1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title: Polarimetric studies of stars with circumstellar disks

1.1. Project goals

Stars surrounded by circumstellar disks represent a crucial phase in stellar evolution, involving star and planet formation, mass loss, and disk dissipation. These disks vary with the host star's evolutionary stage. **Protoplanetary disks,** found around young stars like T Tauri and Herbig Ae/Be types, are gas-rich and dusty structures where planets form. They exhibit strong infrared excess and polarimetric signatures due to scattering by micrometer- to millimeter-sized grains, often revealing flared structures and inner cavities. As these disks evolve, they become **transitional disks**, showing inner gaps or holes – likely cleared by forming planets or photoevaporation – while retaining outer dusty components. Their complex, often variable, polarization patterns help trace disk-clearing processes and planet-disk interactions. **Debris disks** represent a later stage: optically thin, gas-poor systems formed from collisions between planetesimals. Though they show weaker polarization, high-sensitivity polarimetry can still detect disk asymmetries, warps, and clumps. Studying all three types provides a comprehensive view of disk evolution and planet formation.

Optical polarimetry is a powerful tool for exploring the structure, dust properties, and evolution of such disks. This PhD project will focus on characterizing their geometry and composition using polarization data to derive disk inclination, asymmetries, grain alignment, and scattering mechanisms. Radiative transfer and scattering models will be developed and applied to interpret the data and constrain dust properties and disk morphology.

In parallel, the project will explore disk evolution across stellar types by examining young and evolved systems to identify polarimetric indicators of formation, dissipation, or dynamical interactions. Time-series polarimetry will also be used to monitor variability, revealing events such as disk warping or stellar occultations by disk inhomogeneities.

1.2. Outline

The research will be conducted through observational work, data analysis, and theoretical modeling:
- comprehensive literature review and selection of a target sample representing different disk types;
- training on polarimetric instruments and reduction pipelines (at the Institute of Astronomy NCU and via international collaborations);
- initial observing runs and/or mining of archival data, calibration and reduction of polarimetric data;
- first-phase analysis of disk properties, development of initial radiative transfer models using dedicated Monte Carlo codes;
- time-domain monitoring of selected targets to study polarimetric variability and its correlation with photometric and spectroscopic data;
- advanced modeling of disk structure and dust properties, comparison of model predictions with observations;
- interpretation of disk evolution across stellar types, masses and ages;
- finalization of thesis, presentation of results at conferences, and publication in peer-reviewed journals.

1.3. Work plan

The candidate will participate in observing runs at local and partner observatories, focusing on multi-band polarimetric data with high spatial and temporal resolution. Data analysis will involve the use of dedicated software for determining Stokes parameters, performing error analysis, and correcting for instrumental and interstellar polarization. Modeling will involve radiative transfer simulations of polarized light, tailored to each object's disk parameters, and will account for grain size, composition, and potential magnetic alignment. The project includes collaboration with international experts in polarimetry and stellar astrophysics, offering opportunities for mentoring and research exchanges. Results will be disseminated via peer-reviewed journal publications, conference talks, and posters.

1.4. **Literature** (max. 7 listed, as a suggestion for a PhD candidate preliminary study)

[1] Clarke, D. (2010). *Stellar Polarimetry.* Wiley-VCH.
[2] Tinbergen, J. (2005). *Astronomical Polarimetry*. Cambridge University Press.
[3] Reissl, S., Wolf, S., & Brauer, R. (2016). *POLARIS: A new radiative transfer code.* A&A 593, A87.
[4] Whitney, B. A., & Wolff, M. J. (2002). *Scattering and Absorption by Aligned Grains in Circumstellar Environments.* ApJ 574, 205.
[5] Wiktorowicz, S.J., et al. (2023). *A Decade of Linear and Circular Polarimetry with the POLISH2 Polarimeter.* ApJS 264, 42.

1.5. **Required initial knowledge and skills of the PhD candidate**

- Master degree in Astronomy or related fields of Exact and Natural Sciences;
- basic knowledge of the evolution of stars and their environments;
- experience in optical polarimetric observations, instrument calibrations, data reduction and analysis;
- very good Python programming skills highly required;
- communicative English written and spoken;
- ability to work both independently and in a team;
- strong motivation to conduct scientific research.

1.6. **Expected development of the PhD candidate's knowledge and skills**

Through this project, the PhD candidate will develop strong expertise in observational astronomy, particularly in high-precision optical polarimetry. She/he will gain hands-on experience with telescope instrumentation, data acquisition, and advanced data reduction techniques. The candidate will also acquire skills in modeling radiative transfer and scattering in circumstellar environments. Additionally, she/he will strengthen their ability to interpret astrophysical data and conduct independent research. The project will enhance scientific communication skills through presentations, publications, and international collaboration.