Cosmological QUOKKAS

Using the “Causality Distance” method





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KIAS, October 7, 2024

What does QUOKKA(S) stand for?

Cosmological Quasar Observations on the KVN from Korea to Australia (and Spain? South Africa?!)

What does KVN stand for? → Korean VLBI Network (We will come back to this…)

What does VLBI stand for? → Very Long Baseline Interferometry



Measuring distances using radio variability → What is Dark Energy?

What even is Dark Energy?!

No idea really - a kind of anti-Gravity

I don’t like the name: over interprets

Could be the cosmological constant

Could be variable with time

Could be something completely different

DESI results → time variable Dark Energy?

How can we find out? → Measure redshift vs distance to even larger distances!

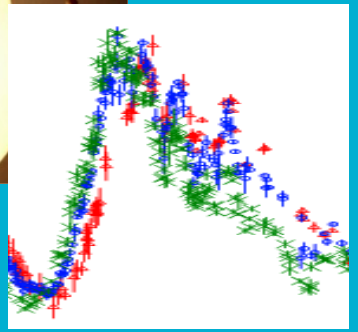


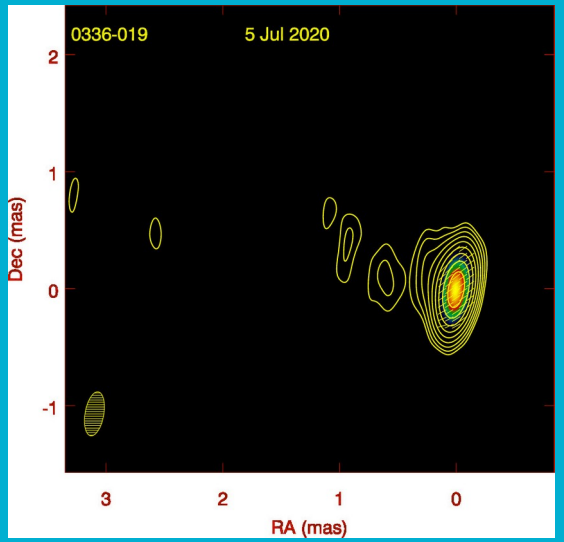
QUOKKAS - Causality Distances for Dark Energy

Uses the speed of light to calibrate a standard ruler

Biggest issue is with Doppler factors







= Distance

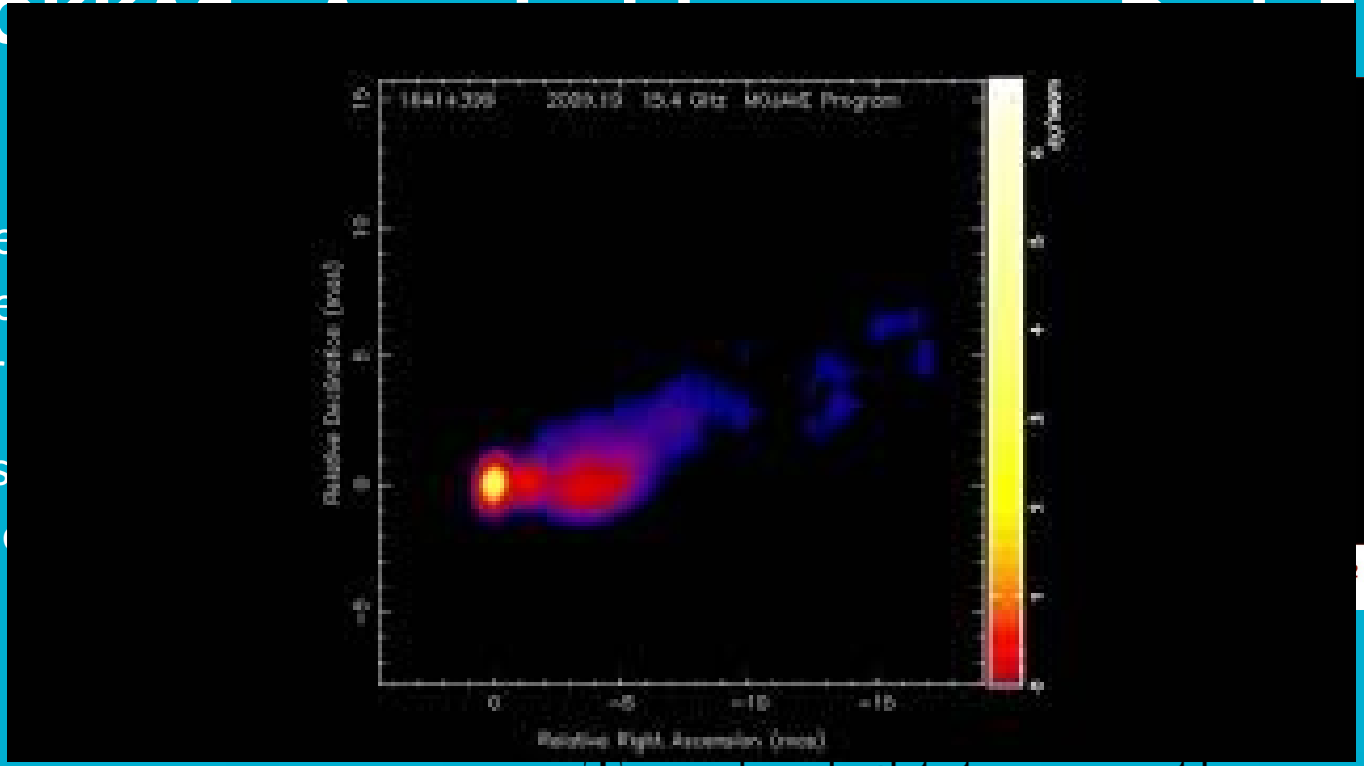
$$\text{Distance} = \frac{\text{Time for light to cross the source} \times \text{c}}{\text{Apparent angular size (measured with VLBI)}}$$

