Report from the event supported by RadioNet

TITLE	*A CENTENARY OF ASTROPHYSICAL JETS: OBSERVATIONS, THEORY, AND FUTURE PROSPECTS*
DATE:	*23 – 26 JULY, 2019*
LOCATION:	*SKA GLOBAL HEADQUARTERS, JODRELL BANK OBSERVATORY, CHESHIRE, UNITED KINGDOM*
MEETING WEBPAGE:	*https://indico.skatelescope.org/e/astrojets100*
HOST INSTITUTE:	*UNIVERSITY OF MANCHESTER / SKA ORGANISATION*
RADIONET BENEFICIARY / NO:	*UMAN/06*

RadioNet has received funding from the EU's Horizon 2020 research and innovation programme under the grant agreement No 730562

Report:

1 SCIENTIFIC SUMMARY

Since the first description of an observation of an astrophysical jet, by Heber D. Curtis (Curtis 1918; *Descriptions of 762 nebulae and clusters*, Pub. Lick Observatory 13, 9), countless jets of high-energy particles from compact objects, such as neutron stars and Galactic black holes, to the relativistic jets in Active Galactic Nuclei have been studied across a wide range of physical scales. In addition to their transport properties, jet outflows serve as laboratories for probing the physics of energetic processes and are implicated in the regulation of large-scale structure in the Universe. Although jet studies have seen much progress over the past century, there are many open questions about jet formation, collimation, and acceleration.

To commemorate the centenary of the discovery of this remarkable astrophysical phenomenon, a team of astronomers led the organization of the international conference *A Centenary of Astrophysical Jets: Observations, Theory & Future Prospects.* The main purpose of this conference was to bring together multi-wavelength observers and theorists to review the progress made over the past century in our attempts to understand jets on all scales, and as well, to provide the 'jets astronomy community' with an opportunity to review key questions in jet studies, and to discuss the prospects for future research on jets at a time when major new facilities, such as SKA and JWST, are on the horizon. The conference was held in the Council Chamber of the newly-inaugurated Square Kilometre Array Organisation global headquarters at Jodrell Bank Observatory, from 23rd to 26th July 2019. Key topics addressed included *Jet generation & Launching*, *Propagation*, *Dissipation*, and *Feedback*. Major European radio astronomy facilities and institutes such as Jodrell Bank Observatory (Manchester, UK), the Max Planck Institute for Radio Astronomy (Bonn, Germany) and LOFAR (ASTRON, NL) all of which are part of the RadioNet consortium have contributed immensely towards the scientific inquiry into astrophysical jets over the past decades. Thus, the entire theme of this meeting was directly linked to the RadioNet Objectives, and many audience members were also drawn from the 'RadioNet community'.

In total, 122 delegates attended the meeting from more than 45 different institutes across the globe – including delegates from the USA, South America, the UK, mainland Europe, Russia, Africa, India, China, Australia, Japan, Israel, etc. The majority of attendees was from the UK. Of these attendees >50% were early career scientists (MSc/PhD students or PDRAs) and ~40% were senior academics/researchers (Professors) focussing on various aspects of jets research. The attendance at this meeting only represented a subset of the research community actively involved in the observational and theoretical study of astrophysical jets across varying physical scales. Further conference details, including the programme and book of abstracts is available at the meeting website: (https://indico.skatelescope.org/e/astrojets100)

The meeting began with a welcome address by Philip Diamond (Director-General, SKA Organisation). The first invited talk was delivered by Mitch Begelman (Colorado, USA) who highlighted and attempted to address some key questions in jet theory. Discussions for day one of the meeting focussed on launch and acceleration mechanisms, and VLBI and small-scale jets. Andrei Lobanov (MPIfR, Germany) concluded the discussions for the first day with a talk on 'half a century of VLBI studies of

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relativistic jets' in which he highlighted the role of VLBI in resolving the physics and parsec-scale structure in extragalactic relativistic jets.

