VLBI contribution on AGN jet studies

Keiichi Asada (ASIAA)

Science part: Masanori Nakamura, Makoto Inoue (ASIAA),
Akihiro Doi (ISAS/JAXA) & Hiroshi Nagai (NAOJ)

Greenland Telescope part: On behalf of submm VLBI group at ASIAA
In collaboration with CfA, MIT & NRAO

Key questions for AGN jets

Two fundamental questions:

1. Essential question - What are AGN jets? -

   How are the jets formed?

   How are the jets accelerated?

   How are the jets collimated?

   What are the contents of AGN jet?

2. Philosophical question - Why do AGN jets exist? -

   Why do some AGN (~ 10 %) have jets, some (~ 90%) do not?

   What are the jets triggered by?

   What is the role of AGN jets as a member of the universe?

Key questions for AGN jets

Two fundamental questions:

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VLBI approaches are possible !!

2. Philosophical question - Why do AGN jets exist? -

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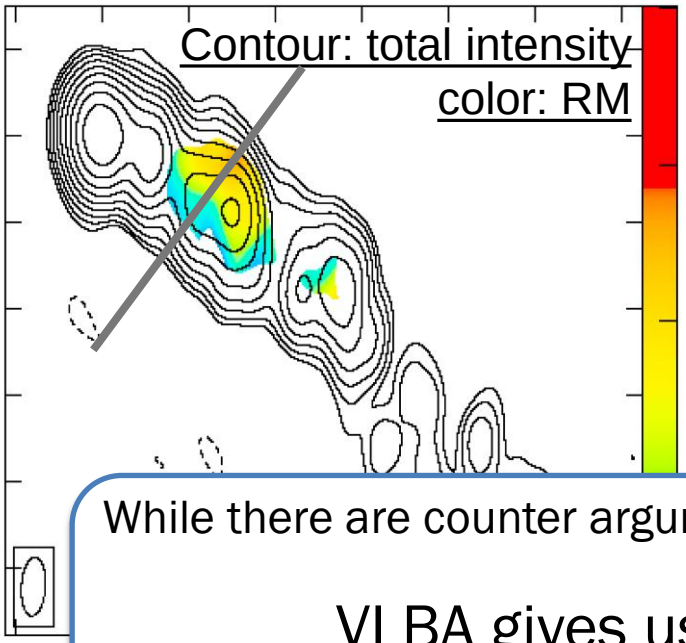
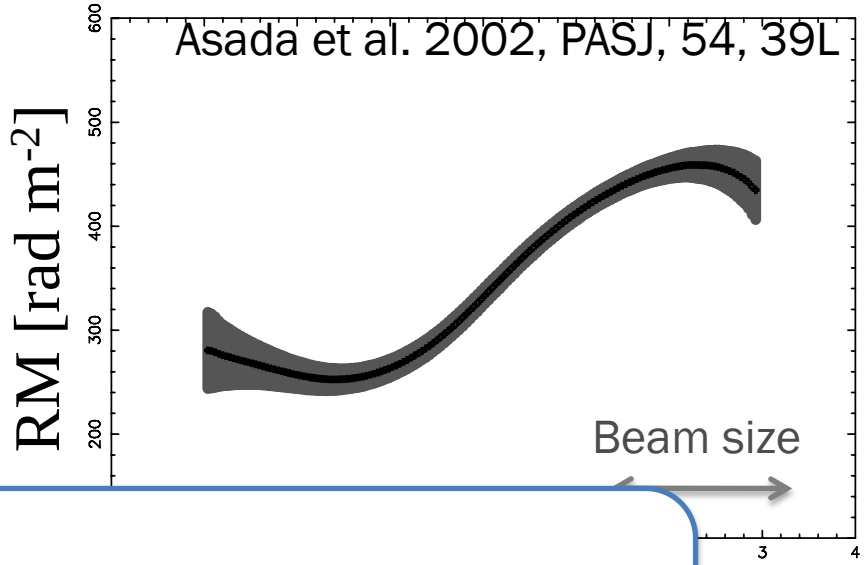
What is the role of AGN jets as a member of the universe?

Toroidal/helical component of B field

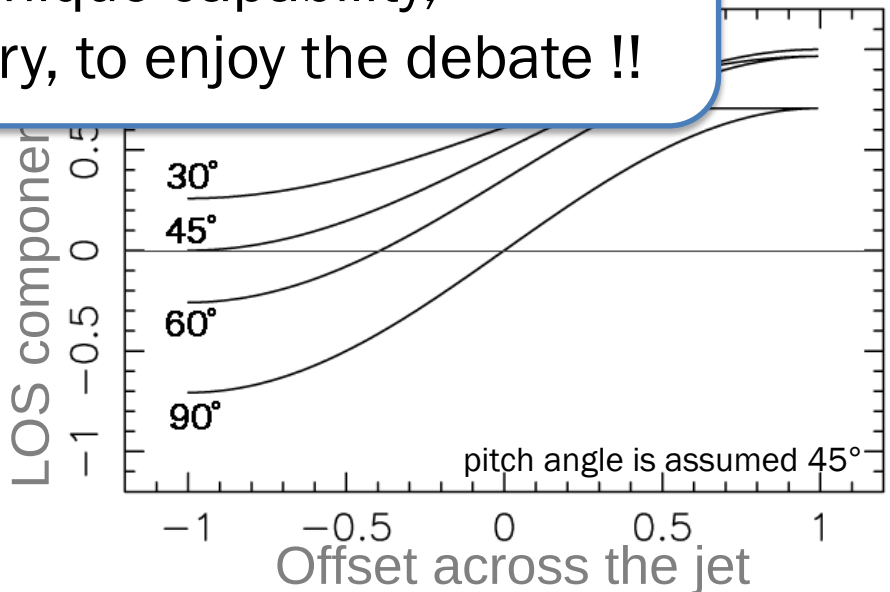




While there are counter argument,

VLBA gives us an unique capability,
multi-frequency polarimetry, to enjoy the debate !!

