JUNE 2021 | VOL. 11

CENTRE FOR ASTRO-PARTICLE PHYSICS

THE OFFICIAL NEWSLETTER OF THE CENTRE FOR ASTRO-PARTICLE PHYSICS

A limited number of top-up bursaries are available for MSc and PhD students from the CAPP.

Interested students should contact Ms Anna Samara Larmuth (**capp@uj.ac.za**) with their academic transcripts.

Further Your Studies

CUTTING EDGE RESEARCH BY CAPP GROUP MEMBERS

Scientists and students at the Centre for Astro-Particle Physics focus on research in Gamma-ray Astrophysics, Neutrino Astrophysics, Neutrino Physics and Gravitational Wave Physics.

We perform theoretical studies as well as data analysis and modelling. All three experimental facilities that we are involved in, namely the Fermi Gamma-ray Space Telescope; the Cherenkov Telescope Array and the KM3NeT Neutrino Telescope, perform cutting edge research.

Thus, working at CAPP can provide students and postdoctoral fellows opportunities to get involved in the science of these state of the art experiments, learn the latest techniques and interpret data collected with various instruments.

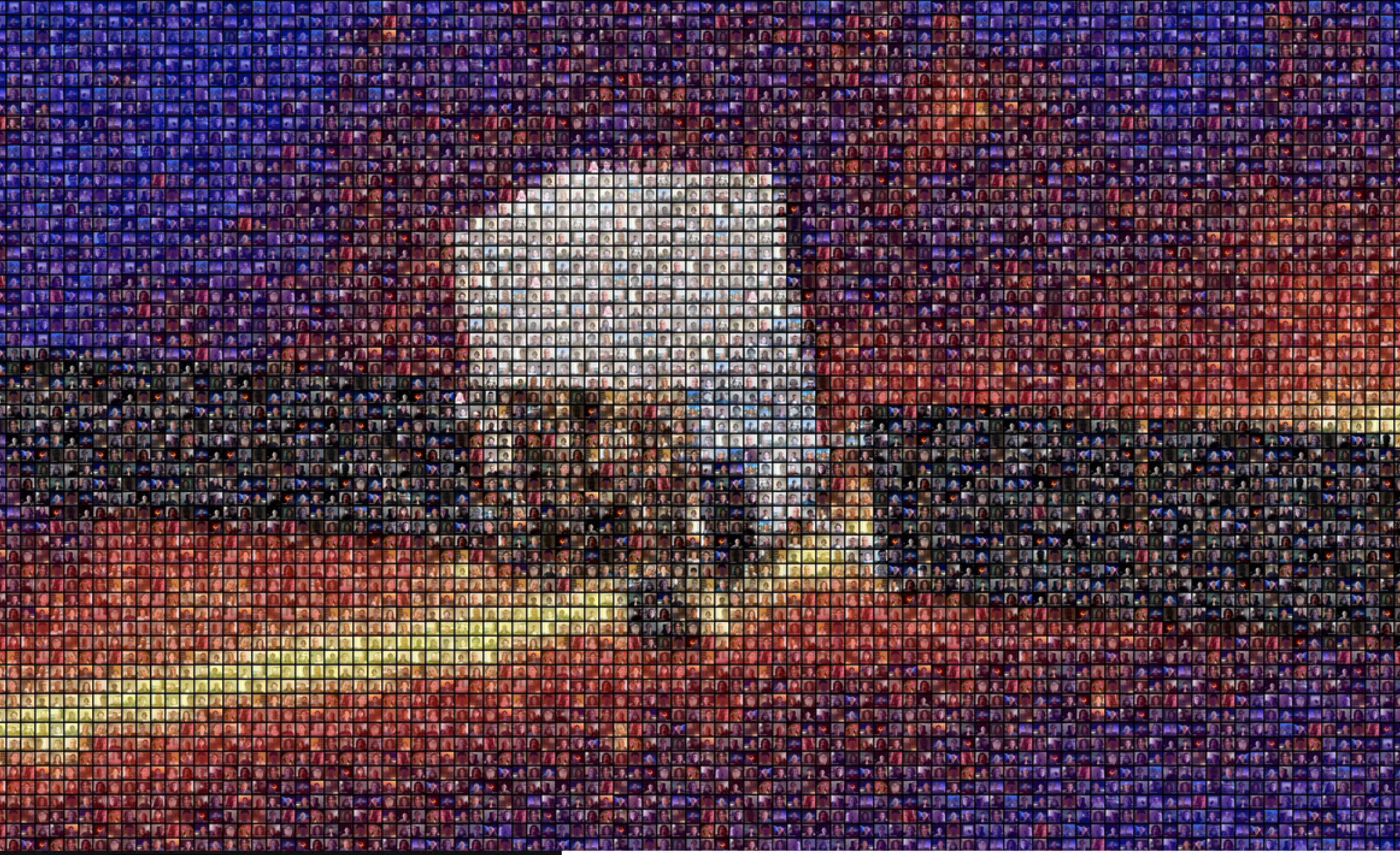
Research in Astro-Particle Physics requires strong background in Physics, Mathematics and computer programming.

