Dr. Sachu Sanjayan

Stellar Astronomy, Planetary Science and Design Science

INTRO

I completed my PhD in Astrophysics at the Nicolaus Copernicus Astronomical Center (CAMK) in Warsaw, Poland. My research focuses on stellar astrophysics, leveraging asteroseismology and modeling variable stars using data from the Kepler and TESS space missions. My work primarily explores the evolution of old open clusters through stellar modeling of various types of variable stars. In addition to my research, I have a passion for designing scientific visualizations and creating web applications in astronomy.

As a data scientist, I thrive on working with big data. My previous projects include analyzing multi-dimensional fMRI and terrain data for planetary science research on Mars and the Moon, as well as using InSAR Earth data for geophysical observations. Currently, I am working with data from the Kepler, TESS, and GAIA space missions, employing techniques such as time-series analysis, advanced statistical methods, and machine learning.

I am also the founder of Spacentity, a platform where I merge science and art through experimental design elements.
"I believe in the profound connection between art and science, which inspires my work.

PhD Topic

Title

Understanding stellar dynamics and evolution of oldest open clusters from variable star observations using modeling.

Supervisors

Prof. Andrzej Baran - Ardastella Asteroseismology Research Group, Krakow
Prof. Gerald Handler - CAMK , Warsaw

Description

The goal of our project is to understand the different channels of stellar evolution in variable stars and understand how they differ that from field stars in dense cluster environments. We searched for variable stars in the field of two old open clusters NGC 6791 and NGC 6819 observed by Kepler mission and discovered many variable targets. We determined the membership probabilities of each variable targets using Gaia data and derived average cluster parameters from the members. We classified them based on the variability and position in the color magnitude diagram. Then We modeled some of these variable targets such as hot sub dwarf B star pulsators to derive cluster properties independently.

CURRENT

Since 2022
Data Analyst Global Research Evidence Lab
UBS, Krakow, Poland.

Since 2018
Researcher and data scientist
Ardastella Reasearch Group, Krakow, Poland.

ALMA MATER

Integrated Masters Degree in Physics

Indian Institute of Science Education and Research
Kolkata
India

EDUCATION

Doctoral Degree in Astrophysics - 2024

Nicolaus Copernicus Astronomical Center (CAMK), Warsaw, Poland

PhD Thesis :
Kepler photometry of two open clusters NGC6791 and NGC6819

Integrated Masters Degree in Physics - 2016

Indian Institute of Science Education and Research, Kolkata, India

Masters Thesis :
A study of Stellar Dynamics - Theory and Simulations

Higher Secondary Education - 2011

Gov. Model Boys School, Kerala, 95%.

High School Education - 2009

Amritha Vidhya Peetham, Kerala,98%

PROFESSIONAL SKILLS

Blender3D
Extensive experience in 3D visualizations.

Designing & Illustration
Certification of Linkedin Design path. Skills in Photoshop, Gimp, and Illustrator

Python
Extensively experienced in python
(Numpy, Pandas, Scipy, Flask, Astropy)

Matlab
Moderate experience in Matlab and Octave

HTML - CSS - Bootstrap - Tailwind
Moderate knowledge for web applications and development

Data Visualization
Using Matplotlib, Bokeh and dash-plotly

Machine learning & AI
Certification in data science and machine learning (Udemy), Python Scikit-learn, Tensor flow & Transformers
Large Language Models, Natural Language Processing, and Gen AI prompt engineering
ML Classification GMM/HDBSCAN Clustering, Dimensionality reduction(PCA, Wavelets), Variational Auto Encoders and Regression Analysis

Flask - Jinja
Basic knowledge for static and dynamic web applications

Fortran & C
Basic knowledge

Unity & C#
Moderate experience in creating and scripting worlds in unity.

