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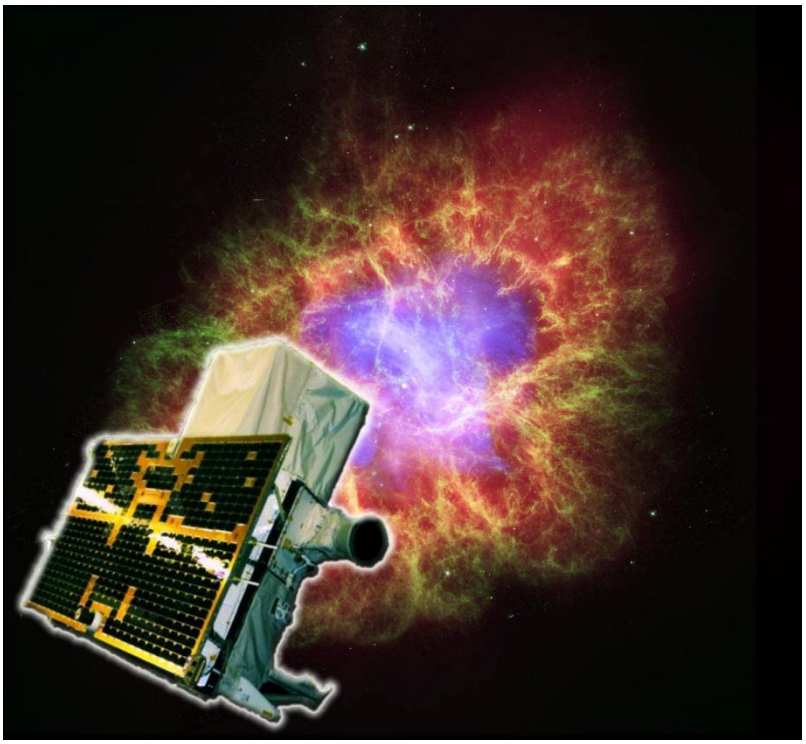
AGILE DISCOVERS CRAB NEBULA FLARES



The AGILE satellite with a composite *Hubble-Chandra* image of the Crab Nebula (photo credits: ASI, NASA).

THE ITALIAN SATELLITE AGILE HAS DISCOVERED THAT THE RENOWNED CRAB NEBULA PRODUCES POWERFUL GAMMA-RAY FLARES LASTING SEVERAL DAYS. CONFIRMED BY THE NASA *FERMI* SATELLITE, THIS STARTLING DISCOVERY WILL REQUIRE ASTROPHYSICISTS TO RETHINK FUNDAMENTAL PARTICLE ACCELERATION PROCESSES IN COSMIC SOURCES.

The most recent AGILE discovery has astonished the scientific community. Astronomers have long believed the Crab to be constant, an ideal standard candle. However, from September 19 to 22, 2010 AGILE detected a giant gamma-ray flare and, due to its rapid alert system, made the first public announcement on September 22, 2010. This finding was confirmed the next day by the Fermi Observatory. AGILE detected a flare from the Crab also in October, 2007. Both the AGILE and Fermi teams have published papers containing their findings in the January 6th' issue of Science Express. AGILE is an astrophysics mission sponsored by the Italian Space Agency (ASI) and the Italian Institutes of Astrophysics (INAF) and Nuclear Physics (INFN).

The Crab Nebula is among the most remarkable sources known to astrophysicists. It is the impressive remnant of a supernova that exploded in 1054 C.E., and is a very bright X-ray and gamma-ray source. At its center lies a pulsar (a neutron star rotating 30 times a second) producing a very energetic electromagnetic wind of waves and particles. The Crab system (the pulsar and nebula) provides an ideal laboratory for studying some of the most mysterious physical processes in the universe. The strength and other unique characteristics of the Crab (including its apparent stability) have led astronomers to use it as a standard reference for X-ray and gamma-ray measurements.

