Measuring the Core Shift of Sgr A*

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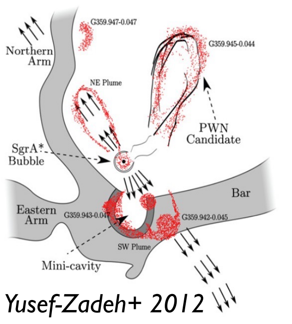
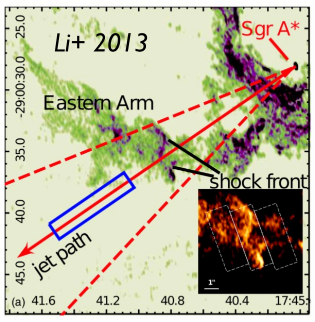
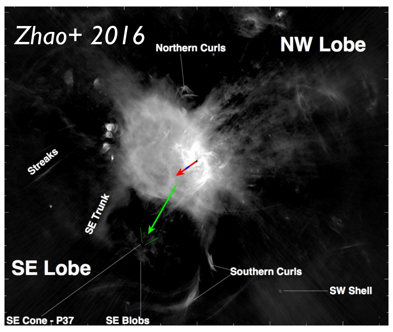
The SMBH at Galactic center: Sgr A*

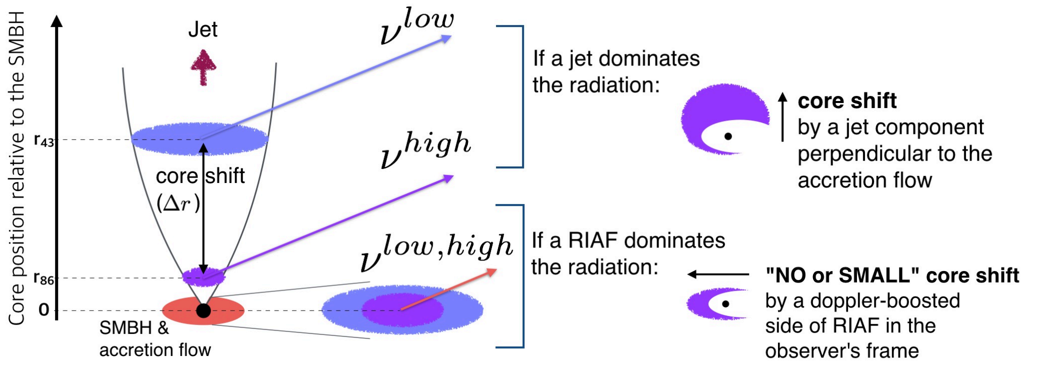
Sagittarius A* (Sgr A*), a supermassive black hole (SMBH) in Our Galaxy, is the best laboratory to study the vicinity of the SMBH (e.g., *Genzel et al. 2010*). At present, **the strong radio emission from Sgr A* is thought to be from either the jet base of Sgr A* or a radiatively inefficient accretion flow (RIAF)** (*Falcke & Markoff 2000, Yuan et al. 2003*). The matter accretion onto the SMBH results in radio jets as a relativistic outflows stretching from sub-pc to Mpc scales. Sgr A* also shows a few evidences of the outflow at cm-wavelengths (e.g., *Yusef-Zadeh et al. 2012*), but it has never detected at mm-wavelengths.





