Andreas Korn (Uppsala University) - **Testing webSME for abundance determination & probing atomic diffusion in NGC 6397**
2. Camila A. Galante (Instituto Argentino de Radioastronomía, Universidad Nacional de La Plata), Gustavo E. Romero (Instituto Argentino de Radioastronomía, Universidad Nacional de La Plata), Juliana Saponara (Instituto Argentino de Radioastronomía), Paula Benaglia (Instituto Argentino de Radioastronomía) - **Radio studies of edge-on starburst galaxies**
3. Camila N. Koshikumo (IAG - Universidade de São Paulo), Reinaldo Santos-Lima (IAG - Universidade de São Paulo), María V. del Valle (IAG - Universidade de São Paulo) - **Magnetic amplification at supernova remnant shocks: impact on synchrotron radio emission**
4. Carlos E. Cedeño M. (Universidad Santiago de Cali), Sandra M. Conde C. (Universidad Surcolombiana), Maicol F. Perdomo C. (Universidad Surcolombiana) - **Study of oscillations along solar magnetic tubes using semi-empirical models**

5. Claikson Benedito (IAG - Universidade de São Paulo), Zulema Abraham (IAG - Universidade de São Paulo, INPE - Instituto Nacional de Pesquisas Espaciais), Pedro P. B. Beaklini (NRAO - National Radio Astronomy Observatory), Tânia Dominici (INPE - Instituto Nacional de Pesquisas Espaciais) - **Jet knots proper motion of PKS1510-089**
6. Douglas F. Carlos (IAG - Universidade de São Paulo), Ciriaco Goddi (IAG - Universidade de São Paulo) - **VAPOLA mm survey of AGN and Sgr A* with ALMA**
7. Elis C. Silva Sales (IAG - Universidade de São Paulo), Ciriaco Goddi (IAG - Universidade de São Paulo) - **Characterizing Thermal and Non-Thermal Components in Protostellar Jets**
8. Estrella Guzmán Ccolque (IAR, Argentina), Manuel Fernández López (IAR, Argentina), Luis A. Zapata (IRyA, México) - **Unveiling the Origins of Explosive Outflows: High-Resolution Study of IRAS 16076-5134**
9. Flávio B. da Silva Junior (NAT – Universidade Cidade de São Paulo) - **Kinematic and Precession Study of the Blazar Jet AO 0235+164**
10. Gabriele da Silva Ilha (IAG - Universidade de São Paulo) - **The connection between outflows and radio emission at Cosmic Noon**
11. Jaqueline de Fatima Masotti (IAG - Universidade de São Paulo), Maria Victoria del Valle (IAG - Universidade de São Paulo) - **Investigating PeVatron source LHAASO J1908+0621: A multi-wavelength model**
12. João Victor Corrêa Rodrigues (IAG - Universidade de São Paulo), Jane Gregorio-Hetem (IAG - Universidade de São Paulo) - **A multi-wavelength perspective of Canis Major star-forming region**
13. Larissa Ribeiro Magalhães (IAG - Universidade de São Paulo), Maria Victoria del Valle (IAG - Universidade de São Paulo), Reinaldo Santos de Lima (IAG - Universidade de São Paulo) - **Cosmic ray acceleration and non-thermal synchrotron emission in supernova remnants**
14. Lucas M. R. Volpe (IAG - Universidade de São Paulo), Jane Gregorio-Hetem (IAG - Universidade de São Paulo) - **A Seagull Nebula associated young stellar cluster and the gas around it**
15. Luiz H. S. De Paula (IAG - Universidade de São Paulo), Antônio M. Magalhães (IAG - Universidade de São Paulo), Reinaldo Santos-Lima (IAG - Universidade de São Paulo) - **Galactic Magnetic Fields: Polarimetry of High-Latitude Clouds**
16. Luiza Olivieri Ponte (IAG - Universidade de São Paulo), Ciriaco Goddi (IAG - Universidade de São Paulo) - **Characterizing SiO outflows in W51 at mm waves with ALMA**
17. Luna C. L. Espinosa (IAG - Universidade de São Paulo), María V. del Valle (IAG - Universidade de São Paulo) - **Modeling Nonthermal Radio Emission in the Stellar Bubble G2.4+1.4**
18. Maitê S. Z. de Mellos (Universidade Federal de Santa Maria), Rogemar A. Riffel (Universidade Federal de Santa Maria) - **Feeding and feedback in 3C 293 observed with JWST NIRSpec**

19. Natália F. S. Andrade (IAG - Universidade de São Paulo), Vera Jatenco-Pereira (IAG - Universidade de São Paulo) - **The Impact of Resonant Damping of Alfvén Waves on Accretion Disk Dynamics**
20. Nícolas D. V. de Oliveira (IAG - USP), Jane Gregorio-Hetem (IAG - USP) - **Spectroscopic characterization of the star PDS 70**
21. Parth Bambhaniya (IAG - Universidade de São Paulo), Saurabh (Max-Planck-Institut fur Radioastronomie, Bonn, Germany), Elisabete M. de Gouveia Dal Pino (IAG - Universidade de São Paulo) - **Shadow Formation Conditions Beyond the Kerr Black Hole Paradigm**
22. Pedro Humire (IAG - Universidade de São Paulo) - **Spatially-resolved spectro-photometric SED Modeling of NGC 253's Central Molecular Zone: I. Studying the star formation in extragalactic giant molecular clouds**
23. Raphael Pereira Rolim e Silva (IAG - Universidade de São Paulo), Ciriaco Goddi (IAG - Universidade de São Paulo) - **Sgr A* and AGN physics using spectral lines with ALMA**
24. Sandra M. Conde C. (Universidad Surcolombiana), Vera Jatenco-Pereira (IAG - Universidade de São Paulo) - **Multi-wavelength analysis of slow magnetoacoustic modes observed during flare events**
25. Thainá A. Sabino (IAG - Universidade de São Paulo), Jane Gregorio-Hetem (IAG - Universidade de São Paulo) - **Investigating the Interstellar Medium Surrounding Young Clusters**
26. Thais Santos-Silva (UEFS; IAG/USP) - **Photometric variability from young stars in the Lupus association revealed by TESS**
27. Thomaz Dean Bailona Cotrim (IAG - Universidade de São Paulo), Jane Gregorio-Hetem (IAG - Universidade de São Paulo) – **Circumstellar emission: modeling T Tauri stars**
28. Vinicius Ruedas Simião (IAG - Universidade de São Paulo), Ciriaco Goddi (IAG - Universidade de São Paulo) - **Imaging Launch Regions Of An Outflow From A High-Mass Protostar With SiO Masers**
29. Yasmmin F. Tamburus (IAG - Universidade de São Paulo), Reinaldo Santos de Lima (IAG - Universidade de São Paulo), Maria V. del Valle (IAG - Universidade de São Paulo) - **Thermal and non-thermal radio emission from massive stars cluster**
30. Augusto Carvalho (IAG - Universidade de São Paulo), Reinaldo Santos de Lima (IAG - Universidade de São Paulo), María Victoria del Valle (IAG - Universidade de São Paulo) - **Cosmic-ray transport and radio emission around bowshocks of runaway stars**

