

Millimeter VLBI with ALMA and Its User Support

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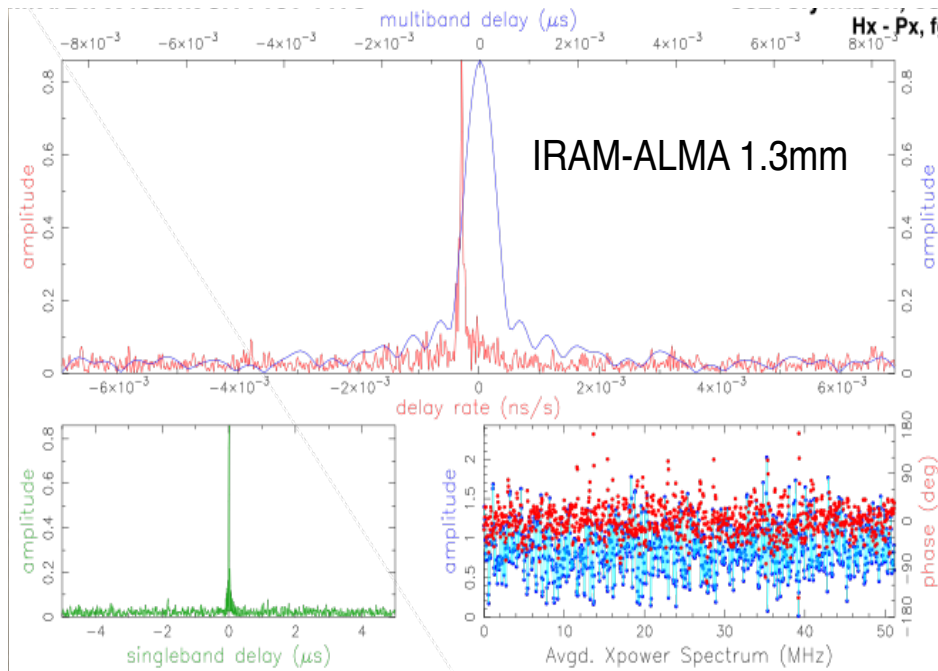
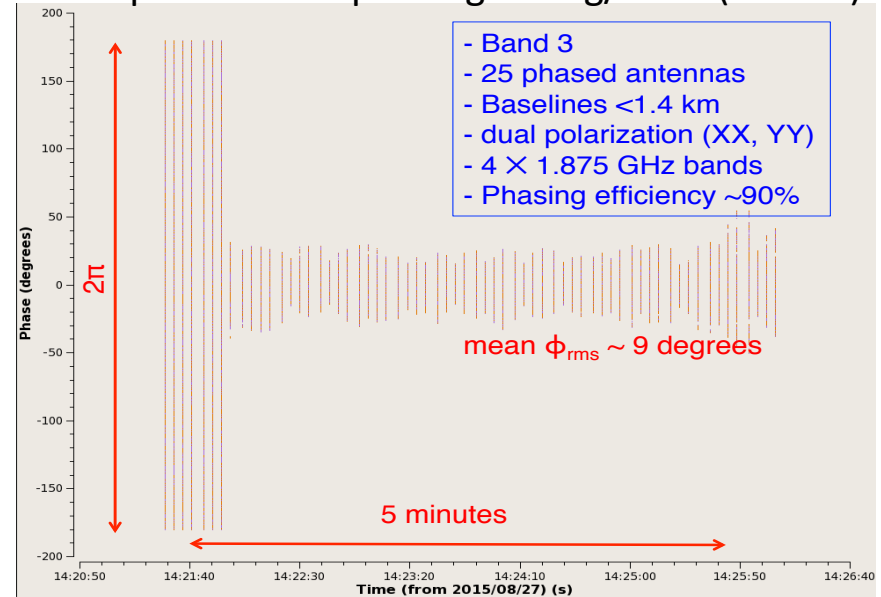
Millimeter VLBI with ALMA

