An ASKAP Survey for Variables and Slow Transients

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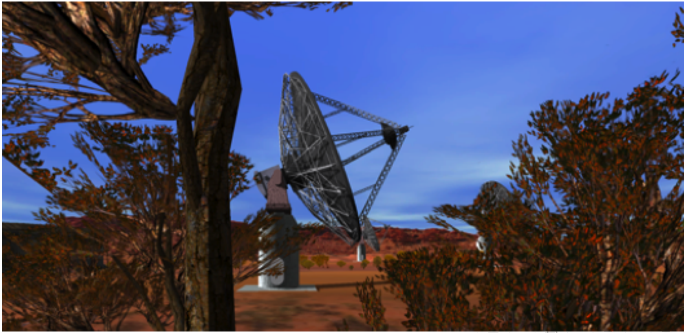
ASKAP: Australian SKA Pathfinder

- The main strengths of ASKAP are:
  1. its fast survey speed in both line and continuum,
  2. its excellent u-v coverage,
  3. its southern hemisphere location,
  4. its radio quiet site.



What is ASKAP?

- ASKAP is a world class survey instrument
- The technical specifications are:

Number of dishes	36
Dish diameter (m)	12
Dish area (sq m)	113
Total collecting area (sq m)	4072
Aperture efficiency	0.8
System temperature (K)	50
Field-of-view (deg2)	30
Frequency range (MHz)	700–1800
Bandwidth (MHz)	300
Maximum channels	16384
Maximum baseline (km)	6

Location of ASKAP

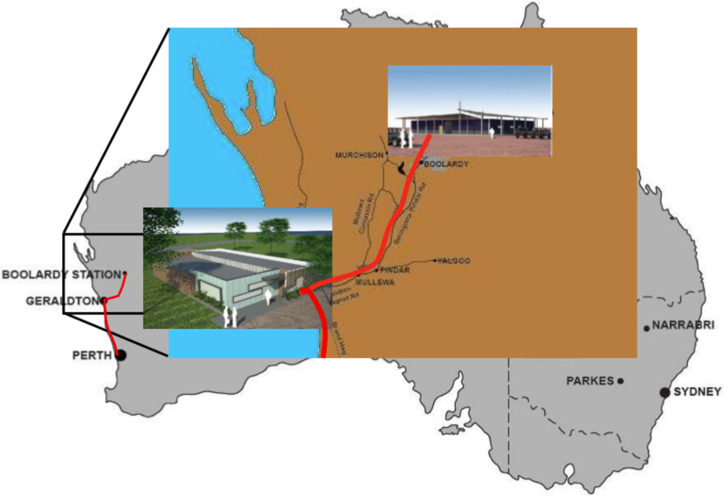


Image ref: Dave DeBoer

The first six antennas are under construction

Image Ref: Simon Johnston, CSIRO

http://www.ska.gov.au

The VAST collaboration

- Collaboration with diverse scientific interests

Hayley Bignall[1], Geoffrey Bower[2], Joshua Bloom[2], Jess Broderick[3], *Edwin Budding[4], Robert Cameron[5], David Champion[6], Shami Chatterjee[7], *Stéphane Corbel[8], James Cordes[7], David Coward[9], *Steve Croft[2], James Curran[10], Avinash Deshpande[11], George Djorgovski[12], Richard Dodson[9], Philip Edwards[13], Simon Ellingsen[14], Alan Fekete[10], Rob Fender[3], Dale Frail[15], Bryan Gaensler[10], Duncan Galloway[16], Matthew Graham[12], Anne Green[10], Lincoln Greenhill[17], *Paul Hancock[10], George Hobbs[13], Richard Hunstead[10], *Scott Hyman[18], Simon Johnston[13], Glenn Jones[12], *Atish Kamble[19], David Kaplan[19], Aris Karastergiou[20], *Slava Kitaeff[21], Michael Kramer[6], *Casey Law[2], Joseph Lazio[23,36], Jim Lovell[14], Jean-Pierre Macquart[1], Ashish Mahabal[12], Walid Majid[23], Maura McLaughlin[24], Andrew Melatos[25], Tara Murphy[10], Ray Norris[13], *Roopesh Ojha[22], Steve Ord[17], Sabyasachi Pal[9], Michele Pestalozzi[35], Andrea Possenti[27], Peter Quinn[9], Nanda Rea[28], Cormac Reynolds [1], Roger Romani[5], Stuart Ryder[29], Elaine Sadler[10], Brian Schmidt[30], Bruce Slee[13], Ingrid Stairs[31], Ben Stappers[32], Lister Staveley-Smith[9], Jamie Stevens[13], *David Thompson[23], Steven Tingay[1], Ulf Torkelsson[26], Tasso Tzioumis[13], Marten van Kerkwijk[33], *Kiri Wagstaff[23], Mark Walker[34], Randall Wayth[1], Linqing Wen[9], Matthew Whiting[13], *Peter Williams[2], Roy Williams[12]

