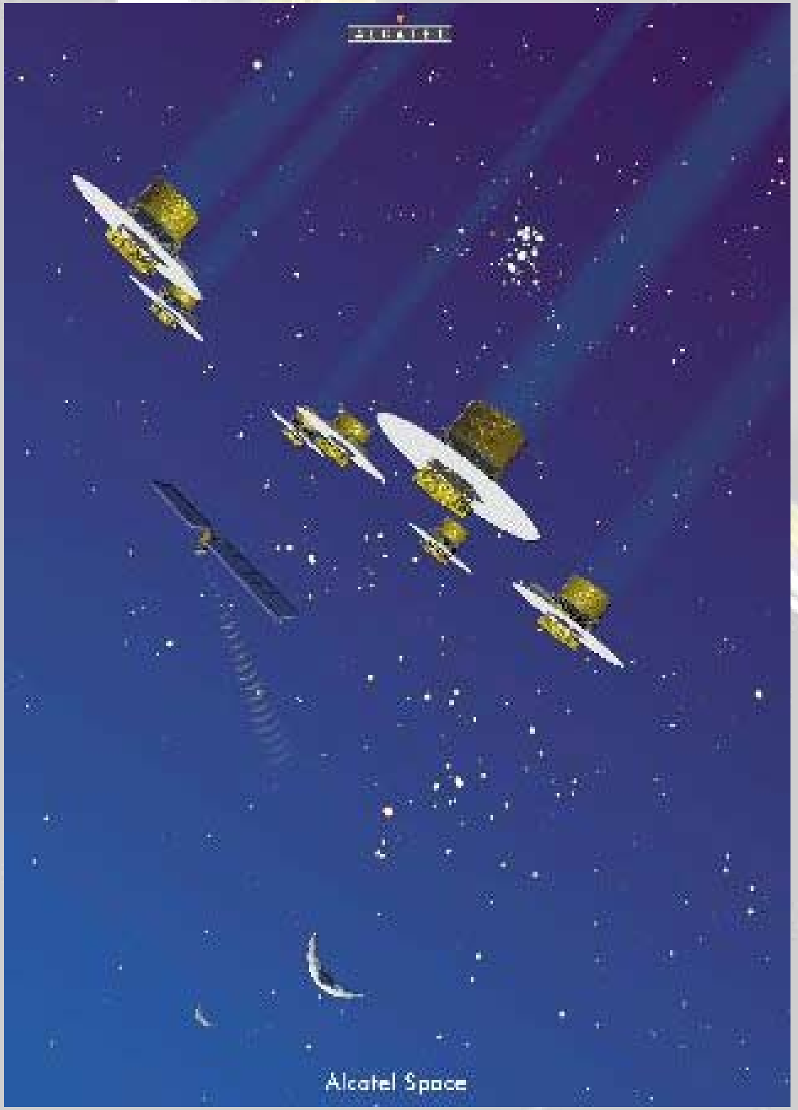
Cophasing and beam combination

for IRSI-Darwin

L.A. D'Arcio
SRON National Institute for Space Research

IRSI/Darwin



ESA's first space interferometry mission:

find/characterize earthlike planets,
AND
perform high resolution imaging

- six 1.5 m telescopes
- baseline range 50 m -> 500 m
  (up to 4 mas resolution at 10 μm)
- science channel: 6 to 20+ micron
- intrasatellite metrology (~ 100 μm)
- mN and mN FEEP thrusters
- passive cooling < 40 K

SRON is active in IRSI/DARWIN since early 2000. Focus on the **imaging** component, together with Leiden Observatory

