Newsletter 6

June 2011

PI Report

Tara Murphy and Shami Chatterjee

In this edition we have lots of science updates from collaboration members, including predictions about detection rates of supermassive black hole mergers, core-collapse supernovae and tidal disruption events. We also have a profile of our Working Group 4 Chair, Simon Johnston.

Earlier this month we submitted a mid-term update on our progress so far in 2011. This report is available on the wiki user Main/Documents, so rather than repeat the Working Group updates in the newsletter, I encourage you to read the report.

The ASKAP website has been updated with news about the first Phased Array Feed testing:

http://www.atnf.csiro.au/SKA

We are looking forward to getting data from BETA in 2012. Several VAST members are working on characterising the planned BETA test fields with a series of ATCA observations. Jamie Stevens will provide an update in the next newsletter.

Science Report

Blindly Detecting Merging Supermassive Black Holes with Radio Surveys

David Kaplan, Richard O'Shaughnessy.

Among the more interesting objects recently proposed as radio transients are merging supermassive black hole (SMBH) binaries. These binaries should exist in moderate numbers at the centers of galaxies, with the mergers likely tracing the hierarchical assembly of galaxies throughout cosmic time. However, only a few observations suggest the presence of binary SMBHs at wide separations. We have explored how EM observations might provide the first accurate numbers and merger rates, focusing on radio surveys such as ASKAP-VAST.

Palenzuela et al. (2010, Science, 329, 927) proposed that, late in the SMBH binary's orbital decay, the binary will largely cease accreting, interacting primarily with the magnetic field provided by the surrounding circumbinary disk. They showed this motion will produce a Poynting flux along each black hole's spin axis. These jets

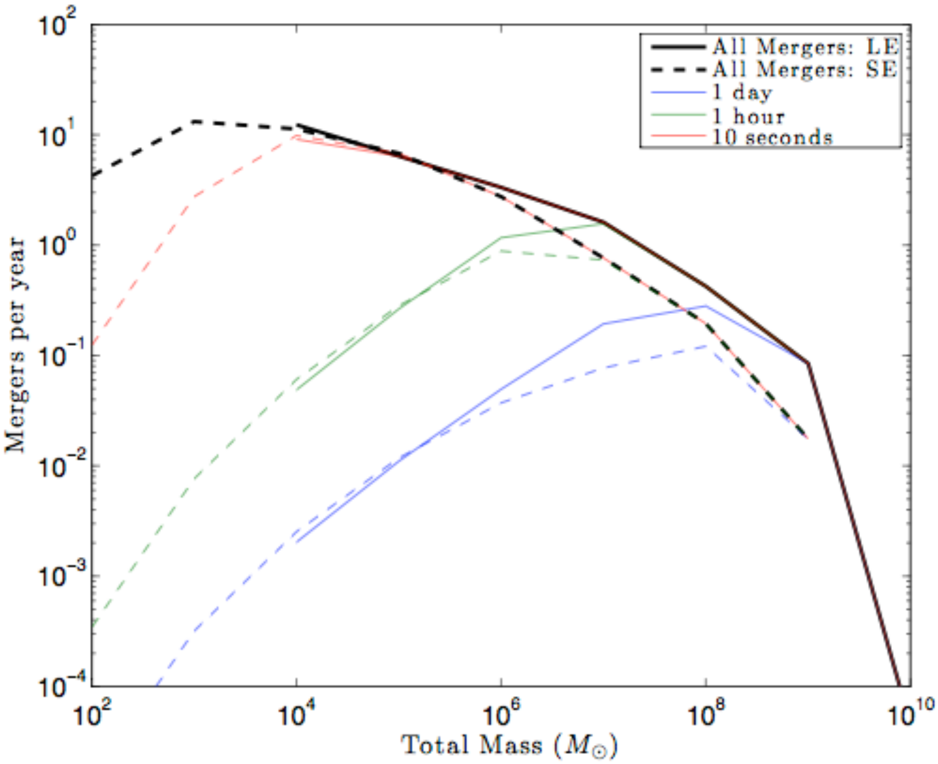


Figure 1: Rate of mergers per year on our light cone, for a range of total system masses. The thick curves include all mergers for two models from Arun et al. (2009, CQG, 26, 094027), with solid and dashed lines representing two different models. The thin curves reduce this number by max(τ_{flare} / T , 1) for cadences T = 1 day (blue), 1 hr (green), and 10 s (red), assuming the flare event duration $\tau_{flare} \simeq 5$ hr ($M/10^8\ M_\odot$).