- Science goals have technical challenges in common
  - Finding transient and variable sources
  - Classifying and identifying sources
  - Triggering follow-up observations
- http://www.physics.usyd.edu.au/sifa/vast

VAST Working Groups

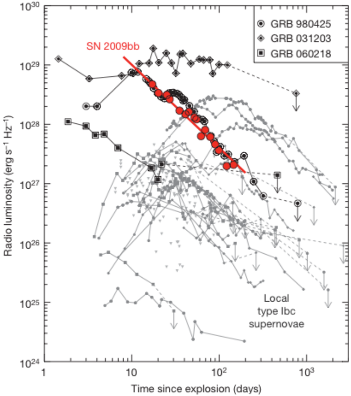
- PI: Tara Murphy, Shami Chatterjee
- WG 1: Simulations, Calibration and Imaging (Randall Wayth)
- WG 2: Source Finding (Tara Murphy)
- WG 3: Survey Strategy (Shami Chatterjee)
- WG 4: BETA Planning (Simon Johnston)
- WG 5: Data Format and Access (Hayley Bignall)
- WG 6: Transient Detection Pipeline (David Kaplan)
- WG 7: Ongoing Science (Duncan Galloway)

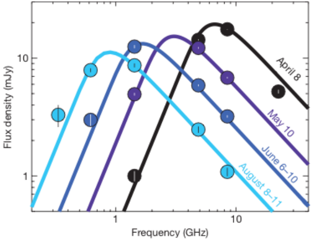
Investigating the physics behind transient phenomena

1. **Explosions**
   - e.g. supernovae, Gamma-Ray bursts, orphan afterglows
2. **Propagation**
   - e.g. Extreme Scattering Events, intra-day variables
3. **Accretion**
   - e.g. neutron stars, black holes, quasars, X-ray binaries
4. **Magnetospheric**
   - e.g. magnetars, flare stars, planetary variability
5. **Unknown**

Explosions: the search for orphan afterglows

- Highly beamed emission means most GRBs are undetected
- Afterglow can be detected in radio days to months later

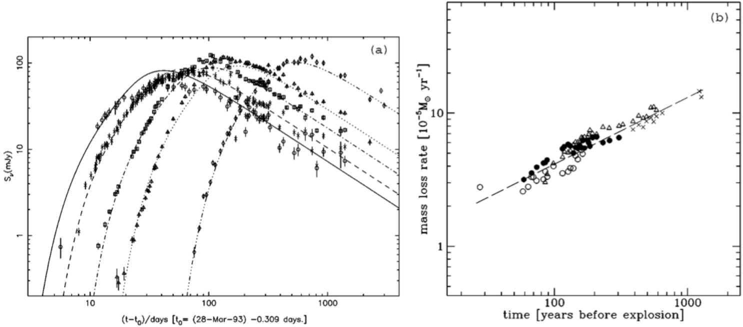




Soderberg et al. 2010, Nature, 464, 513

Explosions: an unbiased census of supernovae

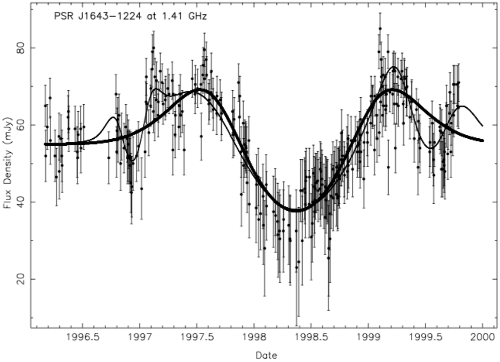
- Radio SNe probe the CSM and stellar mass outflow history
- We can detect new SNe that are obscured by dust



