# Abhijit Chakraborty

- **Present Designation:** Senior Professor at the Astronomy Division of Physical Research Laboratory (PRL), Ahmedabad, 2.5m telescope Project Director, Head/Chair A&A division
- **Date of Birth:** August 3rd 1967
- **Educational Qualifications:**
    - PhD. in Astronomy, 1999, Physical Research Laboratory & Gujarat University
    - MSc in Physics, June 1991, MS University, Vadodara,Gujarat
- **e-mail:** abhijit@prl.res.in, achak966@gmail.com **mobile:**+91-9227124096
- **Marital Status:** Married

- **Employment details:**

| Position | Institution/University | Period |
|---|---|---|
| **1) Senior Professor** | PRL, Ahmedabad | Dec 2022- present |
| **2) Professor** | PRL, Ahmedabad | Jul 2017 - Nov 2022 |
| **3) Associate Professor** | PRL, Ahmedabad | Jan 2012 - Jun 2017 |
| **4) Assistant Professor** | PRL, Ahmedabad | Jun 2006 - Dec 2011 |
| **5) Post Doctoral Research Associate** | University of Illinois, Urbana- Champaign, US | Jun 2004 - May 2006 |
| **6) Post Doctoral Research Fellow** | Pennsylvania State University, US | May 2001 - May 2004 |
| **7) Visiting Fellow (PDF)** | Tata Institute of Fundamental Research, Mumbai | Aug 1999 - Apr 2001 |
| **8) Project Astronomer for IUCAA 2m telescope** | IUCAA, Pune | April 1998 - July 1999 |
| **9) Post Doctoral Fellow (after PhD completion)** | PRL, Ahmedabad | Nov 1997 - Mar 1998 |

- **Research activities/expertise and projects undertaken in brief:**

I have the expertise in optical, near-IR instrument design, high contrast imaging with pupil plane optics, and my particular science interests are exoplanets and planetary systems and stellar astrophysics.

There have been two main science thrusts in the field of Astronomy and Astrophysics globally in terms research funds allocated by the Americans and the Europeans and human interests in the past decades which are a) Cosmology: how the universe and the first stars were formed and b) Exoplanets: looking for planets around Sun-like stars, to know their mass, density, their evolution, composition and the possibility of life.

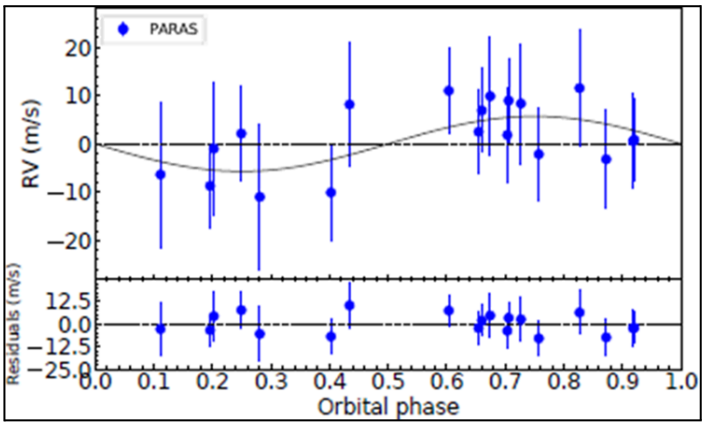
In India while many institutes have actively engaged in theoretical and observational studies of cosmology and various stellar and galactic, and extragalactic astrophysical sciences, none had a specific and dedicated program towards new detection and measuring mass of Exoplanets using facilities within the country. **In the year 2007 after returning to India from the USA, I initiated a new program for detection and characterization of exoplanets using optical**

