AGN Variability, Tidal Disruptions, and Transients from Next Generation Radio Telescopes

Bower et al. 2010, ApJ, 725, 1792 • Bower et al. 2011, ApJ, 739, 76 • Croft et al. 2010, ApJ, 719, 45 • Croft et al. 2011, ApJ, 731, 34 • Croft et al. 2013, ApJ, 762, 93

Steve Croft

University of California, Berkeley & University of Wisconsin-Milwaukee
scroft@berkeley.edu

The next generation of radio telescopes such as the Australian Square Kilometer Array Pathfinder (ASKAP) will provide radio variability information with a cadence of days for samples of hundreds of thousands of active galactic nuclei (AGNs). They will also potentially detect tens to hundreds of transient events per month, including radio afterglows from stellar explosions such as supernovae and gamma ray bursts; but the majority of these radio transients may arise from the tidal disruption of stars passing close to supermassive black holes (Fig. 3).

Fig. 1: The Allen Telescope Array at night - Steve Croft

From 2007-11, UC Berkeley participated in the operation of an early pioneer in the new generation of radio telescopes, the Allen Telescope Array (ATA; Fig. 1). We undertook two large surveys to search for transients and to quantify variability for radio AGNs.

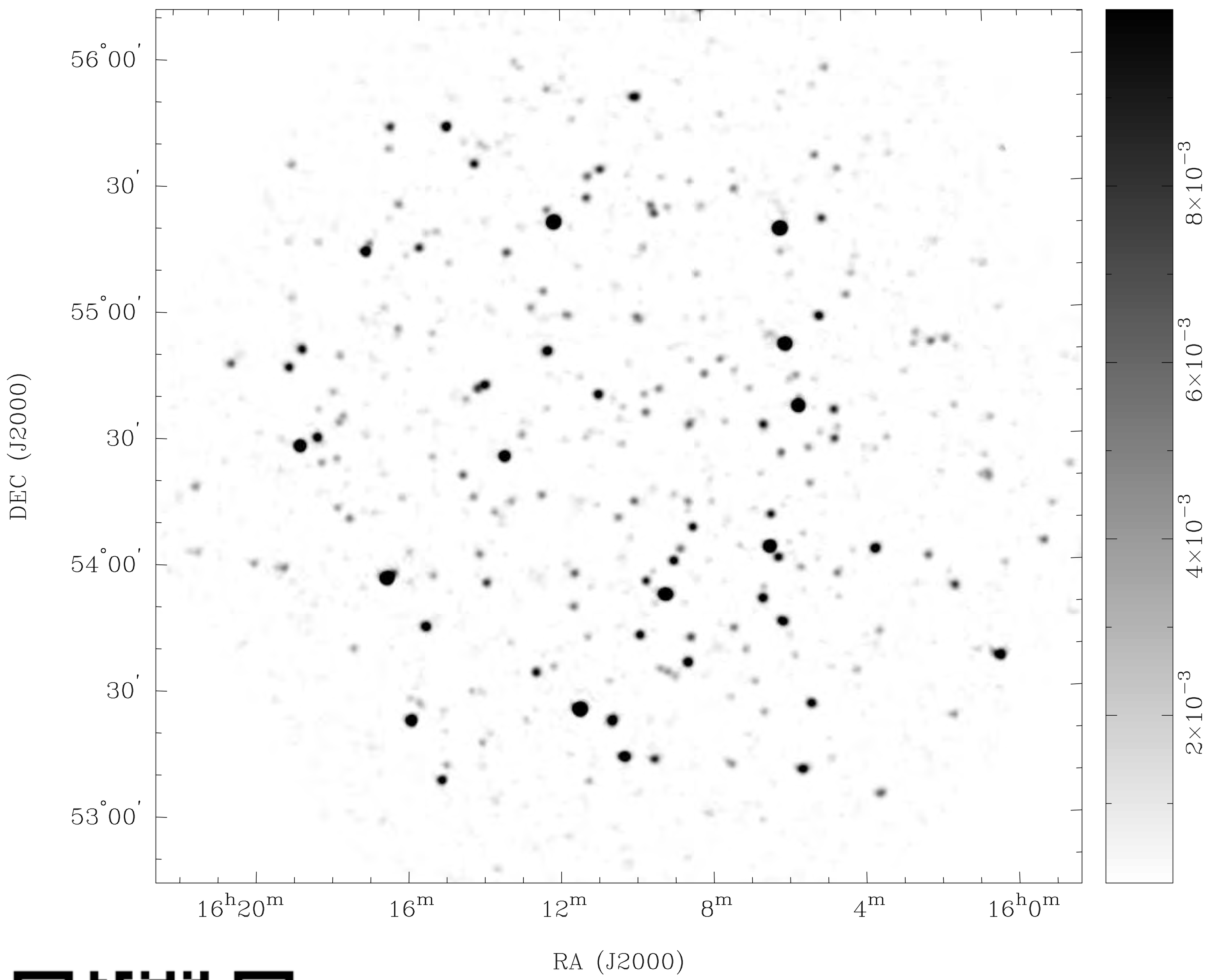

Fig. 2: PiGSS ELAIS-N1 154-epoch deep field

