Fringe tracking and bootstrapping

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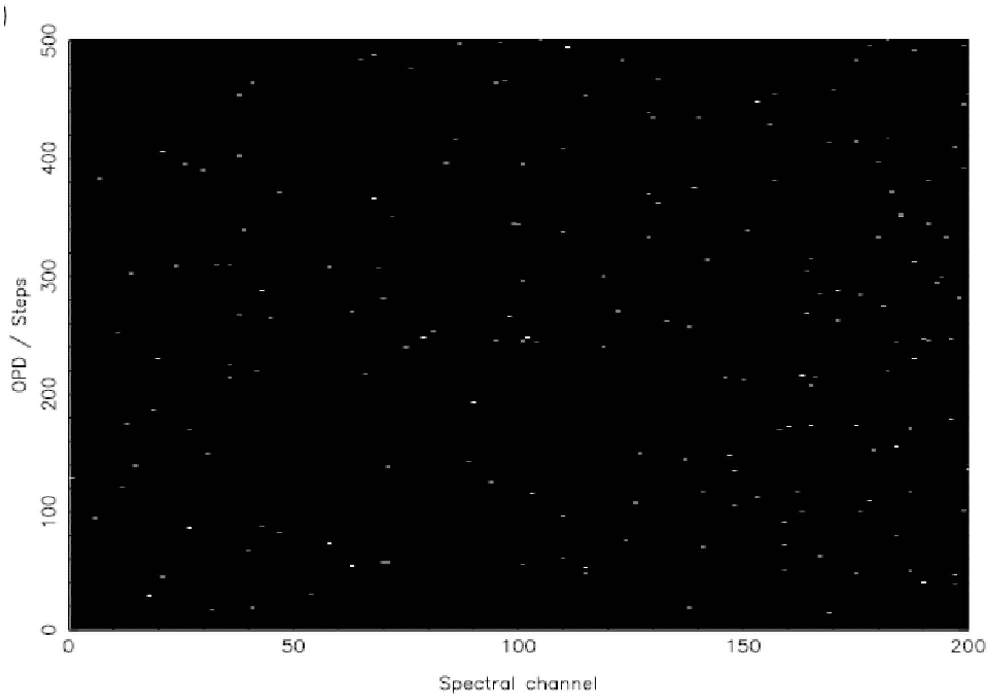
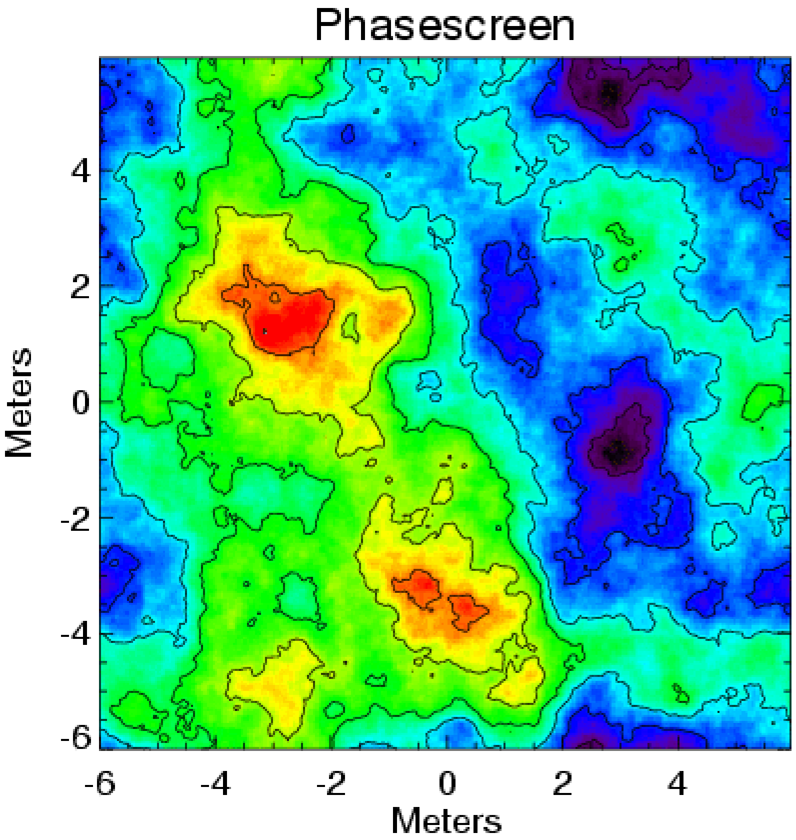
Outline

- The need for fringe tracking
- Limitations of fringe tracking on resolved sources
- Possible solutions
- Technical implications
- Science implications

An interferometer is fundamentally limited by two things





The atmosphere introduces both high-frequency phase jitter and lower-frequency OPD fluctuations

