Why Single Dish?

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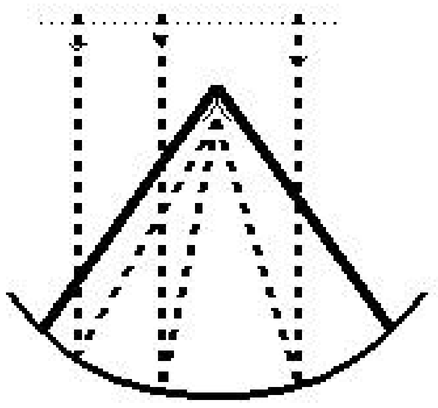
Why Single Dish?

- What's the Alternative?
- Comparisons between Single-Dish, Phased Array & Interferometers
- Advantages and Disadvantages of Correlation Interferometer
- Scale-sizes, Spatial Frequencies, Spatial Filtering: Examples
- Practical Details
- Future Telescopes
- Conclusions

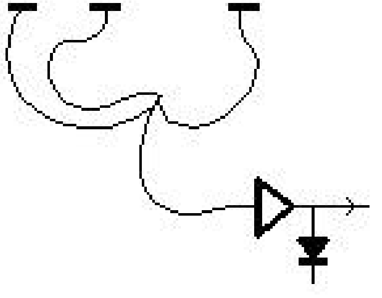
(a)



Single Dish.

Free space propagation & reflection
to bring all signals together in phase

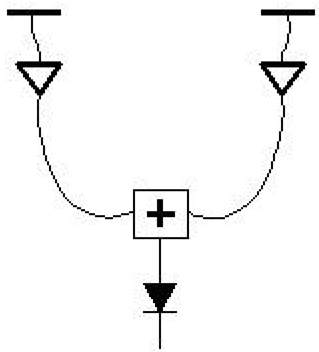
(b)



Phased Array.

Cables of just the right length, to
bring all signals together in phase

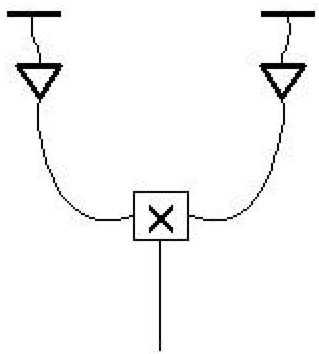
(a)



Adding Interferometer or Phased Array

A single dish with missing metal.

(b)



Correlation or Multiplying interferometer

All aperture synthesis radio telescopes are made up of multiple correlation interferometers

Phased Array (Adding Interferometer) *vs.* Correlation Interferometer

2-Element Phased array:

- Signal into each antenna element: **a, b**
- Noise of each antenna amplifier: **A, B**
- Before detector:

  $$(A + a) + (B + b)$$

- After detector:

  $$[(A+a) + (B+b)]^2$$

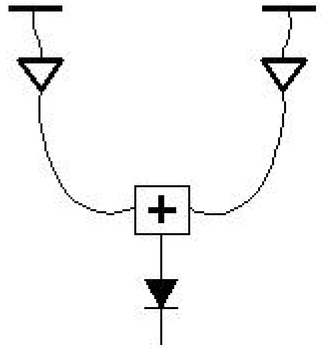
  or

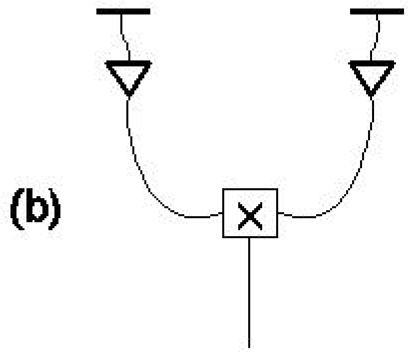
  $$A^2 + B^2 + a^2 + b^2 + 2.(A.a + A.b + B.a + B.b + A.B + a.b)$$

  Time-averaged products of uncorrelated quantities tend to zero, so this averages to just:

  $$A^2 + B^2 + a^2 + b^2 + 2.a.b$$

(a)





Multiplying or Correlation Interferometer:

•After multiplier: **(A + a).(B + b)**

or

A.B + A.b + a.B + a.b

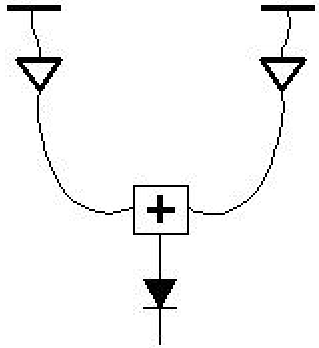
NB:
multiplication + averaging
= correlation

•After averaging, uncorrelated products tend to zero, so this becomes just

a.b

The averaged output no longer depends on A or B, the internally generated amplifier noise voltages ***(ignoring statistical fluctuations)***

