TO MAGNIFICO RETTORE OF UNIVERSITA' DEGLI STUDI DI MILANO

ID CODE 6509

I the undersigned asks to participate in the public selection, for qualifications and examinations, for the awarding of a type B fellowship at **Dipartimento di Fisica Aldo Pontremoli**

Scientist- in – charge: **Stefano Facchini**

Swastik Chowbay

CURRICULUM VITAE

PERSONAL INFORMATION

Surname	Chowbay
Name	Swastik

PRESENT OCCUPATION

Appointment	**Structure**
PhD candidate	5 years program at Indian Institute of Astrophysics

EDUCATION AND TRAINING

Degree	**Course of studies**	**University**	**Year of achievement of the degree**
Doctor of Philoshophy (PhD)	PHYSICS/ ASTROPHYSICS	Indian Institute of Astrophysics and Pondicherry University	Expected 2024
Master of Science in Physics (**cum laude**)	PHYSICS	University of Hyderabad	2018
Bachelor of Science in Physics	PHYSICS	University of Calcutta	2016

REGISTRATION IN PROFESSIONAL ASSOCIATIONS

Date of registration	**Association**	**City**

26/04/2023	Astronomical Society of India	Bengaluru, India

FOREIGN LANGUAGES

Languages	**level of knowledge**
English	Fluent
Bengali	Mother Tongue
Hindi/Urdu	Fluent
Spanish	Beginner

AWARDS, ACKNOWLEDGEMENTS, SCHOLARSHIPS

Year	**Description of award**
2023	Received a grant of INR 150,000 from the Department of Science and Technology to attend an international conference in Porto, Portugal.
2017	Qualified for the National Eligibility Test (NET-JRF) required for doing a PhD in India, which also provides fellowship for the entire PhD duration.
2016	Ranked in the top 15 out of 11535 in the National Graduate Physics Examination conducted across India.

TRAINING OR RESEARCH ACTIVITY

Numerous groundbreaking discoveries have been made in exoplanet science over the past decade. Recent exoplanet search surveys have provided compelling evidence that planets are exceedingly common, with the majority of stars in our Milky Way galaxy hosting one or more planets. The census has also revealed a rich diversity of exoplanetary systems and raised many fundamental and challenging questions. Answers to some of the questions would partly depend on understating the complexity of planet formation and evolution processes and accurately determining host-star and planet properties. In my thesis work, I have studied the different exoplanet populations in terms of their host-star properties and key planetary characteristics. Specifically, I have investigated the mass-metallicity relationship for directly imaged young and massive gas giant planets found at large orbital separations (> 5 AU). The metallicity scatter found in these studies indicates that the formation mechanism of gas giants at large orbital distances is different from the Jupiter analogues found in closer orbits. The age analysis of star-hosting planets, which also forms a part of this thesis, was carried out using elemental abundances, isochrone fitting, and the space velocity of stars determined from GAIA DR3. Combining various pieces of evidence, we were able to show that the formation timeline of small planets precedes the formation of giant planets. That is to say, the stars hosting giant planets are statistically younger compared to those hosting smaller planets. Furthermore, these results are shown to be consistent with planet formation by the core-accretion process and galactic chemical evolution. Finally, using high-contrast imaging data from SPHERE/VLT, I studied two newly formed ($\sim$ 3 Myr old) planetary systems: Lkca 15 and PDS 70. I modelled the properties of dust grains and the morphology of protoplanetary disks in these systems with the goal of understanding the influence of grain properties (size and composition) on the formation of giant planets on short timescales.

