# A New Era For Low Frequency Galactic Center Transient Monitoring


N.E. Kassim[1], S.D. Hyman[2], S. Cutchin[3], T.J.W. Lazio[4]

1: Naval Research Laboratory, 2: Sweet Briar College, 3: NRC-NRL, 4: JPL-Caltech


## OVERVIEW


A major upgrade of the VLA's low frequency observing system, called Low Band (LB), promises to open a rich new era of Galactic Center (GC) transient monitoring with the VLA. Our previous searches using the VLA and GMRT have revealed a modest number of radio-selected transients, but have been severely sensitivity and observing time limited. The new LB system, currently accessing the 236-492 MHz frequency range, promises ≥ 5X improved sensitivity over the legacy VLA system. We present early data from our new transient monitoring program demonstrating the promise of the new system. Fortuitously, it is also emerging from commissioning just in time to catch any enhanced sub-GHz emission from the G2 cloud event, as anticipated by theory, and we review existing limits based on recent observations. Finally, we describe a proposed 24/7 commensal system, called the LOw Band Observatory (LOBO). LOBO offers over 100 VLA GC monitoring hours per year, possibly unleashing a flow of new detections and validating ASTRO2010's anticipation of a new era of transient radio astronomy.


## The VLA Below 1 GHz: Past & Future

Prior to VLA upgrade

- Two narrow-band legacy systems: 74 MHz: Δν=1.6 MHz, 330 MHz: Δν= 6 MHz

After the VLA upgrade

- **Low frequencies return as "Low Band" (LB)**
  - Single receiver samples ~50-500 MHz
  - Current feeds access 54-86 MHz, 236-492 MHz.
  - **Significant improvements over old VLA system.**


74 and 330 MHz band primary focus feeds

## LOBO Transient Science

**GC Transients**: Requires maximizing Ω (field-of-view) * t (observing time). Dish-based, cm-wave telescopes are inefficient because transient observing time is scarce and Ω is small. LOBO naturally inflates Ω & t, offering tremendous advantages over GHz searches. **The statistics of slow, radio-selected, low frequency GC transients already indicate LOBO should detect dozens of GC events per year.**

**Radio LSST**: The simplest LOBO pipeline will deliver calibrated images & source catalogs. With time, these images will spread to cover the sky. **With the cadence afforded revisiting a popular target like the GC, LOBO will acquire ~100 hours per year for GC transient monitoring.**

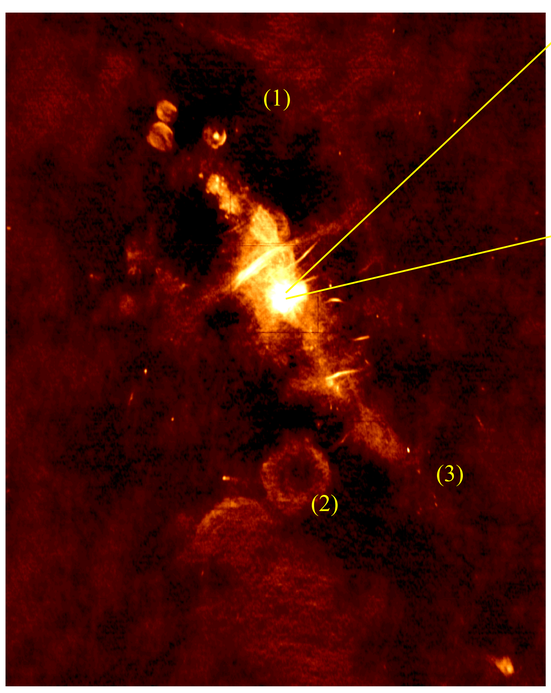
## Galactic Center Monitoring Program

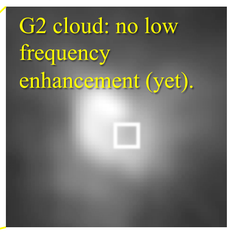
Locations of the three unidentified radio transients discovered in our previous monitoring program (below, left), each with no detected high-energy counterpart, shown on the 90 cm VLA image of the Galactic center (3.5° x 2.5°) region (LaRosa et al. 2000):