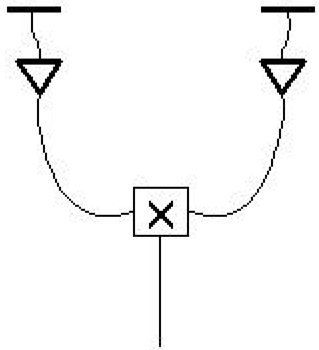
(a)



Adding Interferometer or Phased Array

- $A^2 + B^2 + a^2 + b^2 + 2.a.b$

(b)



Correlation or Multiplying interferometer

- **a.b**

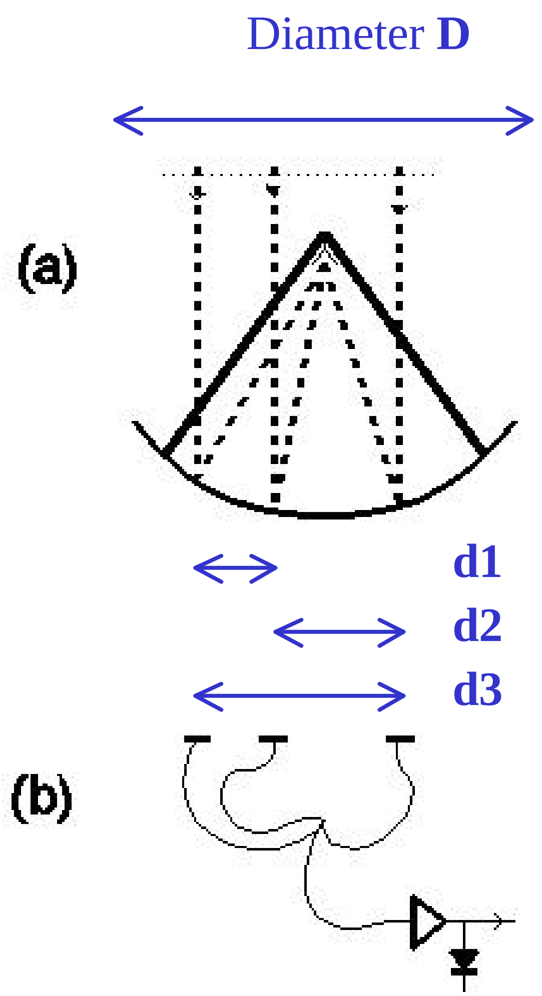
Phased Array (Adding Interferometer) *vs.* Correlation Interferometer

- Phased Array (Adding Interferometer) is the same as the Single-dish telescope (just missing some metal & using more cable instead).

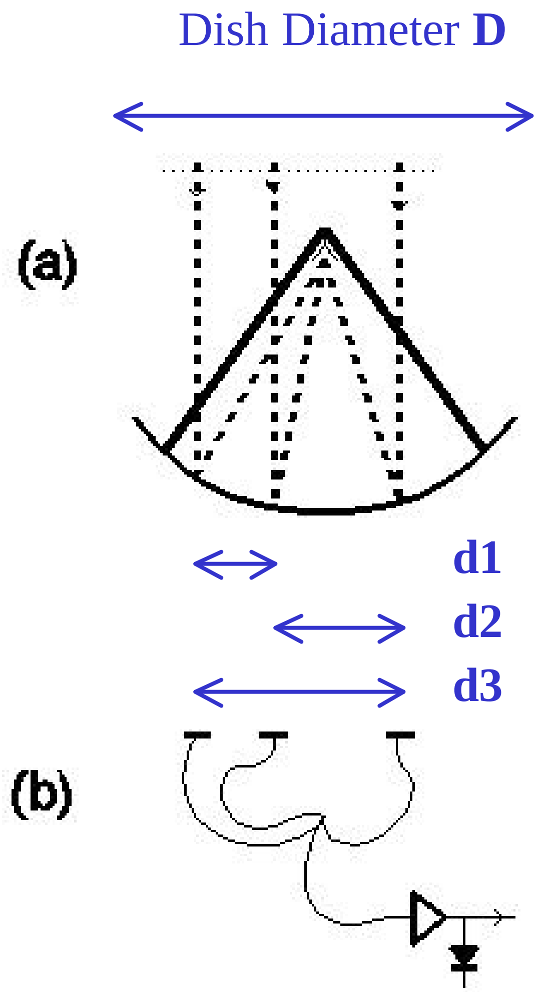
- Single Dish ***very*** susceptible to changes in receiver gain, and to changes in receiver noise temperature

