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JCMT AS A MM/SUBMM VLBI STATION
James Clerk Maxwell Telescope (JCMT)

- Diameter: 15 m
- Surface Accuracy: 24 μm
- Location: Mauna Kea, Hawaii
  - 19°49’22.2” N, 155°28’37.0” W
  - Altitude: 4092 m

JCMT re-started its operation under East Asian Observatory (EAO) since Mar. 1, 2015. Director is Paul Ho.
Past mm-VLBI with JCMT

Sgr A*
Size ≈ 40 μas
(≈ 4 r_{sch})

Vir A* (M 87)
Size ≈ 40 μas
(≈ 5 r_{sch})

Doeleman et al. (2008)

Doeleman et al. (2012)

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Event-horizon-scale structure in the supermassive black hole candidate at the Galactic Centre


Letters

Jet Launching Structure Resolved Near the Supermassive Black Hole in M87

Shepherd S. Doeleman,1,* Vincent L. Fish,1 David E. Schenck,1,† Christopher Bouman,1 Roy Blundell,1 Geoffrey C. Bower,1 Avery E. Broderick,2†, Robert Freund,2 Per Friberg,2 Mark A. Gurwell,2 Paul T. P. Ho,2 Marek Hodge,2 Makoto Inoue,2 Thomas P. Krichbaum,3 James Lamb,2 Abraham Loeb,2 Colin Longdale,2 Daniel P. Marrone,2 James M. Moran,2 Richard Chamberlin8, Gary R. Davis3, Thomas P. Krichbaum11, James Lamb9,10, Holly Maness9, Arthur E. Niel9, Alan Roy9, Peter Stittmatter9, Daniel Werthimer9, Alan R. Whitney11 & David Woody11

Reports

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LETTERS

Jet Launching Structure Resolved Near the Supermassive Black Hole in M87

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The cores of most galaxies are thought to harbour supermassive black holes, which power galactic nuclei by converting the gravitational energy of accreting matter into radiation. Sagittarius A* (Sgr A*), the compact source of radio, infrared and X-ray emission at the centre of the Milky Way, is the closest example of this phenomenon, with an estimated black hole mass that is 4×10^6 times that of the Sun. A long-standing astronomical goal is to resolve structures in the innermost accretion flow surrounding Sgr A*, where strong gravitational fields will distort the appearance of radiation emitted near the black hole. Radio observations at wavelengths of 3.5 mm and 7 mm have revealed a compact structure in Sgr A*, but the spatial resolution of observations at these wavelengths is limited by interstellar scattering. Here we report observations at a wavelength of 1.3 mm that set a size of 3.7 ± 0.2 microseconds on the intrinsic diameter of Sgr A*. This is less than the expected apparent size of the event horizon of the presumed black hole, suggesting that the bulk of Sgr A* emission may not be centred on the black hole, but arises in the surrounding accretion flow.
JCMT Receivers

- **Heterodyne Receivers**
  - **RxA (230 GHz single pixel receiver)**
    - Tunable range: 211.5 - 276.5 GHz (gap at 251 - 253 GHz)
    - DSB, BW ~ 2 GHz, IF = 4 GHz
    - $\eta_{mb} = 0.57$, $\eta_{fss} = 0.66$.
  - **HARP (Heterodyne Array Receiver Program)**
    - 16 SIS mixer array (SSB)
    - Tunable range: 325 - 375 GHz
    - BW ~ 2 GHz, IF = 5 GHz
    - $\eta_{mb} = 0.64$, $\eta_{fss} = 0.75$

- **Continuum Receivers**
  - **SCUBA-2**
    - 10,000 pixel bolometer camera
    - Operating simultaneously at 450 $\mu$m and 850 $\mu$m
The oldest receiver in JCMT.
Need to fill liquid nitrogen and liquid helium constantly.
LO can be locked using both JCMT generated and SMA generated reference signals.
JCMT is looking for some lab(s) to replace with a latest technology receiver.
ROVER is a polarizer to create circular polarization signal for RxA.
Location of Hydrogen Maser

In here.

Side of the SMA building

Mar. 17, 2015
Reference Signal

- **Hydrogen Maser**
  - Located at the vault of the SMA building.
  - It is for both SMA and JCMT VLBI.
  - This signal is sent to JCMT via SMA Antenna 5 IF2 (high frequency IF) backend.
  - When high frequency IF is in use for the normal SMA operation, the Hydrogen Maser signal cannot be used for JCMT.
VLBI Backends

- R2DBE and Mark 6 recorder have been used for the last EHT 2015 observation.
- Brought by MIT Haystack Observatory.
- Located at the SMA correlator room.
Problems for JCMT VLBI

- JCMT stand-alone VLBI has never been done.
  - Reference signal, backends, and some of the cables are shared with the SMA.
    - This is a historical reason, since the VLBI mode is using the eSMA mode system.
    - Currently, reference and IF signals sent out via SMA Antenna 5 IF2 (high frequency IF) backend.
  - Backends belong to MIT.
    - There is no VLBI backends that belong to SMA or JCMT.
    - Not clear whether MIT supports EAO VLBI activities.
  - No signal injection system for JCMT.
    - JCMT-VLBI mode always work with SMA, so always check fringes with SMA.
    - Currently under discussion with SMA engineers.
Conflicition with SMA

- JCMT VLBI needs to use 1 IF backend to send out the reference signal to JCMT, and receive the IF signal back to SMA.
  - If SMA is in the use of
    - 2 frequency mode,
    - 1 frequency mode with the wide band (4 GHz BW) mode, then we cannot use JCMT VLBI mode.
  - If SMA is in the use of
    - 1 frequency mode with the narrow band mode, then OK.

- The most popular SMA observation modes are the first 2 modes, so it is almost hopeless to use JCMT as a stand-alone VLBI station, independent from the usual SMA operation under this configuration.
How to avoid this problem?

- Use eSMA mode and VLBI together with SMA.
  - Fringe check can be done before VLBI, so very convenient.
  - Need to obtain both JCMT and SMA observation time. (i.e., need to submit proposals to both observatories)
  - Need extensive help of the SMA scientists and engineers in both Hawaii and Cambridge.

- Move H-Maser, backends, & recorders to JCMT.
  - At this moment, it is not clear whether JCMT observational building has a temperature controlled and motion stable room.
    - Note that most of the JCMT observational building moves together with the telescope.

- Use new/available cable to send the H-Maser signal directly to JCMT
  - Currently under discussion with SMA engineers.
The Biggest Problem of JCMT
(Message from the EAO Director Paul Ho)

- **Need budget!!!**
  - JCMT totally lacks the operation budget.
  - EACOA contribution from each region is basically for normal JCMT operation (i.e., single-dish mode).

- 1 night observation costs US$ 20,000.
- Usually, VLBI needs 2-3 nights or more, different from the normal JCMT single-dish observations.
- If some groups are going to ask VLBI observations for more than a few nights, those groups need to bring in significant amount of budget to JCMT.
Summary

- JCMT VLBI mode is working even JCMT moved to EAO.
- JCMT VLBI mode is highly relying on SMA.
- VLBI backends need to be brought in to SMA for each observation.
- There is a confliction with the SMA normal operation.
- To avoid this, it needs special technical consideration, which is under discussion with SMA engineers.
- If some of the receiver labs can replace RxA to the latest receiver, it would be welcome.
- Need budget!!!