* Critical review of Alcatel imaging study

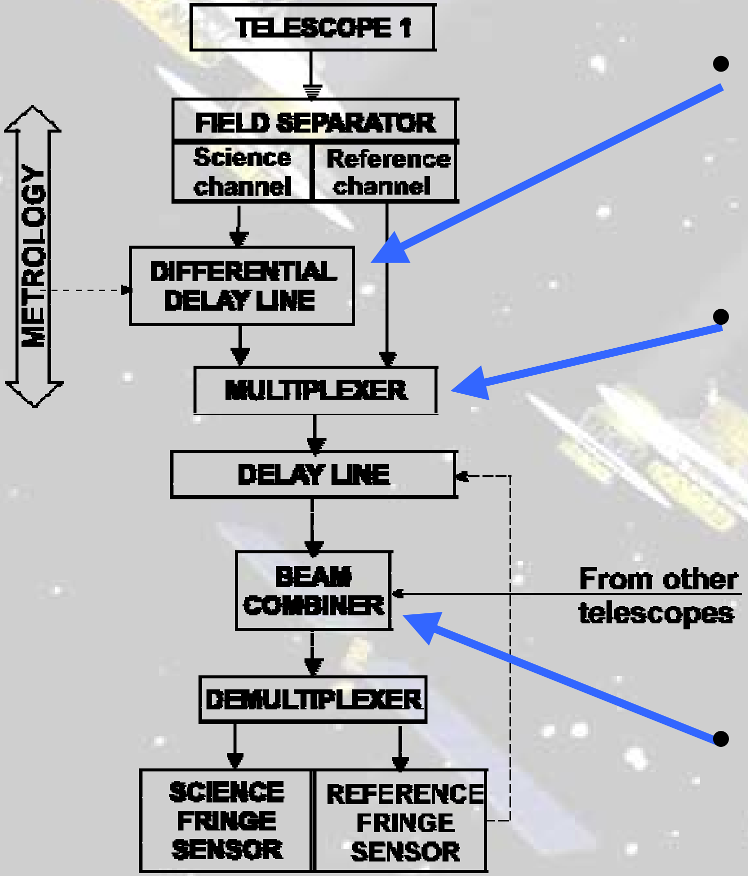
* PhD student from november 2001 working on:

    * end-to-end modelling (τ_0 on axial/science channels)

    * hardware validation (wide-field beam combiner within the TPD/TUD Dutch Testbed Interferometer)

• **SMART2** (DARWIN precursor, fringe tracking from star?)

Critical review of Alcatel imaging study



- Assessment of additional metrology needs driven by imaging
- Comparison of available multiplexing techniques
- Six-way beam combiner for imaging

Blind tracking of external OPD evolution $\mathbf{OPD_X = \vec{B}\,\vec{\theta}}$

Compensate blindly the evolution of OPD_X with DDL.

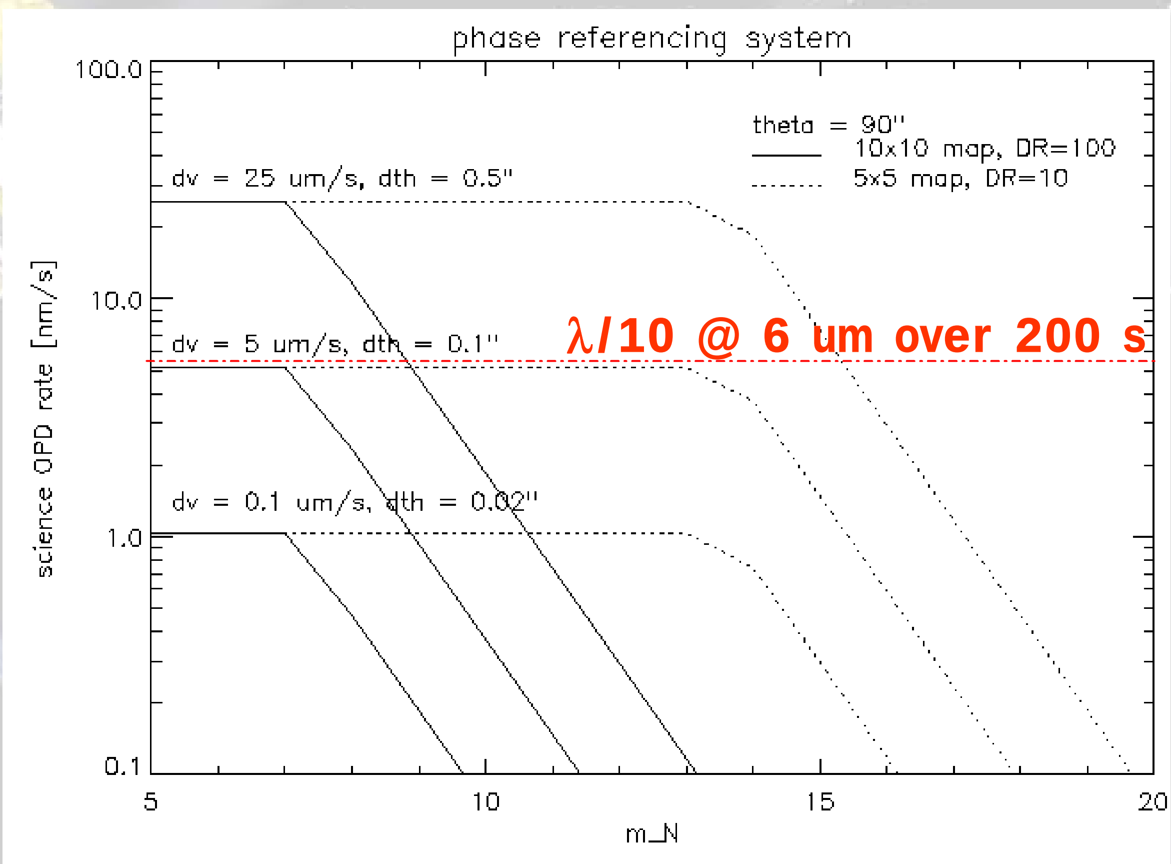
Tracking requirement: < 600 nm OPD change within one coherence time T_{CI} (~200 s)