PROJECT ACTIVITY

Year	Project
2024	**Artefact-free total intensity and polarimetric imaging of the LkCa 15 system** Brief description: In this work, the LkCa 15 protoplanetary disk was imaged using Ks-band total intensity and polarimetric techniques, specifically the star-hopping RDI method, to overcome self-subtraction common in previous ADI observations. The study aimed to detect new planets and analyze the disk's morphology and composition. Using RADMC-3D modeling, I successfully replicated the disk's morphology with a mix of grain sizes, finding submicron grains in the inner zone (21-52 au), micron-sized grains (26-90 au), and millimeter-sized grains (46-131 au). The disk showed considerable flaring and radial distribution of dust grains, with smaller grains closer to the star and larger grains in the outer regions. Despite not detecting new planets, I am able to place upper mass limits for potential planets within the disk. The findings suggest a complex structure of the LkCa 15 disk, influenced by various factors like grain size distribution and disk flaring. However, the exact determination of dust composition and the disk's physical history remain challenging, highlighting the need for future spectroscopic studies. **Under Review:** C. Swastik et. al, A & A (under review)
2024	**Age analysis of exoplanet hosting stars from isochrone models** Brief description : In this study, the ages of over 2336 stars hosting exoplanets were estimated using isochrone fitting techniques, revealing a close relationship between the mass of exoplanets and their host stars. Despite model dependence and variations in individual age estimates, the findings consistently showed that a majority (70\% to 85\%) of planets orbit stars younger than 7 billion years, indicating that planet formation predominantly occurred after the ISM was sufficiently enriched. A notable age difference was observed between stars hosting small planets and those with giant planets, with the latter being significantly younger. This trend also supports the core-accretion theory of planet formation, suggesting that Jupiter-sized planets formed later in the galaxy's evolution. The study highlights that while small planets began forming around 6-7 Gyrs ago, the formation of giant planets is a more recent phenomenon, occurring predominantly in the last 4-5 Gyrs from now. **Under Review:** C. Swastik et. al, MNRAS (under review)
2023	**Age Distribution of Exoplanet host-stars: Chemical and Kinematic Age Proxies from GAIA DR3** Brief description: This study used GAIA DR3 data to study the chemical abundances, kinematics, and ages of stars hosting exoplanets. My key findings include that giant planet-hosting stars are typically metal-rich and alpha-poor, suggesting they belong to a younger population formed later in the galaxy's history after the Interstellar Medium (ISM) was enriched with Fe-peak elements. Most planet-hosting stars are part of the thin disk population, indicating a younger generation. The study also

	finds differences in galactic space velocities and orbital parameters between stars hosting small and Jupiter-like planets. Small planet-hosting stars exhibit higher Zmax and eccentricities, trends of older stars, compared to their giant planet-hosting counterparts. The findings support the idea that giant planets formed later in the context of the galactic chemical evolution (GCE) when the ISM had sufficient Fe-peak elements, necessary for the core-accretion theory of planet formation. **Published:** C. Swastik et. al, Astronomical Journal, 166 91 (2023)
2022	**Galactic chemical evolution of exoplanet host-stars: Are high-mass planetary systems young?** Brief description: This study investigated the chemical compositions of 968 exoplanet hosts by analyzing the chemical abundance of 17 elements to understand their role in planet formation. I used data from HARPS-GTO, CKS, and CPS surveys. My key findings include a negative correlation between alpha-elements wrt Fe and planet mass, indicating stars with smaller planets are alpha-rich compared to those with giant planets. For Fe-peak elements, we don't see any such correlations. These results imply that systems with smaller planets formed earlier in the galaxy's history, while high-mass planetary systems emerged later as alpha elements enriched the ISM at much earlier stages of the galaxy when compared with Fe-peak elements. Multi-planetary systems with both low and high-mass planets showed no specific trends, suggesting a younger age. Overall, the study connects planetary formation to the chemical evolution of the interstellar medium, indicating low-mass planets formed across various epochs, while giant planets formed around chemically enriched, younger stars. **Published:** C. Swastik et. al, Astronomical Journal, 164 60 (2022)
2021	**Host-star metallicity of directly imaged wide-orbit planets: implications for planet formation** Brief description: This study analysed the high-resolution spectra of 22 young stars hosting planets that are detected by direct imaging. I used spectroscopic archival data from HARPS, FEROS, and UVES, and using the Bayesian Monte Calo Markov Chain technique, I estimated the stellar atmospheric parameters and metallicity. My findings indicate that metal-rich stars host Jupiter-type planets planet mass (Mp) < 5 mass of Jupiter (MJ), supporting the core accretion model of planet formation. In the case of super-Jupiters Mp > MJ, we see a more scattered distribution with no dependence on metallicity, suggesting gravitational instability as a likely formation mechanism. **Published:** C. Swastik et. al, Astronomical Journal, 161 114 (2021)

CONGRESSES AND SEMINARS

Date	Title	Place
02-2024	**Galactic chemical evolution of planet-hosting stars.** *Contributed Talk*	ICPEH, Physical Research Laboratory (PRL), Ahmedabad, India
01-2024	**The Search for Planet around LkCa 15 protoplanetary disk**	42nd meeting of the Astronomical Society of India, IISc, ISRO and JNP, Bengaluru,

