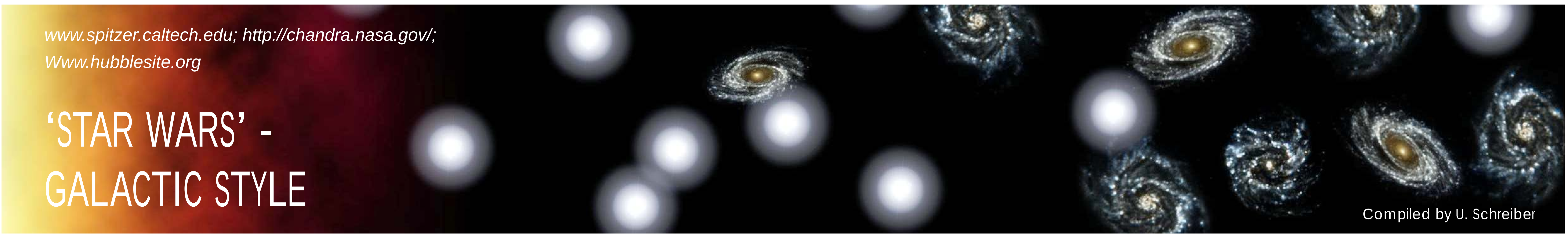
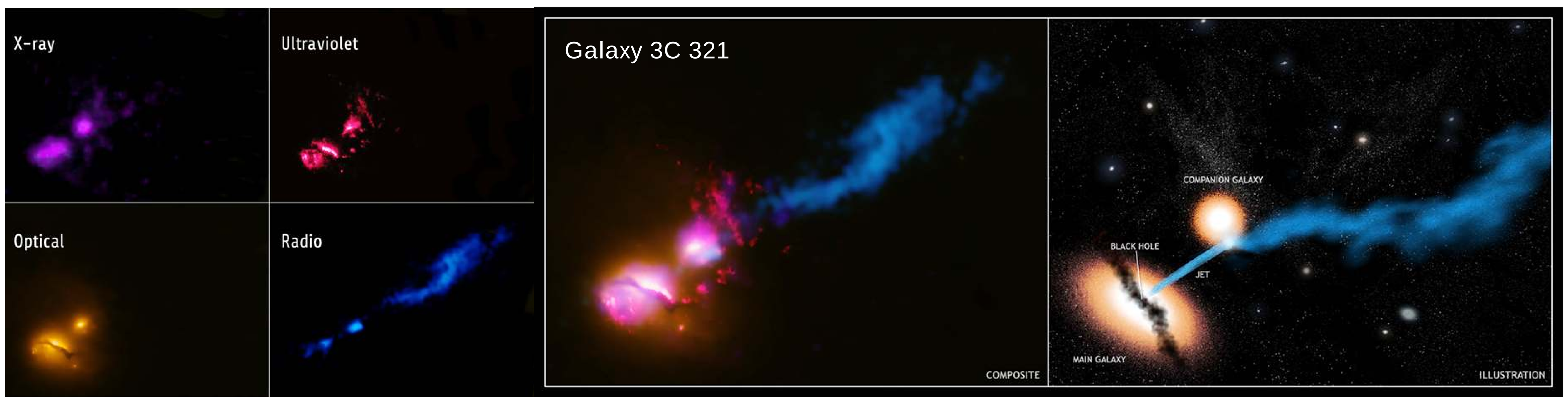


www.spitzer.caltech.edu; http://chandra.nasa.gov/; Www.hubblesite.org

'STAR WARS' - GALACTIC STYLE

Compiled by U. Schreiber

The "quiet and emptiness" of space is a phrase well-known to science-fiction fans, but actually nothing could be further from the truth... for instead of being 'empty' the universe is full of exotic objects, such as black holes, dark matter, galaxies and particle jets, all of them hurtling through unimaginable distances at unimaginable speeds. And not always is the interaction between these entities orderly, but quite frequently chaos reigns, for instance when galaxies collide - the resulting violence being many orders of magnitude greater than the imaginary altercations between the warring inhabitants of neighbouring systems of the movie world! With the aid of space- and ground-based telescopes humankind now is in a position to observe these on-goings, some of which happened more than a billion years ago (i.e. the time it took the light from these far-flung regions of the universe to reach us), from a safe distance - for life on Earth and maybe even Earth itself would be facing doom, if ever it got caught up in one of these galactic tangles.