(1) GCRT J1746-2757: ~200 mJy transient detected at 90 cm once in 1998 with the VLA (Hyman et al. 2002);

(2) GCRT J1745-3009: ~1 Jy bursting transient detected at 90 cm in 2002 (VLA) and 2003 and 2004 (GMRT) (Hyman et al. 2005);

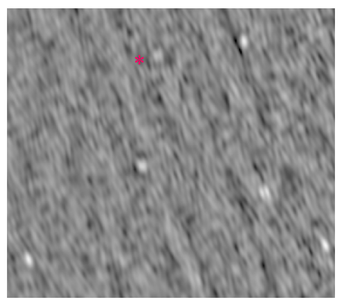
(3) GCRT J1742-3001: ~100 mJy transient detected at 130 cm with the GMRT for 6 months from 2006 to 2007 (Hyman et al. 2009).

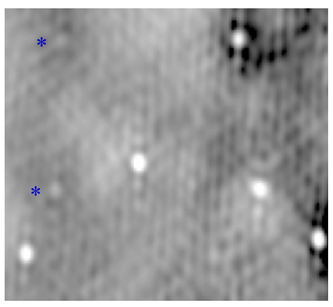



Top: The gas cloud, G2, is colliding with Sgr A* (Gillessen et al. 2012) and theory predicts enhanced low frequency emission (~1 - 40 Jy; Narayan et al. 2012). Our 9 Sept. 2013 VLA LB image (above) of the region around Sgr A*, located at the center of the white box, detected no enhancement (≤ 3 Jy), nor did earlier GMRT observations (≤0.5 Jy @330 MHz, Kassim et al. 2013, ≤ 0.2 Jy @610 MHz, Roy & Kanekar 2013). Much more sensitive observations are scheduled over the next 9 months.

New VLA LB GC monitoring program consists of two 1 hr observations per month from September 2013 to May 2014 in CnB, B, BnA, and A configurations. Notable improvement in signal-to-noise is evident in preliminary images made from the first CnB configuration data (below), and bodes well for probing fainter and more frequent transients.





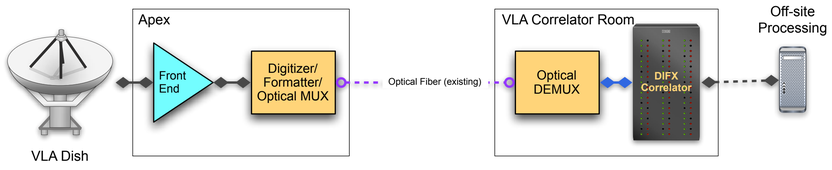
Left: 1 hr Legacy P-band VLA B configuration GC field; rms noise ~12.5 mJy/bm.

Right: 1 hr Low-Band VLA CnB image; rms noise = 5.5 mJy/bm. The new system will be ≥ 5x more sensitive than the legacy system, as will be fully demonstrated in upcoming B and A configuration observations that minimize sidelobe confusion.

Note that the faint source to the right of the red star symbol (*) in the left image is an artifact, as born out by deeper observations with the legacy system (Nord et al. 2004). In contrast, the two faint sources to the right of the *s in the new Low Band image on the right are real sources.

## LOBO and VLITE

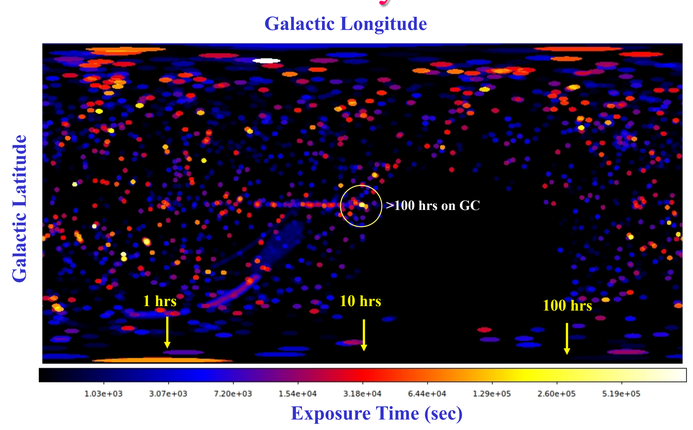
LOBO is a proposed, radio synoptic, high-z spectroscopy, and real time JVLA transient monitoring capability. It will utilize the primary focus feeds to observe in parallel with the Cassegrain feeds. With ~5 deg$^2$ FoV @ 330 MHz, LOBO will perform continuous, blind searches for non-thermal transients and high-redshift spectral lines, annually surveying over 25% of the available sky. A block diagram is shown below. **A 10-antenna LOBO pathfinder called, the VLA Low Band Ionosphere and Transient Experiment (VLITE) is currently funded by NRL and under development with NRAO.**




