AGN Research with Future Interferometric Arrays

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The VLT Interferometer

Optical / Infrared Interferometry Today

- Access to milliarcsecond-scale phenomena
- Perform interferometric spectroscopy
- Sensitivity sufficient for a few bright AGN
- Important information on dust distribution from observations in 10μm band (talk Walter Jaffe)

- Small number of telescopes $\Rightarrow$ parametric model fits to visibilities, no images
- Sensitivity insufficient for larger samples
- Resolution insufficient for details / more distant objects

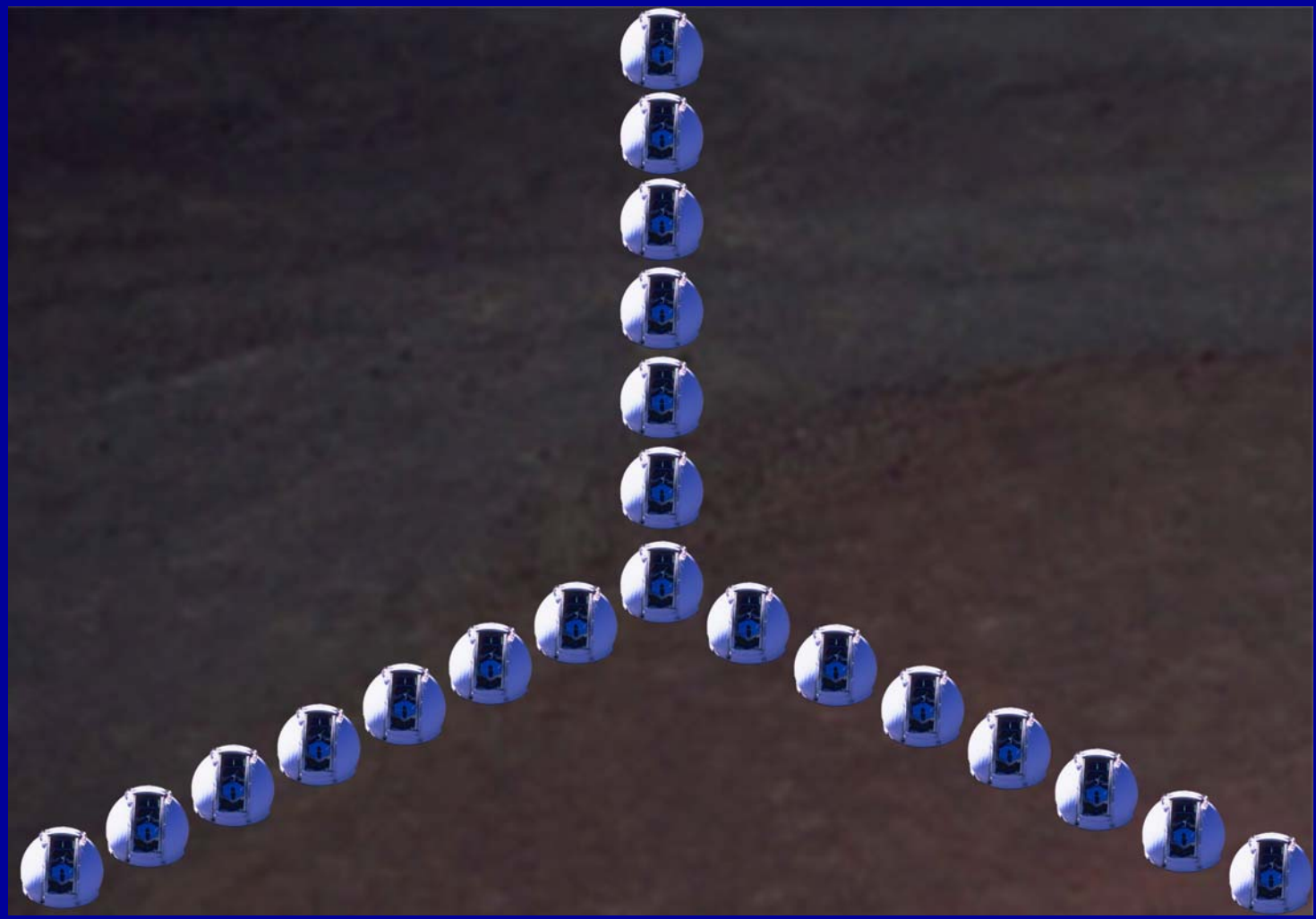
Desirable Capabilities of a Next-Generation Interferometer

