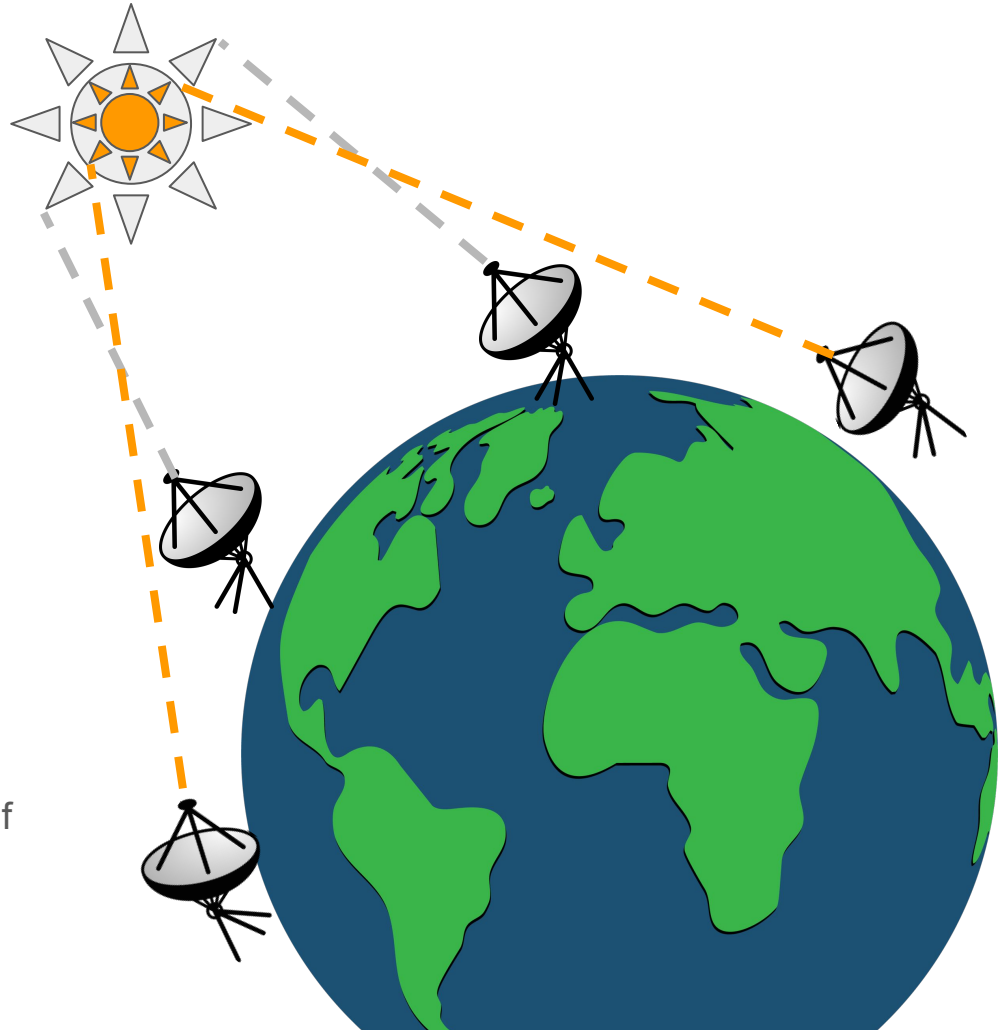


VLBI response to MM triggers *The GLAMM-ARRAY*

Jeff Hodgson
Sejong University, Seoul
세종대학교



Come say hi if
you're in
Seoul/Korea!