The second and third day focussed on propagation, feedback, high-energy processes, cosmic ray and neutrinos. There were also two special sessions. The first special session was on M87 – with Masanori Nakmura (ASIAA, Taiwan) highlighting some lessons learned from the radio galaxy, M87 in attempts to provide unification of AGN jets. The second was on microquasar jets – with Ralph Spencer (University of Manchester, UK) and Felix Mirabel (IAFE-CONICET-UBA, Argentina) giving an extensive review of half a century of research in this field.

The fourth and final day of the meeting was dedicated to radio source lifecycle, and jet population in radio surveys. These sessions provided insights into the energetics and duty cycles of radio galaxies, with an extensive discussion on the ever-growing large numbers of 'jetted sources' observed in large sky radio surveys. Finally, Annalisa Celotti (SISSA, Italy) provided a succinct summary of the entire meeting, and consequently led an extensive discussion on future perspectives on jets.

2 AGENDA OF THE EVENT

Attached

3 PARTICIPANTS

In total, 122 delegates attended the meeting from more than 45 different institutes across the globe – including delegates from the USA, South America, the UK, mainland Europe, Russia, Africa, India, China, Australia, Japan, Israel, etc. Of these attendees:

- >50% were early career scientists (MSc/PhD students or PDRAs)
- ~40% were senior academics/researchers focussing on jets studies
- ~30% of delegates were women
- ~30% of speakers were women
- Preference was given to speakers at early-career stages were possible.
- Full attendance list (including signatures) is sent alongside this document.

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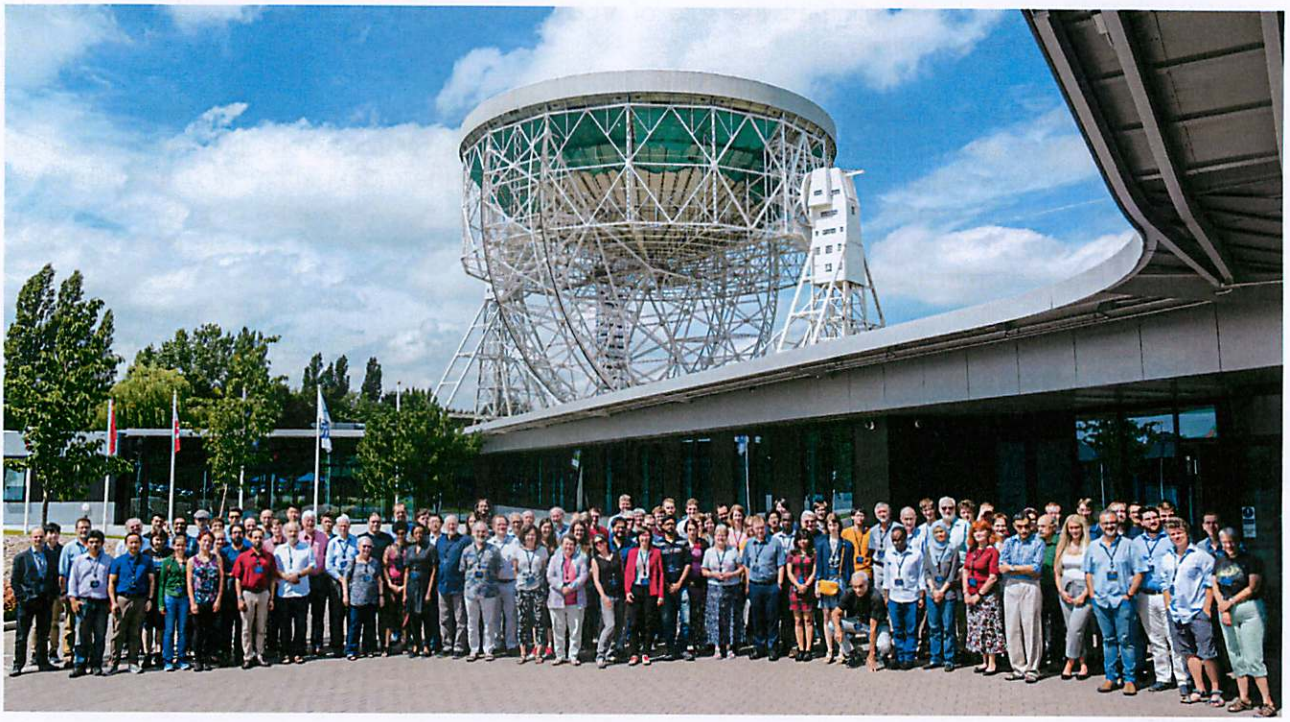