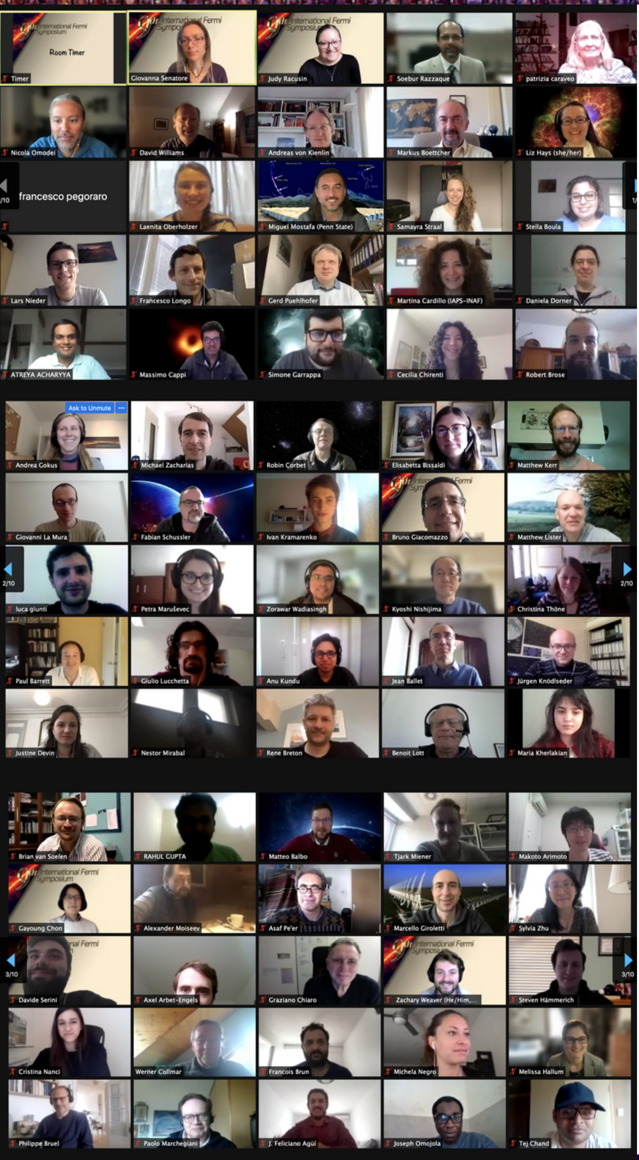
Although some theoretical studies are still done on papers with pencils, numerical computations and simulations on computers are the main tools to make theoretical predictions these days. Data analysis and modeling also require significant computer skills and learning specialised software.

