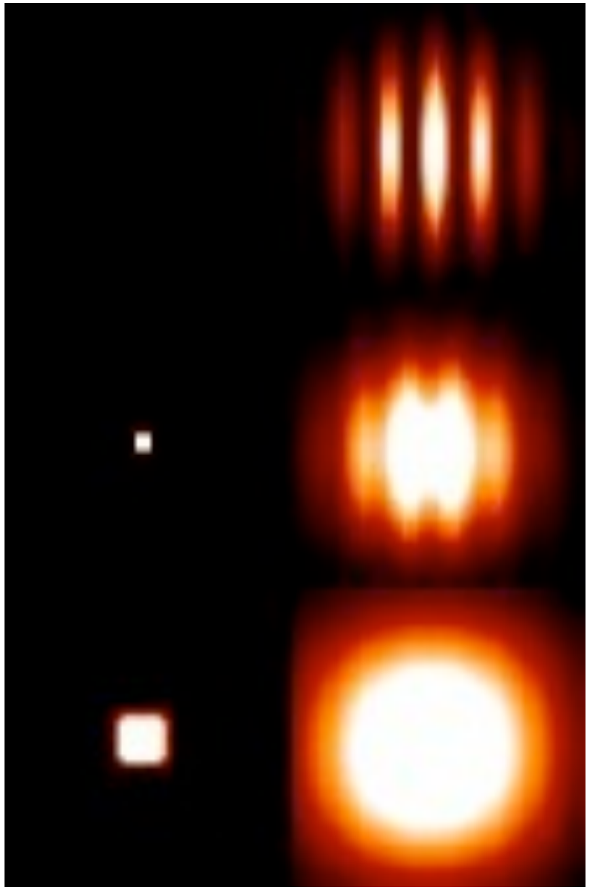
The Very Large Telescope Interferometer

Sridharan Rengaswamy

La Silla Paranal Observatory, ESO, Chile

Interferometry: Basic measurements

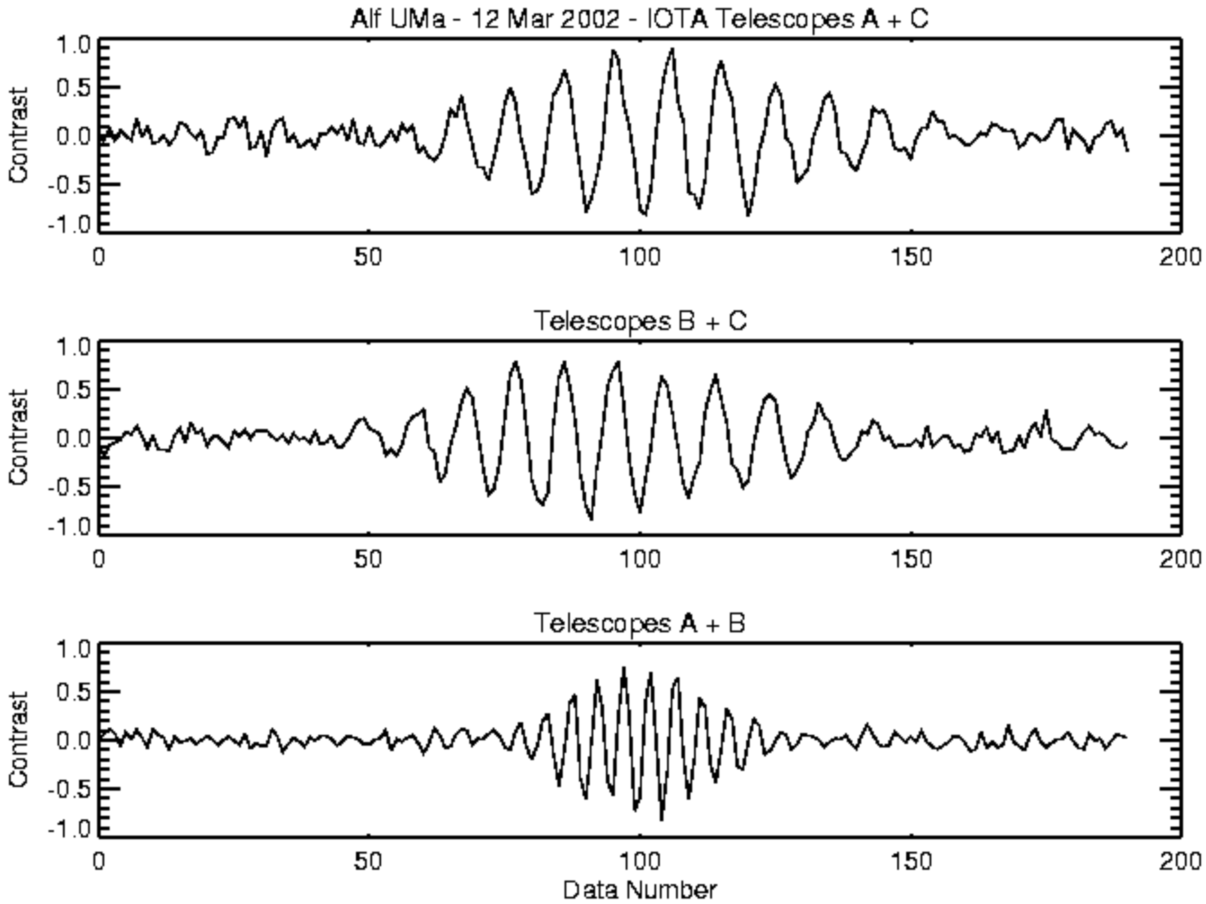
Multi-axial or Image plane combiner



Visibility = $(I_{max} - I_{min})/(I_{max}+I_{min})$

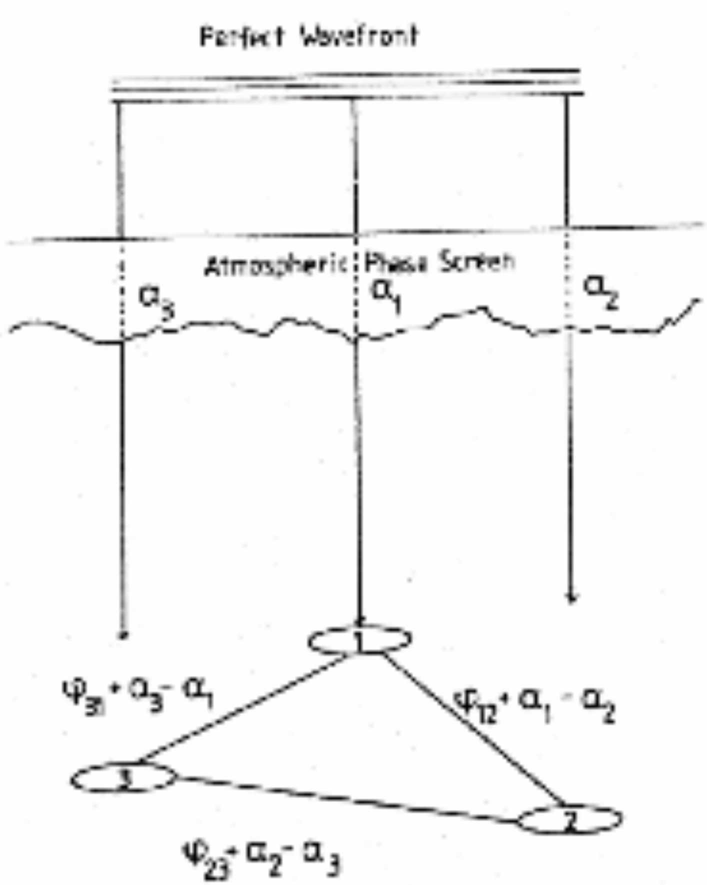
Visibility = measure of size

Co-axial beam combination (pupil plane interferometer)



