# GARIMA SINGH

**Postdoctoral Fellow** https://www.iau.org/administration/membership/individual/19074/
National Research Council of Canada https://www.linkedin.com/in/garima-singh-2a9843124
Herzberg Astronomy & Astrophysics Research Centre garima.singh@obspm.fr
5071 W Saanich Rd, Victoria BC V9E 2E7, Canada Tel: +33652479587

## Research Interest

- Astronomical instrumentation, mainly Adaptive Optics (AO) and Extreme-AO
- High contrast imaging (HCI) of exoplanets and circumstellar disks
- Speckle suppression & coronagraphic wavefront sensing & control techniques
- Exoplanet post-processing techniques

## University Education

**Ph.D.,** *High Honors*, **Astronomy & Astrophysics (Instrumentation)** *October 2012 - September 2015*
Laboratoire d'études spatiales et d'instrumentation en astrophysique (LESIA)
*Observatoire de Paris-Meudon, France and Subaru Telescope, Hawaii, USA*
**Dissertation:** Low-order wavefront control and calibration for phase mask coronagraphs.
**Thesis Advisors:** Prof. Olivier Guyon, Dr. Pierre Baudoz

**M.Tech.,** *Honors*, **Astronomy & Astrophysics** *July 2008 - September 2010*
*Université de Paris XI Sud and Ecole Normale Superieure de Cachan, France*
**Domain:** Astronomical & Space-based System Engineering
**Thesis Advisors:** Dr. Guy Perrin (LESIA), Dr. Yutaka Hayano (Subaru Telescope)

**B.Tech.,** *First Division*, **Information Technology** *July 2004 - May 2008*
*College of Engineering Roorkee, Uttar Pradesh Technical University, India*

## Employment History

**Research Officer (postdoctoral fellow)** *February 2021- present*
*National Research Council of Canada (NRC)*
*Herzberg Astronomy & Astrophysics Research Centre, Victoria, BC, Canada*
Developing an end-to-end simulation of the Planet System Imager instrument for the Thirty Meter Telescope. Leading the development of a specialized calibration sub-system for the Gemini Planet Imager instrument upgrade project, while testing and further improving this technique at the NRC NEW EARTH laboratory.

**Marie Skłodowska-Curie Actions (MSCA) Postdoctoral Fellow** *June 2018 - September 2020*
*LESIA, Observatoire de Paris-Meudon, France*
Improving current technological limits and proposing upgrades to the SPHERE instrument installed at the Very Large Telescope. Our published article demonstrated that a focal plane wavefront sensor can minimize the quasi-static speckle intensity in long exposure science images down to a limitation set by the adaptive optics halo residuals. If such a technique is implemented on-sky on the current high contrast imaging instruments, then an improvement in raw contrast by a factor of roughly 10 could be obtainable in long-exposure imaging. Apart from strengthening my instrumentation skills, I studied and processed SPHERE data of a gas-rich debris disk HD 141569 in polarimetric imaging (article under review).

**NASA Postdoctoral Program Fellow** *November 2015 - November 2017*
*NASA Jet Propulsion Laboratory, Pasadena, USA*
Worked at Palomar observatory to improve the wave-front capabilities of the stellar double coronagraph system, and contributed to the development of a compact coronagraphic bench which is a technological demonstrator for NASA's next generation space telescope for exoplanet science.
Supervisor: Dr. Eugene Serabyn, JPL

**Subaru Telescope Research Intern** *October 2012 - September 2015*
*Subaru Telescope, Hawaii, USA*
Executed entire three years of my Ph.D. research as a Subaru research intern working full time on the SCExAO instrument installed on the Nasmyth platform of the Subaru Telescope. I developed the Lyot-stop low order wavefront sensor (LLOWFS, Singh et al. PASP 2014), which is operational on-sky and is available for the science observers at the telescope. The LLOWFS is a linear wavefront reconstructor, which measures the low-order wavefront aberrations occurring upstream of coronagraphs. This sensor is essentially designed to stabilize the pointing errors and other low-order aberrations for non-reflective phase mask coronagraphs. On-sky results have demonstrated correction of 10 Zernike modes, with a closed-loop pointing residuals of 0.15 mas for tip-tilt with a vector vortex coronagraph (Singh et al. PASP 2015).
Advisors: Prof. Olivier Guyon, Dr. Pierre Baudoz