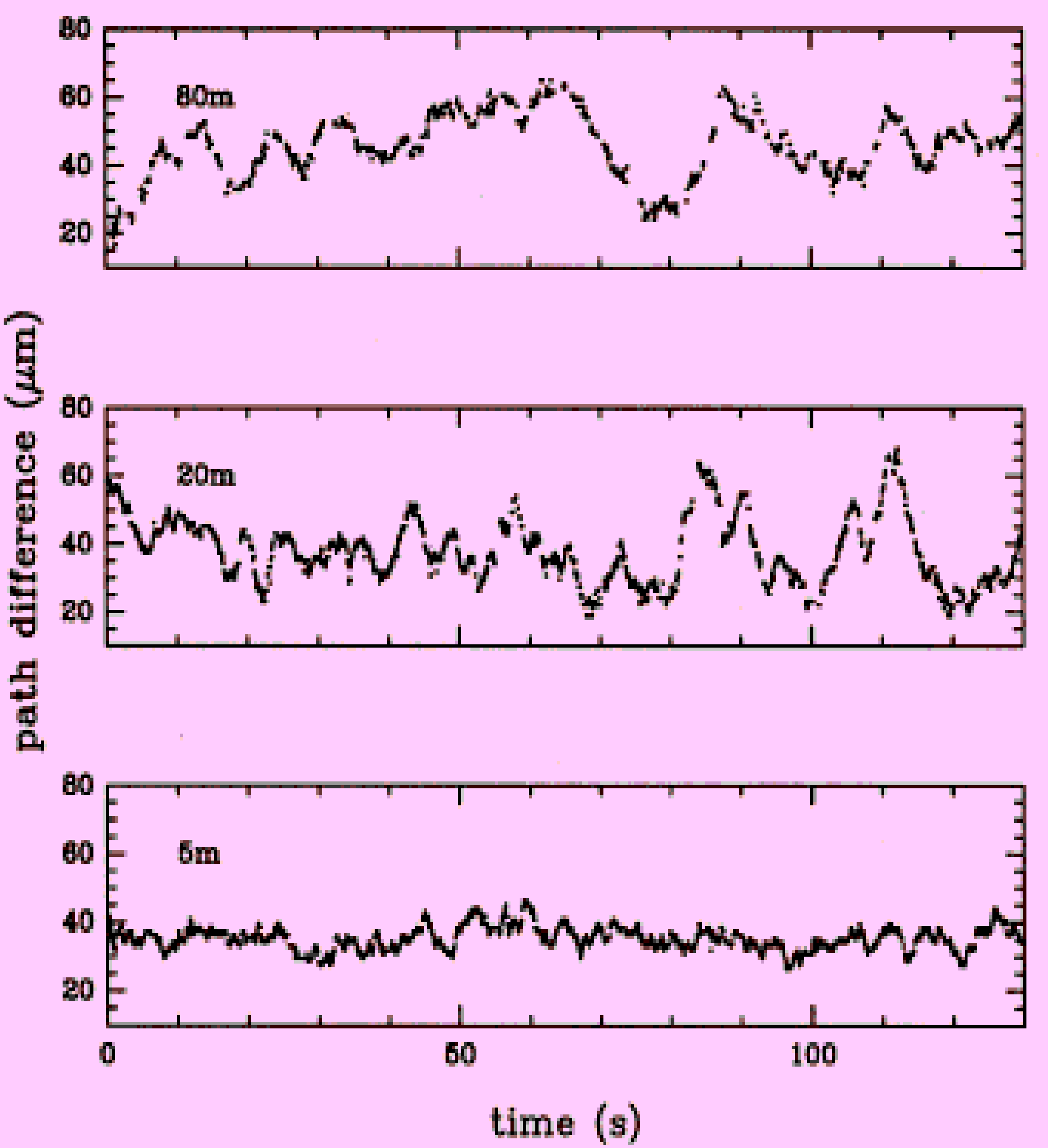
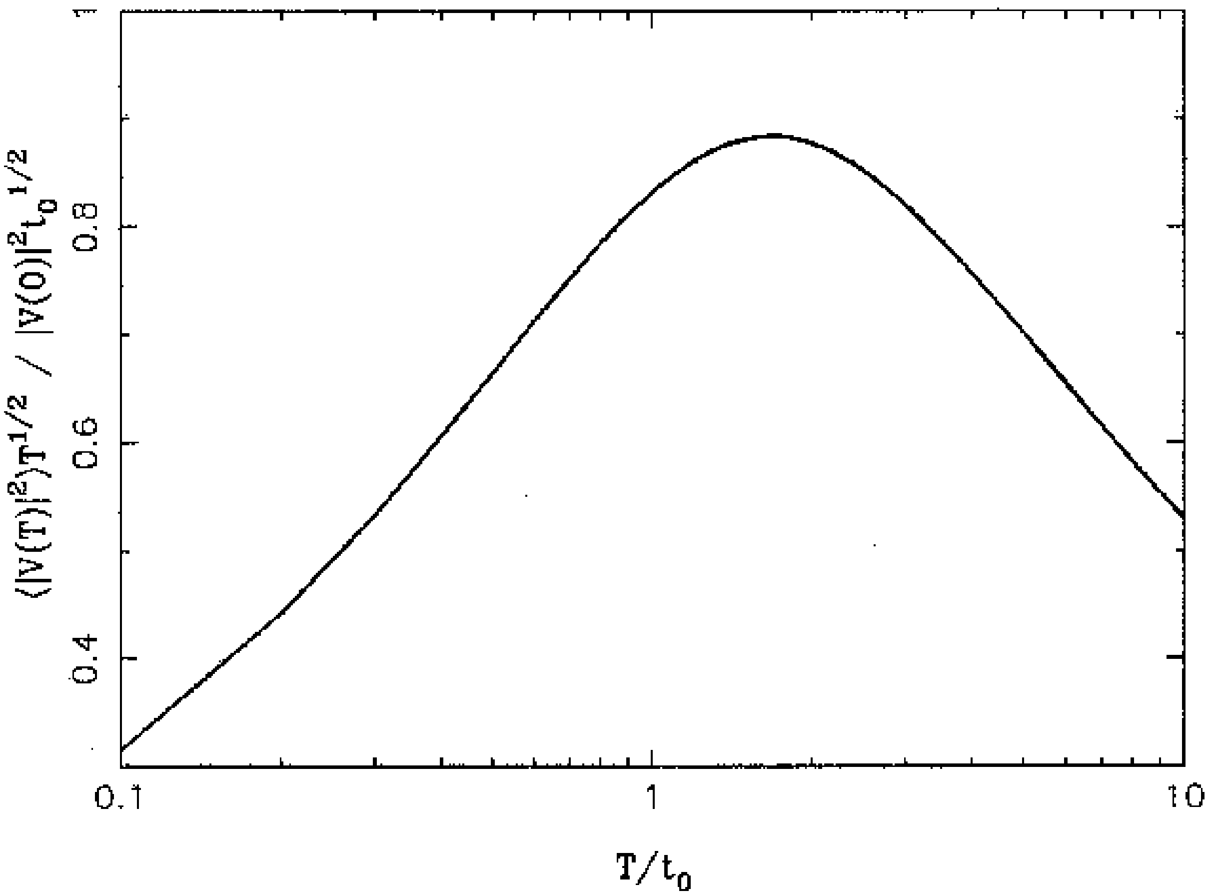
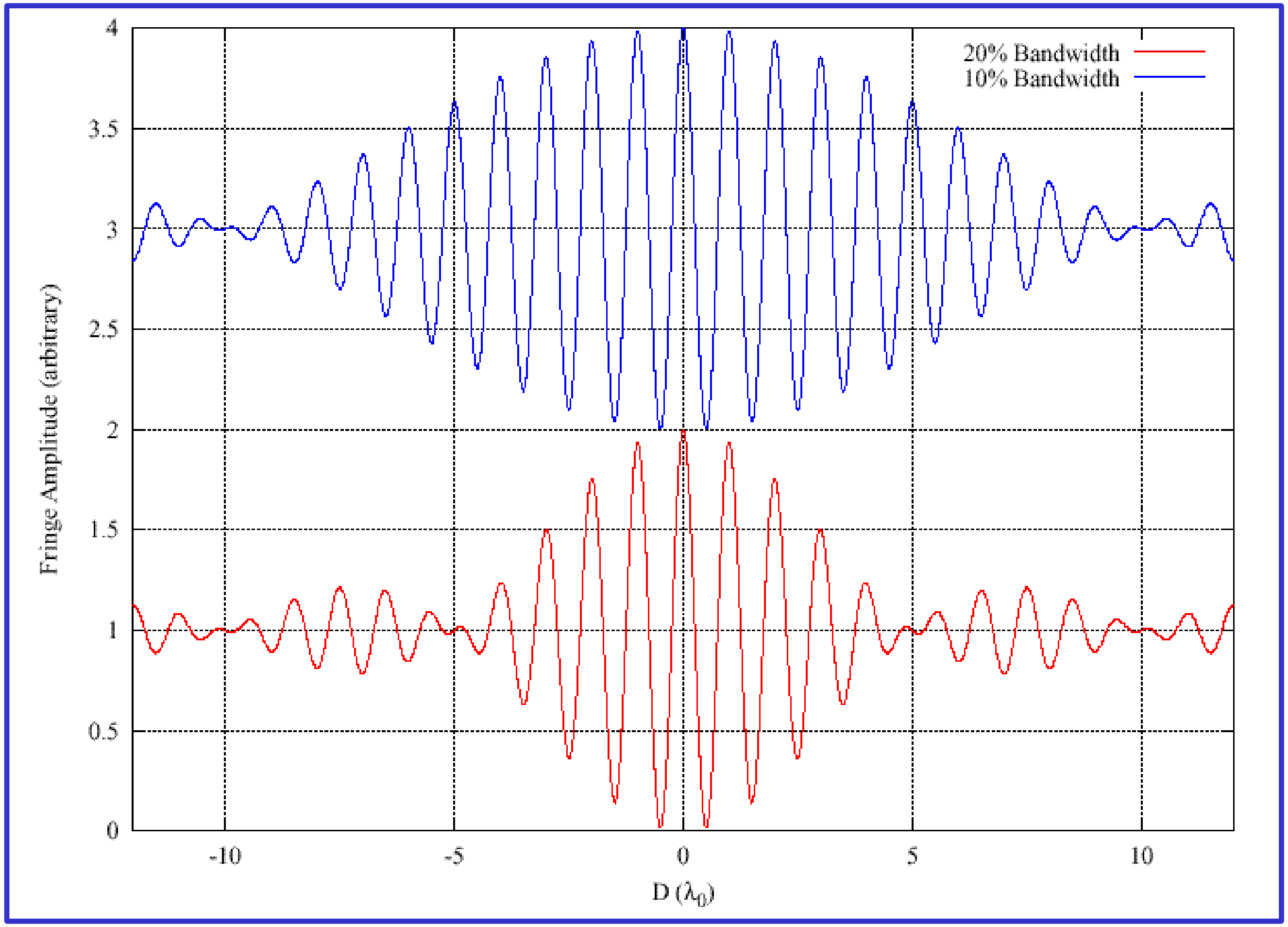


