

## Aishwarya Girdhar



### Title

Quasar Feedback Survey – the impact of jets and multi-phase outflows on their host galaxies

### Abstract

I will present an overview of the Quasar Feedback Survey (QFeedS) and will illustrate its powerful capabilities to establish the role of rapidly growing supermassive black holes (i.e., quasars) in galaxy evolution. Using spatially-resolved ionized gas and stellar kinematic measurements from MUSE data, molecular gas kinematics from ALMA data, and high-quality imaging from the VLA, we are measuring in exquisite detail how  $z < 0.2$  quasars interact with the host galaxy's interstellar medium (ISM). By combining these data, we can infer the feedback effects on the host galaxy: 1) there are clear signatures of the impact of radio jet-ISM interactions in both the ionized and molecular phases; 2) we observe outflowing, dense turbulent gas, perpendicular to the jet-axis, extending to galactic scales; 3) we observe evidence for jet-induced feedback on the stellar properties. Recent simulations of jet-ISM interactions, qualitatively agree with our observations; specifically, as inclined, low power jets move through the galaxy, they strongly interact with the ISM, causing highly turbulent material to be stripped, which then escapes above and below the galaxy disk. The overall impact is to both remove gas from the host galaxy (globally suppressing star formation) and to compress the gas (locally inducing star formation). Through my analysis, I present a discussion of how such jet-induced feedback could be an important, previously underappreciated, feedback mechanism for bolometrically luminous 'radio quiet' quasars.

# AISHWARYA GIRDHAR

📍 European Southern Observatory, Karl-Schwarzschild-Strasse 2, Garching bei Munich 85748, Germany  
✉ aishwarya.girdhar@eso.org | 📞 +49-8932006175 | 📅 01.07.1994 | ♀ Female | 🇮🇳 Indian

## Education

- Oct 2019 - Present    **PhD at the European Southern Observatory, Garching (pursuing)**  
*IMPRS at the Ludwig Maximilians University, Munich*  
Research Topic: “*Characterising the multi-phase AGN outflows at high resolution with observations from MUSE, ALMA and VLA*”  
Supervisors: Dr. Chris Harrison (Newcastle University); Dr. Vincenzo Mainieri (ESO); Prof. Andreas Burket (LMU)
- Sep 2017 - Sep 2019    **Masters in Astronomy and Astrophysics**  
*ASTROMUNDUS - 2 years E+ :Erasmus Mundus Joint Master Degree (E+ :EMJMD) programme- Full Scholarship student*  
Master Thesis: “*Spatial Variation of stellar ages in GASP galaxies observed with MUSE*”  
Supervisors: Prof. Giulia Rodighiero, *University of Padova*; Dr. Marco Gullieuszik, *INAF-Padova*  
Grade: **1.1** (Austrian) = **110/110 cum laude** (Italian); 120 ECTS  
• 1st Sem : University of Innsbruck, Austria  
• 2nd, 4th Sem : University of Padova, Italy  
• 3rd Sem : University of Belgrade, Serbia
- Jul 2012 - Jul 2015    **B.Sc.(Hons.) Physics**  
*University of Delhi, Kirori Mal College, India: Grade: 81.44% (A)*

## Research Experience

- **Quasar Feedback Survey: Jet-ISM interactions and feedback in  $z \sim 0.1$  quasars**  
Multi-phase outflows, turbulence and evidence for feedback caused by low power radio jets inclined into the galaxy disk, with MUSE, ALMA, VLA  
**Dr. Chris Harrison, Newcastle University, Dr. Vincenzo Mainieri, ESO, Munich**
- **Master Thesis: Study of spatial variation of stellar ages for 34 undisturbed galaxies of GASP Survey observed with MUSE.** (Mar 2019 - September 2019)  
**Prof. G. Rodighiero, Dr. M. Gullieuszik, University of Padova and INAF, Padova, Italy**
- **Multi-wavelength study of the effects of ram pressure stripping in jellyfish galaxy - JW100, in the Abell 2626 cluster with observations in  $H\alpha$  from MUSE on VLT and in UV from Astrosat.** (Jul 2018 - Sept 2018)  
**Dr. Bianca Poggianti, Dr. Marco Gullieuszik, INAF - Istituto Nazionale di Astrofisica, Padova, Italy**
- **Predicting effects of Gravitational Lensing on observability of high redshift galaxies ( $z > 6$ )** (Apr 2017 - Jul 2017)  
**Prof. Andrea Ferrara, Scuola Normale Superiore, Pisa, Italy**
- **Cis-Lunar Exploration for Realizing Transit Habitat (Project CLERTH)** to enable long duration missions for astronauts; research presented at NASA forum. (Nov 2013 - Jun 2014)  
**Prof. Sumitra Mohanty, University of Delhi, India, Prof. N. Patel, University of North Florida, USA**

## Publications List

- **Girdhar A., Harrison C.M., Mainieri V. et al.**  
Quasar Feedback Survey: Multi-phase outflows, turbulence and evidence for feedback caused by low power radio jets inclined into the galaxy; Accepted to MNRAS, *in press*
- **Silpa S., et al. [including Girdhar A.]**  
The Quasar Feedback Survey: An interplay of jets, winds, & emission line gas in Type 2 quasars; Submitted to MNRAS