could then have EM emission, with synchrotron emission at ~1 GHz plausible (although the detailed emission mechanism is still unknown). During merger, the EM emission from these jets would be expected to track the brightening GW emission, with a flare right at merger. Could this flare be detectable with planned surveys?

Unfortunately, we found that this was unlikely (Kaplan et al. 2011, ApJ, 734, L37). The obstacle is not necessarily each flare's brightness. Independent of all other concerns, merger flares are simply too fast and infrequent. We know from the number of SMBHs observed today that there cannot be many SMBH mergers on our past light-cone, with <50 per year expected for masses of $>10^4$ $M_\odot$. The flare duration was likewise reasonably well determined, since it is roughly the orbital period at merger. Thus, long merger flares (>10 seconds) are very rare, with only 1 per year expected over the whole sky (Figure 1). While shorter flares could still be visible, a survey such as VAST that samples a given patch of the sky at most once per day has little chance of finding one: 1 flare every 10 years or so. So we are stuck: long flares are infrequent, and short flares are almost impossible to see.

However, all is not lost. Systems are brightest when they merge, but they spend thousands to millions of years spiraling in toward merger with a jet nearly as bright and, critically, strongly modulated. For example, if the spins of the two BHs are misaligned with the orbit, the EM jets will precess. The highly relativistic motions ubiquitous in the late stages of merger can introduce modulations as well. These modulations occur on a wide range timescales. Depending on the mechanisms for modulation, jet emission, and host background variability, as many as hundreds of thousands of binaries could be accessible to a once-per-day survey like VAST, in many cases with distinctive flux modulations versus time (O'Shaughnessy et al. 2011, in prep).

Gravitational wave (GW) observations from the ground (for low-mass or very high mass systems) or space (for intermediate masses) may be able to directly observe these binaries inspiral and merge. Any simultaneous observation with both EM and GW detectors would provide invaluable constraints on the detailed processes involved (e.g., Bloom et al. 2009, "Astro2010 Decadal Survey Whitepaper: arXiv:0902.1527).

Profile – Simon Johnston

Simon, our WG4 chair, is a Senior Research Astronomer at CASS and one of the ASKAP Project Scientists. He is about to start a new role as the Astrophysics Theme Leader at CASS.

What are your main research interests?

Radio pulsars are really my thing, finding them, timing them, using them as tools and figuring out how they work has kept me busy over the last 20 years. I've always found time-domain astronomy fascinating, hence my involvement in VAST and the **vast** areas of phase space still to be explored in the radio transient domain.

What papers are you working on at the moment?

We're conducting the High Time Resolution Universe (HTRU) survey with the Parkes telescope which eventually will cover the entire southern sky at a time resolution of 64us. Three papers are in progress now, one on the discovery of millisecond pulsars (led by my postdoc Mike Keith) one on follow-up studies of the radio magnetar we found last year (led by my student Lina Levin) and one on single pulse properties (led by my postdoc Sarah Spolaor).

What excites you about ASKAP?

As you know, I'm also ASKAP Project Scientist so I've been excited about ASKAP since its conception many years ago. Phased-array feeds are a revolutionary leap forward for radio astronomy: wide field of view capability is absolutely necessary for the SKA. The science that ASKAP will do is tremendously exciting over a huge range of topics. From the VAST perspective I'm excited about finding about the cause of the Extreme Scattering Events - only ASKAP is capable of answering that question in the near future.

What is the main challenge for Working Group 4?