Figure 1. Path offset from the equal optical path position as a function of time for three baselines.

Phase jitter limits the usable integration time



Low-frequency OPD drifts mean we may not see the fringes at all



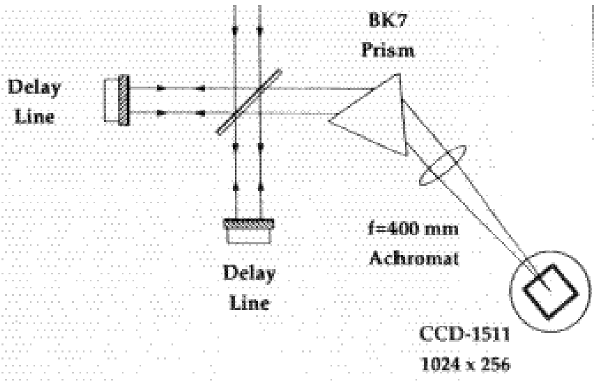
We employ fringe trackers to solve these problems

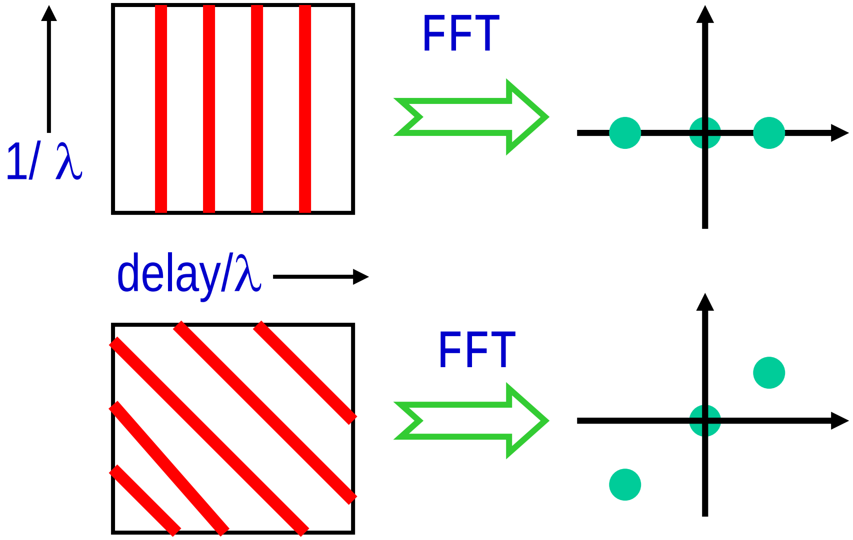
- Cophasing systems:
  - Phase residuals ~λ/20
  - “Hardware cophasing” vs “Software cophasing”
  - Bright-source high-SNR/high dispersion science
  - Science camera in long-integration mode

