Compact Fizeau Array as an ELT alternative

Medium baseline, high sensitivity, high efficiency imaging interferometer for general astrophysics

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Heritage from Keck, LBT, GMT, 20/20, TMT.
Is this a step in the direction of an 100m ELT ? Or an alternative to 100m ELT ?
Maybe the only practical way to get 100m baseline is interferometer rather than ELT.

Would have unique capabilities for an interferometer:

Large sky coverage (100%)

Large field of view (1') -> interferometric cophasing on field stars -> ability to image faint objects

High throughput thanks to simple Fizeau focus

Extremely efficient for **astrometry** (observes many sources at once)

Imaging:

- crowded fields OK
- coronagraphy OK

Wide range science goals, complementary with longer baseline interferometers (for stellar physics and AGN accretion):

Extragalactic science

- galaxy formation & evolution
- absorption of background QSO light by moderately distant galaxies
- galactic archeology for nearby galaxies with photometry & astrometry
- BH/AGNs/QSOs and their environment – Comparative study between our galaxy and nearby galaxy

Galactic science

- Galactic archeology with astrometry & photometry
- Galactic center – seeing close to black hole, motion of stars
- Star formation
  - Proto-Planetary nebula and accretion disks are complex time-variable objects which greatly benefit from imaging
- Exoplanets
  - Coronagraphy possible at Fizeau focus (with “hypertelescope” concept). Hot Jupiters, imaging of young giant planets in complex exozodi environments.
  - Exoplanet searches with astrometry on cool faint stars

Solar system

- Asteroids, satellites of other planets, KBOs surface imaging

- **Imaging with ~150m wide interferometric array with high fill factor (10% or more). ~8m individual apertures.**
- **Full or almost full (u,v) plane coverage** (possibly with help of Earth rotation for a few hours).
- **Fizeau focus greatly simplifies mixing of the beams** (few optics, high throughput): this is the way to go for a dense interferometric pupil and a wide field of view. *Note: wide field of view (wider than diffraction limit of each subaperture) requires Fizeau combination*
- **Common mount**: no moving delay lines (maybe ~cm)
- Each aperture equipped with **LGS AO**. Cophasing between apertures using natural guide stars.
- **Cophasing is easier with this design** (internal laser metrology desirable)

Why a ~150m sparse array rather than an ELT ?

It is easier to build

- No dome needed ?
  Individual mirror covers rather than huge dome
- lower mass
  Less glass -> lighter frame
  possibly very short focal length (see later)
- To some extent, wind can go through the telescope instead of pushing a large “sail”
- by design, independent active control of individual mirrors
  -> robust to moderate vibration & bending of the structure

ELT-type telescope may be practically impossible to scale beyond ~50m

100m is a good baseline for cophasing: most stars are unresolved or only very partially resolved.

(1) Aperture geometry considerations

Non redundant

+ optimal (u,v) plane coverage
+ phase closure between baselines (deconvolution)

Redundant

+ easier for hypertelescope: can provide narrow-field images with single diffraction peak

Compromise: System exit pupil could be remapped ?

(2) Pupil aspect ratio / pointing (see also next slide)

Circular, pointing anywhere (Green Bank style)

+ optimal (u,v) plane coverage
- tall structure

Rectangular (long, not so tall), pointing next to transit (Nancay style)

+ easier to build/steer
- reduced instantaneous sky coverage

(3) Focus

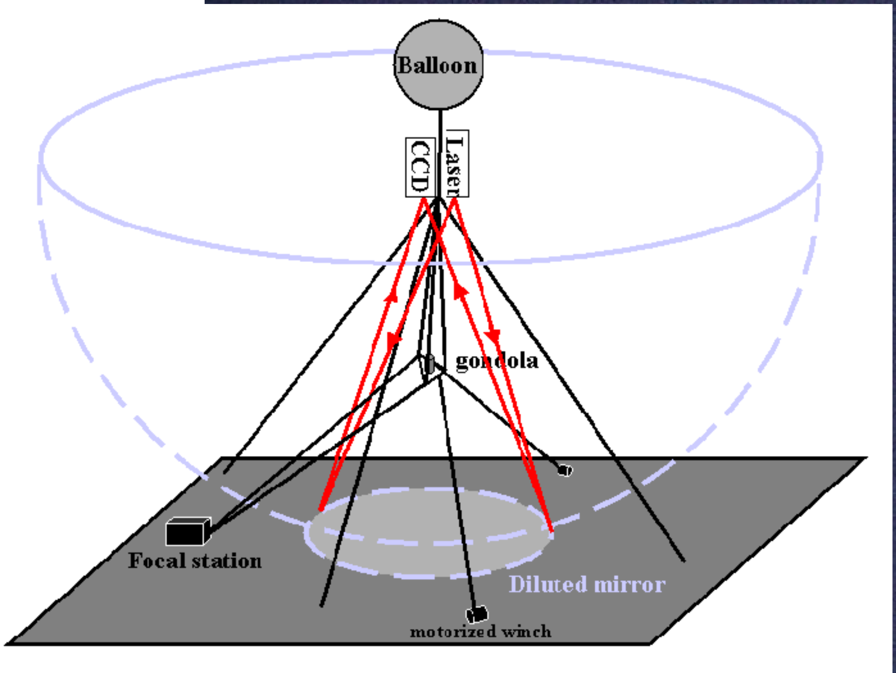
Common focus (Carlina style)

