Astrophysics

Peter L. Biermann

published in

NIC Symposium 2004, Proceedings,
Dietrich Wolf, Gernot Münster, Manfred Kremer (Editors),
John von Neumann Institute for Computing, Jülich,
NIC Series, Vol. **20**, ISBN 3-00-012372-5, pp. 23-24, 2003.

http://www.fz-juelich.de/nic-series/volume20

Astrophysics

Peter L. Biermann

Max-Planck-Institut für Radioastronomie, 53010 Bonn, Germany
Department for Physics and Astronomy, University of Bonn, Germany
E-mail: plbiermann@mpifr-bonn.mpg.de

Recent advances in astronomy, astrophysics, and astroparticle physics include the discovery of a supermassive black hole at very high redshift, the unambiguous association of a gamma ray burst with a supernova explosion, and the first release of results from the cosmic microwave background fluctuation measurements taken with the WMAP satellite. We will briefly discuss each of these steps in turn, as examples for the interplay of theory, new technology and new discovery, all here requiring the heavy use of numerical simulation.

The discovery of a gigantic black hole at redshift higher than 6, of a mass of 3 billion solar masses, defies a simple understanding of black holes evolution. We first need to understand how black holes form, either from the collapse of a supermassive star directly, as had been surmised already some 30 years ago, or by the collapse of a dense star cluster, or simply by fast growth of a stellar size black hole, which forms in a stellar collapse, perhaps in consequence of a gamma ray burst. To explore any of these avenues implies an understanding of thousands and millions of stellar orbits; one of the best concepts is to grow black holes by mergers with other black holes, an inevitable process since many galaxies have central black holes, and galaxies merge frequently; this ensures by dynamical friction, that the two black holes lose momentum to the surrounding stellar populations, until the two black holes get so close that the mass of all the stars between them is less than their combined mass. Related simulations are discussed in an accompanying article. Then the two black holes exert a torque on the stars, and so come close enough to start losing orbital angular momentum by gravitational waves. If the two black holes get quite close, then the angular momentum depends on the relative orientation of the spin of the primary black hole and orbital spin; if the two spins diverge appreciably in direction, then the angular momentum transport by gravitational waves appears to be diminished, again a question which for its final resolution requires numerical simulation. Such calculations will be required to provide a template for the final chirping of merging spinning black holes.

We still do not know where the cosmic magnetic fields come from, and all our concepts were invented and originally tested on the Sun, and its magnetic phenomena. An accompanying article describes related work. We also do not know why massive stars explode, and a theory by Bisnovatyi-Kogan, the magneto-rotational mechanism, has gained prominence again after the discovery of a clear association of one new gamma ray bursts with a supernova. Since gamma ray bursts are commonly believed now to involve jet-like features, almost certainly involving magnetic fields, the question is now resurging, whether the magneto-rotational mechanism can indeed provide the physical explanation why massive stars explode. Numerical simulation is necessary to test these ideas, and such work is being done, perhaps allowing us to understand why massive stars explode, why just some of them turn into gamma ray bursts, and what the role of magnetic fields is in all this - maybe we will also then understand where magnetic fields come from.

The last scattering of the photons of the microwave background show us the spatial irregularity spectrum of the baryonic matter very close the Big Bang, and measuring this spatial spectrum with the WMAP satellite allows to determine the parameters of any cosmological model with unprecedented accuracy. It obviously also gives us insight whether any specific cosmological model is actually successful in fitting all the data, especially when using other constraints, from the observed structure of the Universe, from the observations of standard candles, such as supernovae type Ia are believed to be. These new very high precision results need to be matched with a model using the entire sky available, and many additional boundary conditions, a task only doable numerically. From such an analysis we now know the baryonic content of the Universe, about 4 percent of the critical density, but we also know that the critical density is very accurately matched with about 1/3 dark matter, and 2/3 dark energy; dark energy has tension, just like magnetic fields in one dimension. Dark matter and dark energy both are an enigma to us, with some speculation for dark matter centering on new particles, possibly as suggested by supersymmetry. But the biggest surprise of all is that the model actually works very well, despite our lack of understanding.

New discoveries, big black holes in the young ages of the Universe, gamma ray bursts, that are also supernovae, possibly exploded by the interplay of magnetic fields with rotation, and the fluctuations of the microwave background all require supercomputers to either analyze the data, or also to understand the implications for our physical understanding of the phenomena of the Universe.