

GARIMA SINGH

Postdoctoral Fellow

National Research Council of Canada
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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., Très Honorable, Astronomy & Astrophysics (Instrumentation) *October 2012 - Sept. 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: Dr. Olivier Guyon, Dr. Pierre Baudoz and Dr. Daniel Rouan

M.Tech., Mention Bien, Astronomy & Astrophysics *July 2008 - September 2010*
Université de Paris XI Sud and Ecole Normale Supérieure 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

National Research Council (NRC) postdoctoral fellow *February 2021- present*
Herzberg Astronomy & Astrophysics Research Centre (HAA), Victoria, BC, Canada

Developing an end-to-end simulation of the Planetary Systems Imager instrument of the Thirty Meter Telescope. Involved in the development of a specialized calibration sub-system for the Gemini Planet Imager instrument upgrade project and NRC's pathfinder SPIDERS testbed at Subaru Telescope. I am leading the implementation of a low-order wavefront sensor and merging the loop with a focal-plane wavefront sensor for these upcoming systems. Preliminary R&D of my work is performed on NRC's NEW EARTH lab at HAA.

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. The published results provided constraints on the dust distribution in the inner-most ring (at roughly 40 au) of the system known to date.

NASA Postdoctoral Program Fellow *November 2015 - November 2017*
NASA Jet Propulsion Laboratory, Pasadena, USA

Worked at Palomar Observatory to improve 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.

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 residual of 0.15 mas for tip-tilt with a vector vortex coronagraph (Singh et al. PASP 2015). Given the success of the LLOWFS demonstration on SCEXAO (Singh et al. PASP 2017), it has been implemented by the THD2 bench (Paris Observatory), NASA's PICTURE-C balloon mission and is under implementation for the upcoming upgrade of the calibration unit (CAL2) of Gemini Planet Imager-2.0 (GPI-2.0) instrument.

Research Associate on a Temporary Contract

July-September 2012

LESIA, Observatoire de Paris-Meudon, France

Adaptive Optics System Developer

July 2011 - January 2012

Inter-University center for Astronomy & Astrophysics (IUCAA), Pune, India

Research Associate

January - June 2011

Aryabhata Research Institute of Observational Sciences (ARIES), Nainital, India

Subaru Research Intern

April - September 2010

Subaru Telescope, Hawaii, USA

Master Thesis: Focus tracking of the laser guide star (LGS) using the guide star acquisition unit of Subaru Telescope's LGS adaptive optics system.

Fellowships & Awards

- NRC Postdoctoral Fellowship, Life Signatures on Exoplanets *February 2021 - present*
- Marie Skłodowska-Curie Actions Postdoctoral fellowship *June 2018 - September 2020*
(Awarded 173,076.00 Euros to cover Research, Travel and Institutional costs)
- Honorary Professor, Amity Institute of Space Science & Technology, India *February 2017*
- NASA Postdoctoral Program (NPP) Fellowship *November 2015 - October 2017*
(Awarded 136,910.00 USD to cover Research and Travel costs.)
- French Gov. scholarship “**Conseil Région île-de-France**” *September 2008-2010*
(Awarded 20,200 Euros for master studies.)

Reviewer

2019 & 2020 FINESST (Future Investigators in NASA Earth and Space Science & Technology) Astrophysics proposals.

Journal of Astronomical Telescopes, Instruments, and Systems (JATIS).

Invited to review HORIZON-MSCA-PF-2021 Marie-Curie Fellowship proposals. Could not participate due to pre-planned travel.

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 (Network of Young Researchers in Instrumentation for Astronomy) workshop organizing member.

Observing Experience

July 2021

Observatory: Keck Telescope, 7 nights of remote observing assistance with instruments NIRC2 and OSIRIS.

November 2015 - 2017

Observatory: 5.1-meter Hale Telescope, Palomar Mountain, California

Instrument: Palm-3K Extreme AO (P3K), stellar double coronagraph (SDC) system and the imager PHARO.

Nights: 4 science and 4 engineering nights to test the performance of the SDC downstream P3K, 5 engineering nights with P3K to test the capabilities of the Zernike wavefront sensor.

November 2012 - December 2016

Observatory: 8.2-meter Subaru Telescope, Maunakea, Hawaii

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 (Ph.D. research work).

Computing Experience and Data reduction

Python, IDL and Julia (basics).