Students who would like to pursue postgraduate studies in AstroParticle Physics should choose Physics and Mathematics for their BSc degree.

The BSc Honours programme at the Department of Physics offer a wide range of advanced courses, including Astrophysics courses, that can prepare students for future MSc and PhD research in Astro-Particle Physics.

Honours students also get a taste of research by doing a project that helps them to prepare for MSc and PhD studies.





9TH INTERNATIONAL FERMI SYMPOSIUM

12 – 17 APRIL 2021

Due to the COVID-19 pandemic and current lock-down restrictions in South Africa, the Ninth International Fermi Symposium was held virtually for participants around the world.

This Symposium focused on the new scientific investigations and results enabled by Fermi, the mission and instrument characteristics, future opportunities, and coordinated observations and analyses.

As many as 500 participants from 5 continents around the world attended the virtual event from 12 to 17 April 2021, and will hopefully be able to attend the in-person conference at Misty Hills in 2022.

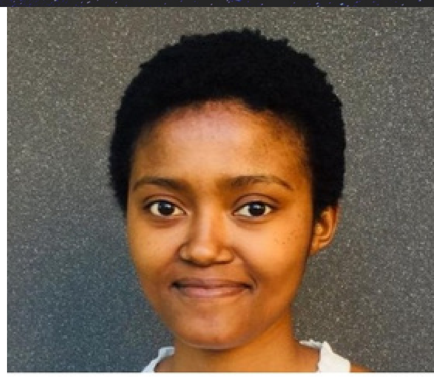
View participants' talks and posters using the following link:
https://indico.cern.ch/event/1010947/

or by viewing it on our website under the '**Fermi Symposium 2021**' tab.

RESEARCH FROM OUR CENTRE

Modelling the Diffuse Extragalactic Radio Background

RESEARCH BY NOMTHENDELEKO MOTHA



The radio emission from galaxies fills up the universe and accumulates over cosmic time to form a diffuse extragalactic radio background (ERB). Major contributors to the ERB are radio galaxies characterized by an active galactic nucleus (AGN) and normal galaxies associated with active star-formation typically observed near galactic regions with supernova remnants (SNRs). The radio emission from these galaxies is due to a mechanism called synchrotron radiation, resulting from relativistic electrons propagating helically in the presence of magnetic fields. In the case of radio galaxies, this radiation is modified by synchrotron self-absorption. In addition to this process, normal galaxies are additionally subjected to free-free absorptions from hot ionized gas in the interstellar medium (ISM).

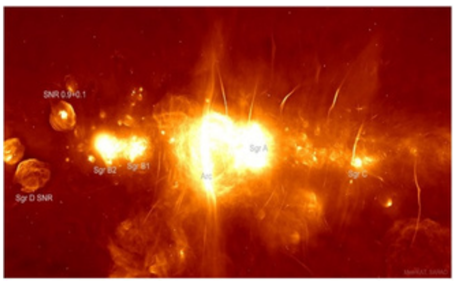


Figure 1: A detailed radio image of the Milky Way center captured by MeerKat, 2019. Credit: MeerKaT, SARAO

Thendi's research at CAPP is focused on updating the current estimate of the ERB model, proposed by Protheroe and Biermann in 1996, using the latest observational data from radio telescopes.

The intensity of the radio background depends on the radio luminosity spectra of galaxies and the number of galaxies per luminosity interval (also known as the luminosity function). To maintain consistency with the observed radio source count data, we took account of recent models for the source density evolution and luminosity evolution. We also considered for the strong correlation between infrared and radio luminosities of normal galaxies. The results show a dominance of normal galaxies at low flux densities. See figure 2.

