Quantifying Sky Signals: Simulating Visibility Correlations in Radio Interferometry

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Institute for Computing in Research
August 1st, 2025

What is Radio Interferometry?

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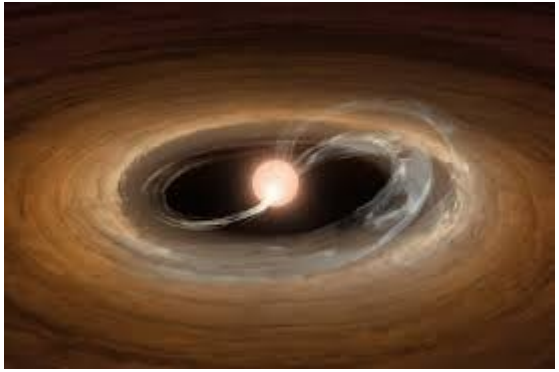

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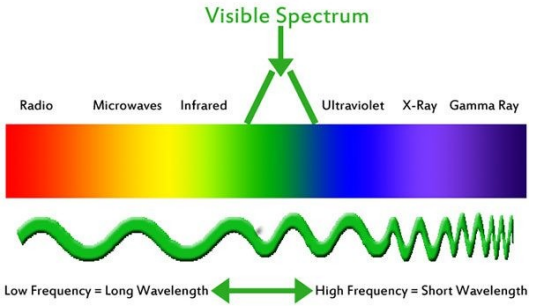
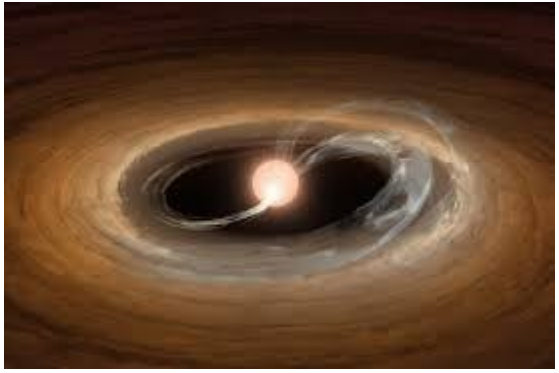
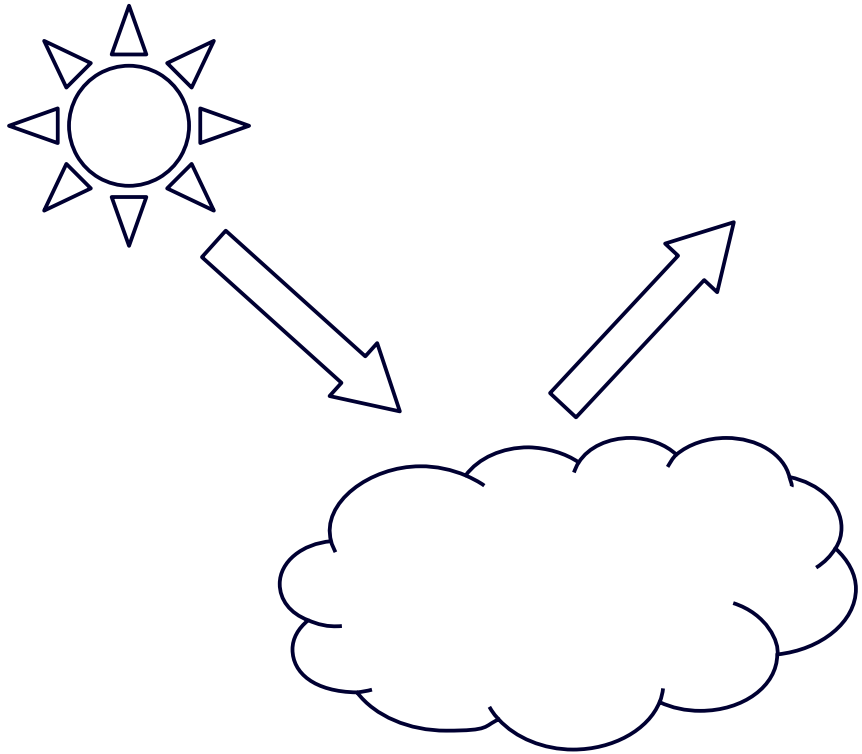




Why Radio Interferometry?



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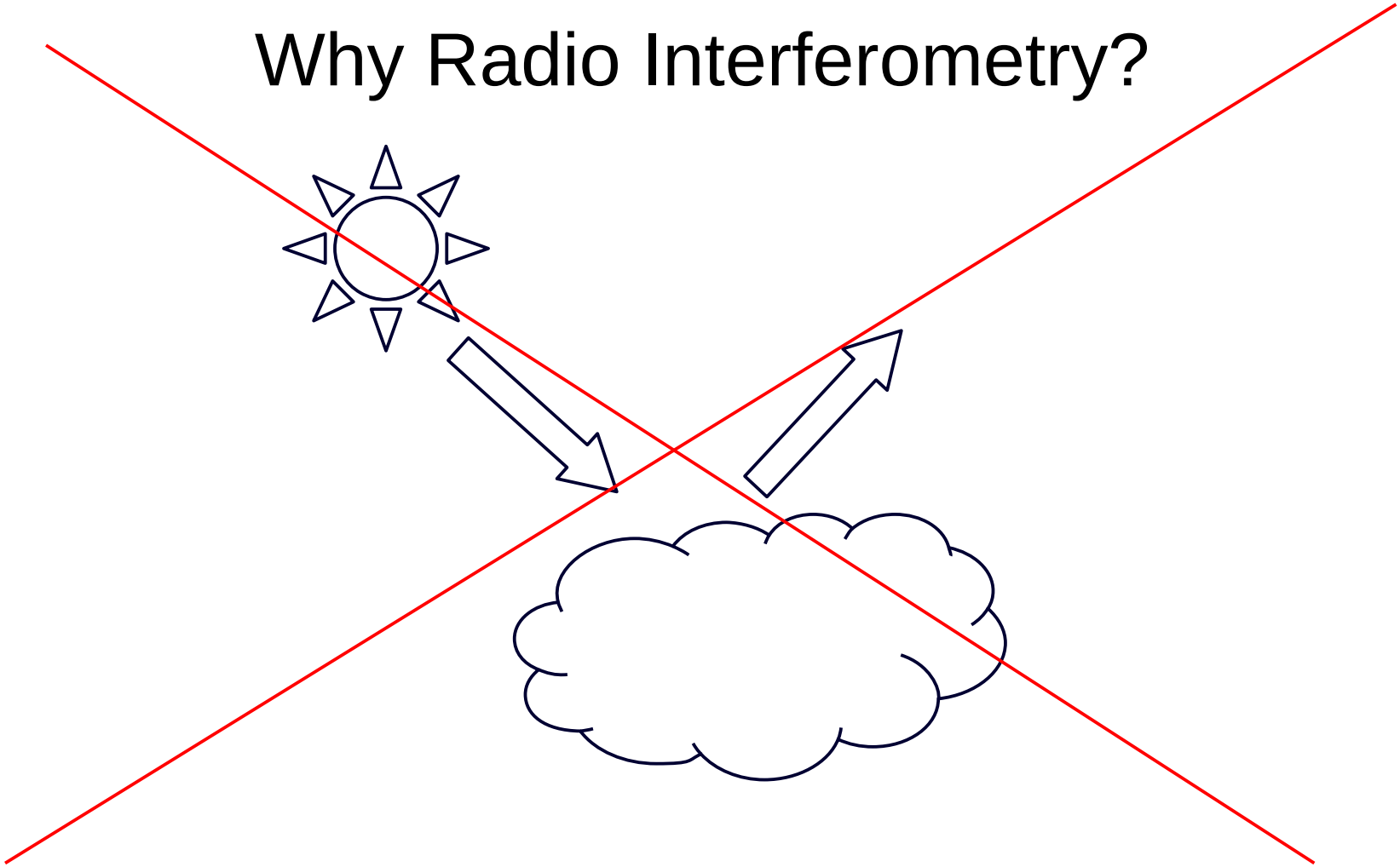

How Does it Work?