Laboratory and on-sky coronagraphic performance evaluation and spectral analysis of SCEXAO instrument, SDC system and THD2 bench. End-to-end PROPER simulation (Python) and implementation of control algorithms (Julia) for wavefront sensing for NRC's NEW-EARTH testbed, pathfinder SPIDERS/Subaru and CAL2/GPI-2.0 projects. Angular differential imaging of debris disks imaged with the SPHERE instrument.

Professional Development

Invited Lecture

"Wavefront sensing and reconstruction", **August 20, 2019 and August 17, 2021.**

Center for Adaptive Optics summer school (CfAO), University of California, Santa Cruz

Presentations & Seminars (Selected talks)

- How to image Exoplanets? **(Invited talk)**
San Francisco State University A&A Colloquium series (online) October 2021
- SPHERE observation of the complex structure of HD 141569 inside 50 AU. May 2021
Canadian Astronomical Society (CASCA) 2021 online conference, Canada
Subaru 20th anniversary conference, Big Island of Hawaii November 2019
- 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
Museum of Natural Sciences in Brussels, Belgium
- Reconstruction of high-contrast images with the low-order wavefront sensor telemetry. May 2017
NYRIA workshop, Paris, France
- Direct imaging of Exoplanets at small inner working angle: Techniques. **(Invited talk)**
Indian Institute of Astrophysics, Bangalore, India February 2017
- Optimizing coronagraphic observations at small inner working angle. November 2016
High-Contrast Imaging in Space workshop, Space Telescope Science Institute, Baltimore
- PSF calibration using the Lyot-based low-order wavefront sensor telemetry. **(Invited talk)**
Keck Institute for Space Studies workshop, CalTech, Pasadena, California August 2016

- Low-order wavefront control and calibration for phase mask coronagraphs. **(Invited talks)**
Large Binocular Telescope Observatory (LBTO), Arizona *May 2015*
STScI Star and Planet Formation Seminar Series, Baltimore *September 2015*
- Low-order aberrations control and PSF calibration on SCEXAO. **(Invited talk)**
LOWFS & PSF for Exoplanets meeting, Jet Propulsion Laboratory, California *February 2014*

Conference Posters & POP

- Active minimization of non-common path aberrations using a self-coherent camera for imaging exoplanetary systems.
In the Spirit of Lyot, Tokyo, Japan *October 2019*
Adaptive Optics for Extremely Large Telescopes (AO4ELT6), Québec city, Canada *June 2019*
- Discovery of an azimuthal density gradient in a gas-rich debris disk possibly related to massive collision.
In the Spirit of Lyot, Tokyo, Japan *October 2019*
New Horizons in Planetary Systems, Victoria, Canada *May 2019*
- Wavefront sensing for high contrast imaging. *May 2016*
UCLA Lake Arrowhead Conference Center, California
- 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.
Sagan Workshop, California Institute of Technology, Pasadena *July 2014*
SPIE Astronomical Telescopes & Instrumentation, Montreal, Canada *June 2014*
- Lyot-based low-order wavefront sensor for phase mask coronagraphs.
Search for life beyond the solar system, Arizona *March 2014*
5th Subaru International Conference: Exoplanet & disks, Kona, Hawaii *December 2013*
AO4ELT3 conference, Florence, Italy *May 2013*

Summer Schools and Workshops attended

- Network of Young Researchers in Instrumentation for Astronomy (NYRIA)
Leiden Observatory, Netherlands *8-12 October 2018*
Observatoire de Paris-Meudon, Paris, France *16-19 May 2017*
- Preparing Thirty Meters Telescope Future Science and Technology Leaders
 Science Advisory Committee (SAC) member for the workshop activity.
Santa Cruz, California, USA *22-29 August 2017*
Hilo, Hawai'i, USA *3-7 December 2016*
- Exoplanet Imaging and Characterization:
 Coherent Differential Imaging and Signal Detection Statistics
California Institute of Technology, Pasadena, California *22-26 August 2016*
- Sagan Workshop *21-25 July 2014*
California Institute of Technology, Pasadena, California
- 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
Center for Adaptive Optics, University of Santa Cruz, California