http://www.stevecroft.co.uk/ata.html

Fig. 3: Artist's impression of a tidal disruption
Mark Garlick / University of Warwick

Allen Telescope Array Surveys

The ATA Twenty-cm Survey (ATATS; Croft et al. 2010, 2011) surveyed 700 square degrees 11 times to $\sigma \sim 12$ mJy/beam per epoch. We placed limits of < 0.004 transients deg^{-2}, for transients brighter than 40 mJy with characteristic timescales $\gtrsim 3$ months (upper green line in Fig. 6) and $< 6 \times 10^{-4}$ transients deg^{-2}, for transients brighter than 350 mJy with characteristic timescales of minutes to days (lower green curve in Fig. 6).

The ATA Pi GHz Sky Survey (PiGSS; Bower et al. 2010, 2011; Croft et al. 2013) surveyed four 12 sq. deg. fields (NDWFS, Lockman, Coma, ELAIS-N1) at 3.1 GHz with 100″ resolution, for 50-180 epochs each (approx daily) to $\sigma \sim 3$ mJy/beam per epoch. Deep fields (e.g. Fig. 2) reached $\sigma \sim 250$ μJy/beam and contained a total of 800 sources.

Some sources are highly variable (Figs. 4 & 5), but no sources varied by a factor 10 or more; surface density upper limits for such transients brighter than 10 mJy (see Fig. 6) are:

- < 0.08 deg^{-2} (timescales of years; magenta curve)
- < 0.02 deg^{-2} (timescales of months; cyan curve)
- < 0.009 deg^{-2} (timescales of days; blue curve)