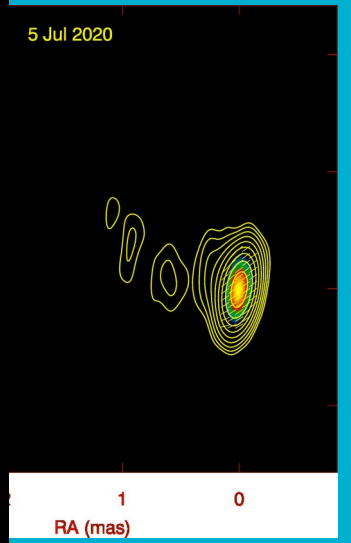
QUO… …nergy

—

"Single… no nee… ladder…

Bigges… Doppl…

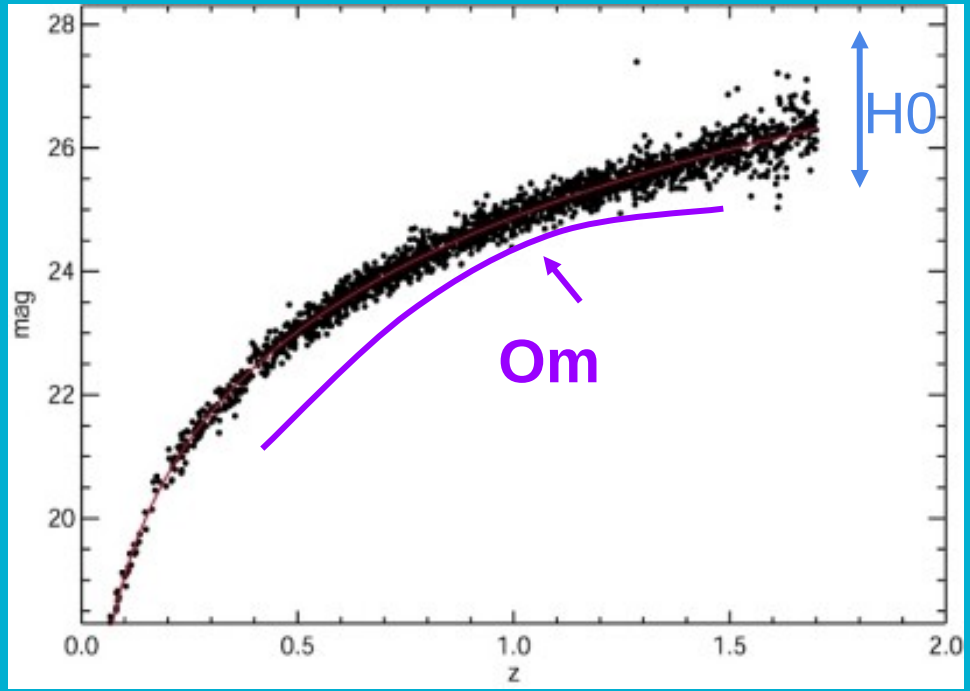




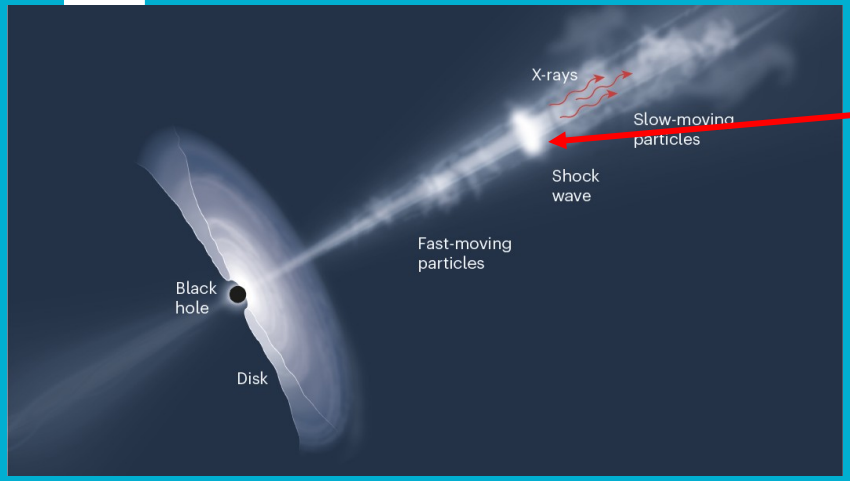
$$\text{Distance} = \frac{\text{Time for light to cross the source} \times \text{c}}{\text{Apparent angular size (measured with VLBI)}}$$

Source based or z-dependent systematics

- Two main model parameters we are trying to measure:
  - H0 and Omega_m
- H0 sensitive to *source-based* systematics and z-based systematics
  - C*t_var assumption etc
- Om sensitive to *redshift* dependent systematics
  - Source based systematics will only add scatter
  - **Doppler factor**



Quick and dirty Doppler (Hodgson+ 2023)