**fiber-fed stabilized high-resolution spectroscopy at the Mt. Abu Gurushikhar Observatory of PRL using its 1.2m telescope.** The project is called **P**RL **A**dvanced **R**adial-velocity **A**bu-sky **S**earch (**PARAS**). The program was supported by DOS, GOI. In 2016 PARAS appeared in a review article (**Fischer et al. 2016, PASP**) where it stood third globally in terms of radial velocity precision achieved in terms of 200 S/N per resolution element (see table below):

| Spectrograph | slit or fiber | Stability Ranking | Spectral Resolution | Wavelength range [nm] | Wavelength calibrator | SMP [m $s^{-1}$] SNR = 200 | Number of stars | Duration of program |
|---|---|---|---|---|---|---|---|---|
| HARPS | f | Y | 115,000 | 380 – 690 | ThAr | 0.8 | 2000 | 2003 – |
| HARPS-N | f | Y | 115,000 | 380 – 690 | ThAr | 0.8 | 500 | 2012 – |
| PARAS | f | Y | 67,000 | 380 – 690 | ThAr | 1.0 | 27 | 2012 – |
| CHIRON | f | Y | 90,000 | 440 – 650 | Iodine | 1.0 | 35 | 2011 – |
| SOPHIE | f | Y | 75,000 | 387 – 694 | ThAr | 1.1 | 190 | 2011 – |
| PFS | s | Y | 76,000 | 390 – 670 | Iodine | 1.2 | 530 | 2010 – |
| HIRES | s | Y | 55,000 | 364 – 800 | Iodine | 1.5 | 4000 | 1996 – |
| Levy (LCPS) | s | Y | 110,000 | 376 – 970 | Iodine | 1.5 | 100 | 2013 – |
| Levy (CPS) | s | Y | 100,000 | 376 – 940 | Iodine | 2.0 | 300 | 2013 – |
| SONG | s | N | 90,000 | 440 – 690 | Iodine | 2.0 | 12 | 2014 – |
| HRS | s | Y | 60,000 | 408 – 784 | Iodine | 3.0 | 100 | 2001 – 2013 |
| Hamilton | s | N | 50,000 | 390 – 800 | Iodine | 3.0 | 350 | 1987 - 2011 |
| UCLES | s | N | 45,000 | 478 – 871 | Iodine | 3.0 | 240 | 1998 – |
| Tull | s | N | 60,000 | 345 – 980 | Iodine | 5.0 | 200 | 1998 – |

- **<u>The first discovery of an exoplanet from the country (India):</u>**

After following a dozen K2 possible candidates which were towards the limit of the 1.2m telescope in terms of their faintness (~10 magnitude in the V band) for about a couple of years we were able to ascertain and claim that the astrophysical body going around the source EPIC 211945201 is indeed a planet of 27 Earth mass and have density of similar to that of Saturn. It falls under the category of sub-Saturn or super-Neptune. The source was followed for about 1.5 years in order to negate the possibility of it being an EB or a background contaminating light from the source EPIC 211945201. It was not considered as a planet from K2 transit photometry alone because there was a probability of up to 13% of it being an EB system. PARAS data negated that possibility and discovered the first planet by measuring its mass.




*Radial Velocity Curve of EPIC211945201*

EPIC 211945201b lies in the overlapping region between super-Neptunes and sub-Saturns. There are only 23 sub-Saturns in the range of 4-8 $R_\oplus$ whose mass and radius are precisely known, and that makes this discovery very important in terms of understanding planet formation and migration. The planet goes around the star in approximately 19.5 days. NASA have acknowledged this discovery based on our paper and have named it as K2-236b. **This discovery had generated a lot of public interest in India and the Prime Minister Narendra Modi had tweeted congratulation to the PARAS team and PRL for the discovery.**

- **<u>Discovery of an inflated hot Jupiter around a slightly evolved star TOI-1789:</u>**

