Beyond the Hubble Space Telescope

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NASA needs to develop a new generation of space observatories embracing the theme of 'cosmic origins' if it is to maintain its lead in the exploration of space.

WHAT is past is prologue in astronomy: the content of the modern Universe — even the presence of life — is a product of events that took place billions of years ago. Fundamental questions about this epoch in cosmic evolution, about the origins of matter, structure and life in the cosmos, await a new generation of space observatories.

In 1993, the US National Aeronautics and Space Administration (NASA) and the Associated Universities for Research in Astronomy recognized that there were profound scientific questions that could not be answered with current space astronomy missions. Moreover, no new advanced space observatories were being considered for the period after the Hubble Space Telescope completes its primary science mission in 2005. In response, a committee of 18 astronomers from North America and Europe was established to identify core scientific questions about the cosmos that were unlikely to be answered with existing observatories and to recommend space missions capable of investigating them. This "HST and Beyond" committee, of which we are members, proposed "cosmic origins" as a unifying theme for a handful of fundamental problems involving the birth of normal galaxies, star formation and the possibility of Earth-like planets beyond our Solar System.

Fortunately, we can see the history of our Universe directly: the farther we peer out into space, the further back we see into time. But the first few billion years of cosmic history are shrouded from the view of even the largest telescopes on Earth. The difficulty arises because the expansion of the Universe causes light from distant — and, consequently, young — galaxies to be shifted to longer wavelengths. Light from normal galaxies, such as our own Milky Way, is emitted by billions of stars at wavelengths mainly between 0.4 and 2 micrometres. But the large redshifts of young galaxies mean that this ancient light reaches Earth shifted to a wavelength longer than about 2.5 micrometres. At these wavelengths, Earth's atmosphere becomes opaque, and what light struggles through is overwhelmed by the thermal emission from both the atmosphere and the telescope. Only the most luminous, and most atypical, young galaxies can be detected by Earth-bound telescopes: the birth of the most common galaxies are accessible only from space.

As well as being interested in the birth of stars and galaxies, scientists and the public are intensely interested in whether Earth is alone in the cosmos in supporting life. A search for the origins of life, beginning with a search for Earth-like planets, requires a technology different from that used to study primaeval galaxies: spatial interferometry, where the optical system of many different telescopes can be combined destructively to cancel out the blinding light from a central star. This leaves behind the faint but detectable emission from surrounding planets. This residual light would be searched spectroscopically at infrared wavelengths for signatures of molecules believed to be necessary for life.

Important steps in understanding our cosmic origins are already being taken by both NASA and the European Space Agency. The latter is operating the Infrared Space Observatory, which is targeting luminous, very energetic galaxies. Similarly, NASA will launch its own powerful Space Infrared Telescope Facility, which will probe into the history of the Universe. Both observatories are essential milestones, but both are limited by modest apertures and lifetimes.

As a result of these considerations, our committee last week published three recommendations to NASA intended to guide the agency in space science at the start of the next century. First, NASA should develop an infrared-optimized space observatory with an aperture of more than 4 metres to study normal galaxies in the early Universe. The wavelength of optimum sensitivity of this observatory — about 1–5 micrometres — covers diagnostic spectral features from a wide range of other objects: the youngest and oldest stars, Solar System objects and galaxies throughout the local Universe. Furthermore, enlarging the wavelength coverage of the facility would greatly increase its usefulness to the broader astronomical community.

Second, NASA should develop the capability for space interferometry at optical and infrared wavelengths. The next major direction in space astronomy will be a notable increase in angular resolution: that is, we will be able to study very fine structure and determine positions and motions extremely accurately. A challenging application of interferometry in space will be the mission to search for Earth-like planets around neighbouring stars, and to explore their atmospheres for the molecules essential for life. The first main step in interferometry will be the Space Interferometry Mission, which will measure stellar positions to the limits of accuracy allowed by today's technology.

Third, the Hubble Space Telescope should continue to operate after 2005, when it is scheduled to complete its primary scientific mission, but in a 'no repair, no upgrade' mode. This would ensure the maintenance of a unique facility for ultraviolet astronomy and a continued return on the unprecedented US investment of thousands of man-years and billions of dollars in the observatory, whose success has dazzled people everywhere.

These three initiatives, along with a suite of smaller, more focused missions, will become the backbone of NASA's "Origins Program", which is intended to be a principal theme for future US research in space. In making these recommendations for the next generation of major ultraviolet–optical–infrared space astronomy missions, our committee was aware that NASA is likely to face severe constraints on its resources. So total costs cannot be comparable to those of the Hubble telescope. Alternatives to expanding costs range from applying innovative technologies, perhaps developed within defence-related industries, to exploring new management techniques, which would cut costs through accelerated development and international collaboration.

The initiatives recommended above would ensure NASA's continuing lead in the exploration of space well into the next century. By embracing our age-old human fascination with cosmic origins, such programmes will, we hope, excite humanity's imagination and encourage wider public participation in the exploration of the Universe. The recommendations do not chart an easy course for NASA, but the rewards of pursuing them are great. □

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