Closure –phase (Van Citteret- Zernike Theroem for imaging)

Atmosphere alters the Fourier phases of the measurements.
Summing the phases over Closed triangle (triple product) preserves the “SUM”, & removes the corruption



Astrometric Interferometer

Measure OPD as a function of time: OPD(t)

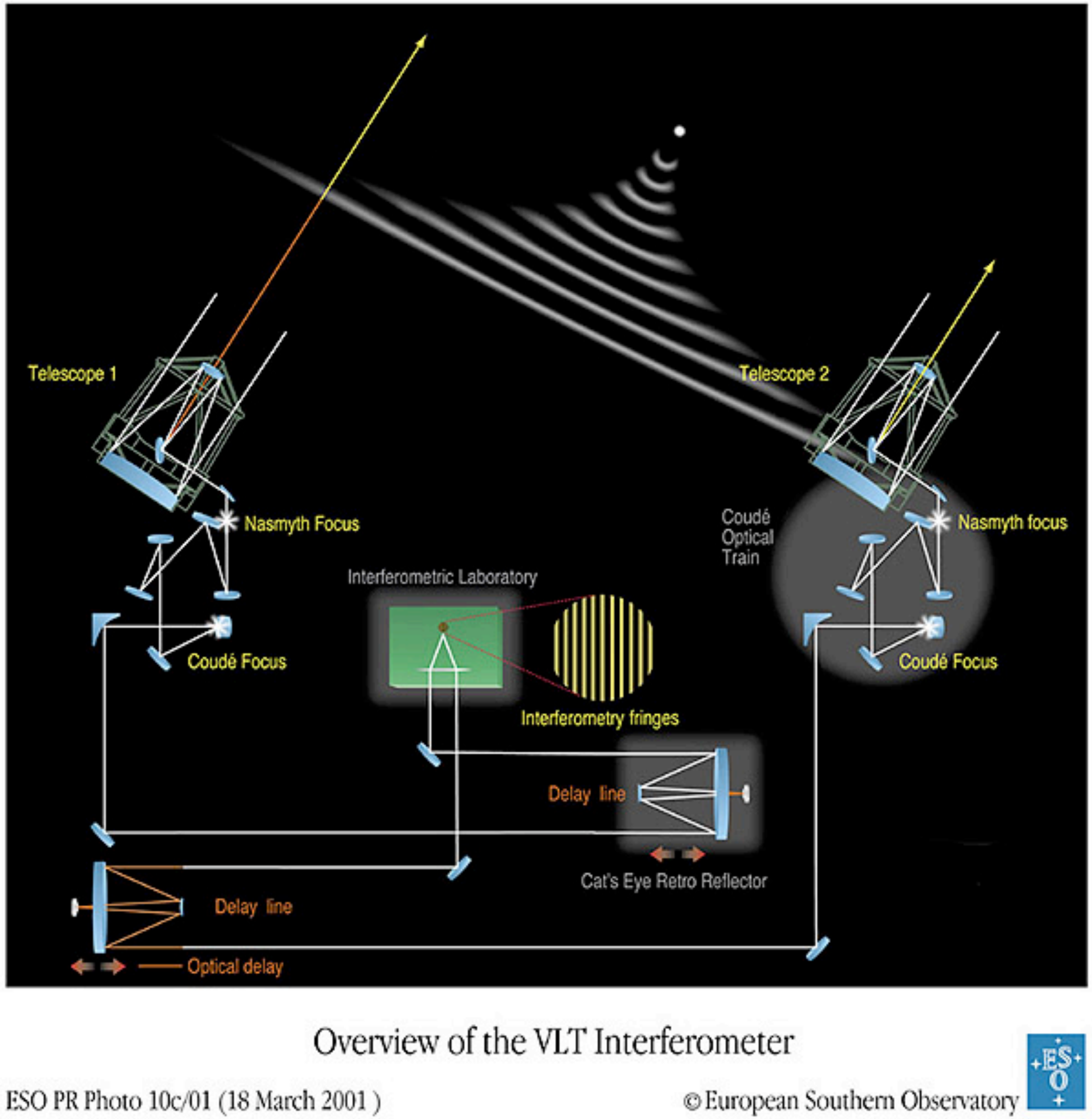
Fringe position = Constant + **B.S**

OPD = Internal OPD + External OPD+ Atmospheric OPD + phase (precise angular separation)

Phase Referenced Imaging

Measure Visibility and Phase (directly) and Compute image:

Use bright calibrator to stabilize fringes, integrate on fainter, measure phase with offset



1. Telescopes

(AO for UTs)

2. Delay lines

3. Alignment & guiding systems

(inside VLTI lab)

4. Fringe Sensors

5. Instruments

VINCI, MIDI, AMBER (1^{st})
PIONIER (visitor; Oct 2010)
PRIMA (AMBER/MIDI)
GRAVITY, MATISSE (2^{nd})