**Research Associate on a Temporary Contract** *July-September 2012*
*LESIA, Observatoire de Paris-Meudon, France*
Development of a high performance coronagraph for SCExAO at the Subaru Telescope.
Advisor: Prof. Pierre Baudoz

**Adaptive Optics System Developer** *July 2011 - January 2012*
*Inter-University center for Astronomy & Astrophysics (IUCAA), Pune, India*
Design and setting up of a prototype of Robo Adaptive Optics (Robo-AO) bench for IUCAA's Girawali Observatory (IGO), Pune.
Advisor: Prof. A.N. Ramprakash

**Research Associate** *January - June 2011*
*Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital, India*
Analysis and documentation of prototyping an adaptive optics system for ARIES optical laboratory.
Advisor: Prof. Amitesh Omar

**Subaru Research Intern** *April - September 2010*
*Subaru Telescope, Hawaii, USA*
Master Thesis: Focus tracking of the laser guide star using the guide star acquisition unit of the Subaru Telescope's laser guide star adaptive optics system (LGSAO188).
Developed a technique to track the focus of Subaru's laser guide star acquisition system. The position of the laser projected at 90 km is a time dependent function of the elevation. While tracking the science object, the position of the laser spot on the detector changes with respect to the elevation. This change in elevation defocuses the laser spot, which is sensed as a focus aberration in the wavefront normally caused by the Earth's atmosphere. The requirement is to prevent the adaptive optics system in correcting defocus in the laser spot that is actually caused by the change in the elevation during tracking. To address this issue, I developed an IDL control algorithm to track and correct the spot defocus using a guide star acquisition unit.
Advisors: Dr. Guy Perrin, Dr. Yutaka Hayano

**Summer Project** *June - July 2009*
*Galaxies Etoiles Physique et Instrumentation (GEPI), Observatoire de Paris-Meudon, France*
Spectroscopic analysis and determination of the mass ratio of HD 61273: a semi-detached binary system with an accretion disk (Tool: FDBinary, Programming language: IDL).
Advisor: Dr. Frédéric Royer

**Summer Project** *May 2009*
*Université de Paris XI Sud, France*
PSF reconstruction of the James Webb Space Telescope simulated images in Matlab.

## Fellowships & Awards

NRC Postdoctoral Fellowship, Life Signatures on Exoplanets — *February 2021 - present*
Marie Skłodowska-Curie Actions Postdoctoral fellowship — *June 2018 - September 2020*
Honorary Professor, Amity Institute of Space Science & Technology, India — *February 2017*
NASA Postdoctoral Program (NPP) Fellowship — *November 2015 - October 2017*
French Government scholarship **"Conseil Région île-de-France"** — *September 2008-2010*

## Observing Experience

**November 2015 - 2017**
Observatory: Palomar's Hale Telescope (5.1 meters), San Diego county, California, USA
Instrument: Palm-3K Extreme AO (P3K), stellar double coronagraph (SDC) system and the high-contrast imager PHARO.
Nights: 4 science and 4 engineering nights to test the performance of SDC downstream P3K, 5 engineering nights with P3K to test the capabilities of the Zernike wavefront sensor.

**November 2012 - December 2016**
Observatory: Subaru Telescope (8.2 meters), MaunaKea, Hawaii, USA
Instrument: Subaru's AO188 system, Extreme AO system SCExAO and the high-contrast imager HiCIAO.
Nights: 33 engineering and 17 science nights. During these nights, the performance of different components of the SCExAO instrument was tested including the analysis and feasibility of control loops of the high-order Pyramid wavefront sensor and the LLOWFS.

