

Exploring the Universe

Roger Blandford



In mid-February, I participated in a NASA Science Update press briefing that presented gamma-ray and radio observations of a flaring neutron star. A neutron star is a solar-mass worth of mundane and exotic nuclei and fundamental particles trapped by gravity at supranuclear densities, exhibiting superfluidity and superconductivity. The star is encased within a solid crust, a liquid ocean, a gaseous atmosphere, and a relativistic plasma magnetosphere capable of inducing zettavolt electromotive forces and radiating intense, coherent emission. Neutron stars are used to test general relativity and to search for gravitational radiation. The neutron star in question is also a “magnetar,” which gives it one further remarkable feature. The magnetic field strength is around a petagauss, a billion times larger than can be sustained on Earth and well over the quantum electrodynamic critical field. A magnetar is a star designed by a committee of physicists, each trying to outdo the other. On this occasion, it appears that a stellar flare occurred, released 13 orders of magnitude more magnetic energy than the greatest solar flare, and created a burst of gamma rays intense enough to reach across the galaxy and rattle our atmosphere.

The public reaction to this announcement, naturally, emphasized the apocalyptic. Of course, we have statistically larger threats to worry about, but the magnetar explosion does serve as a dramatic reminder that the human race is living in rented accommodations. By contrast, the astrophysicist’s response is to try to explain the details (and modesty plus lack of space preclude my telling you the true explanation). However, there is a third response that is germane at this time. The discovery of a magnetar explosion, for all its impressive credentials, is actually commonplace. It exemplifies the strange new worlds we usually find every time

we develop a new observing capability. No one has called astrophysics “normal science” recently.

Vision for Space Exploration

In January 2004, President Bush announced his Vision for Space Exploration, in which he committed the nation to exploring the “solar system and beyond,” returning humans to the Moon before 2020, and ultimately sending them to “Mars and beyond.” NASA then began a radical transformation directed towards achieving the president’s ambitious goals. At the same time, and somewhat ironically, the funding for the wildly successful Explorer program was halved. It was *Swift*, the latest Explorer, that produced the most detailed observations of the exploding magnetar just one month after launch.

Most astronomers and physicists have reacted to the president’s announcement and NASA’s response with suspicion. I do not think their response is because of hostility to the manned space program. Although some of us embrace it enthusiastically, others have a position similar to mine on football. I do not care much for football, but most Americans, including the rest of my family, do. So when the Superbowl comes around, I am happy for them and do not storm around the house trying to turn off the TV. We astronomers and physicists fear that the Vision for Space Exploration is being implemented too hastily, with a daunting schedule, whose technical realism has not been validated, and whose likely total cost is not being addressed. I recall the admonishment of Richard Feynman in a similar context: “For a successful technology, reality must take precedence over public relations, for nature cannot be fooled.” The manned space program does not seem to be following the “go as you pay” strategy advocated in 1990 by the Augustine Commission and echoed by subsequent National Research Council studies. Instead, there appears to be a headlong rush to commit precious resources in a manner that could lead to disappointment and waste.

In addition, we worry about the impact of the president’s vision on US space science missions. These take a long while, sometimes decades, to complete. The careers of some of the most capable and creative engineers and scientists in the US are invested in space science. Accordingly, there is a careful and painful process—involving comprehensive and inclusive decadal surveys—that transforms a wish list, whose execution would exhaust the gross national product of the Milky Way into a prioritized, realizable, and updatable program, which NASA, to its credit, has largely adopted. The process is not perfect, but it works, and the results are there for all to see.

Now the fine print of the vision and subsequent implementing documents, together with the president’s 2006 budget, leaves room for a robust space science program. However, NASA is taking on an expanding portfolio of new responsibilities with large and unknown costs. The Moon–Mars program has top priority, and its integrated cost, not yet estimated, has been guessed to be many hundred billion dollars. The immediate bill for returning the space shuttle to flight has been far greater than anticipated. The long-term commitment to the International Space Station, whose purpose has not yet been clearly articulated, is as strong as ever despite NASA’s estimated price-tag, including the shuttle, of a *further* \$44 billion. In addition, the far-sighted Prometheus nuclear reactor program, which was to have supplied the propulsion for the *Jupiter Icy Moons Orbiter*, has had its liver pecked out by the federal eagle. *JIMO* has been put on hold in the current budget, three months after a \$400 million contract was awarded. However, like its namesake, Prometheus will live on as a very expensive program. To put it bluntly, the overall NASA budget is hardly likely to grow in the present climate, and so, given the huge commitments, space scientists fear serious triage in future budgets.

The *Hubble Space Telescope* dilemma illustrates the impending crisis perfectly. Astronomers were ex-

Roger Blandford is the director of the Kavli Institute for Particle Astrophysics and Cosmology at Stanford University.

pecting the space shuttle to mount a fourth servicing mission to keep the *HST* operating and to install a new camera and a spectrograph, to allow it to continue its remarkable program of discovery, for an advertised cost of roughly \$350 million. Following the *Columbia* tragedy, NASA Administrator Sean O'Keefe decided to cancel the mission on safety grounds. It was then proposed to service the *HST* robotically, and a \$150 million contract was awarded. A month later, that option was terminated on the grounds that the final cost would be much greater than \$350 million and too high to justify. The future of the *HST* will likely be decided in the political arena, and astronomers nervously wait to learn its fate.