Operating systems
Microsoft and Linux

Data Environment Management
SQL, Pyspark (Moderate)
Apache Airflow, Hive workflows, DAGs, Docker (Moderate)
Git, GitHub, GitLab (Extensive)
Jupyter Notebooks, Google Colab (Extensive)
VS Code, PyCharm, Anaconda (Extensive)
Linux command line, Bash script (Extensive)

Astronomy tools
Lightkurve - Kepler, TESS lightcurve processing in Python
Phoebe - Binary star modeling package in python
MIST - MESA Isochrones and stellar tracks
ADQL - Astronomical Data Query Language
TOPCAT - Tool for OPerations on Catalogues And Tables

SCIENTIFIC PROJECTS

- Cluster Membership Analysis Program
  CMAP: A tool designed to discover and analyze open star clusters within the Milky Way's most crowded stellar regions using advanced ML classification algorithms and parallelized Ischrone MIST grid fitting methods (repository not publically available).
- Song of the Stars
  Anahata: Composing music from stellar frequencies. Pulsation classifications and music theory (Uses Astral Python engine, live coding and Synth environments). (repository not yet made publically available).
- Advanced Eclipse Timing Analysis for Binary Star Research
  Legolas: A precision tool for deriving eclipse timings in binary star systems, using automated eclipse trimming and hyperbolic fitting (repository not public).
- Stellar frequency extraction module
  PyFEM: A precision tool for extracting frequencies from time series data via least square fitting and prewhitening process.
- Kepler Super Aperture Analysis tool
  Gandalf: A tool for extracting light curves from Kepler's super aperture data and analyzing the stellar frequencies.

- MESA GYRE fitter for hot subdwarf B stars
  MESAGYREsdBFit: A parallelized tool for fitting MESA and GYRE model grids to observed identified modes of pulsating hot subdwarf B stars.
- Astrofly
  Astrofly: An educational game designed to teach basics of stellar evolution. A star dust picking shard of memories of it's past life, re creating different stellar evolutionary phases (repository not public).

CREATIVE PROJECTS

- DIY Projects
  Mew Scope - A mobile tech for micro photography (2017), VR Hologram
- Documentaries
  Mirrors of Mind, Childhood, World of Termites

SCIENTIFIC INTERESTS

- **Stellar Physics & Asteroseismology**: I specialize in using high precision time series photometry (Kepler, TESS) to study stellar interiors and evolution. Applying asteroseismic techniques to derive precise stellar properties (mass, age, rotation, internal mixing) for variable stars. This work directly involves using and validating stellar evolution models (MESA/MIST) and pulsation models from GYRE. I am interested in exploring the age-metallicity degeneracies in modeling outcomes.
- **Time Domain Analysis & Stellar Activities**: Measuring low frequency brightness variations to quantify stellar rotation and magnetic activity cycles. Lightcurve modeling and understanding the methods of effectively masking the intrinsic and extrinsic variations to study the planetary and third body signatures.
- **Stellar Populations**: Characterizing stellar populations with inferences from stellar modeling, observations from photometry, spectroscopy, and astrometry. Using the derived stellar parameters to infer cluster evolution and Galactic Archaeology.
- **Binary systems**: Understanding the effect of companions on evolution of different binary systems. Especially focused on hot cool companions and their evolution in tight environments where possible mass transfer and envelope stripping mechanisms happens.
- **Planetary science**: Exploring the exoplanets in the Goldilocks zone and their dynamics with their parent star, understanding their chemical composition, exploring and correlating their signatures with our solar system bodies.
- **Scientific Visualizations**: Designing environments and scientifically accurate visualizations of concepts in physics using open source 3d art tools.
- **Scientific Game Designing**: Developing visually engaging scientific educational games for better learning experience and outreach.

CORE ABILITIES

- Undertake tasks to completion within the timeline of the project
- Social communication skills with the team and clients in fluent English
- Creative thinking for visualizing problems and solving them in smarter ways
- Open to learning new interesting fields
- Ability to creatively link multiple disciplines to make smart bridges
- A team player with personal reflection
- Opposition thinking to ensure positive outcomes

EXPERIENCE

Since 2018 : Data analysis and visualizations

Ardatsella Research Group, Krakow.
Analysis and processing of Kepler data of open clusters NGC 6791 and NGC 6819
Prof. Andrzej Baran, Professor, Uniwersytet Pedagogiczny w Krakowie

Details:

- Developing modules for searching variable stars.