Weiler et al. 2002, ARA&A, 40, 387

Propagation: the origin of extreme scattering events

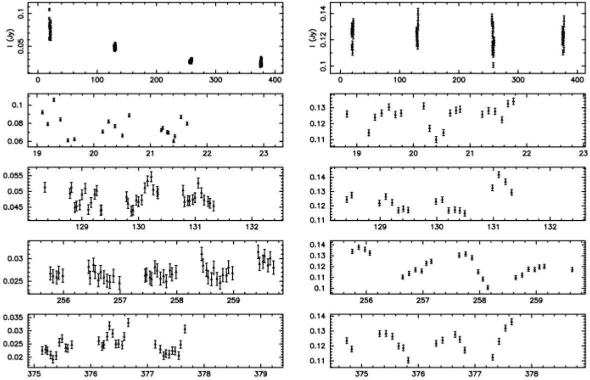
- We will be able to characterise ESEs in real-time
- Map out dense neutral gas clouds in our Galaxy



Maitia et al. 2003, ApJ, 582, 972

Propagation: investigating interstellar scintillation

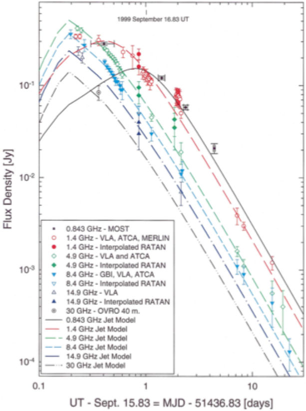
- What is the cause of IDV intermittency?
- Could provide a direct detection of baryons in the IGM



Lovell et al. 2008, ApJ, 689, 108

Accretion and Magnetism: microquasars

- Understanding the accretion disk/jet connection
- Flare from V4641 Sgr



Hjellming et al. 2000, ApJ, 544, 977

Exploring the unknown. . .

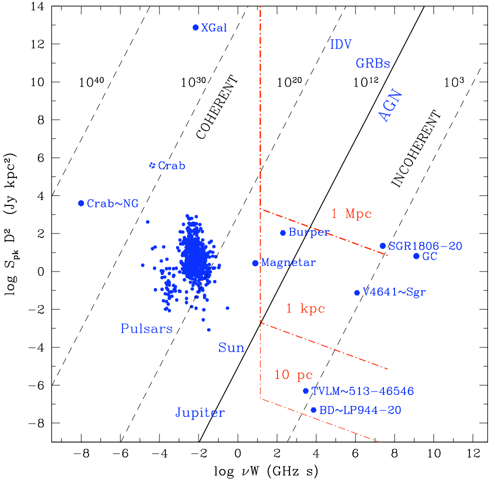
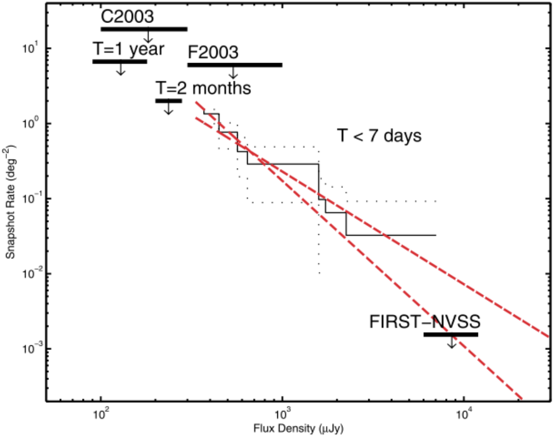


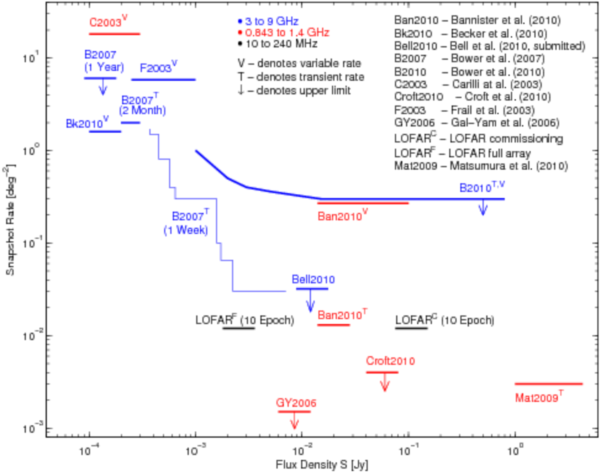
Image ref: Kaplan, Chatterjee, adapted from Cordes

Limits on transient snapshot rates (c. 2007)