Hubble's optical light image shows the glow from the stars in each galaxy, with a darker dust lane evident across the larger one, while a bright spot in the radio image indicates where the jet has struck the companion galaxy, dissipating some of its energy in doing so. An even larger "hotspot" of radio emission not seen in this view reveals that the jet continues on after hitting the companion galaxy, only terminating at a distance of about 850,000 light-years. The Hubble UV image shows large quantities of warm and hot gases, indicating the supermassive black holes at the cores of both galaxies, which appear in the X-ray data, have had a violent past.

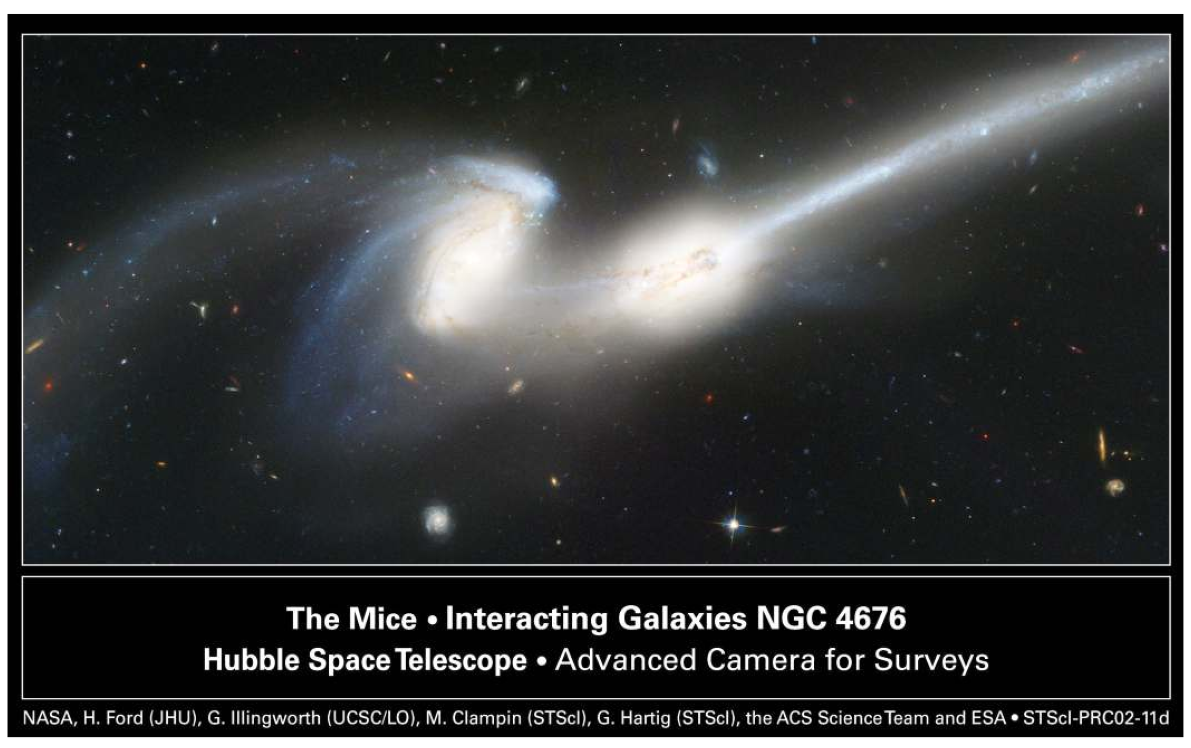
Jet Attack

A hitherto unknown form of galactic violence has recently been observed in a system some 1.4 billion light-years from Earth. Known as 3C 321, it contains two galaxies in orbit around each other, both with a supermassive black hole at the core. In addition, the larger one - dubbed the "Death Star Galaxy"- also has a jet emanating from its centre (left), which is trained on the smaller companion galaxy that apparently has swung into its path.

