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'How to' MultiView

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A (hopefully) useful guide for how we get 10uas astrometry

Multi-Who?

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So What is MultiView?

(and what is VLBI phase referencing?)

VLBI Astrometry

Astrometry: *Measuring the position and movement of objects in the sky*

Phase referencing: *Transferring the phase information from one object to another*

In VLBI relative astrometry, we use phase referencing to position objects relative to one another

In essence, MultiView is multi-calibrator phase referencing

In theory MultiView should allow high accuracy VLBI astrometry in a ***multi***tude areas:

- Trigonometric parallax
  - Astronomical masers**
  - Pulsars
- Proper motion of
  - pulsars/masers** and/or
  - galaxies/quasars**
- Satellite tracking
- Quasar core-shift
- Others?

Why...?

...Do you Need it?

Depending on your frequency and array you may/will encounter residual (after conventional calibration) effects due to:

- Residual baseline
- Uncalibrated troposphere and ionosphere
- Source structure
- Source position offsets

These will affect your ability to *accurately* position your target over time.

Many of these residual effects will also (or are likely to) have a direction-dependence from the phase reference position.

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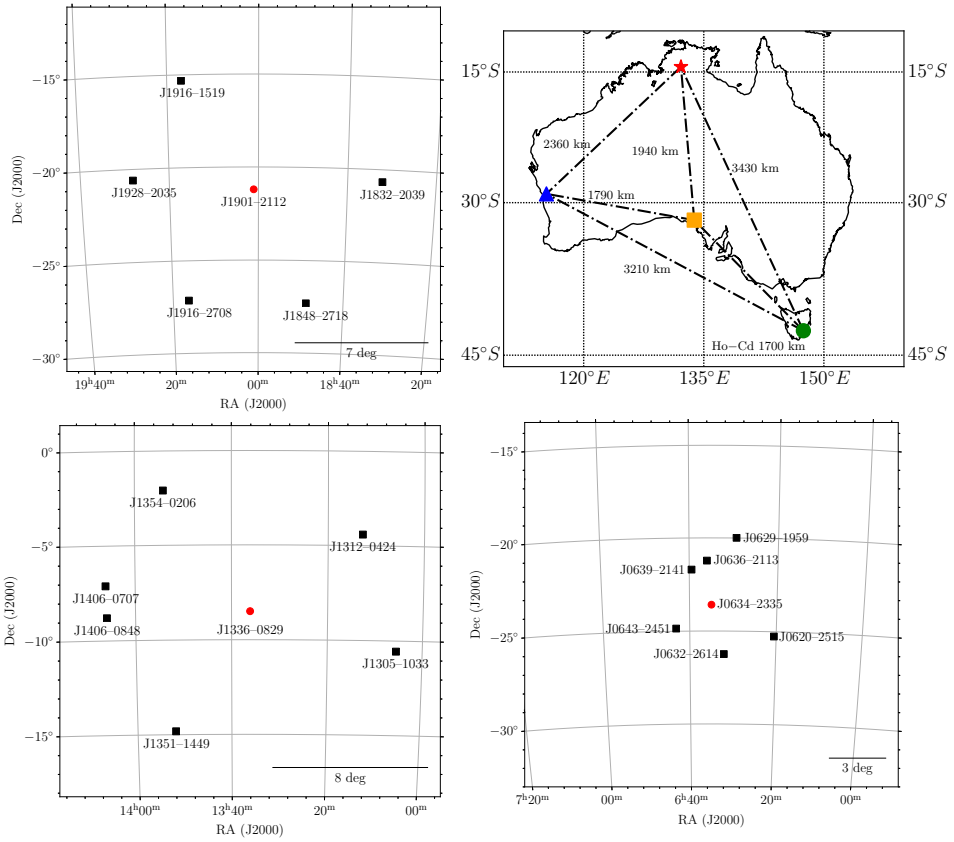
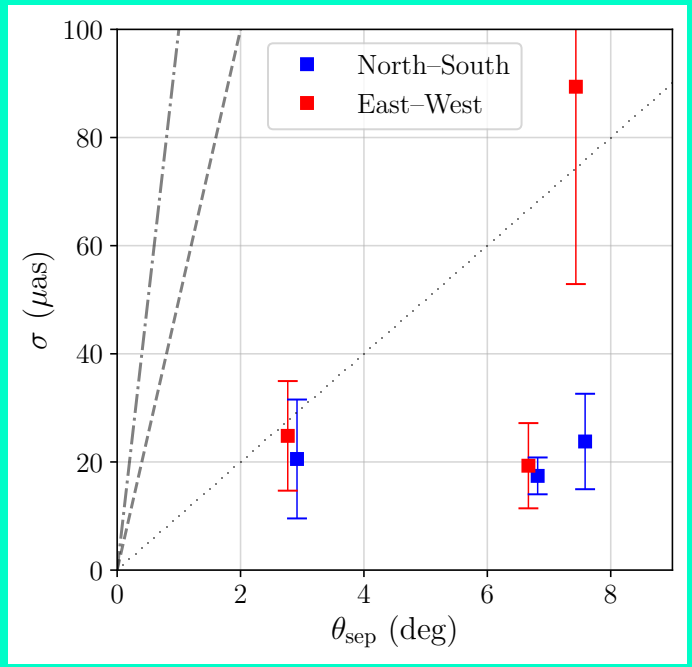
* Not this one though, we'll talk about that later

