Cosmic Gamma-Ray Bursts

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Despite funding cuts, research into the origin of gamma-ray bursts continues as best it can.

Cosmic Gamma-Ray Bursts

Since their accidental discovery during the cold war, Gamma-Ray Bursts have been the object of study for many astronomers and astro-physicists alike. These incredibly powerful explosions were considered to be one of the greatest astronomical mysteries of the modern age, but recent discoveries may give clues as to what causes these catastrophic events. The study of them has led the way for people to develop new technology as well as make new discoveries and theories that may give humans insight into the unknowns of our universe, including its distant past.

In the late 1950's, the United States of America and The Union of Soviet Socialist Republics were engrossed in a Cold War. The greatest danger of both powers was the use of nuclear weapons. These weapons were often tested on the ground and in the upper atmosphere. To reduce the risk of war, nuclear test ban treaties were created to eliminate nuclear weapon tests in space. As these nuclear test ban treaties were being negotiated, President Eisenhower's science advisors warned him that the U.S.S.R. could not be trusted to stop their testing of the weapons. They proposed that satellites should be launched into orbit which would contain detectors that were much like the ones used on the surface to analyze nuclear blasts. These detectors would alert the United States of any secret nuclear test conducted by the U.S.S.R. The project, code-named "Vela," was approved by the Department of Defense, and the Air Force was put in charge. The development of the detectors to be placed on the satellites was assigned to the Los Alamos National Laboratory.

The first spacecraft of the Vela project was launched in October of 1963. It contained six Gamma-ray detectors as well as some other instruments. Three more spacecraft were launched shortly after, and starting with Vela 3, the Gamma-ray detectors were made of a material called cesium iodide, which *scintillates* whenever Gamma-rays pass through it. After the launch of Vela 4, a scientist working at Los Alamos named Ray Klebasabel wanted to test the electronics designed to keep the detectors from going off whenever *cosmic radiation* passed through them. As he and other scientists were sifting through the enormous amount of data required to check the electronics, they found spikes, or bursts, in the data that gradually trailed off. Klebasabel was surprised and stated "One thing that was immediately apparent was that this was not a response to a *clandestine* nuclear test". They then checked for *solar flares* or *supernovae* that may have caused the spikes, but they found none.

After the launch of Vela 5 and 6, Klebasabel and his team got lucky. The detectors on the Vela 5 were not calibrated correctly and as a result were overly sensitive. This sensitivity caused the Vela 5 to report tremendous amounts of information. By using Vela 5 and 6 at far distances, they were able to triangulate the locations of the bursts, by comparing the arrival time of the gamma-rays within 1/64th of a second. Klebasabel and his team found that the bursts came from outside the solar system and at random directions. This hinted that the bursts of gamma-rays originated out into the universe, but because they had only 16 confirmed bursts, no conclusions could be drawn (NASA Marshal Space Flight Center).

In 1973, after confirming that the bursts of gamma-rays were not man made, and after receiving government permission, the bursts were officially announced at a press conference as a new natural phenomenon called "Gamma Ray Bursts" (GRBs). The first observations made were that the bursts came from random directions all over the sky, and that they never came from the same point twice. Speculation arose as to where they were, and what caused them. Many astronomers believed that they were caused by events involving *black holes*, supernovae, or *neutron stars*. They still had no idea how far away the GRBs were, and thus could not determine the energy emitted from them (NASA Marshal Space Flight Center, Mallozzi).

Since gamma-rays are absorbed in the earth's atmosphere, the only way to detect and study the GRBs are from satellites in space. Jerry Fishman, a young astrophysicist that was at the press conference in 1973 realized that a satellite specific to the study of GRBs was needed. "Right away I realized that if the detectors, which were small (only an inch across), could see dozens of bursts per year, then by scaling up the size we could see a dozen a day". He thought of an all sky monitor which he called the Gamma-Ray Observatory (later to be renamed to the Compton Gamma-Ray Observatory) and after approval, the development of it began. However, it would not be completed until 1991.

By the mid-1980's, it was widely thought, through limited data and speculation, that the GRBs came from nearby neutron stars in our galaxy. Also, due to the presence of dark lines in the spectra, it was believed that there were intense *magnetic fields* at the origin of the bursts, in which case the gamma rays could have been emitted by *electrons* accelerated to *relativistic* speeds when the *magnetic field lines* from a neutron star reconnected. Something similar to this happens on the sun at far lower energies, and the result is solar flares. However, at the time there was no way to prove this. (Scientific American, Fishman)

In 1986, scientists gathered at Toulouse, France to try to figure out what the Russians had discovered in 1979. A Russian satellite had discovered a kind of burst which emitted enormous amounts of X-rays for a few seconds, and then was all quiet for months or years before it emitted the rays again from the same point in space. This baffled astronomers because all previous Gamma-Ray Bursts never had come from the same point twice. It was finally decided in 1986 that these were new phenomenon and since they emitted less energy, were called "Soft Gamma

Repeaters (SGRs)". The discovery was not widely sought out because of lack of equipment, but this discovery would later lead to that of a major one; that of a completely new type of star.

The Compton Gamma-Ray Observatory (CGO) was launched on the Space Shuttle Atlantis in April of 1991. It contained the Burst And Transit Source Experiment (BATSE), a piece of equipment designed to locate and record data from Gamma-Ray Bursts. The BATSE consists of eight detectors, one facing outward from each corner of the CGO. These detectors are sensitive to gamma-ray energies from twenty *keV* to over a thousand keV and contain NaI crystals, which, much like the cesium iodine of the Vela craft, scintillates whenever it is struck by Gamma-rays. The light flashes are then recorded by sensitive detectors whose output is digitized and analyzed to find the arrival time and energy of the Gamma-ray photons. Each BATSE module contains a large area detector most sensitive to faint *transient* events, as well as a smaller detector optimized for *spectroscopic* examination of bright events, such as GRBs (LHEA at NASA/GSFC, Leonard).

After only one year of operation, the BATSE data confounded astronomers. When it was launched, it was believed it would prove that GRBs came from our galaxy by detecting such a quantity of GRBs that, through their density distribution, would map out the Milky Way in the sky, much in the same way the stars do when you look at them away from city lights. This was not to be so. By 1992, the BATSE had recorded enough bursts to show without a doubt that the GRBs were completely *isotropic* in the sky with near-computer randomness. This caused scientists to come up with two theories about the location of the bursts. One was that they came from a huge galactic halo surrounding the Milky Way, the other was that they originated at *cosmological* distances. The galactic halo theory would mean that since the earth is 25,000 light years off center from the middle of the Milky Way, the galactic halo would have to be enormous in order to eliminate asymmetry in the readings; along the lines of a million light years across. If this is so, then the halo surrounding our nearest galaxy, Andromeda, should overlap the halo around the Milky Way and start to appear in the distribution of GRBs. No observations of that nature were observed (Marshal Space Flight Center).

