VAST Newsletter 8/9

December 2011, March 2012

PI Report

Tara Murphy and Shami Chatterjee

Things got a bit crazy over the break, but we're back with a bumper edition of the VAST newsletter! We have lots of science results including an important new paper from Dale Frail and collaborators, "*A Revised View of the Radio Transient Sky*" which has implications for the transient rate in future blind surveys.

The ATCA and Parkes schedules have just been released for the next season, and there are lots of exciting VAST projects that have time – more on those in the next edition.

The ASKAP Working Group 4b (Commissioning) is now coming to life, so please consider attending the telecons if you want to get more involved in commissioning, discussions of the ASKAP-12 configurations. Simon Johnston is the VAST representative. Presentations from the last meeting are available on the ASKAP wiki.

We have just published a new VAST Memo on lightcurve classification:

http://www.physics.usyd.edu.au/sifa/vast/index.php/Main/Documents

Finally, congratulations to Keith Bannister whose PhD thesis has just been accepted!

Science Report

Pulsed Radio Emission from CU Virginus

Kitty Lo, Justin Bray, George Hobbs et al.

CU Vir is a unique magnetic chemically peculiar (MCP) star. It is very nearby (distance of 80 pc) and is a fast rotator (period of around 0.52 days). Whilst quiescent radio emission has been observed on other MCP stars, CU Vir is the only one that has been observed to emit radio pulses. Furthermore, the radio pulses are 100% circularly polarised and occur twice in a rotation period. The pulse periodicity can be explained using the oblique rotator model, similar to the argument used to explain pulsar emission. The circular polarisation suggest the emission mechanism is based on the electron cyclotron maser (ECM).

We observed CU Vir on six separate occasions with the ATCA and detected at least one pulse in each epoch. The pulse arrival times have a frequency dependence which is shown in Figure 1. The key feature is that the 13cm pulses have a shorter pulse separation time than at 20cm.

We created a simple geometrical model to explain the pulse arrival times. The model assumes electrons are accelerated by magnetic reconnection in the magnetic equatorial plane of the star, and

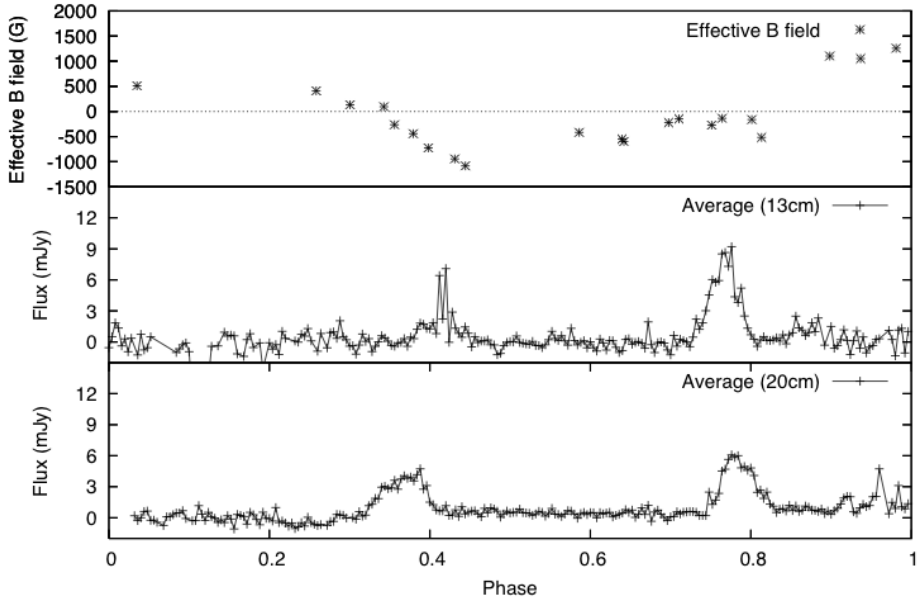

Figure 1. Top: Effective magnetic field Beff from Pyper et al. (1998) vs. rotation phase. A negative Beff means the field lines are directed into the star.

