Focus on astrophysical jets

2015 New J. Phys. 17 110202

(http://iopscience.iop.org/1367-2630/17/11/110202)

New Journal of Physics
The open access journal at the forefront of physics

Deutsche Physikalische Gesellschaft DPG
IOP Institute of Physics
Published in partnership with: Deutsche Physikalische Gesellschaft and the Institute of Physics

CrossMark

OPEN ACCESS

RECEIVED
5 November 2015

ACCEPTED FOR PUBLICATION
5 November 2015

PUBLISHED
23 November 2015

EDITORIAL

Focus on astrophysical jets

Daniela Tordella

Dipartimento di Ingegneria Meccanica e Aerospaziale, Politecnico di Torino, Torino 10129, Italy

E-mail: daniela.tordella@polito.it

Fast, axially collimated outflows, or 'jets', are ubiquitous in astrophysics. Sources belong to most classes of compact objects that experience a combination of accretion, rotation and magnetic fields. Astrophysical jets play an important feedback role in the evolution of their host systems. Plasma physics processes govern energy transfer among gravitational, kinetic, thermal and magnetic-electric components, as well as particles. However it can be but plasma physics in jets is insufficiently understood.

Astrophysical jets studies encompass observations and interpretations of jets from young stars and AGNs, comparisons of models with observations; magneto-hydrodynamical accelerations of jets: steady self-similar models and numerical simulations of time-dependent accelerations mechanisms; jet stability and interaction with the ambient: formation of knots in YSO jets, jet survival to instabilities, deceleration of relativistic jets in Fanaroff and Riley Class I (FRI) sources, simulations of jets-IGM interactions, jets propagation and galaxy formation; numerical codes and their validation: relativistic MHD codes, comparisons among different numerical schemes, jets in the laboratory and code validation.

Many open questions remain in the study of jets emanating from young stellar objects (YSO) and Seyfert galaxies (Beall 2014, Melioli and de Gouveia Dal Pino 2015). These nonrelativistic beams of hypersonic plasma are likely magnetized and are known to cool effectively via radiation losses. Of particular interest for astrophysics are issues related to the internal jet structure.

Depending on the stability conditions of the jets this question speaks directly to the launch mechanisms of the jets as structurally smooth jets, implying time independent conditions at the central engine launching the jet. Recent observations using the *Hubble Space Telescope* and other high resolution platforms indicate that jets may contain significant sub-radial structure, which implies that jets may be inherently heterogeneous or 'clumpy' phenomena (e.g. Hartigan and Morse 2007, Hartigan *et al* 2011).

This *New Journal of Physics* 'Focus on' series includes contributions about the observational measure of the motion of the brightest condensations of young stellar bipolar outflows (Noriega-Crespo *et al* 2014), a critical analysis of *in situ* particle reacceleration (ISR) within radio lobes of radio sources as Centaurus A (Eilek 2014), two articles discussing aspect related to shear instabilities (Belan *et al* 2014 and Alves *et al* 2014), and self-emission of charged particles from laboratory magnetically driven plasma jets in partial similitude with astrophysical magnetic-tower jet launching model.

These five contributions, while covering only partially the issues outlined above, fully cover the spectrum of possible investigation methodologies (observational, theoretical and analytical modeling, laboratory experiments and numerical simulation), a fact that highlights the liveliness of the research in this context. In particular, I observe that two contributions out of five are based on laboratory experiments. On the one hand, this confirms that laboratory astrophysics and complementary theoretical calculations are fundamental for astronomy and astrophysics and will be so in the foreseeable future. On the other, it is true that this figure does not correspond to the frequency of 'astrophysics in the lab' investigations in the community at large (by searching the WOS one verifies that the actual figure is about one paper out of seven).

In perspective, one can see that laboratory astrophysics is a promising methodology because by its very nature is interdisciplinary and requires a deep understanding of core laboratory science plus knowledge of astrophysics, and often much more besides. It therefore offers excellent training opportunities as it produces multi-skilled and flexible scientists who are experienced in interacting with scientists from other disciplines.

It should be noted that laboratory experiments in partial similitude with astrophysical phenomenologies are becoming increasingly common and were recently recommended in White Papers endorsed by the US Astronomy and Astrophysics Advisory Committee (AAAC) and the Strategic Plan for European Astronomy (www.astronet-eu.org). See e.g. the web pages by the Working Group on Laboratory Astrophysics (WGLA) (http://www.aas.org/labastro/lawg_chapter.php) and by the European Task Force Laboratory Aastrophysics (ETFLA) (http://www.labastro.eu/index.html).

Physical understanding of the many phenomenologies present in astrophysical jet dynamics,the feedbacks on their sources, as well as of the interaction with other compact objects and the interstellar/intergalactic media is key to the reliable understanding of possible extreme astrophysical environments and will be fan area of future active research.

In the following, a brief description of the principal outcomes from the papers published in this *New Journal of Physics* focus issue is given.