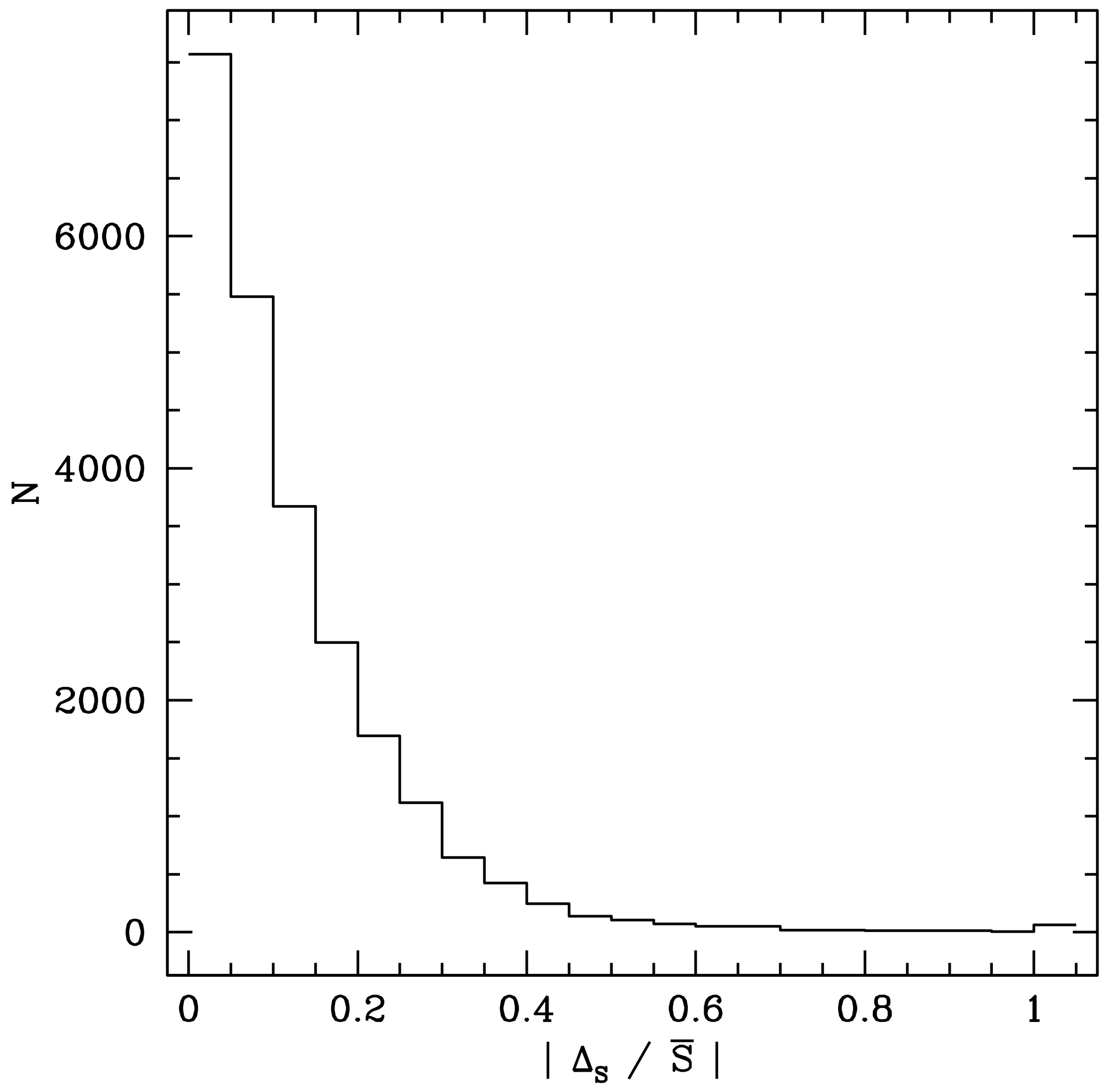

Fig. 4: PiGSS fractional modulations (offset of each flux density measurement from the mean, divided by the mean for each source). The majority of measurements are consistent with < 10% variability.

Acknowledgments

Work was undertaken with Geoff Bower, David Whysong, and the ATA Team at UC Berkeley and the SETI Institute. The first phase of the ATA was funded through generous grants from the Paul G. Allen Family Foundation. UC Berkeley, the SETI Institute, and the National Science Foundation (Grant No. 0540599). Sun Microsystems, Xilinx, Nathan Myhrvold, Greg Papadopoulos, and other corporations and individual donors contributed additional funding.