The idea that GRBs came from cosmological distances became more accepted. However, if the GRBs came from such distances, they should show signs of the expansion of the universe, or *redshift*. This is where the light of an object is "stretched out" in proportion to the overall size of the universe, changing the color from high frequencies on the *electromagnetic spectrum*, to lower frequencies such as radio waves (Hogan 62). The main problem in proving the theory was that unlike the Vela satellites, the BATSE does not see dark lines in the spectrum of Gamma-rays whose displacements would show a shift to the red (Scientific American, Fishman).

It became apparent that in order to prove that GRBs came from cosmological distances, *counterparts* outside the spectrum of Gamma-rays would need to be found. Such counterparts would have positional accuracy's to link the GRB to other objects such as galaxies, or allow a redshift measurement from an optical spectrum. These things would not be seen if the GRBs came from a galactic halo (Marshal Space Flight Center).

Finding these counterparts became possible in 1996 with the launch of the Italian-Dutch Satellite BeppoSAX, which contains the Wide Field Camera (WFC). The WFC, which is sensitive to X-rays, can pinpoint a GRB in the sky to within 6 *arcminutes* and can provide the position to astronomers around the world within a matter of hours, much faster than was possible before. It's one drawback however, is that it does not map the whole sky, so it only detects about one GRB per month. This is solved by the onboard Gamma-Ray Burst Monitor, which searches its data for GRBs every satellite orbit of 1.5 hours and when it finds one, it tells the WFC to search its data for an accurate position (Scientific American, Fishman).

On February 28, 1997 the BeppoSAX detected a flash coming from the constellation Orion that was recognized by other instruments as a Gamma-ray Burst. Within eight hours, the sensitive X-ray telescopes on the BeppoSAX were pointed at the location of the burst and saw a rapidly fading X-ray emission. Another satellite, Ulysses, also saw the X-ray emissions and by comparing the arrival times of the rays between the two satellites, the location was accurately determined. With this information, astronomers used optical telescopes like the Keck Telescope and the ESO New Telescope to look at the area 21 hours after the burst and saw a fading afterglow. This afterglow was then viewed by the Hubble Space Telescope. It saw that the optical transient consisted of a point source (determined to be the GRB counterpart) and a long fuzzy source thought to be a faint galaxy or nebula where the GRB could have occurred. Although this was not complete proof that GRBs came from very far away, it fit the theory very well.

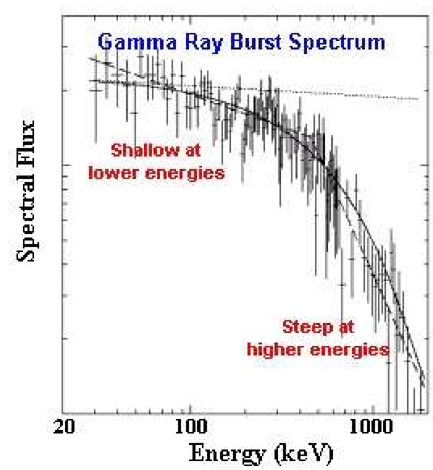
Solid proof of the cosmological origin of GRBs came on May 8, 1997. The WFC observed a GRB, and on closer inspection, a faint optical variable star was detected at the origin of the burst. This burst's afterglow lasted much longer than the one on February 28th, and as a result, astronomers were able to study the spectrum closely using the Keck II Telescope in Hawaii. They discovered that some of the light from the afterglow had been absorbed by intervening material shown to be magnesium and iron. However, the spectral lines of these materials were at much longer wavelengths than normal. This was due to redshift, which when calculated turned out to be 0.835, meaning that the burst took place 7 billion light years away. Even more impressive was a burst discovered in December of 1997. It was seen to be coming from a faint galaxy that had a redshift of 3.4, indicating that the distance of the burst was an enormous 12 billion light years away. Not only did these results prove that GRBs are cosmological in origin, but they also gave clues as to what causes them (Physics World, Wijers).

GRBs (renamed Cosmic Gamma-Ray Bursts due to cosmological origin) are very hard to study mainly because of their vast variety. A burst may last anywhere from 30 milliseconds to 1,000 seconds. One burst even lasted 1.6 hours. Some bursts show spikes of intense radiation with no emissions in between, while others are smooth. Also, the spectra of the bursts are in the 100,000 to 1 million electron volt range which makes study of it complicated. In order for the light from the bursts to reach us, the CGRBs must have had energies of up to 10^{52} *ergs*. This energy is emitted within seconds or less from a very small region of space. This lead people to believe that the CGRBs are highly energetic fireballs.

Theories were made as to the circumstances that would create such an energetic fireball. The most accepted one is that of a binary neutron star system collapsing. Theoretical models predict that such an event occurs every 10,000 to one million years in a galaxy, and since their are about 10 billion galaxies in the volume of space that BATSE can look at, it yields 1000 bursts a year. This is approximately how many are actually observed.

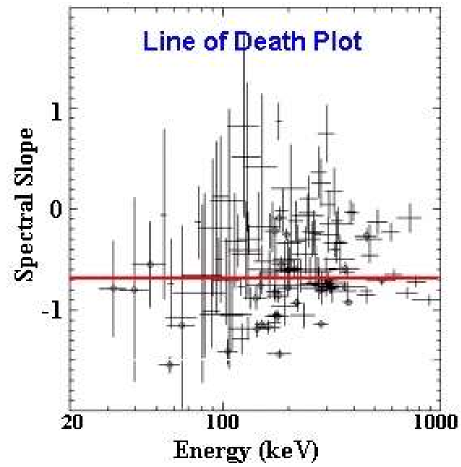
The theory states that as the two stars spiral into each other, they release gravitational energy in the form of radiation. They then merge to create a black hole. Right before this happens, the stars death throes release up to 10^{53} ergs. This energy is released as *neutrinos* and *antineutrinos*, which must be converted into Gamma-rays somehow. In order for that to happen a chain of events must occur. The neutrinos must collide with the antineutrinos to form electrons and *positrons*, which must annihilate one another in order to create *photons*. However, this process is very inefficient and simulations done at the Max Planck Institute in Munich showed that it may not give off enough photons to account for a CGRB. Also, if there are a lot of heavy particles such as protons in the fireball, it reduces the energy of the Gamma-rays. This "proton pollution" is to be expected because the collision of two neutron stars would create a huge variation of particles. This would mean that all the energy emitted ends up as *kinetic* energy of the particles, and none is left for the radiation. (Scientific American, Fishman).