Noriega-Crespo *et al* (2014) show that tangential velocities of the north and south bipolar Cep E outflow lobes are slightly different (62 ± 26 km s^{-1} and 94 ± 26 km s^{-1}, respectively). Both observations and models agree on the fact that the molecular hydrogen gas moves at high supersonic velocities without being dissociated. In order to achieve as high a resolution as possible, they have employed a high angular resolution enhancement of the IRAC images, reaching a resolution of 0.6–0.8″ (see Noriega-Crespo and Raga 2012, Velusamy *et al* 2014).

Belan *et al* (2014) show resilience against asymptotic growth of asymmetric instabilities is shown in purely hydrodynamic hypersonic jet collimated for hundred of jet radii and in similitude with YSO jets as far as the Mach number and the ambient/jet density ratio (Belan *et al* 2004, Tordella *et al* 2011). Both laboratory observation and numerical simulation show that low amplitude long perturbation waves grow transiently only.

The paper by Eilek (2014) contains a critical view about possible models of *in situ* particle reacceleration (ISR) within the radio lobes of Centaurus A on the base that radio and γ-ray data require neither homogeneous plasma nor quasi-equipartition between the plasma and magnetic field . Both flow driven and magnetically driven models are consistent with current observations; each requires Cen A to be on the order of a Gyr old. Thus, ongoing ISR must be occuring within the radio source. Alfven-wave ISR is probably occuring throughout the source, and may be responsible for maintaining the γ-ray-loud electrons. See also the more recent contributions by Neff *et al* (2015a and 2015b).

The paper by Alves *et al* (2014) focuses on electron-scale instabilities, namely the collisionless, unmagnetized electron-scale Kelvin–Helmholtz instability and large-scale DC magnetic field generation mechanism on the electron scales. It is shown that these processes are important candidates to generate magnetic fields in the presence of strong velocity shears, which may naturally originate in energetic matter outbursts of active galactic nuclei and gamma-ray bursters.

Suzuki-Vidal *et al* (2013) show preliminary results of the self-emission of charged particles from magnetically driven plasma jets has been investigated. This configuration has shown to reproduce some aspects of the astrophysical magnetic-tower jet launching model (e.g. Huarte-Espinosa *et al* 2012, see also the recently approached experimental model by Lebedev *et al* 2005), in which a jet is collimated by a toroidal magnetic field inside a magnetic cavity. Evidence is given that the ions are trapped inside the cavity due to the strong toroidal magnetic field which drives the jet. Estimates of the energy and fluence of protons for future laser-driven proton probing diagnostics aimed at measuring the magnetic field in these experiments are also provided.

References

Alves E P, Grismayer T, Fonseca R A and Silva L O 2014 Electron-scale shear instabilities: magnetic field generation and particle acceleration in astrophysical jets *New J. Phys.* **16** 035007

Beall J H 2014 A review of astrophysical jets *Acta Polytechnica CTU Proc.* **1** 259–64

Belan M, De Ponte S, Massaglia S and Tordella D 2004 Experiments and numerical simulations on the mid-term evolution of hypersonic jets *Astrophys. Space Sci.* **293** 225–32

Belan M, Tordella D, De Ponte S, Mignone A and Massaglia S 2014 Hypersonic jets in astrophysical conditions: focus on spreading and asymmetric stability properties *New J. Phys.* **16** 085002

Eilek J A 2014 The dynamic age of Centaurus A *New J. Phys.* **16** 045001

Hartigan P, Frank A, Foster J M, Wilde B H, Douglas M, Rosen P A, Coker R F, Blue B E and Hansen J F 2011 *Astrophys. J.* **736** 29

Hartigan P and Morse J 2007 *Astrophys. J.* **660** 426–40

Huarte-Espinosa M *et al* 2012 *Astrophys. J.* **757** 66

Lebedev S V *et al* 2005 *Mon. Not. R. Astron. Soc.* **361** 97

Melioli C and de Gouveia Dal Pino E 2015 *Astrophys. J.* **812** 90

Neff S G, Eilek J A and Owen F N 2015a *Astrophys. J.* **802** 88

Neff S G, Eilek J A and Owen F N 2015b *Astrophys. J.* **802** 87

Noriega-Crespo A and Raga A C 2012 *Astrophys. J.* **750** 101

Noriega-Crespo A, Raga A C, Moro-Martín A, Flagey N and Carey S J 2014 Proper motions of young stellar outflows in the mid-infrared with spitzer II HH 377/Cep E *New J. Phys.* **16** 105008

Suzuki-Vidal F *et al* 2013 Observation of energetic protons trapped in laboratory magnetic-tower jets *New J. Phys.* **15** 125008

Tordella D, Belan M, Massaglia S, De Ponte S, Mignone A, Bodenschatz E and Ferrari A 2011 Astrophysical jets: insights into long-term hydrodynamics *New J. Phys.* **13** 043011

Velusamy T, Langer W D and Thompson T 2014 *Astrophys. J.* **783** 6