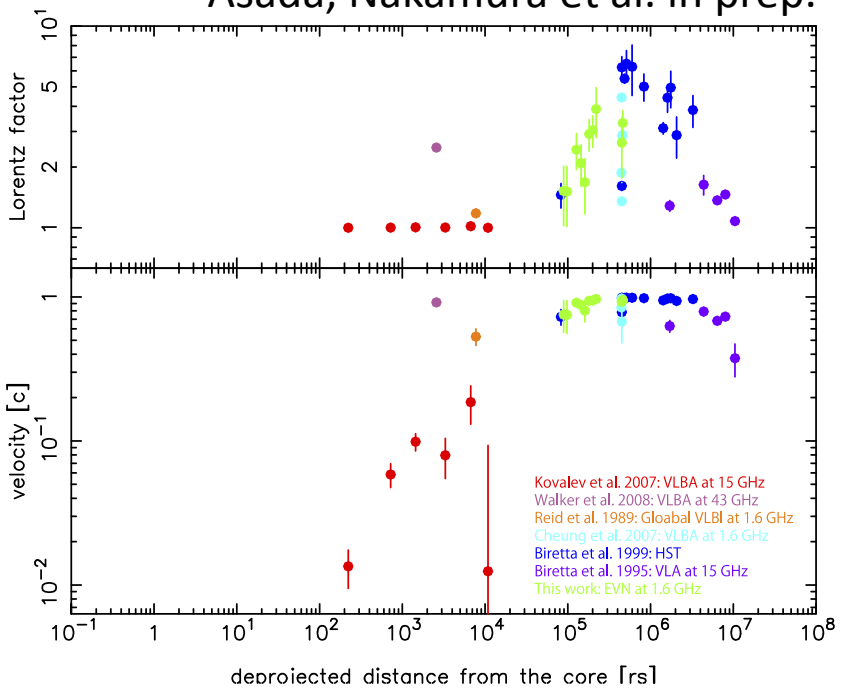
The gradient of RM can be explained by a helical B field.



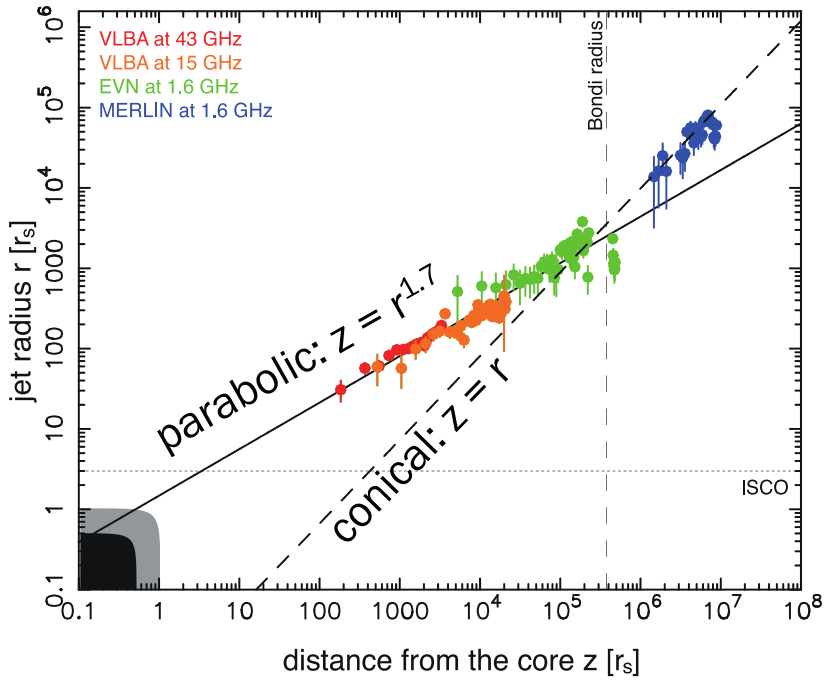
So far, ~30 sources with RM gradient.
(summarized in Contopoulos+09)
Though, there are counter argument....

Collimation and Acceleration region

Asada, Nakamura et al. in prep.



