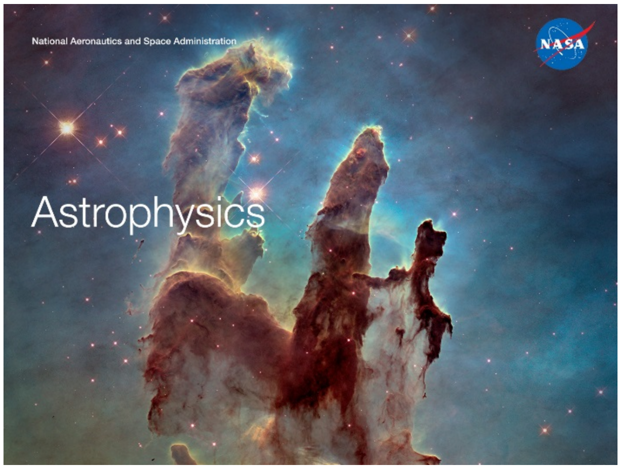
NASA Science Mission Directorate: Astrophysics Division



People have gazed at the stars, given them names, and observed their changes for thousands of years. NASA joined the ancient pursuit of knowledge of our universe comparatively recently.

Goals: The science goals of Astrophysics are breathtaking: we seek to understand the universe and our place in it. We are starting to investigate the very moment of creation of the universe and are close to learning the full history of stars and galaxies. We are discovering how planetary systems form and how environments hospitable for life develop. And we will search for the signature of life on other worlds, perhaps to learn that we are not alone.

NASA's goal in Astrophysics is to "Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars."

Big Questions

- How does the Universe work? Probe the origin and destiny of our universe, including the nature of black holes, dark energy, dark matter and gravity.
- How did we get here? Explore the origin and evolution of the galaxies, stars and planets that make up our universe.
- Are we alone? Discover and study planets around other stars, and explore whether they could harbor life.

Current Programs

Astrophysics comprises of three focused and two cross-cutting programs. These focused programs provide an intellectual framework for advancing science and conducting strategic planning. They include:

- Physics of the Cosmos
- Cosmic Origins
- Exoplanet Exploration
- Astrophysics Explorer Program
- Astrophysics Research

Current Missions

The Astrophysics current missions include three of the Great Observatories originally planned in the 1980's and launched over the past 25 years. The current suite of operational Great Observatories include the Hubble Space Telescope, the Chandra X-ray Observatory, and the Spitzer Space Telescope. Additionally, the Fermi Gamma-ray Space Telescope explores the high-energy end of the spectrum. Innovative Explorer missions, such as the Swift Gamma-ray Explorer and NuSTAR, complement the Astrophysics strategic missions. SOFIA, an airborne observatory for infrared astronomy, is in its operational phase and the Kepler mission (in the Discovery program) is now actively engaged in K2 extended mission operations. All of the missions together account for much of humanity's accumulated knowledge of the heavens. Many of these missions have achieved their prime science goals, but continue to produce spectacular results in their extended operations.

NASA-funded investigators also participate in observations, data analysis and developed instruments for the astrophysics missions of our international partners, including ESA's LISA Pathfinder, XMM-Newton, Herschel, and Planck missions, and JAXA's Suzaku.

Near Future

The near future will be dominated by several missions. Currently in development, with especially broad scientific utility, is the James Webb Space Telescope. Explorer mission TESS and Explorer Mission of Opportunity NICER are also in development. TESS will provide an all-sky transit survey, identifying planets ranging from Earth-sized to gas giants, orbiting a wide range of stellar types and orbital distances. The NICER mission will study the gravitational, electromagnetic, and nuclear-physics environments of neutron stars. Also in work are detectors for ESA's Euclid mission.

Completing the missions in development, supporting the operational missions, and funding the research and analysis programs will consume most of the Astrophysics Division resources.

The Future

Since the 2001 decadal survey, the way the universe is viewed has changed dramatically. More than 1000 planets have been discovered orbiting distant stars. Black holes are now known to be present at the center of most galaxies, including the Milky Way galaxy. The age, size and shape of the universe have been mapped based on the primordial radiation left by the big bang. And it has been learned that most of the matter in the universe is dark and invisible, and the universe is not only expanding, but accelerating in an unexpected way.