...Should you use it (1)?



Hyland et al. 2022 [2022ApJ…932…52H]

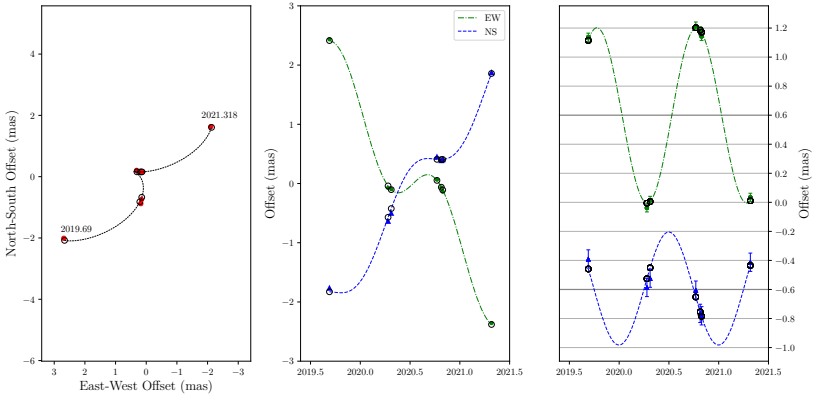
We found that you can achieve **~25uas** positional accuracy (per epoch) out to separations of **7degs** at 8.4GHz after application of MultiView



...Should you use it (2)?

We have been able to measure trigonometric parallaxes for **6.7GHz** methanol masers with an accuracy of **~10uas** (~30uas/epoch)

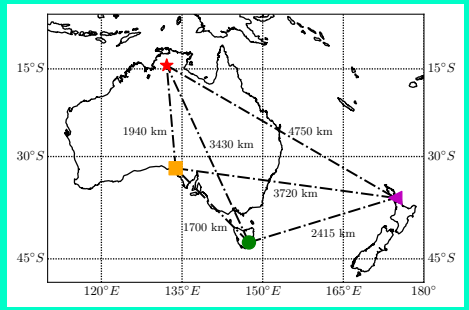
Here we are using **four** antennas, a maximum baseline of **4750km** and an average separation of between **3-5**deg.

