What in the Universe Lies Beyond Hubble?

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The aftermath of the Columbia tragedy and budgetary pressures are forcing NASA to reconsider its plans for the end of the mission of the Hubble Space Telescope and for the transition to Hubble's successor, the James Webb Space Telescope. Part of the debate concerns the role of astronauts for activities other than the completion of the International Space Station. The sense of that discussion awaits the report of the Columbia Accident Investigation Board, expected later this month. Another part of the discussion relates to Hubble's role as part of an integrated program of astronomical research. It is to this aspect of the debate that I offer these remarks.

Hubble has been a spectacular success for astronomy, for NASA and human spaceflight, and for the nation through an inspiring program of education and public outreach. Hubble has observed objects everywhere in the cosmos, from within our solar system and the Milky Way out to the most distant quasars, and it has advanced almost every field of astronomy, from the formation of stars and planets to the evolution of the Universe itself.

Hubble achieved its breakthroughs by making ten- to hundred-fold improvements in resolution, sensitivity, and wavelength coverage compared to earlier space and ground observatories. After Hubble was launched and subsequently repaired by astronauts whose courage and skill we recognize now even more acutely, it represented another giant leap in the observational capability that has been the driving force in a 500-year long revolution in astronomy. Just as Hubble represented a major advance over the Palomar 200-inch telescope, so too, was Palomar an advance over the Mount Wilson 100-inch telescope, and so on back in time to Galileo's first telescope.

But we must see Hubble as a point along this continuum of expanding capabilities. *Astronomy makes its greatest gains as new technologies open our eyes to new phenomena.* In the coming decade, new technology will improve our sensitivity to faint objects by factors of thousands with the Space Infrared Telescope Facility (launching later this summer) and the Webb Space Telescope. With these new telescopes as well as with the Space Interferometry Mission, the Terrestrial Planet Finder, and the Laser Interferometer Space Array, NASA is shifting its budgetary focus to new observatories that can find the first galaxies, locate habitable planets around

nearby stars, and open a completely new window on the Universe using gravitational waves. These new facilities represent the priorities of the astronomical community as expressed through numerous studies by the National Academy of Science.

We should assess the continuing role of Hubble within this broader context. Exploiting a new capability implies taking enough data to fill in the details of these new phenomena. Thus, NASA should not shortchange the investment inherent in Hubble's existing or planned instruments by curtailing the mission before its time. While ground-based telescopes equipped to correct atmospheric distortion are catching up with or surpassing some of Hubble's capabilities, two new instruments awaiting installation in the telescope will make major discoveries not possible from the ground. But there are exciting observational opportunities in store that not even a refurbished Hubble can achieve.

Pending the findings of the board investigating the Columbia accident, and recommendations for a return to flight, we should call on the bravery of NASA's astronauts for one last flight to Hubble. This servicing mission would add its final suite of instruments, service its aging systems, and extend Hubble's mission until about 2010, when it would be safely de-orbited into the Pacific Ocean. But we should not let our attachment to a cherished telescope hold back a new and more capable generation of observatories that will produce the breakthroughs of the future.

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