Modelling the ERB enables us to study the evolution of different types of galaxies observed at various radio frequencies, the star-formation rate in normal galaxies and in our case, the implications for ultra-high energy γ-ray propagation in the universe. The high-resolution of modern radio telescopes such as the Square Kilometer Array (SKA) telescope and its precursor, the South African MeerKAT telescope, are expected to detect radiation from the most faint galaxies, including radio remnants that fill the intergalactic space, with a sensitivity limit of about 1 nJy/beam. This will enable more accurate and detailed predictions of the ERB.

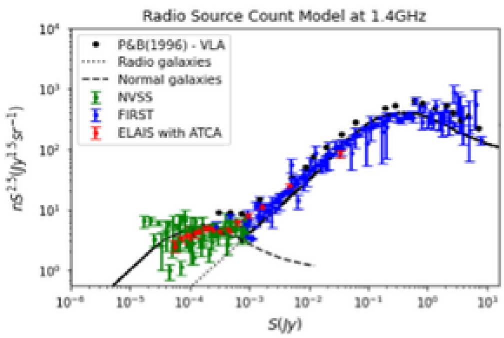


Figure 2: Normalised source counts $S^{2.5}n(S_\nu)$ model for normal galaxies and radio galaxies tested against data.

RESEARCH FROM OUR CENTRE

Propagation of High Energy Gamma Rays in the Blazar Jets and resulting effects on their Spectral Energy Distribution

RESEARCH BY MFUPHI NTSHASHA

Active galactic nuclei (AGN) shine brightly across the whole electromagnetic spectrum. According to the unified model for AGN, they come in several "flavours", differentiated mainly by their spectral features. One of the most brightest are quasi-stellar radio sources (quasars). Quasars are particularly bright in gamma radiation, and their emission fluctuates on short timescales indicating compact emitting regions. The brightest are the subclass of quasars known as blazars. These are thought to have their gamma-ray jets aligned very close to our line of sight.

An interesting aspect of AGN research is that by studying the light they emit, we can learn about their physical attributes. Some blazars display a distinct "dip" feature in their spectral energy distributions (SEDs). This dip is a deviation from the general shape of the SED in the gamma-ray band of the spectrum. The flux of gamma rays ~ 10 - 100 GeV fades slightly, producing a distinct dip in this energy range.

To address this problem this work explores the effect of the dense UV/optical photon fields orbiting close to the central engine (in a region of space called the broad-line region (BLR)) on these gamma rays. If indeed the effect is that BLR photon fields are responsible for absorbing 10 - 100 GeV gamma-ray photons then this will have implications on the production zone of gamma rays. To study this effect one needs to have a detailed spectrum of the BLR photon field.

The broad-line region of blazars were modelled with several mathematical functions, namely the Gaussian (Ga), Briet-Wigner (BW), power-law (PL), broken power-law (BPL) and smoothly broken power-law (SBPL). Success of the model was judged by fitting it to a composite absorption line spectrum of quasars. It was then applied to the well-known bright blazar 3C 279. Knowledge of the BLR spectrum allows us to determine its opacity to gamma rays in the jet.

It turns out that gamma rays in the ~ 10 to 200 GeV energy range are largely susceptible to the BLR photon fields of quasars. This can be seen in FIGURE 1 where the opacity value goes to a maximum around this energy range. The higher the opacity, the more difficult it is for the gamma-rays to pass through the BLR as they are absorbed. But energy and momentum must be conserved, and absorbed gamma rays obey this law via the pair production process. Pair production is a process whereby two colliding photons of different energies are annihilated and an electron and positron take their place. We calculated the spectrum of the electron-positron pairs produced in this way. Now with the presence of secondary pairs in the BLR, several scattering and radiation processes can take place. The mixture of the magnetic fields and the secondary pairs give rise to synchrotron radiation. The synchrotron photons are then inverse-Compton scattered as gamma rays. This is known as synchrotron self-Compton (SSC) radiation.