Asada & Nakamura 2012, ApJL



Collimation

Parabolic stream line < 10^5 r_s : under gradual collimation process

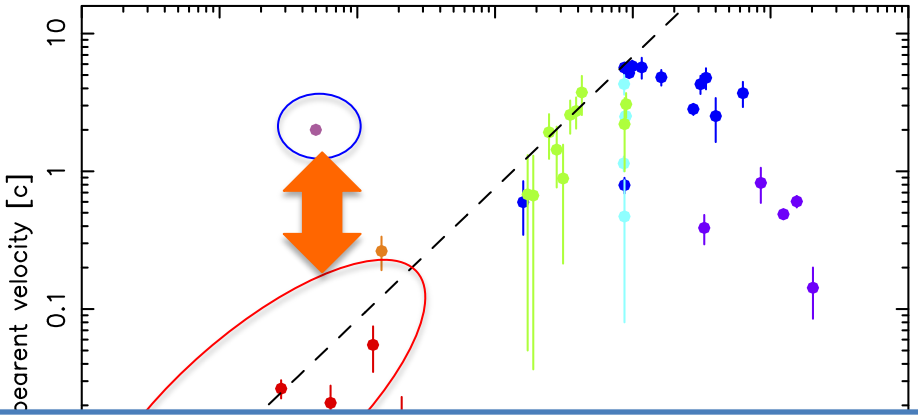
Conical stream line > 10^5 r_s : freely expanding phase

Acceleration

Gradual acceleration in $10^{3\text{-}5}$ r_s from the core !!

Those properties can be explained by MHD jet!!

Gradual Acceleration?



Observing

Pattern velocity
and
bulk velocity?

Or

ers
ath)?

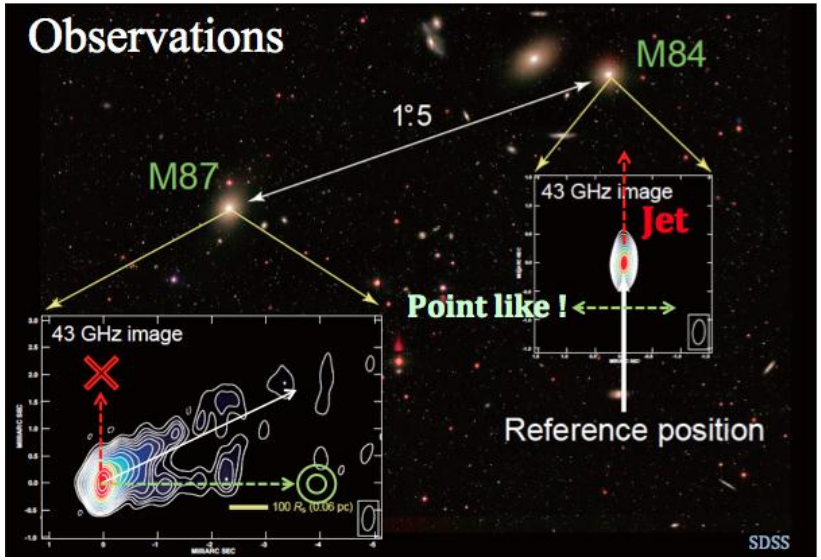
We are likely to be accessing to the acceleration region of M87 jet !!

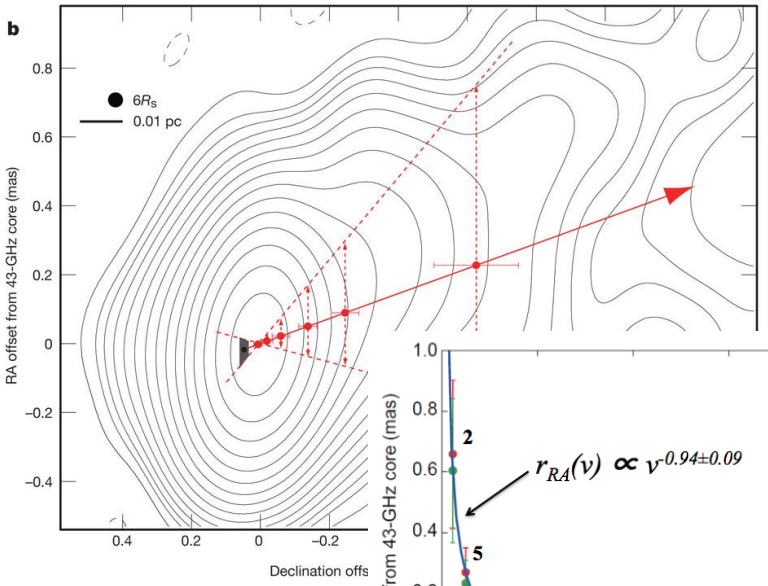
This is an another opportunity to enjoy the debate !!

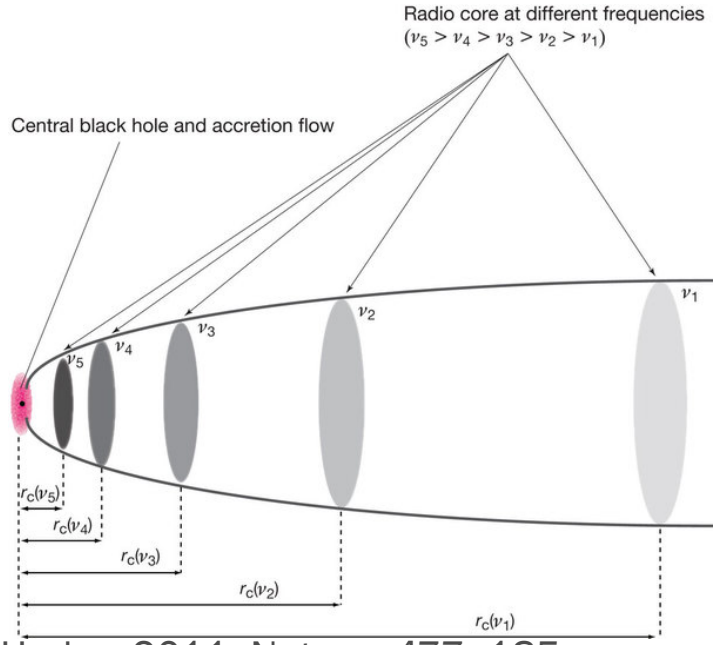
Superluminal < 10 mas (VLBA 43 GHz results)	- No counter jet	- No detection at the other freq. - No accelerating jet?
Subluminal < 10 mas (VLBA 15 GHz results)	- Consistenct with gradual collimation	- No counter jet?

