CURRENT SCIENCE

Volume 90 Number 10 25 May 2006

GUEST EDITORIAL

Reaching for the skies

Astronomy is much in the news these days. Newspapers and TV channels have easy access to the internet, which in turn is used by institutions and agencies (e.g. NASA) to showcase recent developments. These could be the detection of new planets, or distant galaxies, or even the latest computer simulations of colliding black holes. The topic of our origins, as a solar system or as a universe, often occupies centre stage. The public shares the unfolding answers to the mysteries of the universe, and hopefully influences legislators who influence funding.

Professional astronomers have always known that there is both more and less to this than meets the eye. Developments in less trendy/photogenic areas can get ignored. Newsworthiness does not guarantee real depth, novelty, or progress. For perspective about the science of the skies in the context of India's education and research, we need to look at a bigger picture. Astronomy today is the confluence of many streams, which are traced briefly (and subjectively!) below. For a start, it has a strong claim to the title of the oldest (data and calculation based!) profession. From the earliest times, the chaos of earthly events must have stood in sharp contrast to the order and predictability of the heavens. The stars provided reckoning of time and location to the very first travellers and voyagers. In ancient Egypt, Mesopotamia, China, and India, a cadre of mathematicians-cum-astrologers kept astronomy alive and progressing for millennia. One of my own maths teachers in the 1960s in Chennai fitted this 3-in-1 role quite well! Medieval times were dark in Europe but not in 11th century Isfahan, where Omar Khayyam practised astronomy, algebra, and spherical trigonometry along with his better known pursuits and determined the length of the year to an accuracy of less than a minute. Or in fifteenth century Samarkand, where Ulugh Beg, (grandson of Timur!) did even better, and catalogued nearly a thousand stars.

Of course, Copernicus, Galileo, Kepler changed the ancient view forever. Newton's laws of motion and universal gravitation followed swiftly to connect heaven and earth – one could say that astrophysics began then. A great tradition of celestial mechanics was born, with the likes of Laplace, Gauss, Poincaré, and Kolmogorov bringing the highest intellectual power to bear on dynamical astronomy, over two centuries. And Einstein, no mathematician himself, used the discrepant motion of the planet Mercury to validate his general relativity, itself a major force in the astrophysics of the twentieth century (if one can use this term for a theory which banished the concept of gravitational force!).

But gravity and dynamics are not all of astrophysics. The unravelling of the solar spectrum by Fraunhofer and Kirchoff in the nineteenth century was followed by the corresponding feat for stellar spectra, well into the twentieth century. Like its more primitive cousin, the flame test, a spectrum tells you what elements are present. The pattern first seen was bizarre, helium and hydrogen prominent in hot stars, dwarfed apparently by calcium and even titanium in cooler stars. Saha's 1920 equation was the missing link needed to translate spectra into real abundances. This was taken up in 1925 by Celia Payne. She found about 90% hydrogen, a result which took more than two decades to gain acceptance – one fewer than it took Harvard to give her a full professorship! This tradition of unravelling stellar spectra continues with ever-increasing elaboration to the present time. Who would have guessed that unstable technetium (lifetime, 4.2 million years) would be found in some stars? In what inner furnaces is it forged, and what churnings bring it to the surface? You will not see too many breathless bulletins on stellar spectra, but do not underestimate their value for real science.

Fainter objects are more difficult to study. What we call galaxies today entered the scene as a subclass of 'nebulae', diffuse wisps in the sky originally catalogued by Charles Messier so that his fellow comet hunters would not be misled by them. The realization in the early twentieth century that they were like our Milky Way, just more distant, was as painful as the dethronement of the sun. only quicker. Taking their spectra required the biggest telescopes of that era, mostly located on the Pacific Coast of the US. Edwin Hubble's expanding universe which resulted from his measurements and those of the unsung Humason and Slipher has stood the test of time. Fortunately, the estimate of the age of the universe has stretched from Hubble's 1.6 billion years to a less claustrophobic 13.7 billion years (yes, the community actually believes the 0.7!).