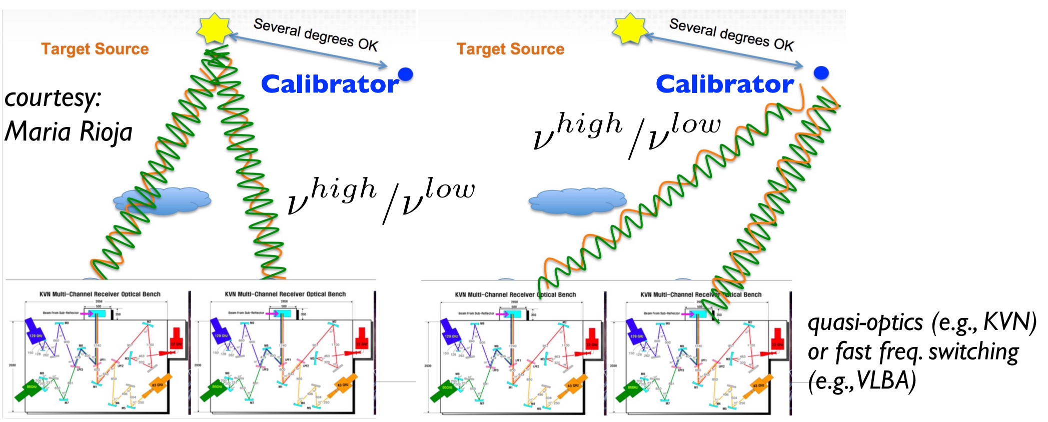


In VLBI observations, however, **while the positions of an optically thick surface (i.e. radio core) are expected to get closer to the central SMBH at higher frequencies when a jet is assumed as the emission region, there will be no changes in the core positions when an accretion flow is only responsible for the emission.** This is known as **core shift effect** (*Blandfold & Konigl 1979, Lobanov 1998*), which is an important tool to constrain the jet models and to register an accurate position of SMBH (*Hada et al. 2011*).



Astrometric information acquisition

The source frequency phase-referencing (SFPR; *Rioja & Dodson, 2011*) is delicate techinique to effectively remove the uncertainties of measured visibility phase, such as the earth's tropospheric and ionospheric effects, and give the positional differences between frequencies. It's achieved by the source switching between target and calibrator and multi-frequency simultaneous observations.



As a result, the SFPRed phase mainly have the four informations so the target's core shift can be obtained by constaining the other terms.

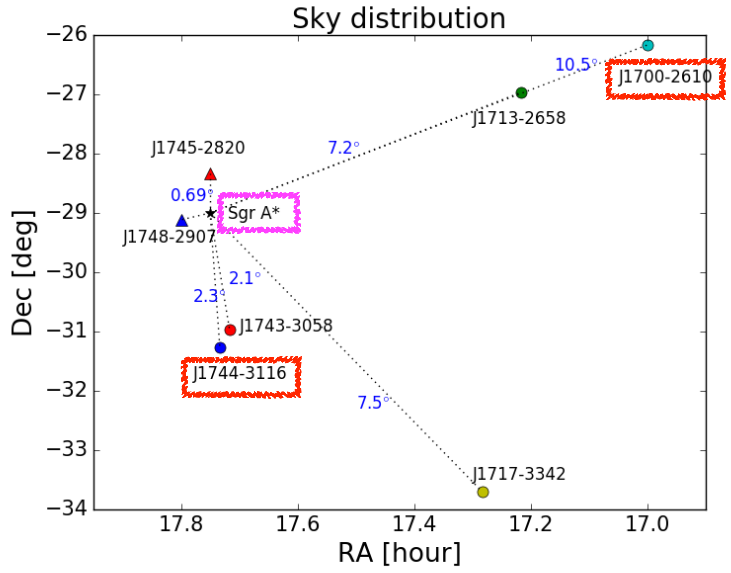
$$\phi^{SFPR}_{tar} = \phi^{high}_{tar,str} + \left(\phi^{high}_{tar,pos} - \phi^{low}_{tar,pos}\right) + \left(\phi^{high}_{cal,pos} - \phi^{low}_{cal,pos}\right) + \Delta_{i,T_{swt}}$$

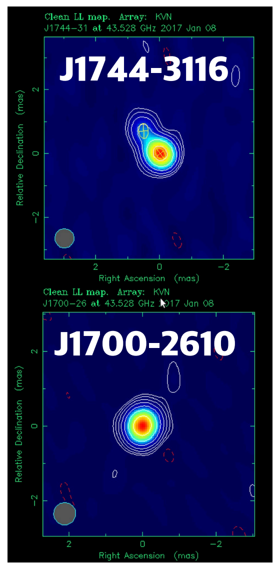
Target structure at target frequency. | Target's core shift: | Calibrator's core shift. | Interpolation error

Calibrator selection

We have conducted the astrometric observations toward Sgr A* not only using KVN since 2015, but also using VLBA since 2018.