Middle and bottom: Average Stokes V pulse profiles at 13 cm and 20 cm. If we assume CU Vir has a dipolar field structure, then the magnetic South pole is closest to our line of sight during the shorter of the two pulse separations.

propagate along field lines towards the magnetic poles. Electrons with sufficiently small pitch angles will intersect the surface of the star whilst other electrons will be reflected due to magnetic mirroring. This results in a loss cone anisotropy in the pitch angles of this population of electrons, allowing them to produce radio emission through the ECM mechanism. Since the pulses are right-hand circularly polarised, we assumed all the emission originates from the North pole.

The simplest ECM model, where the emission is directed perpendicular to the magnetic field line, did not fit with our observations. A model in which the emission is refracted through cold plasma in the magnetosphere is shown to have the correct pulse arrival time frequency dependence.

VAST will likely detect many more CU Vir-like sources. If we use the peak pulse flux density of CU Vir as a guide, then VAST-wide should be able to observe sources out to ~280pc. Drake et al. (1987, ApJ, 333, 902) surveyed 61 Ap stars and detected 20cm emission from 5 sources. This gives us an estimate for the fraction of potential sources with CU Vir-like pulses. Using these figures, we estimate VAST will be able to detect up to 23 CU Vir-like sources. However, ECM emission has also been used to explain radio emission from brown dwarfs (Hallinan, 2008, ApJ, 284,644) which suggest ECM emission could be common place amongst stellar objects with strong magnetic fields. In which case, VAST will be able to find many more CU Vir-like sources.

This work has recently been published in MNRAS and is available online at:

http://adsabs.harvard.edu/abs/2012arXiv1201.3678L

Profile – Martin Bell

Martin is a postdoctoral researcher at the University of Sydney. He recently completed his PhD on radio transients at the University of Southampton with Rob Fender.

Some of the work from Martin's PhD thesis was published in MNRAS last year – the papers are available online at:

http://adsabs.harvard.edu/abs/2011MNRAS.415....2B

http://adsabs.harvard.edu/abs/2011MNRAS.411..402B

What are your main research interests?

My main research interests are searching for and understanding transient and variable radio phenomena at MHz and GHz frequencies. I am also interested in the technical aspects of radio transient detection and radio interferometry imaging in general.

What papers are you working on at the moment?

I am currently working on a paper about the serendipitous detection of radio flaring from the (RS CVn) flare star RT Lacertae. We recently (and serendipitously) detected RT Lac in archival Westerbork observations (supplied be our collaborators at ASTRON). The VAST transients pipeline was used to inspect the Westerbork images and RT Lac was quickly picked out as a candidate variable source. These images have also been processed through the LOFAR transients pipeline and complementary results were found. I also plan to publish a paper on transients and variable searches with prototype low frequency MWA data using the VAST transients pipeline.

What excites you about ASKAP?

VAST will provide one of the largest datasets to date at GHz frequencies to search for radio transients. This project will allow us to push our understanding of unexplored transient parameter space, which will in turn hopefully provide new populations of transient sources to study.

What are the main challenges for your work?

The biggest challenge will be working with such enormous amounts of data in real time.

What do you enjoy outside astronomy?

Trying to play guitar like Jimi Hendrix (which is tricky); riding my motorcycle (when it is not broken down - it usually is!) and the occasional bit of surfing.

News and Updates

Discovery of a meter-wavelength slow-transient in the SWIRE Deep Field: 1046+59

T. Jaeger, S. Hyman, N. Kassim, J. Lazio

We recently completed a slow-transient and variability search using data from the VLA archive. We selected six nearly-identical 325 MHz radio observations centered on the Spitzer-Space-Telescope Wide-area Infrared Extragalactic Survey (SWIRE) Deep Field: 1046+59. Each observation covered approximately 6.5 deg sq. with a typical peak flux sensitivity below 0.2 mJy per beam near the field pointing center. Observations were spaced between 1 day to 3 months. The calibration, imaging, and identification of the 950+ field sources was performed automatically using a UV processing pipeline we developed in Obit.