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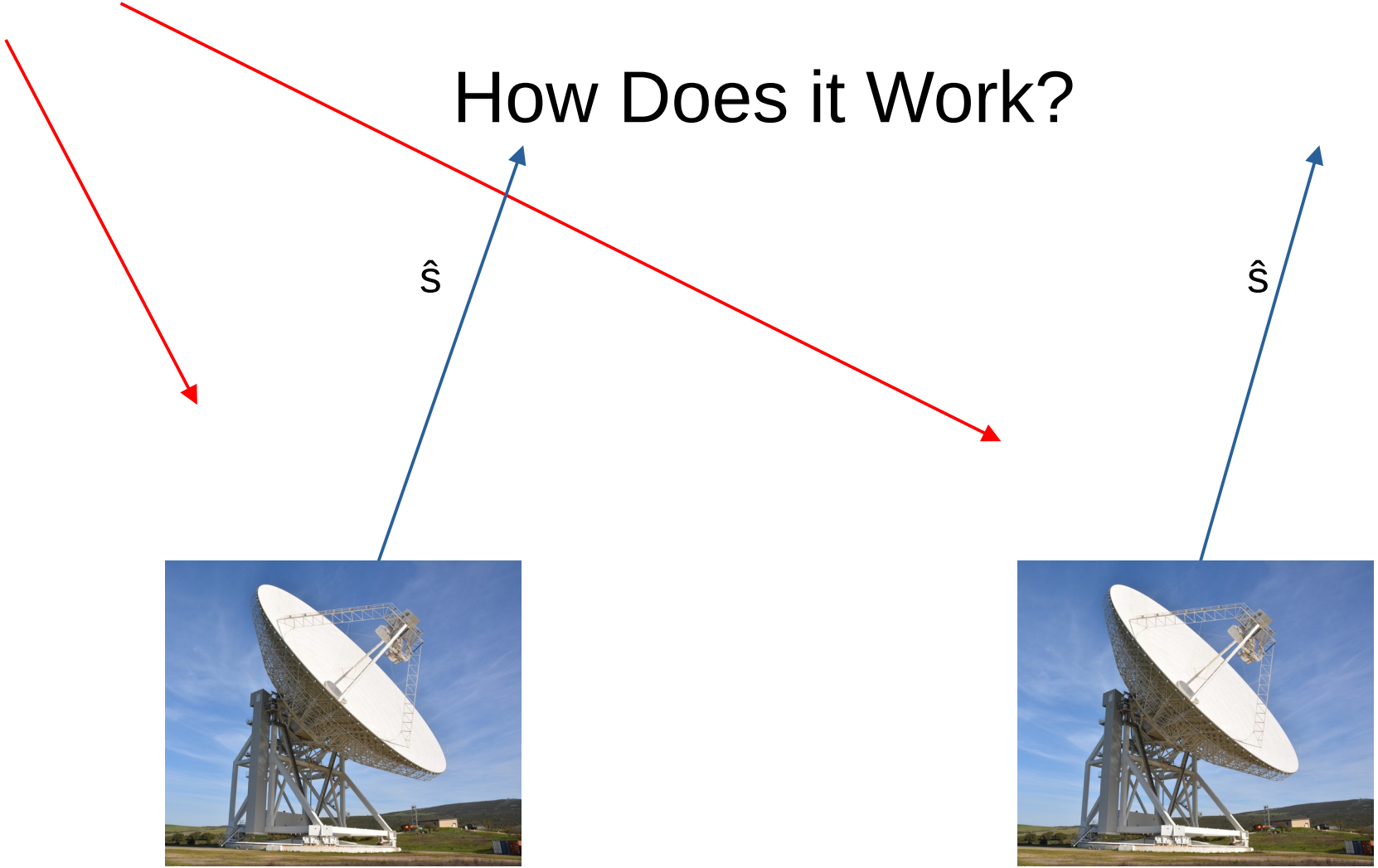

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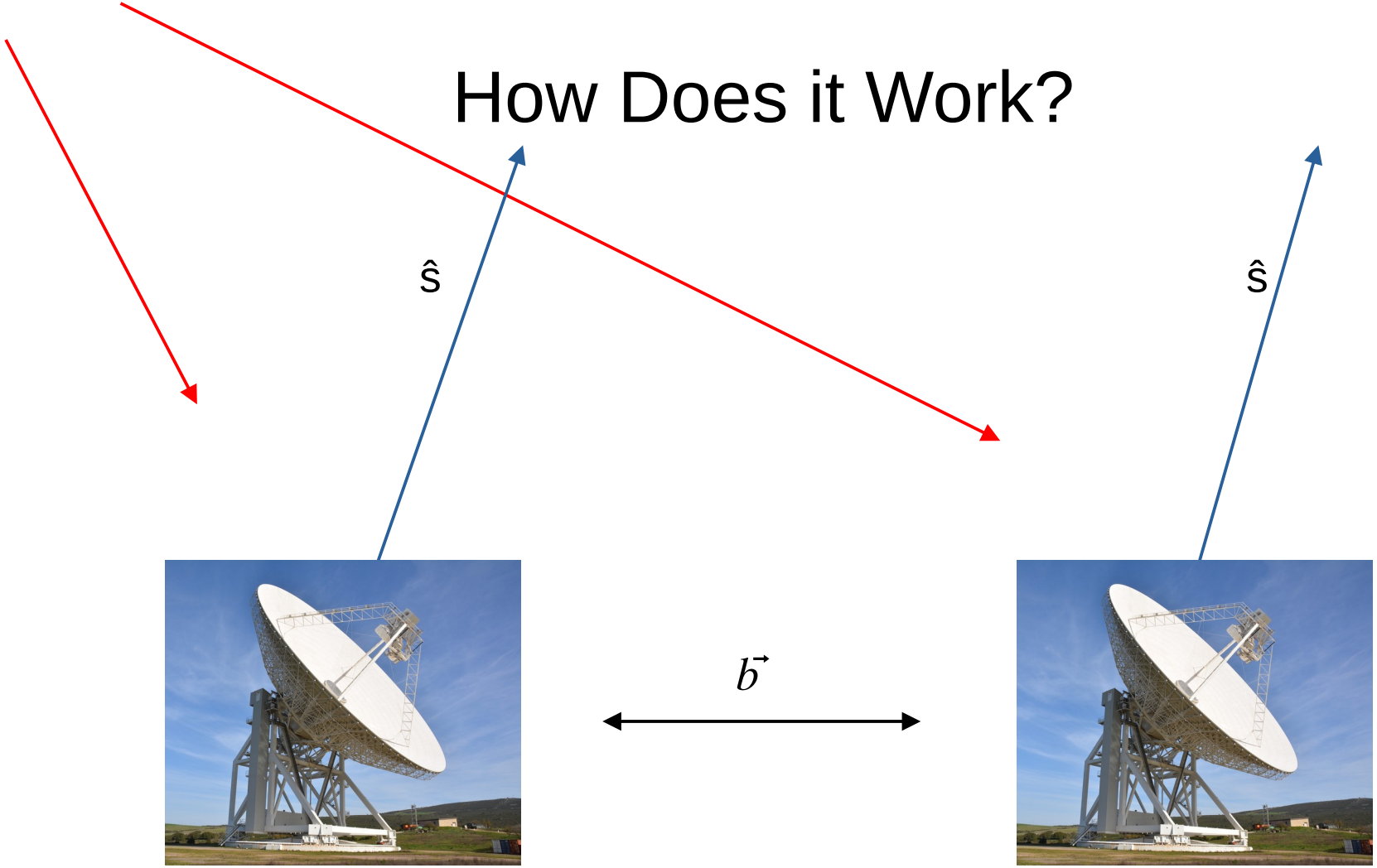