The discovery of a hot Jupiter at an orbital period of 3.208664 ± 0.000015 d around TOI-1789 (TYC 1962-00303-1, $TESS_{mag}$ = 9.1) based on the TESS photometry, ground-based photometry, and high-precision radial velocity (RV) observations. Using PARAS on the PRL 1.2m telescope and ground based photometry with the PRL 43cm telescope, the mass of the exoplanet and radius of the exoplanet was measured respectively. The simultaneous fitting of the multiple light curves and the RV data of TOI-1789 reveals that TOI-1789 b has a mass of $M$P = 0.70 ± 0.16 $M$J, a radius of $R$P = 1.44(+0.24; −0.14)$R$J, and a bulk density of $\rho_P$ = 0.28(+0.14−0.12) g $cm^{-3}$ with an orbital separation of a = 0.04882au. This puts TOI-1789 b in the category of inflated hot Jupiters. It is one of the few nearby evolved stars with a close-in planet. The detection of such systems will contribute to our understanding of mechanisms responsible for inflation in hot Jupiters and also provide an opportunity to understand the evolution of planets around stars leaving the main-sequence branch. https://ui.adsabs.harvard.edu/abs/2022MNRAS.509.3339K/abstract Discovery of an inflated hot Jupiter around a slightly evolved star TOI-1789.

- **PARAS have also contributed towards discovery of a 50 Jupiter Mass Brown Dwarf** as a part of global collaborations with SAO, Harvard, and Europe's KESPRINT group although PRL is not part of KESPRINT. PARAS contributed very importantly RV data for this discovery. See https://ui.adsabs.harvard.edu/abs/2020AJ....159..151S/abstract TOI-503: The First Known Brown-dwarf Am-star Binary from the TESS Mission.

- **PARAS not only have contributed in exoplanet sciences but also in stellar astrophysics and has come up to be one of finest spectrographs to this date for very precision RV research. In fact, one of the referee's comment on the EB studies has marked it as a bench-mark work for galactic studies on EB systems consisting of extreme low mass stars and resulted a very fine PhD thesis:** https://ui.adsabs.harvard.edu/abs/2018AJ....156...27C/abstract Masses and Radii of Four Very Low-mass Stars in F+M Eclipsing Binary Systems.

- **Discovery of a massive exoplanet (TOI 4603b) of mass 12.7Jupiter mass and with extreme density of 14** was also made recently in 2022, The work will soon be published in Astronomy and Astrophysics letters. This discovery will form part of my student's PhD thesis.

- **<u>Future of exoplanet program at PRL:</u>**
    - The PARAS spectrograph on the 1.2m telescope has its limitations in terms of S/N on stars fainter than 6.5 magnitude due to poor telescope performance, and the smaller 1.2m aperture on which it is currently attached. The spectrograph also has its own temperature stability limitations that prevent it to go below 1 m/s precision (- 50cm/s RV) over a long period of time (one year to few years). **50cm/s or less RV precision is essential to detect massive or super Earths around G, K dwarf (Sun-like) stars that may be in the Habitable zone of the star.** In spite of a large number of known exoplanets, only a handful is known to be in the Habitable zone.

- **Development of PARAS-2 for the PRL 2.5m Telescope:**
    - The new PRL new Telescope which saw the first light in November 2022 opens up new opportunities to address the issue of finding rocky massive Earth-like planets (4 to 10 Earth Masses) around G and K dwarf stars. **I have successfully developed a high-resolution spectrograph PARAS-2 at a resolution of 110,000, which can do extreme precision RV measurements at sub-m $s^{-1}$ precision. This happens to be the largest spectrograph in the country (India) and a few globally. PARAS-2 is under vacuum of 0.003 mbar or better and temperature control of 0.002C peak to valley at 22.5C for doing stellar velocimetry for exoplanet detections and characterizations and stellar astrophysics.** The design of the PARAS-2 spectrograph can be found in https://ui.adsabs.harvard.edu/abs/2018SPIE10702E..6GC/abstract. **PARAS-2 will open up new opportunities to address the issue of finding rocky massive Earth-like planets (4 to 10 Earth Masses) around G and K dwarf stars. Initial results show that PARAS-2 has achieved 30 to 35 cm $s^{-1}$ instrument stability.**