- Correlation Interferometer nearly immune to receiver gain and noise changes

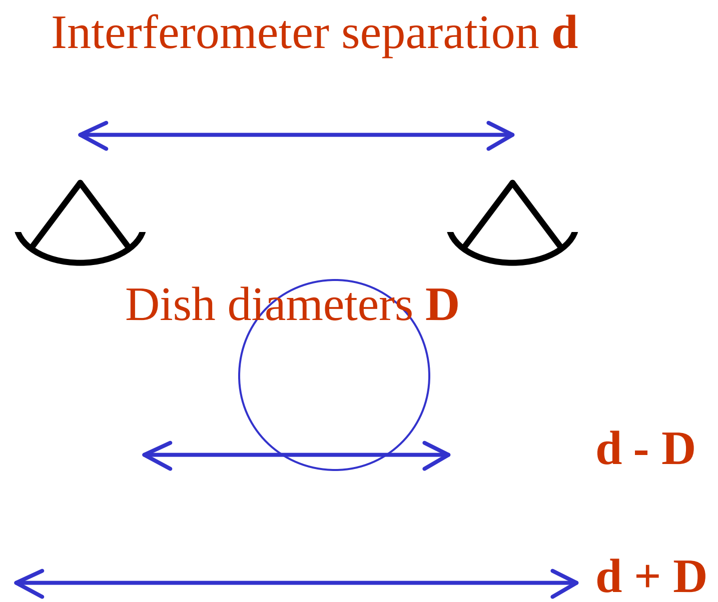
- Some source distributions, or combination of sources may be ***invisible*** to the correlation interferometer.



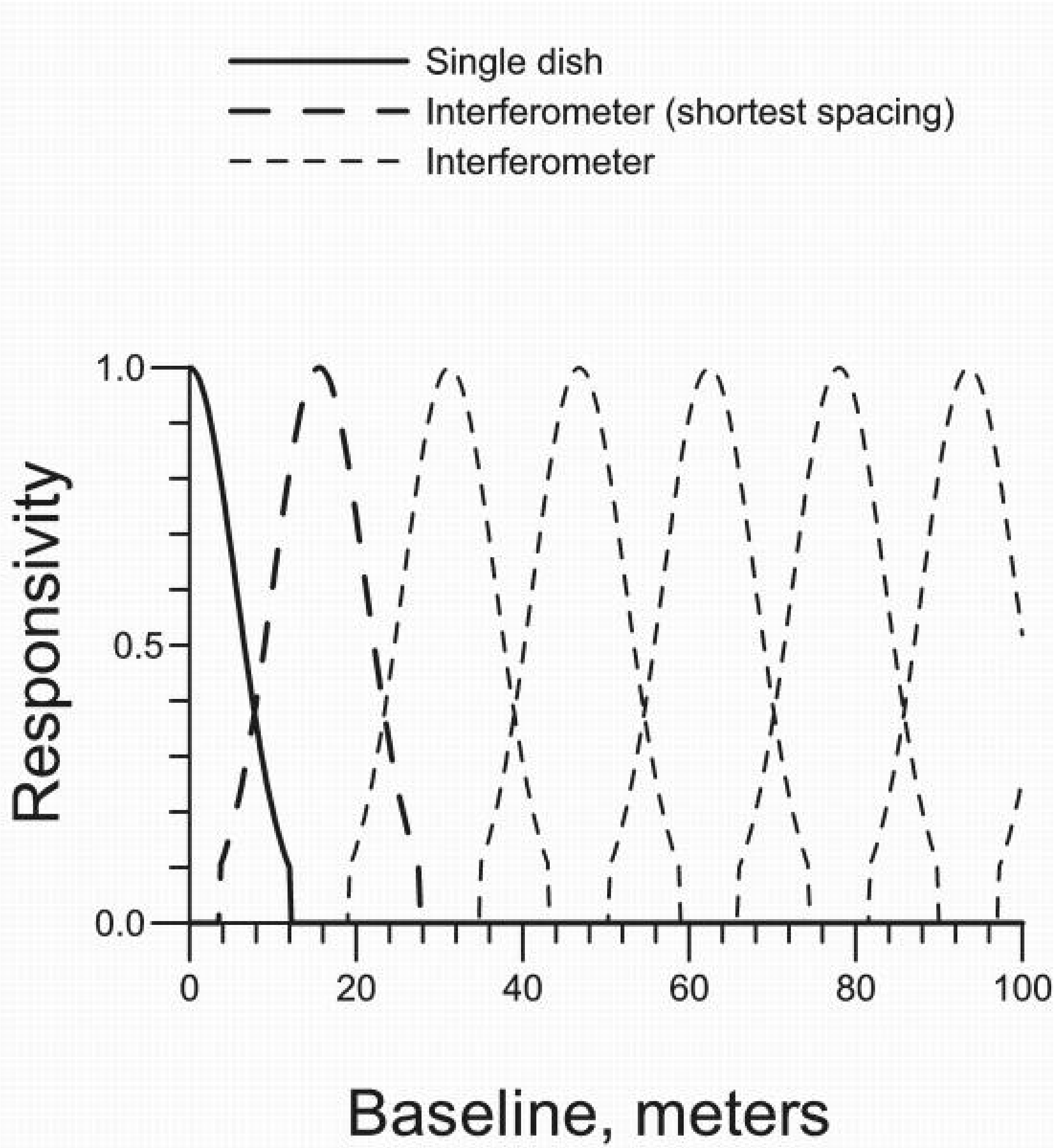
A single dish of diameter **D** includes all baselines from **0** to **D**