Very Long Baseline Interferometry

VLBI in its own world :(

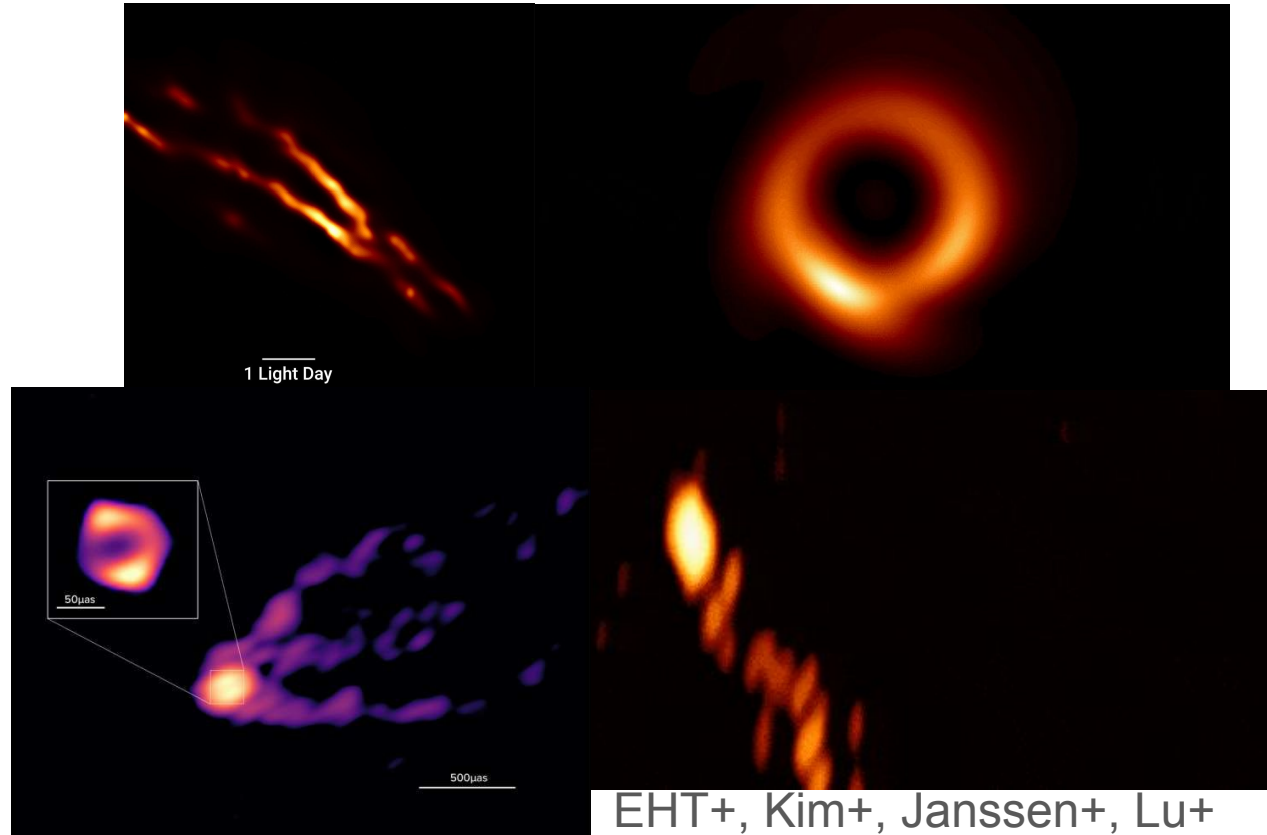
Highest angular resolution

- 20 μas (EHT)
- <40 μas (Space VLBI)