Figure 1: Centenary of Astrophysical Jets Conference (SKA Global Headquarters, Jodrell Bank Observatory, July 2019). Credit: Joe Diamond (SKAO).

3.1 RadioNet newsletter

26 signed -up to RadioNet newsletter – This was provided as an option in the online registration on the conference website.

4 RadioNet financial contribution

The €6000 RadioNet contribution was used as support for 17 delegates.

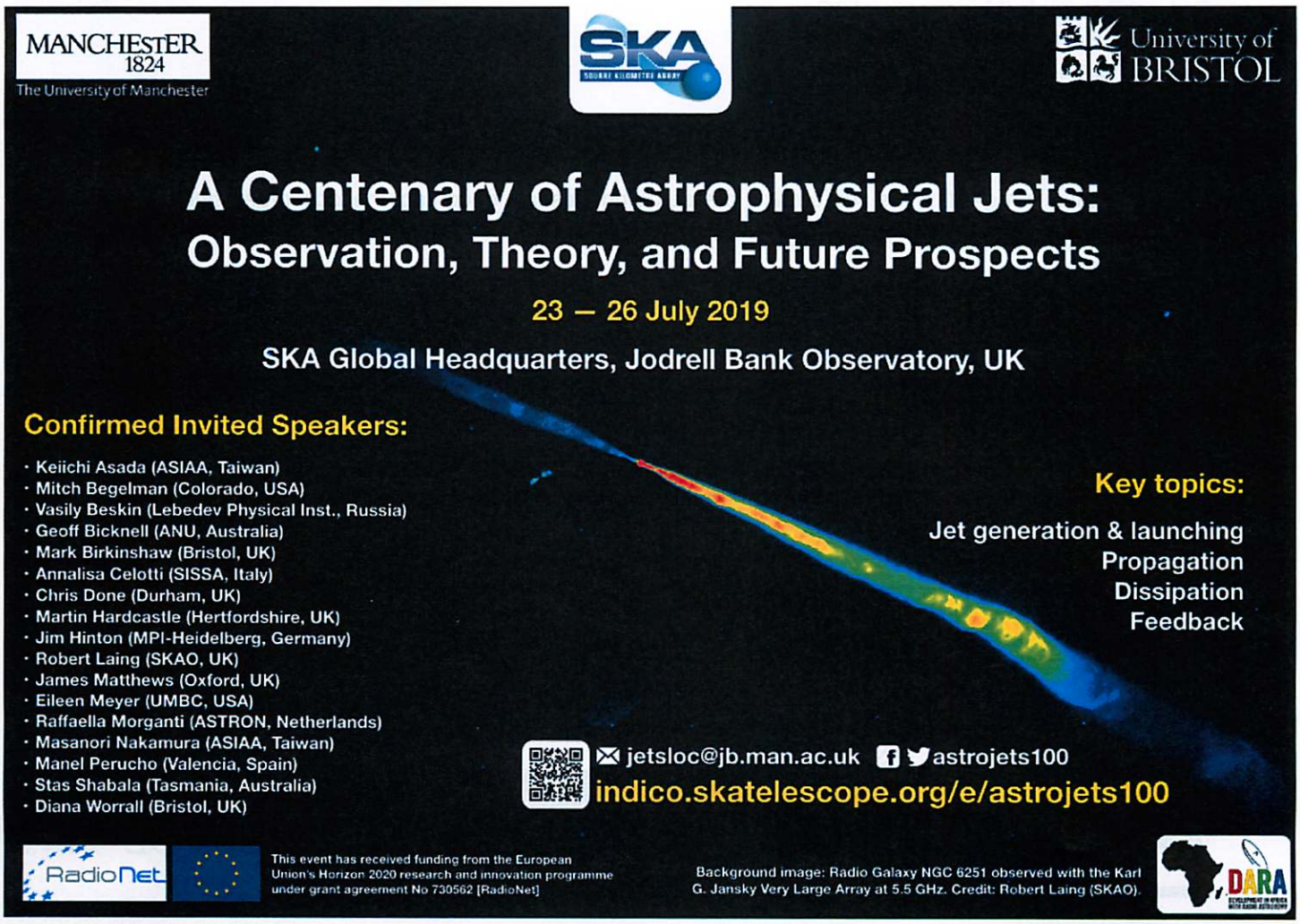
5 Publications

The abstracts, presentations, and posters will soon be published online [https://www.zenodo.org] and indexed on ADS to make the proceedings widely available to the scientific community.

The project leading to this publication has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730562 [RadioNet]

A Centenary of Astrophysical Jets

Conference Programme



Organisers, Contact and Sponsors

Local Organising Committee:

- **Robert Beswick** (Manchester, UK)
- **Robert Laing** (SKA Organisation, UK)
- **Emmanuel Bempong-Manful** (Bristol, UK)
- **Vijay Mahatma** (Hertfordshire, UK)
- **Emma Alexander** (Manchester, UK)
- **Patrick Leahy** (Manchester, UK)
- **Katie Hesterly** (Manchester, UK)
- **Naomi Asabre Frimpong** (Manchester, UK)
- **Isaac Mutie** (Manchester, UK)
- **Emma Thomas** (Jodrell Bank Obs. UK)
- **Sarah Lamb** (SKA Organisation, UK)