By using observations of the X-ray, optical, and radio counterparts of CGRBs, astro-physicists in mid-1998 came up with a theory to eliminate the problem of the "proton pollution" in the fireball. By looking at the light curves of the counterparts it seems that they are consistent with that of an expanding fireball that is glowing due to "Synchrotron Shock". The Synchrotron Shock Model is that a tremendous explosion shoots a shock wave of material that accelerates charged particles (such as protons or electrons) to velocities near the speed of light. This shock wave can be compared to a wave on the beach. "A shock forms when the wave crest starts to fall over, and scud from the wave shoots out ahead" (Preece). The 'scud' in the cosmic wave is the electrons and protons. They shoot out ahead of the wave of material and spiral around the magnetic field lines producing synchrotron emission, a kind of radiation. This radiation can be seen elsewhere, such as the blue glow in *particle accelerators*.



The Synchrotron Shock Model made a testable prediction. The graph on the right is that of a typical CGRB's spectrum. At lower energies (the top of the graph) the slope of the tangent lines to the fit curve of spectral flux vs. energy is shallow. However, according to predictions from the Synchrotron Shock Model, the slope cannot be greater than -2/3.

Rob Preece from the University of Alabama, along with his collaborators examined 100 bright CGRBs and plotted the slope at the low energy part of the spectra vs. the peak burst energy. The position of the plots shown to the right were compared to the red line signifying the -3/2 slope. If any CGRB's were above this line, they were not caused by Synchrotron Shock.



It was found that 44% of the CGRBs plotted fell above the red line or "line of death" where the Synchrotron Shock Model is "dead". With the assumption that all CGRBs are caused by the same thing, none could be due to Synchrotron Shock. Although this disproved a theory about the origin of CGRBs, there is very strong evidence that the optical afterglow from the bursts are in fact caused by Synchrotron Shock. If this is so, it means that the mechanism that causes the burst is different then that that causes the afterglow, creating yet another mystery (NASA Marshal Space Flight Center).

With the knowledge that fireballs and CGRBs are not the same thing, astro-physicists came up with new and revised theories about the origin of the bursts. One leading theory involves a mechanism which invokes powerful magnetic energies, like the ones in the center of galaxies. Instead of a fireball, a merger of two neutron stars could collapse into a black hole surrounded by a thick rotating disk of debris. This disk would not last very long, but it would possess magnetic fields 10^{15} times that of the earth's. These fields would extract rotational energy from the system and channel it out into two jets shooting out from the rotational axis of the disk. The regions closest to the axis of these jets would be completely free of proton pollution, thereby letting the relativistic electrons inside them to emit an intense, focused pulse of Gamma-rays. A variation on this theory is that of a neutron star orbiting and collapsing into a pre-existing black hole. In this theory, the star is shredded and generates intense Gamma and other radiation as the stars mass is crushed and superheated (Scientific American, Fishman).

The study of Cosmic Gamma-Ray Bursts reached a new era on January 23, 1999. At 4:47 a.m. EST, the most powerful CGRB ever discovered (GRB990123) was observed visually while the 110 second burst was in progress. Normally, scientists had to wait about a day for the accurate position of a burst to be calculated from BATSE, but Dr. Scott Barthelmy came up with a way to locate the bursts much more quickly. They developed and implemented the Gamma-Ray Burst Coordinate Network (GCN), which automatically intercepts BATSE data and quickly transmits it over the Internet to observation sites around the world.

On January 23, 1999, the GCN transmitted the positional information of GRB990123 from BATSE to the Robotic Optical Transient Search Experiment (ROTSE-I) in only four seconds, thereby allowing the ROTSE-I to use its telephoto camera array containing four telephoto lenses and charge-coupled devices to visually watch the CGRB as it occurred, only 22 seconds after the start of the burst. This feat had never before been accomplished because in the past, it took hours to locate the burst and point visual telescopes at the location. The ROTSE-I showed that the burst reached a magnitude of 8.9 at its brightest, about 15 times dimmer than the human eye can see. This means that it could have been viewed on the ground with only a pair of binoculars. According to Dr. Chryssa Kouveliotou of the Marshall Space Flight Center, “If the burst had occurred somewhere in our galactic neighborhood, it would have been so bright that night would’ve turned into day.”

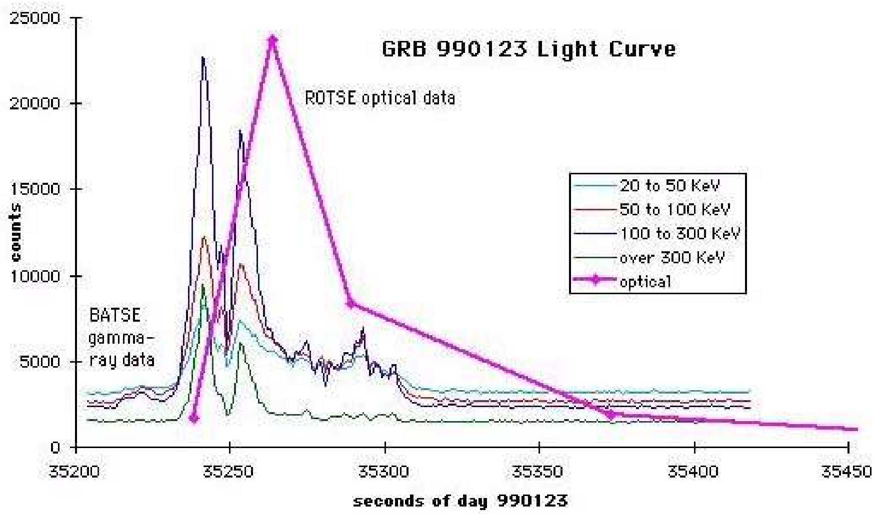
So soon after the burst, the precise location was still unknown. GCN only directs observers to general areas in the sky, and since the ROTSE images are extremely detailed (about 17 million pixels each), scientists had to use data from BeppoSAX to pinpoint the burst location within the images. After 8 hours, they had located the position of the burst to within 4 arc-minuets. Using this accurate position, observations of the burst were made from the CCD camera mounted on a 60-inch telescope at the California Institute of Technology and by the Keck II telescope in Hawaii.

The CCD camera showed that the afterglow of the burst was 5000 times dimmer than the peak brightness during the burst. It also discovered a faint galaxy near the burst. This galaxy was later observed closely on February 8-9, 1999 by the Hubble Space Telescope, which showed that the fading optical counterpart (4 million times dimmer than on Jan. 23rd) was seen to be embedded in the faint, irregular galaxy. This was the fourth time a CGRB was associated with a distant galaxy. "These galaxies are so distant and so faint that it's difficult to say much about them" (qtd. in NASA Space Science News).