Bower et al. 2007, ApJ, 666, 346

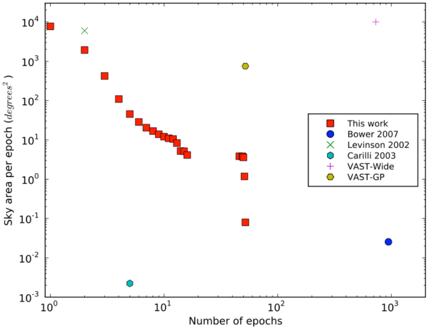
Limits on transient snapshot rates (c. 2010)

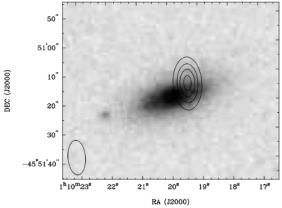


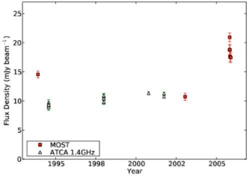
Bell et al. 2011, MNRAS, *in press*, arXiv:1103.0511

Results from Molonglo: blind archival search

- 843 MHz, $\sim 3\,000$ deg^2, to 5 mJy, many epochs
- $\sim 30\,000$ lightcurves $\Longrightarrow$ 53 highly variable, 15 transient



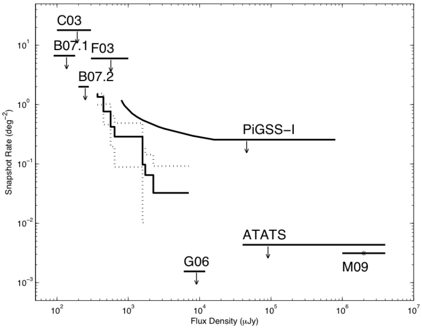


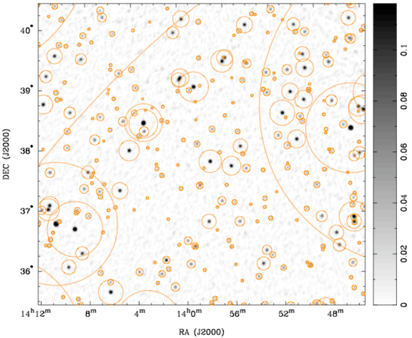


Bannister et al. 2011, MNRAS, 412, 634

Results from the ATA: PiGSS and ATATS

- PiGSS — 3.1 GHz, 10 000 deg^2, to 1 mJy, 2 epochs
- ATATS — 1.4 GHz, 690 deg^2, to 20 mJy, 12 epochs

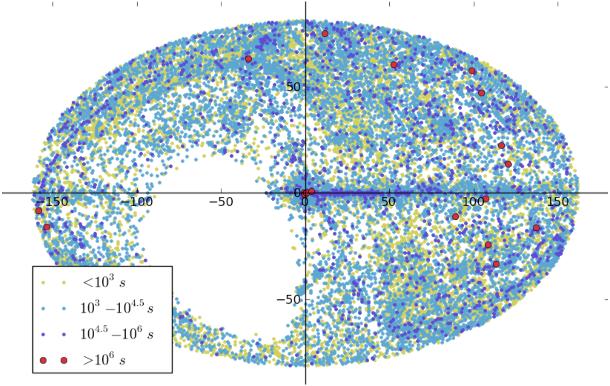




Croft et al. 2010, ApJ, 719, 45
Bower et al. 2010, ApJ, arXiv:1009.4443

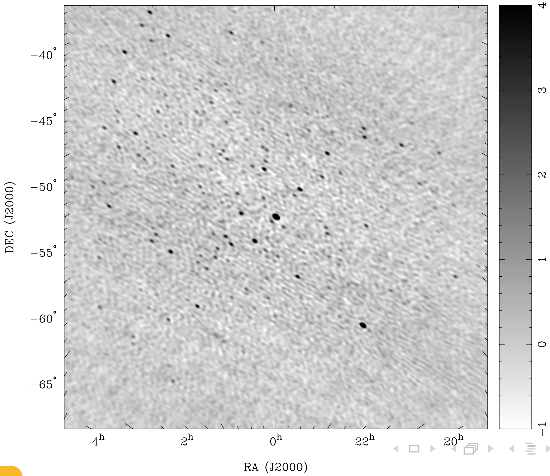
Results from the VLA: automated archival search

- Chatterjee, Kaplan et al. VLA archival search



Results from the MWA: X14 data (PKS 2356–61)