- Coherencing systems
  - Phase residuals ~ 3 λ for R=30
  - Faint-source science
  - Science camera needs to be in “speckle mode”

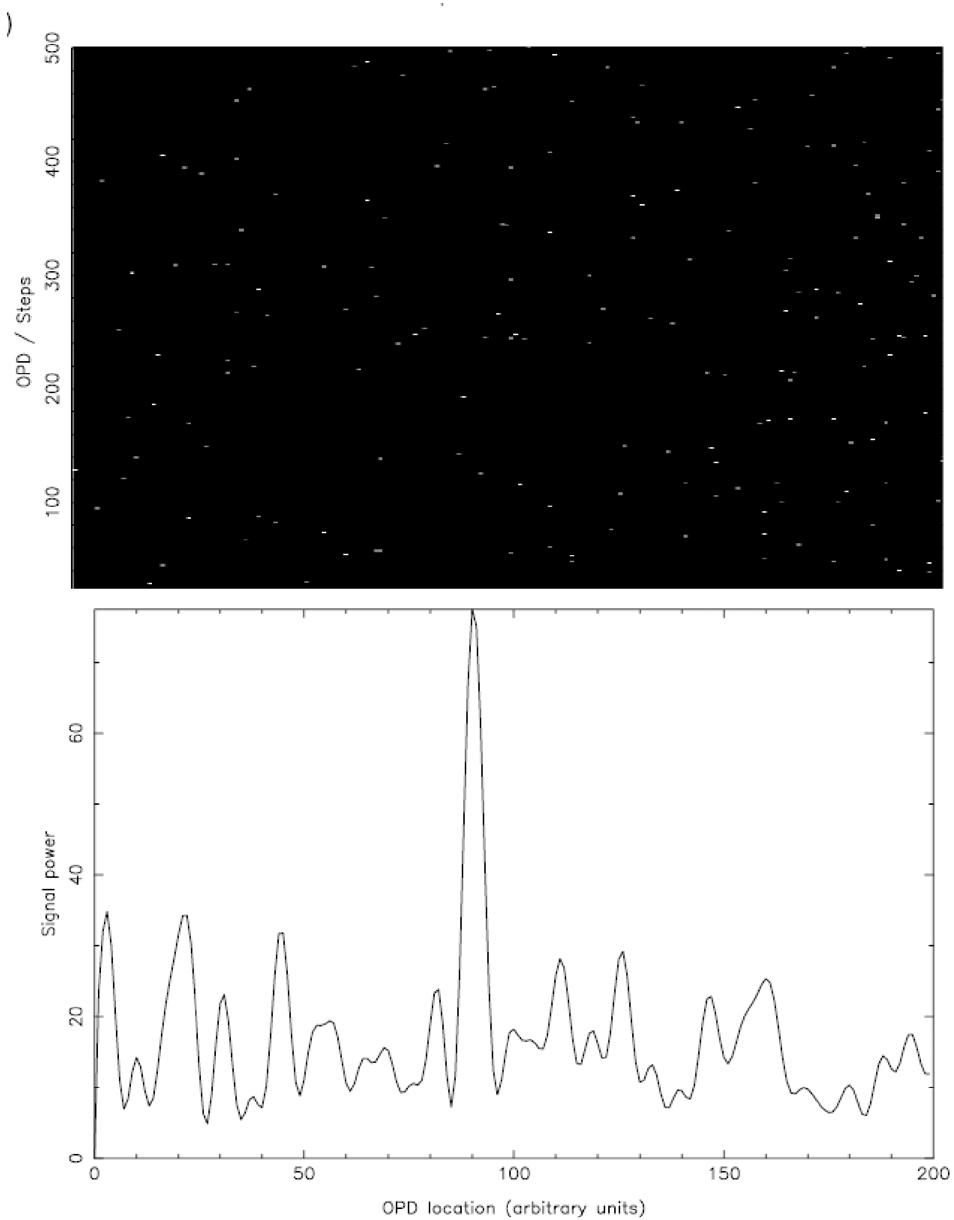
Fringe tracking methods

- Phase tracking
  - Follow 180° phase “wraps”
  - Requires sampling time $<<t_0$
- Group delay tracking
  - Dispersed fringes are tilted when OPD non-zero
  - Recover fringe envelope position using 2-D power spectrum.





Group delay coherencing can track fringes on sources at least 2.5 magnitudes fainter than phase-tracking cophasing