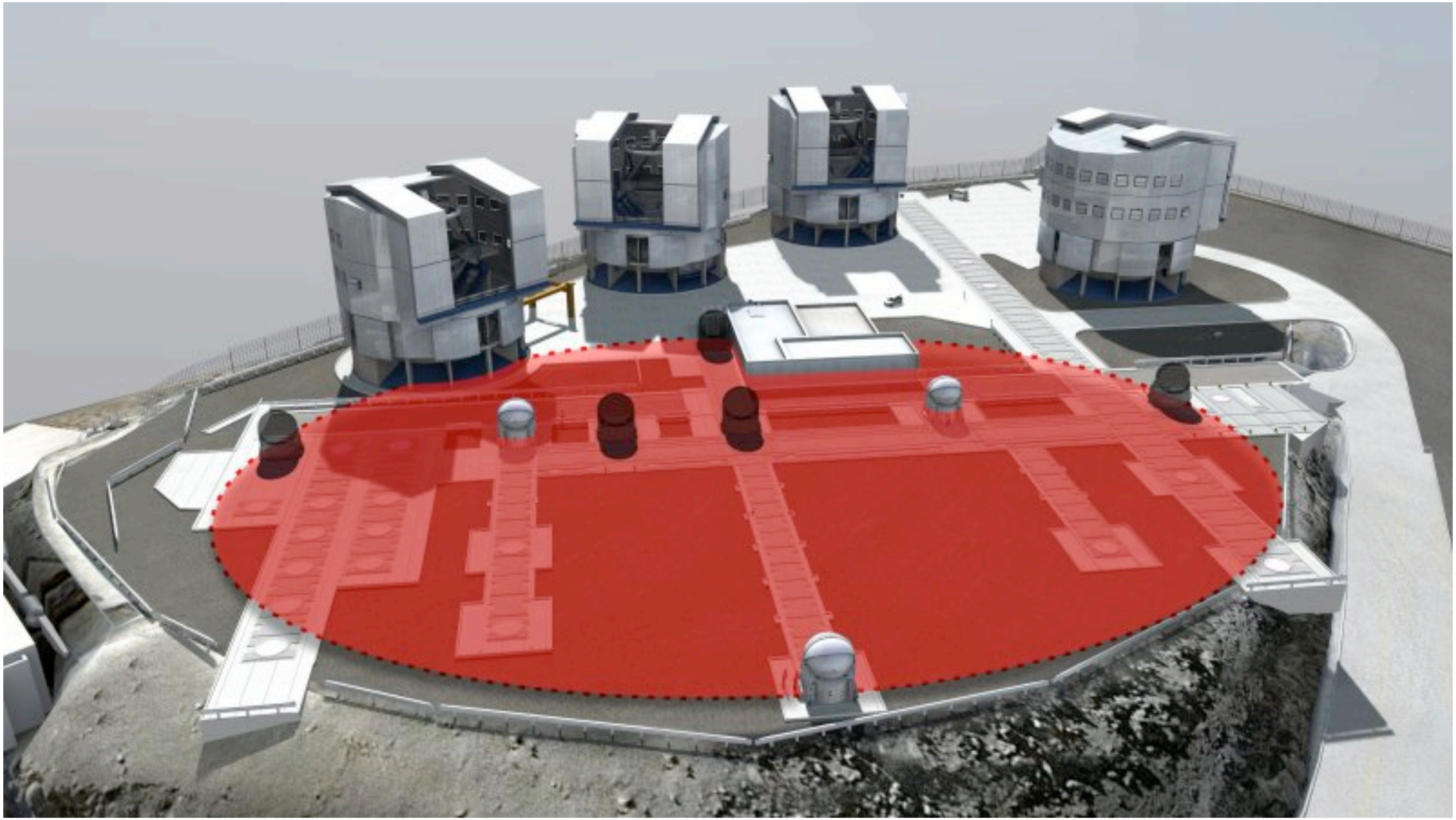
Telescopes

-- 4 Unit Telescopes (Antu , Kuyen, Melipal, Yepun) 8 m class
Coudé Focus, ~f/46, VIMA (VLIT-UT) runs 6 to 10 days per month

Multiple Application Curvature Adaptive Optics systems for
clean/flat flat wave-front with 8 m class telescopes.
(4 similar systems for the VLTI, CRIRES (UT1), SINFONI (UT4))

-- 4 Auxiliary Telescopes exclusively for Interferometry, 1.8 m dia.,
Identical to UTs, Coude Focus ~f/36 , VISA (VLTI-AT)
No-AO systems for ATs as of now. Will have AO in future.
30 Stations, Relocations during the day depending upon need.
2 or 3 or 4 telescopes at a time can be used

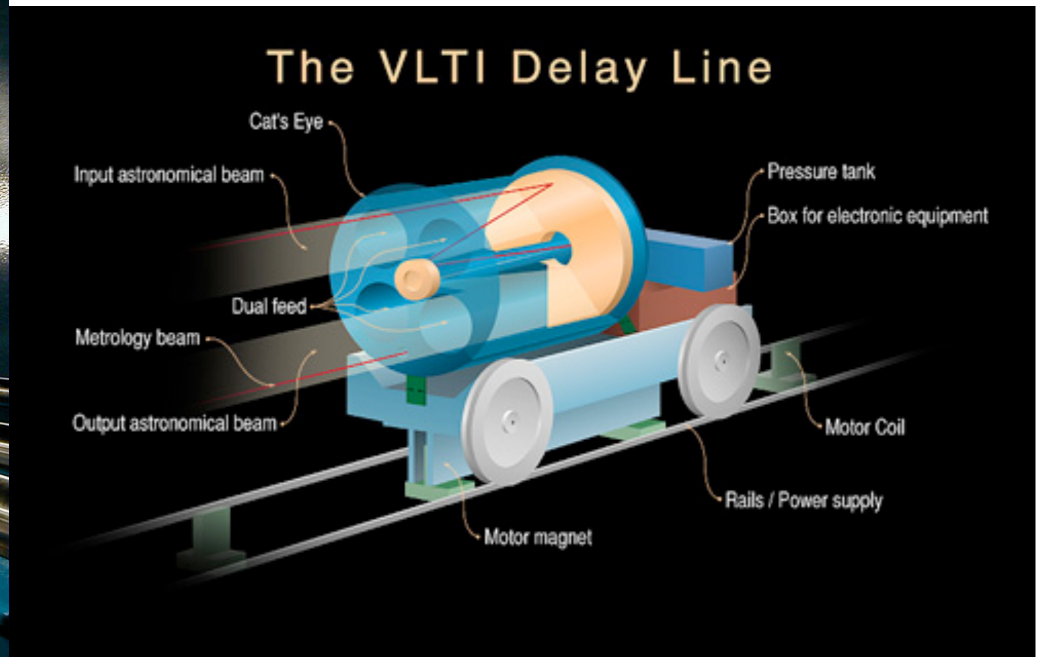
VLTI achieves 15 times more angular resolution (from 60 mas with single UT to 3.5 mas. at 2.2μ)



Delay Lines (DL)