- Time series analysis and processing of light curves.
- Prewhitening and frequency extraction tools development in Python3
- Improving midtime estimations in eclipsing systems using modified kwee methods
- Developing modules for third body detection in eclipsing systems
- Deploying web applications for data processing and visualization

2017 - 2018 : Researcher and Data analyst

National Geophysical Research Institute, Hyderabad.
Earth Observation using Radar interferometer data from satellites using Sentinel Application Platform (SNAP)
Dr.V.M.Tiwari, Director, National Geophysical Research Institute, Hyderabad

2016 - 2017 : Researcher

Institute of Science Education and Research, Kolkata.
Martian crater planetary science data using correlation and wavelet studies.
Prof.P.K.Panigrahi, Professor, IISER Kolkata

2015 : Project Fellow

Indian Institute of Science Education and Research,Kolkata
Crater detection algorithms (CDA) for detecting, finding number of craters and methods of finding depth of craters on Mars.
Prof.P.K.Panigrahi, Professor, IISER Kolkata

2015 : Research Project

Indian Institute of Science Education and Research,Kolkata
Study of stellar structures using Tolman Oppenheimer Volkoff equation
Dr.R.K.Nayak, Associate Professor, IISER Kolkata

2015 : Research Project

Indian Institute of Science Education and Research, Kolkata
Correlation studies on functional MRI data
Dr.Pei Liang, Visiting Professor, IISER Kolkata

2014 - 2016 : Master Project

Indian Institute of Science Education and Research, Kolkata
Study of Dynamics of stellar systems (Globular cluster Evolution), Modeling and Simulation
Dr.R.K.Nayak, Associate Professor, IISER Kolkata

2014 : Project

Indian Institute of Science Education and Research, Kolkata
Simulations of optimal conditions on Laser Interferometer Gravitational Observatory (LIGO) using Finesse simulation.
Dr.R.K.Nayak, Associate Professor, IISER Kolkata

2014 : Research Project

Indian Institute of Science Education and Research, Kolkata
Presentation on how Mirror neurons link between Action, Observation and Social skills

TALKS & CONFERENCES

2019-Jun : Conference

9th Meeting on Hot Subdwarfs and Related Objects, Hendaye, France
On Musical orchestra of pulsating subdwarf B stars in NGC 6791

2019-Jun : Conference

First conference of young researchers, CAMK, Warsaw
On Musical orchestra of pulsating subdwarf B stars in NGC 6791

2020-Jan : Public outreach

Night under the stars, Astronomical Observatory of the Jagiellonian University, Krakow
Astrophotography and variable star observations using DSLRs and mobile devices

2020-Jun : Zoom-Conference

Second conference of young researchers, CAMK, Warsaw
On evolutionary modeling of subdwarf B stars in oldest open cluster NGC 6791

2021-Jun : Zoom-Seminar

Annual PhD seminar, CAMK, Warsaw
Search for variable stars in oldest open cluster NGC 6791

AWARDS & ACHIEVEMENTS

2023 : Featured our discovery of 300+ variable stars and their classification in NGC6791, at the popular research and technology news at phys.org

2021 : Highlighted our research on 'Hot subdwarf B stars in NGC6791' at the popular research and technology news at phys.org

2018 : Selected for doctoral program in Nicolaus Copernicus Astronomical Center, Warsaw, Poland.

2017 : Inspire fellowship for Doctoral program, India

2014 : First Prize in 4R-Documentary Event-Pravega at Indian Institute of Science, Bangalore

2011 : Inspire Fellowship for 5 year integrated Maters Program, India.

2009 : Award for maximum scores in all subjects, India.