WG4 will enter an exciting phase next year when BETA comes on-line and we start getting our hands on photons! An enormous challenge lies ahead in commissioning BETA and I hope that VAST members will play a big part in sorting out all the issues.

What do you enjoy outside astronomy?

In May I ran the Sydney half-marathon which was surprisingly enjoyable. One of these days I might make the full marathon. So running is a good winter activity, to complement lying on the beach in the summer and imbibing red wine all year round.

Working Group Reports

See the mid-term report (Main/Documents): http://www.physics.usyd.edu.au/sifa/vast/wiki/uploads/Main/vast_update_june2011.pdf

for an update from each Working Group.

News and Updates

Constraining the Rate of Relativistic Jets from Tidal Disruptions Using Radio Surveys

Geoffrey Bower

This paper explores limits on the rates of tidal disruption events based on the model of Giannios & Metzger (2011). This model argues that the reverse shock associated with jet interaction with the interstellar medium of the host galaxy will lead to a bright, long-duration radio transient that appears about 1 year after the disruption event. This mechanism is distinct from the blazar-like emission seen from Swift J1644+57. We examine existing radio surveys with an emphasis on month to year timescales. There are two candidate events from the MOST analysis (Bannister et al 2010). Additionally, we set a limit on the rate of relativistic jets from tidal disruptions at approximately 10^{-6} $Mpc^{-3}yr^{-3}$. This rate is an order of magnitude lower than the highest theoretical rate estimated for tidal disruptions and an order of magnitude higher than the best estimate of the rate from optical, UV, and X-ray surveys. Future radio surveys should emphasize month to year durations at frequencies of approximately 10 GHz to have the best sensitivity to events of this kind.

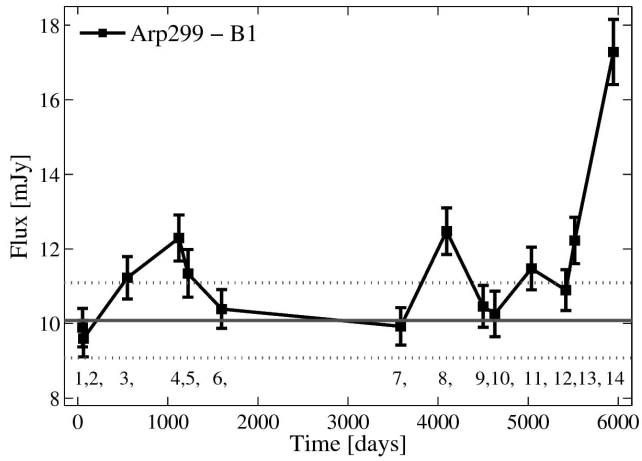
http://adsabs.harvard.edu/abs/2011ApJ...732L..12B

The core-collapse supernova rate in unresolved host galaxies

Stuart Ryder

One of the key science goals of VAST is to conduct an unbiased survey of radio supernovae in the local Universe. VAST Memo 3 summarises our current understanding of how radio supernovae evolve, and methods to simulate their expected behaviour when spatially resolved from nuclear and extended disk continuum emission from their host galaxies. But what about the millions of potential supernova host galaxies that will not be resolved by ASKAP?

A recent study led by PhD student Cristina Romero-Canizales (astro-ph/1104.1955) offers hope that careful monitoring of the total radio continuum flux from starbursting galaxies could allow useful constraints to be placed on the core-collapse supernova rate in these galaxies, even when the supernovae themselves are not spatially resolved at radio, optical, or infrared wavelengths. Near-infrared and optical monitoring of the Luminous Infrared Galaxy Arp 299 has found 7 supernovae since 1992, while VLBI imaging reveals a host of compact, non-thermal sources in the core regions which may be young radio supernovae.



We have analysed 14 epochs of VLA imaging at 8.5 GHz since 1990 which allow us to spatially resolve the multiple star-forming cores, but not the individual sources resolved with VLBI. One of these cores, known as B1 (see Figure) shows significant variations in total flux, with 3 epochs having a >5-sigma increase. These are too large to be due to AGN outbursts, but are comparable in timescale and flux to those observed in moderately luminous core-collapse (Type Ib/c and Type II) supernovae.