- **Uranium as new Calibration source for PARAS-2:**
    - **The need for finding alternate calibration sources for High Resolution Spectrographs:** I also have initiated a new calibration procedure with Uranium lines for precision radial velocity measurements using Uranium lines instead of Thorium lines as the later 99.9 pure hollow Cathode spectral lamps are no longer available. Uranium hollow cathode lamps are an extremely cheap alternative for precision calibration costing less than 50K in Indian rupees. **This work has identified about 4000 lines in Uranium out of which about 2000 are fully resolved at 110,000 resolution (about 1200 at 65,000 resolution) and is a low-cost effective solution to million dollars laser frequency comb solution.** See for eg: https://ui.adsabs.harvard.edu/abs/2021JATIS...7c8005S/abstract Precision wavelength calibration for radial velocity measurements using uranium lines between 3800 and 6900A˚ Sharma, Rishikesh; Chakraborty, Abhijit. The publication contains a complete line list of Uranium which can be very useful to the High Resolution Spectrograph Community.

- **The PRL 2.5m telescope:**
    - I have been the Project Director of the PRL 2.5m telescope which was completed and successfully completed in record time in November 2022 in spite of the Covid-19 era between 2020 and mid-2022. The telescope basic design parameters were fixed by my team and it was manufactured by M/s AMOS from Belgium. The telescope consists of state-of-the-art most advanced active optics systems and as well as for the first time in the country a tip-tilt correction system which corrects the first order atmospheric seeing conditions for stable stellar *PSF* image for PARAS-2 input. This project almost consumed 50 to 60% of time between 2016 and 2022.

- **PhD Students (Research Scholars) under my guidance:**
    - **Present PhD Students: 5**
        - Shubhendra Nath Das
        - Sanjay Baliwal
        - Rohan Das (Mizoram University, co-guide)
        - Rishikesh Sharma
        - Kapil Kumar Bharadwaj

- **Past PhD students who has got their degree: 2**
  - Akanksha Khandelwal (PDF at Instituto de Astronomía UNAM, Mexico)
  - Priyanka Chaturvedi (Associate Professor at TIFR, Mumbai, India )

- **Interactions with Graduate students or PRL Research Scholars:**
  - I have been taking advanced level graduate courses in alternate years since 2007 and between 2017 and 2019 every year (about 20 lectures on Astronomy and Instrumentation). In 2019 however, I am taking full 40 lectures on stellar photosphere and observations and analysis.

- **Interactions with Project Trainees:**
  - One Project Engineer trainee worked on precision temperature control systems in 2014 as a part of their BE final year program.
  - One MTech electronics student did a development program on lab-view programing of hardware-software control interface as a part of her semester project in 2013-2014
  - One MTech electronics student did a development program micro-controller electronics system for hardware control systems as a part of his semester project in 2014-2015
  - One Project Associate with MSc (Physics) background for a year who was trained in High Resolution Observations and programming in IDL and effectively worked towards science observations and data analysis in 2014- 2015.
  - One Summer Trainee has worked upon developing a new way to trace the echelle orders in 2017.
  - One IIST Physical Sciences student did summer trainee in 2019 on the topic of spectral line formation in the stellar photosphere.