- Address wide range of scientific topics $\Rightarrow$ flexibility
- Observe faint objects $\Rightarrow$ high sensitivity and dynamic range
- Complex objects / limited prior knowledge $\Rightarrow$ imaging capability
- Access "famous" archetypical and rare objects $\Rightarrow$ good sky coverage
- Observe time-variable phenomena $\Rightarrow$ good snap-shot capability

What's Next?

What's Next?

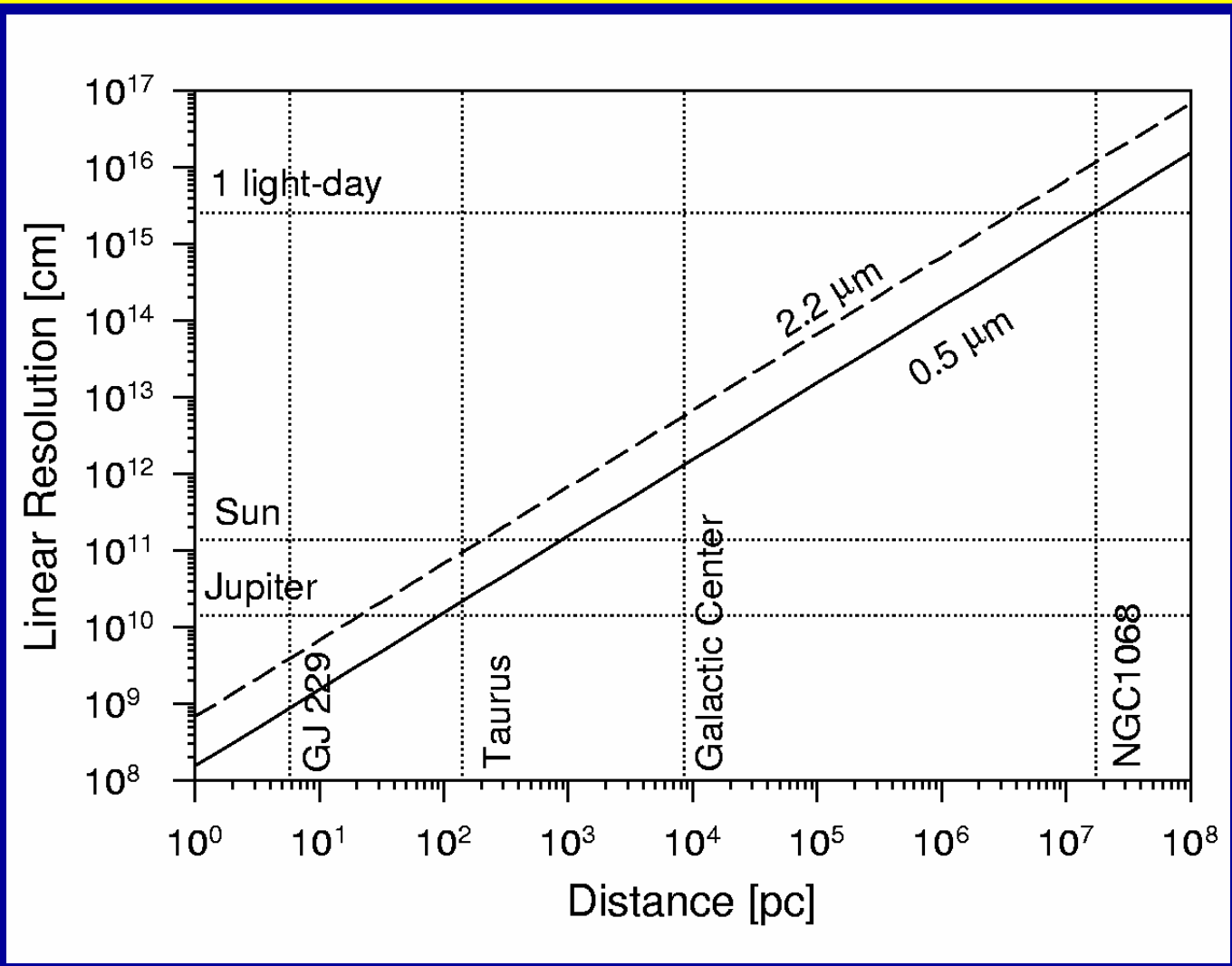
Think BIG!



