Press Note from NCRA-TIFR, Pune

A Team of International Scientists including from NCRA discover mildly relativistic outflow from an intriguing transient.

Scientists from the National Centre for Radio Astrophysics of the Tata Institute of Fundamental Research (NCRA-TIFR) were key members of an international team which succeeded in measuring unusually high speed of the ejected material, close to half the speed of light, from a rare class of explosive transient known as Fast Blue Optical Transients (FBOTs). They used the Giant Metrewave Radio Telescope (GMRT), the Karl G. Jansky Very Large Array (VLA) and the Chandra X-Ray Telescope. The GMRT provided the most crucial measurement at low radio frequencies to estimate the speed of the ejected material. This is only the second such highly-luminous transient known and this discovery establishes a new class of transients with extremely powerful central engine. Scientists involved in the research are Prof. Poonam Chandra, Dr. A. J. Nayana, from NCRA-TIFR, Pune India and Dr. Deanne Coppejans and Dr. R. Margutti from Northwestern University, Mari-Ela Chock from W.M. Keck Observatory and several others.

FBOTs:

In 2018, astronomers witnessed a powerful astronomical explosion, much brighter than a normal supernova, which displayed bright emission at X-Ray, UV, Optical and Radio wavelength, but faded rapidly in a matter of days. It was named as "Cow" (AT 2018cow). It dazzled the astronomers due to its peculiar properties, and was classified as Fast Blue Optical Transients (FBOTs).

What makes these luminous FBOTs unique is they primaface look like supernova explosions, but flare up and vanish much faster. They're also extremely hot, hence appear more blue in color than the standard supernovae. These new FBOTs explosions are just as violent as gamma-ray bursts (GRBs) and can eject outflows at speeds close to speed of light, but their observational signatures suggest them to be different from GRBs. They are surrounded by a lot of matter including hydrogen around them.

CSS161010 is the second closest FBOT (after AT 2018cow) and lies at a distance of around 500 million light years. Now we know total three such radio bright FBOTs, the third one named as Koala (from its official name –ZTF18abvkwla). This trio of FBOTs appear to be relatives, belonging to a highly-luminous family with their fast, powerful bursts of energy.
Due to their extremely rapid rise to maximum light, FBOTs are difficult to detect. But recent developments in high-cadence optical surveys scanning huge swaths of the sky every night hunting for rare, short-duration transients more feasible. However, once discovered, rapid follow-up with multi-wavelength observations are essential to determine their true nature.

This discovery:

Deanne Coppejans, a postdoctoral fellow at Northwestern University, and her team conducted follow-up radio observations of CSS161010 with the Karl G. Jansky Very Large Array (VLA) and the GMRT, along with other multi-wavelength observations. CSS161010 is unique as our radio observations revealed that this transient launched large amount of material into space at speeds close to half the speed of light. "This was unexpected," said Coppejans, "We know of energetic stellar explosions that can eject material at almost the speed of light, specifically

gamma-ray bursts, but they only launch a tiny amount of mass – about 1 millionth the mass of the Sun. In contrast, CSS161010 launched 1 to 10 percent the mass of the Sun to relativistic speeds – this is clearly a new class of transient!"

"We detected CSS161010 in late 2016, but initially everyone thought CSS161010 to be a normal transient, but we noticed some peculiar properties usually not seen in normal supernovae," said Coppejans. "It was only after we conducted follow-up radio and X-ray observations that the true nature of CSS161010 revealed itself. The data showed we were looking at something new and highly energetic, it also highlighted the importance of data at multiple wavebands."

Role of the GMRT and Indian Scientists:

The GMRT played a critical role by detecting CSS161010 due to its unique high sensitivity at low frequencies. The GMRT is an array of thirty 45-m antennas spread over 25 sq-km area in Khodad village, NarayanGaon, India, built and operated by NCRA-TIFR, Pune. Currently it is one of the most sensitive low frequency radio telescope in the world. The GMRT observed CSS161010 nearly a year after the discovery and clearly detected this even at this late time, providing the most crucial measurement at low radio frequencies needed to estimate the speed of the ejected material. "This was an intriguing discovery" says Poonam Chandra, Associate Professor at NCRA-TIFR, "even after one year the ejected material was found to be moving with 40% of speed of light despite obstruction due to lot of hydrogen and other material along the way. Only a very powerful central engine can do this."