- **Talks/Lectures/Colloquiums at International and National Conferences in the last decade:**

  - Invited Colloquium at the Physics Department at IISc Bangalore in August 2014 on Exoplanets
  - Invited talk at the Exoplanet conference and workshop at the Yale University in July 2015 on Radial Velocity Precision achieved with PARAS
  - Invited (with financial support from Aspen Center of Physics) in the 3 weeks Aspen meeting which included Brainstorming session on The Future of Radial Velocities and how to reach the goal of 10cm/s, at the Aspen Center of Physics, Colorado, US in September 2016
  - Invited lecture at the IIA-ISAC exoplanet conference at Kodaikanal, in October 2016 on Exoplanet instrumentation and PARAS-2
  - Invited lecture at SAO, Harvard, US in August 2017
  - Invited talk at the Extreme at the Exoplanet conference and workshop at the Pennsylvania State University in August 2017 on The art of precision Radial Velocity and the design of PARAS-2 for the PRL 2.5m telescope
  - Invited talk in October 2019 at the Astrophysical Conference at ARIES Nainital on PARAS-2 and the PRL 2.5m telescope
  - Invited talk at the Indo-Israel collaboration conference held at Jerusalem, Israel in December 2019 on “The limits of Radial Velocity Precision and PARAS-2”

- IAPT Vikram Sarabhai lecture on February 11, 2022 on Challenges and detection limits of Exoplanets
- Invited talk in BINA-3 conference at ARIES, Bhimtal on "The PRL 2.5m telescope and its first light instruments" in March 2023

- **Awards:**
  - 2019 Lunar & Planetary Science Society's Lecture Award given by Gujarat Science Academy (GSA) to Prof. Abhijit Chakraborty for his discovery of an exoplanet using PARAS. It consists of a Gold medal and an invited lecture at the venue of the annual GSA conference in Feb 2019.
  - NASA group achievement award for contributing towards successfully NEID spectrograph for the WYIN 3.5m telescope for exoplanet hunting or detections. **The NEID spectrograph adapted the PARAS cross-disperser PRISM design and the PARAS data pipeline for radial velocity data reduction. NASA had considered these two important contributions from PARAS as heritage. Once NEID demonstrated 30cm $s^{-1}$ precision after installation with the telescope, the award was given as recognition in September 2020.**
  - **2022 Space Science Application Award by Astronautical Society of India, for contribution in exoplanet sciences given by DOS Secretary and ISRO Chairman Dr. P Somnath.**

- **Organisation of Conferences/Summer Schools, etc.**
  - I Organized an International conference on Exoplanets at PRL in January 2013, in which people from Harvard, USA, Geneva Observatory Switzerland and Paris Observatory Meudon, France came and gave talks in the field of exoplanets. **This was the first international conference on exoplanets in the country.**
  - Member of Scientific Organizing Committee for International Conference On Planets, Exoplanets and Habitability held in February 2024 at PRL, Ahmedabad.

- **Technological developments initiated at PRL:**
  - I initiated for the first time in the country (India) the evaporation technique of Aluminum coating of large (>1.5m) and used this for the PRL 2.5m telescope. Until this work sputtering technique was used for mirrors larger than 1.5m aperture. The evaporation technique developed by him provides a more uniform coating thickness within 1 to 2% of the coating thickness and therefore preserves the quality of the optical surface. **My team at PRL helped M/s Hind High Vacuum, Bangalore, to develop this technology that is currently being installed at the 2.5m telescope building at Gurushikhar, Mt. Abu.** This development implied a 70% cost reduction compared to similar systems from overseas.
  - Fiber optics involves mm size doublet and triplet lenses which are difficult to manufacture and are usually imported. **My team designed such optics for PARAS-2 and helped Luma Optics, at Vadodara, India to manufacture these within the country again at 70% cost reduction compared to similar imported items.**
  - **My team at PRL also helped developing cryogenic Vacuum Dewar for housing optical sensors like CCDs which operates at -120C or lower using Liquid Nitrogen as cooling agent under vacuum of $10^{-6}$ mbar, in the country with M/s. Aditya High Vacuum, Ahmedabad.** PARAS 1 and PARAS-2 use such optical sensors.

