Posters – Colloque de prospective PNPS 2024

The PROMETHEE project

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Magnetism plays an important role during the star formation by regulating angular momentum, fragmentation, and accretion onto the star. In particular we believe it to play a decisive role during the protostellar age via star-disk interaction, and by triggering powerful jets and outflows. In addition, we also believe that nonetheless the convective protostars are able to generate very strong magnetic fields, but are also the birthplace of the stellar magnetic fields. Yet, our knowledge on the magnetic properties in protostars is currently very poor. The Protostellar Magnetism: Heritage vs Evolution (PROMETHEE) project aims at filling this gap by: (i) determining the magnetic properties of a sample of class I protostars with SPIRou and CRIRES+, (ii) modelling the magnetic field of an accreting protostar using realistic prediction of the stellar internal structure, and initial conditions, and (iii) study the protostar-disk interaction using the SPIRou observations, and state-of-the-art models of magnetospheric accretion processes. PROMETHEE will allow to draw for the first time a global picture of stellar magnetism during the protostellar phase. In this poster we will present the funded ANR project that has started on February 1st, the objectives, and the timeline.

Retrieving stellar parameters and dynamics of AGB stars with Gaia parallax measurements and radiative hydrodynamics simulations

Béguin Elysabeth, Chiavassa Andrea, Freytag Bernd, Ahmad Arief, Uttenthaler Stefan

Low to intermediate-mass stars evolve into the Asymptotic Giant Branch (AGB) phase, releasing potent stellar winds that enrich the interstellar medium. This complexity affects parallax measurements using Gaia Data Release 3, particularly for Mira stars with significant magnitude variations for which the stellar parameters are extremely difficult to extract with spectro-photometric techniques. Recent 3D radiative-hydrodynamics (RHD) simulations reveal AGB star surface intricacies impacting Gaia's parallax measurements. Our study, drawing from 31 RHD simulations that cover a substantial part of the Hertzsprung-Russell diagram across the AGB phase, explores photocentre displacement and its correlation with stellar parameters, comparing with parallax uncertainty in 53 Mira stars observed with Gaia. The goal is to obtain an analytical approach, using the uncertain Gaia parallax data and 3D RHD simulations of stellar convection to determine AGB star parameters, refining our understanding of these giants.

Gaia Benchmark Stars

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Large spectroscopic surveys devoted to the study of the Milky Way, including Gaia, use automated pipelines to massively determine the atmospheric parameters of millions of stars. The Gaia FGK Benchmark Stars are reference stars with Teff and log g derived through fundamental relations, independently of spectroscopy, to be used as anchors for the parameter scale. The first and second versions of the sample have been extensively used for that purpose, and more generally to help constrain stellar models. We provide the third version of the Gaia FGK Benchmark Stars, an extended set intended to improve the calibration of spectroscopic surveys, and to use as constraints for stellar models. We have compiled about 200 candidates which have precise measurements of angular diameters and parallaxes. We determined their bolometric fluxes by fitting their spectral energy distribution. Masses were determined using two sets of stellar evolution models. We provide a new set of 192 Gaia FGK Benchmark Stars with their fundamental Teff and logg, and with uncertainties lower than 2% for most stars. Compared to the previous versions, the homogeneity and accuracy of the fundamental parameters are significantly improved thanks to the high quality of the Gaia data reflecting on distances and bolometric fluxes.

Calculating the centrifugal deformation of stellar and planetary models with RUBIS

Houdayer Pierre, Reese Daniel

RUBIS (Rotation code Using Barotropy conservation over Isopotential Surfaces) is a python-based code that calculates the centrifugal deformation of a star or planet for a given cylindrical rotation profile, starting from a spherically symmetric non-rotating model. RUBIS is capable of very rapid and stable computations, which can handle both continuous and discontinuous models. It thus already allows many applications: from the calculation of gravitational moments to that of gravity darkening, as well as providing suitable models for the computation of 2D oscillation modes. This work led to a recently published paper in A&A: Houdayer & Reese (2023). The code is freely available at: https://github.com/pierrehoudayer/RUBIS.

Détermination photométrique de la masse, du taux de rotation et de l'inclinaison des étoiles de masse intermédiaire en rotation rapide

Lazzarotto Axel

Les étoiles de masse intermédiaire sont souvent des rotateurs rapides et sont donc aplaties de manière centrifuge et particulièrement affectées par l'assombrissement gravitationnel. Pour bien analyser ce type d'étoiles, il faut alors recourir à des modèles 2D afin de calculer le flux radiatif visible tout en prenant en compte les effets géométriques dus à l'inclinaison de l'axe de rotation. En supposant un âge stellaire et une composition chimique donnés, notre objectif a été de dériver rapidement la masse, le taux de rotation et l'inclinaison des rotateurs rapides de la séquence principale. Nous utilisons pour cela des quantités photométriques affectées par l'assombrissement gravitationnel. Nous avons choisi trois observables variant en fonction de la masse, de la vitesse de rotation et de l'inclinaison: la température dérivée par la méthode du flux infrarouge TIRFM, l'indice de couleur c1 de Strömgren, et un deuxième indice c2 construit de la même manière que l'indice c1, mais sensible au côté UV du saut de Balmer. Ces observables sont calculées à partir de spectres synthétiques produits avec le code PHOENIX s'appuyant sur des modèles de structure stellaire issus du code ESTER. Ces grandeurs sont calculées pour une grille de modèles aux masses allant de 2 à 7 masses solaires, et des taux de rotation allant de 30% à 80% de la rotation critique. Nous avons ensuite tenté, pour tout triplets (TIRFM, c1, c2), de retrouver la masse, le taux de rotation et l'inclinaison en utilisant un algorithme de