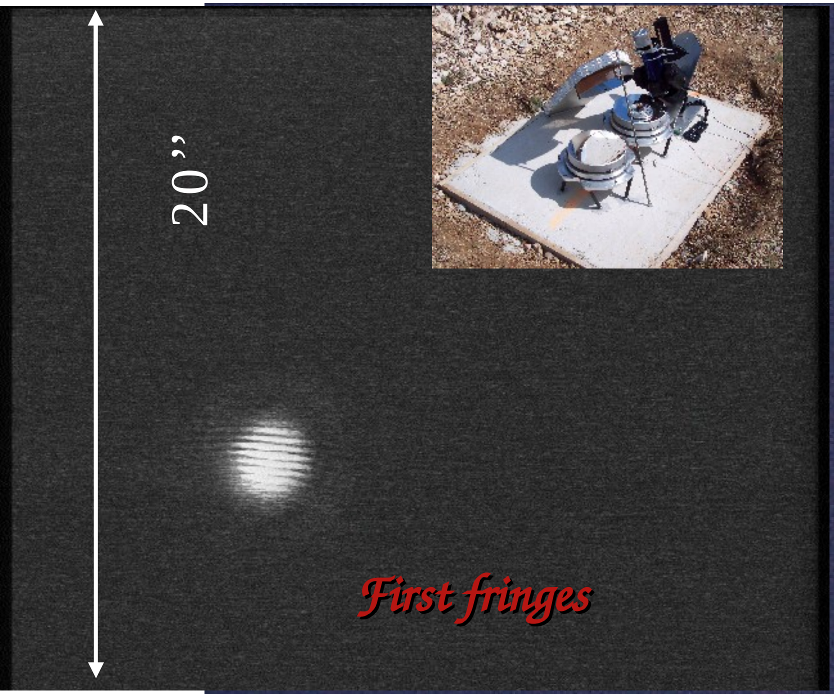
+ few optical elements
- long (~150m) focal length -> very tall structure

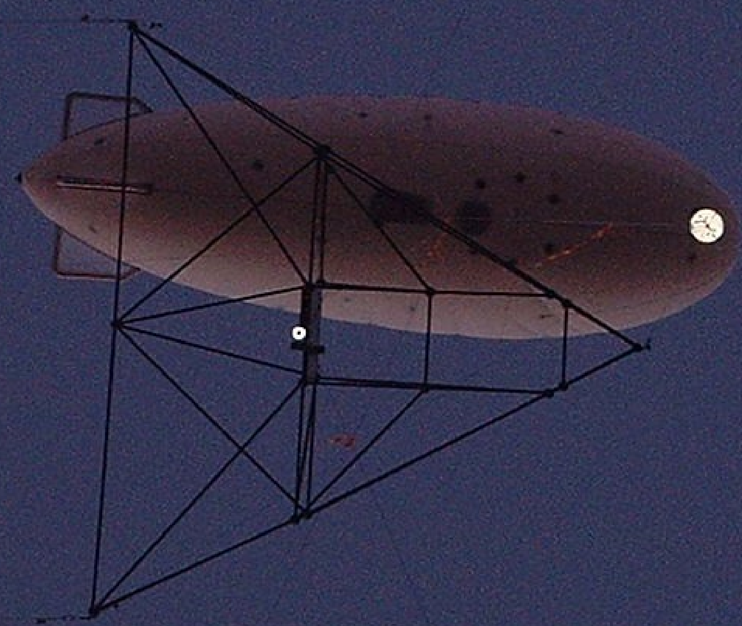
Individual foci + beam transfer (as most current interferometers)