RESEARCH FROM OUR CENTRE

Findings

It was found that if the magnetic field in jet is of the order ~ 0.1 G or more, SSC emission from secondary pairs has the effect of filling the 10 - 100 GeV SED dip observed in 3C 279. Furthermore, this result implies that these gamma rays are produced near the outer edge of the BLR. This result is summarised by FIGURE 2.

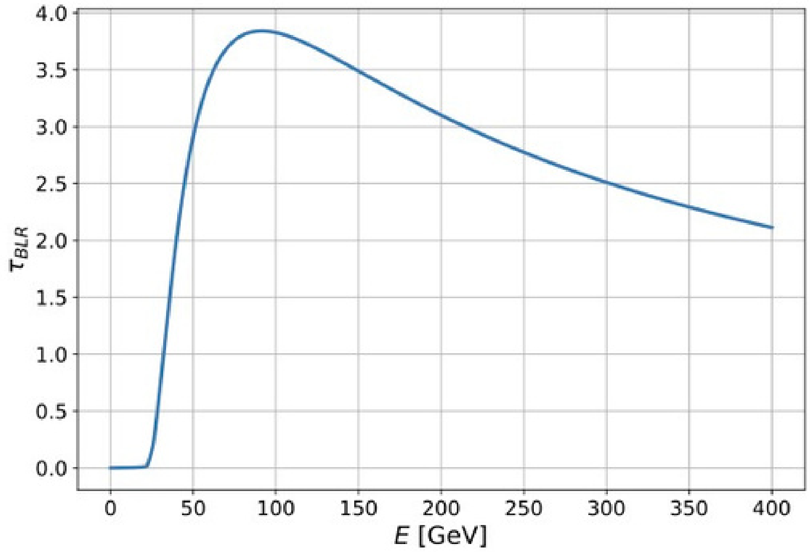


FIGURE 1. BLR opacity vs gamma-ray energy.
Gamma rays in the 10 - 200 GeV range experience greatest absorption.

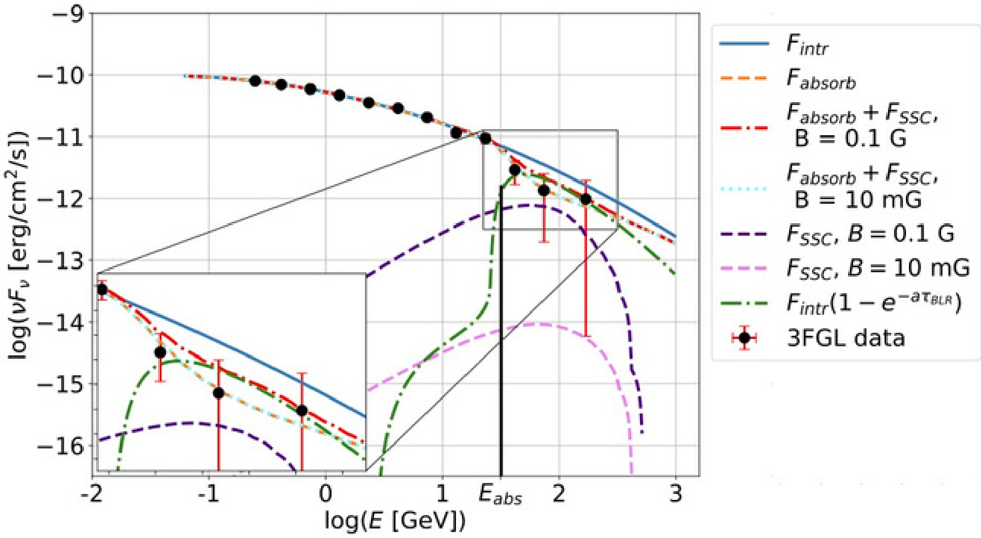


FIGURE 2. Spectral Energy Distribution of 3C 279 fitted with a log-parabolic function. The dip feature is fitted with BLR absorption. SSC emission by secondary electron-positron pairs partially fills the dip feature.