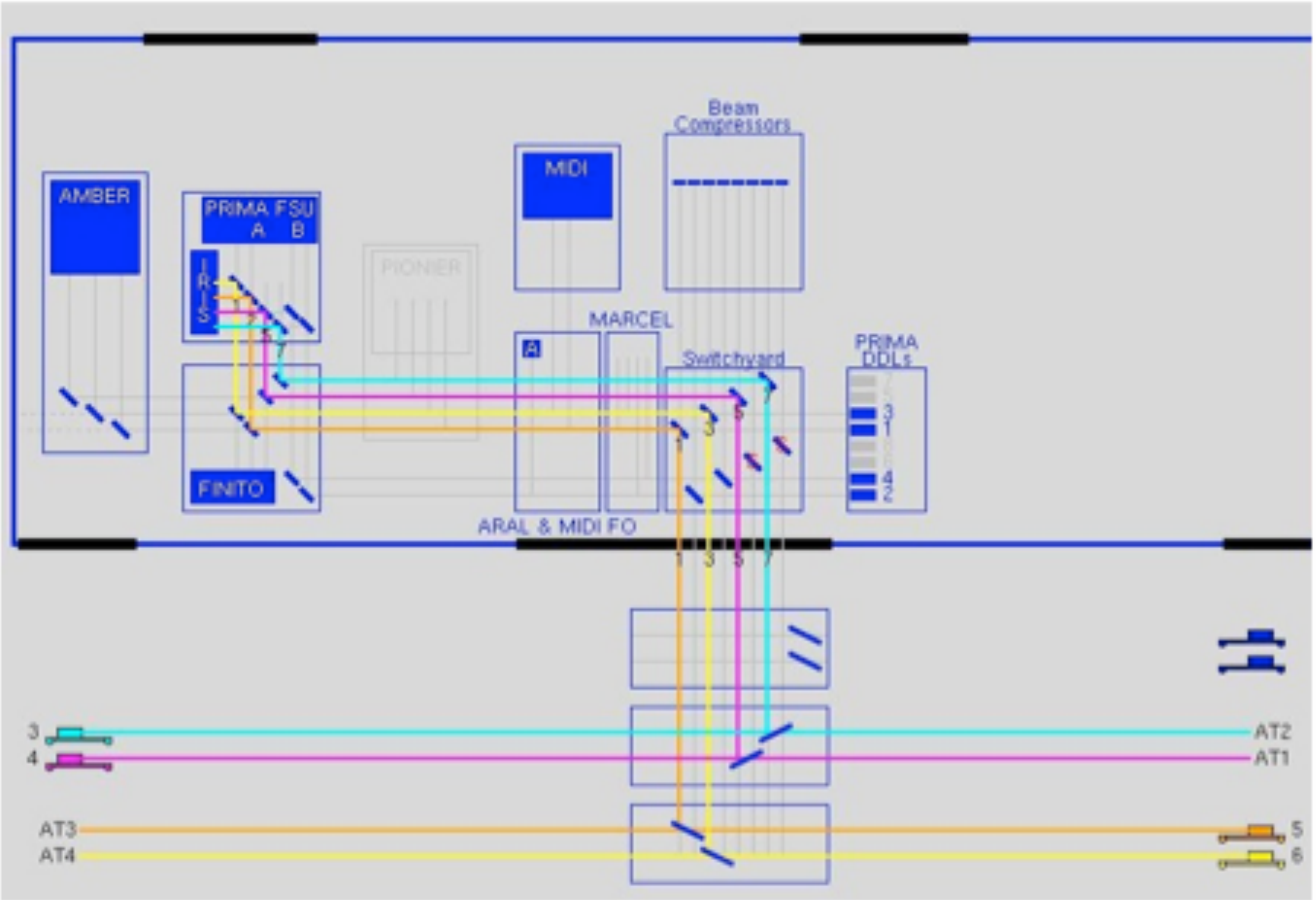
To compensate for OPD (Internal (static), External (diurnal, slow, Earth rotation), atmospheric, vibrations (fast)). 120 m long underground tunnel. Also reimage pupil inside VLTI Laboratory at fixed location. Allow FOV of 2 arcsec.

A cat's eye optical system, placed on a carriage moving using linear motors (first stage). Laser metrology measures position of DL. The VCM on piezo translator for fine control (2^{nd} stage)

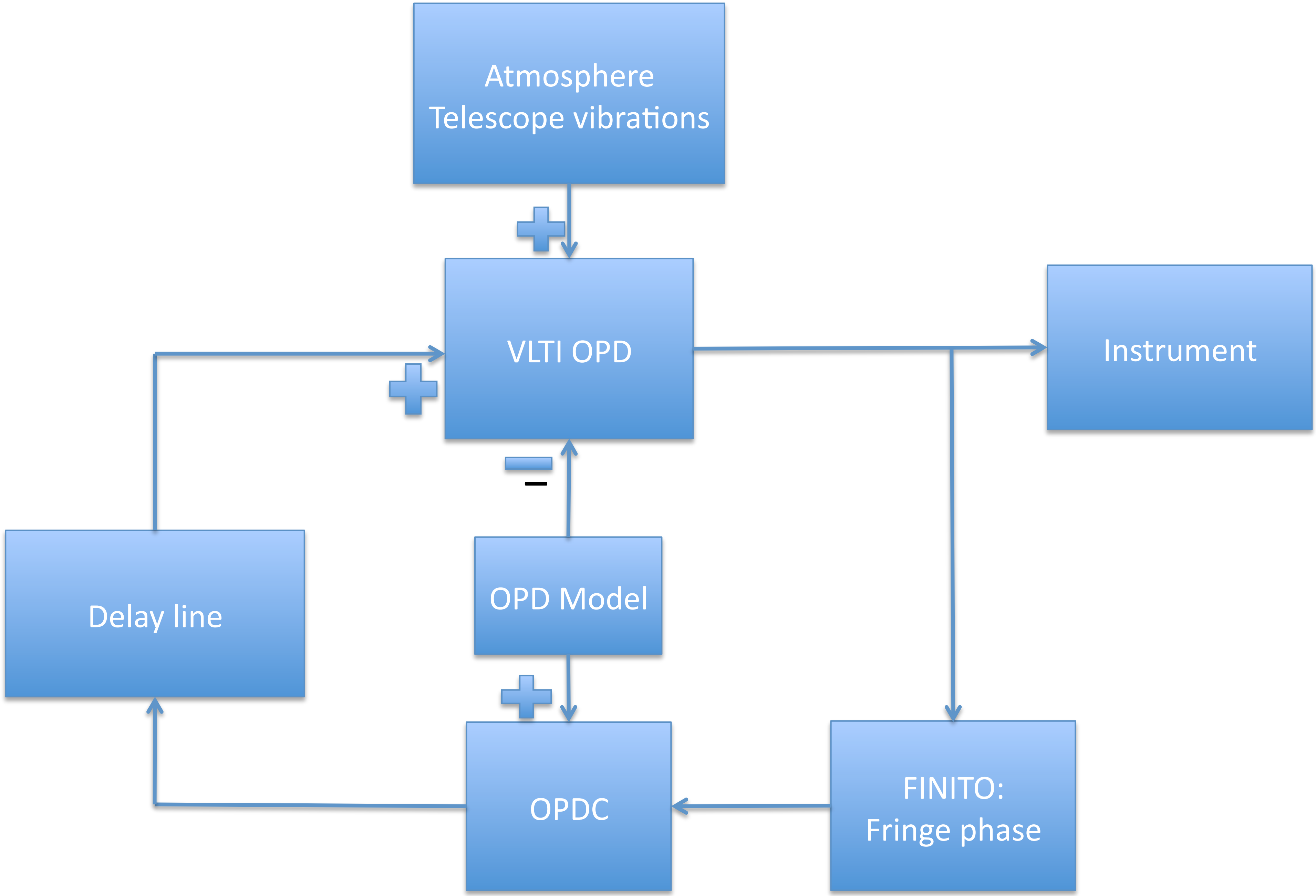


Schematic layout of the VLTI –Laboratory

ARAL – for internal alignment and IRIS for VLTI acquisition and guiding



Schematic of fringe sensing and DL tracking



Fringe Sensors (FINITO & PRIMA FSU)

FINITO – Fringe tracking Instrument of NIce and TOrino

Ca-axial (pupil plane) interferometer, in H-band, 10 μ coherence length

Spatial filtering with mono-mode fibres

3 beam combiner (for two baselines, baseline bootstrapping)