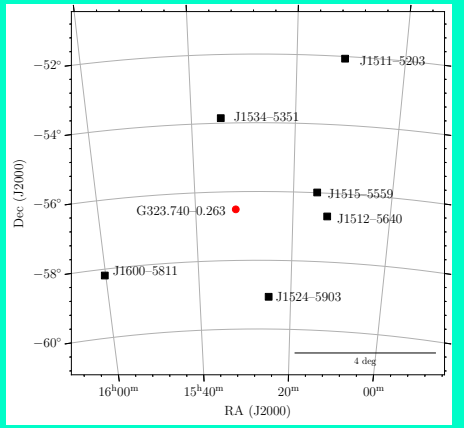


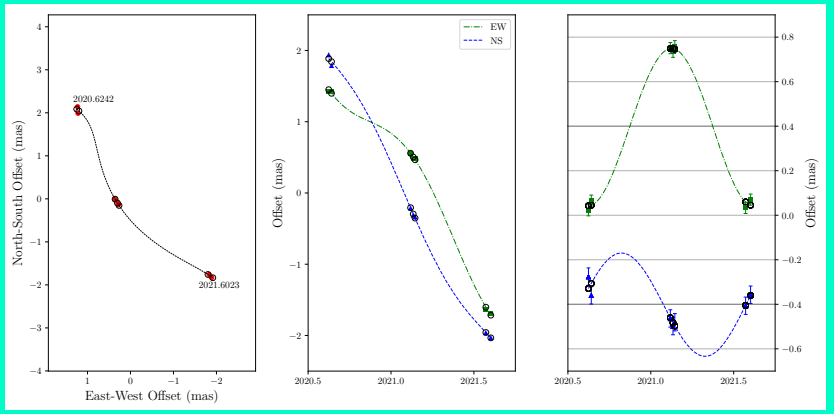
G232.620+0.996: $\varpi = 0.611 \pm 0.011$mas

$\mu_x = -2.26 \pm 0.02$, $\mu_y = 2.25 \pm 0.05$ mas/yr

Hyland et al. *in prep*







G323.740-0.263: $\varpi = 0.364 \pm 0.009$mas

$\mu_x = -3.24 \pm 0.03$, $\mu_y = -3.98 \pm 0.04$ mas/yr

HOW...?

...Does it work?

Many residual delays in the line-of-sight towards the target/ calibrators have a direction and time dependence - a time variable delay surface $\tau(\alpha, \delta, t)$

As with any smooth function, a Taylor expansion about a reference position (α_0, δ_0) is possible:

$$\tau(\alpha,\delta,t) = \tau_0(t) + \frac{\partial\tau}{\partial\alpha}(t)[\alpha-\alpha_0]\cos\delta + \frac{d\tau}{d\delta}(t)[\delta-\delta_0] + O(2) + \cdots$$

The following effects have a direction dependence:

- Baseline error
- Troposphere
- Ionosphere
- Source position offsets

Even if the effect is not perfectly planar over the FoV, a plane fit to the delay (or phase-delay) should do a better job than ordinary PR

The blobby elephant in the room

Source structure: *cannot be directly removed by MultiView*

Source structure and evolution does not lead to a phase surface that is correlated between calibrators (except the phase reference)

But that's the trick! The necessity for more calibrators for MultiView means source structure effects are minimised by a factor of √N

Or… with MultiView, you can risk going further away from your target to get 'better' calibrators!

How can You do it Yourself?

Have to remember and balance the S's of MultiView:

- Sensitivity/SNR
- Sky sampling
- Slewing
- Sequence
- Source structure

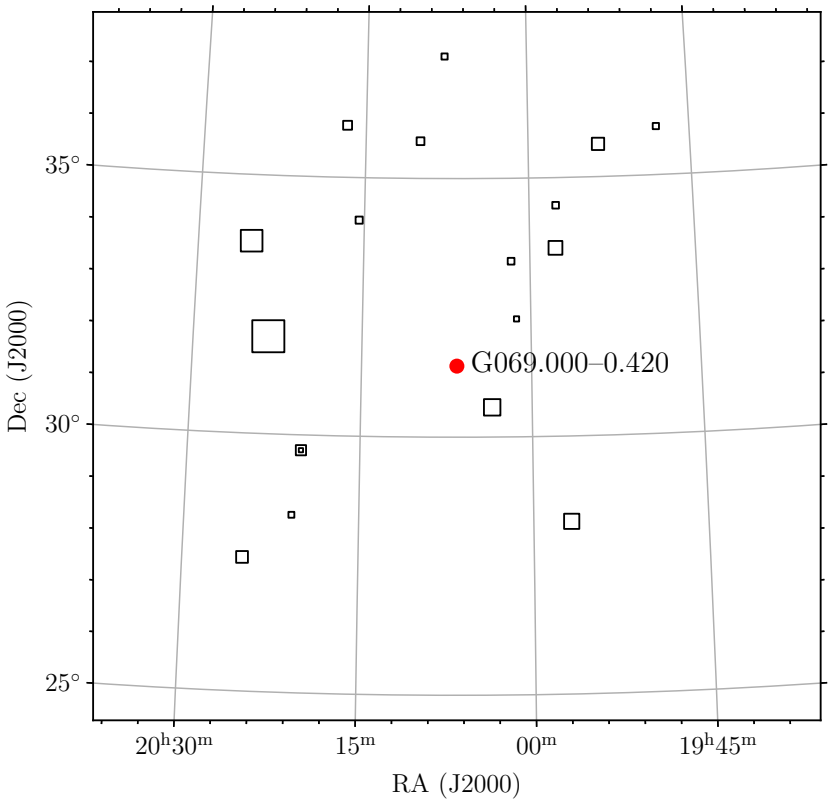
(At the moment) Observations need to be tailored for the array, target, frequency and available calibrators