LATEST NEWS AND DISCOVERIES

The TESS telescope, which hunts for exoplanets, has discovered a bright gamma-ray burst.

WRITTEN BY ANNA SAMARA LARMUTH

There is no doubt in saying that NASA is well-known for its 'out of the blue' discoveries, and there is no exception when it comes to its TESS telescope, which has recently discovered a bright gamma-ray burst. A gamma-ray burst has never been discovered in such a way before, thus making it the first of its kind.

Discovering a bright gamma-ray burst is not an unusual find for astrophysicists. However, what makes this an interesting find, is that this is the first gamma-ray burst that has been discovered by a TESS telescope, which is usually designed to hunt exoplanets, not gamma-ray bursts.

This particular gamma-ray burst occurred on Oct. 16, thus inheriting the name 'GRB 191016'. A group of scientists were able to locate where the gamma-ray burst had occurred and how long it had occurred for. The new information uncovered from this discovery has led scientists to believe that the TESS telescope will not only be beneficial towards the hunting of exoplanets, but also towards the field of high-energy astrophysics as a whole. The peak magnitude of the gamma-ray burst is 15.1, which is not considered to be very bright, as it is 10,000 fainter than stars that can be seen by man. However, it must be kept in mind that gamma-ray bursts tend to be fainter, 160,000 times fainter to be exact, than even the faintest of stars.

In saying this, when we refer to how bright a burst is, it usually refers to how far away this burst occurred. This particular gamma-ray burst had been travelling for 11.7 billion years before the TESS telescope was able to detect it.

The burst started gradually fading after reaching its highest peak of brightness between 1,000 and 2,600 seconds, therefore, the TESS telescope was unable to pick up on any activity from the burst 7000 seconds after it had first detected it.

Now, the most important question surrounding the discovery is why an exoplanet-hunting satellite was unable to pick up on GRB 191016A, and a TESS telescope was. Well, actually NASA's Swift-BAT satellite, which is designed to hunt exoplanets, was the first to detect the burst. However, a mandatory check-up to find out the necessary details about the burst could not take place hours later, as the burst was located too close to the moon.

The reason why the TESS telescope was also able to detect the burst was because it happened to be looking at the same part of the sky where the burst had occurred, which if you ask an astrophysicist, is extraordinary because the TESS telescope moves its attention to a different section of the sky monthly.

Even though the TESS telescope was able to detect such a bright-gamma ray burst, scientists at the ground-base were unable to receive

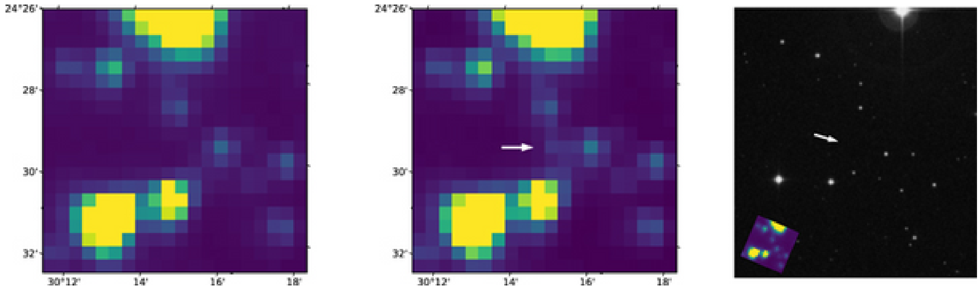
LATEST NEWS AND DISCOVERIES

data from the telescope until months later, and were not equipped to handle such data, as they were exoplanet hunters. While exoplanet-hunters were looking for new planets, the data from the TESS telescope was handed over to high-energy astrophysicists who were interested in finding out more about GRB 191016A.