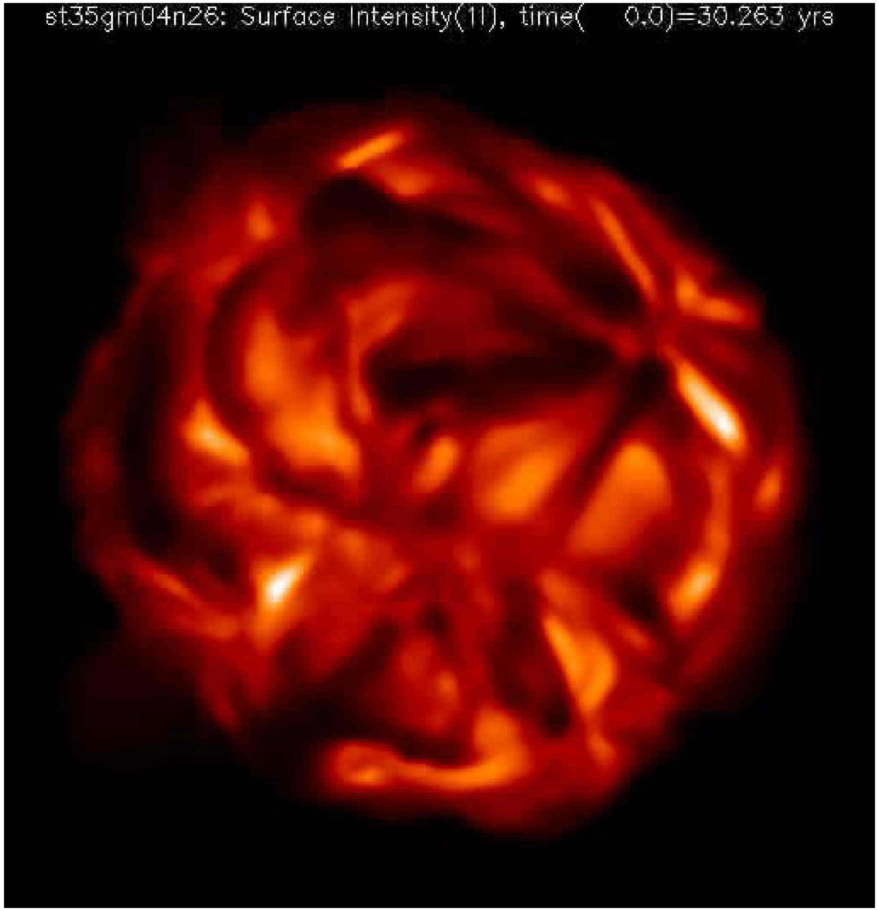


The fringe tracker determines what kind of science we can do

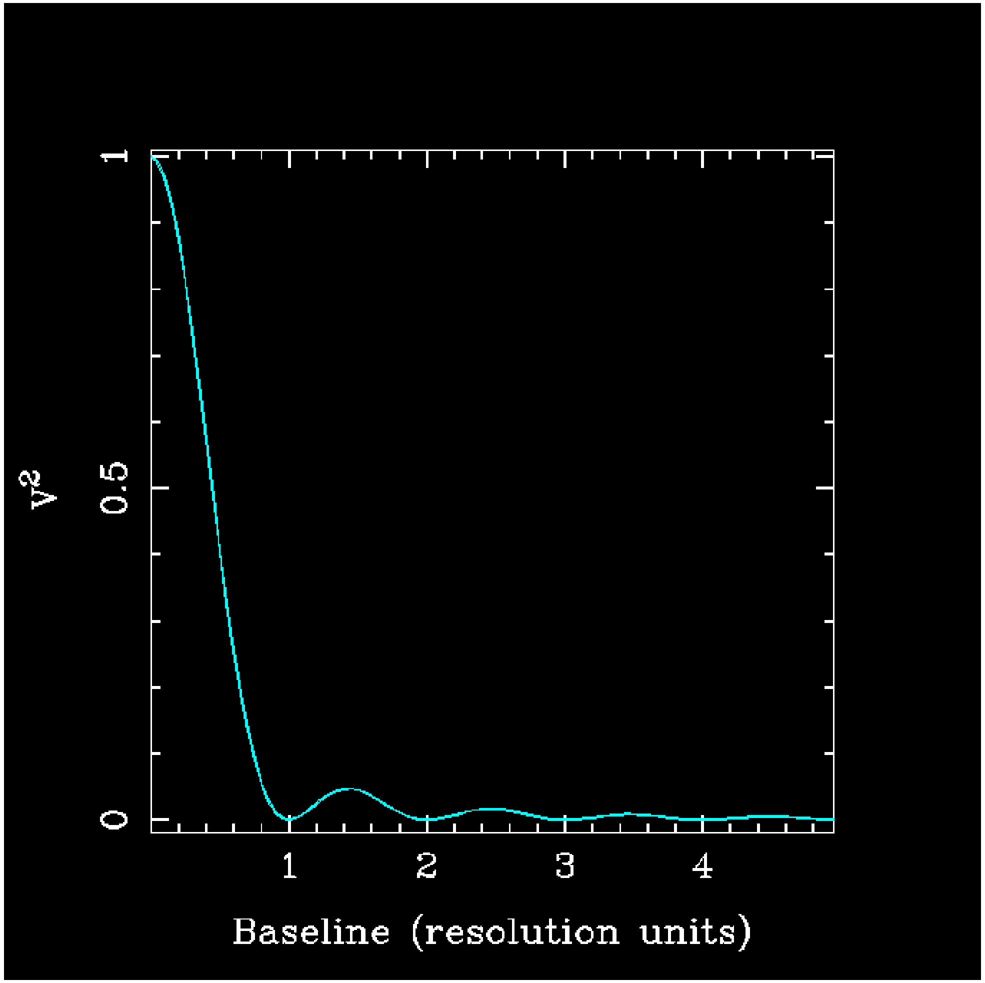
- The fringe tracker must achieve a usable signal-to-noise ratio in an integration time fixed by the atmosphere.

- If we cannot fringe-track on a target, we can never observe it interferometrically, no matter how much observing time we have.

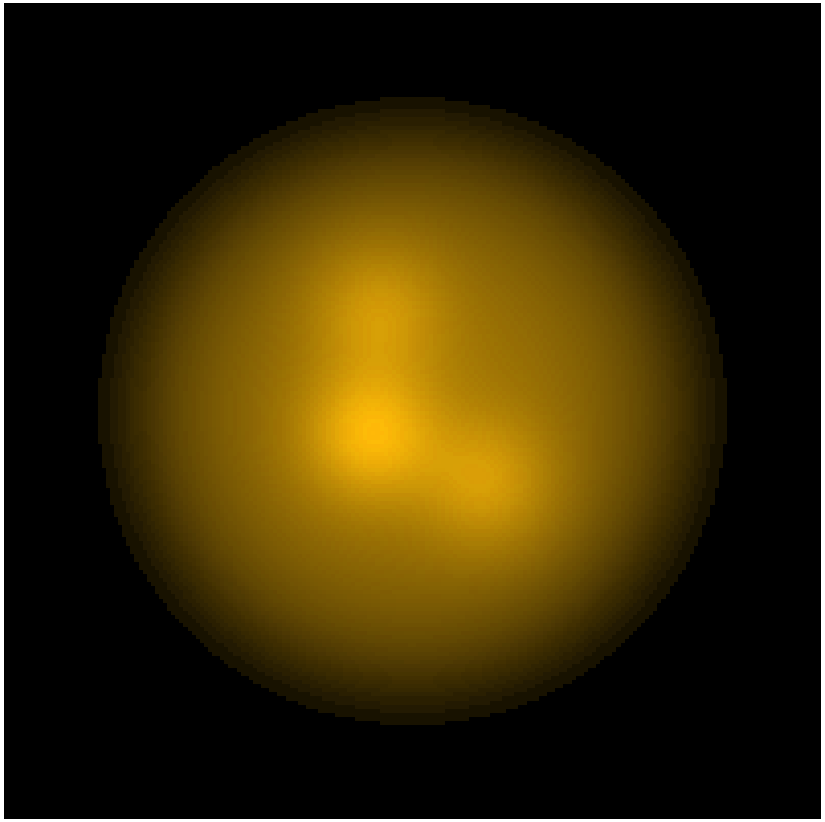
Many observations require several pixels across a resolved source