Needs VLBA monitoring at **22** or 15 GHz with short interval and
Needs deeper multi-frequency imaging to investigate the counter jet.

Location of the Central Engine





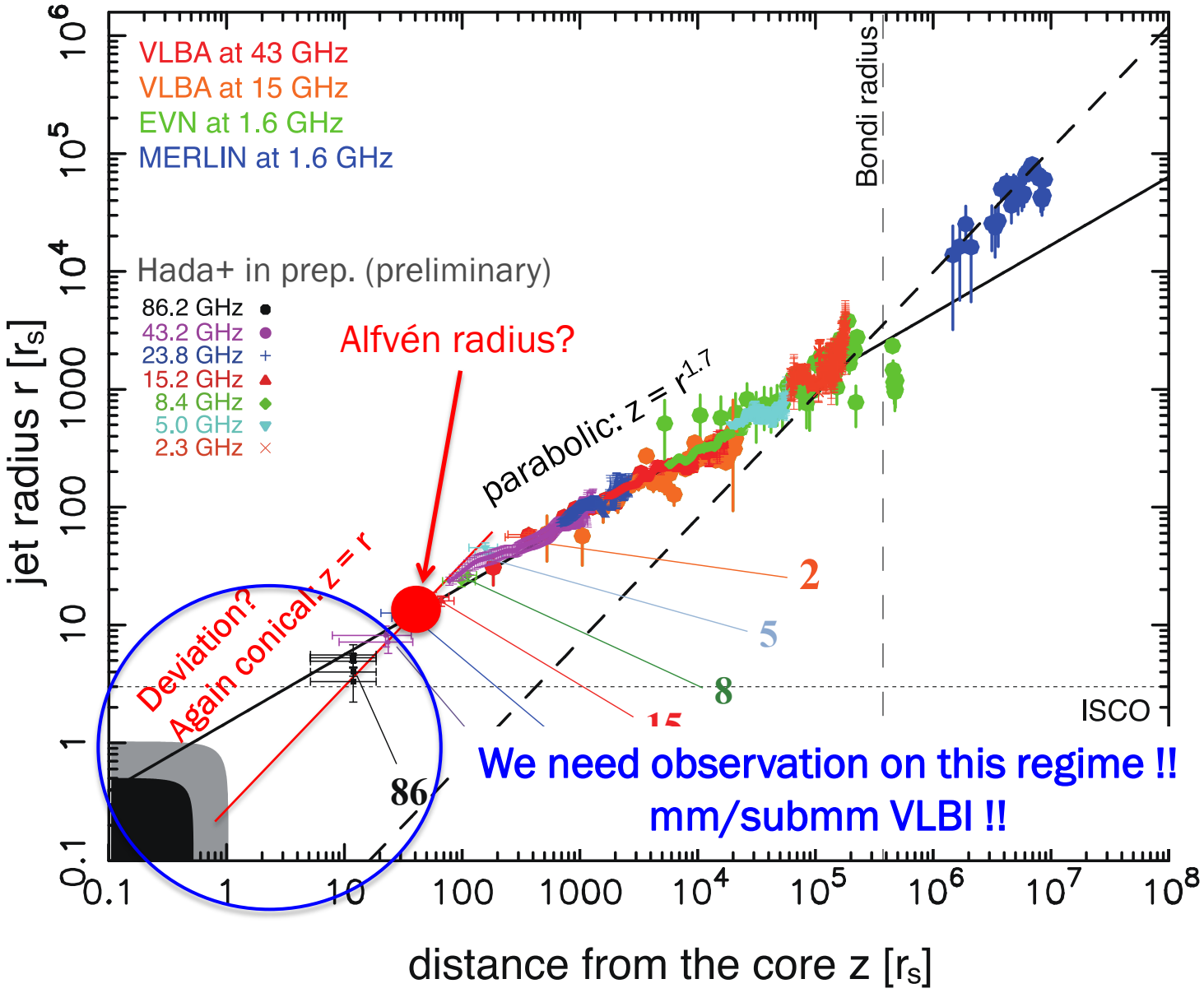


Hada+ 2011, Nature, 477, 185

Central engine is located at (41±12) μas (6±2 Rs) eastward of the 43-GHz radio core.

Importance of astrometry !!

Where is Alfvén radius?