BH image cool but
scientifically not that exciting

“VLBI is an awesome
technique used on boring
science” - Jeff circa 2016

MM transient a perfect fit



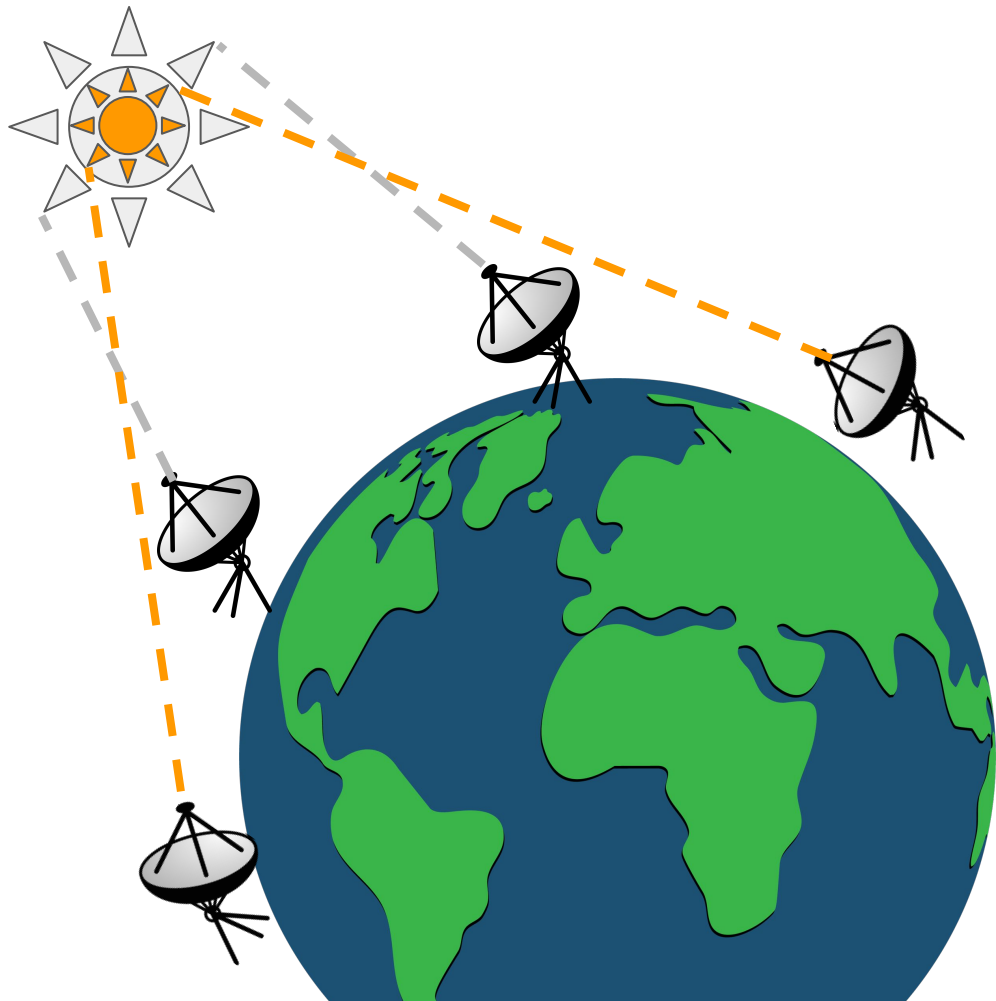
Very Long Baseline Interferometry

In **Astronomical** VLBI, we assume that we know where the stations are and then try to determine where the **radio light** is coming from

The further apart the dishes, more precisely we can determine where on the sky the radio light is coming from

Lots of the 1D slices \rightarrow Image

(Actually more complicated.. Ignoring phases, but basically the Fourier Transform of the sky image)



Very Long Baseline Interferometry

In **Astronomical** VLBI, we assume that we know where the stations are and then try to determine where the **radio light** is coming from

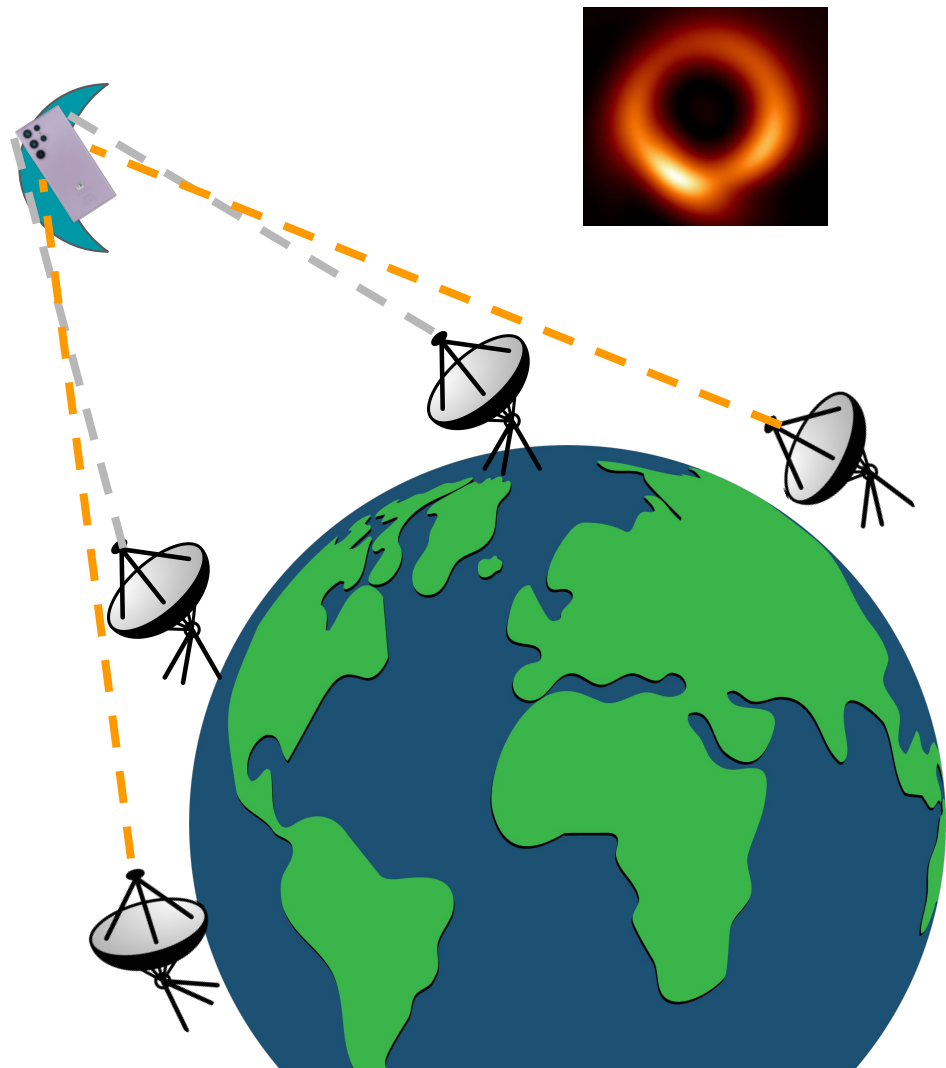
The further apart the dishes, more precisely we can determine where on the sky the radio light is coming from