**Data reduction**
Laboratory and on-sky data reduction of coronagraphic images obtained with the SCExAO instrument, SDC system and THD2 bench for the performance evaluation of these systems.
Analysing the power spectrum density of the open- and closed-loop residuals obtained from a wavefront sensor.
Angular differential imaging of circumstellar disk data obtained with the SPHERE instrument (starting mid 2018).

**Computing Experience**
Coding experience in iPython, C and IDL.
Software experience in Solidworks (Mechanical designs), ZEMAX (Optical Design).
Modelling:
End to end numerical simulations of a coronagraphic system.
Intermediate experience with GRaTER (Grenoble Radiative Transfer) coding which simulates the scattered light images of debris disks and forward modelling for extracting disk photometry with SPHERE data.

## Talks & Seminars

**Professional Development (Talks)**

- SPHERE observation of the complex structure of HD 141569 inside 50 AU. — *November 2019*
  *Subaru 20th anniversary conference, Big Island of Hawaii*
- The complex structure of HD 141569 inside 50 AU. — *October 2019*
  *SPHERE General Science Meeting, Laboratoire d'Astrophysique de Marseille, France*
- Falling Walls Lab - Marie Skłodowska-Curie Actions — *25 September 2018*
  (A challenging interdisciplinary platform that invites academics, professionals and entrepreneurs from around the world to present their research within 2.5 minutes (+0.5 minute of questions) each to an

audience of industry experts, decision makers and scientists.)
*Museum of Natural Sciences in Brussels, Belgium*

- Reconstruction of high-contrast images with a low-order wavefront sensor telemetry. *May 2017*
  *NYRIA workshop, Paris, France*
- Direct imaging of Exoplanets at small inner working angle: Techniques. *February 2017*
  *Indian Institute of Astrophysics, Bangalore, India* (Invited talk)
- Optimizing coronagraphic observations at small inner working angle. *November 2016*
  *High-Contrast Imaging in Space workshop, Space Telescope Science Institute, Baltimore, USA*
- PSF calibration using the Lyot-based low-order wavefront sensor telemetry. *August 2016*
  *Keck Institute for Space Studies workshop, CalTech, Pasadena, USA* (Invited talk)
- PSF calibration using the Lyot-based low-order wavefront sensor telemetry. *August 2016*
  *1st international Vortex workshop, CalTech, Pasadena, USA*
- Low-order wavefront sensor for phase mask coronagraphs. *January 2016*
  *Cahill Center for Astronomy and Astrophysics, CalTech, Pasadena, USA*
- Low-order wavefront control and calibration for phase mask coronagraphs. *September 2015*
  *STScI Star and Planet Formation Seminar Series, Baltimore, USA* (Invited talk)
- Low-order wavefront control and calibration for phase mask coronagraphs. *May 2015*
  *Large Binocular Telescope Observatory (LBTO), Arizona, USA* (Invited talk)
- Low-order aberrations control and PSF calibration on SCExAO. *February 2014*
  *LOWFS & PSF for Exoplanets meeting, Jet Propulsion Laboratory, Pasadena, USA* (Invited talk)

**Conference Posters & POP**

- Active minimization of non-common path aberrations using a self-coherent camera for imaging exoplanetary systems.
  *Adaptive Optics for Extremely Large Telescopes (AO4ELT6), Québec city, Canada* *June 2019*
  *In the Spirit of Lyot*, Tokyo, Japan *October 2019*
- Discovery of an azimuthal density gradient in a gas-rich debris disk possibly related to a massive collision.
  *New Horizons in Planetary Systems, Victoria, Canada* *May 2019*
  *In the Spirit of Lyot*, Tokyo, Japan *October 2019*
- Wavefront sensing for high contrast imaging. *May 2016*
  *UCLA Lake Arrowhead Conference Center, California, USA*
- PSF calibration using the LLOWFS telemetry: First simulations. *June 2016*
  *SPIE Astronomical Telescopes & Instrumentation, Edinburgh, UK*
- Lyot-based low-order wavefront sensor: Implementation on the Subaru Coronagraphic Extreme Adaptive Optics System and its Laboratory Performance. *July 2014*
  *Sagan Workshop, California Institute of Technology, Pasadena, USA*
- Lyot-based low-order wavefront sensor: Implementation on the Subaru Coronagraphic Extreme Adaptive Optics System. *June 2014*
  *SPIE Astronomical Telescopes & Instrumentation, Montreal, Canada*
- Lyot-based low-order wavefront sensor for phase mask coronagraphs. *March 2014*
  *Search for life beyond the solar system: Exoplanets, Biosignatures & Instruments conference, Arizona, USA*