The ELSA Concept – a Strawman Interferometric Facility

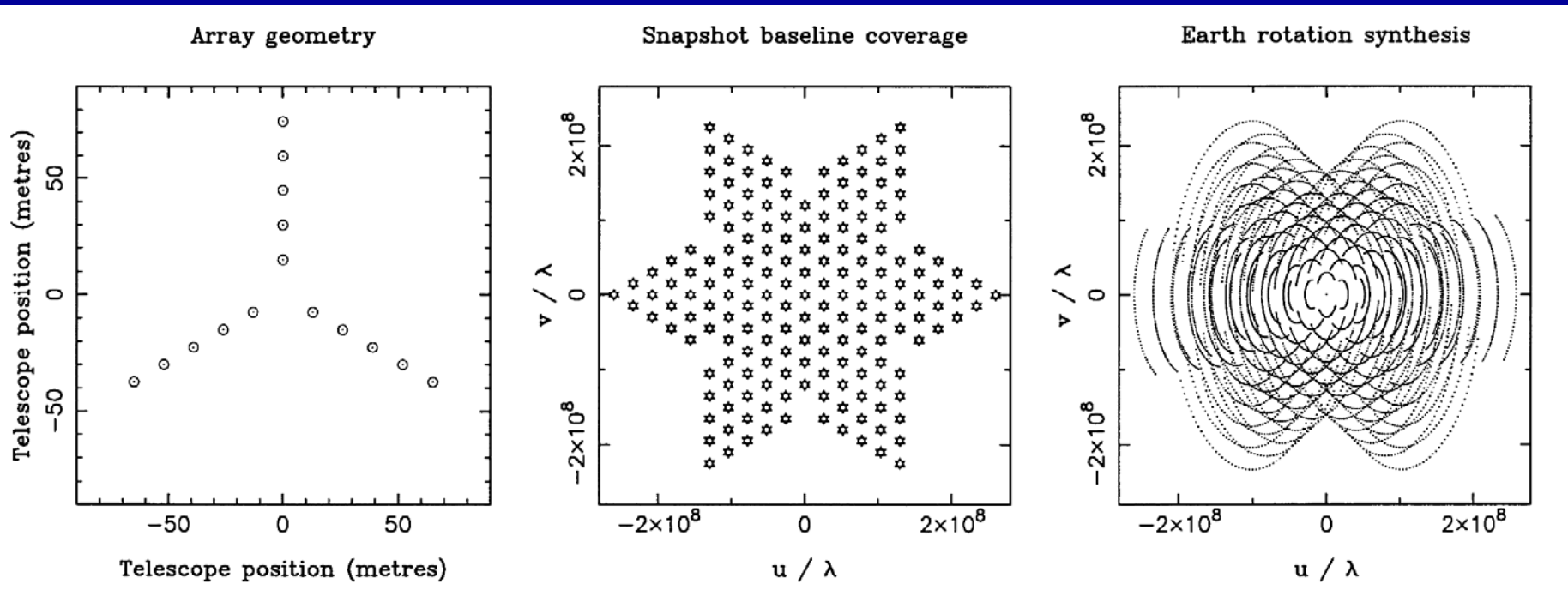
- Number of telescopes: 27
- Telescope diameter: 8 m
- Maximum baseline: 10 km
- Wavelength range: 500 nm … 20 μm (?)
- Beam transport: Single-mode fiber bundles
- Beam combination: Michelson
- Sky coverage at 600 nm: $\gtrsim$ 10%
- Cost: $\approx$ 400 M€