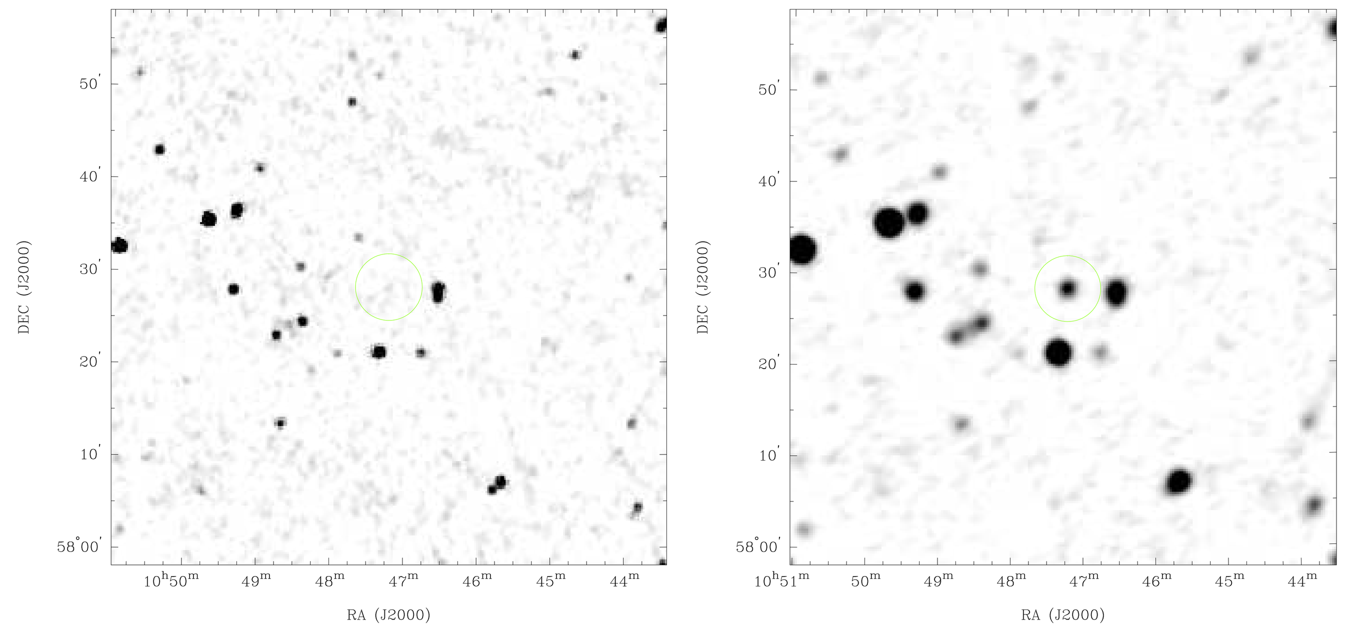

Fig. 5: PiGSS J104711+582817. This source has no counterpart to 2.5 mJy in the Very Large Array NVSS survey (left) but was detected at 3.4 mJy in VLA FIRST (both at 1.4 GHz), and at 10.8 mJy in ATA PiGSS (right). It is associated with a z = 0.55 SDSS source and appears to be a variable AGN.