- Phase mask ultra-fine pointing control system. *December 2013*
  *5th Subaru International Conference: Exoplanet & disks, Kona, Hawaii, USA*
- Phase mask coronagraphic low-order wavefront sensor. *May 2013*
  *AO4ELT3 conference, Florence, Italy*

**Summer Schools and Workshops attended**

- Network of Young Researchers in Instrumentation for Astrophysics (NYRIA) *8-12 October 2018*
  *Leiden Observatory, Netherlands*
- Thirty Meters Telescope Early Career Workshop *22-29 August 2017*
  *Santa Cruz, California, USA*
  Science Advisory Committee (SAC) member for the workshop activity.
- NYRIA workshop. *16-19 May 2017*
  *Observatoire de Paris-Meudon, Paris, France*
- Preparing Thirty Meters Telescope Future Science and Technology Leaders. *3-7 December 2016 Hilo, Hawai'i, USA*
- Exoplanet Imaging and Characterization: Coherent Differential Imaging and Signal Detection Statistics *22-26 August 2016*
  *California Institute of Technology, Pasadena, California*
- Sagan Workshop *21-25 July 2014*
  *California Institute of Technology (CalTech), Pasadena, CA, USA*
- Search for Life beyond the Solar System (Exoplanets, Biosignatures & Instruments) *14-16 March 2014*
  Biosphere2, University of Arizona, Tucson, USA
- Astronomy & Astrophysics summer school *11-16 August 2013*
  *Dunlap Institute for Astronomy, University of Toronto, Canada*
- Adaptive Optics summer school *4-9 August 2013*
  *Center for Adaptive Optics, University of Santa Cruz, California, USA*

## Community Work

**Reviewer**

- 2019 & 2020 FINESST (Future Investigators in NASA Earth and Space Science and Technology) Astrophysics proposals.
- Journal of Astronomical Telescopes, Instruments, and Systems (JATIS).

**Invited lecture**

Wavefront sensing and reconstruction, *August 20, 2019*
*Center for Adaptive Optics summer school (CfAO), University of California, Santa Cruz*

**Professional services**

- International Astronomical Union (IAU) junior member.
- Marie Skłodowska-Curie Alumni Association Member (France & India).

- Volunteer mentor at The Supernova Foundation for providing scientific career guidance to women.
- NYRIA workshop organizing member.

**Outreach activities**

- Three invited outreach lectures on exoplanet detection techniques. *January 2021*
  *Women in STEM Series (WoAA) India, NSS USA-Mumbai and Hilwood College Kandy, Sri Lanka*
- Four invited outreach lectures on the adaptive optics and direct imaging of exoplanets. *August 2019*
  *Nehru Planetarium in Delhi, Miranda House in University of Delhi and College of Engineering Roorkee in Uttarakhand, India*
- Regular volunteer stay at the campus of Sri Ram Ashram. This organization provides shelter and schooling to the abandoned children. My motivation has been to execute one to one discussion with the kids/adults about science, astronomy and cultural and ethical issues faced in the Indian society. This experience is always a two-way transfer of knowledge both on a scientific and on a personal level.
  *Haridwar, Uttarakhand, India* *January 2018*
- How to directly image exoplanets with adaptive optics and coronagraphy *February 2018*
  **(Invited Talk)** *University of Petroleum and Energy Studies, Dehradun, India*
- Volunteer stay for one month at SECMOL school (altitude: 3500 meters) to teach high-school students the basics of astronomy and recognizing constellations and other astronomical objects in our galaxy visible in the Himalayan skies. *December 2017*
  *Leh Ladakh, Kashmir, India*
- Discussion on science, astronomy and women empowerment *February 2017*
  **(Volunteer Talk)** *Pardada Pardadi Educational Society, India*
- Techniques to find extrasolar planets *February 2017*
  **(Invited Talks)** *Nehru Planetarium & SPACE India in collaboration with AMITY University, Delhi, India*
- *"Journey through the Universe"* educator, a public education program held annually by GEMINI Observatory in Hilo, Hawaii. *March 2014*
- An active volunteer for astronomy talks, activities and discussions with public during *Astroday*, an annual event organized by Mauna Kea Astronomy Outreach Committee, Hawaii. *May 2015*