Max energy density (brightness temperature) that a source can reach – apparent brightness temperature over this limit is the Doppler factor!

$$D_{\mathrm{A}} = \frac{2 \ln 2 c^3 S \Delta t}{\pi k_{\mathrm{B}} T_{\mathrm{B,int}} \nu^2 \theta^3_{\mathrm{VLBI}}}.$$

3C 84 →

Hubble Constant km s Mpc	Doppler factor -	$T_{\mathrm{B,int}}$ $[\times 10^{11}\mathrm{K}]$
67.40 ± 0.50	$1.07^{0.13}_{0.13}$	$4.06^{1.07}_{1.62}$
73.04 ± 1.04	$0.99^{0.12}_{0.12}$	$4.44^{1.17}_{1.70}$

Can we use these to solve for our systema

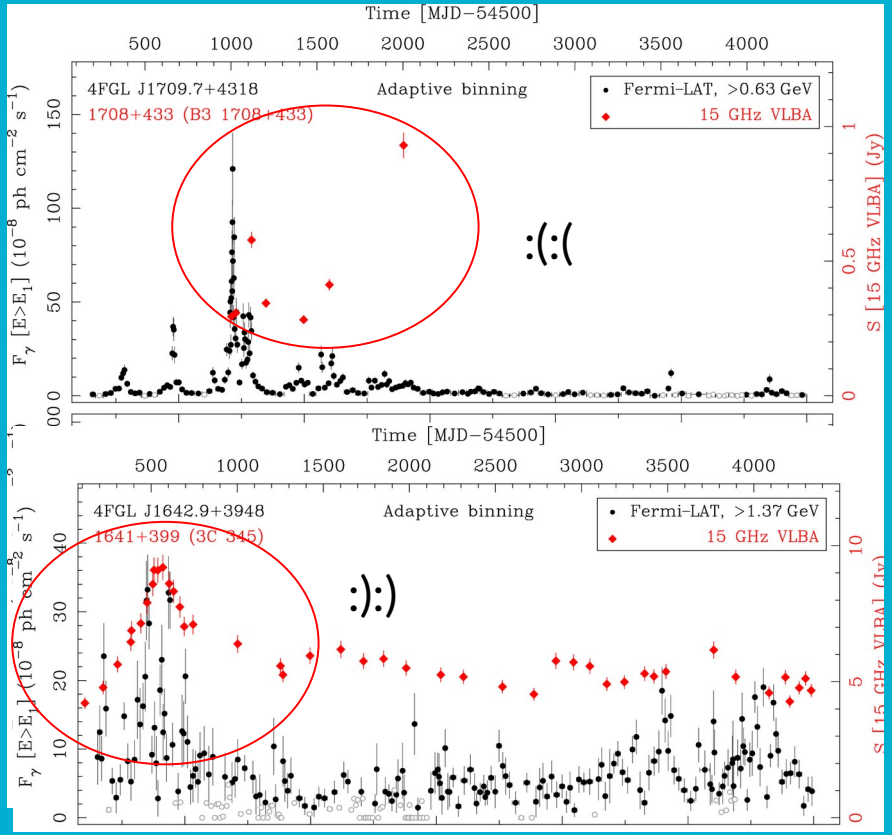
TLDR: we can calibrate relativistic effects with just a number! (Tbint is a sort of maximum energy density)