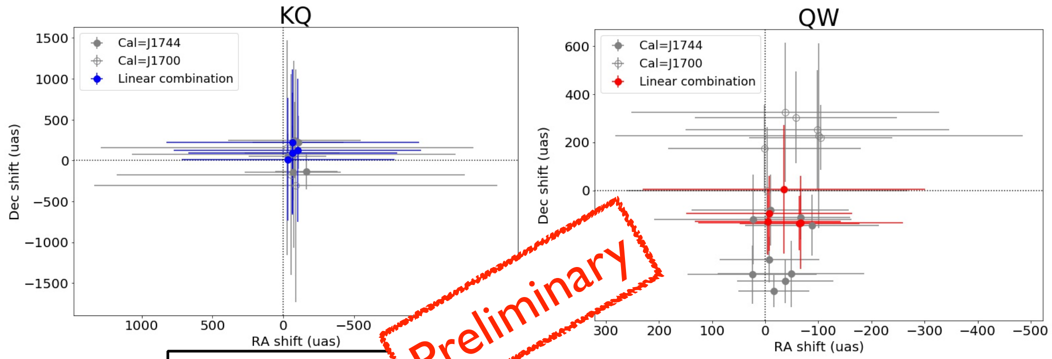
For phase-referencing, we tested 7 calibrators around the Sgr A* within ~7 deg. separation but only two of them have been successfully detected: 1) J1744-3116 at ~2 deg. separation, and 2) J1700-2610 at ~10 deg separation.

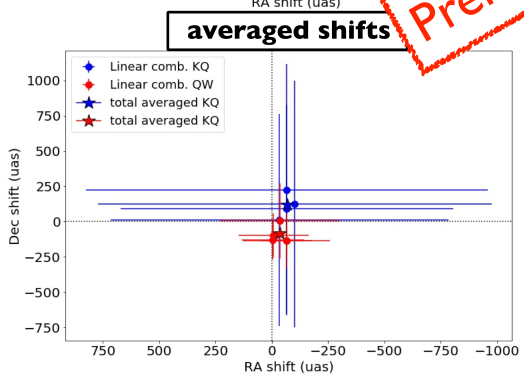




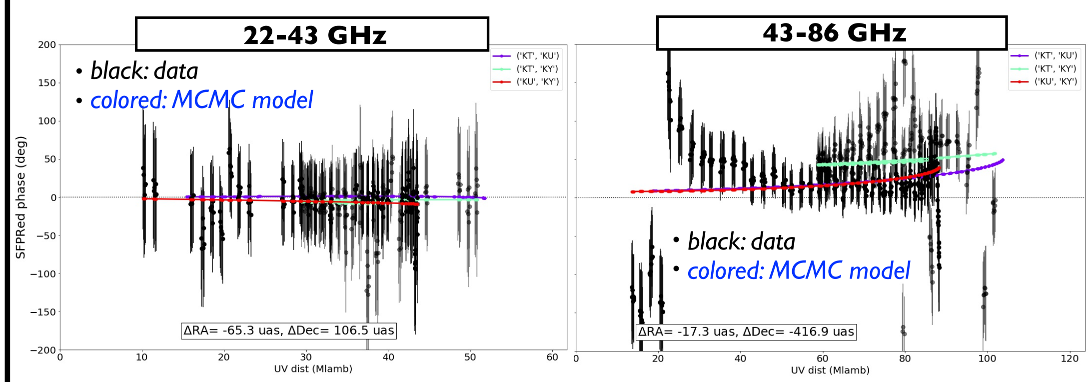
"Centroid" shift of Sgr A*

As a result, we found the centroid shift of Sgr A* through MCMC optimization at two frequency pairs (i.e, 22-43 GHz and 43-86 GHz) from each calibrator and averaged shift of it.





In our measurements, *the centroid shifts of Sgr A* have been shown less than ~400 uas, which is* ***comparable to the theoretical expectation*** *(e.g., Moscibrodzka et al. 2014).*



Note that the "centroid shift" indicates the positional shift resulted from the SFPRed phase, not the intrinsic core shift of Sgr A*. Thus, the residual effects should be further constrained, such as the calibrator's core shift and systematic error by source elevation and/or separation angle between target and calibrators. For instance, while the results at 22-43 GHz do not have significant systematic uncertainties, the SFPRed phase including 86 GHz shows a correlation with secZ (Z: zenith angle) difference between two telescopes and sources. This effect has been carefully investigated by comparing the KVN and VLBA data.

References

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