Jets at all Scales
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The astrophysical jets

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Abstract. In this published note I attempt to sketch my understanding of the universal working scheme of all the astrophysical jet sources, or 'bipolar flows', on both stellar and galactic scales, also called 'microquasars', and 'quasars'. A crucial building block will be their medium: extremely relativistic $e^{\pm}$-pair plasma performing quasi loss-free **E** x **B**-drifts through self-rammed channels, whose guiding equi-partition **E**- and **B**-fields convect the electric potential necessary for eventual single-step post-acceleration, at their terminating 'knots', or 'hotspots'. The indispensible pair plasma is generated in magnetospheric reconnections of the central rotator. Already for this reason, black holes cannot serve as jet engines.

Keywords. black hole physics, plasmas, ISM: jets and outflows, galaxies: jets

1. How to make jets?

Astrophysical jet sources involve powerful engines of the Universe: The engines can eject charges at very-high energies (VHE), continually at almost luminal speeds to astronomical distances of order $\lesssim$Mpc, for $\gtrsim 10^7$yr, in two antipodal directions, in a beamed manner, aimed within an angle of $\approx$1%, whereby particles arrive with $\lesssim$PeV energies at their termination sites. Militaries would appreciate availing of such guns. How does non-animated matter achieve such a difficult goal, time and again, on various size and mass scales? After years of intense deliberation, it is my distinct understanding that all the jet engines follow a uniform working pattern.

For its multiple tasks, biology uses reliable molecular engines with stable working patterns that can be easily reproduced; but here we deal with anorganic matter! How to achieve reliability? No jet without abundant jet substance, or rather jet 'plasma', which should be much lighter than its surrounding medium − for confinement reasons − i.e., much smaller in rest mass, and much hotter. This constraint is optimised by relativistic pair plasma, the lightest plasma in the Universe; and the lighter the higher its Lorentz factors.

This jet plasma must be supplied continually, throughout the lifetime of a jet engine. We know that our Sun can generate relativistic $e^{\pm}$-pairs, at a low rate, even nowadays, in connection with its establishing a hot corona. When the Sun was young, born at the inner edge of its (planetary) accretion disk with a spin period of 3.6 hours (instead of the present 27.3 days), its pair-formation rate has been estimated to have well sufficed to power its young-stellar-object (YSO) stage (Blome & Kundt 1988, Kundt 2005). Whereby the necessary magnetic reconnections are thought to result from 'magnetic spanking' of the inner edge of its accretion disk, which serves as a heavy and sharp-edged obstacle. Correspondingly, forming white dwarfs, as well as neutron stars surrounded by accretion disks are expected to be even stronger generators of relativistic pair plasma.

Continual supply of abundant (relativistic) pair plasma is a necessary though not a sufficient condition on a jet engine to function: The freshly generated plasma must be post-accelerated, and funneled into two antipodal channels. We maintain that for the above-listed engines, the funneling of their twin-jets is achieved by buoyancy, in the quasi-spherical gravitational potential of their central rotator, and that the bunching in momentum space, and post-acceleration of the charges take place via (i) their scattering on the ambient photon gas, via (ii) phase-riding on the outgoing low-frequency magnetic waves (LFW) of the central rotator, like in the Crab nebula (Kulsrud et al 1972), and via (iii) blowing its ambient medium into the shape of Blandford & Rees's funneling deLaval nozzles (Kundt & Krishna 1980, 2004).

And what is the working pattern of the central engines (CEs) of active galactic nuclei (AGN), during their – quite similar-looking – jet formations? As is known since the 70s, a supermassive black hole (SBH) cannot anchor a corotating magnetosphere; it can only swallow. No pair formation, no buoyant escape, no LFWs. Fortunately, ever since 1979, I have convinced myself (and even a few of my referees) that the CEs of AGN are not SBHs, rather (nuclear-) burning disks (BDs), which act analogously to heavy, magnetised rotators, via their strongly shearing inner-galactic diskal coronas (Kundt 1979, 1990, 1996, 2001, 2005, 2009a,b; Kundt & Krishna 1980, 2004). They share the magnetic reconnections, the buoyant escape, the LFW post-acceleration, and self-blown deLaval nozzles with the stellar CEs, thus creating quite similar-looking twin jets.

A complete description of the functioning of the jet engines, their dynamics, stabilities, and various morphologies, takes more space than is available here. The reader can find it in the quoted literature, or in the forthcoming proceedings of the XIVth Brazilian School of Cosmology and Gravitation (held in 2010). Suffice it to mention that pair formation via magnetic reconnections have been recently assessed by Dal Pino *et al.* (2010), that pair annihilations in neutron-star jet sources have been first reported by Kaiser & Hannikainen (2002), and that functional regularities in micro-quasars and quasars are described in Körding *et al.* (2006, 2008). Finally, if the CEs of the AGN are BDs rather than BHs, the rare, gigantic, supersoft X-ray outbursts reported by Komossa may have to be re-interpreted as caused by innermost stars on perturbed orbits colliding with the heavy innermost disk of their galaxy.

References

Blome, H.-J., Kundt, W. 1988, *Astrophys. & Space Sci.*, 148, 343-361

Dal Pino, E. M. de G., Piovezan, P. P., Kadowaki, L. H. S. 2010, *Astron. Astrophys.*, 518; arXiv:1005.3067v1

Kaiser, C. R. & Hannikainen, D. C. 2002, *MNRAS*, 330, 225-231

Körding, E. G., & Jester, S., & Fender, R. 2006, *MNRAS*, 372, 1366-1378

Körding, E. G., Jester, S., & Fender, R. 2008, *MNRAS*, 383, 277-288

Komossa, S. 2005, in *Growing Black Holes, ESO Symposia, Springer*, 159-163

Kulsrud, R. M., Ostriker, J. P., & Gunn, J. E. 1972, *Phys. Rev. Lett.*, 28, 636-639

Kundt, W. 1979, *Astrophys. & Space Science*, 62, 335-345

Kundt, W. 1990, *Astrophys. & Space Sci.*, 172, 109-134

Kundt, W. 1996, in *Jets from Stars and Galactic Nuclei, Lecture Notes in Physics 471, Springer, W. Kundt (ed.)*, 140-144

Kundt, W. 2001, in *MICROQUASARS, Proceedings of the Third Miroquasar Workshop, A.J. Castro-Tirado, J. Greiner & J.M. Paredes (eds.), Kluwer*, 273-277

Kundt, W. 2005, *Astrophysics, A New Approach, Springer*, Chapter 11

Kundt, W. 2009a, in *XIIIth Brazilian School of Cosmology & Gravitation, AIP Conf. Proc. 1132, M. Novello & S.E.P. Bergliaffa (eds.), Melville, N.Y.*, 288-302

Kundt, W. 2009b, in *General Relativity and Gravitation, 1967-1980*, 9, 41

Kundt, W. & Gopal-Krishna 1980, *Nature*, 288, 149-150.

Kundt, W. & Krishna, G. 2004, *J. Astrophys. Astr.*, 25, 115-127