Archival data

Mostly sparsely sampled in VLBI

But nevertheless can try to make measurements with any pair of observations

But bad sampling → biases in the data



Archival results

Thanks to: Lorena Amaya-Ruiz

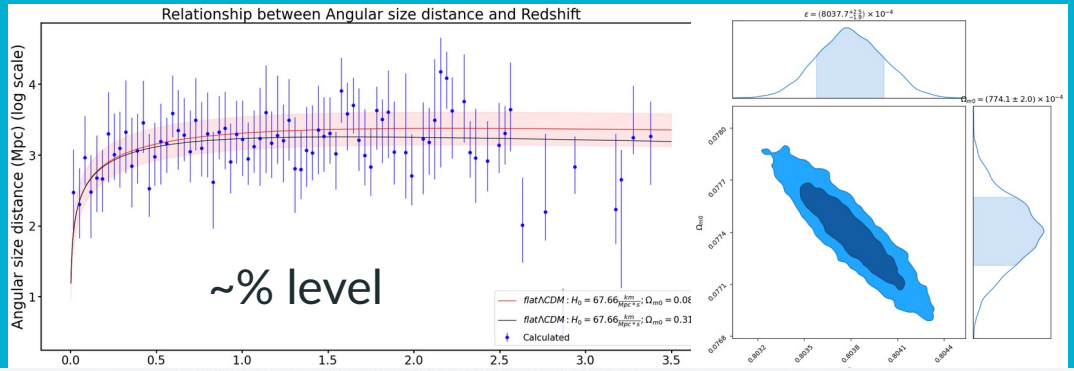
Includes *all* data

- Good precision, poor accuracy

Filtering for ‘good’ data

- Better accuracy, poor precision

Good news! Can get good accuracy and precision: *just need more data*



Cosmological QUOKKAS

Getting more data!

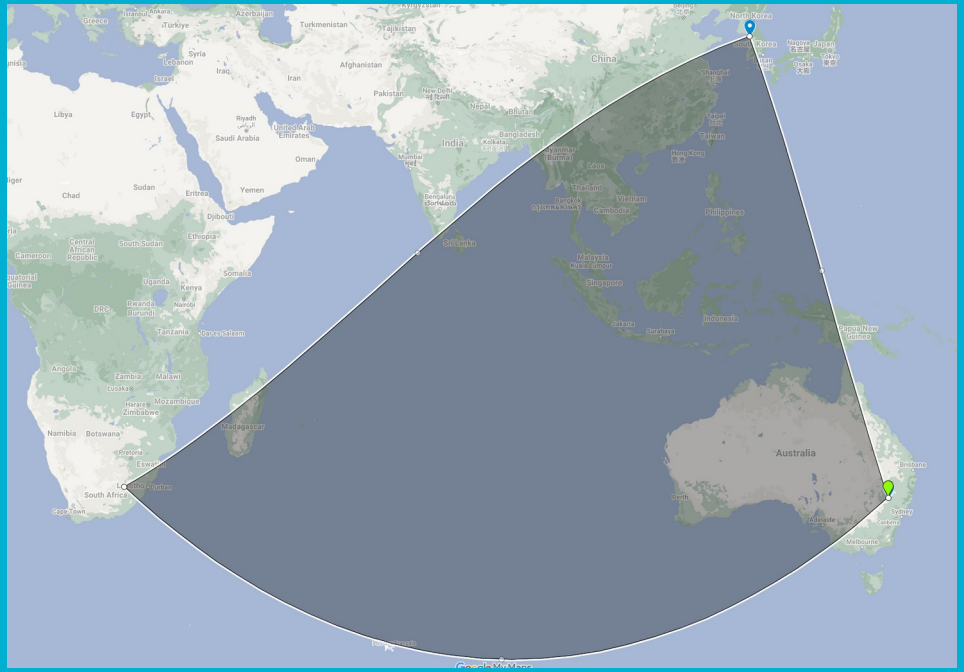
Weekly observations on the QUOKKArray

Working on the data now ~60 sources initially:

- $0 < z < 4.5$

Limited uv coverage: combining imaging with QUOKKArray data with nested sampling (Jaehyeon Myeong, Whee Yeon Jeong)

SKA-VLBI + Widefield VLBI → could be a game-changer



Conclusions

QUOKKAS uses (in theory) single-rung the “causality-distance” method that can be used from galactic microquasars to z>4 AGN

Archival data shows that there is a trade off between precision and accuracy - but can be resolved simply with more observations

QUOKKAS is ongoing using weekly global VLBI to refine the measurements

Ideal science case as we go into the SKA era