Since a still poorly-determined fraction of supernovae do not give rise to prompt radio emission (something VAST will go a long way to addressing), we can only place a lower limit on the core-collapse supernova rate in core B1 of 0.28 +/- 0.16 per year. Paradoxically the more prodigious star formation in core A of Arp 299 makes it harder to distinguish the contributions of individual supernovae to its total flux, so this technique may not be universally applicable. Nevertheless we are sufficiently encouraged by this case study to investigate further the potential of VAST to determine the complete rate of core-collapse supernovae in the local Universe.

VAST Lightcurve Analysis

Umaa Rebbapragada, Kiri Wagstaff, David Thompson

We have recently expanded our VAST data analysis team at JPL and we continue to make progress on the development of classification and anomaly detection methods. In January 2011, Umaa Rebbapragada joined project members Kiri Wagstaff and David Thompson and brings a background in machine learning applied to time-domain astronomy. This summer we are joined by Colorado Reed, an applied physics major from the University of Iowa. Colorado was awarded a summer undergraduate research fellowship through the California Institute of Technology.

Our work to date has focused on classifying simulated VAST light curves and establishing upper bounds on the classification performance of transients (e.g. ESEs, IDVs, Novae, and Supernovae) and background sources. Current (and future) results are documented on wiki: http://www.physics.usyd.edu.au/sifa/vast/wiki/index.php/WG1/TransientClassification.

The focus of our work this summer is the development of classification and anomaly detection methods for the proposed VAST survey strategies (e.g., Deep, Wide). Underlying this work is the development of interpolation methods and feature representations for light curves that have missing observations and are sparsely and unevenly sampled. We plan a comparative analysis of these methods and their impact on classification and anomaly detection performance per source type and survey strategy. We are currently evaluating our results on simulated VAST data provided by Tara Murphy and Kitty Lo, but also plan to evaluate against real radio light curve data (e.g., VLA, Green Bank Interferometer). Our group has submitted three abstracts to the IAU Symposium on time domain astronomy. We look forward to presenting our results and meeting VAST collaborators in September.

New VLA Transients Surveys

Dale Frail and collaborators

We have several recent publications from surveys we are carrying out at the Very Large Array (VLA). The goal of this work is aid the VAST project by characterizing the variable and transient radio sky at frequencies between 1.4 and 5 GHz and at milliJansky to sub-milliJansky flux density levels.

In Ofek et al. (http://arxiv.org/abs/1103.3010) we carried out a 5 GHz survey over 16 epochs in a 2.7 square degree region, uniformly sampling timescales between 1 to 45 days and out to a 2 year timescale. The cadence, angular resolution, and sensitivity were well-matched to those planned for VAST. Other notable features of our survey included a uniform observing process (in LST range and array configuration) and the real-time calibration and imaging of the visibility data, with any transient candidates followed-up immediately with optical, X-ray and radio facilities.

We used our derived transient event rate to compare with predictions of Bower et al. (2007) and compared these to the literature values.

We were also able to use the sample of 464 persistent sources to characterize the level of variablity of radio sources at flux density levels of 0.2 to 50 mJy. We find that a significant fraction (30%) of radio source vary on daily timescales, but that most are stable of yearly timescales.

In Ofek and Frail 2011 we explore the radio variability of radio sources at 1.4 GHz on time scales between several months and five years using NVSS and FIRST. From a sample of 4367 point sources we identify a tiny fraction (0.1%) of sources which vary by more than 4-sigma. On these timescales the structure function is relatively flat. A plausible explanation to these observations is that a large fraction of the variability at 1.4 GHz is induced by scintillations in the interstellar medium, rather than by intrinsic variability.

http://arxiv.org/abs/1105.3479

Upcoming Meetings

New Horizons in Time Domain Astronomy

University of Oxford, September 19 to 23, 2011

http://www.physics.ox.ac.uk/IAUS285