For the long term future, the Astrophysics goals will be guided based on the results of the 2010 Decadal survey New Worlds, New Horizons in Astronomy and Astrophysics. The priority science objectives chosen by the survey committee include: searching for the first stars, galaxies, and black holes; seeking nearby habitable planets; and advancing understanding of the fundamental physics of the universe. In 2013 the Astrophysics Implementation Plan was released (updated in 2014) which describes the activities currently being undertaken in response to the decadal survey recommendations within the current budgetary constraints.

The Astrophysics roadmap Enduring Quests, Daring Visions was developed by a task force of the Astrophysics Subcommittee in 2013. The Roadmap presents a 30-year vision for astrophysics using the most recent decadal survey as the starting point.

In February 2016, NASA formally started the top Astro2010 decadal recommendation, the Wide Field Infrared Survey Telescope (WFIRST). WFIRST will aid researchers in their efforts to unravel the secrets of dark energy and dark matter, and explore the evolution of the cosmos. It will also discover new worlds outside our solar system and advance the search for worlds that could be suitable for life.

Focus Areas

The Astrophysics Division has laid out a strategy to discover the origin, structure, evolution of our cosmos…

Planets Around Other Stars: Throughout recorded history and perhaps before, we have wondered about the possible existence of other worlds, like or unlike our own. The earliest understanding of the solar system showed us that there were indeed other worlds in orbit about our Sun, and steadily growing understanding of their natures shows that all are dramatically different from Earth, and mostly very different from one another. As we came to understand that the stars in the sky are other suns, and that the galaxies consist of billions of stars, it appeared a near certainty that other planets must orbit other stars. And yet, it could not be proven, until the early 1990's. Then, radio and optical astronomers detected small changes in stellar emission which revealed the presence of first a few, and now many, planetary systems around other stars. We call these planets "exoplanets" to distinguish them from our own solar system neighbors.

The Big Bang: The night sky presents the viewer with a picture of a calm and unchanging Universe. So when scientists noticed that the Universe is in fact expanding at enormous speed this was revolutionary. Astronomers noted that galaxies outside our own Milky Way were all moving away from us, each at a speed proportional to its distance from us. There must have been an instant in time (now known to be about 14 billion years ago) when the entire Universe was contained in a single point in space. The Universe must have been born in this event which came to be known as the "Big Bang."

Dark Energy, Dark Matter: What is dark energy? More is unknown than is known — we know how much there is, and we know some of its properties; other than that, dark energy is a mystery — but an important one. Roughly 70% of the Universe is made of dark energy. Dark matter makes up about 25%. The rest - everything on Earth, everything ever observed with all of our instruments, all normal matter adds up to less than 5% of the Universe. Then again, maybe it shouldn't be called "normal" matter since it is a small fraction of the Universe!

Stars: How do stars form and evolve? Stars are the most widely recognized astronomical objects, and represent the most fundamental building blocks of galaxies. The age, distribution, and composition of the stars in a galaxy trace the history, dynamics, and evolution of that galaxy. Moreover, stars are responsible for the manufacture and distribution of heavy elements such as carbon, nitrogen, and oxygen, and their characteristics are intimately tied to the characteristics of the planetary systems that may coalesce about them. Consequently, the study of the birth, life, and death of stars is central to the field of astronomy.

Galaxies: Our galaxy, the Milky Way, is typical: it has hundreds of billions of stars, enough gas and dust to make billions more stars, and about six times as much dark matter as all the stars and gas put together. And it's all held together by gravity. Like more than two-thirds of the known galaxies, the Milky Way has a spiral shape. At the center of the spiral, a lot of energy and, occasionally, vivid flares are being generated. Based on the immense gravity that would be required explain the movement of stars and the energy expelled, the astronomers conclude that at the center of the Milky Way is a supermassive black hole.

Black Holes: Don't let the name fool you: a black hole is anything but empty space. Rather, it is a great amount of matter packed into a very small area - think of a star ten times more massive than the Sun squeezed into a sphere approximately the diameter of New York City. The result is a gravitational field so strong that nothing, not even light, can escape. In recent years, NASA instruments have painted a new picture of these strange objects that are, to many, the most fascinating objects in space. What happens at the edge of a Black Hole?