Poster 01

Testing webSME for abundance determination & probing atomic diffusion in NGC 6397

1- Arthur S. Magalhães (IAG - Universidade de São Paulo)
2- Andreas Korn (Uppsala University)

Atomic diffusion represents a physical process that operates inside stars, where atoms can be brought to the surface (radiative acceleration) or sink to the core (gravitational settling). It has been theorized for over a century, and later incorporated into solar and other stellar models. This process is expected to show larger effects in warm, metal-poor stars due to their thinner convective envelopes, and was first confirmed observationally in the globular cluster NGC 6397. Our work is a reanalysis of high-resolution VLT/FLAMES-UVES spectra of NGC 6397, in order to test the developing abundance determination software webSME, and to search for abundance signatures of atomic diffusion in elements not previously studied in this context. The data consists of 18 stars in different evolutionary stages, from the turn-off point (TOP) to the red giant branch (RGB). The elements Fe and Ba were re-analyzed in this framework and showed good agreement with literature results. The other elements investigated (Na, Mn, and Ni) are present in theoretical models but had not been analyzed before in this context. For Na and Mn, we did not find diffusion trends, due to severe blending of the spectral lines and a lack of suitable lines for measurement. For Ni, however, we found a clear abundance trend with a variation of ~ 0.2 dex from the TOP to the RGB stars, in both LTE and NLTE, that agrees very well with theoretical predictions. We also performed a re-analysis using a hotter temperature scale, which confirmed the consistency of our results. Therefore, this work presents the first evidence of an atomic diffusion trend for nickel in the globular cluster NGC 6397, confirming a theoretical prediction in an element not previously analyzed in this context.

Poster 02

Radio studies of edge-on starburst galaxies

1 - Camila A. Galante (Instituto Argentino de Radioastronomía, Universidad Nacional de La Plata)
2 - Gustavo E. Romero (Instituto Argentino de Radioastronomía, Universidad Nacional de La Plata)
3 - Juliana Saponara (Instituto Argentino de Radioastronomía)
4 - Paula Benaglia (Instituto Argentino de Radioastronomía)

Starburst galaxies undergo intense episodes of star formation, which can drive large-scale winds powered by the combined effects of massive stars and supernovae. When these winds interact with the surrounding medium, they can produce shocks capable of accelerating cosmic rays. The resulting non-thermal radiation, primarily synchrotron radiation in the radio band, is a powerful tool for probing cosmic ray transport and energetics beyond galactic disks. For my PhD, I am conducting a multi-frequency radio analysis of a sample of nearby edge-on starburst galaxies, searching for and

characterizing their radio halos. Using interferometric data from the uGMRT, JVLA, and MeerKAT, I am modelling the disk and halo components in order to measure the radio scale heights, and explore how these quantities relate to the main properties of the galaxies. This work has led to the detection of several previously unreported radio halos and revealed correlations between halo features and global galaxy parameters. I also present a detailed case study of NGC 4527, a peculiar starburst+LINER galaxy, in which we resolve compact nuclear structures and find evidence for both star formation and low-luminosity AGN activity. These results contribute to understanding the connection between star formation, cosmic ray populations, and the large-scale structures observed in star-forming galaxies.

Poster 03

Magnetic amplification at supernova remnant shocks: impact on synchrotron radio emission

1 - Camila N. Koshikumo (IAG - Universidade de São Paulo)
2 - Reinaldo Santos-Lima (IAG - Universidade de São Paulo)
3 - María V. del Valle (IAG - Universidade de São Paulo)

Galactic cosmic rays (CRs) are believed to be accelerated mainly at shocks in supernova remnants (SNRs). This could be supported by observations of SNRs in radio, which could be interpreted as synchrotron emission of accelerated electrons. The mechanism to accelerate particles is believed to be Diffusive Shock Acceleration (DSA); however, observations of radio synchrotron emission require magnetic fields inside SNRs much higher than those corresponding to typical ISM values, and this could be explained by magnetic field amplification. A mechanism capable of amplifying the large-scale magnetic field through turbulent dynamos has been proposed to address or at least mitigate the issue. In this work, we revisit this mechanism using a computationally efficient approach to represent the already accelerated CRs and consider an acceleration efficiency rate based on previous kinetic studies. We use 2D simulations with scales of ~0.1 pc around a non-relativistic shock, employing a modified technique of Particle-In-Cell-Magnetohydrodynamics, in which we use the relativistic guiding-center equations to solve the particles' dynamics. We studied the influence of the inclination of the magnetic field with respect to the direction of the velocity propagation of the shock. We obtained a factor of ~10 for the amplification factor in both parallel and perpendicular configurations of the magnetic field. The amplification efficiency obtained here is below the values obtained with the CR streaming instability. Still, the dynamo can provide a considerable pre-amplification, which can help to maximize the energy achieved in the acceleration process. Finally, global simulations that account for the non-linear evolution of the DSA will be important to produce more realistic synchrotron emission models of the SNRs.

