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Paper Session I-B - The Great Observatories Program

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THE GREAT OBSERVATORIES

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Although astronomy has been practiced since ancient times, the universe remains veiled in mystery. Limited for centuries to observations in the visible band of the electromagnetic spectrum, the ability to place instruments in space above the filtering atmosphere has given scientists access to the Universe at virtually all wavelengths revealing intriguing objects and events. Over the past two decades, NASA has introduced increasingly sensitive telescopes into space to make observations across the electromagnetic spectrum. Each successive telescope has exploited newly developed technologies to extend the limits of sensitivity and provide greater insight into the structure of stars, galaxies, and the cosmos.

A new generation of space observatories now offers significant new gains in sensitivity through the use of state-of-the-art technologies. These observatories include: the Gamma Ray Observatory which will explore the most energetic part of the spectrum across a much greater wavelength range than its predecessors; the Advanced X-Ray Astrophysics Facility that will cover the X-ray portion of the spectrum with a hundred-fold improvement in sensitivity; the Hubble Space Telescope which will penetrate deep into the Universe in visible and ultraviolet light, observing objects with at least ten times more clarity than is now possible with ground-based optical telescope; and the Space Infrared Telescope Facility which will span the infrared part of the spectrum with a thousand-fold increase in sensitivity. These new observatories, along with supporting facilities on the ground and in space, will open the Universe to greatly increased scrutiny. While the introduction of new technologies, particularly over the last decade, has led to a dramatic increase in astronomical discoveries, the discoveries to date constitute only a fraction of the total to be made.

Our own galaxy, the Milky Way, is populated by star clusters, dusty clouds of turbulent gas, exploding or collapsing stellar masses, and gradually evolving systems of stars - phenomena that are revealed by observations at differing wavelengths. At radio wavelengths, cool clouds can be detected in space; some are destined to contract to form new stars. At infrared wavelengths clouds can be probed that are warmed by stars that have formed within them; also, dying stars throwing off shells of matter can be registered. At visible wavelengths, millions of stars like our sun can be seen and their evolution studied. At ultraviolet wavelengths, the hottest stars and most massive can be detected; all still actively consuming nuclear energy; others, like white dwarfs, dying remnants of once small stars. At X-ray wavelengths matter at ultra-high

temperatures can be observed falling on neutron stars - the remains of more massive dead stars. At gamma-ray wavelengths sudden bursts of intense emission can be detected from sources not yet understood. The combination of these observations made at different wavelengths will result in a much greater understanding of our galaxy and the universe, whereas any one, by itself, could be puzzling.

Considerations of the long-term future of the human race evolve fundamental questions about the nature of the cosmos. Typical of these are: How did the Universe form and evolve in the first few seconds? How did galaxies and clusters of galaxies initially form and evolve? Will we need new laws of physics to describe observed phenomena? How are black holes formed? How do these powerful sources affect the galaxies in which they reside? How do stars and star clusters form and die? How do magnetic fields arise in interstellar matter and in stars? How are planetary systems formed? How many stars have planets? Where and how did life start? Are there intelligent civilizations elsewhere in the Universe? The increased sensitivities and wide range of wavelengths provided by the new generation of observatories will allow some of these and many other questions to be addressed in a meaningful way and permit investigations to determine whether our Universe is open and expanding forever, or closed and bound to collapse on itself billions of years from now.

This family of permanent observatories in space will open the way to new, comprehensive studies of key remaining problems in astrophysics, leading to a better understanding of: the birth of the Universe, its large-scale structure, and the formation of galaxies and clusters of galaxies; the fundamental laws of physics governing cosmic processes and events; and, the origin and evolution of stars, planetary systems, life and intelligence.