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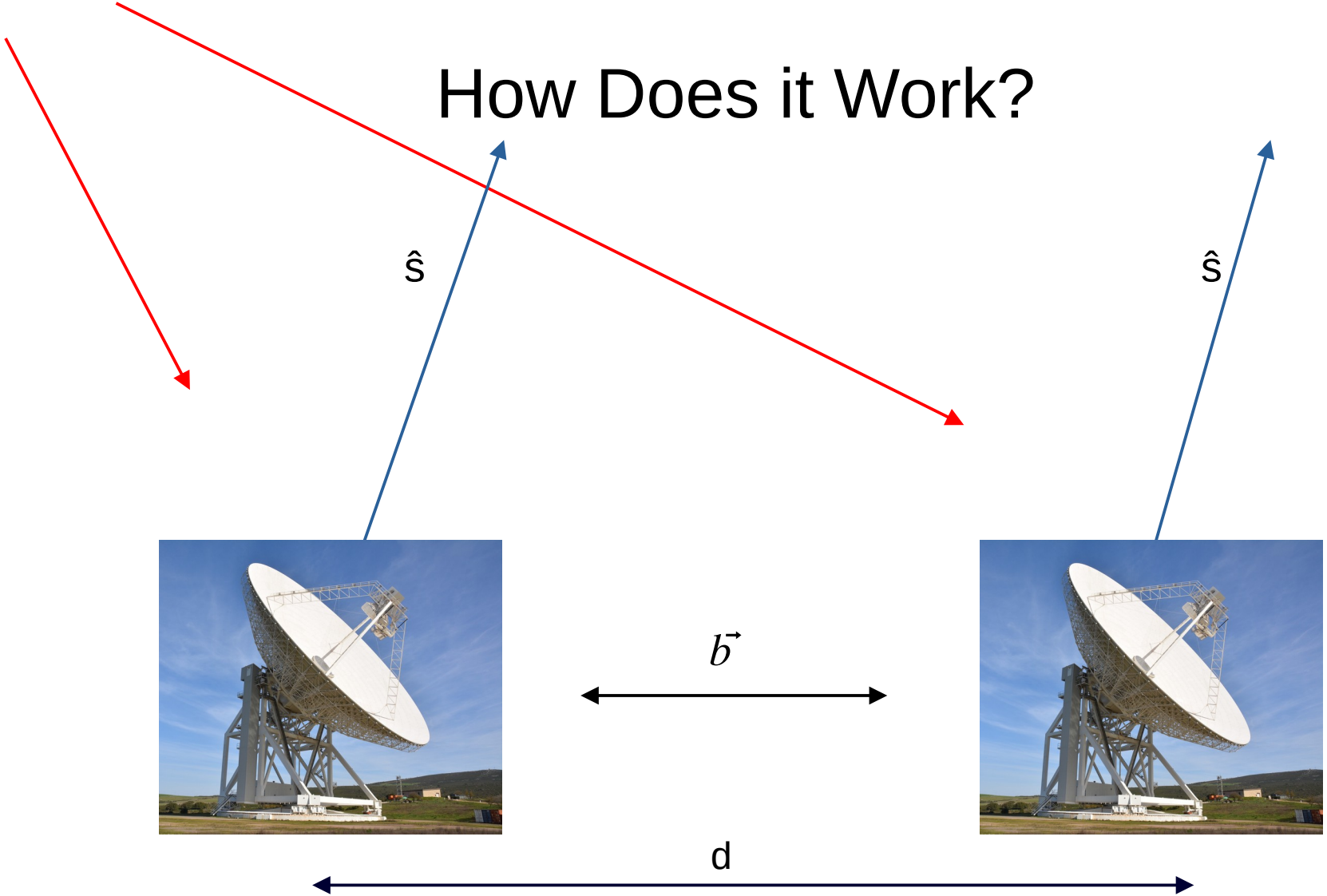
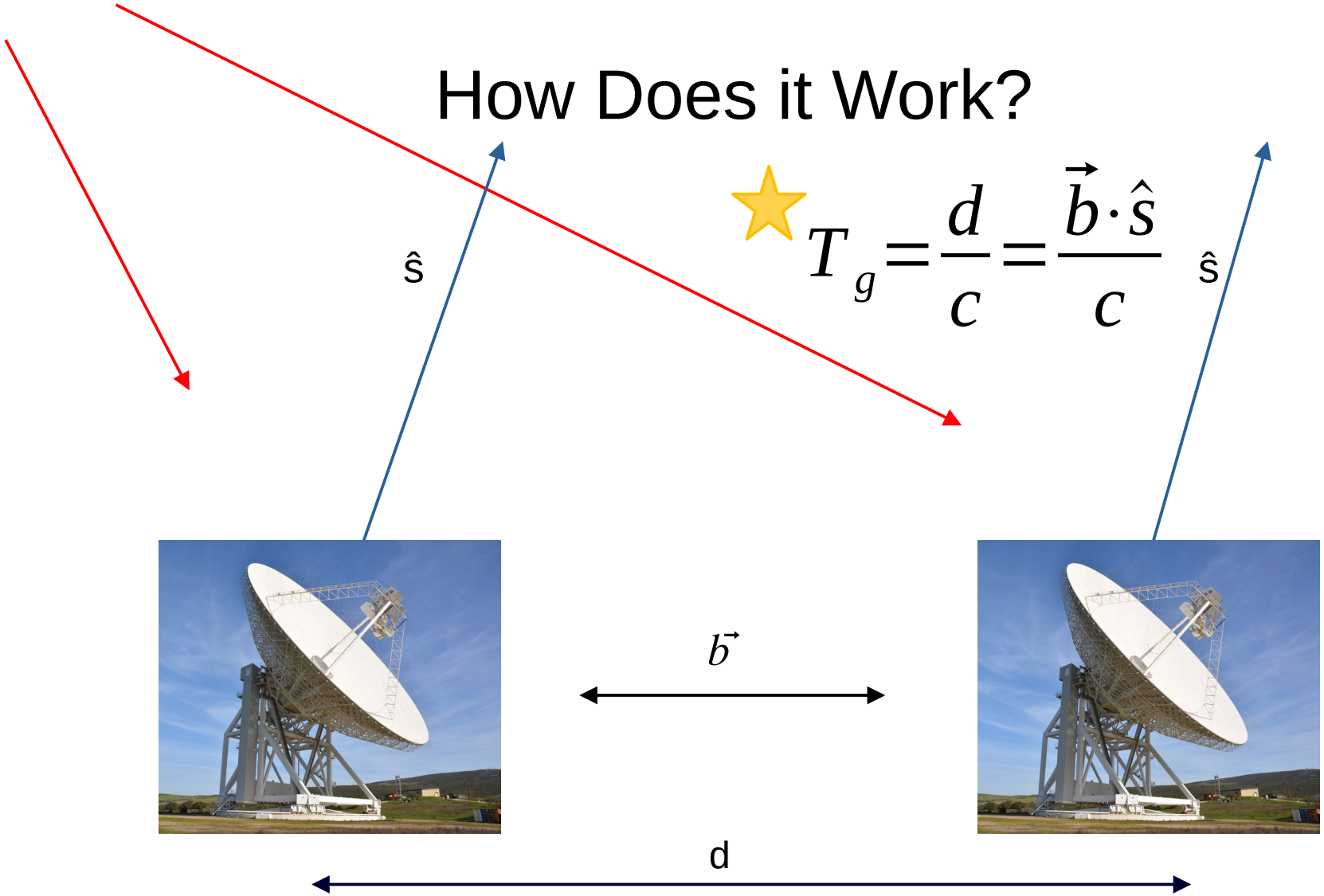