The galactic "war" in 3C 321 was discovered by NASA's space- and ground-based telescopes. In the composite image, data from several wavelengths, showing different aspects of the system, are combined, each having been assigned a different colour. X-ray data from Chandra (purple), optical and ultraviolet (UV) data from Hubble (orange and red), and radio emissions from the Earth-based Very Large Array (VLA) and MERLIN telescopes (blue) show how the jet from the main galaxy is striking its smaller companion. Upon impact the jet, which is about 1,000 light-years across, is disrupted and deflected. Features in the VLA and Chandra images further indicate that the jet began battering the smaller galaxy only about one million years ago, a very short time span in cosmic terms.

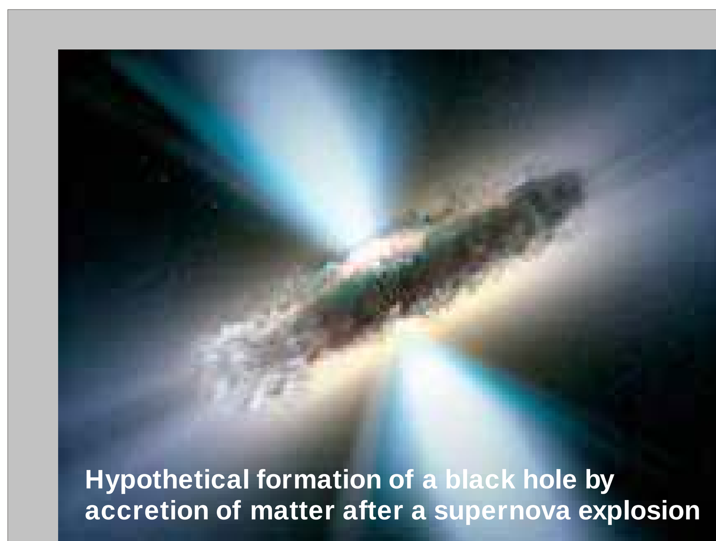
Racing out at the speed of light jets from supermassive black holes transport enormous amounts of radiation, especially high-energy X-rays and gamma-rays, far from their origin, thus affecting matter on scales vastly larger than the black hole itself. The effect of this jet in 3C321 on the companion galaxy is likely to be substantial, because of the short distance - again in galactic terms - between the two galaxies of only 20000 light-years. For an Earth-like world lying in its path this would mean severe damage to the atmosphere, with resulting mass extinctions. Yet the massive influx of energy from the jet could also induce the formation of new stars and planets in its destructive wake, and so eventually become a source of new life. Although jets like this have been found all over the universe, their origin, evolution and general behaviour is as yet little known, and a key goal for astrophysical research.

Shock Wave in Stephan's Quintet — Spitzer Space Telescope • IRAC, Visible: Calar Alto Observatory
NASA / JPL-Caltech / Max-Planck Institute / P. Appleton (SSC/Caltech) ssc2006-08a



The Mice • Interacting Galaxies NGC 4676
Hubble Space Telescope • Advanced Camera for Surveys
NASA, H. Ford (JHU), G. Illingworth (UCSC/LO), M. Clampin (STScI), G. Hartig (STScI), the ACS Science Team and ESA • STScI-PRC02-11d

On Black Holes



Hypothetical formation of a black hole by accretion of matter after a supernova explosion

"Spaghettification" of an object approaching a black hole

Inside a black hole

Within a black hole *gravity* has gotten so strong that the necessary *escape velocity* is faster than light, i.e. everything that comes within a certain distance of it, is sucked in and trapped forever. The most common way for a black hole to form is from a collapsed stellar core in a supernova explosion. But there are also "supermassive" black holes located at galactic centres, with millions or billions of times the mass of the Sun, whose formation is still not clear. According to Einstein black holes create gravitational ripples in the fabric of space, like a rock thrown into a pond, so black holes may form a "gateway" to understanding space, time and their complex relationship to each other.