Poster 04

Study of oscillations along solar magnetic tubes using semi-empirical models

1. Carlos E. Cedeño M. (Universidad Santiago de Cali)
2. Sandra M. Conde C. (Universidad Surcolombiana)
3. Maicol F. Perdomo C. (Universidad Surcolombiana)

The physical processes that describe the behavior of the oscillations and waves from the photosphere to the corona are still subjects of active research. Some studies suggest that the waveguides directed along the magnetic field, from regions where the frequency coincides with the harmonics of the main oscillation mode, are influenced by the atmospheric cut-off due to the inclination of the magnetic field lines. Here, we present an analysis of oscillations found in sunspots in the active region AR12726 on November 12 2018. The Atmospheric Imager Assembly (AIA), on board the Solar Dynamics Observatory (SDO), observed these oscillations at wavelengths of 171, 1600, and 1700 A. We used methods such as Running Difference and Pixelised Wavelet Filtering to detect the oscillations. We obtained the magnetic configuration of the coronal loops by using the Linear Force-Free (LFF) method on the line-of-sight (LOS) magnetogram obtained from the SDO/Helioseismic and Magnetic Imager (HMI). Our analysis points out the comparison between observational and semi-empirical physical parameters along the magnetic field lines and the tracks of the oscillations from the base of the magnetic tubes.

Poster 05

Jet knots proper motion of PKS1510-089

1 - Claikson Benedito (IAG - Universidade de São Paulo)
2 - Zulema Abraham (IAG - Universidade de São Paulo, INPE - Instituto Nacional de Pesquisas Espaciais)
3 - Pedro P. B. Beaklini (NRAO - National Radio Astronomy Observatory)
4 - Tânia Dominici (INPE - Instituto Nacional de Pesquisas Espaciais)

Blazars are Active Galaxy Nuclei (AGN) known for having a non-thermal spectrum, high variability from radio to gamma-rays, and components with apparent superluminal velocities. In addition, the angle between the relativistic jet, where emission occurs, and our line of sight is very small, which would explain these characteristics. Our study object, the blazar PKS1510-089 ($z=0.360\pm0.002$), is a flat spectrum radio quasar (FSRQ), that has had simultaneous radio and gamma-ray flares observed and has an angle of 3 degrees between the relativistic jet and our line of sight. Its jet has been observed by some monitoring programs, but the identification and, consequently, the dynamics of the components are still a matter of debate. In this work, we used high spatial resolution images at 15 GHz obtained by the MOJAVE (Monitoring Of Jets in Active galactic nuclei with VLBA Experiments) program, where VLBI (Very Long Baseline Interferometry) techniques were used. The components were identified by fitting two-dimensional Gaussians to the image of the source itself, using ~50 observations made between 1995 and 2010. The distance from the core, the flux density, and the position angle in the sky plane of each of the components identified in each of the images were calculated from

the parameters of the adjusted Gaussians. Assuming that these components have a ballistic trajectory, the association of these components over the years has made it possible to determine 10 components with superluminal velocities between 10c and 26c.

Poster 06

VAPOLA mm survey of AGN and Sgr A* with ALMA

1 - Douglas F. Carlos (IAG - Universidade de São Paulo)
2 - Ciriaco Goddi (IAG - Universidade de São Paulo)

We present an analysis of the spectropolarimetric properties of a sample of AGN and Sgr A* observed with the Atacama Large Millimeter/submillimeter Array (ALMA), over five VLBI campaigns conducted from 2017 to 2023. We perform a comprehensive characterization of the compact cores in total intensity and polarization, investigating the trends of the linear polarization fraction (LP), the electric vector position angle (EVPA), and rotation measure (RM). The analysis includes both time-domain and spectral-domain, allowing us to track the variability of each source on weekly and annual timescales, and to compare their behavior across millimeter/submillimeter wavelengths. We apply this approach to individual sources such as M87, 3C273, 3C279, Sgr A*, and others, as well as study broader source classes, examining differences between flat-spectrum radio quasars, BL Lacs, and radiogalaxies

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Poster 07

Characterizing Thermal and Non-Thermal Components in Protostellar Jets

1 - Elis C. Silva Sales (IAG - Universidade de São Paulo)
2 - Ciriaco Goddi (IAG - Universidade de São Paulo)

In this work, I present the results of my master's research and outline future directions for my PhD. My study focused on the high-mass young stellar object (HMYSO) TW, located in the W3(H$_2$O) region, which is one of the few confirmed cases of synchrotron-emitting jets in protostellar systems. Using multi-frequency VLA observations (3, 6, 10, 15, and 22.25 GHz), I produced interferometric radio maps and spectral index distributions to investigate the nature of the jet emission. The spectral index is negative at low frequencies ($\alpha = -1.64 \pm 0.82$), consistent with synchrotron radiation, and becomes positive at high frequencies ($\alpha = 1.06 \pm 0.40$), indicating an increasing contribution from thermal free-free emission. This transition reflects a change in the dominant emission mechanism as a function of frequency. I also mapped the 22.25 GHz H$_2$O maser emission, identifying hundreds of maser spots distributed along the jet axis. Their line-of-sight velocities range from –90 to –20 km/s, assuming a systemic velocity of –55 km/s, and their spatial alignment suggests that they trace shock fronts within the jet. These findings support the interpretation of a hybrid jet composed of both thermal and non-thermal components. For my PhD, I will expand this analysis to a statistically significant sample using the Protostellar Outflows at the Early Stages (POETS) Survey, which includes ~40 HMYSOs with detected water masers. I will work with data from the VLA, as well as high-angular resolution observations from VLBI, including the VLBA and the EVN, in addition to data from ALMA. My goal is to combine spectral index mapping and linear polarization analysis to disentangle the thermal and non-thermal contributions, probe the magnetic field structure, and investigate particle acceleration mechanisms. This approach aims to establish observational links between synchrotron emission, maser activity, and magnetic field morphology in massive star formation.