The study of galaxies which really took off in the 1980s quickly revealed that they were messier objects than stars. They come in a variety of sizes and shapes, are clearly products of their initial conditions, history and environment, and have been built up by mergers of smaller constituents. Remarkably, the gravitational pull which holds them together is dominantly not from stars, nor gas, but 'dark matter' as first decisively revealed by Vera Rubin and her collaborators in the 1980s (again by taking spectra with the best available detectors!). Twenty years after, we now know a lot about how much dark matter there is and where it is, and some things about what it is not, but we do not know what it is. The best guess, alloyed with some wishful thinking, is some member of the large number of particles predicted by various theories but not otherwise detected.

The latter half of the twentieth century saw a dramatic explosion: the use of almost thirty decades of the electromagnetic spectrum to gather information from the cosmos. Radio waves really took off after about 1950 and have the proud record of revealing black holes lurking in the centres of galaxies, swallowing gas and spitting out jets, spinning neutron stars with teragauss magnetic fields, and the dimly glowing embers of the big bang. Infrared, observed from hilltops, balloons, and space, is revealing the history and geography of star formation, a fundamental process on which there is much data, still described by largely empirical rules. X-rays, observed from rockets, balloons, and satellites, revealed the hottest gas and most energetic processes, occurring around compact stars bathed in matter from their companions. And gamma ray astronomy, first done from space, has returned to the ground at the highest energies to give new surprises.

On the theoretical side, relativistic/particle astrophysics emerged as a fertile meeting ground of fundamental physics and gravitation on a cosmic scale. One of the giants in this area who should be better known to all scientists is Yakov Zeldovich (1914–1987). Armed with a high school diploma, he started with chemical physics in the 1930s, studying catalysis, combustion, detonation and shock waves. Clearly these were not explosive enough for him, since he went on over the years to the Russian bomb projects and to the big bang! His astrophysical work includes fundamental contributions to accretion, the cosmic microwave background radiation, dark matter, vacuum energy, black holes, magnetic fields… the list goes on, as does the field he pioneered.

Astronomy thus has a rich tradition, broad sweep, linkage to physics, and explosive progress. Educators can ask how much, and at what level of sophistication, needs to go into each stage of the curriculum. There is a real danger of its becoming quiz material, related to terminology and memory, but it would be a pity to miss it out altogether even at the school level. The challenge is to prepare syllabi and material meaningful to the majority of students. Coming to higher education, a bachelor's or even master's programme in astronomy seems overspecialized in the Indian context. The standard undergraduate curriculum could, however, still have more examples from astronomy woven in. At the master's level, a one or two semester optional paper exists in some universities and deserves to be strengthened. All this depends on infiltrating traditional college and university physics departments with members who have astronomy exposure, or co-opting existing members. IUCAA, the Inter-University-Centre for Astronomy and Astrophysics in Pune, has tried valiantly to bring about some of these changes, but it is fair to say there is far to go.

Our research institutes in astronomy by and large select physicists/engineers and do the training in-house. One laudable attempt to go beyond this is the Joint Astronomy Programme at the Physics Department of the IISc, which has offered a broad range of courses to those starting a Ph D in astronomy, taught by researchers from five institutions, for more than twenty years. Such exercises raise interesting questions – how much does one emphasize the techniques and phenomena and how much the physical principles? My answer is not very different from what chemists might give – clearly you have to know principles but to identify all of astronomy with astrophysics is about as reasonable as identifying chemistry with chemical physics. Astronomical theory has made impressive strides but its limitations are perhaps better known to theorists than observers!

What prospects await those students who take up research in astronomy? Facilities in India are getting better. I would like to imagine, or hope, that each of the students I see studying supernovae, or small or metal poor galaxies, or pulsars, or micro-quasars with the GMRT feels her share of excitement and exploration, of looking at something of her own, not seen before. (No, I am not being politically correct. They really are all women!). A reasonable Ph D in astronomy should also offer broad training in modelling physical processes and analysing observations. Access to international facilities and data, and opportunities for postdoctoral work are good. The truly ambitious and globalized can set their sights on the giant international projects of the future. One is the Overwhelmingly Large (~50 metre diameter optical!) telescope (OWL), and another is the Square Kilometre Array (SKA), promising a hundred times greater sensitivity than existing radio telescopes. A good parallel would be the International Linear Collider described by Rohini Godbole in these columns (10 April 2006). Astronomy today is truly a transnational enterprise, of the kind that India seems to be embracing in less celestial spheres. Are we ready to reach for the skies?

Rajaram Nityananda