Scientific Organising Committee:

- **Emmanuel Bempong-Manful** (Bristol, UK) - Chair
- **Martin Hardcastle** (Hertfordshire, UK) - Co-Chair
- **Mark Birkinshaw** (Bristol, UK) - Co-Chair
- **Masanori Nakamura** (ASIAA, Taiwan)
- **Robert Laing** (SKA Organisation, UK)
- **Aneta Siemiginowska** (Harvard CfA, USA)
- **Robert Beswick** (Manchester, UK)
- **Lakshmi Saripalli** (RRI, India)
- **Silke Britzen** (MPIfR Bonn, Germany)

Contact

If you have any questions regarding the conference, please do not hesitate to contact the local organizing committee: jetsloc@jb.man.ac.uk

Sponsors

The local and scientific organising committees are grateful to our sponsors, without whom this conference would not have been possible.

We thank **RadioNet**, the **Square Kilometre Array Organisation (SKAO)**, the **Development in Africa with Radio Astronomy (DARA)**, the **University of Manchester**, and **University of Bristol** for their generous contributions.

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Tuesday 23 July 2019

Registration/Welcome + General Overview – (11:10 - 11:55) – Chair: Robert Laing (SKAO)		
Time	**Title**	**Speaker**
10:00	***Registration & Coffee/Tea***	
11:00	Welcome	Philip Diamond (Director-General, SKAO)
11:10	Jet Theory: Some Key Questions	Mitch Begelman (Colorado, USA) – [Inv.]