Linear Resolution of ELSA in the Local Universe



Linear Resolution of ELSA at $\lambda = 500$ nm

A Y-Shaped Configuration (15 Telescopes)



AGN Science with ELSA

- Black-hole mass from stellar and gas dynamics
- Reverberation *mapping* (watch line response to continuum variations in movies) $\Rightarrow$ physics of BLR, geometric distances
- Optical emission from milliarcsecond jets $\Rightarrow$ jet collimation, shocks, particle acceleration, …
- Details of clumpy (?) obscuring torus $\Rightarrow$ dust properties, unification schemes
- "Mirror(s)" in HBLR objects $\Rightarrow$ AGN physics, unification schemes

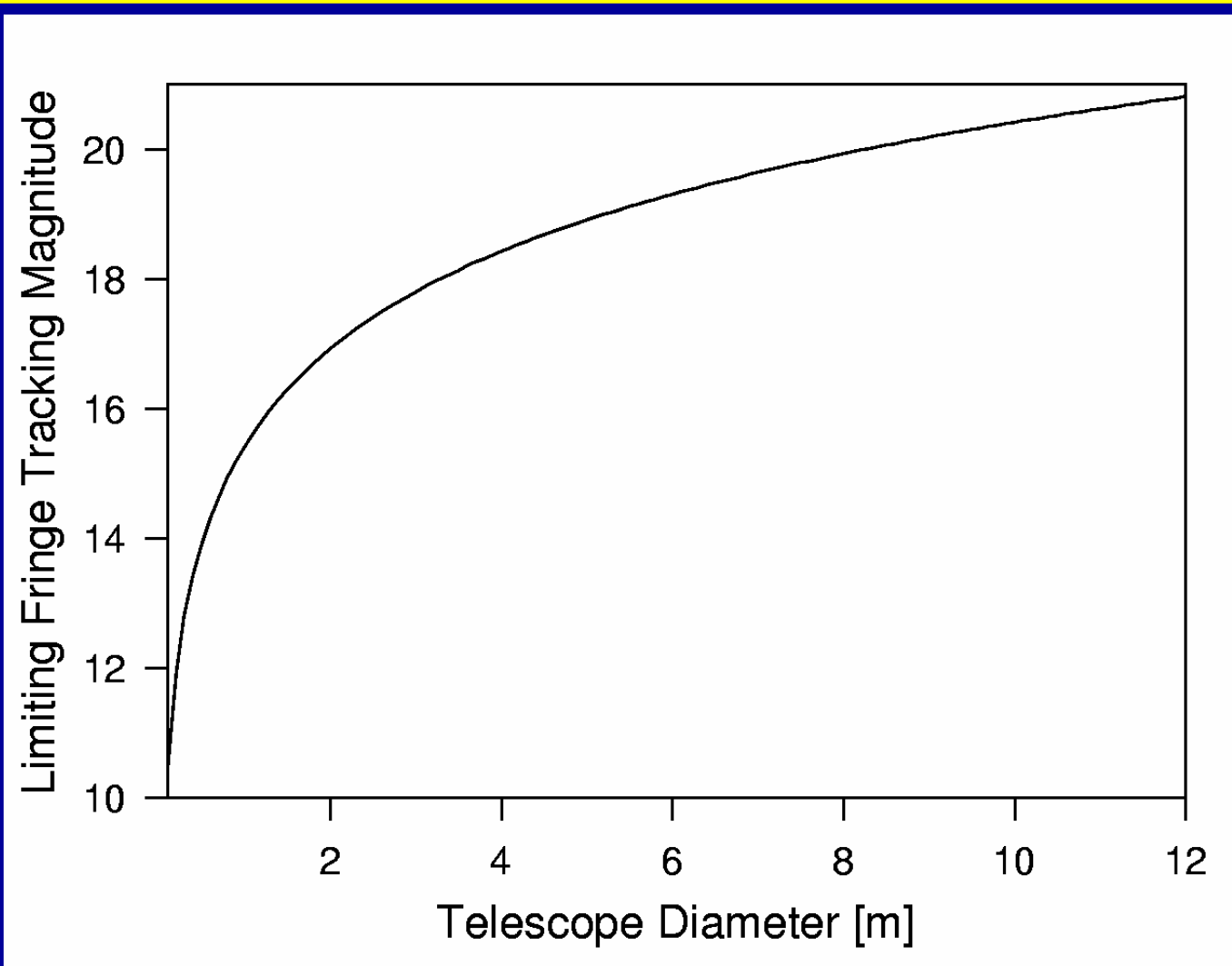
ELSA Critical Technologies

- Telescopes
- Array co-phasing
- Beam transport
- Beam combination
- Delay compensation