- **Latest Publications:-**

  **Refereed Journals**

1. Baliwal Sanjay, Sharma Rishikesh,, **Chakraborty**, **Abhijit** et al., 2023, "Discovery and characterization of a dense sub-Saturn TOI-6651b"**,** 2024**,** Astron. & Astrophys., forthcoming article, DOI:10.1051/0004-6361/202450934
2. **Abhijit Chakraborty**, Kapil Kumar Bharadwaj, Neelam J.S.S.V. Prasad, Rishikesh Sharma, Kevikumar A. Lad, Ashirbad Nayak, Nikitha Jithendran, Vishal Joshi, Vivek Kumar Mishra, Nafees Ahmed, **"The PRL 2.5m Telescope and its First Light Instruments: FOC & PARAS-2"**, Volume 93, 2024, No 2 - Proceedings of the 3rd BINA Workshop on the Scientific Potential of the Indo-Belgian Cooperation)DOI: 10.25518/0037-9565.11602

- **Other Publications:-**

  **Refereed Journals**

3. A Khandelwal, R Sharma, **Chakraborty**, **Abhijit** et al., 2023, "Discovery of a massive giant planet with extreme density around the sub-giant star TOI-4603"**,** 2023**,** Astron. & Astrophys., 672, L7.
4. Khandelwal, Akanksha; Chaturvedi, Priyanka; **Chakraborty, Abhijit**; Sharma, Rishikesh; et al., Discovery of an inflated hot Jupiter around a slightly evolved star TOI-1789; 2022 MNRAS. 509. 3339K
5. Sharma, Rishikesh; **Chakraborty, Abhijit** Precision wavelength calibration for radial velocity measurements using uranium lines between 3800 and 6900A, 2021˚JATIS...7c8005S
6. Subjak, J˘án; Sharma, Rishikesh; Carmichael, Theron W.; Johnson, Marshall C.; Gonzales, Erica J.; Matthews, Elisabeth; Boffin, Henri M. J.; Brahm, Rafael; Chaturvedi, Priyanka; **Chakraborty, Abhijit**; and 10 other co-authorsTOI-503: The First Known Brown-dwarf Am-star Binary from the TESS Mission; 2020AJ....159..151S
7. **Chakraborty, Abhijit**; Roy, Arpita; Sharma, Rishikesh; Mahadevan, Suvrath,Chaturvedi, Priyanka; Prasad, Neelam J. S. S. V.; Anandarao, B. G., 2018AJ....156. 3C; Evidence of a Sub-Saturn around EPIC 211945201
8. Chaturvedi, Priyanka; Sharma, Rishikesh; **Chakraborty, Abhijit**; Anandarao, B. G.; Prasad, Neelam J. S. S. V.2018AJ....156...27C; Masses and Radii of Four Very Low-mass Stars in F+M Eclipsing Binary Systems.
9. Chaturvedi, Priyanka; **Chakraborty, Abhijit**; Anandarao, B. G.; Roy, Arpita; Mahadevan, Suvrath , 2016, "Detection of a very low mass star in an eclipsing binary system", MNRAS, 462, 554-564
10. Fischer, Debra A.; Anglada-Escude, Guillem; Arriagada, Pamela; Baluev, Roman V.; Bean, Jacob L.; Bouchy, Francois; Buchhave, Lars A.; Carroll, Thorsten; **Chakraborty, Abhijit**; Crepp, Justin R.; and 46 coauthors, **2016,** "State of the Field: Extreme Precision Radial Velocities", **PASP, 128, 066001**
11. Kane, Stephen R.; Wittenmyer, Robert A.; Hinkel, Natalie R.; Roy, Arpita; Mahadevan, Suvrath; Dragomir, Diana; Matthews, Jaymie M.; Henry, Gregory W.; **Chakraborty, Abhijit**; Boyajian, Tabetha S.; and 9 coauthors, 2016, "Evidence for Reflected Light from the Most Eccentric Exoplanet Known", ApJ,821, . 65,
12. Chaturvedi, Priyanka; Deshpande, Rohit; Dixit, Vaibhav; Roy, Arpita; **Chakraborty, Abhijit**; Mahadevan, Suvrath; Anandarao, B. G.; Hebb, Leslie; Janardhan, P., 2014, "Determination of mass and orbital parameters of a low- mass star HD 213597B", MNRAS, 442 , 3737-3744
13. **Chakraborty, Abhijit**; Mahadevan, Suvrath; Roy, Arpita; Dixit, Vaibhav; Richardson, Eric Harvey; Dongre, Varun; Pathan, F. M.; Chaturvedi, Priyanka; Shah, Vishal; Ubale, Girish P.; Anandarao, B. G, 2014, "The PRL Stabilized High Resolution Echelle Fiber-fed Spectrograph: Instrument Description and First Radial Velocity Results", PASP, 126, 133-147
14. Thompson, Laird A, Teare, Scott W, Xiong, Yao-Heng, Castle, Richard, **Chakraborty, Abhijit**, Grundel, Robert, Leach, Robert "UnISIS: Laser Guide Star and Natural Guide Star Adaptive Optics System" 2009 PASP 121 498T
15. **Chakraborty, Abhijit**; Thompson, Laird A.; Rogosky, Michael, 2005, 10-7 contrast ratio at 4.5λ/D: New results obtained in laboratory experiments using nano fabricated coronagraph and multi-Gaussian shaped pupil masks, Optics Express, 13,2394