How Does it Work?

$$T_g = \frac{d}{c} = \frac{\vec{b}\cdot\hat{s}}{c}$$



How Do You Calculate Visibility?

$$\widetilde{E}[\vec{r},t]=\widetilde{E}_0 e^{i(\vec{k}\cdot\vec{r}-\omega t)}$$

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$complex-euler's\ formula$

$e^{ix}=\cos(x)+i\sin(x)$

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$\vec{r}=position\ vector$ $\vec{k}=wave\ vector=\frac{2\pi}{\lambda}$ $\omega=2\pi\nu$

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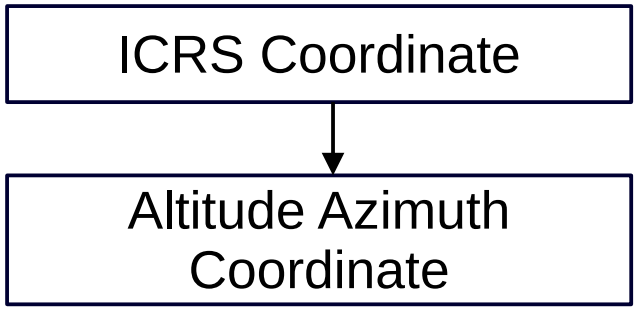
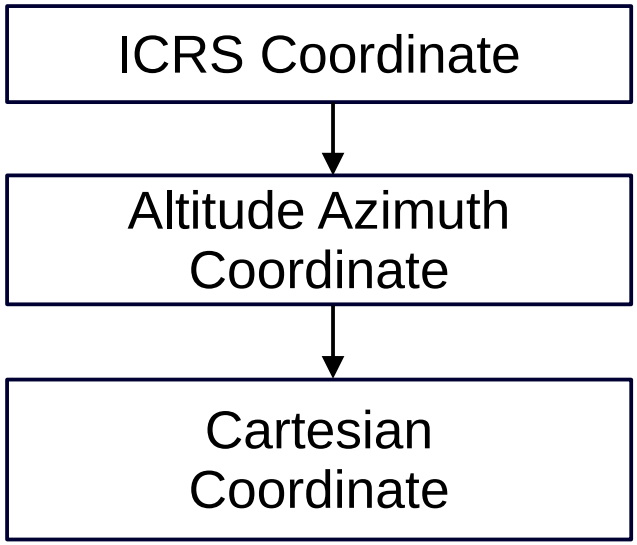
Calculating the Unit Vector

ICRS Coordinate

Calculating the Unit Vector



Calculating the Unit Vector



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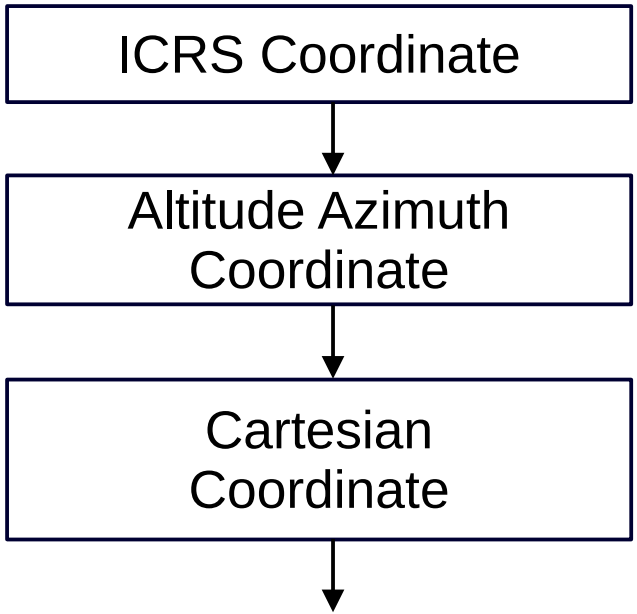
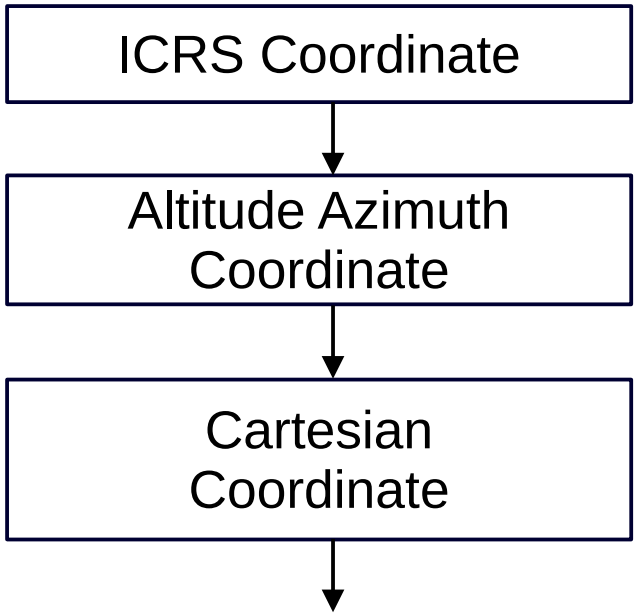


NEU Coordinates?