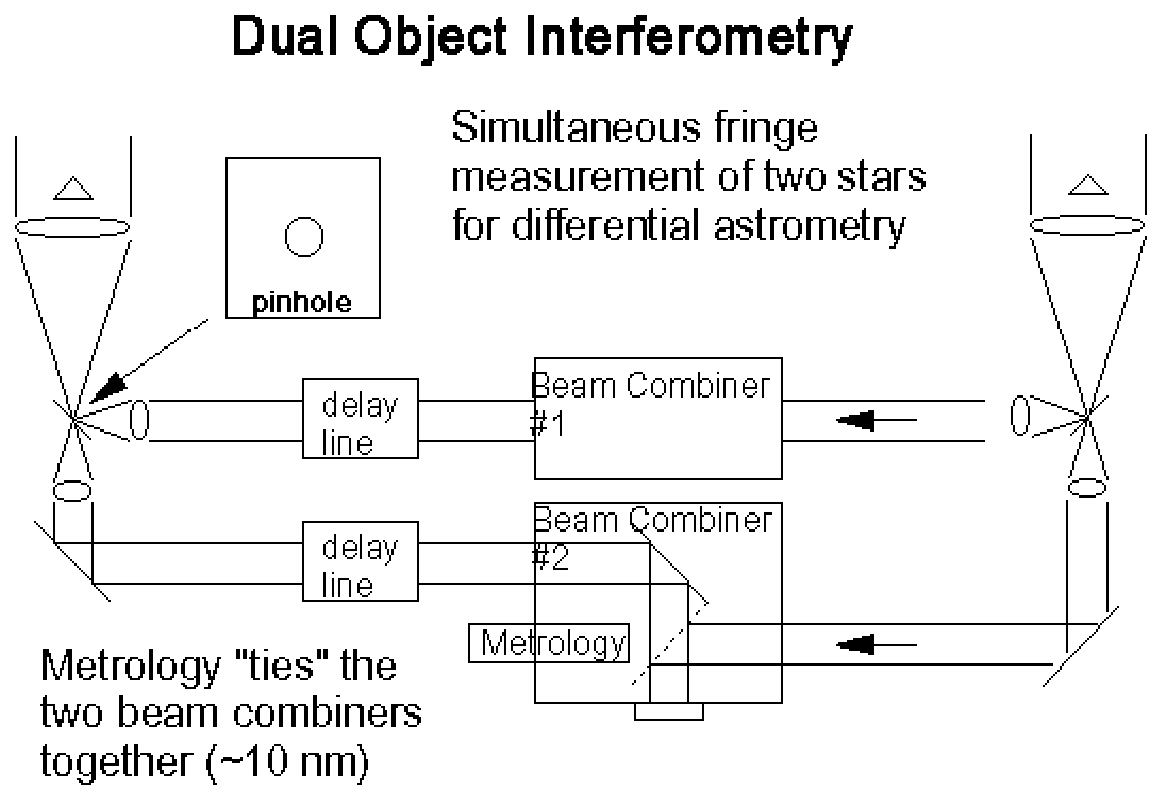
The SNR for fringe tracking scales as V^2N



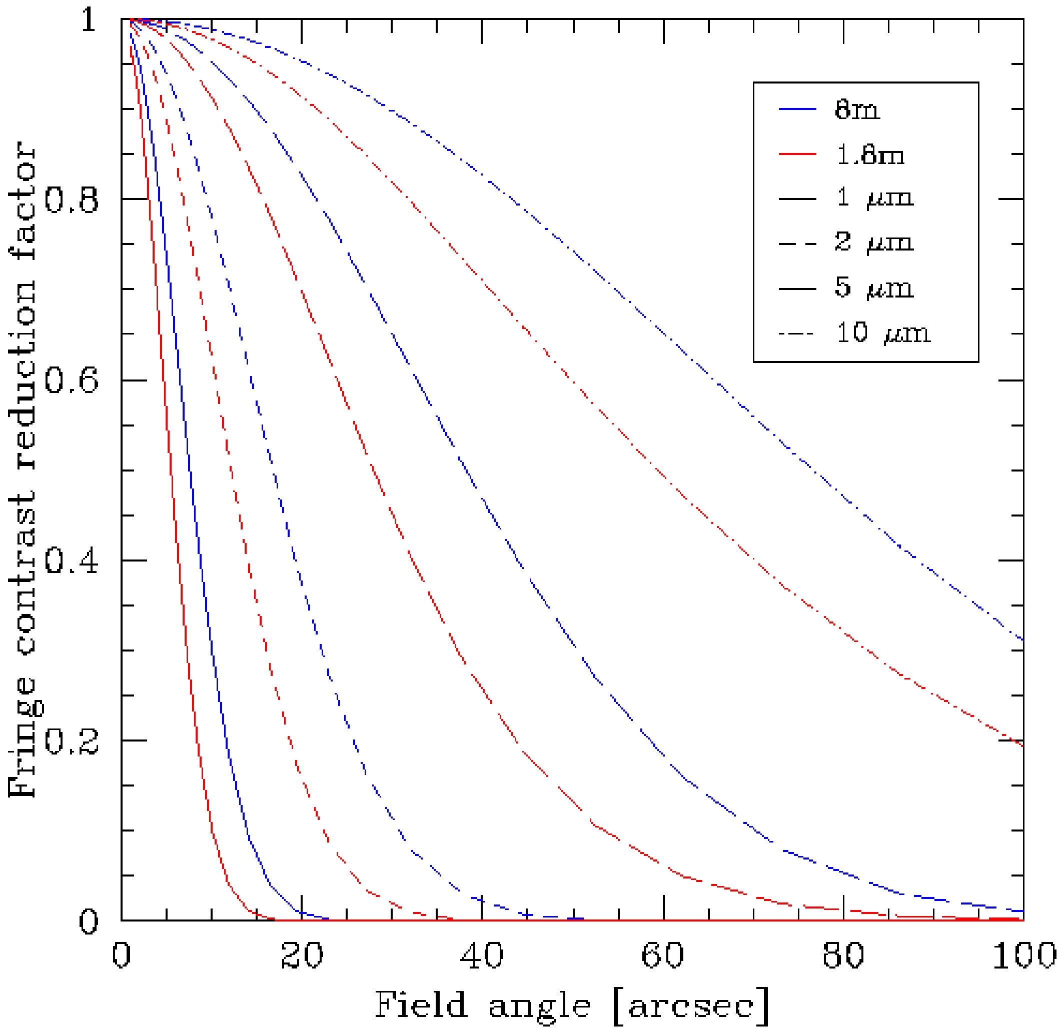
The maximum resolution we can achieve is limited by the source itself