Lots of the 1D slices → Image

(Actually more complicated.. Ignoring phases, but basically the Fourier Transform of the sky image)

< 50uas - Can resolve a Galaxy on the Moon!

Geodetic VLBI reverses the logic: assumes quasars are stationary (not actually true..) and tries to work out where the dishes are



What I do

Main project: Cosmological Quasar Observations on the KVN from Korea to Australia and South Africa / (Spain) (QUOKKAS)

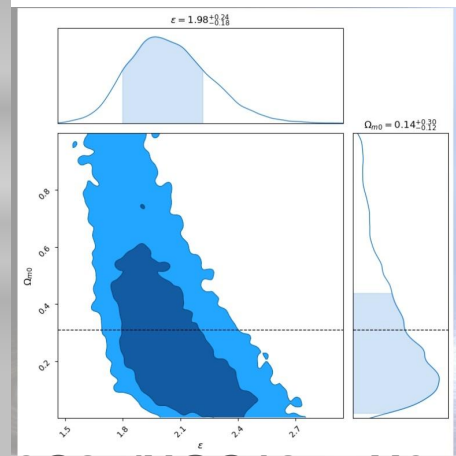
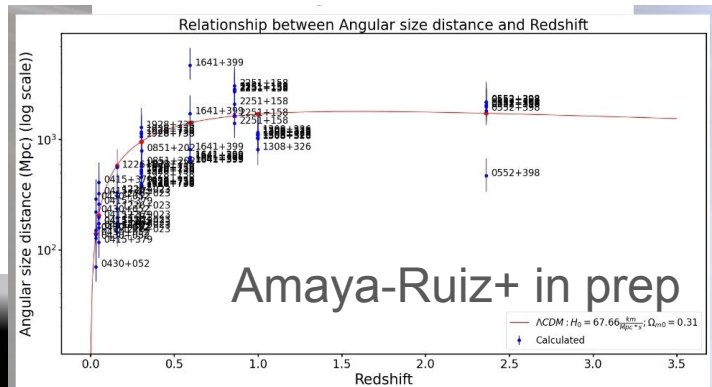
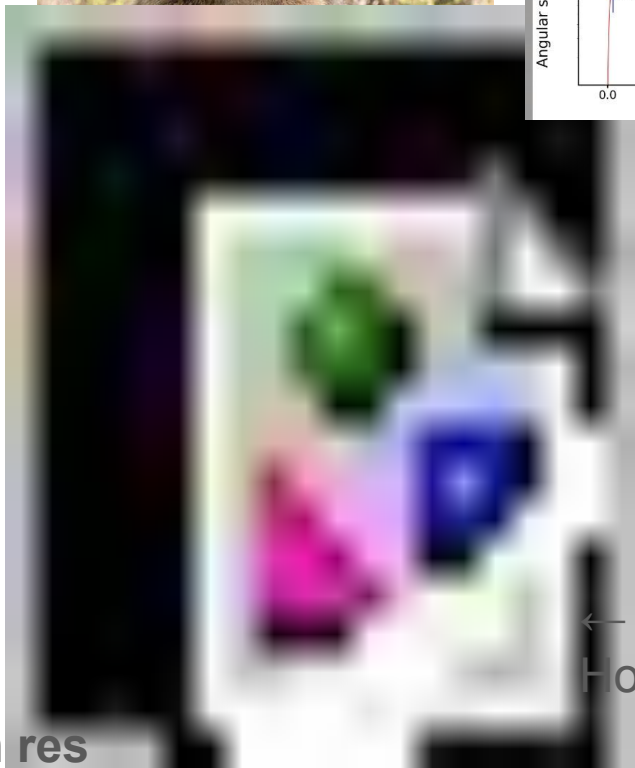
Use the speed of light ($c \cdot dt$) to calibrate a standard ruler \rightarrow Use VLBI to measure the apparent size \rightarrow get the distance “Causality Distance”