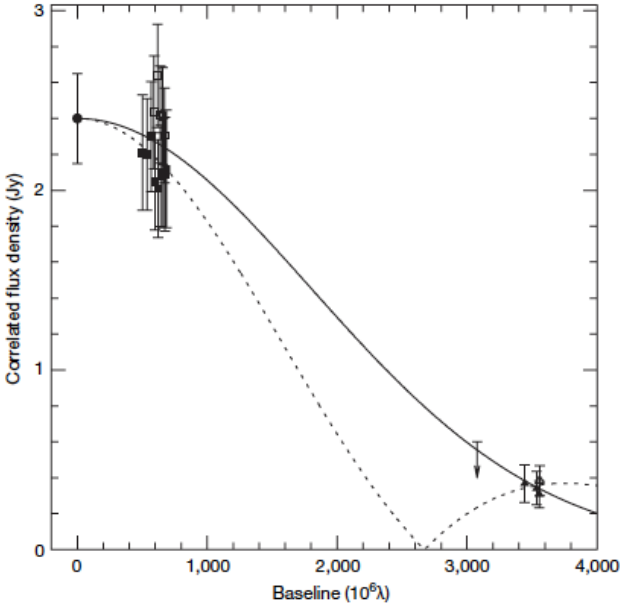
Event Horizon Telescope

nature Vol 455|4 September 2008|doi:10.1038/nature07245

LETTERS

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

Sheperd S. Doeleman[1], Jonathan Weintroub[2], Alan E. E. Rogers[1], Richard Plambeck[3], Robert Freund[4], Remo P. J. Tilanus[5,6], Per Friberg[5], Lucy M. Ziurys[4], James M. Moran[2], Brian Corey[1], Ken H. Young[2], Daniel L. Smythe[1], Michael Titus[1], Daniel P. Marrone[7,8], Roger J. Cappallo[1], Douglas C.-J. Bock[9], Geoffrey C. Bower[3], ...aum[11], James Lamb[12], Holly Maness[3], Arthur E. Niell[1], ...n R. Whitney[1] & David Woody[12]

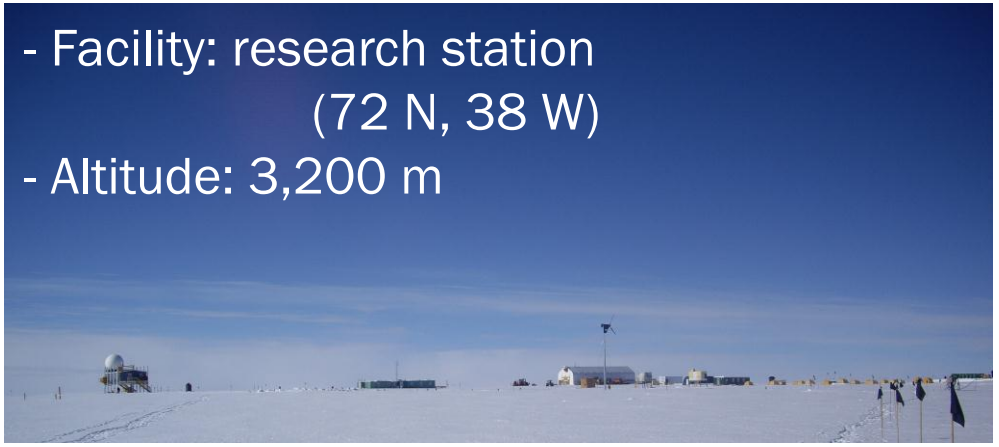


uncertainties resulted in a range for the derived size of 50–170 μas (ref. 12).

On 10 and 11 April 2007, we observed Sgr A* at 1.3 mm wavelength... Radio... Array... Easter... (JCM... time s... at bot... The J... Kea, ... provi... MHz ... site, ... (Gbit s^{-1}). Standard VLBI practice is to search for detections over a range of interferometer delay and delay rate. Six bright quasars were detected with high signal to noise on all three baselines allowing array

Doeleman et al. 2008

Greenland Telescope (GLT) project



We, ASIAA, and CfA jointly acquired

the ALMA NA Test Facility

for submm VLBI purpose

in collaboration with MIT and NRAO.

We plan to retrofit and relocate it to

ice cap of the Greenland !!

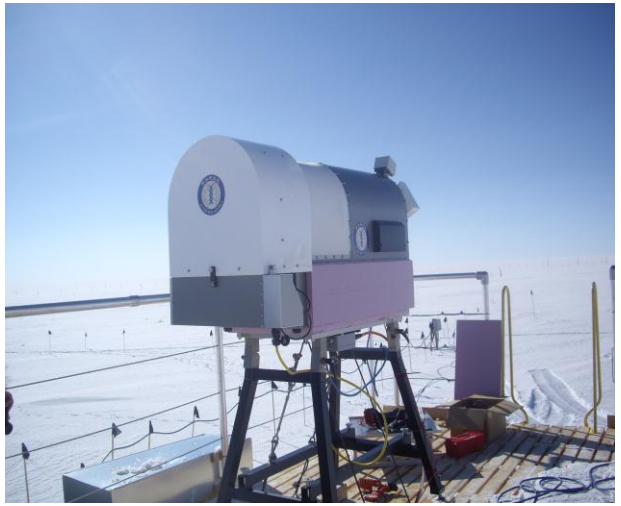
Accessibility:

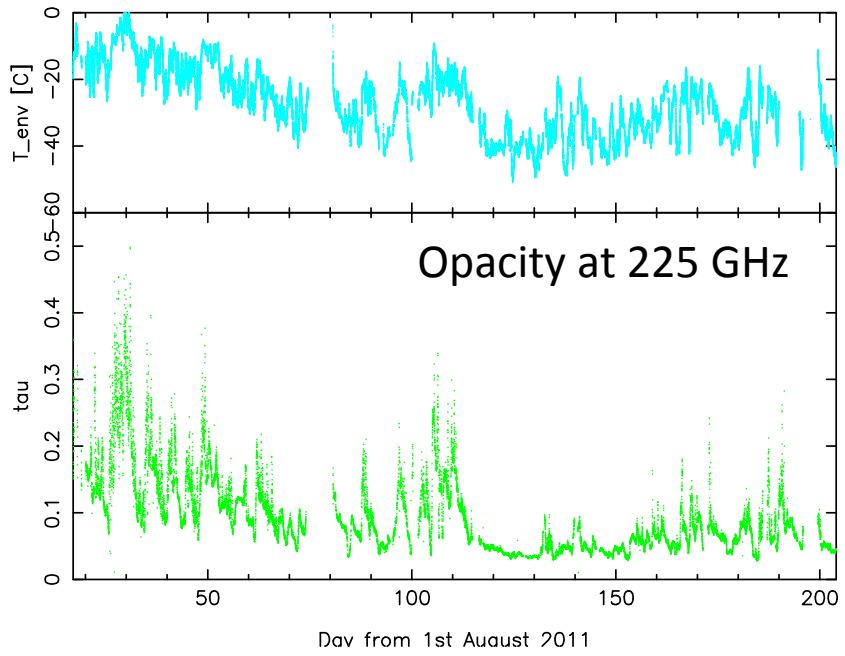
C-130 aircraft (in summer)

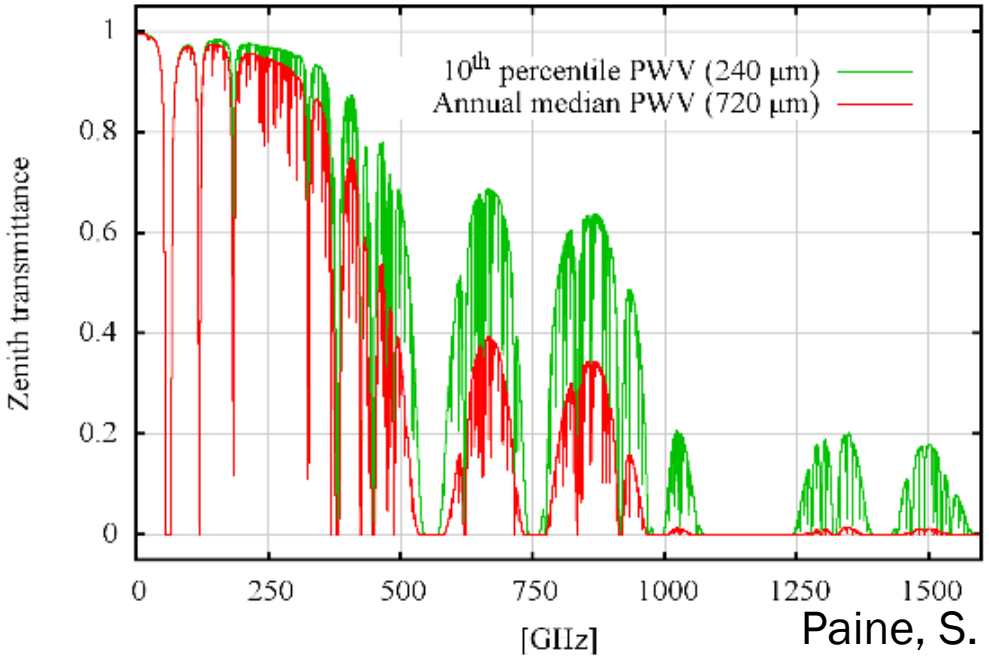
twin otter aircraft (winter)