Poster 08

Unveiling the Origins of Explosive Outflows: High-Resolution Study of IRAS 16076-5134

1. Estrella Guzmán Ccolque (IAR, Argentina)
2. Manuel Fernández López (IAR, Argentina)
3. Luis A. Zapata (IRyA, México)

Massive stars are thought to form through rapid, high-rate accretion, a scaled-up version of low-mass star formation. However, explosive outflows provide compelling evidence that some high-mass stars may instead originate from the dynamical interaction of compact protostellar systems. ALMA observations of the Orion BN/KL system revealed dozens of molecular streamers forming an explosive outflow, and similar events have now been identified in seven more regions: DR21, G5.89-0.39, IRAS 16076-5134, Sh106, IRAS 12326-6245, IRAS 15520-5234, and G34.26+0.15. Understanding the origin of these explosions requires resolving their innermost regions to identify stellar progenitors, determine precise positions, measure radial velocities, estimate masses, and characterize emission properties (ionized, thermal, chemical). We propose to spatially resolve the most energetic explosive outflow, associated with IRAS 16076-5134, to search for runaway stellar members that could have triggered the event. Previous low-resolution data reveal an unresolved millimeter source at the explosion center, potentially hosting a protostellar system. Despite its large distance (~5 kpc), 24 CO streamers have been detected, distributed nearly isotropically — ideal for triangulating and refining the explosion site. High–angular resolution observations will provide unprecedented insight into the physical and kinematic structure of this region, shedding light on the role of protostellar system interactions in massive star formation.

Poster 09

Kinematic and Precession Study of the Blazar Jet AO 0235+164

1 - Flávio B. da Silva Junior (NAT – Universidade Cidade de São Paulo)

Multifrequency observations of AO 0235+164 reveal periodic variability in light curves and changes in position angles and apparent velocities of parsec-scale jet components. Using public radio interferometric maps at 15 and 43 GHz, we applied the Cross Entropy global optimization technique to model elliptical Gaussian components, identifying 36 kinematic structures distributed across all sky quadrants. Results indicate a highly relativistic jet with a minimum Lorentz factor of 34.3 and a maximum viewing angle of 36°.7. The component kinematics are well described by a relativistic precession model:

the best-fit clockwise precession period is 8.4 years, consistent with the previously observed 8.13-year optical periodicity and with Doppler factor modulations correlating with major gamma-ray flares. For counter-clockwise precession, a 6.0-year period is obtained, matching radio and optical periodicities (5–6 years). A binary supermassive black hole system likely drives both the parsec-scale jet precession and inclination oscillations consistent with the short-term variability in the source's emission.

Poster 10

The connection between outflows and radio emission at Cosmic Noon

1 - Gabriele da Silva Ilha (IAG - Universidade de São Paulo)

AGN feedback has emerged as a critical mechanism in the evolution of galaxies. However, constraining its parameters remains a significant challenge. One key aspect of this challenge lies in understanding the multiphase AGN feedback, which has been detected in ionized, molecular, and neutral gas. Furthermore, a connection has been observed between radio emission a ionized gas at low redshift, with evidence suggesting that the radio jet may interact with the interstellar medium and drive outflows. Despite this evidence at low redshift, relatively few studies have investigated the radio-ionized gas connection during cosmic noon for moderate radio power quasars. Thus, our main goal is to conduct a pilot study using VLA data for three quasars with moderate/high radio power, which have outflows identified with SINFONI data from the SUPER survey, to investigate whether this connection also exists at cosmic noon and could be driving the observed outflows. We used SINFONI integral field spectroscopy data, previously analyzed in earlier studies, which provided flux, W80, v10, and centroid maps for [O III]λ5007, along with new VLA radio observations (A and B array), which offer a spatial resolution comparable to that of the [O III]λ5007 data. These datasets allow us to investigate the spatial distribution and correlation between radio emission and ionized gas properties. Additionally, we incorporate radio data from the literature at different frequencies and resolutions, such as MOJAVE, VIPS, and COSMOS-VLA, to explore the presence of possible jets across multiple spatial scales. In all case we determine the angle of the position of the emission to assess a potential connection between the ionized gas and radio emission. We detected an extended radio emission for two AGN (J1333+1649 and CID-346). The extended structure in J1333+1649 (~ 4.16 kpc) aligns with the smaller-scale emission (~ 0.01″–0.02″ or ~ 0.08–0.17 kpc) seen in VIPS and MOJAVE, suggesting jet propagating across different scales. For CID-346, the radio emission aligns with the large-scale structure (~10″) seen in VLA-COSMOS, which also reveals a structure extending 20″ (~ 165 kpc) to the north, possibly associated with a jet. We found a spatial correlation between radio emission and ionized gas, with both components overlapping and exhibiting comparable spatial extents for all quasars. Furthermore, the position angles of the radio emission and ionized gas present offsets smaller than 30 degree. Given that the kinematics of the ionized gas in all three quasars is dominated by outflows, we also observed a spatial overlap between emission and outflow regions. These findings are consistent with results for moderate radio-power quasars at low redshift.

Poster 11

Investigating PeVatron source LHAASO J1908+0621: A multi-wavelength model

1 - Jaqueline de Fatima Masotti (IAG - Universidade de São Paulo)
2 - Maria Victoria del Valle (IAG - Universidade de São Paulo)

The study of Galactic cosmic rays currently relies on the observation and modelling of gamma-ray emission from molecular clouds. In order to find sources at energies ~100 TeV, it is required to find sources known as PeVatrons, capable of accelerating the cosmic rays up to 1 PeV. Usually, the association between molecular clouds and supernova remnants are the favourite candidates as PeVatron sources. Unfortunately, due to source contamination and the angular resolution limitation of the current observatories, it is difficult to identify the exact accelerating source in many of the reported PeVatrons. A particularly notable case is LHAASO source J1908+0621 (MGRO J1908+06), as it was detected by several gamma-ray facilities and is associated with the SNR G40.5-0.5 in interaction with a MC and is also associated with two pulsars, PSR J1907+0602 and PSR J1907+0631. In this work, we aim to develop a model capable of distinguishing which accelerator is responsible for the detected emission or if it is a combination of both pulsar and SNR. Firstly, we calculated the high-energy emission produced in the interaction of SNR G40.5-0.5 with the ambient medium using a time-dependent diffusion model. We fitted the observed very-high emission in the range 10 − 100 TeV by assuming a total energy in protons of ~10^{49} erg. As the source region also has another possible accelerator, we also considered the feasibility of the leptonic contribution from the pulsar PSR J1907+0602 in the detected emission as it would add a component to our pure hadronic model that could explain the lower energies. We conclude that the diffusion of the protons in the cloud should be slow.