$$0 < z < 6$$

Can continuously observe sources, rather than “one-off” Type Ia

(with some luck..) as good as Type Ia within ~ 10 years

Need high cadence + high res



\leftarrow 3C84/NGC1275 $H_0 \sim 73 \pm 6$
Hodgson+ 2020

Korean VLBI Network

Multi-frequency simultaneous:

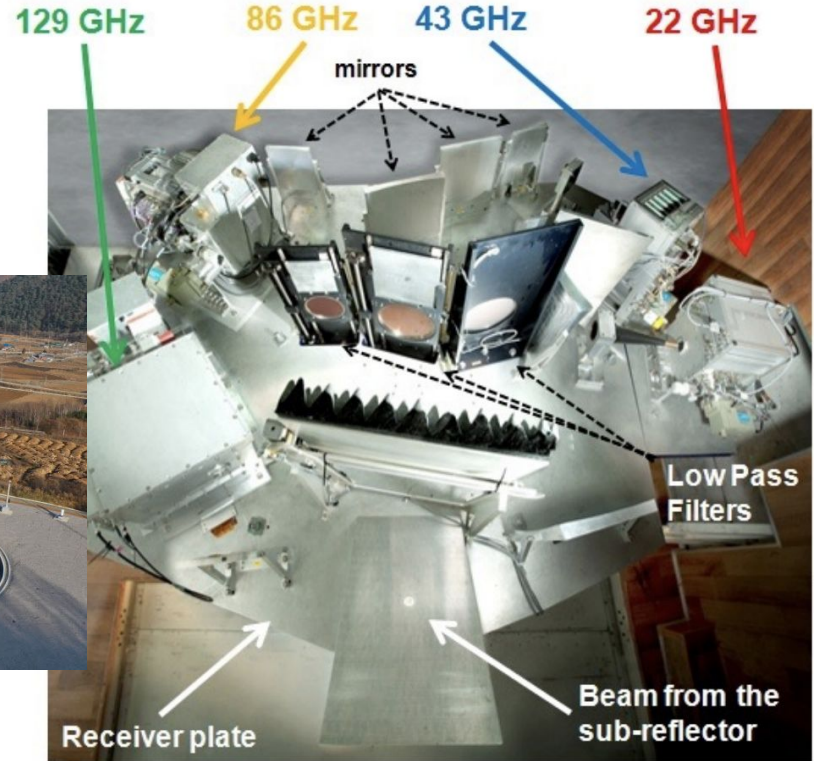
22 GHz (1.3 cm)

43 GHz (7 mm)

86 GHz (3 mm)

129 GHz (2 mm)

230 GHz (1 mm) → New! EHT frequency




One of only a very few dedicated VLBI facilities in the world

KVN taking over the mm-wave VLBI world

+Effelsberg

Simultaneous Multi-Freq. VLBI System in Globe



KVN (K/Q/W/D)
VERA (K/Q)
Sejong (K/Q/W)

Yebes 40m (Spain, K/Q/W)

Nobeyama 45m (Japan, K/Q/W)