Derived measurement requirements:

* Star separation, to $d\theta$ < 0.12" (~ PSF/16)

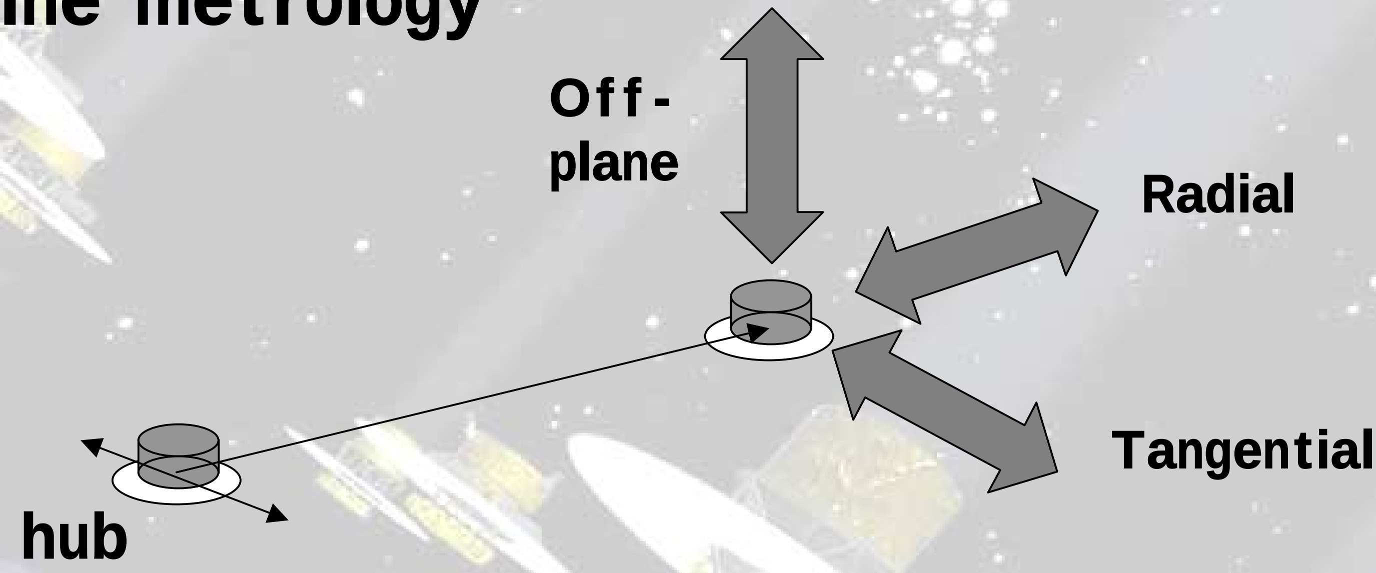
* baseline rates, to dv < 7 μm/s

(assuming a measurement rate of $1/T_{CI}$)