Poster 12

A multi-wavelength perspective of Canis Major star-forming region

1 - João Victor Corrêa Rodrigues (IAG - Universidade de São Paulo)
2 - Jane Gregorio-Hetem (IAG - Universidade de São Paulo)

Over the years, the complexity of the star formation process has become increasingly evident. Numerous factors influence how stars form and evolve, both on large and small scales. This work combines observations at different wavelengths to investigate the physical characteristics of the interstellar material and to correlate them with the spatial distribution and properties of young stellar objects (YSOs). We summarise recent discoveries to present a coherent view of the Canis Major OB1/R1 (CMa) association. CMa is one of the Milky Way's most intriguing star-forming regions. There is evidence suggesting multiple episodes of star formation in this area. Moreover, at least three supernova events appear to have shaped the region, creating a ~60 pc shell-like structure. These events may also have influenced the evolutionary histories of the newly formed stars. In particular, our team is using multi-object spectroscopy from the Gemini South telescope to study the stellar group associated with the HII region Sh2-295. Out of over a hundred candidate stars, we identified 29 T Tauri stars (3 Classical T Tauri + 2 candidates, and 24 Weak-lined T Tauri) based on the presence of Li I absorption (6708

Å) and Hα emission. Nearly 70% exhibit X-ray emission consistent with the pre-main-sequence phase.

Poster 13

Cosmic ray acceleration and non-thermal synchrotron emission in supernova remnants

1 - Larissa Ribeiro Magalhães (IAG - Universidade de São Paulo)
2 - Maria Victoria del Valle (IAG - Universidade de São Paulo)
3 - Reinaldo Santos de Lima (IAG - Universidade de São Paulo)

It is believed that the majority of Galactic cosmic rays, with energies up to ~PeV, are accelerated in shocks produced by the expansion of supernova remnants into the interstellar medium, through the mechanism of non-linear Diffusive Shock Acceleration (DSA). However, several aspects of this process remain not fully understood. For instance, the confinement required to energize protons up to ~PeV, as well as the synchrotron emission from accelerated electrons, demands a magnetic field upstream of the shock stronger than the typical interstellar magnetic fields. Numerical simulations of shock evolution have been employed as tools to investigate these processes and to interpret radio, X-ray, and gamma-ray observations of supernova remnants. A major challenge in such simulations is establishing a connection between "micro-scale" phenomena, such as instabilities and resonant waves that govern cosmic ray transport, and the "macro-scale" evolution of the supernova remnant shock as it interacts with the interstellar medium. With the aim of better connecting these scales in multidimensional magnetohydrodynamic (MHD) simulations that include cosmic rays, we have developed a modified Particle-in-Cell (PIC-MHD) approach based on the guiding-center approximation for the particles. The effects of waves and instabilities of cosmic rays are incorporated via a subgrid model. This new approach enables a realistic representation of the particle acceleration process on spatial and temporal scales much larger than the kinetic scales of the injected particles. These simulations will allow the development of more realistic models of non-thermal emission from supernova remnants, such as radio synchrotron emission, for the interpretation of observational data.

Poster 14

A Seagull Nebula associated young stellar cluster and the gas around it

1 - Lucas M. R. Volpe (IAG - Universidade de São Paulo)
2 - Jane Gregorio-Hetem (IAG - Universidade de São Paulo)

The Canis Major R1/OB1 association of young stars (CMa) represents a fine case study for probing star formation processes in the Galaxy. Our group has been conducting a characterization of the region by doing its star census and mapping the gas distribution of its line of sight, in an attempt to recover the star formation history of CMa. The main nebula in the association is Sh 2-296, also known as the Seagull, which has an arc shape, and recently was shown to be associated with a 60 pc diameter shell structure (CMa Shell), probably a relic of successive supernova events (Fernandes et al., 2019).

The present work focuses on a region yet to be explored in the inner part of the Shell, which we possess photometric data from the SOAR Telescope (Spartan/SAMI) to identify stellar clusters and observe the gas spatial distribution associated with it. Results are presented for the stellar component of one cluster identified with Gaia DR3 astrometric membership determination and infrared analysis, located at the star HD 53456 field. Also, a brief review of works focused on the gas mapping and characterization in CMa is presented as an early step for the analysis we hope to complement with SAMI data.

Poster 15

Galactic Magnetic Fields: Polarimetry of High-Latitude Clouds

1 - Luiz H. S. De Paula (IAG - Universidade de São Paulo)
2 - Antônio M. Magalhães (IAG - Universidade de São Paulo)
3 - Reinaldo Santos-Lima (IAG - Universidade de São Paulo)

Understanding the structure of the Galactic Magnetic Field (GMF) is crucial for comprehending its role in the dynamics of the Interstellar Medium (ISM). This study presents an investigation into the 3D structure of the GMF, centered on ten High-Latitude Clouds, with the primary goals of probing the GMF away from the Galactic plane and assessing its influence on cloud characteristics like morphology and internal turbulence. We used optical polarization data from the Interstellar Polarization Survey, carried out by our group at the Pico dos Dias Observatory (OPD) using the IAGPol polarimeter. To complement our primary dataset, we incorporated distances from Gaia DR3 and related catalogs (e.g., Bailer-Jones et al. 2021; StarHorse2/Anders et al. 2022), along with HI data from the HI4PI survey and the Planck satellite. The methodology includes cross-matching these catalogs (using tools such as TOPCAT) and analyzing the polarization (P, Q, U) and extinction (Av) as a function of distance and position for our targets. Furthermore, we are applying an in-house polarization model that is based on the interstellar dust model of Rodrigues et al. (1997) and a 3D distribution of the Galactic magnetic field's regular and turbulent components. Our results include histograms of P and Av, along with Q-U, P-A, P-distance, and Av-distance plots, with further analysis planned to compare these with HI and Planck data, construct polarization angle structure functions to study the field's correlation, and estimate its strength versus distance. The conclusions will allow us to characterize the morphology of the magnetic field off the Galactic plane and to correlate its structure with the observed properties of each cloud, thereby advancing our understanding of how the GMF shapes these structures.

Poster 16

Characterizing SiO outflows in W51 at mm waves with ALMA

1 - Luiza Olivieri Ponte (IAG - Universidade de São Paulo)
2 - Ciriaco Goddi (IAG - Universidade de São Paulo)

Silicon monoxide (SiO) emission is a powerful tracer of shocked gas in protostellar

outflows, offering valuable clues about feedback processes in high-mass star formation. The W51 star-forming complex, one of the most luminous and active stellar nurseries in the Galaxy, hosts dozens of high-mass young stellar objects (HMYSOs) at different evolutionary stages, making it a great environment for the study of outflow properties.