I think there is another element to our reaction to the vision, and this is where magnetars come in. Astronomers are proud of what they have collectively accomplished, and they are suffering from wounded pride. In recent years, a standard model of a flat, accelerating, underweight universe has been established that has thrown theoretical physics into turmoil. The discovery of extrasolar planets, 150 and counting, demonstrates that our solar system is unrepresentative with immediate consequences for the quest for extraterrestrial life. Black holes of all sizes have been found in abundance and seem to power many of the most dramatic cosmic phenomena we observe. Going beyond astronomy, the impressive evidence for water from the Martian rovers, the daily solar weather reports that enable us to predict the "particlefall" on Earth, and the breathtaking images from *Cassini-Huygens* show NASA at its can-do best. The remarkable success rate of NASA's space science missions is a miracle to anyone who has been involved in one in the months prior to a launch! Just as on any opening night—although with launches there are no successive nights—all that hard work and experience, the collaboration between scientists and engineers, and that between NASA, universities, and industry, really do come together.

These enduring space science discoveries have both used and stimulated other disciplines—physics, of course, but now also planetary science, engineering, chemistry, biology, and computer science. Even more important, space scientists have embraced their responsibility to engage and inform the public, especially schoolchildren. We have an easy job. Sit next to someone on a plane. If you want to talk to them, tell them you are an astronomer; if you don't, try rocket

scientist! The public appears to understand that we are all truly fortunate to live in one of the great epochs of discovery and takes a vicarious interest in what we are doing. I assert that the great success of space astronomy has carried NASA through some rough times.

Future program

The planned astronomy projects (and the prospects in other areas of space science are as exciting) include:

► The *James Webb Space Telescope* will observe the youngest and most distant galaxies in the infrared and show us how they really formed.

► The *Space Interferometry Mission* will observe stars with microarcsecond positional accuracy so as to find new planets.

► The *Constellation-X Observatory* will observe gas just before it crosses a black hole event horizon and test general relativity.

► The *Laser Interferometer Space Antenna* will open up the gravitational radiation spectrum and also test general relativity by observing the merging of distant black holes.

► The Joint Dark Energy Mission is designed to study the details of the universe's acceleration.

► The Inflation Probe should measure the polarized microwave radiation that, it is conjectured, comes from the epoch of inflation.

► The Black Hole Finder Probe will transform very hard x-ray astronomy, largely ignored for 30 years, and enable astronomers to see into the heart of gas-enshrouded quasars.

► The Terrestrial Planet Finder will seek oxygen- and water-bearing Earth-like planets around nearby stars.

These are all wonderful projects, but they are very expensive, and priorities will have to be set. Many astronomers are concerned that future choices will be based less on the proven criteria of scientific timeliness, technical readiness, and fiscal credibility and more on resonance with a narrow interpretation of the president's vision. In particular, they worry that programs with a connection to life will be favored over fundamental investigations in the inanimate, physical sciences. The uncertainty is taking its toll on the talented younger scientists and university students who have started working on these projects. They do not understand why their voyages of exploration are being interrupted and some of the ships recalled to port.

What is to be done?

First we have to adapt, not because we have somehow failed, but because

the rules have been changed and there is no going back. We have to make the case anew for space science, using a different vocabulary. We have to explain why all science is exploration, whereas not all exploration is science. In particular, we must not allow science—the systematic and fundamental understanding of the world around us—to be redefined. We should be careful not to disparage the larger part of the vision, which may be unconcerned with science but which is a valid activity for NASA to undertake if it has a popular mandate to do so. We must now explain why NASA's contributions to astrophysics and cosmology will "improve life here" and are as interesting and important as the wish "to extend life to there" and "to find life beyond," to quote the new NASA vision statement.

We must also exercise our democratic rights, contact members of Congress (and, indeed, buttonhole anyone we meet), and not be reticent about explaining the issues and asking for what we think is best. Congress is getting plenty of help from other sources! Perhaps no community is more important in this regard than our physics students. After all, the vision is so ambitious that they will be in the middle of their careers before it is completed! Those students will provide the core of the technically sophisticated workforce needed in the future. Are they inspired by the opportunities in space science the same way that my generation was aroused by the response to Sputnik? How important is it to them to understand dark energy, how galaxies are born, what happens around black holes, what other planetary systems look like, and so on? If it is important, then maybe they will send an e-mail to their representatives and senators expressing their views.

The coming year will be pivotal for NASA. On paper, its commitment to space science is as strong as ever, but it is taking on some formidable challenges that will put pressure on its ability to continue with its broadly based science program. Moreover, NASA will need to sustain public interest and political support over the coming decade, and wonderful discoveries like the magnetar explosion should surely help. I hope that NASA's leadership will continue to engage the astronomy and physics communities in planning how best to explore the universe. ■