PUBLICATIONS

[1] **S. Sanjayan**, A. S. Baran, J. Ostrowski, P. Németh, I. Pelisoli, R. Østensen, J. W.Kern, M. D. Reed, and S. K. Sahoo. Pulsating subdwarf B stars in the oldest open cluster NGC 6791, MNRAS, 509(1):763–777, January 2022

[2] **S. Sanjayan**, A. S. Baran, K. Kinemuchi, P. Németh, J. Ostrowski, and S. K. Sahoo. A variable star population in the open cluster NGC 6791 observed by the Kepler spacecraft, Acta Astronomica, vol 72, no 2, p. 77-102, 2022

[3] **S. Sanjayan**, A. S. Baran, P. Németh, K. Kinemuchi. Variable Star Population in the Open Cluster NGC 6819 Observed by the Kepler Spacecraft, Acta Astronomica, vol 72, no 4, p. 267-295, 2023

[4] A. S. Baran, **S. Sanjayan** Sounding Interiors of Four Pulsating Subdwarf B Stars with Stellar Pulsations Acta Astronomica, vol 73, no 1, p. 21-34, 2023

[5] Joyce Ann Guzik, A. S. Baran, **S. Sanjayan**, P. Nemeth, Anne M. Hedlund, J. Jackiewicz Variable Blue Straggler Stars in Open Cluster NGC 6819 Observed in the Kepler 'Superstamp' Field, The Astronomical Journal, Volume 165, Issue 5, id.188, 15 pp.

[5] A. S. Baran, S. K. Sahoo, **S. Sanjayan**, and J. Ostrowski. A search for variable subdwarf B stars in TESS Full Frame Images II. Variable objects in the northern ecliptic hemisphere, MNRAS, 503(3):3828-3847, May 2021

[6] J. Ostrowski, A. S. Baran, **S. Sanjayan**, and S. K. Sahoo. Evolutionary modelling of subdwarf B stars using MESA with the predictive mixing and convective pre-mixing schemes, 503(3):4646–4661, May 2021.

[7] S. K. Sahoo, A. S. Baran, **S. Sanjayan**, and J. Ostrowski. A search for variable subdwarf B stars in TESS full frame images - I. Variable objects in the southern ecliptic hemisphere, MNRAS , 499(4):5508–5526, December 2020.

[8] A. S. Baran, R. H. Østensen, U. Heber, A. Irrgang, **S. Sanjayan**, J. H. Telting, M. D.Reed, and J. Ostrowski. Space observations of AA Doradus provide consistent mass determinations, New HW-Vir systems observed with TESS , MNRAS, 503(2):2157–2167,May 2021.

[9] S. K. Sahoo, A. S. Baran, U. Heber, J. Ostrowski, **S. Sanjayan**, R. Silvotti, A. Irrgang,M. Uzundag, M. D. Reed, K. A. Shoaf, R. Raddi, M. Vuckovic, H. Ghasemi, W. Zong,and K. J. Bell. Mode identification in three pulsating hot subdwarfs observed with TESS satellite, MNRAS, 495(3):2844–2857, January 2020.

[10] M. D. Reed, A. Slayton, A. S. Baran, J. H. Telting, R. H. Østensen, C. S. Jeffery,M. Uzundag, and **S. Sanjayan**. Pulsating subdwarf B stars observed with K2 during Campaign 7 and an examination of seismic group properties , MNRAS, 507(3):4178–4195, November 2021.

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REFERENCES

- Prof. Andrzej Baran
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  Ardastella Asteroseismology Research Group, Missouri State University, United States
  andrzejbaran@missouristate.edu
- Dr. Péter Németh
  (Scientific Collaborator)
  Astroserver.org
  pnemeth1981@gmail.com
- Dr. Joyce Ann Guzik
  (Scientific Collaborator)
  Los Alamos National Laboratory, United States
  joy@lanl.gov

DECLARATION

I consent to the processing of my personal data contained in my application for the needs of the recruitment process (In accordance with the Act of 29 August 1997 on the protection of personal data, consolidated text: Journal of Laws of 2016, item 922).