In this work, an observational program with ALMA in the millimeter regime (Bands 3 and 6) is presented, designed to investigate the morphology, kinematics, and energetics of SiO outflows in W51. The dataset spans a wide range of spatial resolutions (from 0."2 to 0."02), enabling the trace of spatial scales from 10^3 to 10^4 AU and connect the immediate vicinity of the driving sources to larger-scale flows.

The project will show the analysis on how SiO outflow properties (such as velocity structure, collimation degree, momentum, and kinetic energy) depend on protostellar mass, luminosity, and evolutionary stage. By comparing the observations with predictions from different outflow driving models (magneto-centrifugal, radiation-driven, and ionization-driven winds), this study aims to shed light on the dominant mechanisms powering massive protostellar outflows and on the conditions under which accretion can persist after the onset of an H II region.

Poster 17

Modeling Nonthermal Radio Emission in the Stellar Bubble G2.4+1.4

1 - Luna C. L. Espinosa (IAG - Universidade de São Paulo)
2 - María V. del Valle (IAG - Universidade de São Paulo)

Strong stellar winds from massive, early-type stars have been suggested as capable of accelerating particles to very high energies. Intense shock waves are formed as the wind propagates and interacts with the interstellar medium, shaping the surrounding region into a stellar bubble. In some cases, part of the kinetic power of the shock contributes to the creation of relativistic particles. In 2019, Prajapati et al. reported the first detection of nonthermal radio emission from the stellar bubble G2.4+1.4, associated with an oxygen-rich Wolf-Rayet star. The observed emission is consistent with synchrotron radiation from relativistic electrons. Assuming the particles are locally accelerated at the termination shock, we have developed a detailed model to estimate the nonthermal emission produced by both electrons and protons. Under very general assumptions, we obtained maximum energies for electrons of the order of TeVs, and protons can reach hundreds of TeVs. In order to account for the observations, a high magnetic field (ca. 250 μG) is required. Our results support the idea that the winds of massive stars are efficient particle accelerators.

Poster 18

Feeding and feedback in 3C 293 observed with JWST NIRSpec

1 - Maitê S. Z. de Mellos (Universidade Federal de Santa Maria)
2 - Rogemar A. Riffel (Universidade Federal de Santa Maria)

Active Galactic Nuclei (AGN) play a crucial role in shaping the evolution of their host galaxies by regulating star formation and influencing key properties such as stellar mass and chemical enrichment. This interaction is primarily driven by AGN feeding, the process in which gas fuels the supermassive black hole, and AGN feedback, which manifests through radiation, jets, and gas outflows. The outflows can coexist in the same galaxy as ionized, neutral atomic, and molecular gas, collectively known as multiphase outflows. To investigate this phenomenon, we present observations of the radio galaxy 3C 293 using the James Webb Space Telescope Near-Infrared Spectrograph (JWST/NIRSpec) aimed at mapping the emission, extinction, and kinematics of hot molecular and ionized gas, as well as stellar kinematics, within the inner 2 kpc. The stellar velocity field is well described by a rotating disk model, with its kinematical center offset by 0.5 arcsec from the continuum peak. The hot molecular gas is traced by the H2 2.12 μm emission line, and the ionized gas by [Fe II]1.64 μm and Paα. The gas presents three main kinematic components: a rotating disk seen as a narrow component ($\sigma \sim 100$ km/s); a blueshifted broad outflow ($\sigma \sim 250$ km/s); and a fast ionized outflow as a very broad component ($\sigma \sim 640$ km/s). Extinction maps reveal high Av values, up to 35, spatially coincident with dust lanes seen in optical images. In addition to the disk and outflows components, inflows along the dust lanes are detected in the H2 gas, with a mass inflow rate of 0.008 Msun/yr, comparable to the AGN accretion rate. For the outflows, we derive peak mass-outflow rates of 0.14 Msun/yr (molecular) and 5.5 Msun/yr (ionized). The outflow, driven by the radio jet, has a kinetic power of 4.5% of the jet power - enough to suppress star formation. Our results highlight 3C 293's turbulent post-merger history and JWST's unique capability to probe dust-obscured AGN.

Poster 19

The Impact of Resonant Damping of Alfvén Waves on Accretion Disk Dynamics

1 - Natália F. S. Andrade (IAG - Universidade de São Paulo)
2 - Vera Jatenco-Pereira (IAG - Universidade de São Paulo)

The transport of angular momentum and matter is a crucial mechanism for the evolution of astrophysical disks, particularly in protostellar disks. It is well established that non-ideal MHD (Magnetohydrodynamics) effects significantly influence angular momentum transport in these objects. Additionally, the damping of Alfvén waves has been proposed as a viable mechanism for disk heating, which increases the ionization fraction and subsequently enhances the disk region susceptible to Magneto-Rotational Instability (MRI). In this study, we employ a semi-analytical approach and a local approximation to investigate how the resonant damping of Alfvén waves affects the dynamics of the disk. We also consider the roles of both viscosity and resistivity. Our results, which corroborate findings in the existing literature, show that the propagation characteristics of the waves can lead to either damping or the development of instability, depending on the specific conditions.

Poster 20

Spectroscopic characterization of the star PDS 70

1 - Nícolas D. V. de Oliveira (IAG - USP)
2 - Jane C. Gregorio-Hetem (IAG - USP)

This work presents a detailed spectroscopic analysis of the T Tauri star PDS 70, focusing on the determination of its atmospheric parameters and the characterization of its lithium abundance. Using high-resolution data obtained with the HARPS spectrograph, line ratio methods and spectral synthesis were applied to estimate the effective temperature, surface gravity, metallicity, and projected rotational velocity of the star. The lithium abundance was determined through spectral synthesis in the region of the 6707.8 Å line. The results indicate an effective temperature of 4176 ± 15 K, a surface gravity of log g = 3.62 ± 0.05, a metallicity of [Fe/H] = -0.11 ± 0.02, and a projected rotational velocity of 16.49 ± 0.04 km/s. The lithium abundance (A(Li) = 3.18 ± 0.59) confirms the youth of PDS 70 and is consistent with previous studies of T Tauri stars with similar mass and age. These results reinforce the classification of PDS 70 as a pre-main sequence star, highlighting its importance as a natural laboratory for the study of star and planet formation. The consistency of the obtained values with the literature validates the applied methodologies and contributes to the understanding of the physical processes governing the evolution of young stars and their planetary systems.