What happens to matter after it passes the *event horizon* and falls towards a Black Hole astrophysicists can only theorize about. A rotating black hole would probably be like a maelstrom where infalling objects are stretched out to a thin stream of matter (or - in technical slang - "spaghettified") due to the gravitational gradient in its vicinity. At the very core of the black hole the seething matter finally collapses down to a point, which is when standard math fails. At the singularity, space and time, as we know them, come to an end.

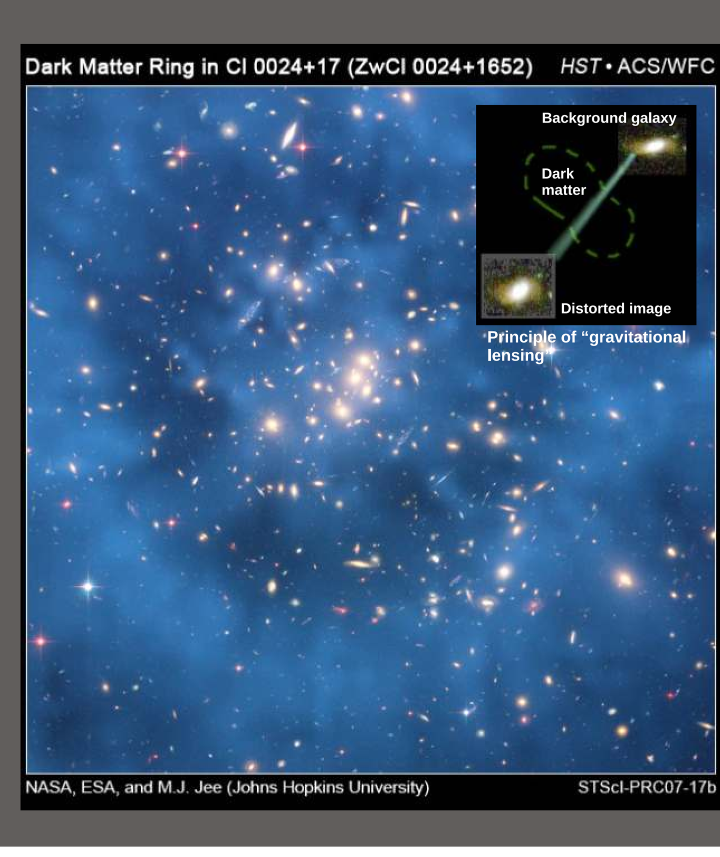
Although a black hole itself may be invisible, its enormous gravity leaves "fingerprints", which can be detected by observation and/or X-rays. Strangely, though, not all black holes are totally black, as infalling material can become hot enough in the process to glow! It is estimated that our Milky Way Galaxy alone contains millions of stellar black holes, apart from the supermassive one at its centre, but at a distance of more than 1500 light-years to the nearest, Earth is in no danger of being sucked into its vortex!

On Dark Matter

In astrophysics and cosmology, *dark matter* is material of unknown composition, which does not emit or reflect enough electromagnetic radiation to be detected directly, but whose presence can be inferred from its gravitational effect upon visible matter. According to observations of structures larger than galaxies, as well as *Big Bang* cosmology, dark matter makes up the bulk of the universe. Only about 4% of the total energy density (as inferred from gravitational effects) can be seen directly. Ca. 22% are thought to be dark matter, while the remaining 74% are dark energy, an even stranger component, distributed diffusely in space. The observed phenomena consistent with the existence of dark matter include the rotational speed of galaxies, orbital velocities of galaxies in clusters, gravitational lensing of background objects (i.e. the distortion of light from distant objects by intervening matter) by galaxy clusters such as the Bullet Cluster, and the temperature distribution of hot gas in galaxies and galaxy clusters. Dark matter also plays an important role in structure formation and galaxy evolution. Current evidence favours models in which the primary component of dark matter is new elementary particles, collectively called "non-baryonic dark matter".