Calculating the Unit Vector



NEU Coordinates?

```
dot_product = np.dot(baseline_vec, unit_vector[[1,0,2]])
```

* Using Astropy, Numpy

How Does the Simulation Work?

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How Does the Simulation Work?

Starting time, duration, total time points

* Using Astropy, Numpy

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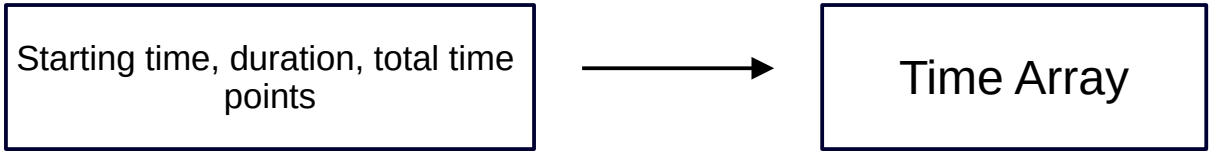

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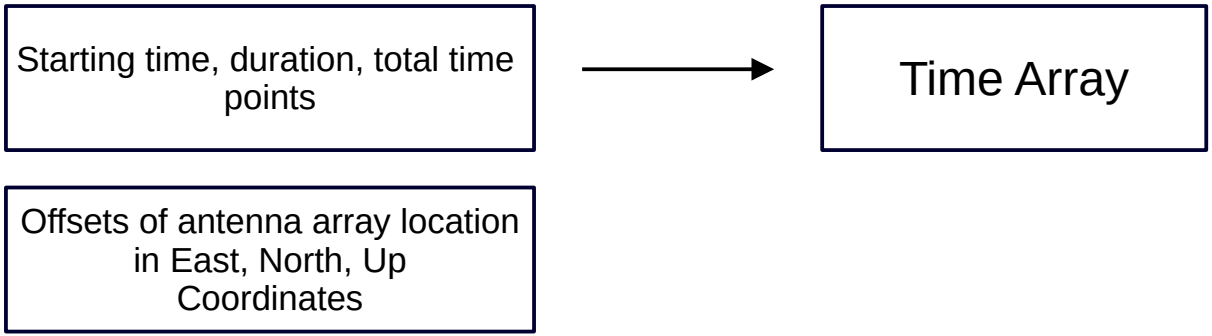

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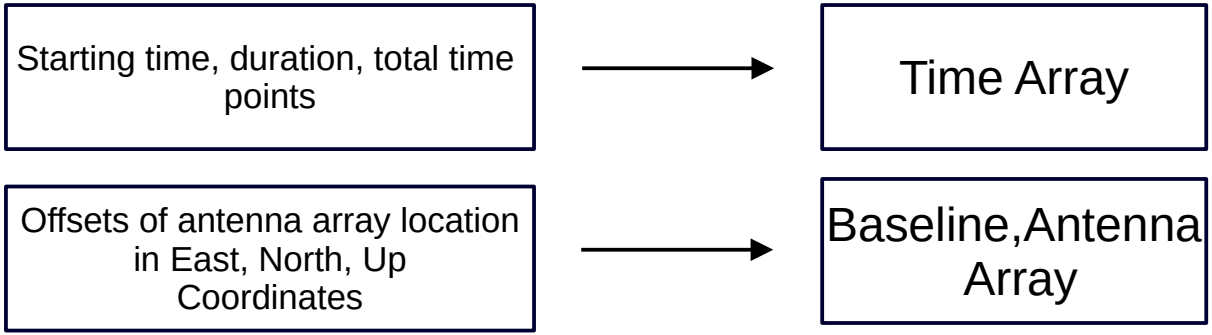

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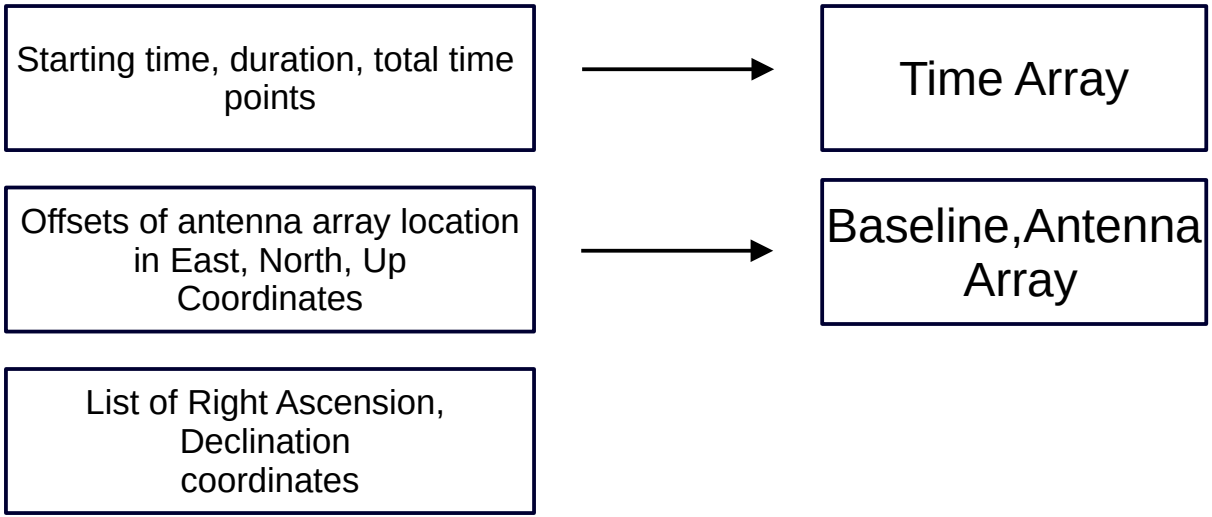

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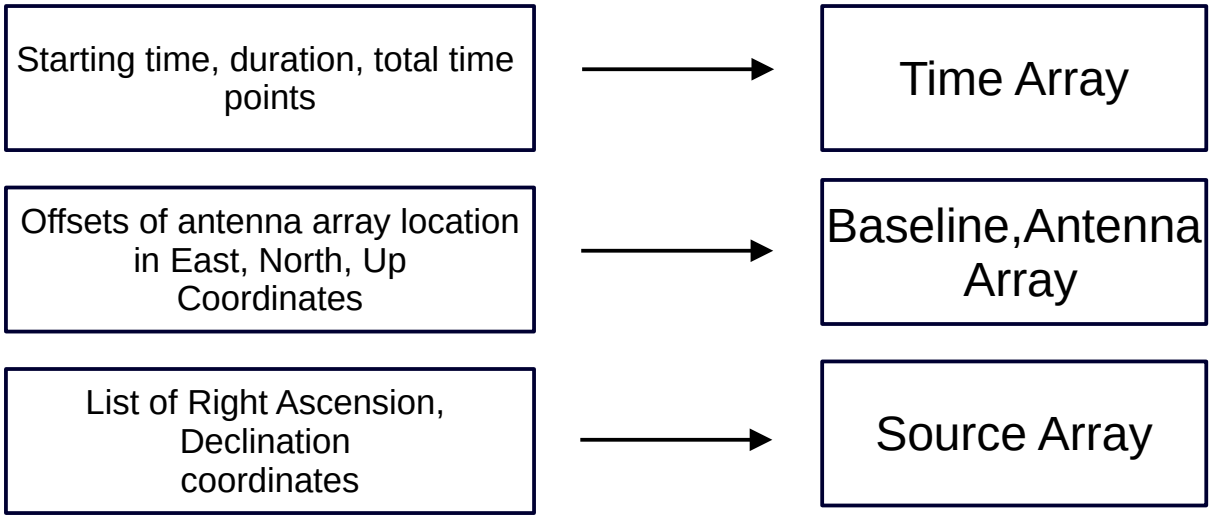