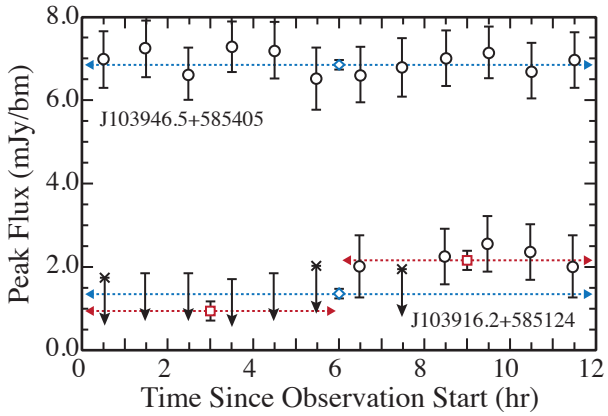

Figure 2: Lightcurve of J103946.5+585405.

Our search revealed multiple variable sources and the presence of one, day-scale transient event (J103916.2+585124) with no published counterpart in optical, IR, or x-ray wavelengths. Further analysis of the transient event revealed hour-scale variability, with the source appearing faint for the first 6 observing hours, then doubling in flux density in the following 6 hours. However, J103916.2+585124 is not detected 4 days earlier in observations nor 12 hours later. Our 325 MHz detection implies a transient rate of 1 +/- 1 event per 6.5 per deg sq. per 72 observing hours in the direction of 1046+59 and an isotropic transient surface density Sigma = 0.12 deg^{-2} at 95% confidence for sources with average peak flux density higher than 2.1 mJy over 12 hr.

More details are available at:

http://arxiv.org/abs/1201.6290

Unlocking the Nature of Ultraluminous X-ray Sources through Transient Variability

Sean Farrell, Eromanga Adermann, Tara Murphy

Ultraluminous X-ray sources (ULXs) are extragalactic X-ray point sources that are located outside the nuclei of their host galaxies (and thus are not the nuclear supermassive black hole) that have spectra similar to accreting black holes but observed X-ray luminosities that exceed the Eddington limit for a stellar mass black hole (e.g. 2.6E39 erg/s for a 20 Msun object). These luminosities (if the emission is isotropic and the Eddington limit is conserved) imply black holes in the intermediate mass range (i.e. ~100 – 100,000 Msun).

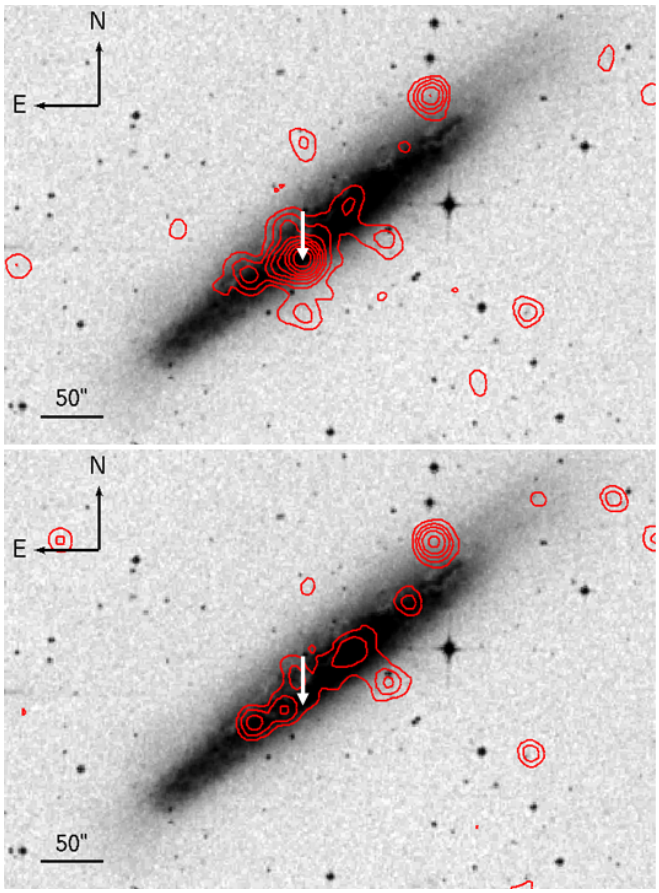

Figure 3: DSS image of a galaxy at 10 Mpc with XMM-Newton contours overlaid showing the detection (top panel) and non-detection (bottom panel) of a transient ULX. The white arrow indicates the position of the ULX.