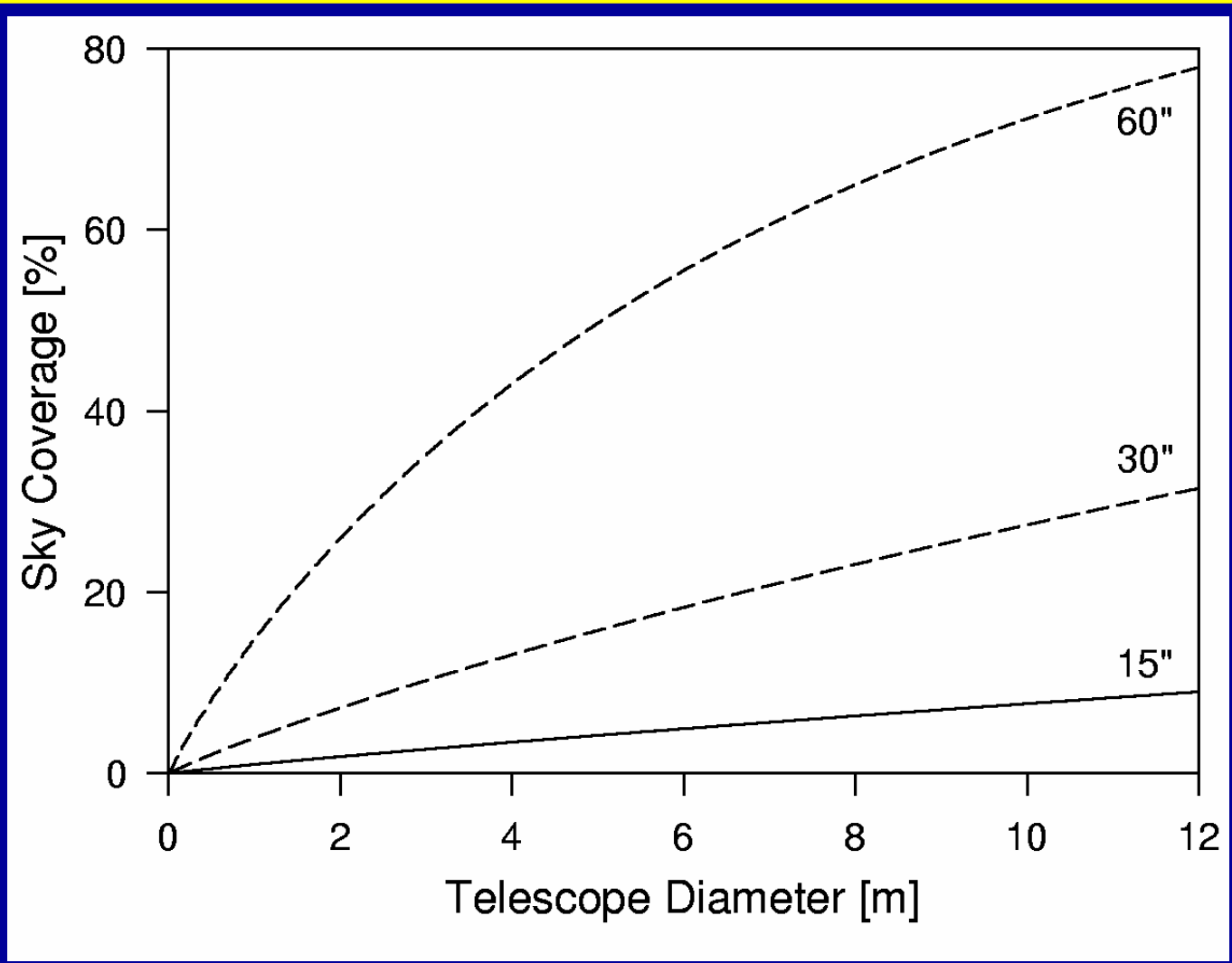
ELSA Co-Phasing Concept

- Phase individual telescopes with multiple (?) LGS adaptive optics
- Off-axis fringe tracking on "bright" star
- Large aperture $\Rightarrow$ good fringe tracking sensitivity $\Rightarrow$ near-complete sky coverage
- Requirement: fringe tracking at K≈19
  - One of the drivers for large array elements
- Fringe-tracking chain of neighboring telescopes for bright (resolved) stars
- Fringe tracking between all telescopes for faint (unresolved) stars