A single dish of diameter **D** includes all baselines from **0** to **D**

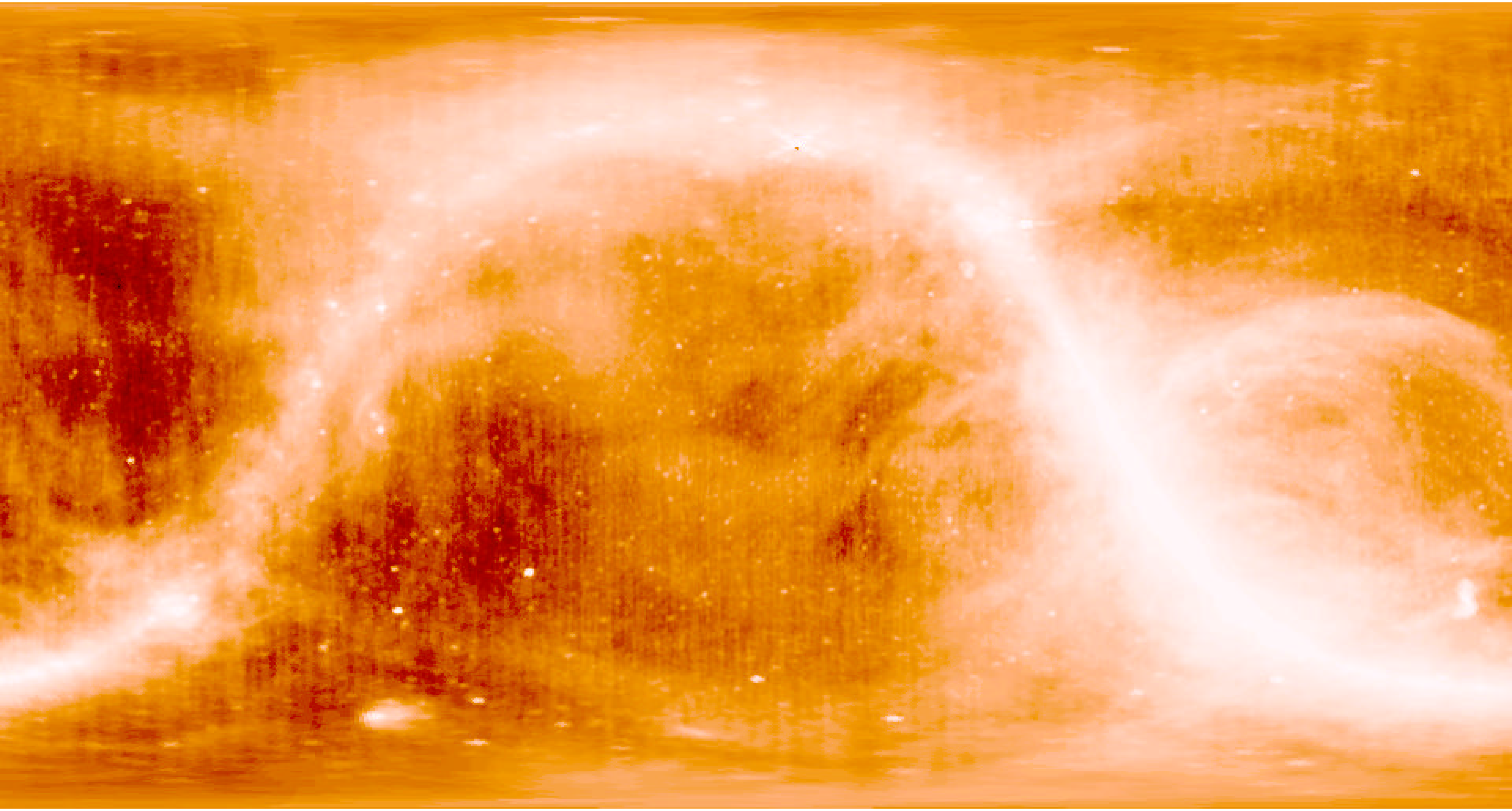


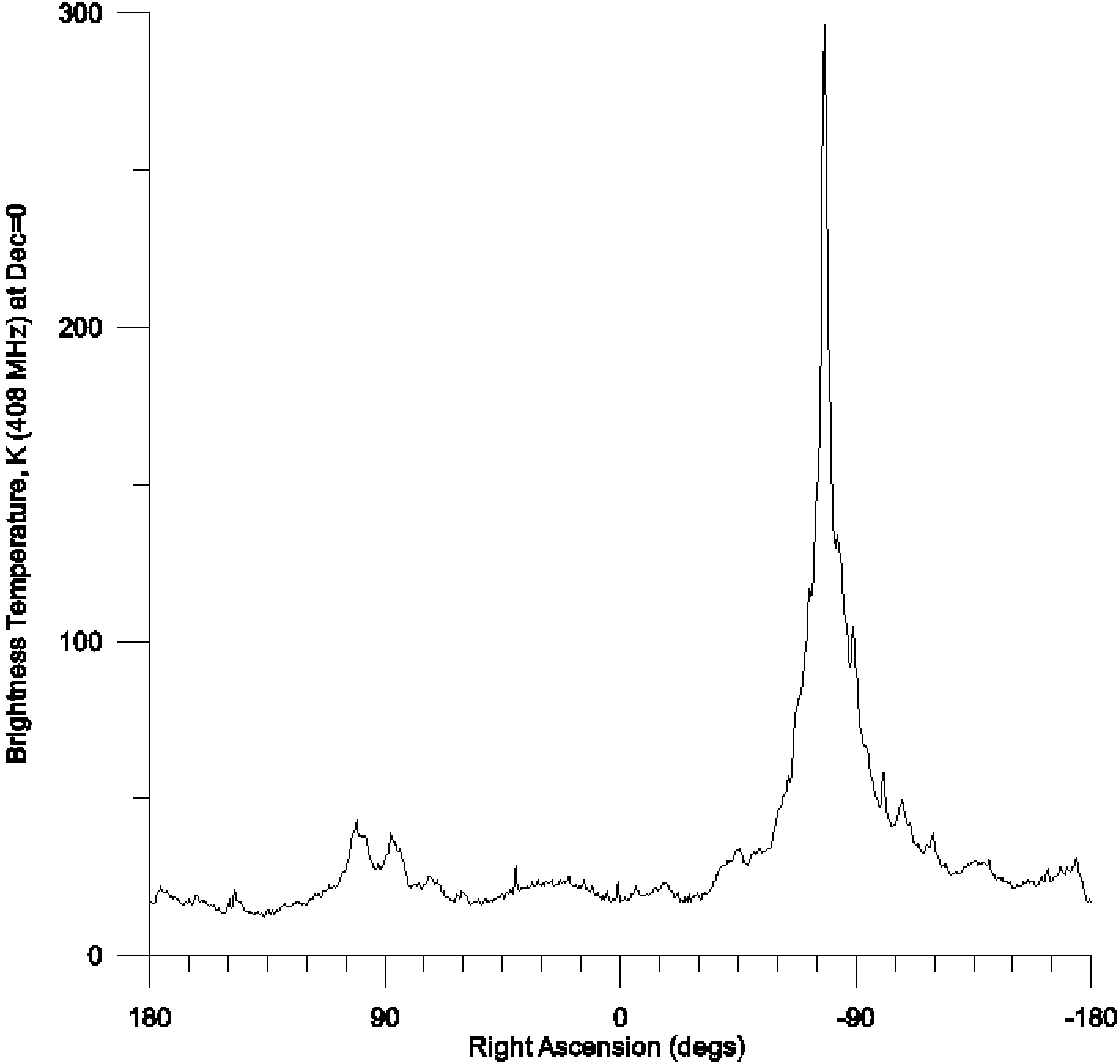
A correlation interferometer of separation **d**, using dishes of diameter **D**, includes all baselines from **d – D** to **d + D**