| Parameter | LOBO |
|---|---|
| Feed | Crossed Dipoles at Primary Focus |
| Frequency Range | 230–436 MHz |
| Bandwidth | 206 MHz |
| Availability | >7000 hours/year (80%) |
| Tsys | 150 K |
| Field of View | 5 deg$^2$ |
| Number of Antennas | 10 |
| Polarization | Dual Linear |
| Receiver Location | Apex |
| A/D Sample Clock | 1024 MHz, 8 bit sampler |
| Correlator HW | 15 Dual 8-core Intel Xeon CPUs |
| Spectral Resolution | 10 kHz |
| Correlator Input Data Rate | 1024 MB/s per antenna |

Block diagram (above) and specs (left) of the proposed LOBO system. LOBO will initially operate in the 330 MHz band, but could be expanded to include the 74 MHz band in the future.

## The LOBO Sky in 1 Year




The fraction of the sky observable by the VLA as a function of dwell time. About [25,10]% of the accessible sky is observed for at least [100 sec, 1 hr] per year, respectively. For a future LOBO operating in the VLA's 74 MHz band, the fractions are 96% and 85%, respectively.

1 YEAR of LOBO:

- ~6000 hrs on sky, ~25% of the VLA sky (~20% of full sky)
- ***> 100 hrs on the Galactic center***

## What does this mean for GC Transients?

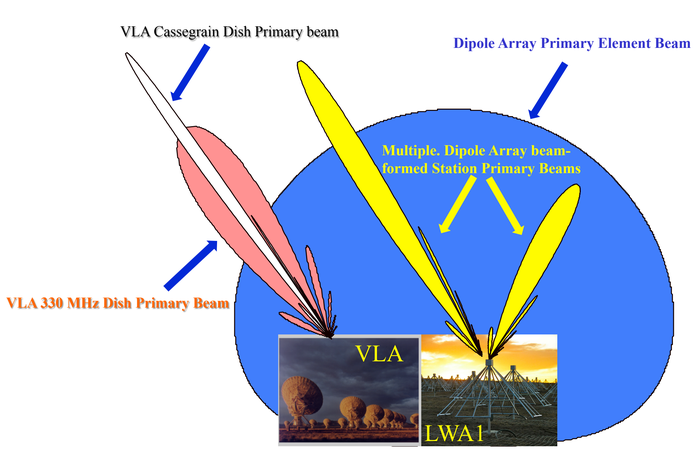
Past experience (Hyman et al.2009)

- ~200 hrs of monitoring yields ~0.05 events at 330 MHz per VLA FoV, S > 50 mJy ($t_{obs}$~ 1.5 hr)

New Low Band VLA:

- ≥ 5X more sensitive
- ~0.2 events per VLA FoV, S > 12 mJy, $t_{obs}$~ 1 hr.
- For ≥ 100 hrs/yr LOBO detects ***≥ 20 GC transients/yr***

## LOBO Synergy with Other Instruments




Telescopes sharing the VLA sky, notably dipole arrays, including LWA1, LoFASM, LWA-OVRO, & LOFAR can track the LOBO FoV. (LWA1: 1st Long Wavelength Array station, co-located with the VLA. See poster by G. Taylor.)


ACKNOWLEDGEMENTS: The Giant Metrewave Radio Telescope is run by the National Centre for Radio Astrophysics of the Tata Institute of Fundamental Research. The Very Large Array of the National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement with Associated Universities, Inc. Basic research in radio astronomy at NRL is supported by the Office of Naval Research, and at SBC by a Gilpin faculty grant. Part of this research was performed while S. Cutchin held a NRC Research Appointment at the Naval Research Laboratory.