	Poster presentation	India
01-2024	**The Search for Planet around LkCa 15 protoplanetary disk** *Contributed Talk*	Star Formation Studies in India, SNBSCS, Kolkata, India
08-2023	**Timeline of planet formation: Trends evidence from stellar isochrone models** *Contributed Talk*	Exoplanet Conference at IISER Pune, IISER Pune, India
07-2023	**Did planet formation happen recently?** *Poster presentation*	Towards Other Earths III, Porto, Portugal.
04-2023	**Galactic chemical evolution of planet-hosting stars** *Poster presentation*	Protostar and Planets VII, Kyoto, Japan.
03-2023	**Did planet formation occur only recently? Evidence from kinematics and chemical properties of exoplanet host stars from GAIA DR3** *Poster presentation*	Planet-Eslab-2023, Leiden, Netherlands (online).
03-2023	**Are giant planet-hosting stars young? Kinematics and chemical properties of exoplanet host stars from GAIA DR3** *Contributed Talk*	41st meeting of the Astronomical Society of India, IIT Indore, India
09-2022	**Chemical analysis of exoplanet host stars: Are high-mass planetary systems young?** *Poster presentation*	(Exo)Planet Diversity, Berlin, Germany (online).
08-2022	**Galactic chemical evolution of exoplanet hosting stars: Are high-mass planetary systems young** *Contributed Talk*	NCTS-ASIAA Workshop: Stars, Planets, and Formosa, NTU, Taiwan (online).
07-2022	**Are giant planet-hosting stars young? Evidence from spectroscopic & kinematic analysis of GAIA DR3** *Poster presentation*	Sagan Exoplanet Summer Hybrid Workshop, NExSci, Pasadena, CA, USA (online).
07-2022	**Exoplanet and its host star in the era of GAIA DR3** *Poster presentation*	Gaia Symposium: DR3 And Beyond, Indian Institute of Astrophysics, Bengaluru, India.
07-2022	**Galactic chemical evolution of exoplanet hosting stars: Are high-mass planetary systems young?** *Poster presentation*	Rocky Worlds II, University of Oxford, Oxford, United Kingdom (online).

01-2021	**Artefact Free Protoplanetary Disk Imaging with Starhopping RDI.** *Poster presentation*	40th meeting of the Astronomical Society of India, IIT Roorkee and ARIES Nainital, India.
12-2021	**Are giant planet-hosting stars young? Evidence from galactic chemical evolution** *Contributed Talk*	21st National Space Science Symposium, Kolkata, India (online).
02-2021	**Host-star Metallicity of Directly Imaged Planets** *Contributed Talk*	39th meeting of the Astronomical Society of India, ICTS - TIFR Bengaluru, IISER Mohali, IIT Indore and IUCAA Pune, India (online).

PUBLICATIONS

Published articles in Journals
Protoplanetary disks in Ks-band total intensity and polarized light. B. B. Ren, M. Benisty, C. Ginski, R. Tazaki, N. L. Wallack, J. Milli, A. Garufi, J. Bae, S. Facchini, F. Ménard, P. Pinilla, **C. Swastik**, R. Teague, and Z. Wahhaj, *Astronomy & Astrophysics, 680, A114 (2023)*
Age Distribution of Exoplanet host-stars: Chemical and Kinematic Age Proxies from GAIA DR3 **C. Swastik**, R. K. Banyal, M. Narang, A. Unni, B. Banerjee, P. Manoj, T. Sivarani, *Astronomical Journal, 166, 91 (2023)*
Galactic chemical evolution of exoplanet host-stars: Are high-mass planetary systems young? C. Swastik, R. K. Banyal, M. Narang, P. Manoj, T. Sivarani, S. P. Rajaguru, A. Unni, B. Banerjee, *Astronomical Journal, 164, 60 (2022)*
Carbon abundance of stars in the LAMOST-Kepler field A. Unni, M. Narang, T. Sivarani, P. Manoj, R. K. Banyal, A. Surya, S. P. Rajaguru, C. Swastik, *Astronomical Journal, 164, 181 (2022)*
Host-star metallicity of directly imaged wide-orbit planets: implications for planet formation **C. Swastik,** R. K. Banyal, M. Narang, P. Manoj, T. Sivarani, B. E. Reddy, S. P. Rajaguru, *Astronomical Journal, 161, 114 (2021)*