The Keck II telescope, using a spectrograph to analyze the ultraviolet and visual light of GRB990123, was able to measure a redshift of 1.6 meaning that the burst took place 10 billion light-years away. At this distance, the power of the burst must have been about ten million billion (10^{16}) times that of our sun (NASA Space Science News).

Using the visual emissions of GRB990123, scientists tried to figure out the structure of the explosion in order to give clues as to the origin of the burst. They found that material flowing out of a CGRB does so at different velocities, which causes collisions to occur. These collisions create shock waves that generate different wavelengths of energy. Studying these different wavelengths may tell scientists how the explosion behaves.

Below is the light curves recorded by BATSE and ROTSE, showing how the peak optical brightness did not coincide with that of the peak of Gamma-rays, but rather occurred several seconds later.



Because of this observation, an accepted theory of how the shock waves behave was constructed.

The theory explains that CGRBs are associated with three different kinds of shock waves. These are external, internal, and reverse. As the burst explodes, material shoots outward creating an external shock wave ring going out from the source of the explosion. The impact of this wave against the *interstellar medium* creates reverse shock waves. Matter is still being shot out of the burst, and when this matter (internal shock waves) collide with the reverse shock waves, it pushes them outward. The reverse shock waves still appear to be moving inward because they are slower and colder than the internal shock waves. “We think these reverse shock waves may be the source of the initial visible light emission” (qtd. in Space Science News, Briggs). This would follow the observations because if the external shock waves were the Gamma-rays and the reverse shock waves were the visible light, then it would make sense that the peak of visual light comes after the peak of Gamma-rays.

The power of GRB990123 was so incredibly intense that scientists began to wonder if the burst was beamed rather than dispersed isotropically. A beamed explosion would be directed much like a flashlight, while an isotropic explosion would be dispersed outward like from a light bulb. Beaming is not uncommon in the universe. For example, radio sources from the center of galaxies are beamed in specific directions. The data from the Hubble Space Telescope of GRB990123 shows a rapid decay of the light curves, which is evidence for beaming because beamed light appears to dim more rapidly than isotropic light. If the explosion were beamed, it would have its energy concentrated into a specific area. If they were isotropic, then only the part of the energy directed towards the earth would be seen. Therefore, isotropic explosions are much more powerful than beamed ones. “If gamma-ray bursts are beamed, then the energies we’re seeing are less than we first thought, but that also means there are more of them out there that we don’t see” (qtd. in NASA Space Science News, Meegan). This is because if the CGRBs are beamed, then observers would only see the ones directed toward the earth, and not the ones aimed in other directions. However, the afterglows from these bursts would in fact be able to be seen because afterglows are always isotropic. If an afterglow was discovered to appear without an initial burst, then it would be proof that CGRBs are beamed. “Afterglows are hard to spot; they’re so faint that they’re just at the limit of our detection devices” (Meegan). To this date, no afterglows have been discovered to be created without an initial burst.

The question of beaming vs. isotropic relates to the two widely accepted theories of the cause of Cosmic Gamma-Ray Bursts. In the binary neutron star system collapse model, the energy is beamed from the rotational axis of the orbiting disk of debris around the black hole. If proof of beaming is found, this theory would have more evidence to back it up. In the model which depicts a neutron star being shredded by a black hole, the explosion is isotropic. This would be the leading contender if no evidence is found of beaming.

Unfortunately, neither of the supported theories solve all the problems of creating a CGRB, including going straight from explosion to Gamma-ray emissions. Because of this, scientists are now studying a hypernova model. This is where a massive star (about 50 times that of our sun) reaches the end of its life. Everything in its core has been burned, so it implodes and then explodes. This would theoretically produce a fireball whose shock front moves near the speed of light and generates the required quantities of energy. Also, this event would be something that would most likely occur in the early universe, and very unlikely to occur in older, closer galaxies (NASA Space Science News).

The study of Cosmic Gamma-Ray Bursts is that of great significance to many people, especially to cosmologists. CGRBs are located billions of light-years away, which means they happened billions of years ago when the universe was in its infancy. Thus by looking at the faintest, most distant bursts, cosmologists can get a glimpse of what the universe was like back then. Before the discovery of CGRBs, the most distant known celestial objects were quasars. These were discovered to take place about 1.3 billion years after the *big bang*. However, the faintest CGRBs seem to have come from even further back in time, taking place only 750 million years after the big bang. If this is confirmed, then by increasing sensitivity of the instruments used to detect the CGRBs, bursts even farther back might be discovered, opening a never been seen before view into the time period known as the “dark age” of cosmology. This coincides to the time when the first stars and galaxies are thought to have formed, but no previous objects have been found to have redshifts high enough to correspond to that time (Physics World, Wijers).

One major finding linked to the study of CGRBs is that of evidence pertaining to the idea that the universe may be accelerating as it expands. Such evidence may undermine many precepts of astrophysics such as that gravity is slowing the universal expansion, and may collapse it eventually. It may even redeem a concept that Albert Einstein called his "greatest blunder." Einstein had thought that the universe was static, but he knew of ordinary gravitational forces that would close the universe in on itself. So to fix this, he came up with a term that would balance these forces. When Einstein learned of the discovery made by Hubble that the universe was expanding, he threw the term away. However, if it is shown that the universe is accelerating as it expands, then there must be a repulsive gravitational force out there that pushes more and more as things get further apart.

Astronomers use the perceived brightness of stars and galaxies to estimate their distance from earth because brightness decreases with distance. If the light sources are evenly distributed throughout the universe, the number of light sources should increase as they get dimmer.

> "Suppose you double the distance out which you can see. Since double the distance means eight times the volume, you're going to see eight times as many lights. But the brightness now goes down to a quarter as bright as before. If you looked at the number of light sources down to one quarter as bright, you would expect to see eight times more" (qtd. in Research Review '94, Emslie).