X-rays and the effect of gravitational lensing show that the Bullet Cluster (above) consists of both normal "baryonic" matter (pink) and dark matter (blue). Apparent distortion of the background galaxies by gravitational lensing also led to the dark matter distribution map of Cl0024+17 (below).

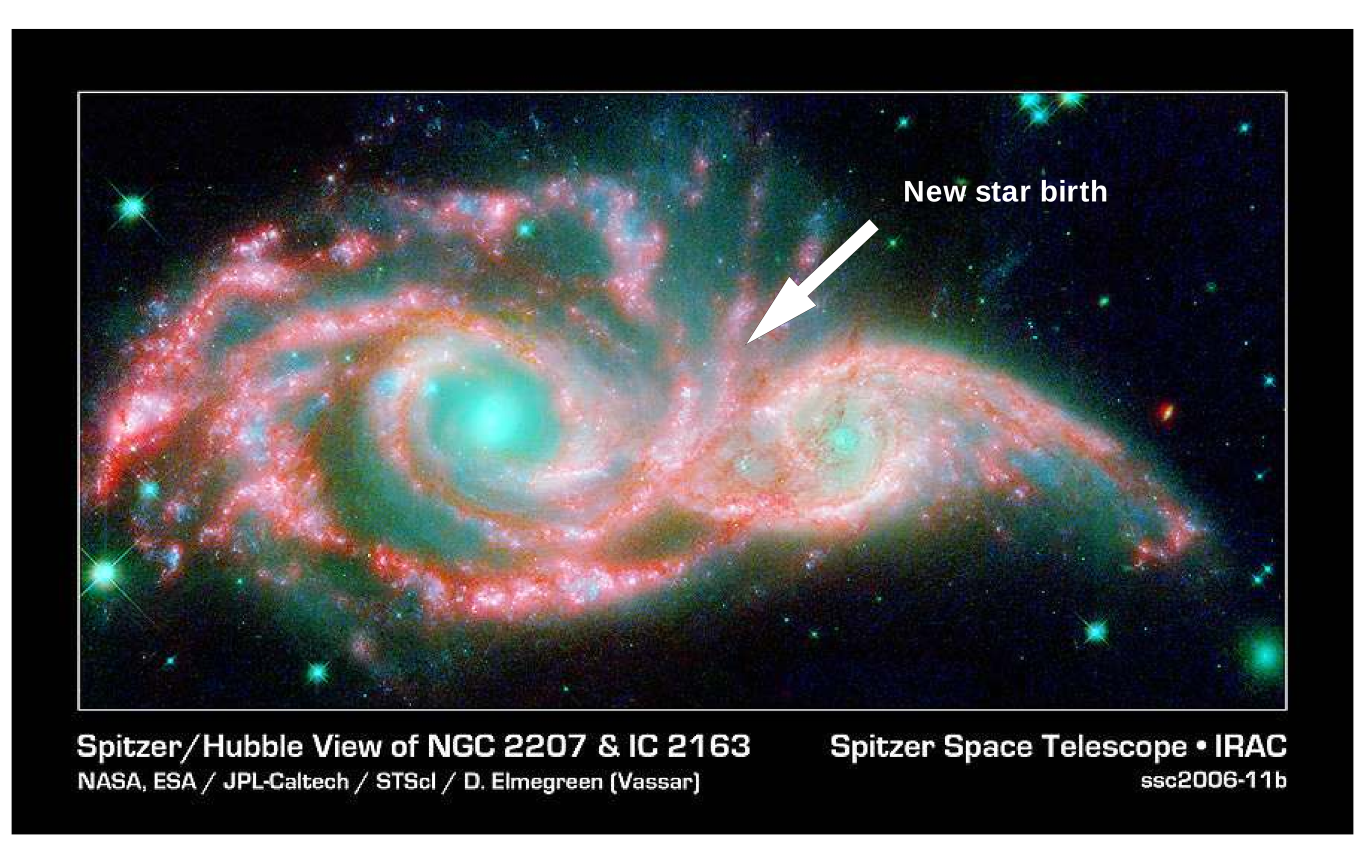
Dark Matter Ring in Cl 0024+17 (ZwCl 0024+1652) *HST* • ACS/WFC