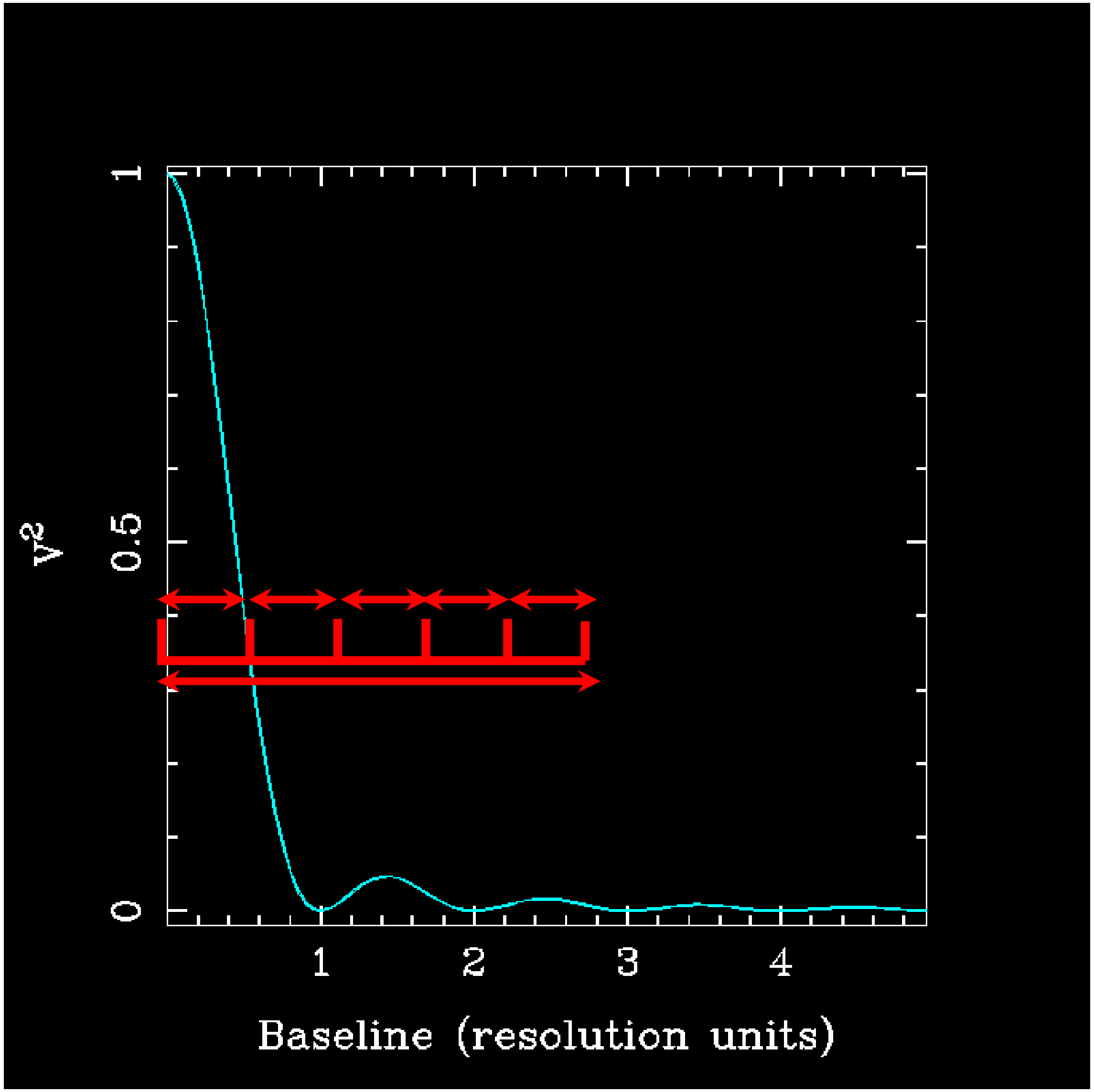
Dual-star systems allow the use of a nearby unresolved reference star