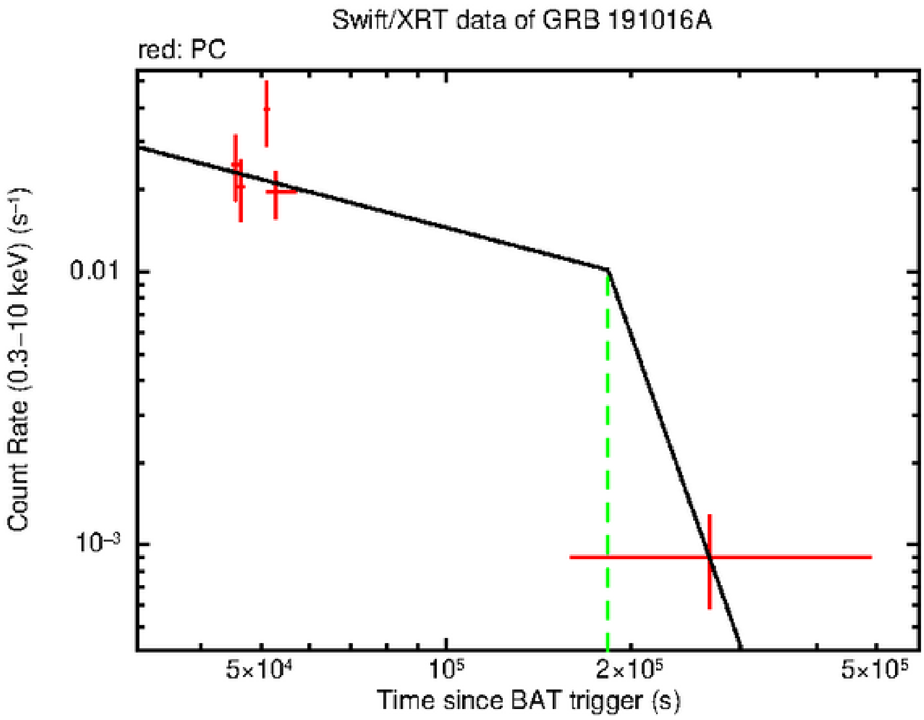
The reason why the data was handed over to high-energy astrophysicists is because the TESS telescope has a lot of potential for high-energy applications, and high-energy astrophysicists actually study explosions like gamma-ray bursts.

The TESS telescope uses light curves in order to determine how bright a gamma-ray burst is. For this burst in particular, three of these light curves were used in order to determine its brightness. Further information about the burst was collected from the ground-base observatories, as well NASA's Swift-BAT satellite.

The only space-based optical follow-up of a gamma-ray burst was able to be provided by scientists because the burst had reached its highest peak of brightness at a later stage, and it was higher than most average bursts, thus also allowing for multiple observations to be made of the burst before it had faded below the TESS telescope could detect.



TESS full-frame image in the cadence just before the BAT trigger (left) and at the peak flux of the burst (center). The emergence of the afterglow is apparent in the center of the image, indicated by the white arrow. The right panel shows the same region of the sky, with a slightly different orientation, in the Digitized Sky Survey (DSS); a small inset of TESS image is provided in the bottom left corner to demonstrate the change in orientation. CREDIT The Astrophysical Journal



TESS telescope spots bright gamma-ray burst. ScienceDaily. Retrieved May 10, 2021 from www.sciencedaily.com/releases/2021/04/210430135440.htm

You can view our website to see events, the latest news, images, and info regarding the research of our group members as they happen and when they happen.