Levenberg-Marquart que nous avons pris soin d'initialiser avec des contraintes physiques. En testant notre inversion sur les modèles de notre grille, l'algorithme parvient à retrouver la masse, le taux de rotation et l'inclinaison avec une bonne précision. La différence entre les paramètres d'entrée et les paramètres récupérés est négligeable pour les modèles situés sur la grille et est inférieure à quelques pour cent dans le cas contraire. Une application au cas réel de Vega a montré que le filtre u utilisé pour l'indice c1, est situé dans une région spectrale où les spectres modélisés et observés sont divergents. Cela nous a conduit à définir un nouveau filtre. Grâce à ce nouveau filtre et à l'index subséquent, les paramètres de Vega sont également récupérés avec une précision satisfaisante. Ce travail ouvre la possibilité de déterminer les paramètres fondamentaux des étoiles de type précoce en rotation rapide à partir d'observations spatiales photométriques.

Quantifying Rossby numbers in the Kepler field: Promising candidates for anti-solar differential rotation

Noraz Quentin

Anti-solar differential rotation (DR) profiles are characterized by a slow equator and fast rotating poles (reversed with respect to the Sun). They have been reported in numerous 3D numerical simulations for solar-like models experiencing high Rossby numbers (typically slow rotators). However, unambiguous detection of anti-solar DR profiles is still pending for main-sequence solar-type stars, although it has been reported for later evolutionary stages. Stars spin-down during their main-sequence, which increases their Rossby number and could induce a transition toward an anti-solar DR state. Such a rotational transition could then have an impact on the large-scale dynamo process, activity and angular momentum evolution. In this work, we develop a new theoretical formula to estimate the effective fluid Rossby number Rof of solar-type stars, as a function of observational quantities such as Teff and Prot. We consider several aspects, such as structure, evolutionary stage, and metallicity. We then quantify the fluid Rossby number of the Kepler catalog of rotational periods by Santos et al. (2019, 2021). After sanity checks, we obtain 22 targets experiencing high Rossby numbers and being promising candidates to host anti-solar differential rotation. The method can also be applied to future observations in order to extend this high-Rossby sample, whose future characterization would increase our understanding of magneto-rotational evolution of solar-type stars. For that purpose, the formula we developed here will be implemented in the PLATO mission analysis pipeline.

Chasing for new proxies of the magnetic activity with SPIRou

Paul Charpentier, Moutou Claire, Donati Jean-François, Cristofari Paul, Ould-Elhkim Merwan, Artigau Etienne, Marion Sandie, Hood Thea, Fouque Pascal

Recent instruments have extended radial velocity observations from the optical to the near-infrared. This has in particular allowed the study of M dwarf stars, known to host a higher frequency of rocky planets. However, to search for planets around such stars, investigating the stellar magnetic activity is crucial. Indeed, the precision of spectrometers depends on both photon noise and intrinsic stellar variations. In this study, a selection of targets from the SPIRou Legacy Survey (SLS) was employed to identify new magnetic activity proxies. By comparing

these with small-scale magnetic field measurements, we study the correlation with activity proxies. With the small-scale magnetic field being a well-established indicator that matches the RV activity jitter in solar studies, further studies of these new activity indicators have promising potential in filtering out RV stellar jitter to uncover low mass exoplanets.

Displacement of the photo-center of Beteleuse: comparision between observations and numerical simulations

Pilate Quentin, Lopez Ariste Arturo, Chiavassa Andrea, Beguin elysabeth

Since 2013, the red supergiant star Betelgeuse has been observed by the polarimeters Narval and Neo-Narval at Pic du Midi, allowing us to produce images of the photosphere that has been successfully compared to interferometric images. In order to test the validity of our images, we compared the displacement of the photo-center of our images with the ones from numerical simulations. We found discrepancies between simulations and observations, leading to either wrong physical hypothesis to produce images, or a miscomputation of the optical depth.

Influence of Progenitor Stars on the Morphology of Pulsar Wind Nebulae

Zakaria Méliani

A considerable number of massive stars traverse rapidly through the interstellar medium of galaxies. These stars, following their demise via core-collapse supernovae, may evolve into fast-spinning, magnetized neutron stars, giving rise to pulsar wind nebulae. The characteristics of these nebulae are intrinsically linked to the evolutionary trajectory of their massive progenitors. Our study employs two-dimensional magnetohydrodynamical simulations to illustrate how the morphology of a pulsar wind nebula, born from a runaway high-mass red-supergiant supernova progenitor, is significantly influenced by the wind of the deceased progenitor star. This wind shapes the stellar environment throughout its entire lifespan. Notably, pulsar wind nebulae of obscured runaway massive stars exhibit asymmetries, dictated by the morphology of the progenitor’s wind-blown cavity. This results in an asymmetric up-down synchrotron emission when observed.