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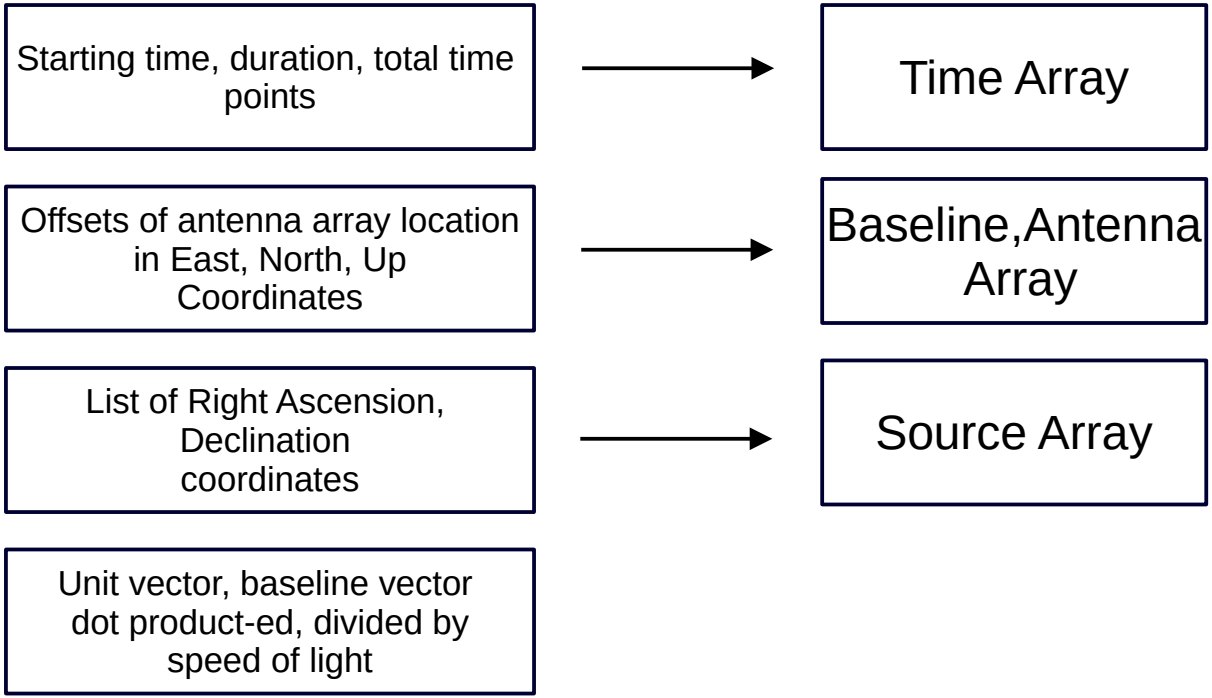

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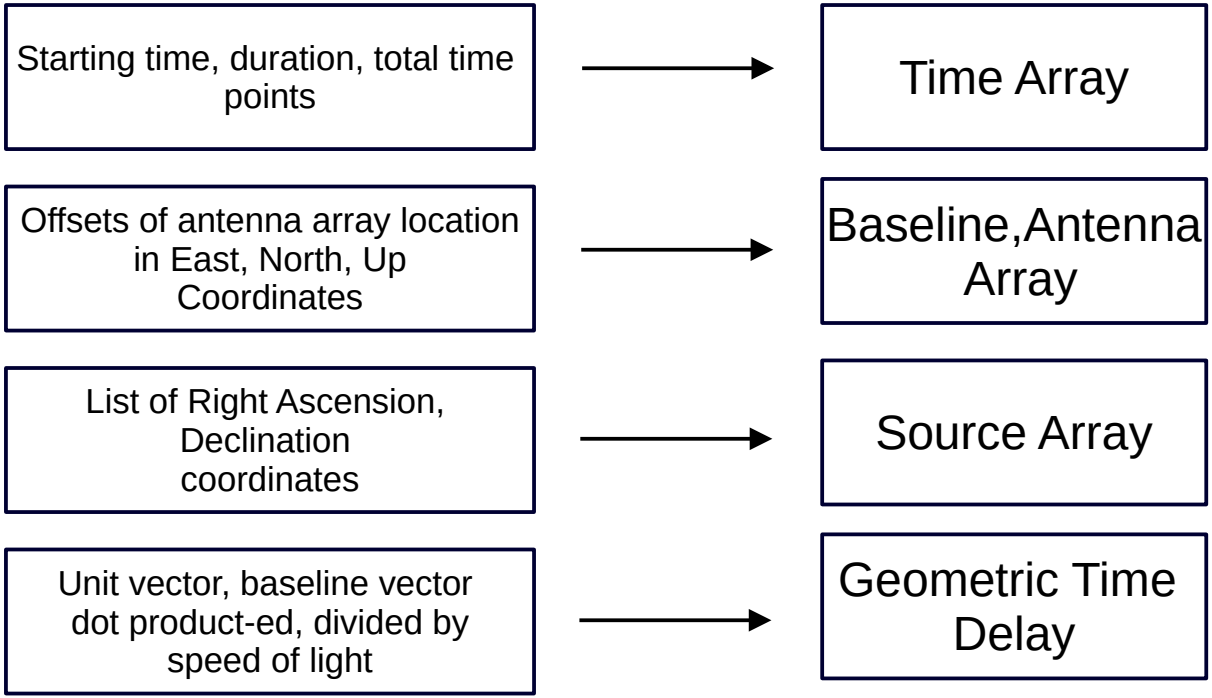