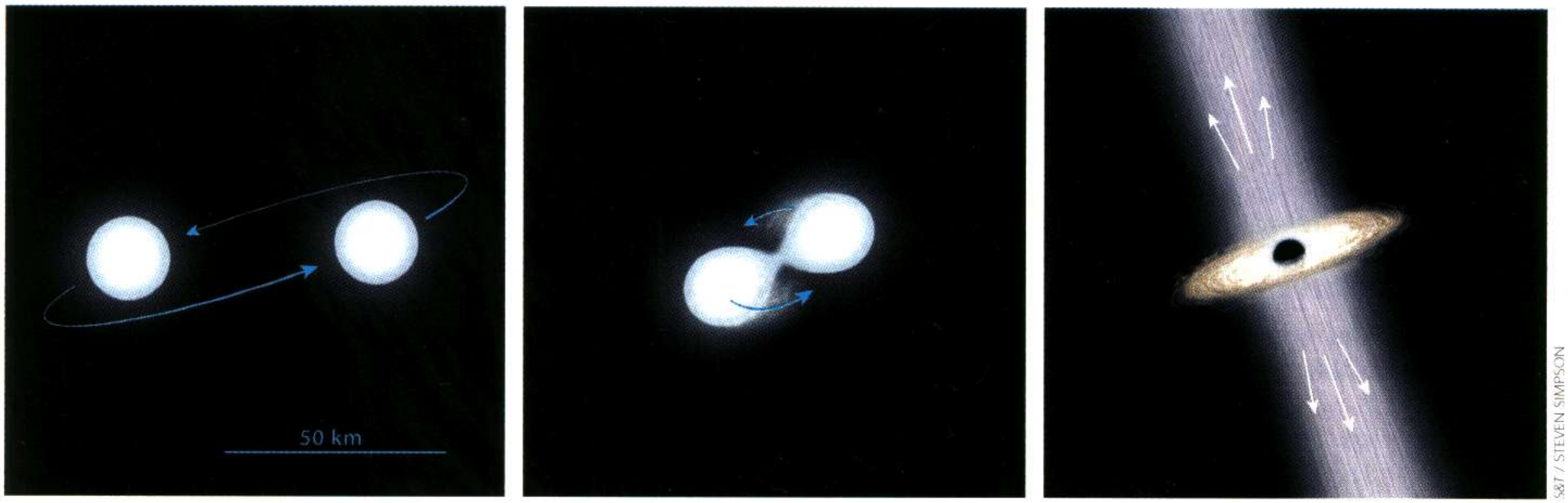
Dr. John Horack, a research scientist in the Space Science Laboratory at MSFC and a former graduate student, Dr. Gorson Emslie plotted CGRBs according to their brightness. They found that at a point midway between the brightest and dimmest bursts, the number of bursts thins out very rapidly. If Cosmic Gamma-Ray Bursts range in power as much as other objects in the sky such as stars (whose strongest are believed to be a million times more powerful than the weakest), then the number of dimmest bursts shouldn't drop suddenly because there would always be brighter bursts farther out to see.

However, the number does drop significantly. This means that one of two things are happening. Either CGRBs do not have a wide range of intensity, thereby making observers lose contact with weak bursts because there would be no brighter ones farther out to see, or that the universe is accelerating as it expands. It was found that 80% of CGRBs have a range of only 6 to 1 from brightest to dimmest. There is however, no known counterpart in nature that is as tightly limited. On the other hand, if the universe is accelerating, then it would thin out what could be seen at the furthest reaches of astronomers' detection devices, thereby creating a sudden drop in the number of dim burst, much like the drop observed. "It's OK to say that the sources of gamma ray bursts range in size by more than a factor of six to one, but if you push it too far I'm going to require that the universe is accelerating. And that means gravity doesn't work the way we thought it did" (Research Review '94, Emslie).

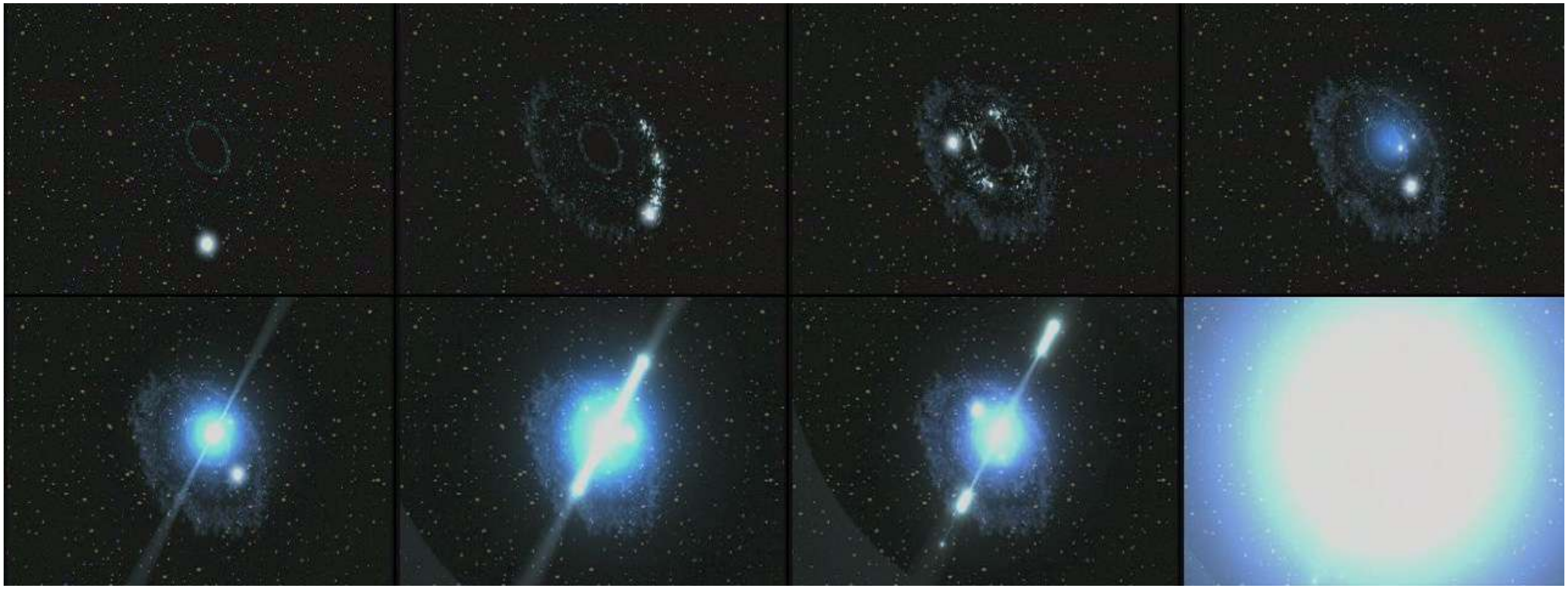
One of the most substantial confirmed discoveries related to Gamma-Ray Bursts is that of the origin of Soft Gamma Repeaters. In 1992, Robert Duncan and Christopher Thompson, both astrophysicists, suggested that SGRs were super-magnetized neutron stars created by supernova explosions, which they called Magnetars. These were to have magnetic fields of up to an astonishing 10^{15} *Gauss*. Many astronomers were skeptical of this claim but Chryssa Kouveliotou and a team of scientists found that Duncan and Thompson were right.