Intermediate mass black holes have important implications for the formation of supermassive black holes, and so confirmation of their existence is a very hot topic. However, while the brightest ULXs are very strong candidates, its believed that the majority of these objects are probably low mass stellar mass black holes in an extreme accretion state whereby the Eddington limit is

violated by a factor of a few, possibly with the addition of some mild beaming. If this scenario is correct, ULXs should not emit persistently at these extreme luminosities, and should drop down to sub-Eddington values as the radiation generated by accretion blows off the in-falling material.

In order to test whether ULXs are hyper-accreting low mass black holes, we undertook a study of transient behaviour in ULXs using archival data from ESA's XMM-Newton space telescope. Over the Christmas break Eromanga Adermann, a 3rd year undergraduate student at the University of Sydney, pored through a sample of candidate ULXs that had been detected fewer times than they were observed. She found that only 10% of the 100 ULXs in the sample were definitely transient, with ~8% of them definitely dropping below the Eddington limit for a 20 Msun black hole. While still a work in progress, these results appear to indicate that the bulk of ULXs are not low mass black holes in an extreme accretion state. Alternative possibilities are that the emission may be significantly beamed towards us, or they might represent the upper tail of the stellar mass black hole mass function (i.e. black holes with masses between ~30 – 100 Msun).

These results were presented at the Aspen Winter Conference on the Physics of Astrophysical Transients in January, and are currently being prepared for publication. An additional paper on a new transient ULX is also the subject of a paper in preparation.

Duncan Galloway also attended the Aspen meeting, presenting a poster giving an overview of the VAST survey and software. If you are attending any meetings where presenting a version of this poster might be appropriate, we're happy to provide a copy for you to use or modify.

Release of Aegean source finding code

Paul Hancock

The paper referred to in last issue's science report "*Compact Continuum Source Finding*" has been accepted for publication in MNRAS:

http://adsabs.harvard.edu/abs/2012arXiv1202.4500H

The paper explores the current generation of source finding algorithms that are frequently used in radio astronomy. We find that the source finders produce complete and reliable catalogues of sources, but are not very good at characterising islands of pixels that contain more than a single component. The newly created Aegean (previously "Tesla") source finding algorithm overcomes this problem by analysing a curvature map in order to estimate the number of components and their parameters. Using a constrained fit, we are then able to accurately characterise and island of pixels with multiple compact components.

We have received a number of requests to use or test the Aegean source finding algorithm. We are happy to announce that after further development and testing within the VAST pipeline prototype the Aegean source finding algorithm is now available for general use. For further details of the program and how to obtain and install a copy, please visit:

http://www.physics.usyd.edu.au/~hancock/index.php/Programs/Aegean.

A Revised View of the Radio Transient Sky

Dale Frail et al.

Co-I Frail with his collaborators continue to carry out variability and transient projects with the Very Large Array (VLA) with a goal of characterizing the variable and transient radio sky ahead of the VAST survey.

Recent work has utilized the VLA archive. In Frail, Kulkarni, Ofek, Bower and Nakar (ApJ, 747, 70, 2012) we re-analyzed the transient detections from Bower et al. (2007). The implied event rate of this population exceeds that of all other known radio transient source populations by an order of magnitude or more. These transients therefore have dominated considerations for designing the cadence, sensitivity and field-of-view of future survey such as VAST. Our re-analysis found a number of false detections due to rare data artifacts, and lowered detection significance for other transients. At best, the rate of these transients is reduced to a factor of several, and the new rate is comparable to that of the class of recently discovered Swift J1644+57 nuclear radio transients. The paper ends with a summary of the rates of known transient populations and concludes that a rich yield awaits future surveys.

The paper is available online at:

http://adsabs.harvard.edu/abs/2012ApJ...747...70F

Real-time Radio Transient Detection

Casey Law, Geoffrey Bower

The data volume generated by next-generation radio interferometers poses a serious challenge transients searches. Science potential is often limited not only by the telescope capabilities but by the ability to collect, save, and search our data.

With this in mind, we have developed an algorithm that simplifies the detection and localization of transients with radio interferometers. The concept uses the bispectrum, an interferometric closure quantity that has sensitivity to transients throughout the field of view at reduced sensitivity compared to imaging.