## Career breaks

November 2017 - May 2018: Voluntary break for traveling, outreach in the Himalayas (altitude: 3500 meters) and at a social service organization. More details can be found in the section Community work.
March 2018 - May 2018: Administrative waiting time for obtaining French visa.

## Languages

Hindi, Punjabi, English (fluent), French ("Diplôme d'etudes en langue Française" B1 level), Basic Italian

## Professional references

**Prof. Olivier Guyon**
University of Arizona, 933 N Cherry Ave., Tucson AZ 85721, USA
Tel: +1 818 293 8826,
Email: guyon@naoj.org

**Dr. Pierre Baudoz**
LESIA, Observatory of Paris-Meudon, 92195 Meudon Cedex, France
Tel: +33 1 45 07 79 11,
Email: pierre.baudoz@obspm.fr

**Dr. Anthony Boccaletti**
LESIA, Observatory of Paris-Meudon, 92195 Meudon Cedex, France
Tel: +33 1 45 07 77 21,
Email: anthony.boccaletti@obspm.fr

## Publications

### Peer-reviewed first author articles

- "Active minimization of non-common path aberrations in long-exposure imaging of exoplanetary systems". **Singh, G.**, Galicher, R., Baudoz, P., Dupuis, O., Ortiz, M., Potier, A., Thijs, S., Huby, E., 2019, A&A, 631, A106
- "A demonstration of a versatile low-order wavefront sensor tested on multiple coronagraphs". **Singh, G.**, Lozi, J., Jovanovic, N., Guyon, O., Baudoz, P., Kudo, T., Publications of the Astronomical Society of the Pacific, Vol. 129, Number 979, 2017
- "On-sky demonstration of low-order wavefront sensing and control with focal plane phase mask coronagraphs". **Singh, G.**, Lozi, J., Guyon, O., Baudoz, P., Jovanovic N., Martinache, F., Kudo, T., Serabyn, E., & Kuhn, J., Publications of the Astronomical Society of the Pacific, Volume 127, issue 955, pp.857-869, 2015
- "Lyot-based low-order wavefront sensor for phase mask coronagraphs: Principle, Simulations and Laboratory Experiments". **Singh, G.**, Martinache, F., Baudoz, P., Guyon, O., Matsuo, T., Jovanovic N., Clergeon, C., Publications of the Astronomical Society of the Pacific, vol. 126, pp. 586-594, June 2014

### Other refereed publications
`https://ui.adsabs.harvard.edu/public-libraries/mIDtSBIcSxmzHIz-SxrjkA`

### Link to Conference Proceedings
`https://ui.adsabs.harvard.edu/public-libraries/V36n3qzlTKm3JWwlH3B8yw`

Alternatively, **ORCID profile:**
`https://orcid.org/0000-0001-8224-9106`

### Submitted, accepted and other relevant publications and articles

- Singh et al. "Revealing asymmetrical dust distribution in the inner regions of HD 141569", submitted
- A public article written for a journal associated with Marie Skłodowska-Curie Alumni Association (MCAA): Worlds beyond ours.
- An article "Improving data interpretation of exoplanet images" written for the 21st MCAA Newsletter. This article is an easy read explaining the motives and significance of my published work as a MSCA fellow at the Observatoire de Paris.
- A public article, "Paving the way for improving exoplanet imaging with ground-based telescopes", published in Volume 5 of the UK-based European Dissemination Media Agency (page number 30).