Kouveliotou and her team found 7.5 second pulsations from SGR 1806-20 indicating a spinning neutron star. The rotation of this star is decreasing in speed rapidly which could only mean that is being slowed down by super strong magnetic fields. Confirmation of their discovery was found on August 27, 1998, when SGR 1900+14 emitted an intense burst of Gamma-rays. Several satellites detected the burst and the X-ray emissions were found to have a period that increased dramatically during the burst. This slowdown implied a magnetic field of almost a quadrillion gauss. "The importance of this discovery goes beyond just adding a new oddity to the list of star types, it ties together two rare, very peculiar classes of stars we have been puzzling over, and puts the evolution of neutron stars and even galaxies in a new light" (Science@NASA: Magnetars, Kouveliotou).

Cosmic Gamma-Ray Bursts are still one of the biggest mysteries of the cosmos. It has been listed as one of the top 100 stories of Discover magazine and in the top ten of Science magazine. It has been the subject of over 3000 papers and has yet to be solved. Even the name 'Gamma-Ray Burst' is misleading because it gives off its energy in many wavelengths. It was named so because observers only saw the Gamma-rays and thought it emitted only this kind of energy. But it was the scientists' ability to see which was limited, not the phenomenon. CGRBs have led to the development of new technologies such as BATSE, ROTSE, GCN, LOTIS (Livermore Optical Transient Imaging System), and others. With the aid of these technologies, recent clues from GRB990123, and clues yet to be discovered, scientists are eager to discover proof of the cause of these catastrophic explosions that take place in the far reaches of space. Some answers might be solved in the upcoming Fifth Huntsville Gamma-Ray Burst Symposium in Huntsville, Alabama taking place in October. There, researchers from all over the world will share their theories and observations to try to find solutions to one of the greatest mysteries of modern astro-physics (NASA Space Science News).



A widely accepted theory of the origin of Cosmic Gamma-Ray Bursts: In the last few seconds of a binary neutron star's life, the two tiny, massive stars spiral together at ever-increasing pace, shredding orbital energy by gravitational radiation. They combine in the last moments to form a black hole briefly surrounded by a disk of debris. The disk is so hot and dense that it blasts jets from its faces powerful enough to account for a GRB.



Another theory of the origin of Cosmic Gamma-Ray Bursts: A star orbiting a black hole is shredded by tidal forces and spirals in, generating an intense bust of gamma and other radiation as the star's matter is compressed and super-heated on its way to oblivion.