traverse

Greenland Telescope (GLT) project

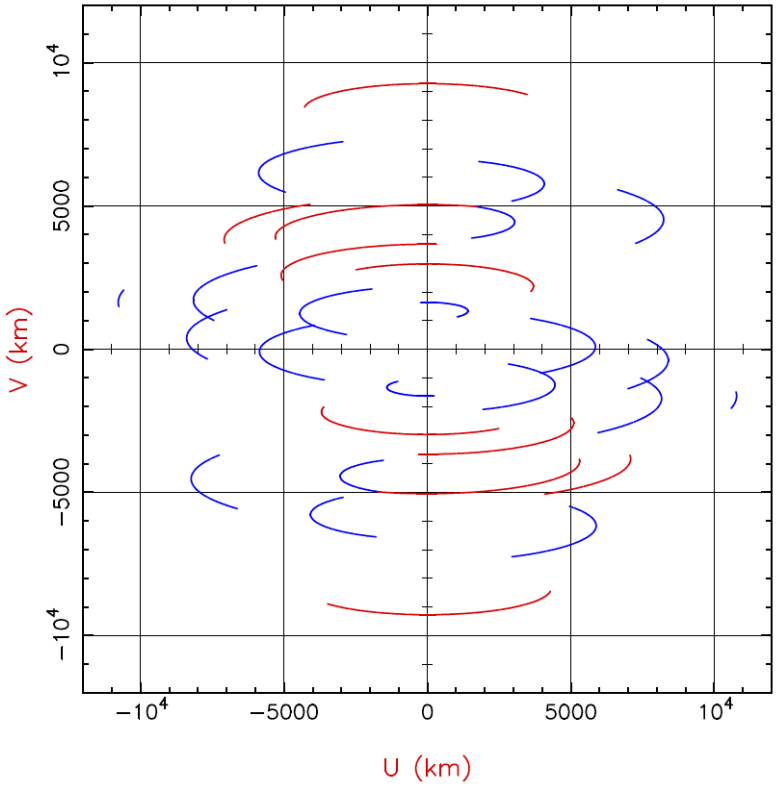






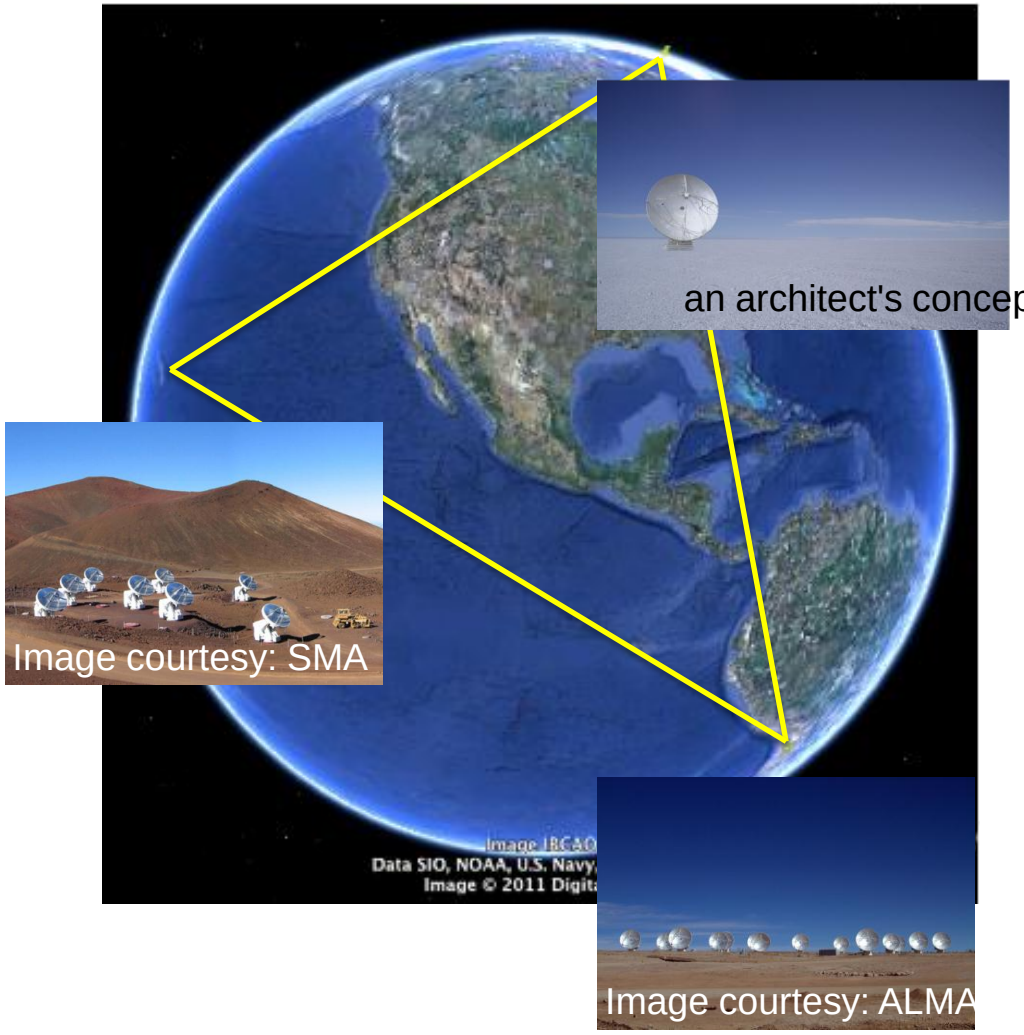
Paine, S.