Dual-star systems have limited sky coverage

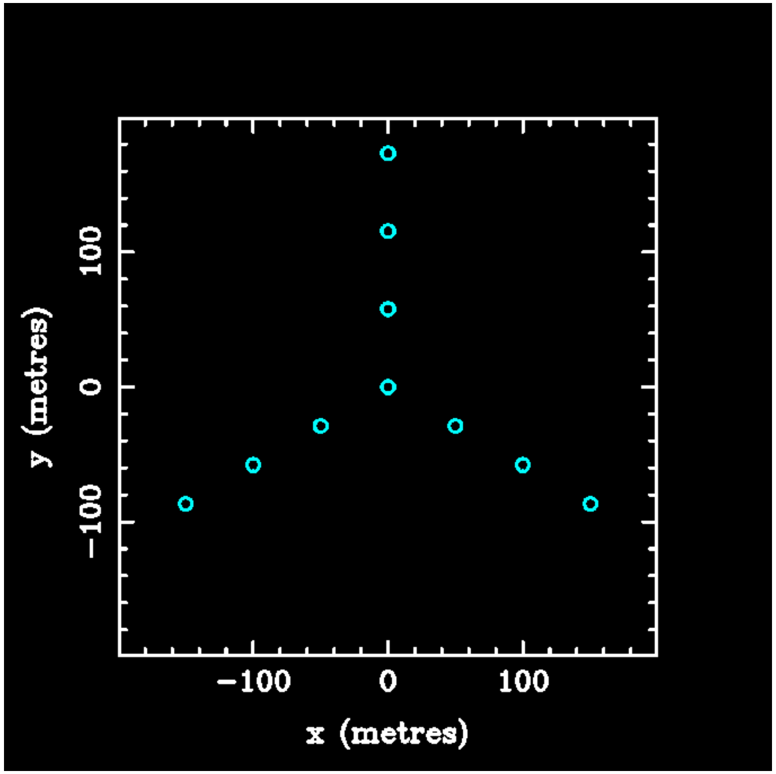


Baseline bootstrapping makes use of the science target itself

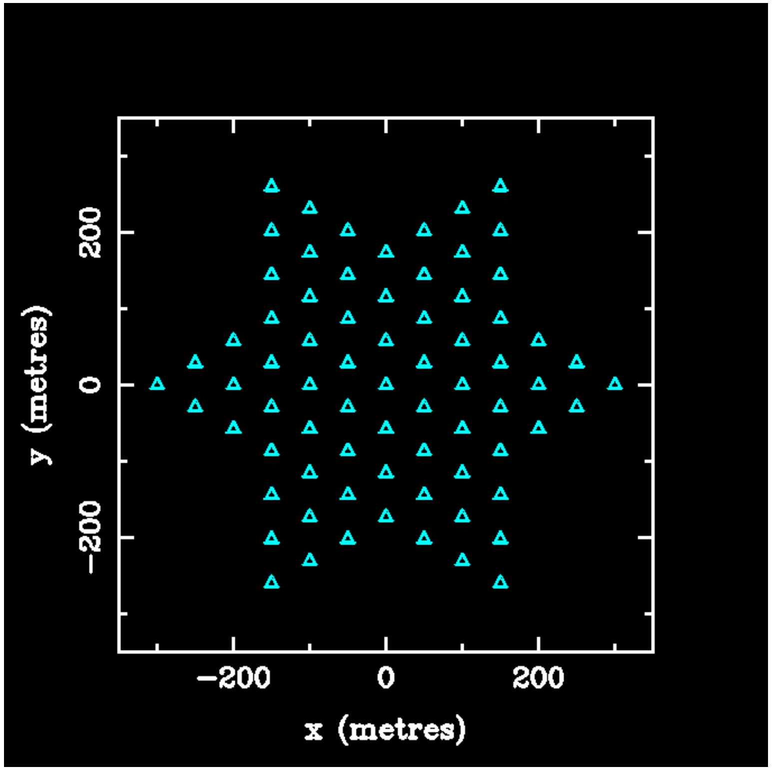


Bootstrapping requires more telescopes than needed for u-v coverage alone

In 2-d arrays the baseline efficiency can be high

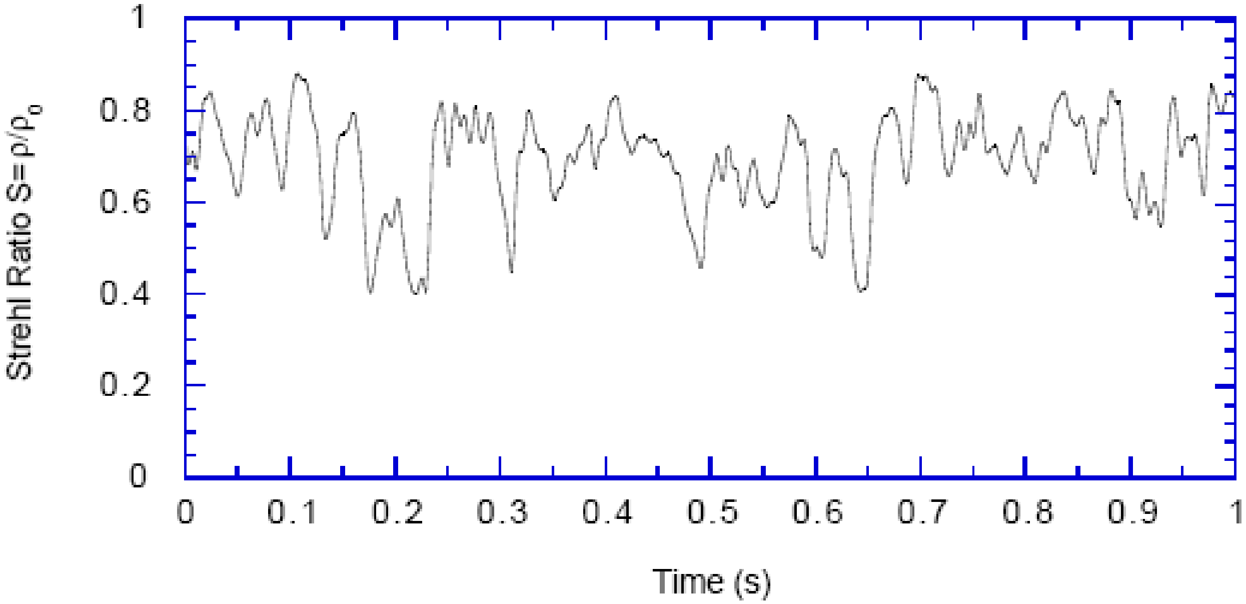


Array layout



Instantaneous (u,v) coverage

Bootstrapping is sensitive to SNR "dropouts" and phase discontinuities



Implications for science

- Fringe tracking determines whether we can observe the object at all
- For resolved objects we need to consider a bootstrapping array
  - What is the longest “link in the chain” we can use?
- We still need to see if the science SNR can be achieved in a reasonable time
  - Consider whether fringe tracker SNR is high enough for cophasing rather than coherencing