- $\sim 30\ \text{deg}^2$ field at 154 MHz with $\sim$ 65 epochs



Survey Strategies

1. Survey entire sky at regular intervals
   - Go shallow but wide in search of ‘rare and bright’ sources
   - Better sky coverage, less coverage of different timescales

2. Survey targeted fields at some hierarchy of time intervals
   - Go deep in search of ‘common and faint’ sources
   - Better coverage of timescales, less sky coverage

3. Piggyback on other major ASKAP surveys
   - Make most of all telescope time, including source monitoring
   - Can be done completely in software

Survey Strategies

4. Regular monitoring of known target sources
   - Aim for detailed characterisation of light curves
   - Can be done completely in software

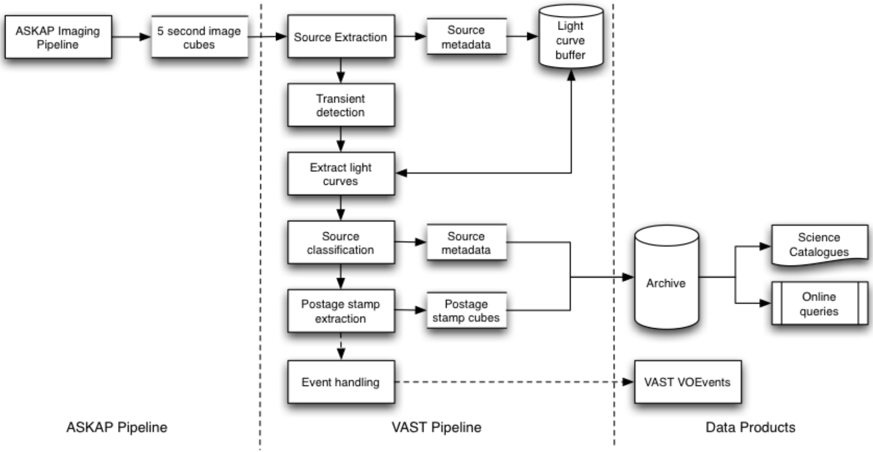
5. Triggered observations
   - ASKAP is not likely to be best instrument for follow-up
   - Could include self-triggers

6. Archival searches for longer timescales (and fainter sources)
   - Allows more sophisticated search techniques
   - Done offline using long term archive

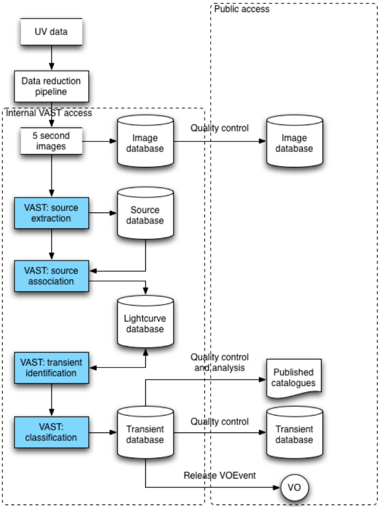
VAST Survey Proposal

	VAST-Wide	VAST-Deep		VAST-GP
Observing time (hrs)	4380	3200	400	600
Survey area (deg sq)	10 000	10 000	30	750
Time per field	40 s	1 hr	1 hr	16 min
Repeat	daily	7 times	daily	64 times
Observing freq (MHz)	1150–1450	1150–1450	1150–1450	1150–1450
Bandwidth (MHz)	300	300	300	300
RMS sensitivity	0.5 mJy/bm	50 μJy/bm		0.1 mJy/bm
Field of view (sq deg)	30	30	30	30
Angular resolution	10″ (Maximum possible)			
Spectral resolution	$\sim$ 10 MHz			
Time resolution	5 seconds (Maximum possible)			
Polarisation products	IQUV	IQUV	IQUV	IQUV

The VAST transient detection pipeline



VAST data rates



1. Transients database
   - Measured properties of all *transients*
   - $\sim$ 200 GB per year
2. Lightcurve database
   - Measured properties of all sources detected
   - $\sim$ 10 TB per year
3. Image database
   - 5-second image cubes
   - 50 TB to 50 PB depending on available space

Challenges for the VAST Design Study

1. Developing a detection pipeline that works in real time
2. Developing reliable source-finding software
3. Designing an optimal survey strategy
4. Automatic classification of lightcurves
5. Multiwavelength identification and triggering
6. Effective RFI removal
7. Ensuring the diverse science goals of VAST can be met!