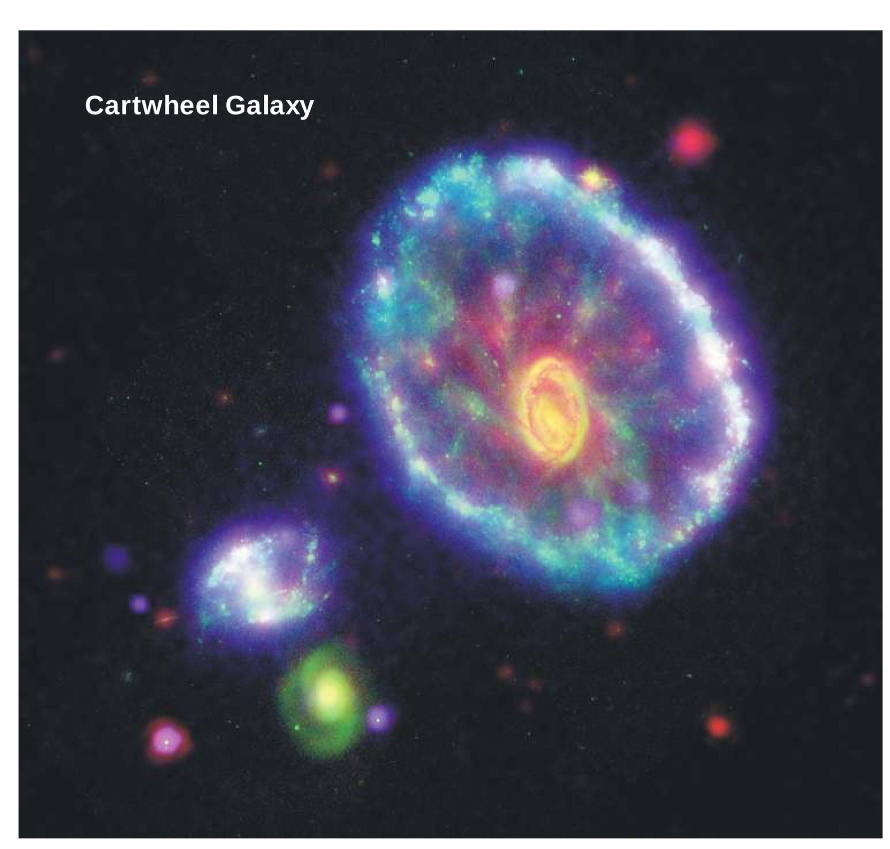
NASA, ESA, and M.J. Jee (Johns Hopkins University) STScI-PRC07-17b

Colliding Galaxies

Collisions between galaxies have been observed throughout the universe. Enhanced and filtered for human eyes, they make pretty pictures, like the huge Cartwheel Galaxy, Stephan's Quintet or "The Mice"... but behind each stands a tale of unimaginable violence, spun out in a cauldron of churning hot dust and gas. Unlike car accidents, galactic collisions take tens of millions of years, during which enormous forces are exerted on the objects involved until they eventually melt into one, but frequently the initial destructive phase is succeeded by new star birth, stimulated by the energies generated in this gigantic whirlpools often more than 100 000 light-years across.



Spitzer/Hubble View of NGC 2207 & IC 2163 — Spitzer Space Telescope • IRAC
NASA, ESA / JPL-Caltech / STScI / D. Elmegreen (Vassar) ssc2006-11b



Cartwheel Galaxy