Tianma 65m (China, K/Q)

Metsahovi 14m (Finland, K/Q/W)

E-KVN (K/Q/W/D+230GHz)




“Standard System” in mm-VLBI

VLBA MK 25m (USA, K/Q/W)

Sardinia 64m, Noto 32m, Medicina 32m (Italia, K/Q/W)

Mopra 22m (Australia, K/Q/W)

ATCA 22m x5 (Australia, Q/W)



The GLAMM-ARRAY

Global Astrogeo Multi-frequency Monitoring And Rapid Response Array

Weekly global VLBI observations @ 22/43/86 GHz

Angular resolution: ~0.2/0.1/0.05 mas

GAMM-ARRAY North and South

Main science: cosmology (QUOKKAS) and geodesy (“the most important science you’ve never heard of”)

BUT: “*Rapid response...*”

“The big triangle”

Ongoing observations

Weekly VLBI (0.2 mas angular res) a 22 GHz

50 sources monitored weekly

~1000 sources monitored for geodesy (~6 month cadence)

Monthly *imaging* with Very Long Baseline Array (with US Naval Observatory)

Data to be public (once pipelines working)

Thailand coming this year (should allow basic imaging)

Working with geodesists: win-win

Most people don't know that there are two VLBI networks in the world.. Astro and geodetic



Why do you care?

MM (GW, Neutrino, TeV/PeV) trigger

On source at VLBI resolution within <1 week

If a jet is formed, possible to detect

Kinematics → **viewing angle, Doppler factor etc**

“Causality distances” (my selfish interest) →

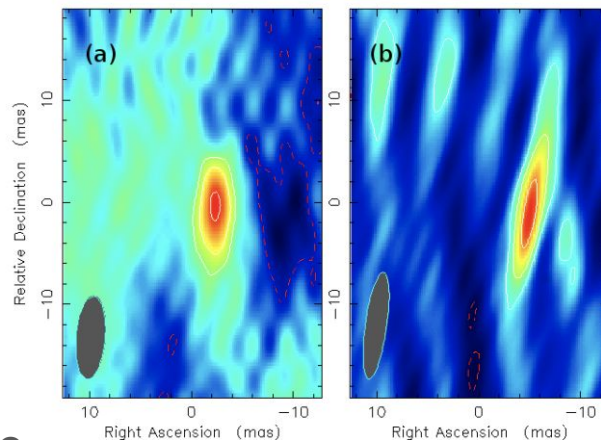
Cosmology → if GW counterpart, direct comparison with standard siren distances

Astrometry → **Precise locations, parallax (if in galaxy)**

Supernovae?? Not sure..

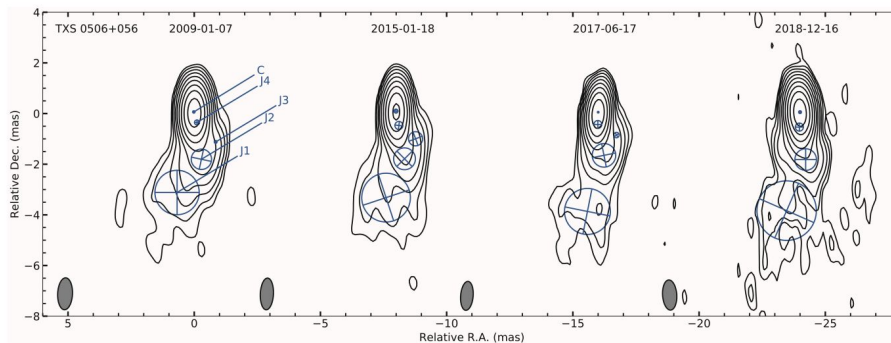
We can do this now! But...