AGILE Principal Investigator Marco Tavani (INAF) discusses the implications of the flares, as well as their possible causes: "We have determined that the pulsar is not the source of the transient gamma-ray emission. Our main "suspects" are the very strong shocks produced by the pulsar particle wind in the inner Nebula. Our observations of the flares give us a fantastic close-up picture of the process of extreme particle acceleration. This process occurs regularly in the Crab in a less dramatic way and is very difficult to study; for this reason, its mechanisms are not yet well-understood by astrophysicists. Our findings demonstrate that particle acceleration is much more efficient than previously believed. These will have profound consequences for astrophysical theories and, possibly, for terrestrial applications of plasma physics. AGILE also detected an earlier episode of powerful gamma-ray flaring from the Crab in October 2007. We are currently working with our collaborators across the globe to monitor the Crab Nebula intensively for additional flares. This is a further demonstration of the ability of AGILE to make important contributions to astrophysics and fundamental physics."

"Despite its relatively small size," says Enrico Flamini, ASI Chief Scientist, "AGILE has achieved optimal performance at a very competitive cost because of its innovative technology. From this point of view, AGILE has kept its promise. The Italian high-energy astrophysics community is demonstrating its competitiveness. This community also plays an important role in *Fermi*, and ASI supports data analysis for both AGILE and *Fermi* at the ASI Science Data Center in Frascati."

"The discovery of Crab Nebula variability by AGILE and its confirmation by *Fermi* will deepen our understanding of the cosmic accelerators that produce much higher particle energies than those obtainable in laboratories on Earth," says Benedetto D'Ettorre Piazzoli of the INFN Executive Board. Ronaldo Bellazzini, an INFN scientist and *Fermi* team member adds: "The occurrence of such brief gamma-ray flares demonstrates a very efficient and unexpected mechanism of particle acceleration. The *Fermi* satellite contributed greatly to determining the spectral properties of the Crab emission."

"It is the first time that a gamma-ray telescope finding has led to an observation by the *Hubble* Telescope (HST)", says Patrizia Caraveo of INAF. The *Hubble* image of the Crab Nebula has helped astronomers to find clues about the origin of the transient emission, and we plan to continue close observation of the Crab with HST in the future". "The *Chandra* Observatory, with its unprecedented imaging capabilities, is also playing a crucial role in studying X-ray emission from the inner Crab Nebula," says Martin C. Weisskopf, *Chandra* Mission Scientist at NASA Marshall Space Flight Center. "*Chandra* has established a program of monitoring the Crab once per month, and this will be critical in the attempt to identify the transient gamma-ray emission site."

More information on the AGILE Mission: http://agile.iasf-roma.inaf.it, http://agile.asdc.asi.it.

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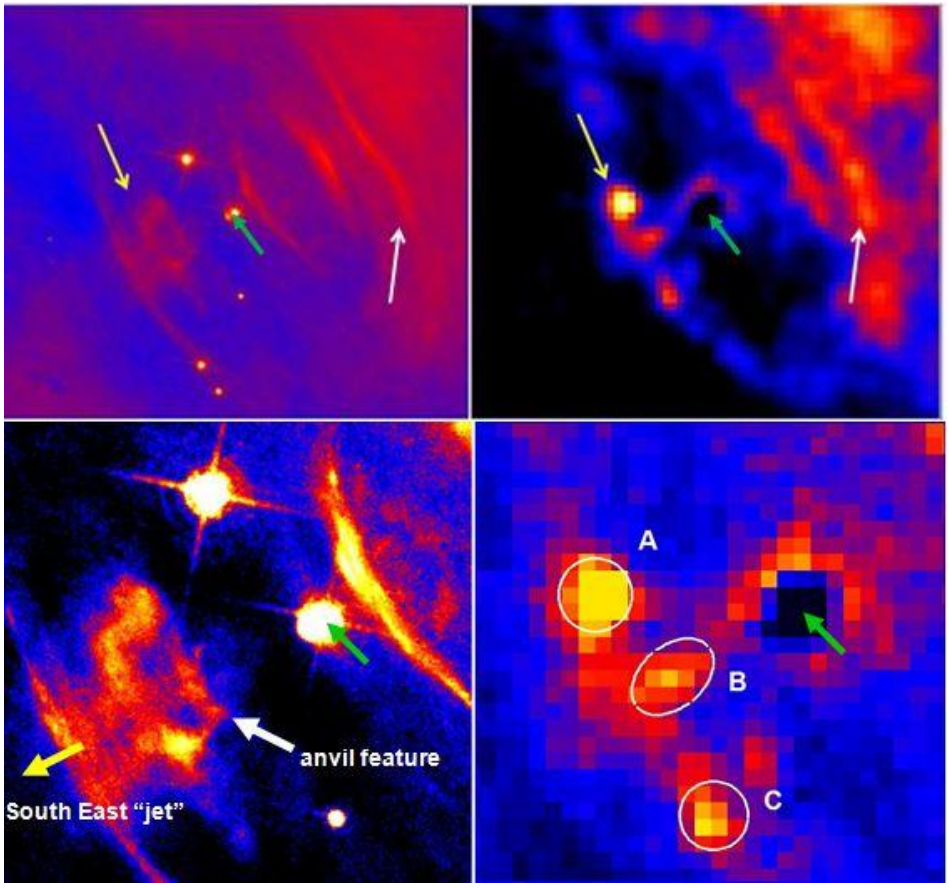