Angle on sky = (?/Baseline) rads

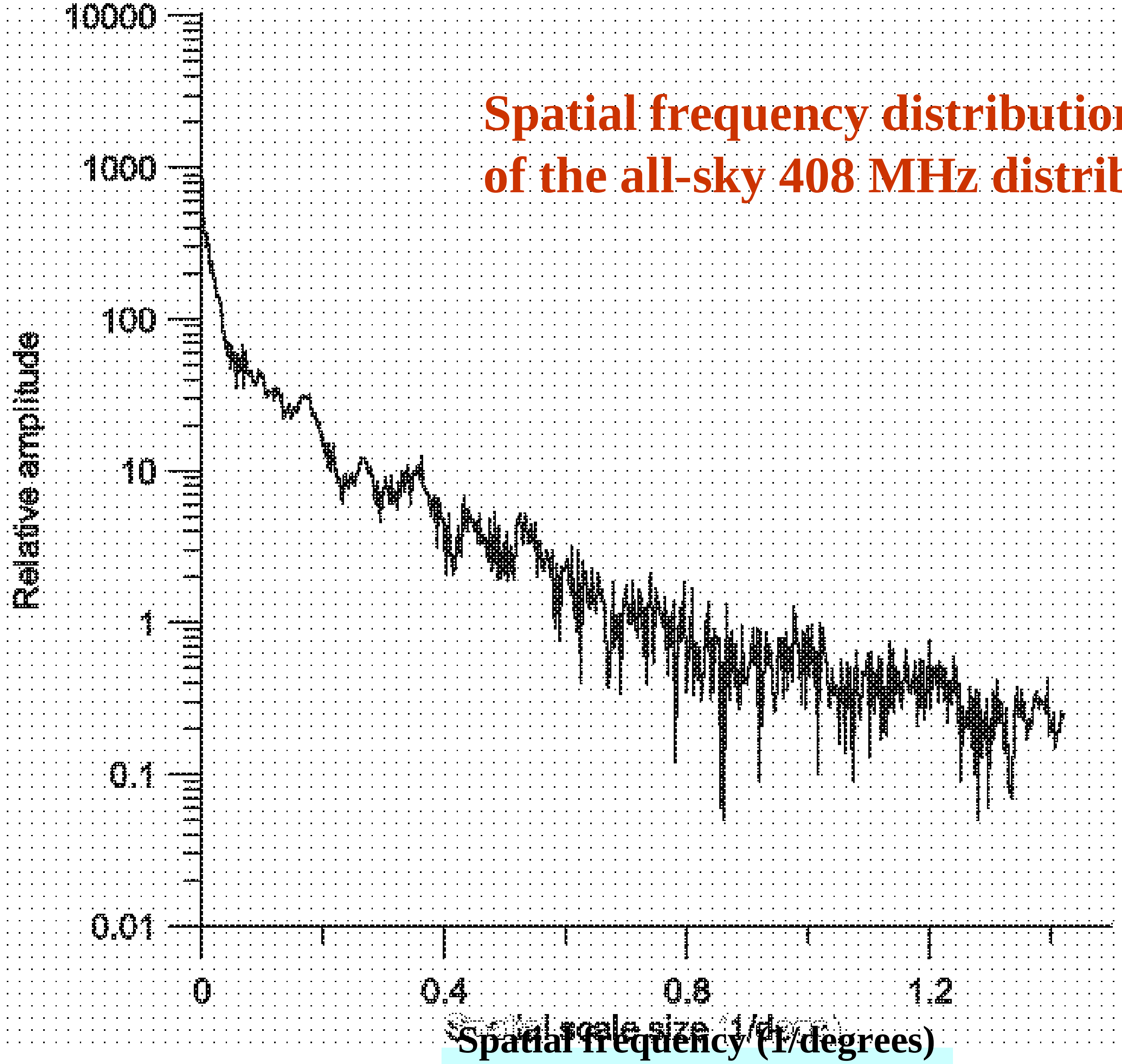
Spatial Frequency** is proportional to **Baseline