Limiting Sensitivity for Fringe Tracking in the R Band



Sky Coverage at NGP for Different Maximum Off-Axis Angles



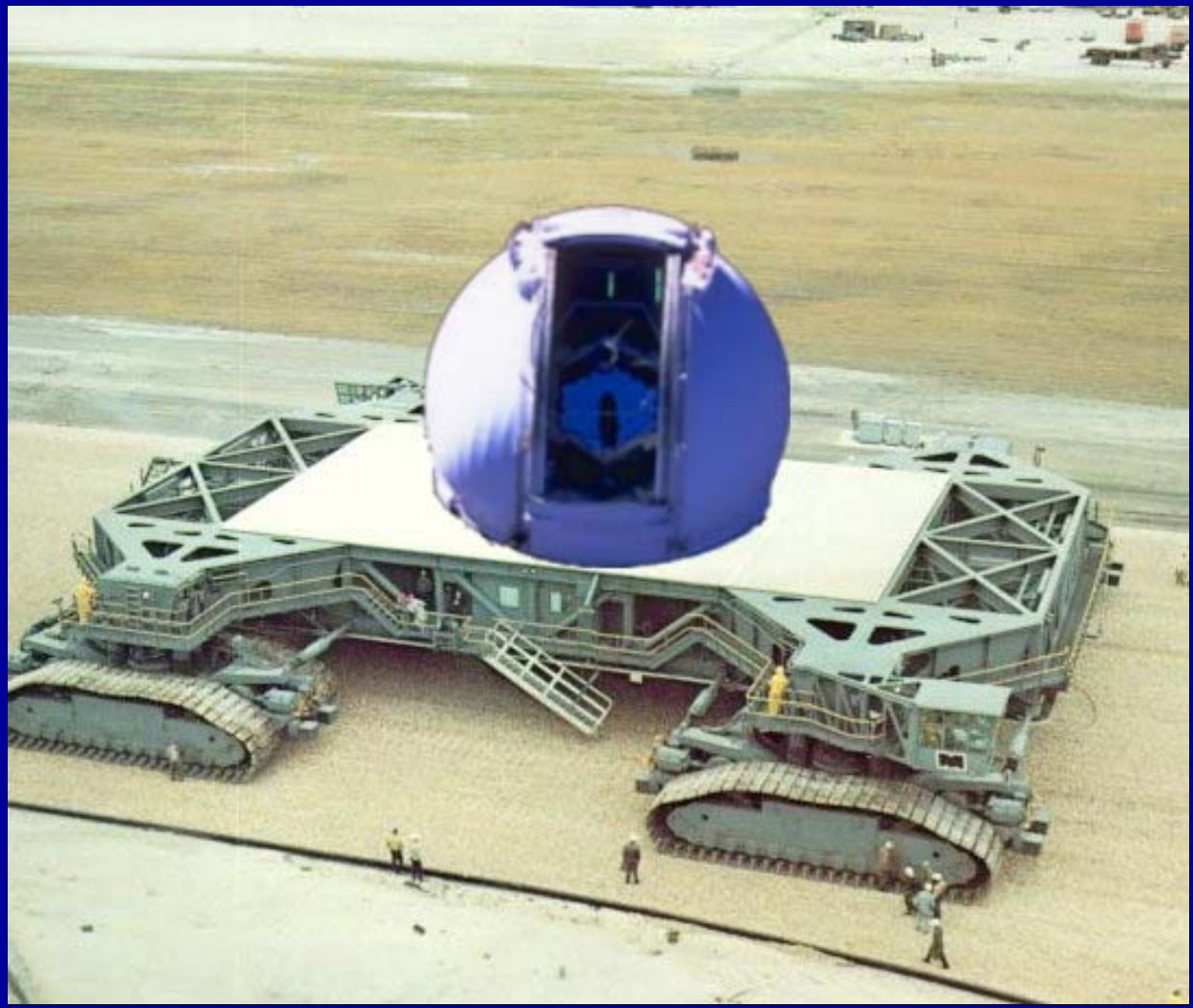
ELSA Telescopes

- Need to produce twenty-seven 8m telescopes for ≈ 200 M€
- Moveable for array reconfiguration if possible
- Small field-of-view
- No scientific instruments (acquisition and fiber-feeds only)
- Take advantage of ELT development
  - Mass production of mirror segments
  - Standardized structural elements

Projected Cost of Telescopes

- Typical scaling of telescope cost with diameter is $€ \propto D^{2.7}$
- Scaling applies at any given time (for similar maturity of technology), not to future projection
- Example: scaling holds for Keck (10m) versus CHARA (1m) telescopes
- Apply scaling to ELT (e.g., European E-ELT concept): 42m for 700 M€ $\Rightarrow$ 8m for 8 M€
- Proof-of-concept for ELT?

Moving Big Telescopes around …



… is Perfectly Doable!

ELSA Site

- Need flat ≈ 10 km plateau
- Good seeing (r_0, τ_0, θ_0) important criterion
- Southern hemisphere preferred
- Requirements different from ELT criteria
- ALMA site probably (marginally) ok

What Needs to be Done?

- Currently there is no formal "Future Large Interferometer" project
- Planning is beginning now
  - Detailed science case
  - Technology development roadmap
  - Site evaluation
- Need to get into "official" facility planning
  - US: Decadal Review
  - Europe: ESO, EU, Astronet
  - Others: ??

Conclusions

- A large interferometer – such as ELSA – will open completely new windows on AGN science
- It is (almost) doable technically now, but some technology development is needed to bring cost down
- The science case needs to worked out in detail
- Planning and lobbying is needed
- International cooperation will be helpful to finance an €xtremely £arge $ynthesis Array¥

Questions to You

- What angular resolution is needed for your science?
- What limiting magnitude do you need?
- What are the imaging requirements (dynamic range, field-of-view etc.)?
- Is polarimetry needed (technically difficult)?
- Which scientific topics have I missed?
- Would you like to help?
- Please send answers to: A.Quirrenbach@lsw.uni-heidelberg.de