- Utilize the ALMA as a single large ($\sim 84\text{m}$) dish by phasing up the individual ALMA antennas
- Incorporate the phased ALMA into existing global VLBI networks at mm wavelengths
- Dramatic boosts in sensitivity ($\times 10$), uv-coverage, and N-S angular resolution ($\times 2$) of the mmVLBI networks
- Ultra-high-resolution (a few $10\text{s } \mu\text{as}$) studies of AGN/SMBHs/compact radio sources
- Opened in Cycle-4, offered in Band-3 and Band-6. (also Band-7 planned in future)

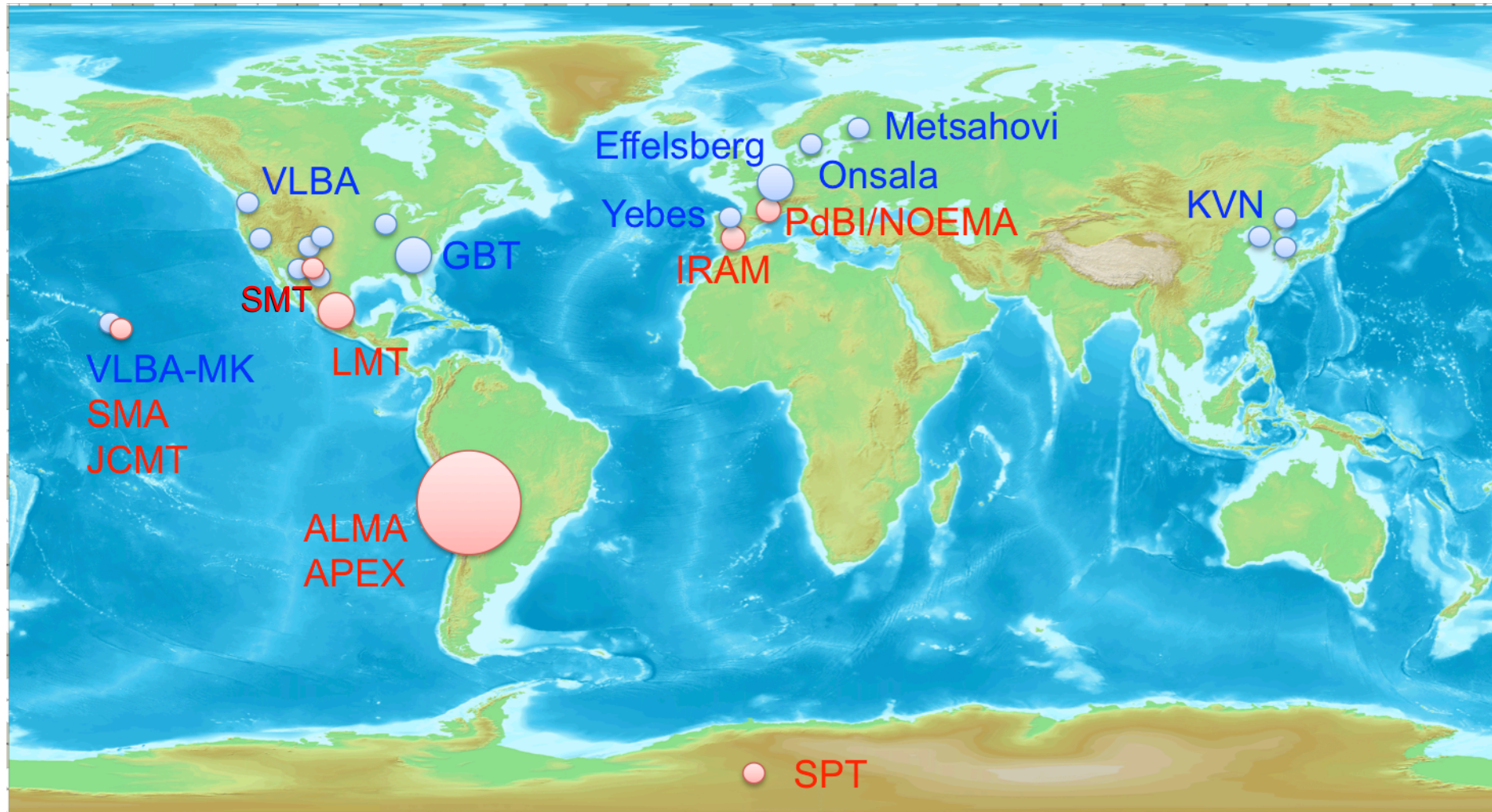
The ALMA Phasing Project (APP)