A. J. Nayana, a Ph. D student worked with Poonam Chandra on this, shares her excitement by stating, "It was very exciting to detect radio emission from CSS161010 with the GMRT, this is the first FBOT seen at low radio frequencies, ~1 year after the event. The GMRT observations were most critical to estimate the speed of the ejected material from the explosion. "

Importance of the discovery:

While the origin of FBOTs is still hotly debated, data on these three radio bright FBOTs provide new insight on how they may have formed. "The observations prove the most luminous FBOTs have a 'central engine' – a source like a neutron star or black hole that powers the transient," said Margutti from Northwestern University. "It's not yet clear if these bright FBOTs are rare supernovae, stars being shredded by black holes, or other energetic phenomena. Multi-wavelength observations of more FBOTs and their environment will answer this question." However, it is clear that CSS161010 establishes a new class of hydrogen-rich relativistic transients.

"A long term follow up, which is only possible at low radio frequencies, may finally hold the key to unveil these intriguing fast transients. The sensitive telescopes at low radio frequencies, such as the upgraded GMRT and later SKA will play a crucial role", says Poonam Chandra.

The research paper is available at https://iopscience.iop.org/article/10.3847/2041-8213/ab8cc7 and is being published in the June 1 issue of The Astrophysical Journal Letters.

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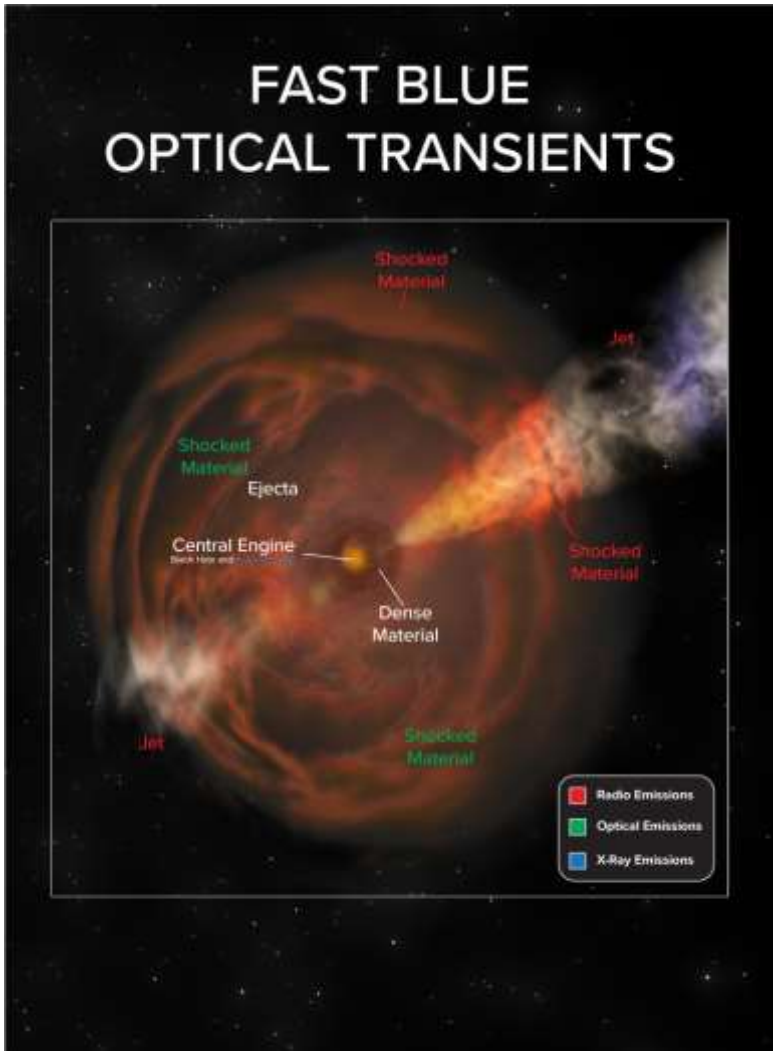
An Artists conception of FBOT (image credit: Bill Saxton, NRAO/AUI/NSF)



Some of the antennas from the GMRT array