4-9 August 2013

Outreach Activities

- Upcoming star party talk for the Friends of Dominion Astrophysical Observatory. *March 2022*
- Three invited outreach lectures (delivered online) on exoplanet detection techniques. *January 2021*
Women in STEM Series (WoAA) India, NSS USA-Mumbai and Hilwood College Kandy, Sri Lanka.
Link to one of the talks on: Youtube.
- 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*
University of Petroleum and Energy Studies, Dehradun, India **(Invited Talk)**
- 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.
Leh Ladakh, Kashmir, India *December 2017*
- Discussion on science, astronomy and women empowerment *February 2017*
Pardada Pardadi Educational Society, India **(Volunteer Talk)**
- Techniques to find extrasolar planets *February 2017*
Nehru Planetarium & SPACE India in collaboration with AMITY University, Delhi **(Invited Talks)**
- "Journey through the Universe" and *Astroday* educator with the Mauna Kea Astronomy Outreach Committee in Hilo, Hawaii. *2014 - 2015*

Languages

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

Professional references

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PUBLICATIONS

Peer-reviewed first author articles

- “*Revealing asymmetrical dust distribution in the inner regions of HD 141569*”. **G. Singh**, T. Bhowmik, A. Boccaletti, P. Thébault, Q. Kral, J. Milli, J. Mazoyer, E. Pantin, R. G. van Holstein, J. Olofsson et al. (36 more), *Astronomy & Astrophysics*, 653, A79, 2021
- “*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., *Astronomy & Astrophysics*, 631, A106, 2019.
- “*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
- “*Lytot-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 peer-reviewed articles

- “*Socio-demographic study of the exoplanet direct imaging community*”. L. Leboulleux, E. Choquet, E. Huby, **G. Singh**, F. Cantalloube, *Bulletin of the American Astronomical Society*, Vol. 52, Issue 2, id. 0209, 2020.
- “*Comparing focal plane wavefront control techniques: Numerical simulations and laboratory experiments*”. A. Potier, P. Baudoz, R. Galicher, **G. Singh**, A. Boccaletti, *Astronomy & Astrophysics*, 635, A192, 2020.
- “*Characterizing vibrations at the Subaru Telescope for the Subaru coronagraphic extreme adaptive optics instrument*”. J. Lozi, O. Guyon, N. Jovanovic, N. Takato, **G. Singh**, et al., *Journal of Astronomical Telescopes, Instruments, and Systems*, Vol 4, id. 049001, 2018.
- “*An H-band Vector Vortex Coronagraph for the Subaru Coronagraphic Extreme-adaptive Optics System*”. J. Kuhn, E. Serabyn, J. Lozi, N. Jovanovic, T. Currie, O. Guyon, T. Kudo, F. Martinache, **G. Singh**, et al., *Publications of the Astronomical Society of the Pacific*, Vol. 130, Issue 985, 2018.
- “*Subaru/SCEXAO First-light Direct Imaging of a Young Debris Disk around HD 36546*”. T. Currie, O. Guyon, M. Tamura, T. Kudo, N. Jovanovic, J. Lozi, J. E. Schlieder, T. D. Brandt, J. Kuhn, E. Serabyn, M. Janson, J. Carson, T. Groff, J. N. Kasdin, M. W. McElwain, **G. Singh**, et al., *The Astrophysical Journal Letters*, Vol. 836, Issue 1, 2017.
- “*The Subaru Coronagraphic Extreme Adaptive Optics System: Enabling High-Contrast Imaging on Solar-System Scales*”. N. Jovanovic, F. Martinache, O. Guyon, C. Clergeon, **G. Singh**, et al., *Publications of the Astronomical Society of the Pacific* Vol 127, Issue 955, pp. 890, 2015.
- “*On-Sky Speckle Nulling Demonstration at Small Angular Separation with SCEXAO*”. F. Martinache, O. Guyon, N. Jovanovic, C. Clergeon, **G. Singh**, et al., *Publications of the Astronomical Society of the Pacific* Vol 126, Issue 940, pp. 565, 2014.

Submitted, under preparation and public articles

- Singh et al. “Pupil-plane LLOWFS simulation and laboratory results from NEW-EARTH’s high-contrast imaging testbed”, under preparation.
- 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).