Phase delay, group delay, sends information to OPDC

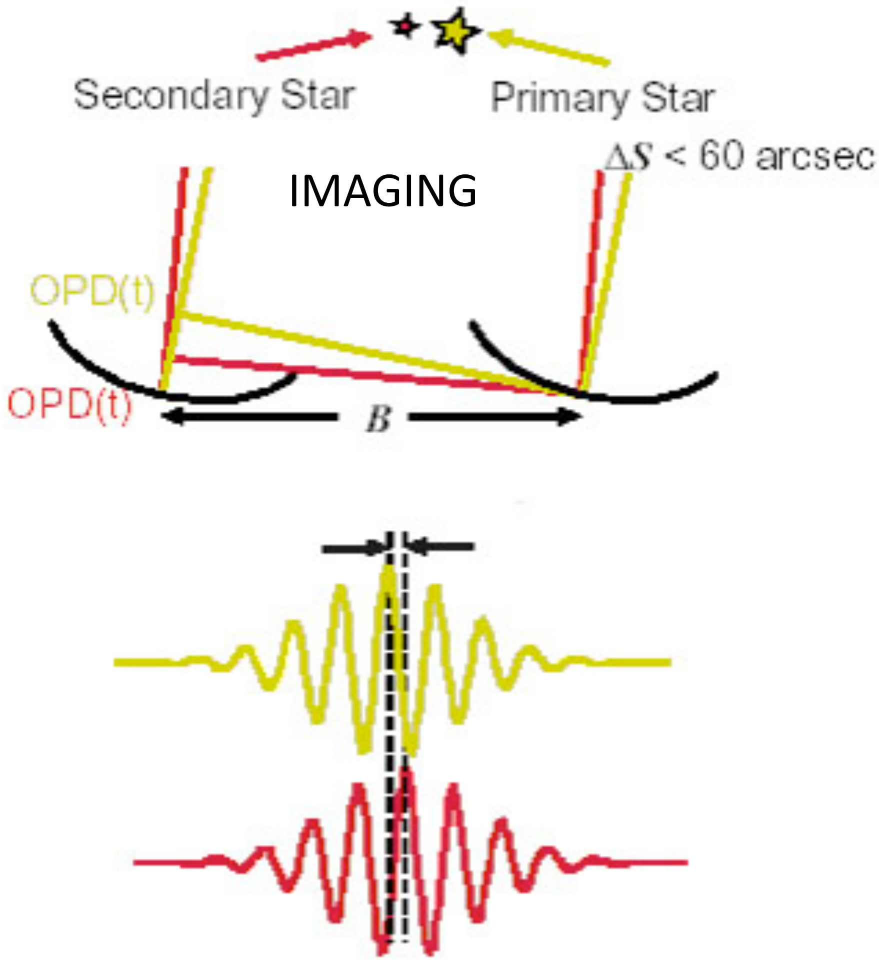
OPDC sends the command to delay line, and also to Scientific instrument

Since fringes are locked, long integration in dispersed fringes
of the instrument is possible (wavelength bootstrapping)

PRIMA – Phase Reference Imaging and Micro-arcsecond Astrometry

Interferometric observations with TWO objects: Bright reference star and faint target

Increase in sensitivity: bright target helps stabilizing fringes, long integrations for faint target



$$\text{OPD bright} - \text{OPD faint} = \Delta\text{OPD} = \Delta S * B + \phi + \Delta A + \Delta L$$

Astrometric mode

Fringe track on two targets simultaneously

Difference between white light fringe
Position +internal metrology enables
Accurate relative angular separation

Instruments

VINCI : First, NIR (2.2 micron), 2 beam combiner, visibility, now de-commissioned

MIDI : MIR (8-13 micron), R = 30, 230, internal fringe tracking, High-Sense (N=4 to 2.8) Sci_Phot mode (N = 3.2 to 2); 1 to 6 Jy range with UT, 20 to 60 Jy with ATs. Measures Visibility (2 beam combiner)

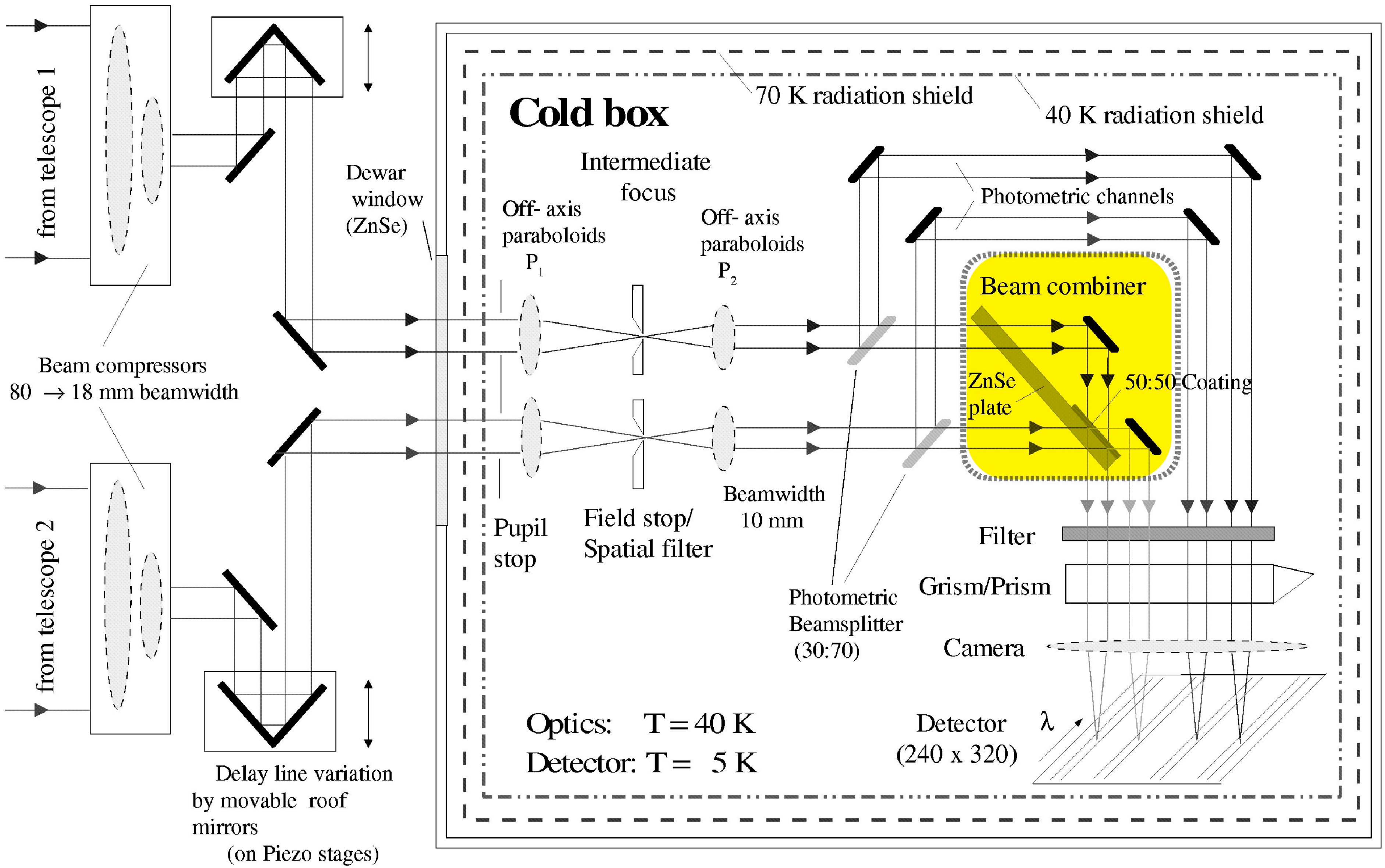
AMBER: NIR (1.2-2.2 micron) LR-HK, MR-K, MR-H, HR-K modes, R = 35, 1500, 12000 Measures Visibility, Closure phase, differential phase. (3 beam combiner)

PIONIER: Visitor instrument, H band, Integrated optics combiner, Visibility and closure phases, tailored for imaging with fast measurements. (4 beam combiner)

GRAVITY: 4 beam combiner, in K band, with AO. Fringe tracking on 2 objects on 6 baselines (phase referenced imaging and precise narrow angle astrometry)

MATISSE 4 beam combiner, N, L, M, Q bands, Imaging in MID-IR.