Since celestial transients and RFI have different spatial structure, the bispectrum can distinguish them without the need for calibration or imaging. The algorithm is computationally efficient and applicable to visibilities on time scales of about a second or shorter. A focus of the application has been on millisecond transients, but VAST may also use it to search for transients in individual integrations. A paper on the concept has now accepted to the ApJ and available at:

http://arxiv.org/abs/1112.0308

Update on MWA Transients

Randall Wayth

The MWA data analysis team, many of whom are also VAST members, has met twice over the last few months, both at the December MWA project meeting in Melbourne and at a working week in Canberra in February. The team has made good progress refining the details of the imaging pipeline and coming to agreement on strategies for dealing with the MWA's primary beam, both in total power and polarisation. The MWA transients group uses and contributes to a post-imaging source extraction and data mining codebase that has many aspects in common with VAST.

Progress has also been made on directly inserting the measured flux density of calibrator sources from the MWA's Real-Time System (RTS) into the post-imaging source database. This will allow lightcurves to be directly generated via database query from sources that are peeled from MWA visibility data in the RTS.

We are currently testing the VAST prototype pipeline using several repeated fields from the 32T commissioning data and expect to publish these results later this year.

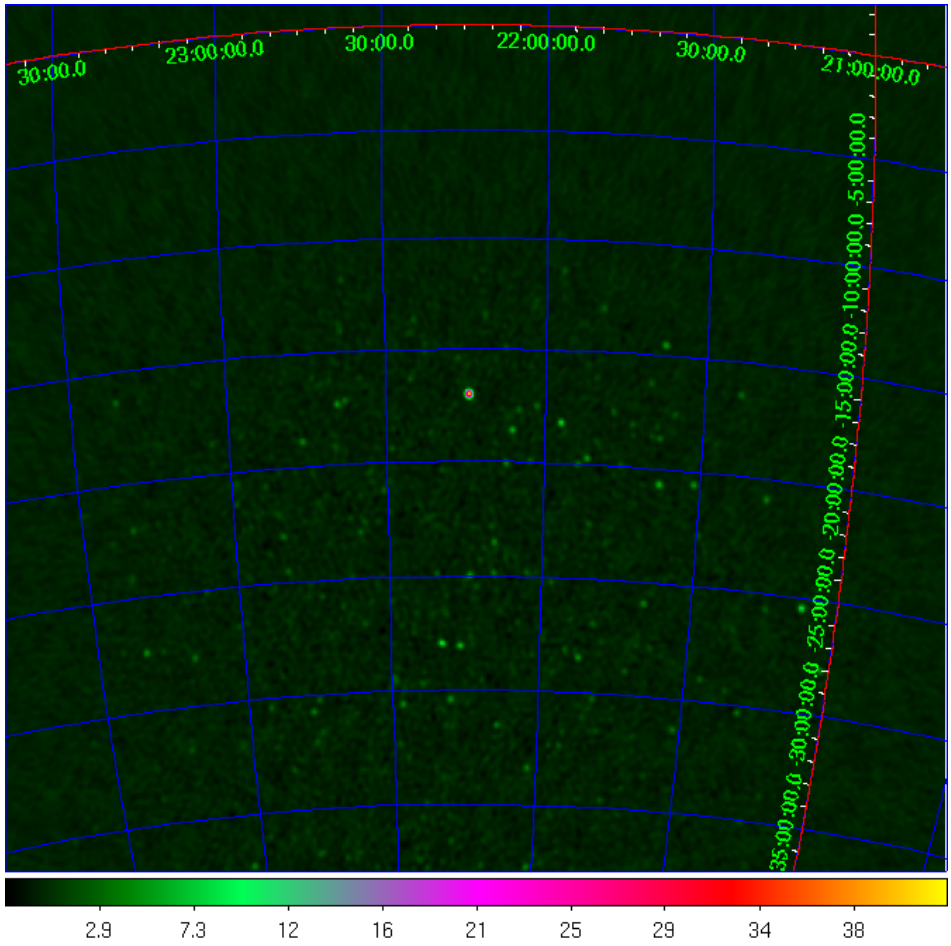

Figure 4: MWA 32T image of the 3C444 field (XX polarisation).