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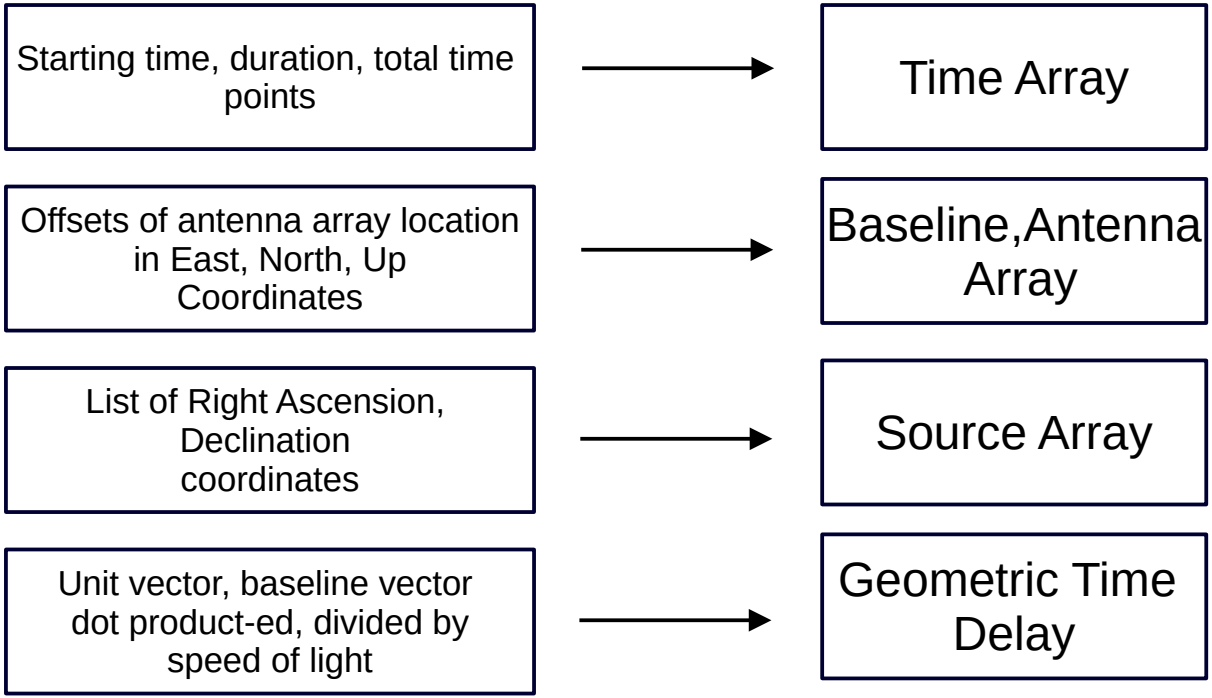

Amplitude, frequency information

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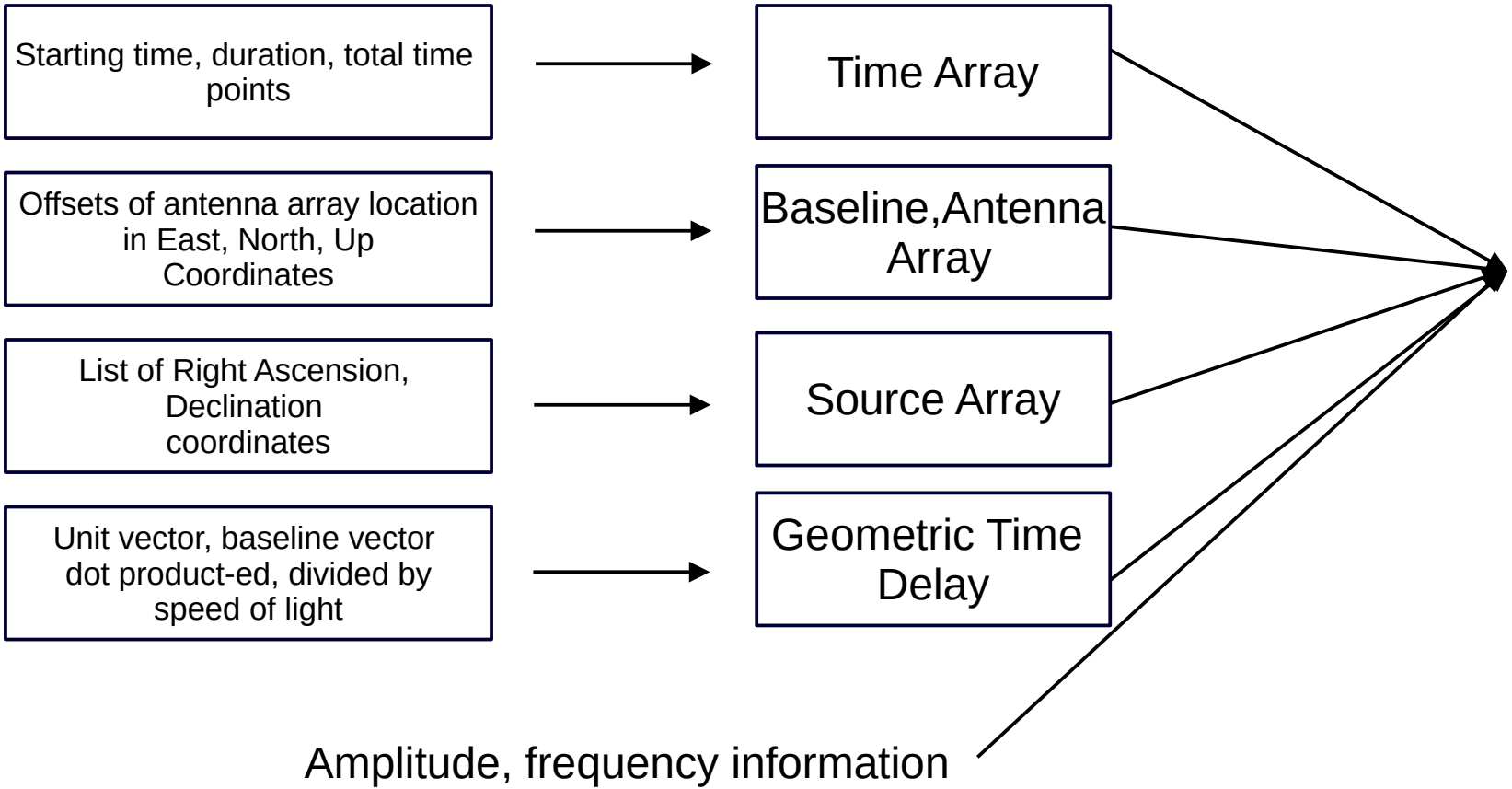

