Astronomy by numbers

Computers have taken astronomy by storm in the past decade or so, and for obvious reasons. Need has been matched by opportunity, but astronomers have also been temperamentally attuned to computerization by the space programmes of recent years. Once it became necessary to work with data transmitted in digital form by telemetry from rockets and satellites, it was certain sooner or later to become habitual to use the same techniques for dealing with other sources of data.

Astronomy has traditionally been profligate in its regard for data. A single plate from a large Schmidt camera, covering a patch of sky just six degrees in each dimension, may include up to 10^6 images of different kinds. Merely recording the positions of these images would occupy a skilled technician for the best part of a lifetime. The libraries of the world's observatories most probably contain enough information to keep the world's astronomers usefully employed for the rest of their lives — perhaps on problems of no particular interest.

The simple solution to the problem of counting stars and measuring plates is similar to that to which high-energy physicists were forced in the 1960s, when it became impracticable to measure the tracks of fast particles in bubble chambers by hand and eye. The first need is a device for converting star images into numerical records of the density of exposure at different points on a plate. Plate reading systems have been developed at several observatories. As always, the tricks lie not in the hardware but the software — in this case the rudimentary programs for telling which image is what. Is it a star? Or a galaxy (and if so which kind)? Or something else?

One neat way of describing the benefits of these systems is that it has taken some fifty man-years of programming time to develop the software used with the COSMOS plate measuring system at the Royal Observatory, Edinburgh and that the result is to make possible the measurement of the images on a single Schmidt plate in one day, not one lifetime (also fifty man-years). This figure of merit is also an index of the true cost of these devices — £500,000 is probably an underestimate of the true cost of developing COSMOS.

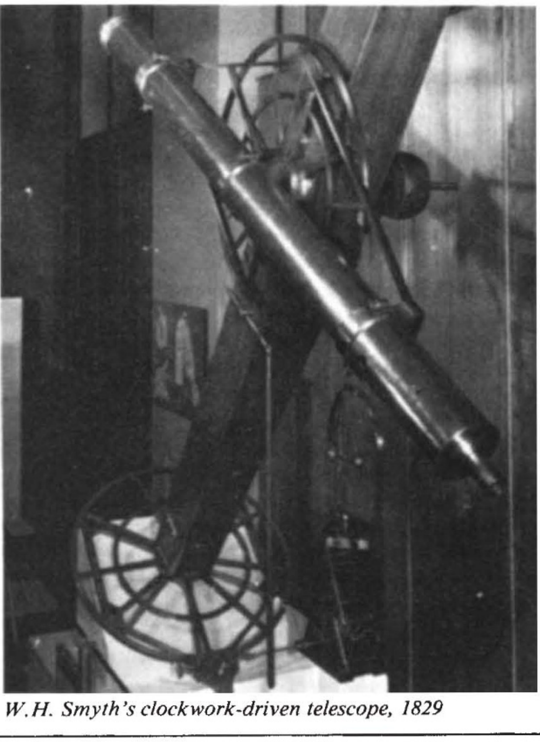
The other component in the recent computerization of astronomy is the digitization of the data base. The most striking illustration so far of the benefits of this technique is the Einstein X-ray satellite (now, happily and surprisingly, restored to working order). The essence of the X-ray telescope is a system of conically shaped glass surfaces from which X-ray photons are deflected at more or less grazing incidence. The detectors are inherently electronic, borrowed from nuclear physics. So the data are inherently digital in form, literally consisting of the spatial coordinates in the image plane of individual X-ray photons. So why not record not merely the angle from which these photons have arrived but the time of their arrival and even information about the energy of the incident photons?

In practice, the Einstein satellite is equipped with a variety of X-ray detectors which separately provide different kinds of data. The detector with the highest resolution, called the High Resolution Imager, is designed to record the arrival of X-ray photons on the MgF_2 plates from which cascades of electrons are generated to within 1 second of arc and within 8 milliseconds. The working spatial resolution of the instrument is less than this (some tens of seconds of arc) because of the properties of the mirror system, but this high resolution instrument provides no spectral information worth speaking of, with the result that the computer systems store merely spatial and temporal information.

Other instruments in the Einstein Observatory, which can generate spectral information (but whose spatial resolution is not as high), yield data streams from which spatial, temporal and spectral information can be regenerated. The

Some things old, some new

Electronic computers are merely the latest stage in the computerization of the laboratory. The earliest aids to laboratory computation were probably the astrolobes and armillary circles going back to the antiquity of astronomy. The first explicit aids to laboratory computation were probably Napier's logarithmic systems of coloured rods (called "bones") introduced early in the seventeenth century, and quickly followed by Pascal's logarithmic scale, much used (with the help of a pair of dividers) by navigators in the eighteenth century.


W.H. Smyth's clockwork-driven telescope, 1829

The needs of astronomers stimulated interest in what may have been the first computerized aid to laboratory observation — sky-following telescopes. Robert Hooke appears to have been the first to have conceived of this innovation, but his proposal for a clockwork-driven telescope was built for G.D. Cassini at the Paris Observatory and commissioned in 1682. This was a huge device, with the objective mounted at the centre of a clockwork-driven structure and with the eyepiece mounted separately at a distance of more than 100 feet. Cassini's telescope was known as his *machine parallatique.*

Attempts at the further development of clockwork-driven telescopes appear to have been few and far between in the eighteenth century. Such instruments seem to have come into their own only in the early decades of the nineteenth century.

Dr John Darius (Science Museum, London) writes:

Driving telescopes around their polar axis to follow the diurnal apparent motion of the stars is useful for visual observations but absolutely vital for astronomical photography. The earliest drives, dating from the beginning of the nineteenth century, were purely mechanical, depending on a clockwork mechanism driven by weights to rotate the telescope in the equatorial plane at the rate of 15 degrees of arc every hour. By around 1870, telescope drives regulated by an electric pendulum clock had been invented, but by 1910 electric motors were coming into regular use. Nowadays digitally controlled synchronous motors as uniform as the frequency of the mains supply have almost wholly replaced their historic forebears. The most modern systems now use servomechanisms which are controlled by computer. □

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