Principle of MIDI - the MID- infrared Interferometer for the VLTI



AMBER – Astronomical Multi BEam combineR

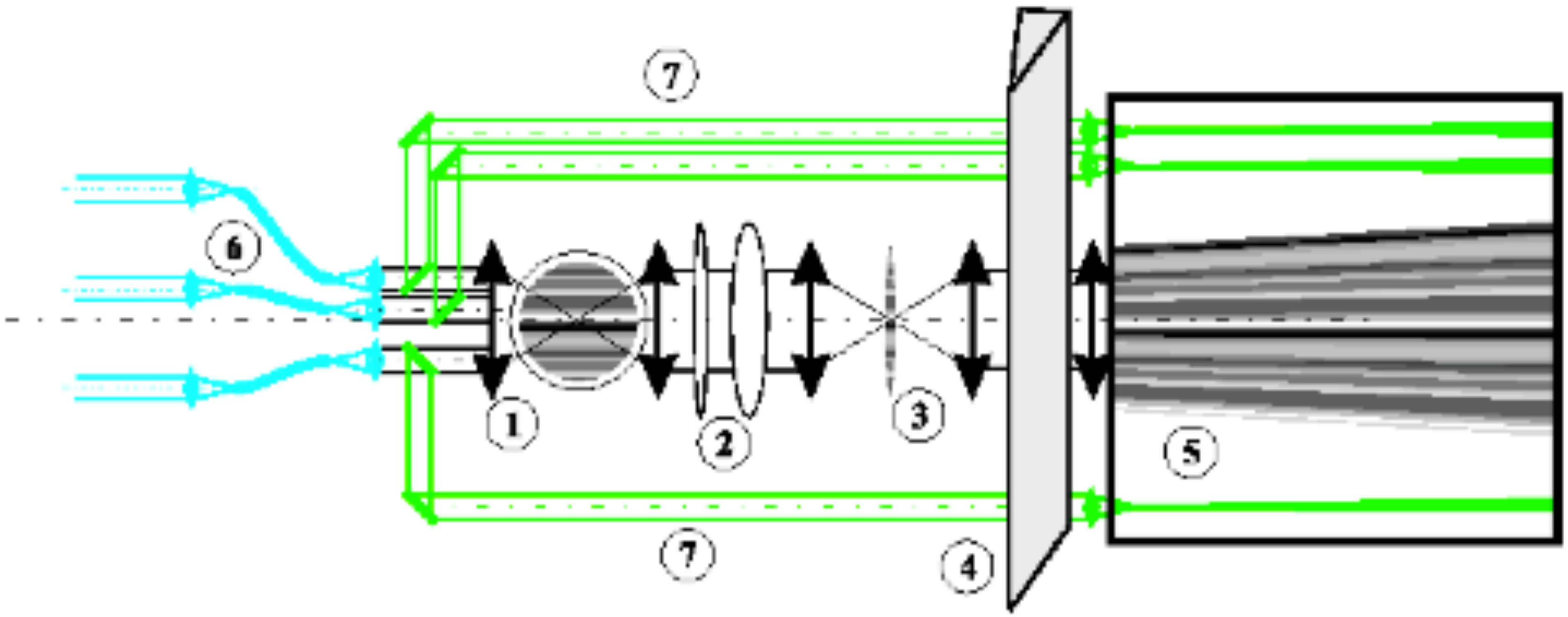
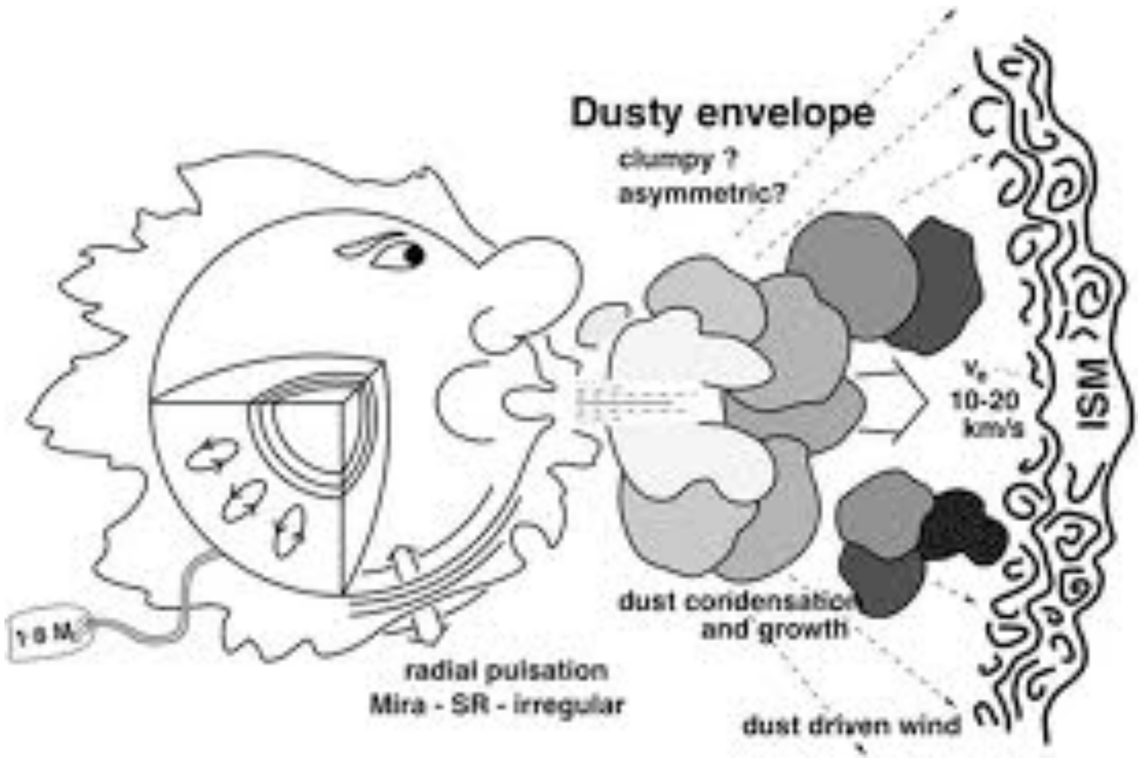