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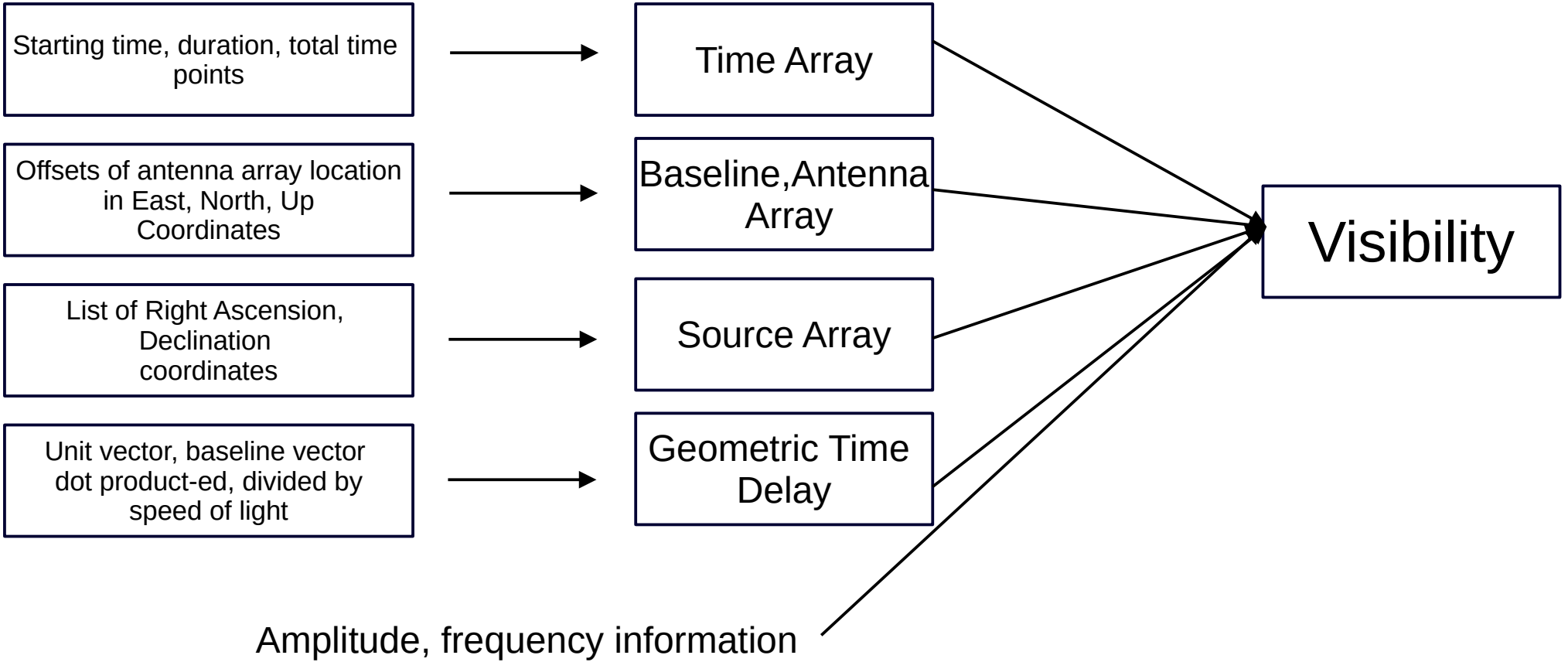
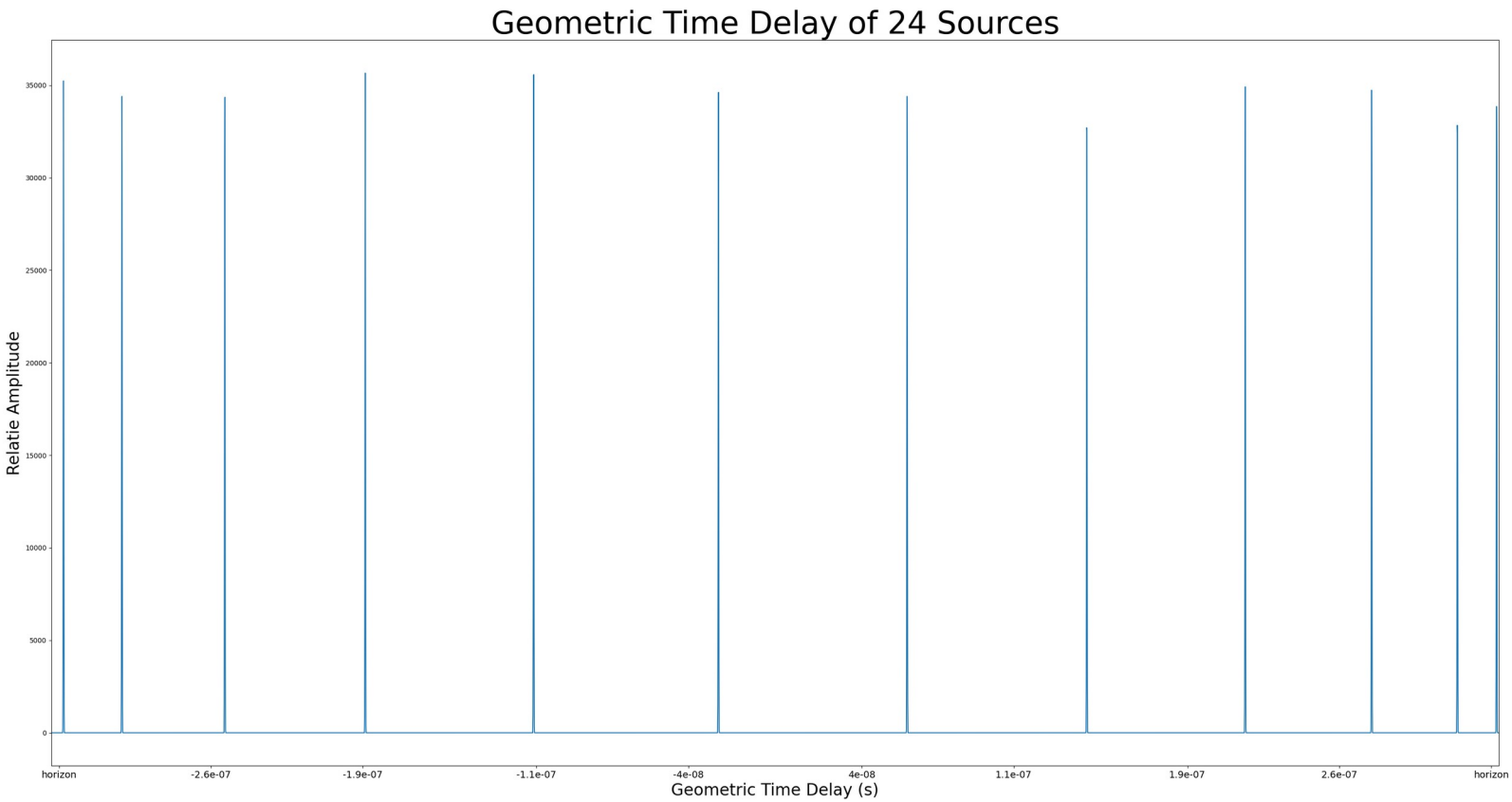


Results


Geometric Time Delay of 24 Sources
Relatie Amplitude
35000
30000
25000
20000
15000
10000
5000
0
horizon
-2.6e-07
-1.9e-07
-1.1e-07
-4e-08
4e-08
1.1e-07
1.9e-07
2.6e-07
horizon
Geometric Time Delay (s)

Limitations

Limitations

Simplification

Limitations

Simplification

Amplitudes

Future Improvements

Future Improvements

More Amplitudes

Future Improvements

More Amplitudes

Parallelization

Future Improvements

More Amplitudes

Parallelization

User Input

Closing

- Radio waves / Radio interferometry lets us observe the sky in more detail
- Simulation inputs amplitude, time, frequency,antenna positions, source locations, array location. Computes visibility
- Use visibility for analysis, like geometric time delay analysis

Thank you!

Questions?

Image References

https://www.space.com/very-large-array.html

https://www.kent.ac.uk/news/science/20641/kent-researcher-helps-identify-young-star-caught-in-a-fit-of-growth

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