16. **Chakraborty, Abhijit**; Ge, Jian; Mahadevan, Suvrath, 2004, Evidence of Planetesimal Infall onto the Very Young Herbig Be Star LkHα 234, ApJ, 606, L69
17. Anandarao, B. G.; **Chakraborty, Abhijit**.; Ojha, D. K.; Testi, L., **2004,** Detection of knots and jets in IRAS 06061+2151, Astronomy and Astrophysics, 421,1045-1050
18. **Chakraborty, Abhijit**; Ge, Jian, 2004, Unveiling SU Aurigae in the Near-Infrared: New High Spatial Resolution Results Using Adaptive Optics, Astronomical Journal, 127, 2898-2903
19. **Chakraborty, Abhijit,** Ge, Jian, Debes, John, The nature of faint companions to G type stars from Adaptive Optics, 2002, Astronomical Journal, 124, 1127
20. Debes John, Ge Jian & **Chakraborty, Abhijit. ,** First High-contrast imaging using Gaussian Aperture Pupil Mask, Astrophysical Journal Letters, 2002, 572, 165,
21. **Chakraborty, Abhijit**.; Ojha, D. K.; Anandarao, B. G.; Rengarajan, T. N., 2000, "Massive and luminous YSO IRAS 05361+3539 and its environment. A study of star formation in the parent cloud – I", Astronomy and Astrophysics,364, 683-688
22. **Chakraborty, Abhijit**.; Anandarao, B. G., 1999, "Expansion and turbulence in the Hourglass region of the Lagoon Nebula (M 8). New [OIII]5007 Å line observations," Astronomy and Astrophysics, 346,947-954
23. **Chakraborty, Abhijit**.; Anandarao, B. G., 1997, Kinematics of the Hourglass Region in the Lagoon Nebula., Astronomical Journal, 114, 1576
24. Smith, Myron A.; Murakami, T.; Ezuka, H.; Anandarao, B. G.; **Chakraborty, Abhijit.**; Corcoran, M. F.; Hirata, R. , Dynamic processes in Be star Atmosphere; ApJ, 1997, 481, 479