- Led by MIT-Haystack, promoted in collaboration with NRAO, MPIfR, ASIAA, NAOJ, CfA etc
- APP-CSV campaign started in Jan/2015. Five CSV campaigns to date
- Confirmed several successful intercontinental fringes at 3mm/1mm
- Ready for Cycle-4 use

Example of ALMA phasing in Aug/2015 (Band 3)



Millimeter VLBI networks in Cycle 4



● 3mm (Band-3): *Global Millimeter VLBI Array (GMVA): $\sim 70\mu\text{s}$*

● 1mm (Band-6): *Event Horizon Telescope (EHT): $\sim 30\mu\text{s}$*

VLBI with ALMA in Cycle 4: Proposal constraints

- Band-3 & Band-6
- Non-standard mode
- Up to 5% of ALMA Cy4 time, shared between Band-3 and Band-6
 - Only Grade-A proposals accepted
- Up to 37 phased 12m antennas
 - Equivalent to a single 73m diameter antenna with SEFD~100Jy
- Targets should have correlated flux densities of:
 - >500mJy on intra-ALMA (1km) baselines
 - >50mJy on intercontinental (~5000km) baselines
- Declination range $-45^{\circ} < \text{Dec} < 45^{\circ}$ recommended
- Recording rate: 2Gbps (Band-3), 32Gbps (Band-6)
- Full-Stokes OK (XY to LR through the “PolConvert” software)
- In addition to submitting a usual ALMA proposal, VLBI programs must also submit the same proposal to the GMVA (Band-3) or the EHT Consortium (Band-6)

Cycle 4 outcome

- Submitted: 10 (Band-6), 12 (Band-3)
 - From non-EHT community: 1
- Accepted: 6 (Band-6), 3 (Band-3)
 - From non-EHT community: 0

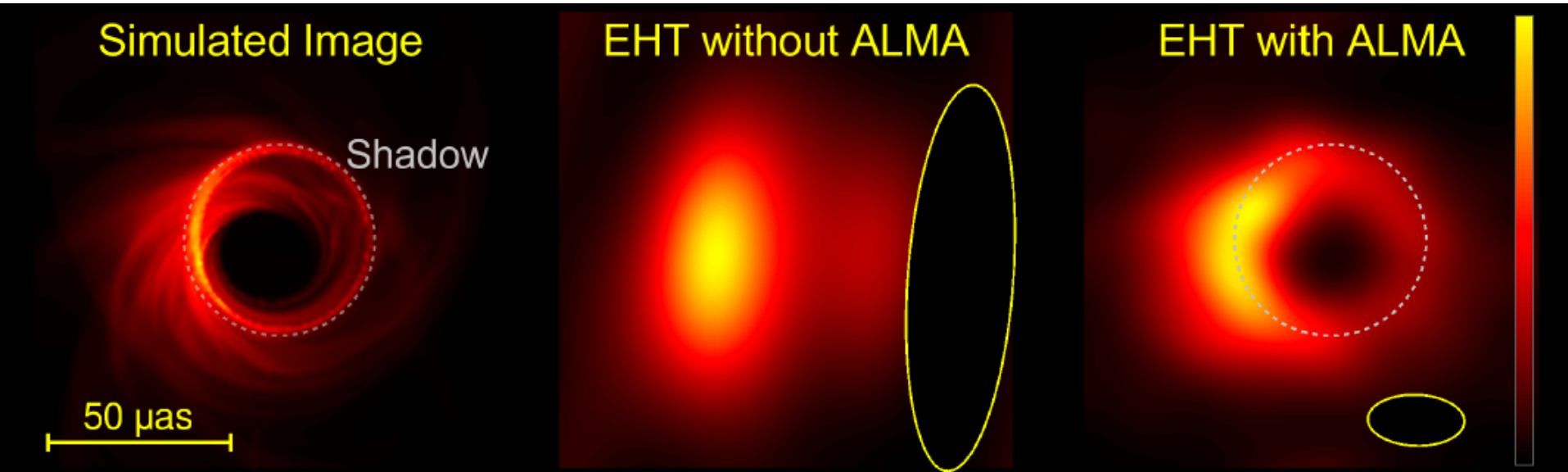
Proposal Type	Number Submitted	Number Grade A & B
All	1571	475 (30%)
ACA	315	79 (25%)
ACA Standalone	30	5 (17%)
Large Programs	27	2 (7%)
Polarization	90	45 (50%)
Solar	53	15 (28%)
Target of Opportunity	21	13 (62%)
VLBI	22	9 (41%)