Conference Proceedings

- “Fast focal plane wavefront sensing as a second stage adaptive optics wavefront sensor”. B. L. Gerard, J. P. Veran, **G. Singh**, et al., Proc. SPIE 11448, Adaptive Optics Systems VII, 1144826, 2021.
- “The SCExAO High Contrast Imaging Platform: Current and Upcoming Capabilities”. O. Guyon, J. Lozi, S. Vievard, A. Sahoo, N. Jovanovic, T. Currie, P. Pathak, F. Martinache, T. Kudo, M. Tamura, **G. Singh**, et al., American Astronomical Society Meeting #233, id.104.03, 2019.
- “PSF calibration using the Lyot-based low order wavefront sensor telemetry: first simulations”. **G. Singh**, J. Lozi, E. Choquet, E. Serabyn, O. Guyon, Proc. SPIE Vol. 9909, id. 99097K 10 pp., 2016.
- “Efficiently feeding single-mode fiber photonic spectrographs with an extreme adaptive optics system: on-sky characterization and preliminary spectroscopy”. N. Jovanovic, N. Cvetojević, C. Schwab, B. Norris, J. Lozi, S. Gross, C. Betters, **G. Singh**, et al., Proc. SPIE Vol. 9908, id. 99080R 10 pp., 2016.
- “The SCExAO high contrast imager: transitioning from commissioning to science”. N. Jovanovic, O. Guyon, J. Lozi, T. Currie, J. Hagelberg, B. Norris, **G. Singh**, et al., Proc. SPIE Volume 9909, id. 99090W 10 pp., 2016.
- “Characterizing and mitigating vibrations for SCExAO”. J. Lozi, O. Guyon, N. Jovanovic, **G. Singh**, et al., Proc. SPIE Volume 9909, id. 99090J 13 pp., 2016.
- “SCExAO: the most complete instrument to characterize exoplanets and stellar environments”. J. Lozi, O. Guyon, N. Jovanovic, **G. Singh**, et al., American Astronomical Society, ESS meeting #3, id.104.03. BAAS volume 47 #6, 2015.
- “SCExAO: the first high contrast exoplanet imager on an ELT?”. J. Lozi, N. Jovanovic, O. Guyon, J. Males, **G. Singh**, et al., Proc. Adaptive Optics for Extremely Large Telescopes IV, id.E79 2015.
- “The low-order wavefront sensor for the PICTURE-C mission”. C. B. Mendillo, J. Brown, J. Martel, G. A. Howe, K. Hewasawam, S. C. Finn, T. A. Cook, S. Chakrabarti, E. S. Douglas, D. Mawet, O. Guyon, **G. Singh**, et al., Proc. SPIE Volume 9605, id. 960519 12 pp., 2015.
- “Lyot-based low order wavefront sensor: implementation on the Subaru Coronagraphic Extreme Adaptive Optics System and its laboratory performance”. **G. Singh**, O. Guyon, P. Baudoz, N. Jovanovic, et. al., Proc. SPIE Volume 9148, id. 914848 9 pp., 2014.
- “On-sky speckle nulling with the Subaru Coronagraphic Extreme AO (SCExAO) instrument”. F. Martinache, O. Guyon, N. Jovanovic, C. Clergeon, **G. Singh**, et. al., Proc. SPIE Volume 9148, id. 914821 10 pp., 2014.

- “Recent progress on phase-mask coronagraphy based on photonic-crystal technology”. N. Murakami, J. Nishikawa, M. Tamura, E. Serabyn, W. A. Traud, K. M. Liewer, D. C. Moody, J. T. Trauger, O. Guyon, F. Martinache, N. Jovanovic, **G. Singh**, et. al., Proc. SPIE Volume 9143, id. 914334 8 pp., 2014.
- “Development and recent results from the Subaru coronagraphic extreme adaptive optics system”. N. Jovanovic, O. Guyon, F. Martinache, C. Clergeon, **G. Singh**, et al., Proc SPIE Volume 9147, id. 91471Q 11 pp., 2014.
- “SCE_{Ex}AO: First Results and On-Sky Performance”. T. Currie, O. Guyon, F. Martinache, C. Clergeon, M. McElwain, C. Thalmann, N. Jovanovic, **G. Singh**, et. al., Proceedings of the International Astronomical Union, IAU Symposium, Volume 299, pp. 34-35, 2014.
- “SCE_{Ex}AO as a precursor to an ELT exoplanet direct imaging instrument”. N. Jovanovic, O. Guyon, F. Martinache, C. Clergeon, **G. Singh**, et al., Proceedings of the Third AO4ELT Conference. id.94, 2013.
- “Lyot-based ultra-fine pointing control system for phase mask coronagraphs”. **G. Singh**, F. Martinache, P. Baudoz, O. Guyon, C. Clergeon, T. Matsuo, Proceedings of the Third AO4ELT Conference. id.7, 2013.
- “The Subaru Coronagraphic Extreme Adaptive Optics Imager: First Results and On-Sky Performance”. T. Currie, O. Guyon, F. Martinache, C. Clergeon, M. McElwain, C. Thalmann, N. Jovanovic, **G. Singh**, et. al., IAU 299/Victoria conference proceedings, 2013.