+ short focal length (~10-30m)
- more optics

The Carlina interferometer





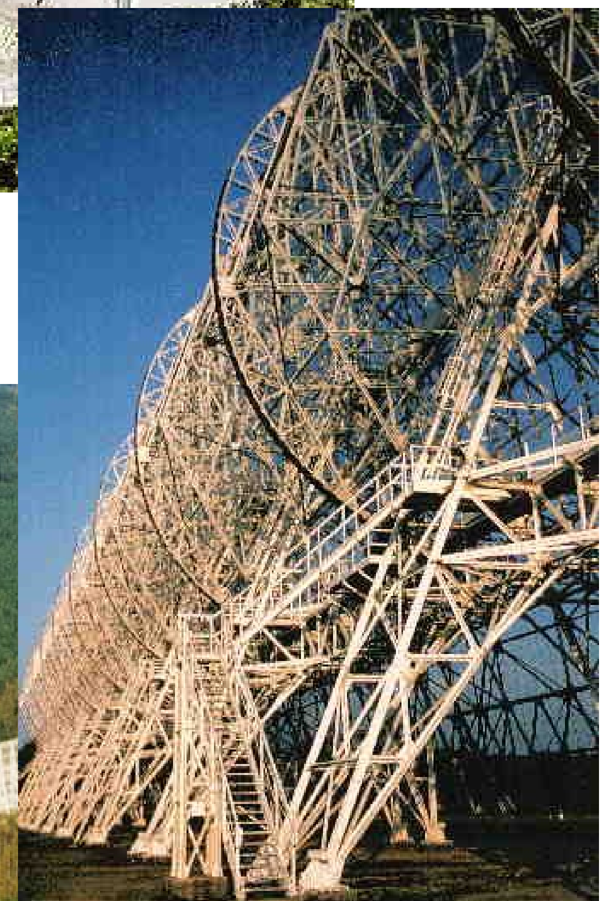


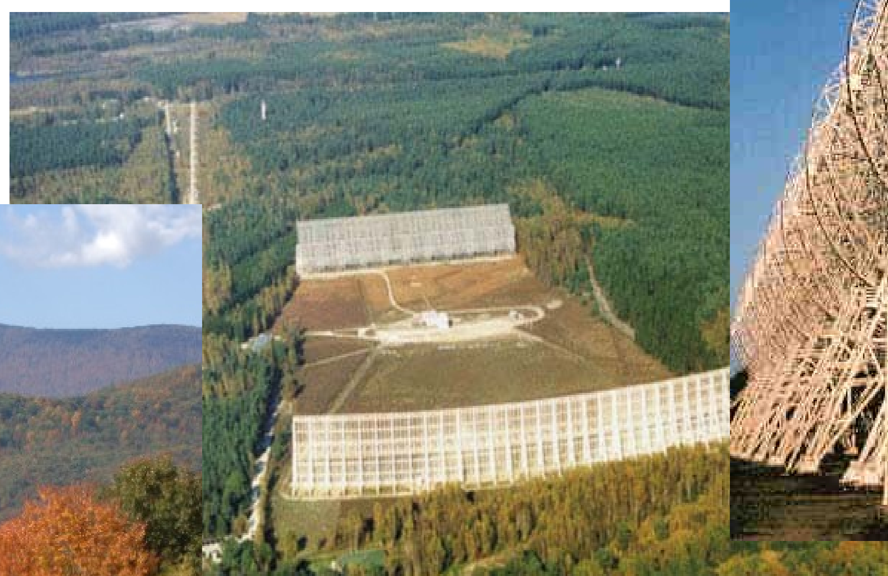
Le Coroller H. et al. 2004, A&A, 426, 721

Arecibo, circular
305m, very limited pointing

Nancay, rectangular
200m x 40m, limited pointing

Green Bank, circular
100m, full pointing





Design & operation requirements

This concept offers “only” a 3x to 5x gain in angular resolution over 30m ELT.
Similar to jump between 8m to 30m. Lesser jump in sensitivity.