Fig. 1 – HST and *Chandra* imaging of the Crab Nebula following the Sept., 2010 gamma-ray flare. *(Top left panel:)* HST optical image of the inner nebula region (approximately 28"x28", North is up, East on the left) obtained on October 2, 2010. The pulsar position is marked with a green arrow in all panels. White arrows in all panels mark interesting features compared to archival data. *(Top right panel:)* the same region imaged by the *Chandra* Observatory ACIS instrument on September 28, 2010 in the energy range 0.5-8 keV (level-1 data). The pulsar does not show in this map and below because of pileup. *(Bottom left panel:)* zoom of the HST image (approximately 9"x9"), showing the nebular inner region, and the details of the "anvil feature" showing a "ring"-like structure at the base of the South-East "jet" off the pulsar. "Knot 1" at 0".6 South-East from the pulsar is saturated at the pulsar position. *(Bottom right panel:)* zoom of the *Chandra* image, showing the X-ray brightening of the "anvil" region and the correspondence with the optical image.

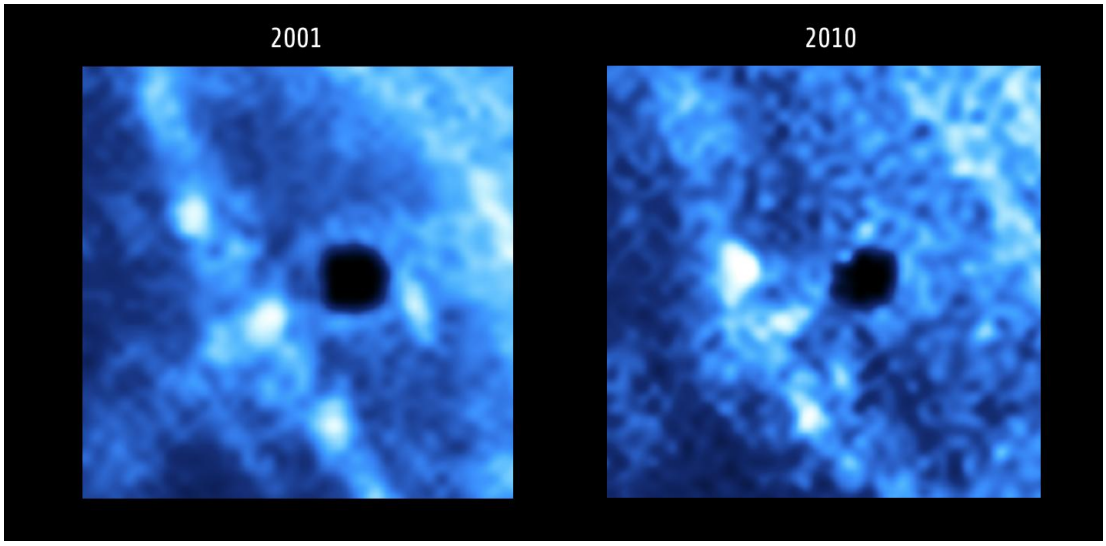

Fig. 2 – A comparison of two different *Chandra* X-ray imaging of the inner Crab Nebula (the Crab pulsar is so bright that it saturates, and shows up as a black region in these maps because of photon pileup). *(Left panel:)* an X-ray image obtained in 2001 (7 hour observation). *(Right panel:)* the same region imaged by *Chandra* on Sept. 28, 2010 (1.4 hour observation). Several of the inner Crab nebula features are known to vary within a timescale of months/years. Future *Chandra* monitoring of the Crab is critical in the attempt to identify the site or sites of the gamma-ray flares.