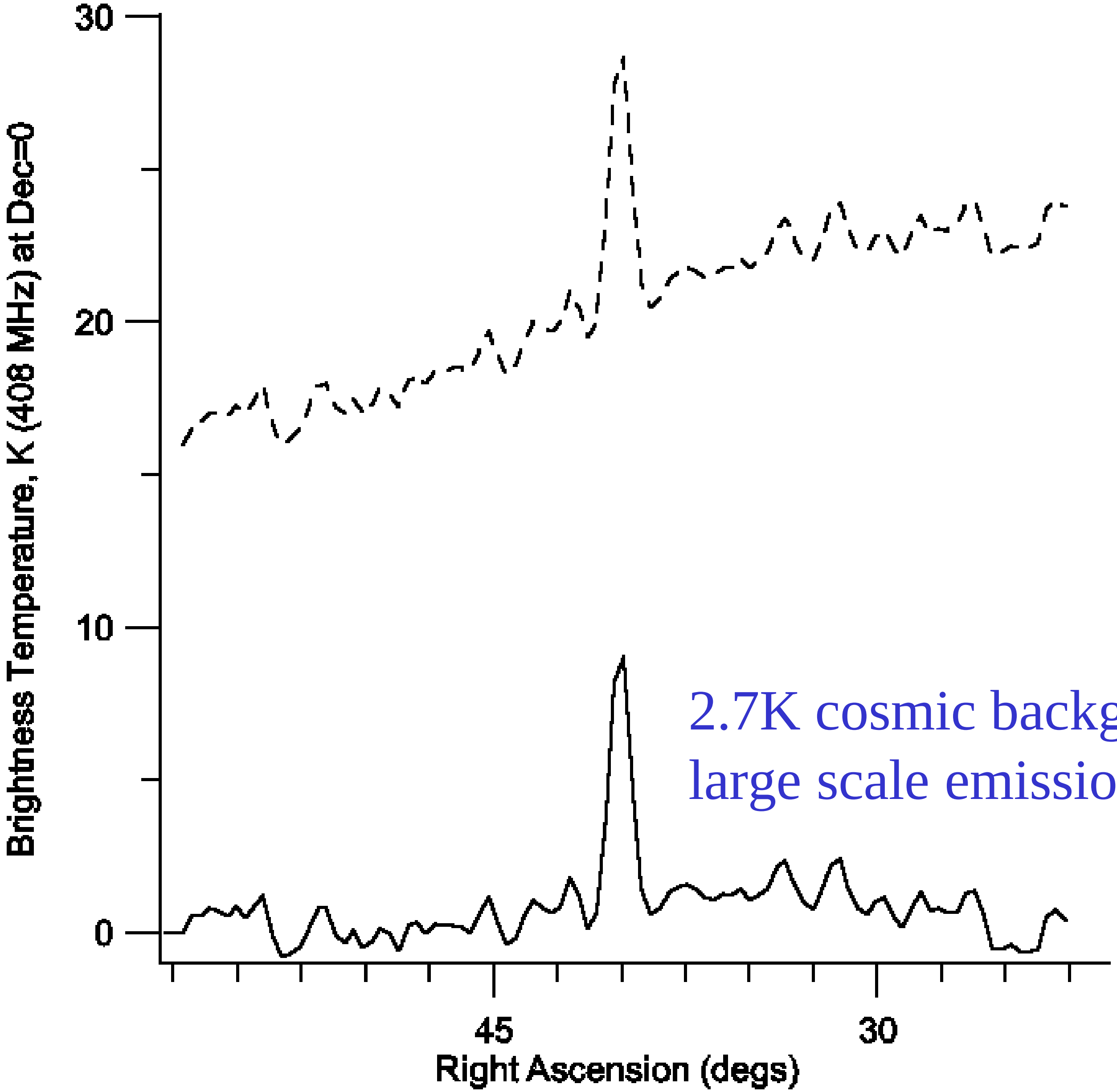


300
200
100
0
Brightness Temperature, K (408 MHz) at Dec=0
180
90
0
-90
-180
Right Ascension (degs)