## Publications List (continued)

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- *Jarvis, M.E. et al. [including Girdhar A.]*  
The Quasar Feedback Survey: Discovering hidden Radio-AGN and their connection to the host galaxy ionised gas; MNRAS, Volume 503, Issue 2, pp.1780-1797
- *Silpa S. et al. [including Girdhar A.]*  
The Quasar Feedback Survey: An interplay of jets, winds and emission-line gas in Type-2 quasars; Submitted to MNRAS
- *Sbordone, L. et al. [including Girdhar A.]*  
A high-resolution, high S/N, optical HARPS public spectrum of Betelgeuse during minimum; The Astronomer's Telegram, No. 13525

## Awards and Achievements

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- 2020 ■ **Featured as the 'Physicist of the Week'** by The Working Group for Equal Opportunities (AKC) of the German Physical Society (DPG) in the 52nd week of 2020.
- 2019-22 ■ Selected for the prestigious International Max Planck Research School's PhD programme with full scholarship to pursue my PhD at the European Southern Observatory.
- 2017-19 ■ **Full Consortium Student Scholarship and Consortium fee waiver** from Institute of Astro- and Particle Physics, University of Innsbruck to participate in the E+ :Erasmus Mundus Joint Master Degree (E+ :EMJMD) programme AstroMundus in Astrophysics
- 2014 ■ **Selected as the sole international entry at NASA and NIA's Revolutionary Aerospace Systems Concepts and Academic Linkage with travel and lodging support**  
In collaboration with University of North Florida, USA, proposed and presented at the NASA forum, a transit habitat design to enable long duration missions for astronauts in cis-lunar space
- 2013 ■ **Second prize at NASA's Lunabotics Mining Competition**, Kennedy Space Centre, USA, in Outreach Project Report Category.
  - Organised outreach events, to promote science in 15 schools and 2 slums of Delhi
- **Second prize at NASA's Lunabotics Mining Competition**, Kennedy Space Centre, USA, in Luna's WorldWide Campaign Category.
  - An international campaign to promote Science and Luna among the public
- 2014-15 ■ **Featured with team in 9 national news journals of India** for selection at university level in NASA and Mars Society competitions

## Employment

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- **Science Communicator and Educator, SPACE, New Delhi, India**  
Mar 2016 - Apr 2017 : *Amateur astronomy, astronomy communication and popularization*
  - Initiated the non profit wing - *SPACE Foundation*, conducted celestial observations for under-privileged sections of society and in NGOs to popularize astronomy and create awareness as part of the 'Sky on Bike' project funded by **International Astronomical Union (IAU)**
  - Developed astronomy content to be taught in schools and conducted lessons and observations for schools, NGOs and common masses.

## Science Communication Experience

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- Aiding in the development of "Audio Universe: Tour of the Solar System" - a planetarium show to bring Astronomy to visually impaired children and adults through sonification and tactile models
- Organised outreach events in 15 schools and 2 slums of Delhi to promote science and spread awareness, during my Bachelors.
- Conducted astronomical outreach with the telescope in over 10 NGOs with under-privileged and specially challenged students.
- Executed the 'Sky on Bike' project funded by the International Astronomical Union (IAU) to make Astronomy accessible to the remotest areas in India.

## Science Communication Experience (continued)

- Delivering talks and online live youtube feeds to promote activities of European Southern Observatory and its observatories for public and prospective students, covering viewership of > 2000.
- Started the “Astronomy on Tap’s” Munich Chapter, as one of the lead-organisers, to bring Astronomy to general public in informal settings
- Organised telescopic observations for public during Mercury Transit, Saturn Opposition, Mars at closest approach, Supermoon in 2016.
- Conducted and participated in events like Sally Ride EarthKAM (taking photographs of Earth from a camera mounted on the ISS), Project Paridhi (training students to measure the circumference of the Earth using Eratosthenes shortest shadow experiment), AIASC (All India Asteroid Search Campaign)

## Co-Curricular

- Summer Schools**
- **ESO’s La Silla Observing Summer School** Training to prepare observations and observe with ESO’s 3.6m telescope, the Danish telescope and the NTT telescope at La Silla Observatory and associated data reduction **La Silla Observatory, Chile, February 2020**
    - Presented our group’s findings on the data and analysis of Omega Centauri cluster.
    - Observed and published a telegram on observations of Betelgeuse
  - 2018 ■ **The Current and Future Observing Facilities.** Advanced Summer School, organised by ESO and Instituto de Astrofísica de Canarias; 02-08 Sept 2018 at Belgrade, Serbia
    - Presented my research on multi-wavelength analysis of star formations in galaxies.
  - **3 nights training to handle 1.2 m GALILEO Telescope at Asiago Astrophysical Observatory, Italy.** Carried observations of novae and white dwarfs under the training and supervision of **Dr. Ulisse Munari, INAF Padova, Italy**
  - 2015 ■ **Participated in Mars Society’s University Rover Challenge:** Headed a 22 member team in senior year to fabricate a Mars Rover, secured funding for fabrication and travel to compete at Mars Desert Research Station, Utah, USA
  - 2014 ■ **Selected with funding to present group’s research at NASA and National Institute of Aerospace’s Revolutionary Aerospace System’s Concepts and Academic Linkage**
  - 2013 ■ **Participated in NASA’s Lunabotics Mining Competition, Kennedy Space Centre, USA** Along with a team, fabricated a lunar rover to compete with elite universities at KSC, led the outreach team to win the second prize.
- Volunteer Work**
- **Robin Hood Army**
    - Collected surplus good quality food or bought food with contributions and provided to under-privileged people
    - Acquainted to the people in slums, addressed their critical issues like substance abuse, unemployment, etc.