GW170817



TXS 0506: Neutrino candidate

Mooley+ 2018,2022



Li+ 2020

Multi-wavelength – GAMM-ARRAY

KVN style multi frequency system allows:

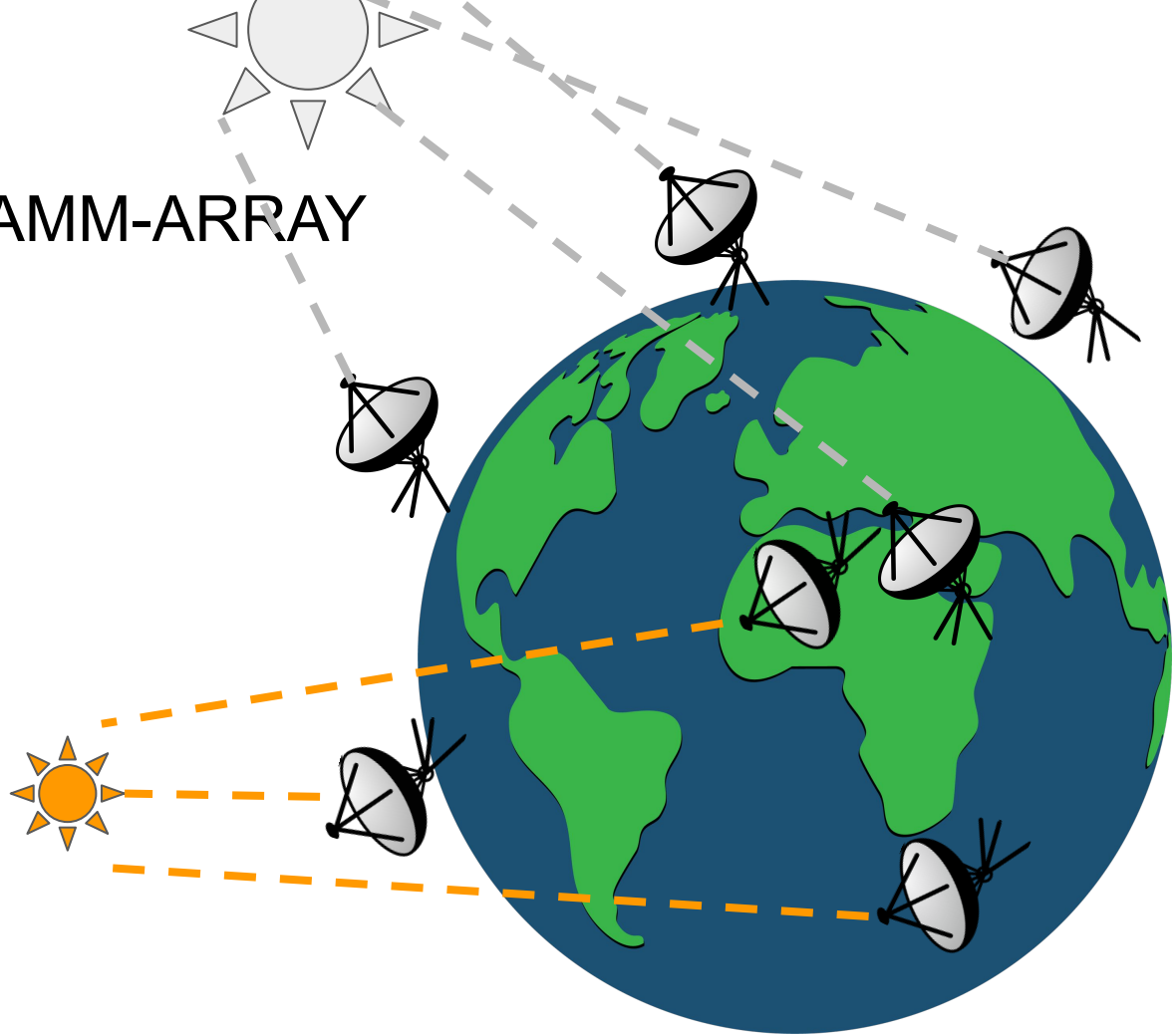
B-field determination via Synchrotron Self Absorption (albeit with large errors)