It **NEEDS to be extremely high duty, high efficiency observatory** (“point and shoot” with very little overhead, comparable to ELT observing efficiency).
Current efficiencies << 1%
-> Should be able to operate if one of the telescopes is down.
-> closed loop cophasing rather than fringe packet scanning

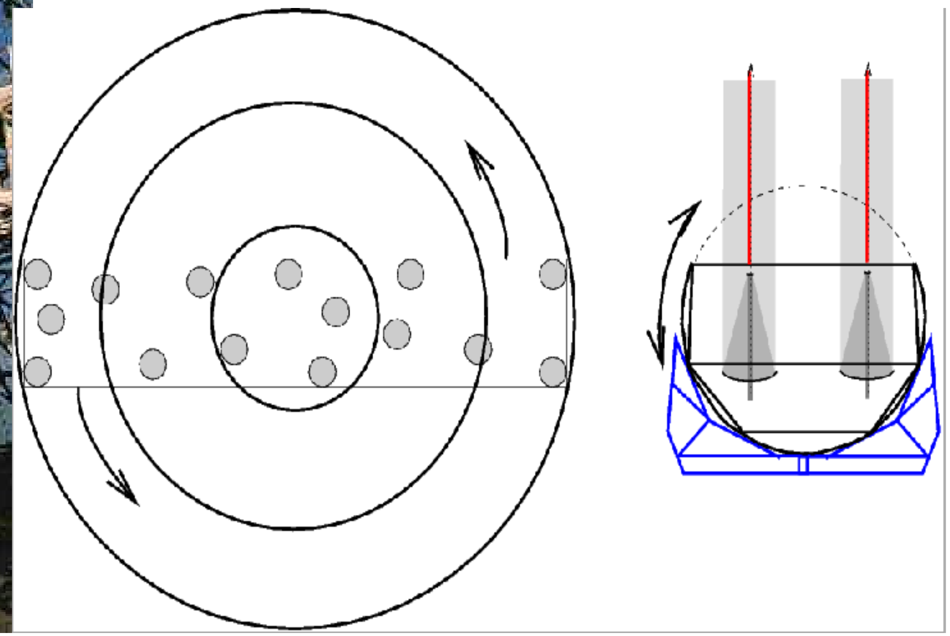
It will be in a good site (top of mountain) exposed to wind.
Interferometer **needs stable structure** to minimize vibration between telescopes and in beam transfer optics.

Cophasing:
(1) Close AO loop on each telescope, using LGS and at least 1 NGS (TT + focus)
(2) Cophase, focus and TT on each aperture in Fizeau focus

Internal laser metrology, accelerometers would help to remove vibrations within the interferometer

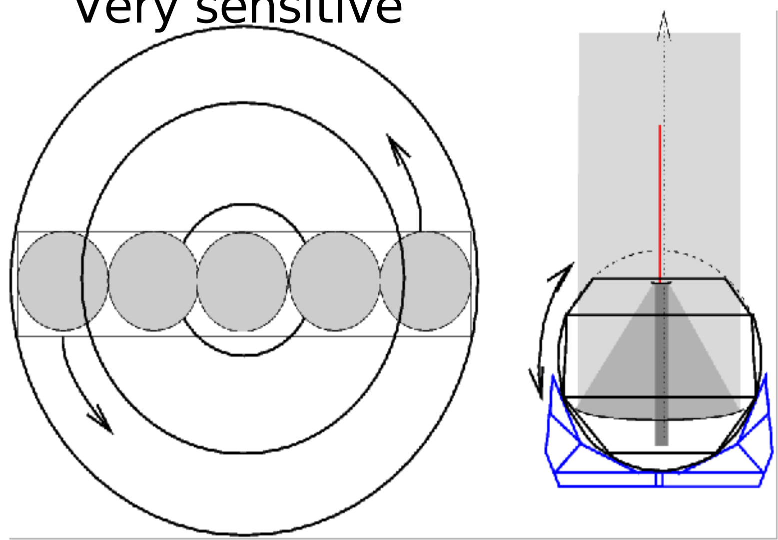
Possible configuration:

- 15 x 8m apertures on 30m x 150m rectangle
- 17% fill factor
- full snapshot (u,v) plane coverage within rectangle
- Same collecting area as 30m ELT
- Rectangle can be tilted and rotated
- No large moving delay lines, easy to cophase



Can be built to be sturdy:
open structure less tall than 30m ELT (important if no dome)
firmly connected to the ground every ~30m: even if it is longer than ELT structure, it can be built to be more rigid

Array of 30m ELTs.
Very sensitive



There is clear advantage in having smaller number of large telescopes
BUT: Choice between 8m and 30m telescopes driven by telescope maturity and cost.
Should avoid to have major challenges in the building of the telescopes.
-> take the largest telescope we know how to build reliably with LGS AO (MCAO?)

Must avoid having to develop simultaneously new telescope technologies and build and interferometer (building interferometer is hard + telescopes need to be very reliable).