Articles in reviews
Artefact-free total intensity and polarimetric imaging of the LkCa 15 system **C. Swastik,** Z. Wahhaj, M. Benisty, S. Arora, C. Ginski, B. B. Ren, R. G. van Holstein, Rob de Rosa, and R. K. Banyal, *Under review in Astronomy & Astrophysics*
PDS 70 Unveiled in Near Infrared Total Intensity Z. Wahhaj, M. Benisty, C. Ginski, S. Arora, **C. Swastik,** R. G. van Holstein, Rob de Rosa, B. Yang,

J. Bae, and B. Ren, *Under review in Astronomy & Astrophysics*
Age analysis of exoplanet hosting stars from isochrone models **C. Swastik,** R. K. Banyal, A. Unni, and T. Sivarani, *Under review in the Monthly notices of the royal astronomical society.*

OTHER INFORMATION

Programming Languages	**Level of Knowledge**
Python	Proficient
C/C++/Fortran/R/IDL	Familiar
JAVA, SQL, ADQL	Basic

Modelling Program	**Description**	**Level of Knowledge**
RADMC-3D	Radiative transfer modelling of protoplanetary disk	Familiar
iSpec	Spectra modelling of stars	Proficient
Galpy	Kinematic and galactic orbital parameters from astrometric data	Proficient
IRAF/PyRAF	Data reduction software	Familiar
EMCEE	Bayesian Sampler	Proficient

Observing Experience

Year	**Observing proposal**
2024	**VLT/SPHERE,** 1.5 hours, as Co-PI, Rings, spirals or planets? A first clear view of the HD 141569A system
2023	**VLT/SPHERE,** 1.5 hours, as Co-PI, Rings, spirals or planets? A first clear view of the HD 141569A system
2022	**VLT/SPHERE,** 3 hours, as Co-PI, Confirming a possible third planet at 16 au separation in the PDS 70 protoplanetary disk.
2021-2020	**HCT/ HFOSC & HESP,** ~100 hours as PI, (3 Cycles), spectroscopic studies of host stars of directly imaged exoplanets and brown-dwarfs.

Mentoring Experience

Year	Student
2024-present	**Tisyagupta Pyne,** Masters in Physics**,** Visva-Bharati University, Santiniketan *Thesis title: The 10 pc stellar neighbourhood of habitable zone planetary systems*
2023-2024	**Satyam Soni,** Masters in Physics, National Institute of Technology, Rourkela *Thesis title: Investigating the brownd-dwarf desert for the directly imaged exoplanets.*
2022-2023	**Athul Rathnakar,** Masters in Physics, St Xaviers university, Bangalore *Thesis title: Investigating the stellar ages of FGK stars using stellar isochrone models*
2021-2022	**Aarthi Krishna,** Masters in Physics, Indian Institute of Science Education and Research Tirupathi *Thesis title: Understanding the brown-dwarf desert by analysing the host stars of directly imaged brown-dwarfs.*
2020-2021	**Catharine John,** Masters in Physics, Christ University, Bengaluru. *Thesis title: Demographics of exoplanet : Analysis of the mass-radius relation. Together with Dr. Ravinder K Banyal*

Service and Outreach

Year	Event
2022	The Department of Science and Technology (India)'s press release on Swastik et al. (2022)
2021	Ministry of Information and Broadcasting (India)'s press release on Swastik et al. (2021)
2020	Got IAU grant as a PI to organise a teacher training program as a part of the Open Astronomy Schools, IAU-100 Global Project.
2019-2021	Student member of outreach committe at Indian Institute of Astrophysics.

Declarations given in the present curriculum must be considered released according to art. 46 and 47 of DPR n. 445/2000.

The present curriculum does not contain confidential and legal information according to art. 4, paragraph 1, points d) and e) of D.Lgs. 30.06.2003 n. 196.

Please note that CV WILL BE PUBLISHED on the University website and It is recommended that personal and sensitive data should not be included. This template is realized to satisfy the need of publication without personal and sensitive data.

Please DO NOT SIGN this form.

Place and date: Bangalore, 15/03/2024