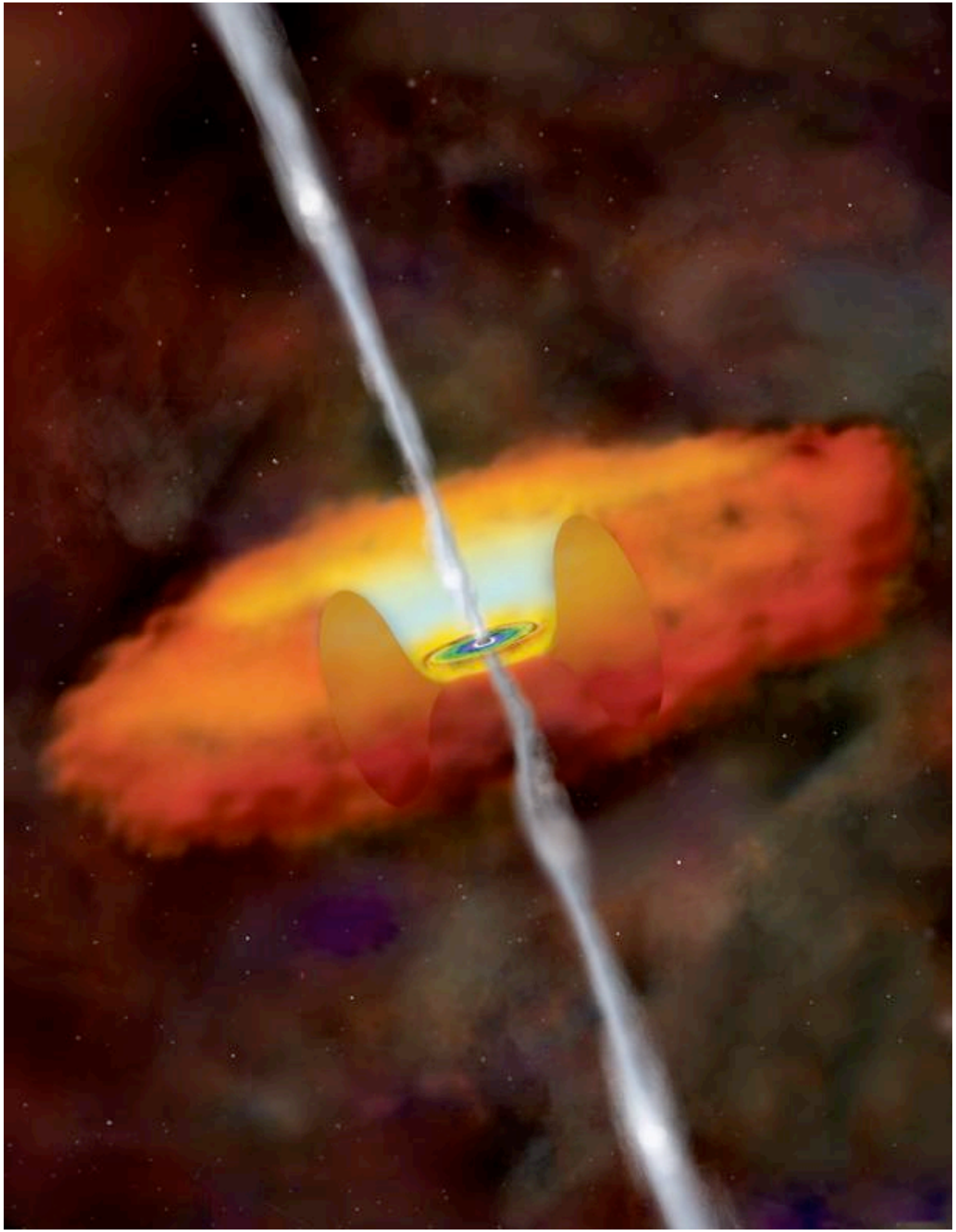
Figure 1: Basic concept of AMBER: (1) multi axial beam combiner. (2) cylindrical optics. (3) anamorphosed focal image with fringes. (4) "long slit spectrograph". (5) dispersed fringes on 2D detector. (6) spatial filter with single mode optical fibers. (7) photometric beams.

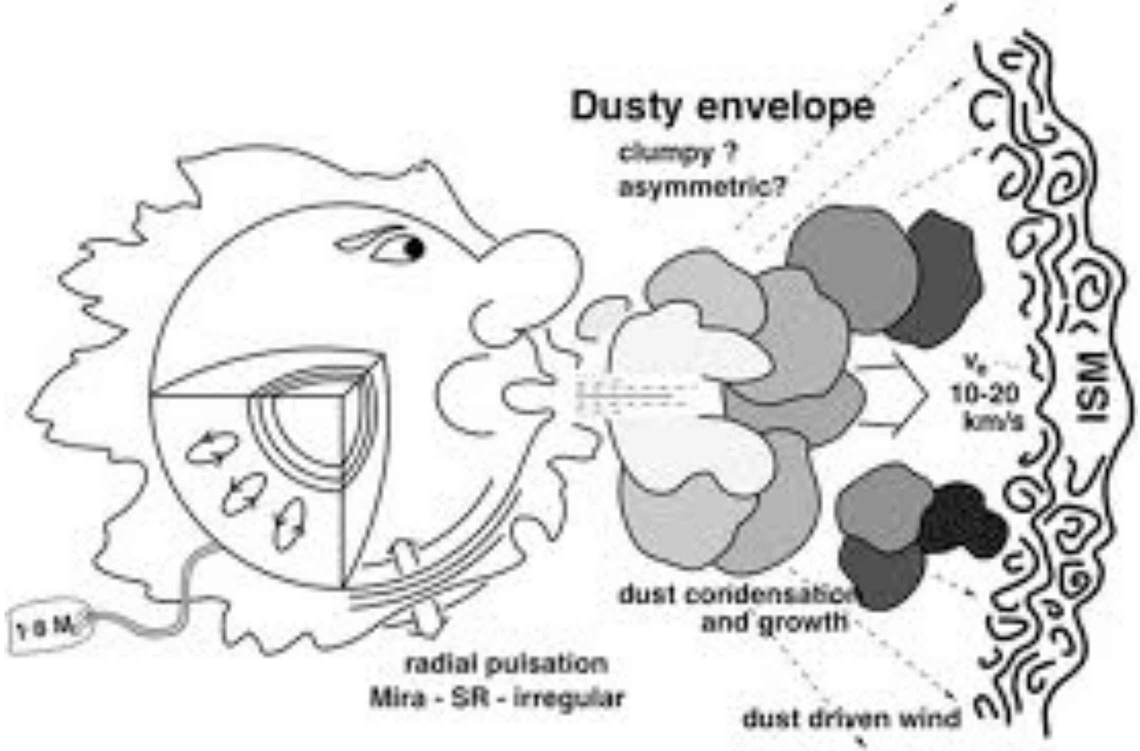


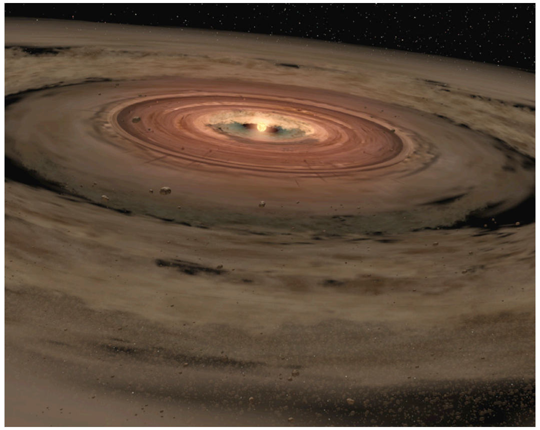
AGB stars: slow, massive and cool winds – dust condensation