Launch & Acceleration: Theory & Observations – (11:55 - 12:55) – Chair: Robert Laing (SKAO)		
Time	**Title**	**Speaker**
11:55	Jets and their connection to the accretion flow	Chris Done (Durham, UK) – [Inv.]
12:25	Numerical simulations of black hole jets	Ramesh Narayan (Harvard CfA, USA) – [Inv.]
12:55	*Lunch Break*	

Launch & Acceleration + VLBI: Observations – (14:00 - 15:45) – Chair: Masanori Nakamura (ASIAA)		
Time	**Title**	**Speaker**
14:00	Comparing radio-loud Swift/BAT AGN with their radio-quiet counterparts	Maitrayee Gupta (NCAC, Poland) – [Cont.]
14:15	Strong lensing reveals jets in a sub-microJy radio quiet quasar	Philippa Hartley (SKAO, UK) – [Cont.]
14:30	Effects of Numerical Resolution and Disc Tilt on Jet Properties	Chris White (University of California, USA) – [Cont.]
14:45	VLBI studies on AGN jets	Keiichi Asada (ASIAA, Taiwan) – [Inv.]
15:15	Synthetic VLBI Imaging of Relativistic Jet Simulations: Applying Polarized Radiative Transfer Through 3D RMHD and 3D PIC Jet Calculations	Nicholas MacDonald (MPIfR, Germany) – [Cont.]
15:30	A mechanism for triple-ridge emission structure of AGN jets	Taiki Ogihara (Tohoku University, Japan) – [Cont.]
15:45	*Afternoon Coffee/Tea*	
15:45	***Poster Session 1***	

VLBI + Small-scale: Theory & Interpretations – (16:15 - 17:45) – Chair: Masanori Nakamura (ASIAA)		
Time	**Title**	**Speaker**
16:15	Modelling relativistic jets via evolutionary algorithms	Christian Fromm (Goethe University, Germany) – [Cont.]
16:30	Powerful blazar jets dissipate their kinetic power to radiation from a single location: the molecular torus	Adam Harvey (University of Maryland, Baltimore County, USA) – [Cont.]
16:45	Resolving the Enigma: Half a Century of VLBI Studies of Relativistic Jets	Andrei Lobanov (MPIfR, Germany) – [Cont.]
17:15	***Poster Session 2***	
17:15	*Centenary of Astrophysical Jets – Welcome Reception/Cocktail*	

Wednesday 24 July 2019

M87: Theory & Observations – (09:30 - 10:30) – Chair: Martin Hardcastle (Hertfordshire)		
Time	**Title**	**Speaker**
09:30	Lessons Learned from M87 - Jet collimation break as a new unification in AGN jets	Masanori Nakmura (ASIAA, Taiwan) – [Inv.]
10:00	Probing signature of black hole spin in M87 shadow in flaring state	Tomohisa Kawashima (NAO, Japan) – [Cont.]
10:15	Long-term, deep millimeter VLBI observations of M87 down to 7Rs and larger spatial scales	Jae-Young Kim (MPIfR, Germany) – [Cont.]
10:30	*Morning Coffee/Tea + Conference Photo*	

VLBI + Small-scale: Theory & Interpretations – (11:00 - 13:00) – Chair: Martin Hardcastle (Hertfordshire)		
Time	**Title**	**Speaker**
11:00	Internal structure of relativistic jets	Vasily Beskin (LPI & MPIT, Russia) – [Inv.]
11:30	The Overall B Field Configuration of AGN Jets	Denise Gabuzda (University College Cork, Ireland) – [Cont.]
11:45	Hot, Pair Dominated Relativistic Jets	Marek Sikora (NCAC, Poland) – [Cont.]
12:00	Numerical simulation of the polarization produced by recollimation shocks in jets with an initially disordered magnetic field	Christopher Kaye (University of Central Lancashire, UK) – [Cont.]
12:15	Are BL Lac jets weakly magnetised?	Emanuele Sobacchi (Ben Gurion University of the Negev, Israel) – [Cont.]
12:30	Optical AGN jets at milliarcsecond scales	Leonid Petrov (NASA GSFC, USA) – [Cont.]
12:45	Coupling between the small and large scale magnetic field configuration in the relativistic jet of OJ 287	Ioannis Myserlis (MPIfR, Germany) – [Cont.]
13:00	*Lunch Break*	