ALMA Cy4 Selection Statistics

- Band 3 (3 accepted):
 - “Imaging the Global Magnetic-field Structure Near *SgrA**: 3-mm VLBI with GMVA+ALMA”
 - “Probing the active collimation region of the *relativistic jet* in *3C 273*”
 - “Understanding *jet formation* and testing the binary SMBH system in *OJ287*”
- Band 6 (6 accepted):
 - “Imaging the *Shadow* of a *Supermassive Black Hole*: Event Horizon Telescope Observations of *SgrA**”
 - “Imaging the *Black Hole Shadow* and *Jet Launching* Region of *M87*”
 - “Zooming into the heart of the closest radio galaxy: 1mm VLBI observations of *Centaurus A*”
 - “Imaging the candidate binary SMBH in *OJ287*”
 - “Looking into the throat of the magnetized gamma-ray *blazar* *3C279*”
 - “Pinpointing the Highly Magnetized *Twin-Jet* Base Near a Supermassive Black Hole”

“Imaging the Shadow of a Supermassive Black Hole: Event Horizon Telescope Observations of *SgrA**”

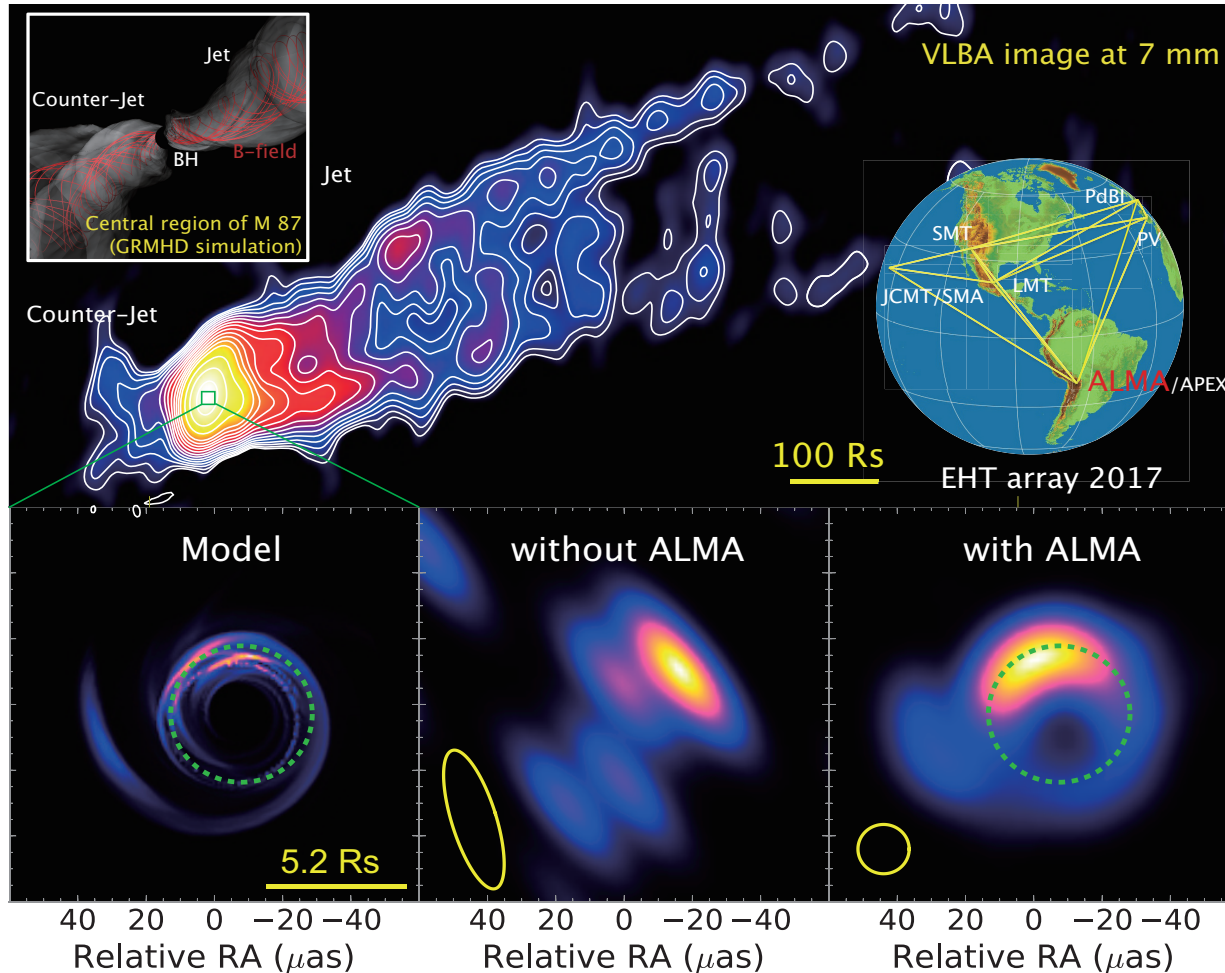
PI: The EHT Consortium



- The nearest SMBH ($1R_s = 10\mu\text{as}$)
- Physics of BH accretion, test GR
- *B*-field structure in accretion flow

“Imaging the Black Hole Shadow and Jet Launching Region of *M87*”

PI: The EHT Consortium



- The nearest SMBH with powerful relativistic jets
- Physics of BH outflows
- *B*-field structure in jet launching region

ALMA-VLBI user support

- So far, the calibration/analysis procedure of ALMA-VLBI data has not been fully established yet
 - Fringe fitting, phased-ALMA properties, amplitude, polarization, imaging etc.
 - Software: AIPS, CASA, HOPS ?
 - Data delivery to users (when, how)
 - Data archival policy
- The EHT Consortium (incl. Miz-VLBI Observatory) will learn and establish standard data processing pathways using the Cycle-4 data
 - Band 6: April/4-15/2017
 - Band 3: prior to April/4/2017
- User-friendly documentation, manual

Towards Cycle-5

- The proposal submission procedure will be similar to Cy4 (probably): requires two steps
 - Band-3: Feb/1/2017 to GMVA & Apr/2017 to ALMA
 - Band-6: Apr/2017 to ALMA and also to EHTC
- The ALMA-VLBI mode is open to the whole astronomy community
 - not just for the EHT community!
- If you are interested in (but not familiar with VLBI), please feel free to contact us. We are happy to support you.