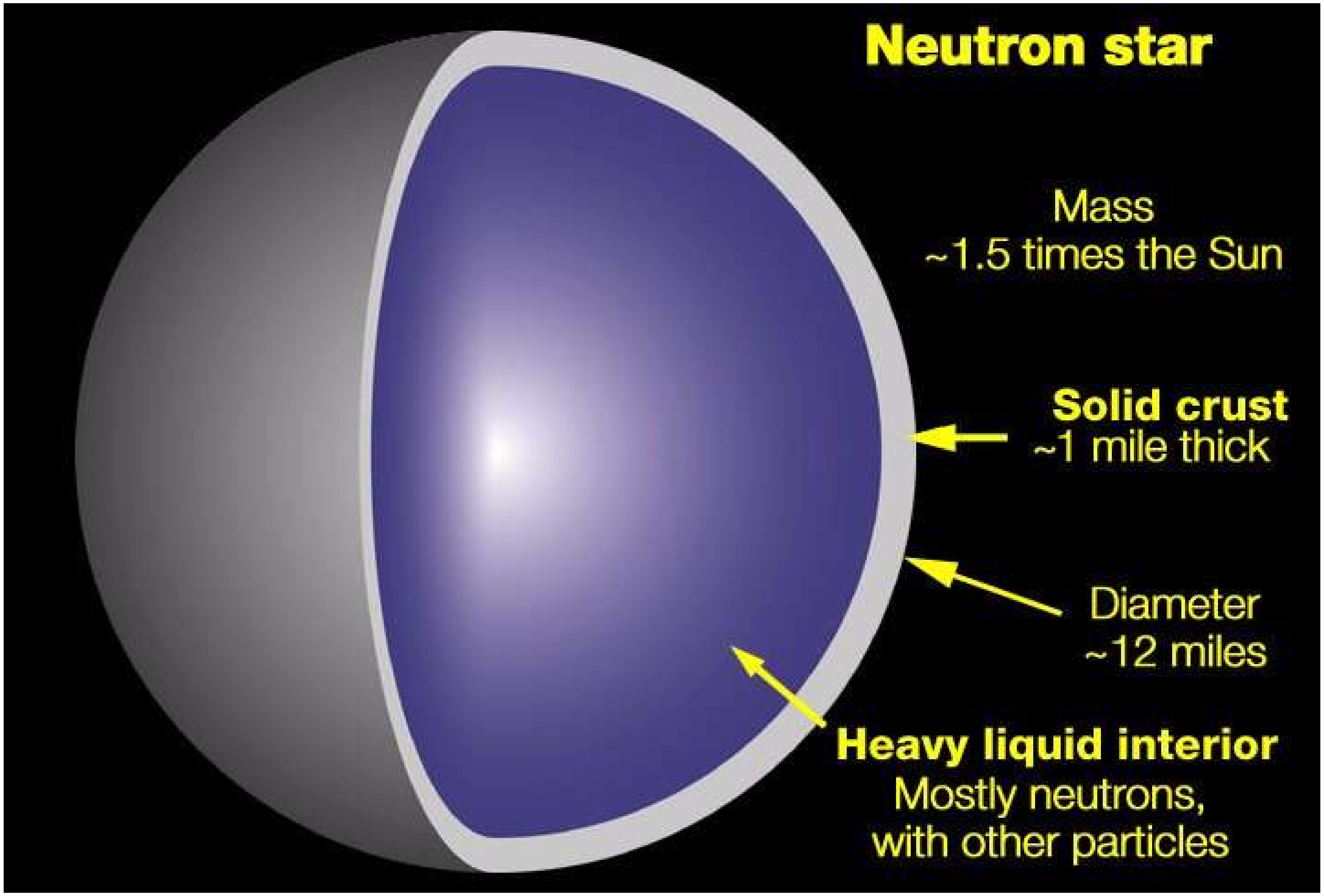
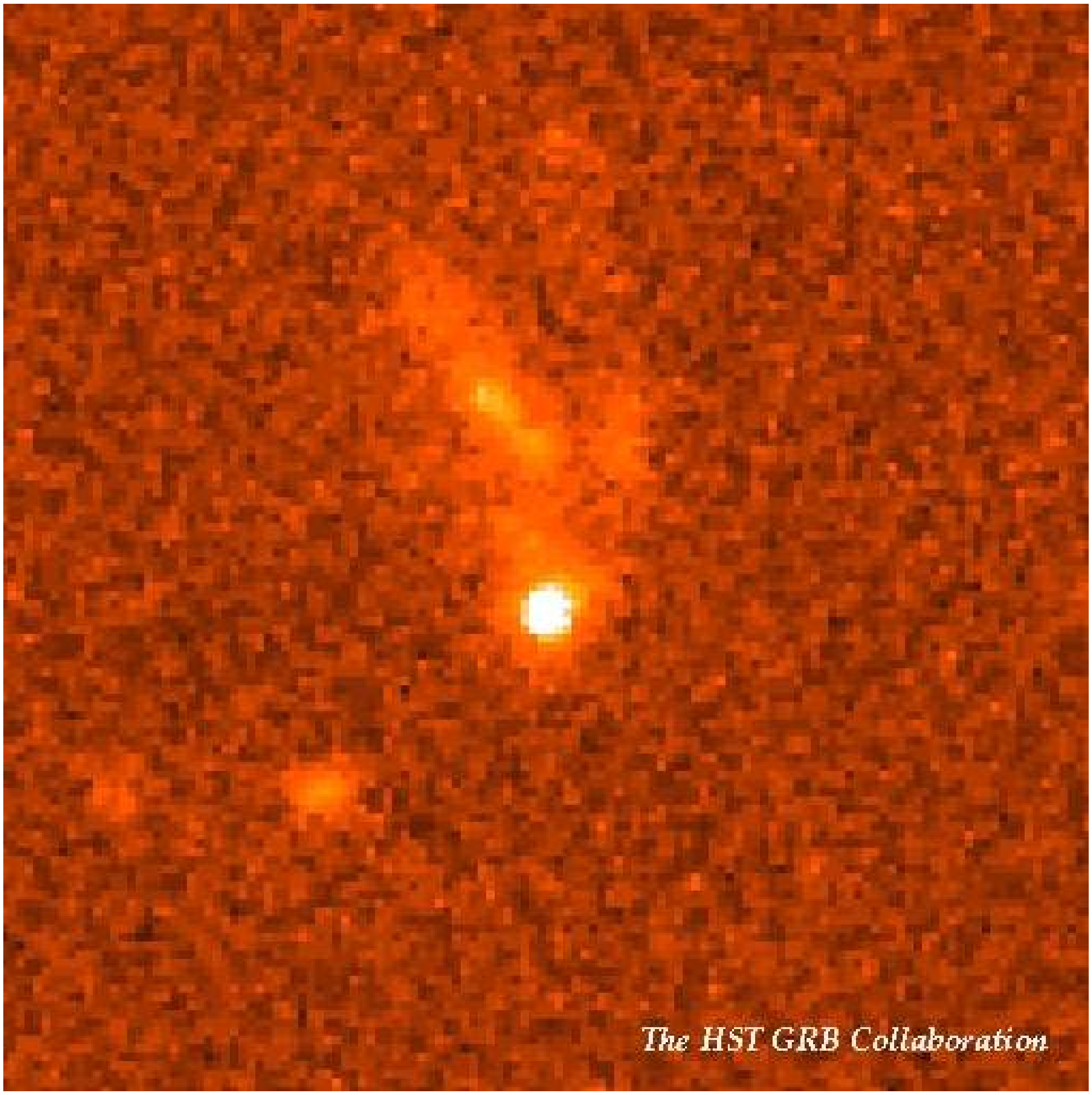
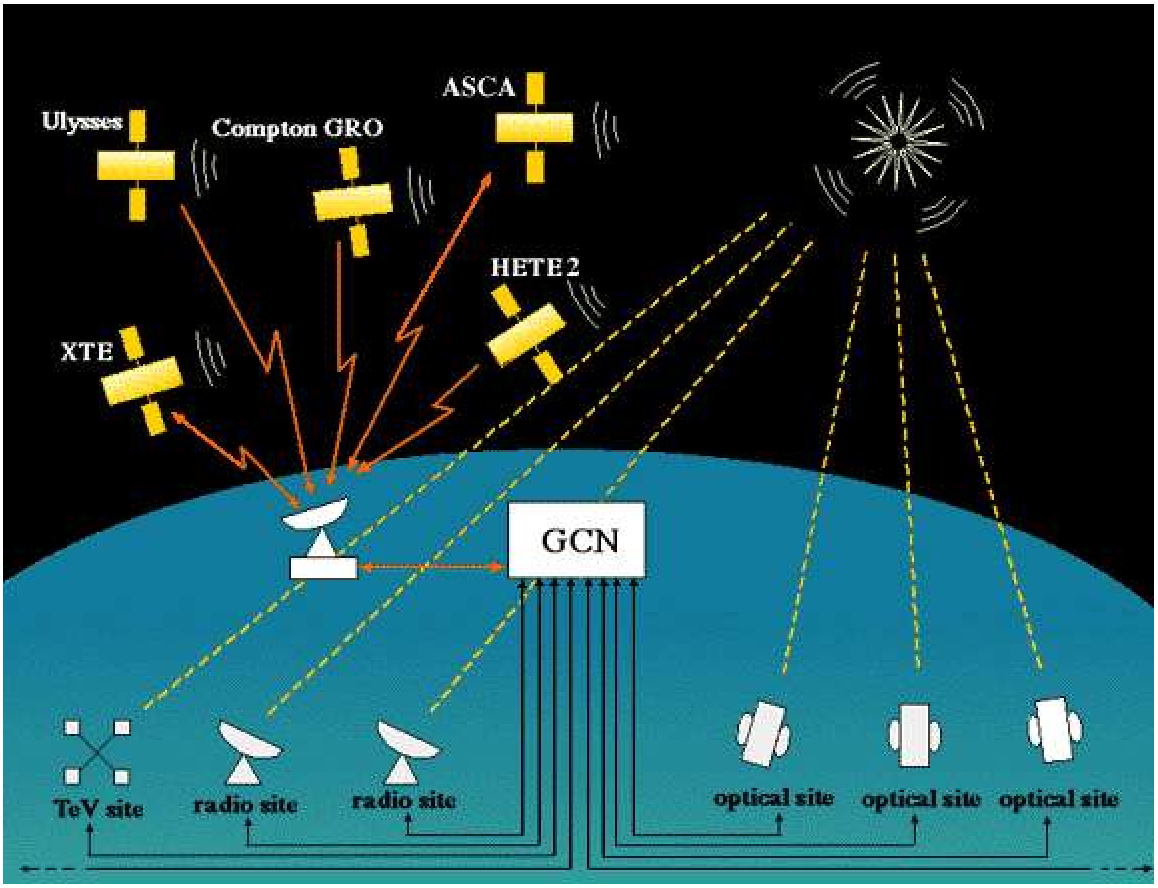


Diagram of a Neutron Star, the primary component of the two most accepted theories of the origin of Cosmic Gamma-Ray Bursts.