Particle Acceleration: Theory – (14:30 - 15:30) – Chair: Beatriz Mingo (Open)		
Time	**Title**	**Speaker**
14:30	Particle acceleration at shocks in astrophysical jets	James Matthews (Oxford, UK) – [Inv.]
15:00	Plasmoid reconnection as a mechanism for rapid radiation flares from relativistic jets	Krzysztof Nalewajko (NCAC, Poland) – [Cont.]
15:15	The Feasibility of Magnetic Reconnection Powered Blazar Flares	Paul Morris (University of Oxford, UK) – [Cont.
15:30	*Afternoon Coffee/Tea*	
15:30	***Poster Session 3***	

Very High-Energy, Cosmic Rays & Neutrinos – (16:00 - 18:30) – Chair: Emmanuel Bempong-Manful (Bristol)		
Time	**Title**	**Speaker**
16:00	High-energy neutrinos from AGN?	Sara Buson (Wuerzburg, Germany) – [Inv.]
16:30	The First Radio Polarization Measurement of a Gamma-ray Burst Jet	Tanmoy Laskar (University of Bath, UK) – [Cont.]
16:45	TeV Gamma-rays from jets	Jim Hinton (MPI-Heidelberg, Germany) – [Inv.]
17:15	Highlights from the VERITAS AGN Observation Program	John Quinn (University College Dublin, Ireland) – [Cont.]
17:30	Lepto-hadronic Blazar Modelling	Bruno Jiménez Fernandez (University of Bath, UK) – [Cont.]
17:45	***Poster Session 4***	
19:30	*Conference Dinner*	

Thursday 25 July 2019

High Energy Processes: Observations – (09:30 - 10:30) – Chair: Aneta Siemiginowska (Harvard)		
Time	**Title**	**Speaker**
09:30	The importance of resolved X-ray data for understanding extragalactic radio jets	Diana Worrall (Bristol, UK) – [Inv.]
10:00	Proper Motions from Radio to X-rays: New Results and Future Prospects	Eileen Meyer (UMBC, USA) – [Inv.]
10:30	*Morning Coffee/Tea*	

Propagation: Theory & observations – (11:00 - 12:30) – Chair: Aneta Siemiginowska (Harvard)		
Time	**Title**	**Speaker**
11:00	The remarkable survivability of AGN jets	Serguei Komissarov (Leeds, UK) – [Inv.]
11:30	Large-scale jets: observations	Robert Laing (SKAO, UK) – [Inv.]
12:00	Revisiting the Fanaroff-Riley dichotomy with the LOFAR Two-Metre Sky Survey (LoTSS)	Beatriz Mingo (The Open University, UK) – [Cont.]
12:15	Unveiling the cause of hybrid morphology radio sources (HyMoRS)	Jeremy Harwood (University of Hertfordshire, UK) – [Cont.]
12:30	*Lunch Break*	

Propagation: Theory & Observations – (14:00 - 15:15) – Chair: Herman Marshall (MIT)		
Time	**Title**	**Speaker**
14:00	Jet propagation: energy dissipation and the FRI/FRII dichotomy	Manel Perucho (Valencia, Spain) – [Inv.]
14:30	The multi-band properties of FR0 radio galaxies	Ranieri Diego Baldi (University of Southampton, UK) – [Cont.]
14:45	Numerical simulations of colliding jets in an external wind: Application to 3C 75	Gibwa Musoke (Radboud University, Netherlands) – [Cont.]
15:00	Jet-environment interaction as diagnostic of the central engine	Martin Krause (University of Hertfordshire, UK) – [Cont.]