dV = error in knowledge baseline rate
dth = error in knowledge of θ

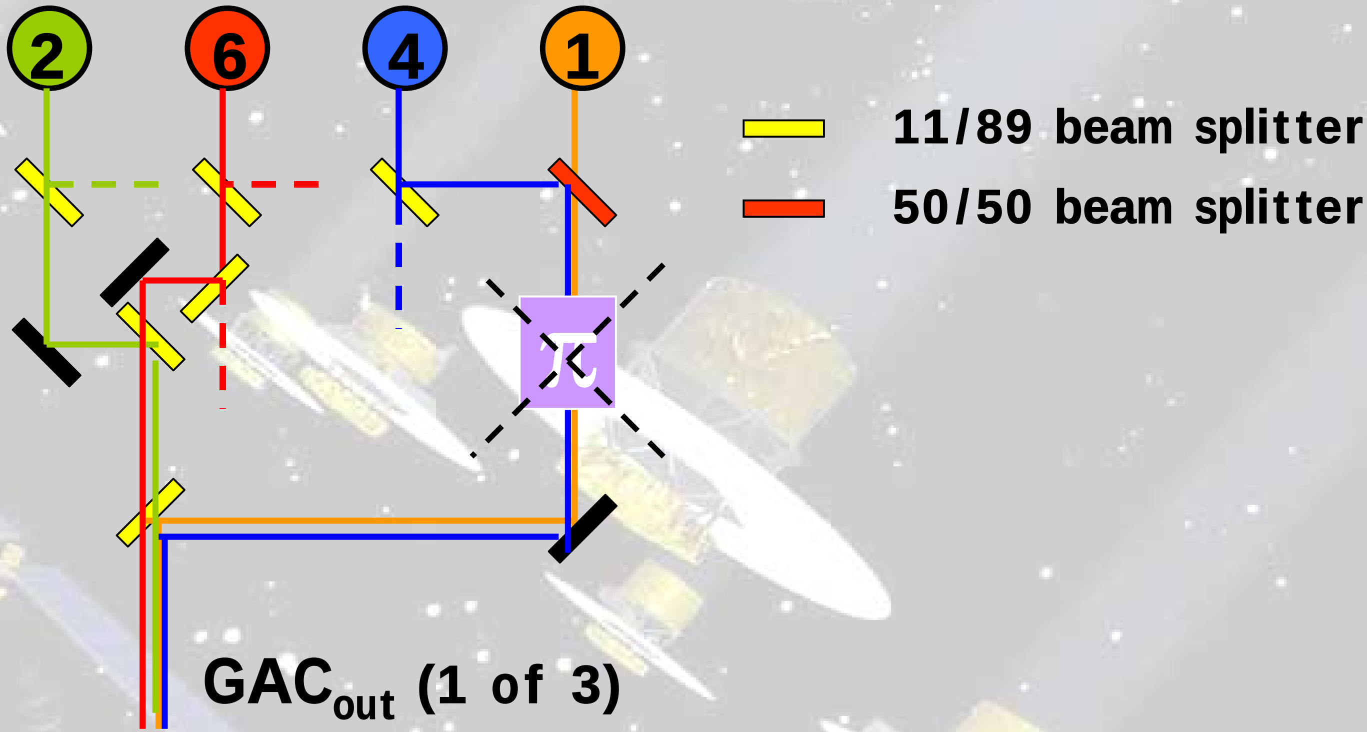
Baseline metrology



Length:	laser metrology	0.1 mm rms @ 1 Hz	OK!
Off-plane:	APS sensor	5 mm/ 25 μm @ 10 Hz	OK!
Tangential:	RF goniometry	B tan(0.1°) @ 10 Hz	no..
	complement with APS sensor	5 mm/ 25 μm @ 10 Hz	OK!

