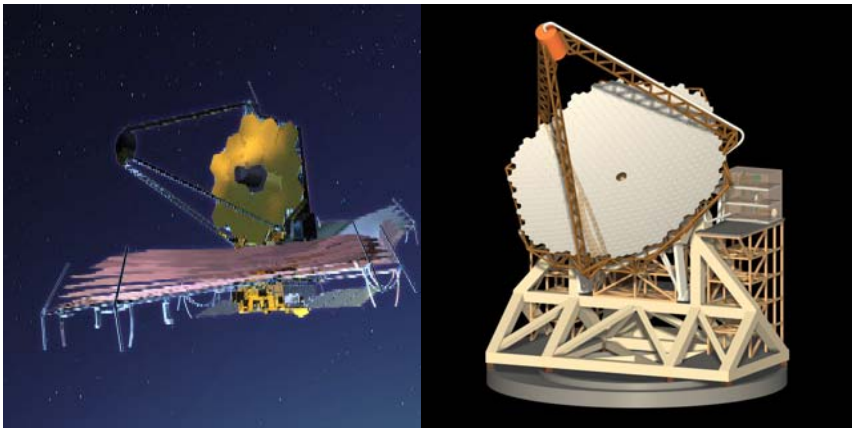
GSMT AND JWST:
Looking Back to the Future of the Universe

History will record that American scientists launched one of humankind's greatest intellectual adventures early in the 20th century. Building giant telescopes that dwarfed their predecessors, astronomers began to wrestle with our ancient, most compelling mysteries: *Where are we? What are we? And where do we come from?* These giant machines of glass and steel, growing decade by decade, revealed a Universe of intimidating size and imponderable age, but more remarkably, one within human understanding.

With an explosion of tools, observations, and ideas building to a crescendo by century's end, astronomers succeeded beyond their expectations: today, we routinely describe the size, age, and contents of a Universe utterly beyond our physical reach. We are mapping our home galaxy, the Milky Way, cataloging and analyzing its stars and following their births and deaths, and discovered a massive black hole at the center of our galaxy, testing our very notions of physical reality by its warping of time and space. We have witnessed our Galaxy and its billion cousins speeding to eventual oblivion in an expanding, accelerating Universe, driven by newly discovered cosmic forces that promise to revolutionize our understanding of fundamental physics.



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We see now that the history of the Universe is the back story to our own existence. We have met all the major characters in this story, from the trillions of common stars to the exotic massive black holes in galaxy cores that power the phenomenal blasts of quasar light. Now, as the 21st century begins, astronomers prepare to read the final chapter in this great mystery story. They seek to use astronomy's powerful magic—looking out into space to see back in time—to see how our modern Universe came to be. Brought to the threshold of this final step by amazing telescopes—notably the Hubble Space Telescope (HST) and the Keck ground-based telescopes—we examine the feeble light that emerged long ago when the Universe was in its youth. Yet we must go further out, further back.

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Why two telescopes? The JWST will orbit far from Earth, so dark and cold that its sensitivity to the infrared light from the first generation of stars will far exceed what can be done from Earth. The GSMT, with its gigantic mirror and state-of-the-art image-sharpening optics, will spread the light for spectral analysis, revealing the birth rate of the new stars and the swirling of the gas cocoons from which they are emerging. Each will do its special job—just as the Hubble and the Keck telescopes collaborated to lift the veil on the "adolescent" Universe in the 1990s. The JWST will find the first quasars, and the GSMT will use them as beacons to illuminate the hidden gas that feeds their ravenous black holes and their explosive episodes of star birth.

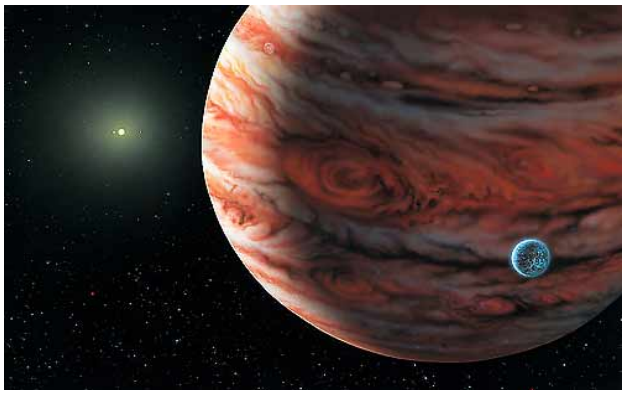
Already science programs have been constructed for these two ambitious new facilities. The concordance of the plans for each to explore the birth of the modern Universe might seem a case of duplication or repetition. Not at all. The detailed programs complement each other; indeed, they require the capabilities of both the JWST and the GSMT to reach a full understanding of how the Universe of stars and galaxies into which humankind was born came to be.

In the dense early Universe, galaxy mergers like the one shown in this Hubble image (right) were frequent and accompanied by violent star formation. JWST will detect these distant galaxies and GSMT will reveal their formation processes, as depicted in the simulation on the left.

The pursuit of this grand goal began here in the U.S.—our scientists must lead the final push. The JWST is well underway at NASA, but the GSMT will require a collaboration of private, state, and federal funding unprecedented in scope and difficulty. Particularly challenging will be the task of bringing the GSMT into operation while the JWST is alive in space. Having the two facilities available simultaneously will significantly enhance what they can accomplish. The U.S. needs to hold its traditional lead in this historic research and coordinate the world-wide effort to finish this extraordinary episode in our intellectual journey.

The GSMT will outlive the JWST, just as the Keck telescopes will survive the Hubble. Fortunately for astronomers, just as the book on the birth of the modern Universe begins to close, the story of the birth of stars, planets, and life beyond Earth is just beginning. Not only will the GSMT solve the riddles of galaxy birth, the extraordinary sharpness and depth of GSMT's images will be revolutionary for studies of star birth and how it leads to the formation of planets.

Not surprisingly, next on NASA's list of major astronomical observatories is the Terrestrial Planet Finder (TPF), a telescope specially constructed for the extraordinarily difficult job of detecting planets as small as Earth around the few hundred stars nearest our Sun. The GSMT will have remarkable, unique capabilities to study the formation of stars, observing how they assemble and how their birth leaves behind a disk of dust and ice that will build their families of planets. Its breakthrough capabilities will provide us with the clearest pictures of stars as they are born. In addition, GSMT will allow us to detect giant planets around nearby stars, the perfect complement for the TPF's search for Earth-sized planets around the same stars. Both will be needed to find true analogues to our own solar system—giant planets on stable orbits guarding the existence of vulnerable Earth-like worlds in the "habitable zone"—where life can begin and flourish. The TPF will be the GSMT's partner after JWST has retired.



Artist's conception of the planetary system orbiting the nearby star 55 Cancri as seen from a Jupiter-like planet, at a distance approximate to that of Jupiter from our own Sun. GSMT will be able to analyze the light from this planet, determine its chemical composition, and infer the mechanism by which it formed. NASA's Terrestrial Planet Finder will enlarge the sample for GSMT analysis.

- **An investment for the long-term, GSMT is essential to maintaining U.S. leadership in science, engineering, and technology.**