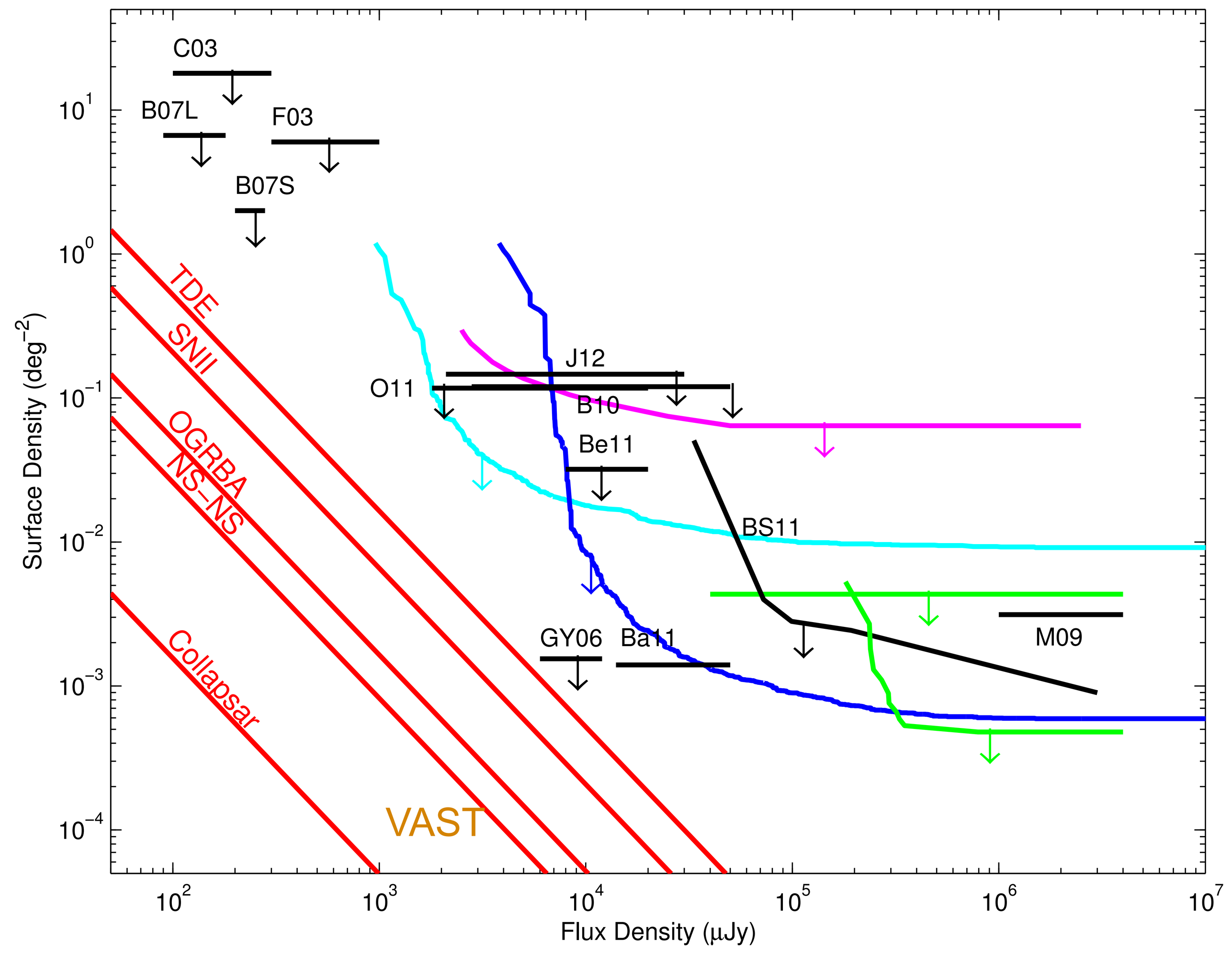

Fig. 6: Surface densities and upper limits for transients from current surveys. Comparison of ATATS deep image to NVSS (upper line) and of ATATS single-epoch images to deep image (lower curve). Upper limit on long-duration transients present in PiGSS but missing in NVSS. Comparison of PiGSS monthly images to PiGSS deep images and of PiGSS daily images to deep images. Predicted ASKAP VAST sensitivity for 10-day average 10,000 deg² image when compared to deep field.

Predicted rates for tidal disruption events, Type II SNe, orphan gamma-ray burst afterglows, neutron star—neutron star mergers, and collapsar-like events (see Frail et al. 2012, ApJ, 747, 70).

ASKAP Variables and Slow Transients (VAST)

The Australian Square Kilometer Array Pathfinder is currently under construction (Fig. 7). The VAST project (Murphy et al. 2012; arXiv:1207.1528) will image 10,000 deg² each day to 0.5 mJy.

The transient surface density reached by VAST in 10-day average images is shown in Fig. 6. This should be sufficient to blindly detect transients — if models are correct, up to 60 new tidal disruptions at z < 0.25 every 10 days. VAST will also obtain daily lightcurves for 250,000 radio AGNs.

Fig. 7: The Australian Square Kilometer Array Pathfinder - Ant Schnickel