Beam combination

Current design: use nulling BC (without π phase shifter) for both ref/science beams. 'Kind-of' all-in-one pupil-plane BC.



$$GAC_{out} = \tfrac{1}{2}\, A_1 + 1/6\, A_4 + 1/3\, A_2 + 1/3\, A_6$$

pros • minimizes added complexity for imaging

cons • small field of view θ = 0.3”, dOPD/dθ ~ 2.5 mm/arcsec (λ = 10 μm, R = 300, dV/V<0.1)

• 10 fringe outputs, unbalanced amplitudes

• temporal modulation imposes short integration times

• temporal modulation is **chromatic**

Alternative approach:

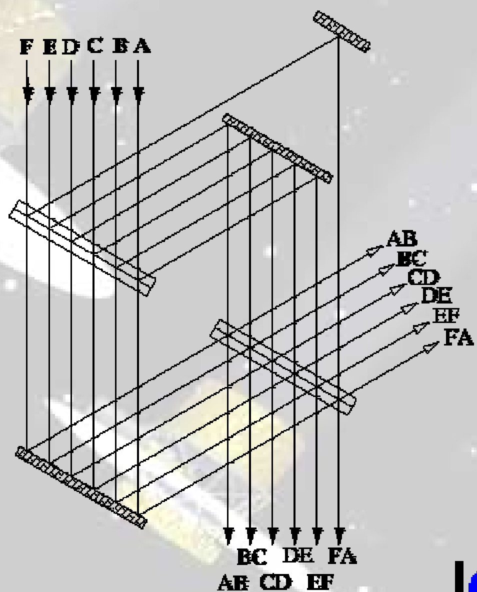
- separate BC spacecraft for imaging (increases redundancy)
- develop dedicated BC’s for OPD tracking and science
- if possible, implement achromatic modulation

Reference (tracking) beam combiner

- Optical bandwidth : 1-2.3 μm
- Only five shortest B’s needed
- Radial laser metrology ensures coherencing to 100 μm rms

A possible approach:

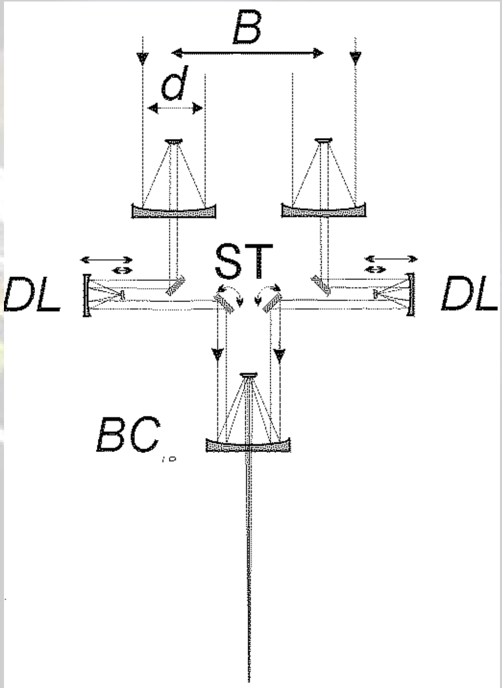
Partial pairwise scheme with 180° achromatic spatial modulation (no moving parts)



Science beam combiner:

- Optical bandwidth : 6-20+ µm
- Visibility measurements on all fifteen baselines
- wide field. Goal: 3xPSF's cophased to λ/4 @ 6 µm

A reasonably cophased field of view can be only achieved with an image-plane beam combiner with homothetic pupil mapping



Main requirements

- Pupil positioning accuracy: 36 μm rms over ~0.5 m stroke
- Calibration of imaging parameters

  image matching reqs.: $dM/M < 10^{-2}$, $d\phi <$ 2 degrees

  pupil mapping reqs.: $dM/M < 1.8 \times 10^{-5}$, $d\phi < 3.6''$
- Optics quality: 450 nm rms in the field for whole optical train
- Focal plane: ~2k x 2k detector, image zooming

Main challenges:

- accurate pupil positioning at cryogenic temperatures
- spectrometer implementation: FTS?
- cryogenic active optics (fine-tuning optical trains, zooming)