Poster 21

Shadow Formation Conditions Beyond the Kerr Black Hole Paradigm

1 - Parth Bambhaniya (IAG - Universidade de São Paulo)
2 - Saurabh (Max-Planck-Institut fur Radioastronomie, Bonn, Germany)
3 - Elisabete M. de Gouveia Dal Pino (IAG - Universidade de São Paulo)

A compact object immersed in background radiation casts a dark silhouette, commonly referred to as a shadow, apparent boundary, or critical curve. In Kerr black holes, this boundary is typically linked to the photon sphere or photon shell, corresponding to the peak of the effective potential for null geodesics. However, we demonstrate that this association is a special case within a more general framework. Specifically, we show that a shadow forms whenever the effective potential possesses a finite, positive upper bound and contains regions where photons can be trapped or scattered. This criterion accommodates a wide range of spacetimes, including horizonless configurations such as naked singularities. We further distinguish between the apparent boundary of the dark region originally defined by Bardeen and the bright photon ring visible to a distant observer, emphasizing that these features arise from different physical mechanisms. Additionally, we explore the impact of reflecting inner surfaces, which can give rise to partial intensity depression rather than complete darkness, offering a potential observational signature that distinguishes horizonless objects from true black holes. These insights provide a unified theoretical basis for interpreting current EHT images and lay the groundwork for identifying subtle yet decisive features in next-generation ultra-high resolution observations of compact objects.

Poster 22

Spatially-resolved spectro-photometric SED Modeling of NGC 253's Central Molecular Zone: I. Studying the star formation in extragalactic giant molecular clouds

1 - Pedro Humire (IAG - Universidade de São Paulo)

This study examines the interstellar medium in the central molecular zone (CMZ) of the starburst galaxy NGC 253 using the first spatially-resolved, multi-wavelength SED from near-UV to cm wavelengths at 3″ (51 pc) resolution. Archival data were analyzed with GalaPy, CIGALE, and STARLIGHT to characterize giant molecular clouds (GMCs). Nuclear and external GMCs show clear differences in stellar and dust masses, star formation rates (SFRs), and bolometric luminosities. The most reliable SFR tracers are 33 GHz radio continuum, radio recombination lines, total infrared luminosity (8–1000 μm), and 60 μm emission. BPT and WHAN diagrams indicate shock signatures in NGC 253's nuclear region, placing it in the composite zone typically associated with AGN/star-forming hybrids, while the AGN fraction from panchromatic emission is negligible (≤7.5%). Overall, the CMZ is highly heterogeneous, with central GMCs showing higher densities and SFRs. Certain centimeter bands are confirmed as effective SFR tracers at GMC scales.

Poster 23

Sgr A* and AGN physics using spectral lines with ALMA

1 - Raphael Pereira Rolim e Silva (IAG - Universidade de São Paulo)
2 - Ciriaco Goddi (IAG - Universidade de São Paulo)

Understanding the formation and collimation of relativistic jets in active galactic nuclei (AGN) remains one of the central challenges in high-energy astrophysics. This PhD project aims to probe the immediate environments of supermassive black holes (SMBHs) through high-resolution radio interferometry, combining state-of-the-art observations from the Event Horizon Telescope (EHT), the Global Millimeter VLBI Array (GMVA), and the Atacama Large Millimeter/submillimeter Array (ALMA). The project will address open questions about jet launching mechanisms, the role of magnetic fields and accretion processes, and the influence of molecular and dusty tori surrounding SMBHs.

The research will focus on two complementary lines of investigation: (1) imaging the base of relativistic jets in AGN at microarcsecond scales using continuum and polarimetric VLBI observations; and (2) developing new capabilities for spectral line VLBI, enabling the first-ever studies of molecular absorption and emission lines at mm wavelengths and ultra-high angular resolution. These studies will be applied to sources such as Sgr A* and a broader AGN sample, with the goal of characterizing molecular cloud kinematics and the structure of AGN tori.

The student will acquire expertise in VLBI calibration and imaging using the CASA-based rPICARD pipeline and will contribute to its extension for spectral line data. Synthetic VLBI observations will be simulated using SYMBA to evaluate the impact of

adding the LLAMA observatory to global mm-VLBI networks. By combining data analysis, software development, and observational campaigns, this project will place the student at the forefront of black hole and jet astrophysics and prepare them for a competitive career in radio astronomy.

Poster 24

Multi-wavelength analysis of slow magnetoacoustic modes observed during flare events

1 - Sandra M. Conde C. (Universidad Surcolombiana)
2 - Vera Jatenco-Pereira (IAG - Universidade de São Paulo)

We carried out a detailed multi-wavelength analysis of 3- and 5-minute oscillations in the active region AR 1734, using data from the Atmospheric Imaging Assembly (AIA) instrument on the Solar Dynamics Observatory (SDO). We observed these oscillations from the photosphere to the corona at the same time that two eruptions, an emerging flux, and a C3.4 flare occurred. We detected 3-minute waves propagating outward from the "footpoint" of the loops observed in the 171 Å channel, with speeds of $\approx 39 \pm 13$ km s−1 . During a short interval of time after the C3.4 flare, we also found 5-minute propagating waves in the coronal loops and lower heights of the solar atmosphere. The 3-minute waves found at the footpoints of the loops coincide with the same periodicities present in the umbra and penumbra of a sunspot located below the loops. Similarly, the presence of 5-minute modes suggests some coupling between the solar atmosphere's inner layers of the solar atmosphere and the corona. Because we detect these oscillations in all of the AIA channels and the presence of events in AR 1734, we suggest that the disturbances started at the lower-photosphere-chromosphere, around the sunspot, where the loops could be rooted. Then, they traveled along the loops until reaching the corona. We also point to the events that occurred in the active region that excited these oscillations

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Poster 25

Investigating the Interstellar Medium Surrounding Young Clusters

1 - Thainá A. Sabino (IAG - Universidade de São Paulo)
2 - Jane Gregorio-Hetem (IAG - Universidade de São Paulo)