Extend coherence time to ~30 mins at 3mm/86 GHz **increased sensitivity**

Multi-frequency synthesis: improved resolution and uv-coverage

If equipartition is assumed, we can measure the hadron/lepton fraction of jets

Source Frequency Phase Referencing:
very precise astrometry



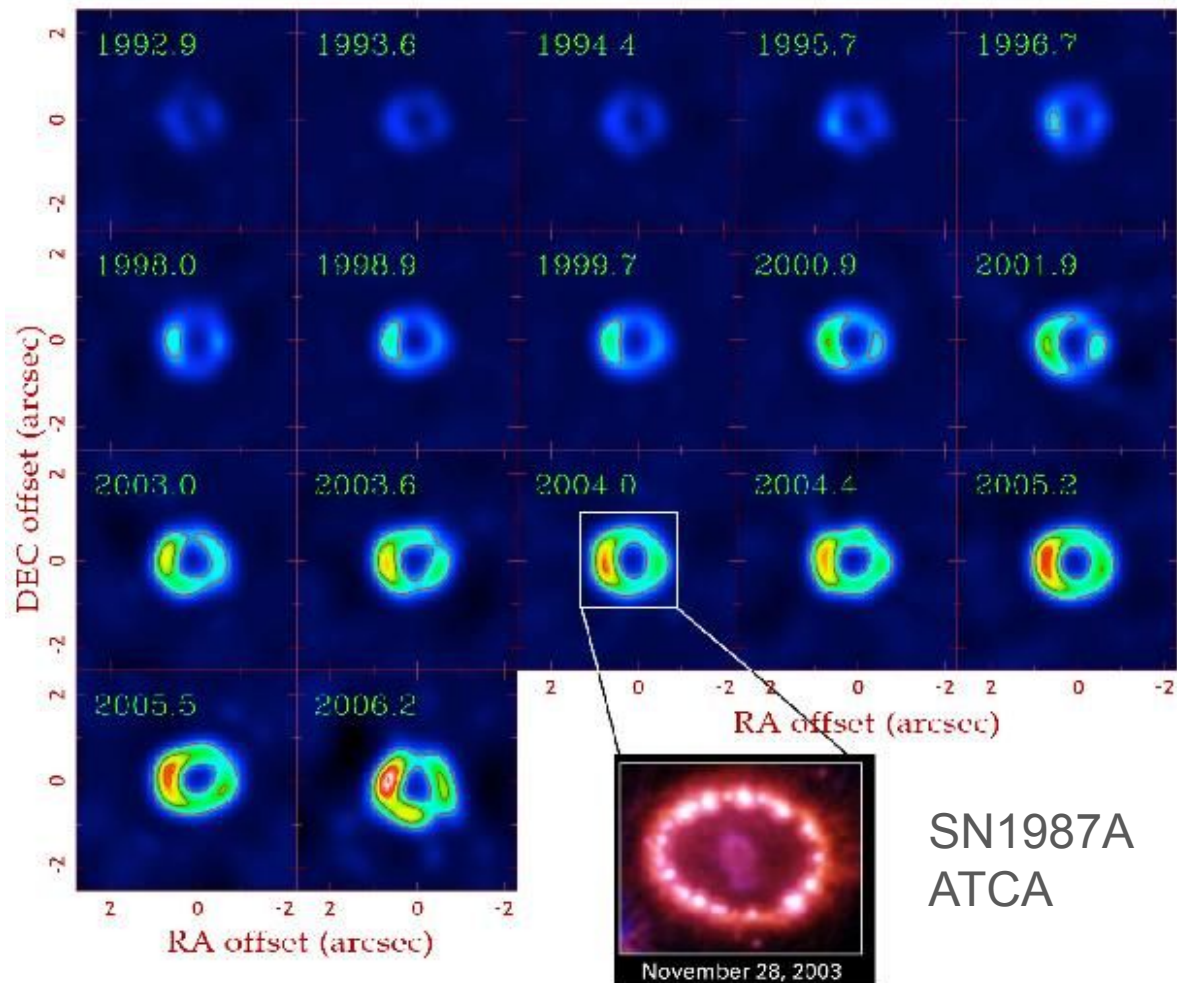
How fast could we be on source (in theory)

Due to discussions at coffee break

Problem: VLBI is normally ad-hoc, have to ask individual telescopes to observe

Solution: dedicated VLBI networks only two exist, VLBA (USA) and KVN

Would require some work 'behind the scenes' but *in theory* could get the KVN on source within ~minutes.. ~hours would be very possible (But KVN is low resolution.. Mopra..)



Conclusions

VLBI offers a powerful way to obtain important physical parameters of MM events

Observations are ongoing **now** at single frequency → just need to ask us nicely to observe something

Can do this for “free” piggybacking off our ongoing observing program

KVN-style triple band receivers are being built out around the world →
GAMM-ARRAY possible within a few years

If you're visiting Korea/Seoul, let me know and give a talk



Narita Airport
BC