Greenland Telescope (GLT) project



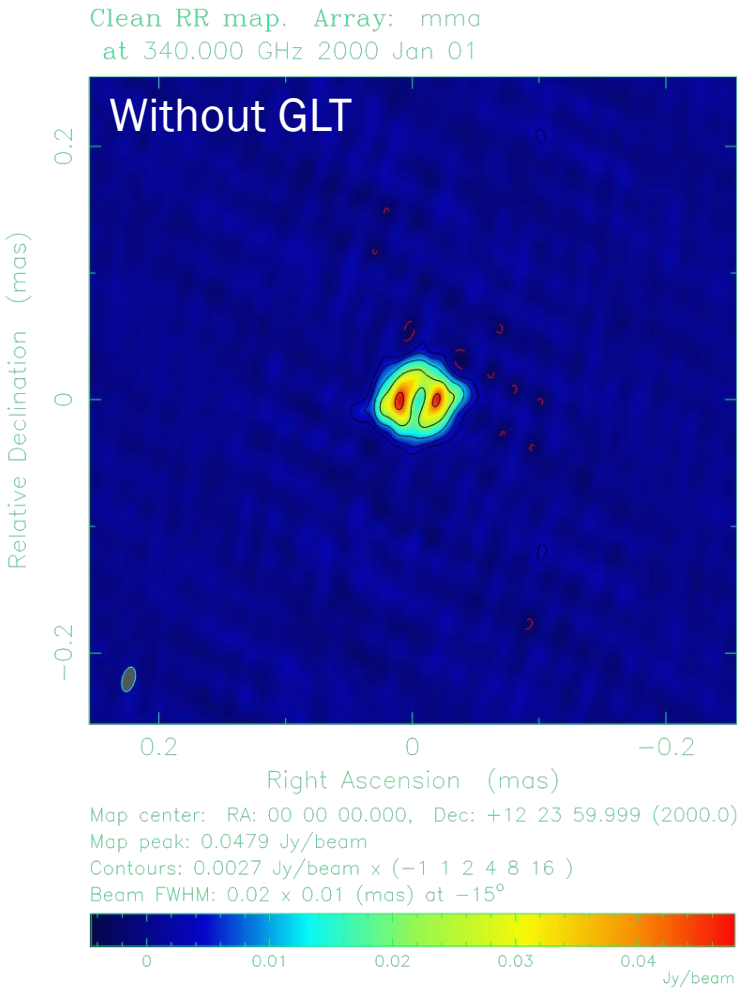
uv coverage for M 87 with GLT, SMA, ALMA, SMT, LMT and IRAM 30m. The Baseline with GLT is red.

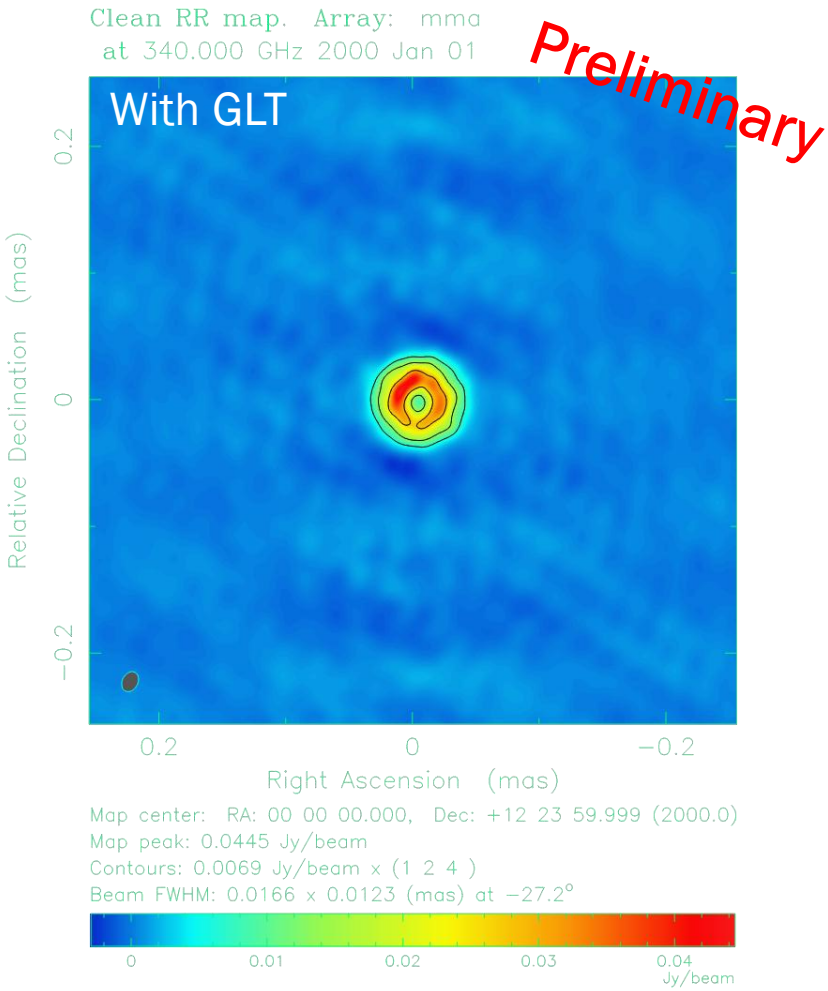
It will provide 9,000 km baseline, and it corresponds to 20 uas (2.5 r_s) at 345 GHz!!



Phase-up ALMA is extremely important; ten times better fringe sensitivity !!

Greenland Telescope (GLT) project





Imaging simulation with toy model (only with Accretion Disk) by Huang, L. (SHAO), Algaba-Marcos, J.-C. (ASIAA) et al.

Key questions and VLBI contributions

How are the jets collimated?

Gradual collimation is likely for M 87.
We need more samples.
(need higher resolution)

How are the jets accelerated?

Not conclusive yet.
Starting with M 87 jet is reasonable,
Then we will need more samples.
(need higher resolution,
& dynamic range)

How are the jets formed?

We will reach the formation
region of the M 87 jet by direct
imaging with submm VLBI !!
(need higher resolution)