Microquasar Jets – (15:15 - 15:45) – Chair: Herman Marshall (MIT)		
Time	**Title**	**Speaker**
15:15	50 years of Microquasar Jets	Ralph Spencer (University of Manchester, UK) – [Cont.]
15:30	Microquasar Jets	Felix Mirabel (IAFE-CONICET-UBA, Argentina) – [Cont.]
15:45	*Afternoon Coffee/Tea*	
15:45	***Poster Session 5***	

Feedback: Theory & Observations – (16:15 - 17:30) – Chair: Raffaella Morganti (ASTRON)		
Time	**Title**	**Speaker**
16:15	Feedback from relativistic jets in evolving galaxies	Geoff Bicknell (ANU, Australia) – [Inv.]
16:45	Is gas outflowing in a direction perpendicular to radio jets?	Davide Lena (SRON & Radboud University, Netherlands) – [Cont.]
17:00	A systematic multi-phase study of galactic feedback by jets in quasars	Miranda Jarvis (ESO, Germany) – [Cont.]
17:15	Varieties of interactions between radio galaxies and the intergalactic medium	Mark Birkinshaw (Bristol, UK) – [Inv.]
17:45	***Poster Session 6***	

Friday 26 July 2019

Feedback: Theory & Observations – (09:30 - 10:30) – Chair: Mark Birkinshaw (Bristol)		
Time	**Title**	**Speaker**
09:30	Radio jets as driving mechanism of gas outflows	Raffaella Morganti (ASTRON, Netherlands) – [Inv.]
10:00	The impact of relativistic jets on the ISM of the host galaxies during the breakout phase	Clive Tadhunter (University of Sheffield, UK) – [Cont.]
10:15	Jet-driven bubbles in Fanaroff--Riley type I sources	Christopher Irwin (Tel Aviv University, Israel) – [Cont.]
10:30	*Morning Coffee/Tea*	

Lifecycle: Observations – (11:00 - 12:30) – Chair: Mark Birkinshaw (Bristol)		
Time	**Title**	**Speaker**
11:00	Radio source lifecycles from the LoTSS survey	Martin Hardcastle (Hertfordshire, UK) – [Inv.]
11:30	Energetics and duty cycles of radio galaxies: insights from models	Stas Shabala (Tasmania, Australia) – [Inv.]
12:00	Probing radio restarting activity and duty cycle in high-energy selected giant radio galaxies	Gabriele Bruni (INAF, Italy) – [Cont.]
12:15	The LOFAR Two-Metre Sky Survey view of radio-AGN in the local Universe: The most massive galaxies are always switched on	Jose Sabater Montes (University of Edinburgh, UK) – [Cont.]
12:30	*Lunch Break*	

Lifecycle: Observations – (14:00 - 15:45) – Chair: Eileen Meyer (UMBC)		
Time	**Title**	**Speaker**
14:00	Numerical modelling of Mpc scale jets - Dynamics and Energetics	Joydeep Bagchi (IUCAA, India) – [Cont.]
14:15	Jet production efficiency in the youngest radio galaxies	Anna Wójtowicz (Jagiellonian University, Poland) – [Cont.]
14:30	Giant radio galaxies as ideal laboratories to study megaparsec jets	Pratik Dabhade (IUCAA, India) – [Cont.]
14:45	Summary + Discussions on future perspectives on jets	Annalisa Celotti (SISSA, Italy) – [Inv.]
15:30	*Afternoon Coffee/Tea -&- Farewell*	

NOTES:

- **Invited Talks** are labelled **[Inv.]** on Tan Background, and will be approximately 30 mins.
- **Contributed Talks** are labelled **[Cont.]** on Plain/White Background, and will be approximately 15 mins.
- **Poster Sessions** will be approximately 30 - 45 mins per session BUT much longer after the end of Day 2. Please note that poster contributions are arranged in alphabetical order (based on author's first name).