Hubble Space Telescope image of the GRB990123 optical afterglow seemingly imbedded in an irregular-shaped host galaxy



Simple diagram of the Gamma-Ray Burst Coordinate Network. It dramatically decreases the time it takes to send positions of CGRBs to various observational sites by use of the Internet. It was the GCN that let the observations of GRB990123 become possible.

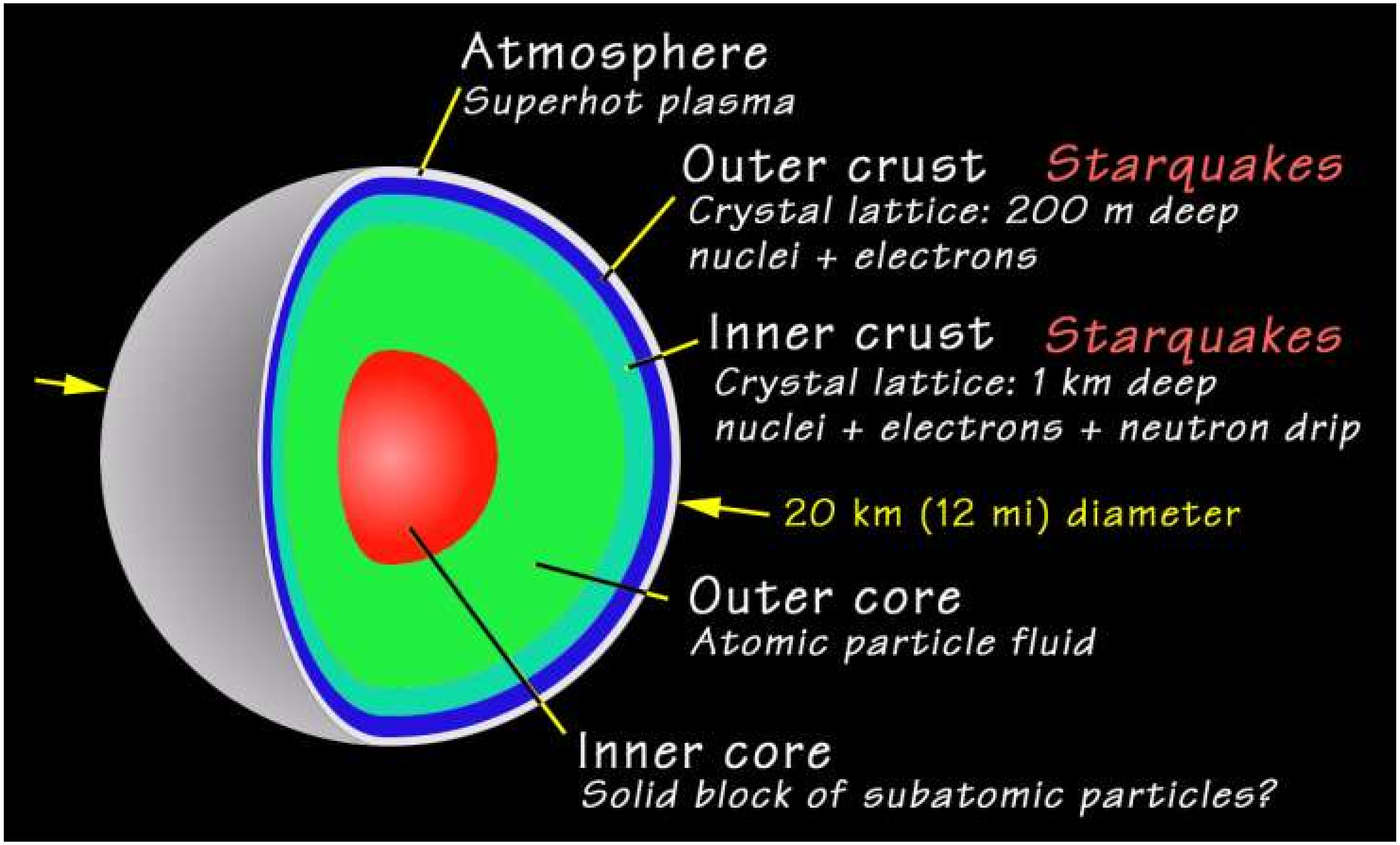


Diagram of a Magnitar, a neutron star with magnetic fields of up to 10^{15} Gauss. It is a major discovery from the study of Gamma-Ray Bursts and is the source of Soft-Gamma Repeaters.

Terrestrial Gamma-ray spike over a violent thunderstorm. One of the many discoveries made by BATSE.

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Glossary

Arc-minute: A measure of angle of view in the sky. The Sun takes up about 30 arc-minuets.

Big Bang: Theory of the origin of the universe.

Black Hole: A singularity in space with gravitational fields so intense that not even light can escape it. It is a possible outcome of a star collapsing.

Cosmic Radiation: Radiation of a very high energy and great penetrative power which emanates from cosmic regions.

Cosmological: Referring to Cosmology, the study of the origin of the universe. "Cosmological Distances" means distances so far away that the events occurred in the early universe.

Clandestine: Secret, Hidden.

Electromagnetic Spectrum: All the different wavelengths of light from Radio to Gamma.

Electrons: Particles with 1 elementary charge. (-)

ergs: A unit of work (About 1000 ergs can lift one gram one centimeter).

Gauss: Common unit of strength of a magnetic field. 1 Gauss = 10^{-4} Tesla. (A refrigerator magnet is about 100 Gauss).

Interstellar Medium: The material which is found in-between stars.

Isotropic: Dispersed evenly.

KeV: Kilo-electron Volt. A unit of energy equaling 1000 electron-volts. (1 Electron-volt is 1 elementary charge per volt which equals 1.6 X 10^{-19} Joules).

Magnetic Field:

Magnetic Field Lines: The lines through which the magnetic field of an object follows.

Neutron Star: One possible remnant of a high mass star. The mass of a neutron star ranges from 1.4 to 3 solar masses. Neutron stars form when the gravitational pull is strong enough to force protons and electrons close enough that they combine into neutrons. Because the force of gravity is so strong, the neutron star is compacted down to 10 to 15 km in size. It's density is about 100 trillion grams per cubic centimeter. As the star collapses the spin increases, as does the magnetic field. This causes strong radio emissions. If we detect these emissions, then we call the neutron star a pulsar (ASTR100 page, Miller).

Particle Accelerator: Machine used to accelerate particles in order to smash them into other particles at high speeds.

Redshift: Stretching of light due to the expansion of the universe.

Relativistic: Pertaining to the Theory of Relativity, meaning close to the speed of light.

Scintillate: To flash light.

Solar Flare: Eruptions on the 'surface' of stars.

Spectroscopic: Pertaining to a spectrum.

Supernovae: When a dying star explodes.

Transient: Temporary / short lived.