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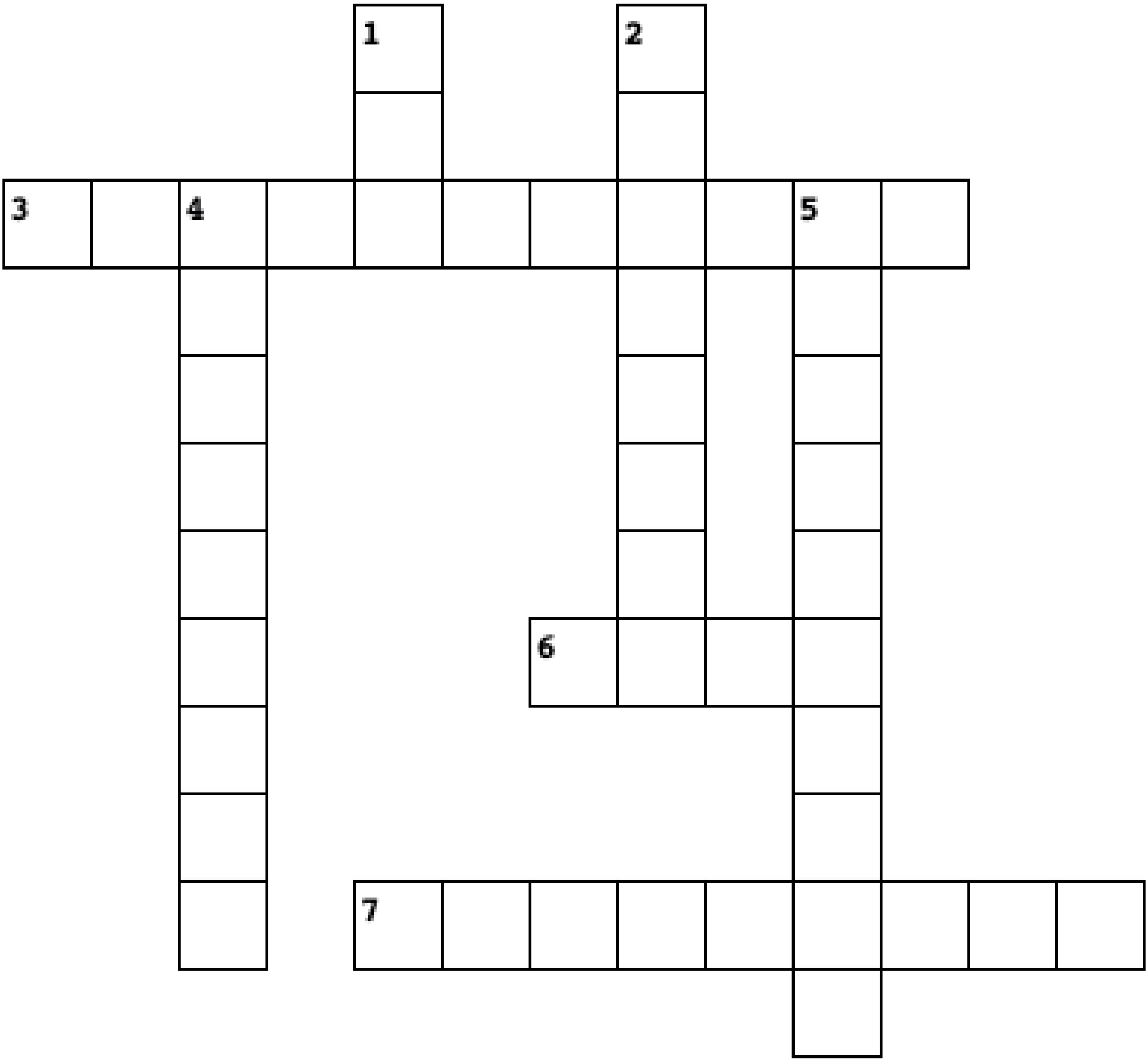
Astro-Physics Themed Crossword



Crossword Clues

Down

1. One of three instruments on the Swift MIDEX spacecraft to study gamma-ray bursts (GRBs)
2. Another name for high-energy physics
4. A gamma-ray burst detected on Oct. 16
5. Another name for an exoplanet

Across

3. graphs that show the brightness of an object over a period of time
6. Designed to discover thousands of exoplanets in orbit
7. A planet outside the solar system

- **Hint:** Find clues to the answers by reading the '**Latest News and Discoveries**' article

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