- **<u>Instrumentation related publications in the SPIE Journal:-</u>**

25. **Chakraborty, Abhijit**; Thapa, Nitesh; Kumar, Kapil; Neelam, Prasad J. S. S. V.; Sharma, Rishikesh; Roy, Arpita **PARAS-2 precision radial velocimeter: optical and mechanical design of a fiber-fed high resolution spectrograph under vacuum and temperature control**; 2018SPIE10702E..6GC
26. **Chakraborty, Abhijit;** Mahadevan, Suvrath; Roy, Arpita; Pathan, Fazalahmed M.; Shah, Vishal; Richardson, Eric H.; Ubale, Girish; Shah, Rajesh, **2010**, "First light results from PARAS: the PRL Echelle Spectrograph", Proceedings of the SPIE, 7735, id. 77354N
27. **Chakraborty, Abhijit;** Richardson, Eric Harvey; Mahadevan, Suvrath, **2008**, PRL advanced radial-velocity all-sky search (PARAS): an efficient fiber-fed spectrograph for planet searches, Ground-based and Airborne Instrumentation for Astronomy II., 7014, 6
28. Anandarao, Boddapati; Richardson, Eric Harvey**; Chakraborty, Abhijit**; Epps, Harland, **2008**, A wide-field near-infrared camera and spectrograph for the Mt. Abu 1.2 m telescope, Ground-based and Airborne Instrumentation for Astronomy II., 7014, 8 .
29. Thompson, Laird A.; Teare, Scott W.; Xiong, Yao-Heng; **Chakraborty, Abhijit;** Gruendl, Robert, **2004**, "Progress with UnISIS: a Rayleigh laser-guided adaptive optics system, **Advancements in Adaptive Optics"., 5490, 90-96**
30. Ge, Jian; **Chakraborty, Abhijit**; Debes, John H.; Ren, Deqing; Friedman, Jerry, **2003,** "Design and Performance of a Versatile Penn State near IR Imager and Spectrograph", **Instrument Design and Performance for Optical/Infrared Ground-based Telescopes,4841, 1503-1514**
31. Ge, Jian; McDavitt, Daniel L.; **Chakraborty, Abhijit;** Bernecker, John L.; Miller, Shane, **2003,** Adaptive optics high-resolution IR spectroscopy with silicon grisms and immersion gratings, **Adaptive Optical System Technologies II., 4839, 1124- 1131**
32. Ge, Jian; McDavitt, Daniel L.; Miller, Shane; Bernecker, John L.; **Chakraborty, Abhijit;** Wang, Junfeng, **2003,** Breakthroughs in Silicon Grism and Immersion Grating Technology at Penn State", **Instrument Design and Performance for Optical/Infrared Ground-based Telescopes., 4841, 1006- 1015**
33. Roy, Arpita; **Chakraborty, Abhijit;** Mahadevan, Suvrath; Chaturvedi, Priyanka; Prasad, Neelam J. S. S. V.; Shah, Vishal; Pathan, F. M.; Anandarao, B. G., 2016, Precision velocimetry planet hunting with PARAS: Current performance and lessons to inform future extreme precision radial velocity instruments, eprint **arXiv:1607.06485, 2016**

- **<u>Publications in conference proceedings and archives :-</u>**

34. Dixit, Vaibhav; Chaturvedi, Priyanka; **Chakraborty, Abhijit**; Mahadevan, Suvrath; Roy, Arpita; Dongre, Varun, **2013**, Precision radial-velocity measurements on bright Sun-like stars, 31st ASI Meeting, ASI Conference Series, 9, 121

35. **Chakraborty, Abhijit**.; Anadarao, B. G.; Mahadevan, S. , **2010**, The Search for Exoplanets in India, Pathways Towards Habitable Planets, proceedings of a workshop held 14 to 18 September 2009 in Barcelona, Spain. Edited by Vincent Coudé du Foresto, Dawn M. Gelino, and Ignasi Ribas. San Francisco: Astronomical Society of the Pacific, 413
36. Roy, Arpita; Mahadevan, Suvrath; **Chakraborty, Abhijit**; Pathan, F. M.; Anandarao, B. G., 2010, Radial Velocities with PARAS, Astronomy of Exoplanets with Precise Radial Velocities, held August 16-19, **2010** Penn State University University Park, PA, USA. Online at http://exoplanets.astro.psu.edu/workshop, id. 18
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