The interstellar medium is a complex galactic component not completely understood yet. These giant regions are composed of gas and dust and represent the major area in spiral galaxies, like the Milky Way. They can be easily affected by radiation, magnetic fields, mass, etc. When surrounded by newborn stars, the environment becomes even more complex and the stellar feedback effects are a crucial factor in the evolution of these kinds of structures. We use SOAR/SAMI and Spartan imaging to characterize the interstellar medium surrounding two young stellar clusters associated with the Carina Complex region: NGC 3590 and NGC 3572. Our data covers ~3x3arcmin fields observed with filters at Ha, S II, O III, BrGamma, H2, J, H, K, Cont. 3 and R bands and we utilise the software StarFinder to extract the background emission and, then, produce comparative maps. Our results have shown that optical and near-infrared imaging can be a powerful

tool to evaluate ionization levels and shock fronts on the interstellar medium. In NGC 3572, we highlight the existence of a peculiar structure, PhJa 1, that seems to be ionised from the outside. In NGC 3590, the comparative maps show completely distinct features regarding the environment surrounding massive stars, molecular clouds and the peripheral region of the cluster.

Poster 26

Photometric variability from young stars in the Lupus association revealed by TESS

1 - Thais Santos-Silva (UEFS; IAG/USP)

Young stars are known to exhibit great variability at different wavelengths, with distinct shapes and time scales, generally between hours and weeks, with an average of 1 to 2 days. This variability is caused by different physical mechanisms that act from the stellar photosphere to the atmosphere of the circumstellar disk. Focused on better understanding the formation and early stages of evolution of young stars, especially those with strong magnetic activity, we perform a study of light curves from TESS in an interesting nearby cloud complex (~ 160 pc), Lupus association, that contain more than 200 low-mass stars in distinct stages of pre-main-sequence evolution housed in 9 low-mass star-forming regions (Lupus I - IX). In this work we present 81 light curves observed in two-minute cadence for which we quantify the type of variability using state-of-the-art metrics developed for YSOs. These light curves are from 61 Lupus members or candidates, which most of them (72%) have disks in different stages of evolution classified based on their near- and mid-infrared (2MASS, WISE and Spitzer) excess emission. In this work, we find that most of the light curves of diskless objects, or those with low infrared excess, are periodic or quasi-periodic, while the light curves of all classes are found in full-disk stars, especially stochastic ones with high infrared excess. However, compared to other stellar associations, such as Taurus, ρ Ophiuchus and Superior Sco, and NGC 2264, the census of the light curves in Lupus shows a distinct behavior, with a large number of periodic light curves and almost no burst. Finally, the largest fraction of Quasi-Periodic Dippers is consistent with the intermediate age of Lupus, between Taurus and Superior Sco.

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CIRCUMSTELLAR EMISSION: MODELING T TAURI STARS

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T Tauri stars are Pre-Main Sequence low-mass objects (<2 $M_\odot$). By studying the spectral energy distribution (SED) of these stars, we can estimate stellar and circumstellar parameters through optical and infrared photometry. By analyzing previously published data on T Tauri stars observed on the Pico dos Dias Survey (PDS), we searched for data in different photometric bands to construct the observed SED, which will be compared with synthetic spectra. The characterization of the star's circumstellar structure is performed through infrared photometry, which allows us to evaluate excess dust emission

due to the presence of a protoplanetary disk. In this undergraduate research project, a Python code is being developed to model the SED of the stars PDS 54 and PDS 59 using synthetic spectra, and we obtained good agreement for the stellar and disk components. Implementation of calculations that consider the presence of an envelope surrounding the star and the disk is currently in progress. In the future, in addition to the sample characterization, we intend to use data from the Gaia DR3 catalog to estimate the star's distance with greater precision and apply the method to a larger number of T Tauri stars.

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Imaging Launch Regions Of An Outflow From A High-Mass Protostar With SiO Masers

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High-mass star formation (HMSF) remains an unsolved problem due to the difficulty of observing disk-accretion and outflow-launching regions. The closest known high-mass young stellar object (HMYSO) is Source-I, in Orion BN/KL (at a distance of ~420 parsecs). Source-I exceptionally powers SiO masers at radii within 100 AU, thus enabling studies of its innermost dynamics and making it an ideal target for studying mass-accretion/loss processes. Previous VLBA observations of 7 mm SiO masers (in 2002) resolved an edge-on accretion disk and a wide-angle rotating outflow, and follow-up observations at 3 mm (in 2011) provided evidence that 3 mm and 7 mm masers are powered by the same outflow. Interestingly, the 3 mm emission arises preferentially further out, at $R \gtrsim 100$ AU, where it seems to outline a bending of the outflow, suggesting the presence of magnetic fields leading to collimation of the outflow. In this project, the student will analyse a new dataset including different SiO maser transitions at 1 mm observed with ALMA. Comparing low-frequency and high-frequency lines will enable us to test the proposed hydromagnetic wind model.

Poster 29

Thermal and non-thermal radio emission from massive stars cluster

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Massive star clusters constitute complex astrophysical environments in which the collective interaction of stellar winds, combined with the presence of intense magnetic fields, plays a fundamental role in particle acceleration and the production of non-thermal radiation. This work presents the stages of the model under development for predicting the radio emission (synchrotron and free-free) originating from these systems. The model integrates magnetohydrodynamic (MHD) simulations to determine the distribution of matter, momentum, and magnetic fields within the cluster, the modeling of cosmic-ray transport in this medium, and the radiative transfer of the resulting non-thermal emission.

Poster 30

Cosmic-ray transport and radio emission around bowshocks of runaway stars

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This work focuses on modelling cosmic ray (CR) transport and acceleration in shocks from stellar winds from runaway stars. These are stars that were ejected from their birth places due to extreme events, such as a super nova explosion or due to gravitational instabilities. They travel space with velocities higher than 30 km/s, developing shocks in their interaction with the interstellar medium. These shocks are believed to be one of the mechanisms that accelerate CRs within the Milky Way. We model the system via 3D-MHD simulations with PLUTO software. In a latter stage, we inject particles via particle-in-cell simulations using the in-house BUTANTAN code, aiming to assess and evaluate how the particles energies grow in the interaction with the shock, and how they cool via synchrotron mechanism.