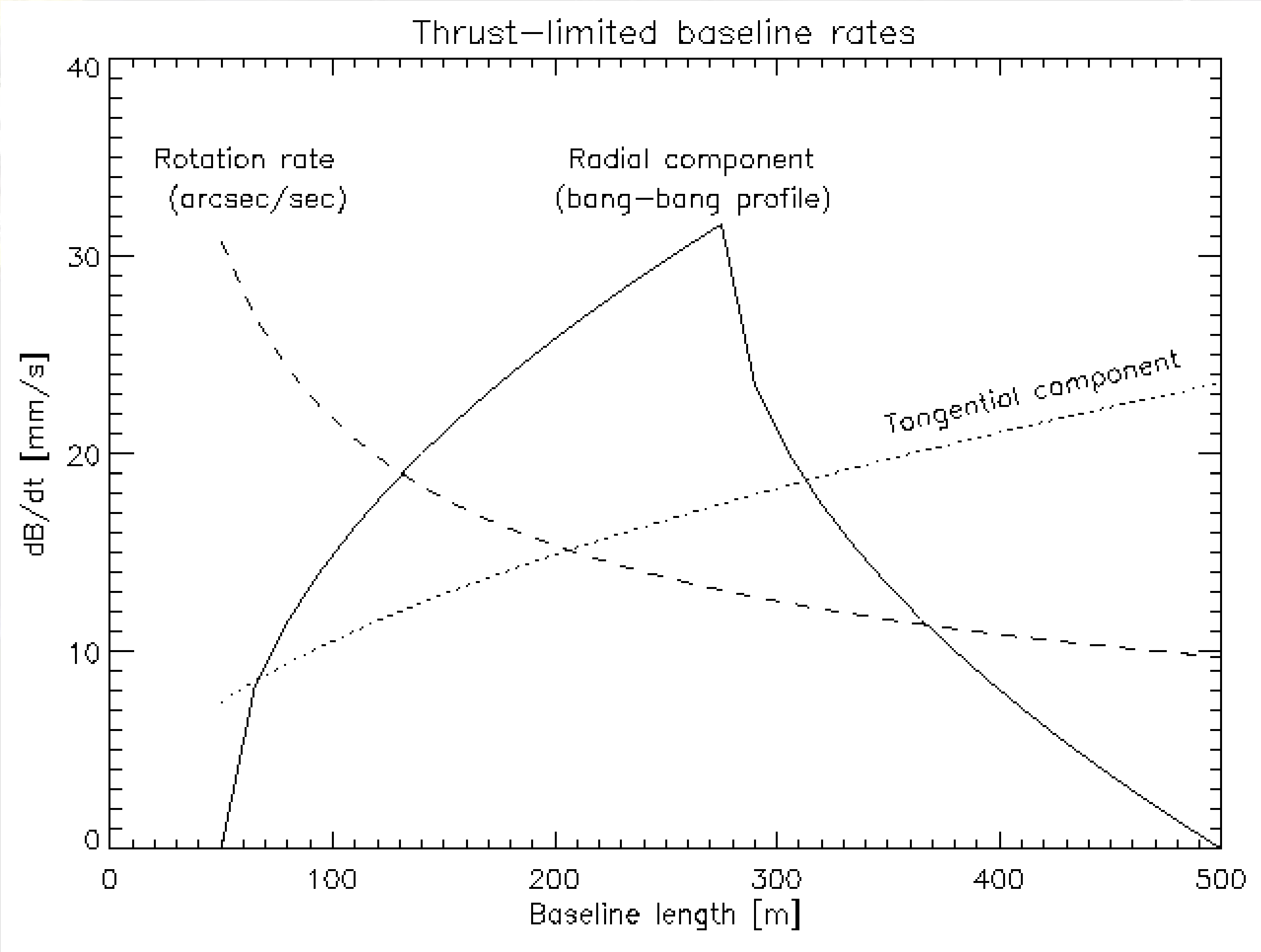
Conclusions

Phase referencing

- need for extra array metrology (duplicate existing subsystem)
- validate multiplexing concept

Beam combiner:

- Define focal plane implementation
- Initiate technical studies for positioning and active optics devices
- Deepen understanding of optics/alignment/calibration requirements, iterate on fov goal



Thrust–limited baseline rates
Rotation rate
(arcsec/sec)
Radial component
(bang–bang profile)
Tangential component
dB/dt [mm/s]
Baseline length [m]
0
10
20
30
40
0
100
200
300
400
500