In the future, where everything is better, this will no longer be necessary

When and where is MultiView?

Here and Now!

The imaginary maser: G069.000-0.420 (1)



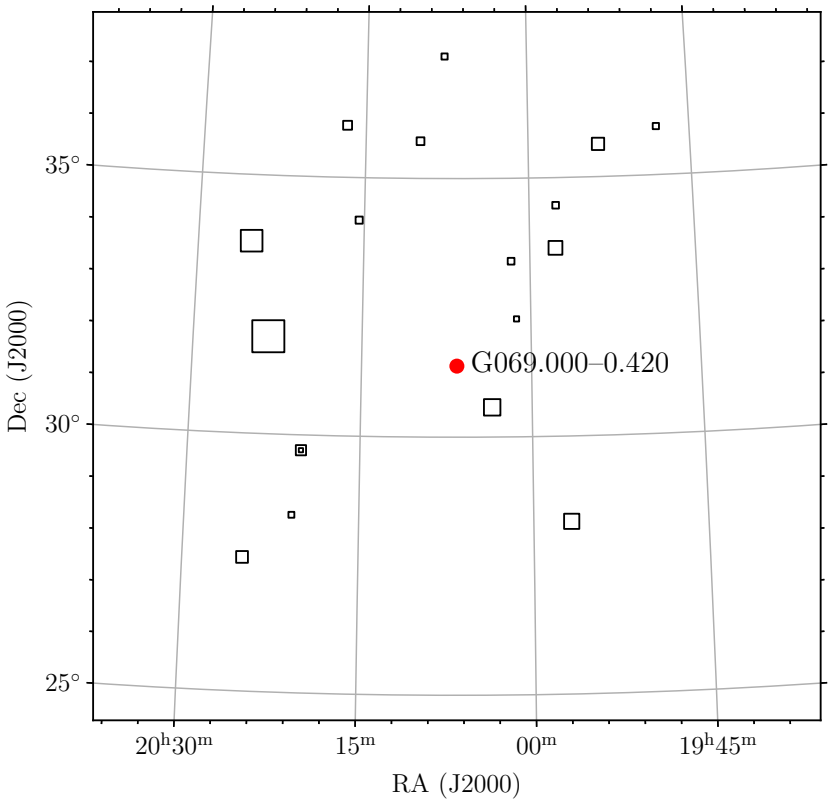
Lets assume:

- The maser is 5Jy unresolved
- We want Effelsberg as the reference antenna
- Torun is the least sensitive in the array

So:

- Which quasars do we choose?
- How many would we use?
- How do we observe them?

The imaginary maser: G069.000-0.420 (2)



S's:

- Sensitivity/SNR
  - Weakest 25mJy, strongest 2Jy
  - Ef 25Jy, Tr 650Jy
- Sky sampling
  - Either linear (if lucky)
  - Otherwise sample 2D plane
- Slewing
  - Ef slow (consider removing sometimes, seriously)
- Sequence
  - Inverse or direct?
- Source structure
  - Check astrogeo