Spatial frequency distribution of the all-sky 408 MHz distribution

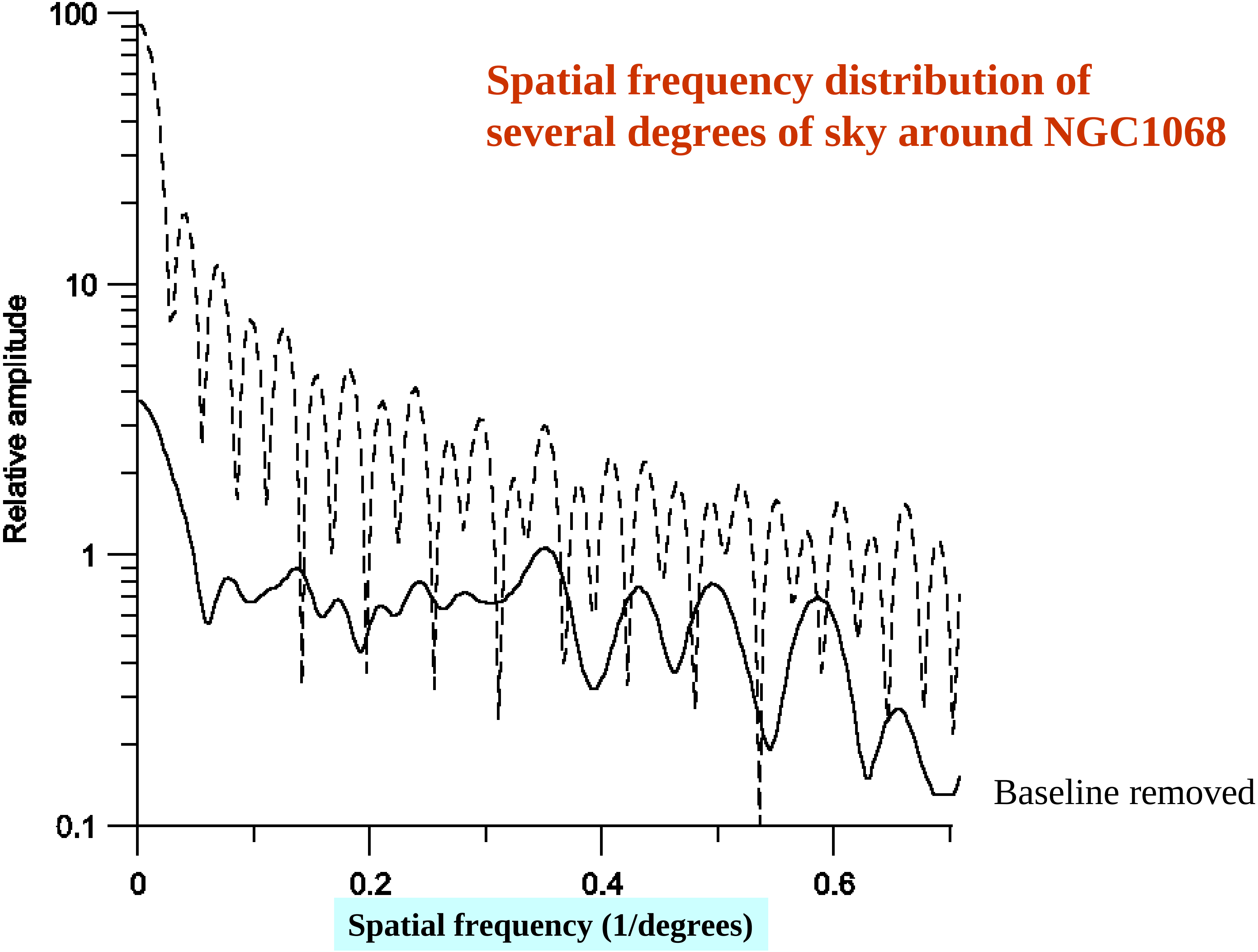


A cut through NGC 1068.



Complete data

2.7K cosmic background and other large scale emission features removed


Spatial frequency distribution of
several degrees of sky around NGC1068
Relative amplitude
100
10
1
0.1
0
0.2
0.4
0.6
Spatial frequency (1/degrees)
Baseline removed

Spatial Frequencies: Single Dish *vs.* Interferometer

- **Single Dish has a high spatial frequency cut-off in resolution set by its diameter**

- **Interferometer has a low spatial frequency cut-off set by its minimum antenna separation**

- **Sometimes, the interferometer low frequency cut-off is advantageous**

- **Usually, Single Dish maps are analysed in a way that removes the lowest spatial frequencies too. We don't normally want the 3 K cosmic background in our data**

- **The relative flux in low spatial frequencies is typically far greater than that at higher spatial frequencies**

- **For cases where we DO want large scale structure, we may HAVE TO use a Single Dish.**

If your science requires the large scale structure, there's probably **NO ALTERNATIVE** to including Single Dish data

Practical Details

- The **fundamental** characteristics of a Single Dish are its good potential sensitivity to large scale structure, and its lack of sensitivity to fine structure, or high spatial frequencies.
- ***Practical*** details are just as important.

Practical Advantages of Single Dish observing:

- Spatial frequency response
- May provide large collecting area with manageable electronic complexity
- Simplicity: one receiver, not N receivers, nor N.(N-1)/2 correlations
- Flexibility:
- Relative ease of upgrading, customizing hardware to an experiment
- Relative ease of implementing imaging arrays, including bolometers
- Multi-frequency receivers relatively easy investment
- Relative ease of implementing radar tx systems
- A single large dish can add significant sensitivity to (e.g.) VLBI arrays
- Software possibly simpler: "Conceptually" easier to understand for novice astronomers.
  (But this is inexcusable!)

Practical Disadvantages of Single Dish observing:

- Spatial frequency response
- Mechanical complexity replaces electronic complexity
- Susceptibility to instrumental drifts in gain and noise - don't have the correlation advantage of interferometers
- Interferometers can *in principle* give high sensitivity and high total collecting area.
- Aperture synthesis imaging is a form of multi-beaming - arguably obtaining more information from the radiation falling on a telescope than is possible with a single dish.

The overall key parameters are

1. Spatial frequency response and
2. Relative complexity.

SUMMARY

- Don't think in terms of a "Single Dish Observer" or an "Interferometrist."
- They both have their advantages and disadvantages. Choose the right tools for the job.
- Often, a combination of both tools may be required in order to do a good job
- Future telescopes (e.g. ALMA) may be built to allow both Single Dish and Interferometer observing, in order to provide the astronomer with the complete range of spatial frequencies needed for the science.

In future the distinction between "Single Dish" and "Interferometer" observing may become blurred.

Single Dish? ALMA is designed to operate as 64 “independent” single dish telescopes, as well as a 2016-baseline interferometer