Haystack astronomy VLBI progress/plans

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Haystack Astronomy Context:

- General Mission and Interest:
  - Develop new VLBI inst. that optimizes science for astronomical community.
    - Digital Backends: DBE1, DBE2/VDBE
    - IF converters to link any telescope to new backends.
    - New VLBI recorders: burst-mode, Mark5C.
    - New frequency standards for VLBI.
    - Collaborate on array phasing (SMA, CARMA, PdeBure, ALMA).
  - Collaborate on deployment of new systems for mm/cm science projects.
  - New proposal submitted to leverage technical work for high frequency observations.
UVLBI Science Directions

• Projects
  – \( \geq 230\,\text{GHz} \) VLBI: SgrA* (\(<50\,\mu\text{as}, \text{few Rsch}\)), M87 (6 Rsch), other AGN.
  – ULIGS – faint RSN, embedded AGN.
  – GRB’s – expansion vs. time
  – Gravitational Lenses – missing images.
  – SgrA* VLBA observations at 4Gb/s: parallax.
Central Gravitational Lens Images

- Lens theory predicts ‘odd’ number of images, but almost all systems have 2 or 4: a mystery.

- ‘Missing’ images are faint and close to lensing galaxy: can’t see them in the optical.

- Only one central image has been detected so far, but UVLBI sensitivities should be sufficient to detect $\sim50\%$.

- Statistical studies of central regions of galaxies possible.
**BD120: Gravitational Lenses**

- Use sensitive Arecibo-GBT 5GHz baseline at 4Gb/s to search for missing images to few micro Jy.
- Use VLBA at lower recording rate to model bright images for removal from data. Also to check calibration of Ar-GBT.
- Postponed since Feb 2007: Ar painting, GBT track work.
- Now pushed to May 2007 (GBT)
- Must schedule and work out details: frequencies, correlation.
VLBA 4Gb/s SgrA* Observations BD131

- 43 GHz VLBA obs. cannot improve on current estimates of distance to Galactic Center: baseline length limits astrometric accuracy.
- At 86GHz scattering decreases and at 4Gb/s the VLBA can use NL baselines to improve astrometry.
- With ~25 epochs, parallax of SgrA* can be measured to 4%. Mass estimates of SgrA* from stellar orbits dependent on Ro.
- Proposal submitted for preliminary observations as result of last VLBI technical meeting – approved.
- Will use 6 VLBA stations: NL, PT, KP, BR, OV, FD.
- Systems: 1 DBE1 + 2 Mark5B+
- Media: 173 TB required for 2x8hours.
System tested in Socorro and now at PieTown for integration.
BD131 Schedule

- Dec 3-7: Test PieTown system and send system to North Liberty.
- Dec 10-14: Test NL and schedule fringe test.
- Jan 1-20: install at remaining 4 sites and arrange media (request to NRAO for portion).
- Jan 31: first 8 hour run
- Feb 7: second 8 hour run.
- Feb: correlation at Haystack.
- NRAO – Haystack Collaboration.
Burst Mode Recorder

- Phase I: DBE2 to 10Gb NIC in Mark5C, storage in RAM, then recording on Mark5 module.
- Phase II: DBE2 to COTS storage.
- 10GbE protocol under development.
New VLBI Freq. Standard

• In 1-100 second range, H-Maser stability causes decorrelation of >230GHz VLBI signals.

• Cryogenic Sapphire Oscillators have x100 better stability.

• Collaborating with UWA group to adapt two CSO units for VLBI.

• Could be used for VLBI at Chilean site.
Phasing mm/submm arrays

J. Weintroub et al developing phased array processor capable of aggregating all collecting area on Mauna Kea for VLBI (CSO, JCMT, SMA)

- Extensible to CARMA and P de Bure.
- Improves SNR on CARMA-Hawaii baseline by ~x8.
- Incorporates DBE for direct output to Mark5b
- Next gen will use DBE2 with 10GbE Output
New Proposal: Focus on submm-VLBI

- Builds on success of 230GHz VLBI in April 2007: fringes on SgrA*, multiple AGN.
- Builds on current programs at Haystack.
- April 2009: 4Gb/s 230GHz obs. with phased Mauna Kea (CSO-JCMT-SMA) and phased CARMA, with SMTO.
- April 2010: 8Gb/s (DBE2, Mark5c) at 230/345GHz, adding Chilean site (ASTE/APEX).
- April 2011: 8-16Gb/s (Burst Mode) at 230/345GHz, at least 4 stations.
Getting to the Event Horizon: The Galactic Center

- SgrA* likely marks the position of a supermassive (3.7x10^6 Msol) black hole in the Galaxy:
  - small proper motion of SgrA*
  - extreme motions and *orbits* of surrounding stars:

- VLBA: intrinsic sizes are
  - ~24 Rsch (7mm)
  - ~12 Rsch (3mm).

- \( \rho \sim 6.5 \times 10^{21} \text{Msol/pc}^3 \)

- To test for strong GR effects, increase \( \rho \) by orders of magnitude and test for asymmetry requires high freq. VLBI.
Viewing the Shadow with VLBI

Falcke et al

Dependent on optically thin emission.
GR effects important and visible as VLBI approaches 230, 345 GHz
Non-Imaging signatures of the Event Horizon
Summary

• VLBI technical projects at Haystack aimed at advancing VLBI infrastructure and science: focus in next proposal on submm VLBI, but also widebanding VLBA.

• Necessary for optimizing impact of VLBI science on future committees and funding sources.

• Items to discuss: ALMA dish participation, ALMA receivers, collaborative DBE obs. with VLBA and Arecibo.