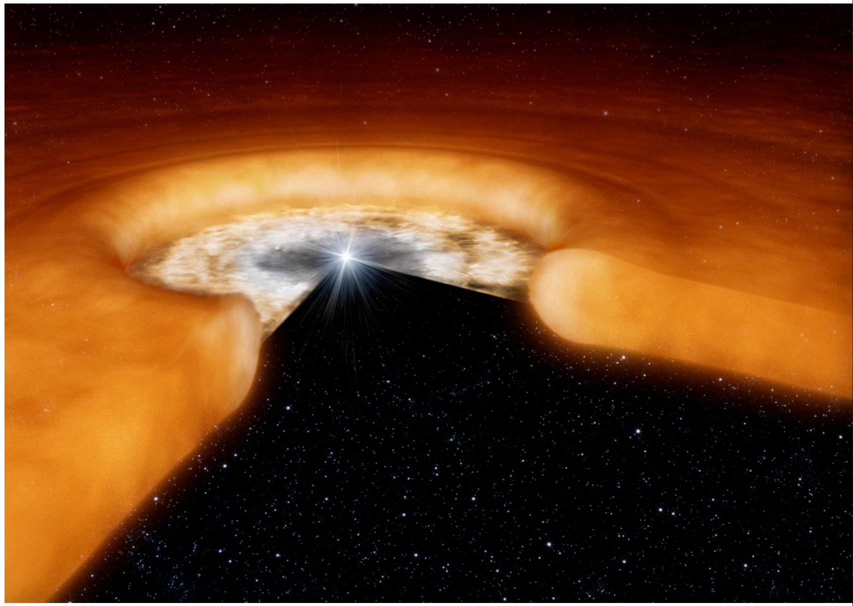
Formation mechanism: Global shock waves, Blobs, clumpiness

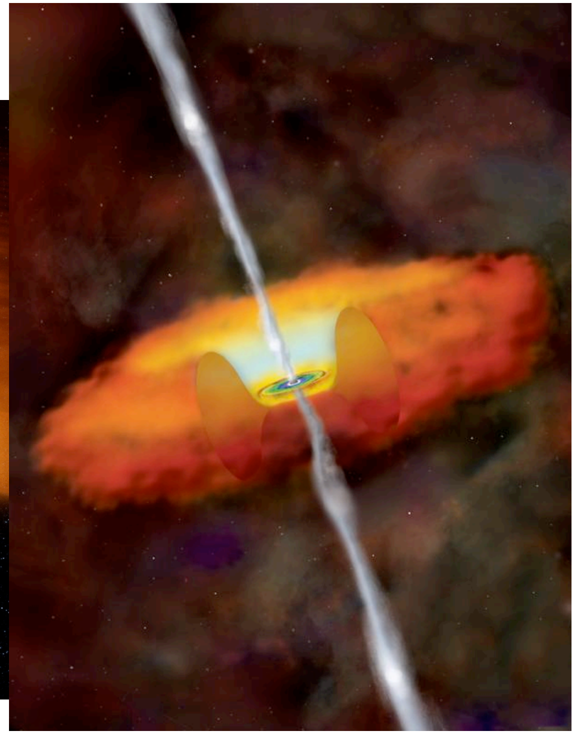
Monitoring of how things evolve.

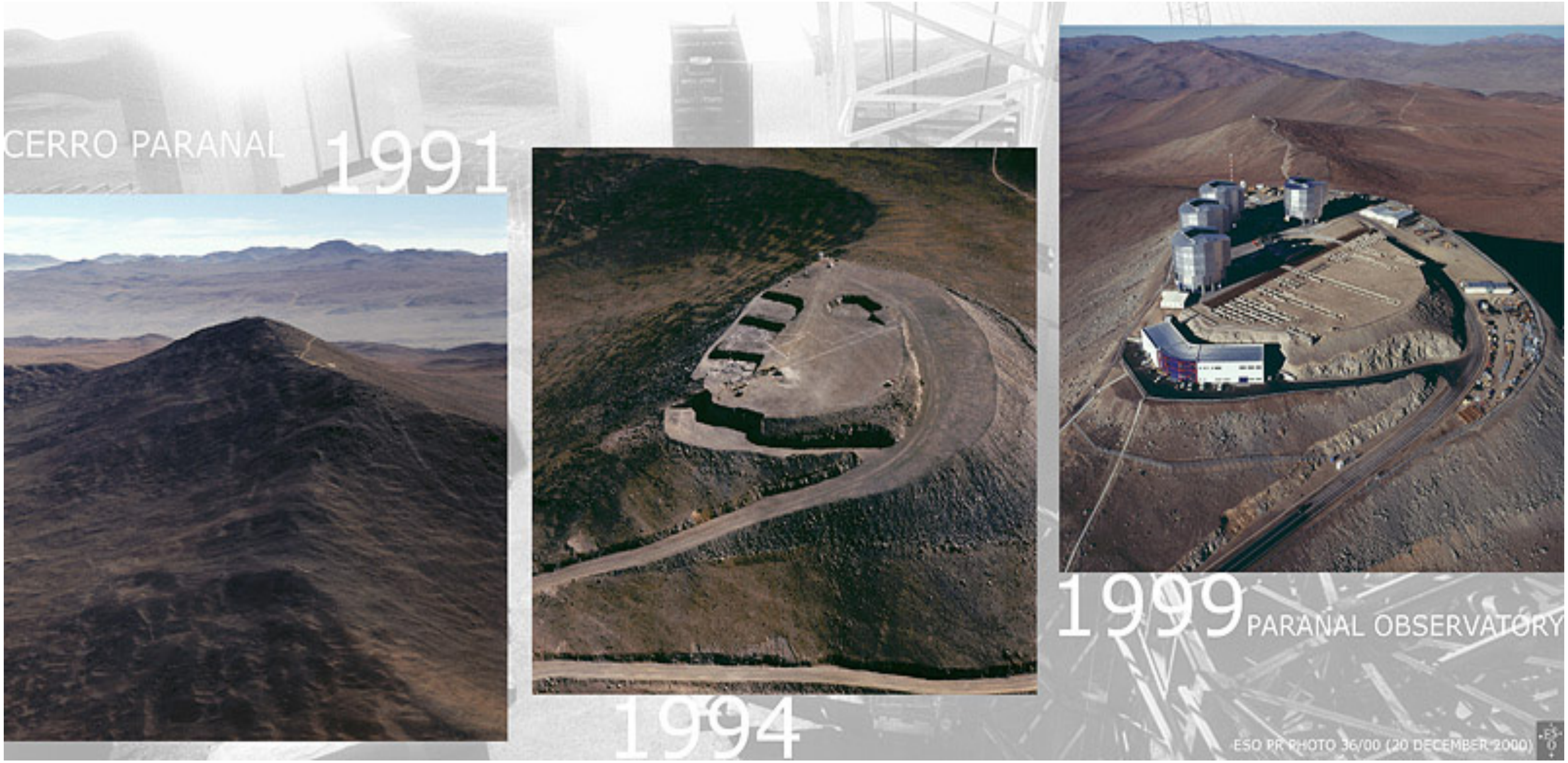



Dusty envelope
clumpy ?
asymmetric?
v_e
10-20
km/s
ISM
dust condensation
and growth
radial pulsation
Mira - SR - irregular
dust driven wind





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