MIDI performance enhancement with FINITO and PRIMA

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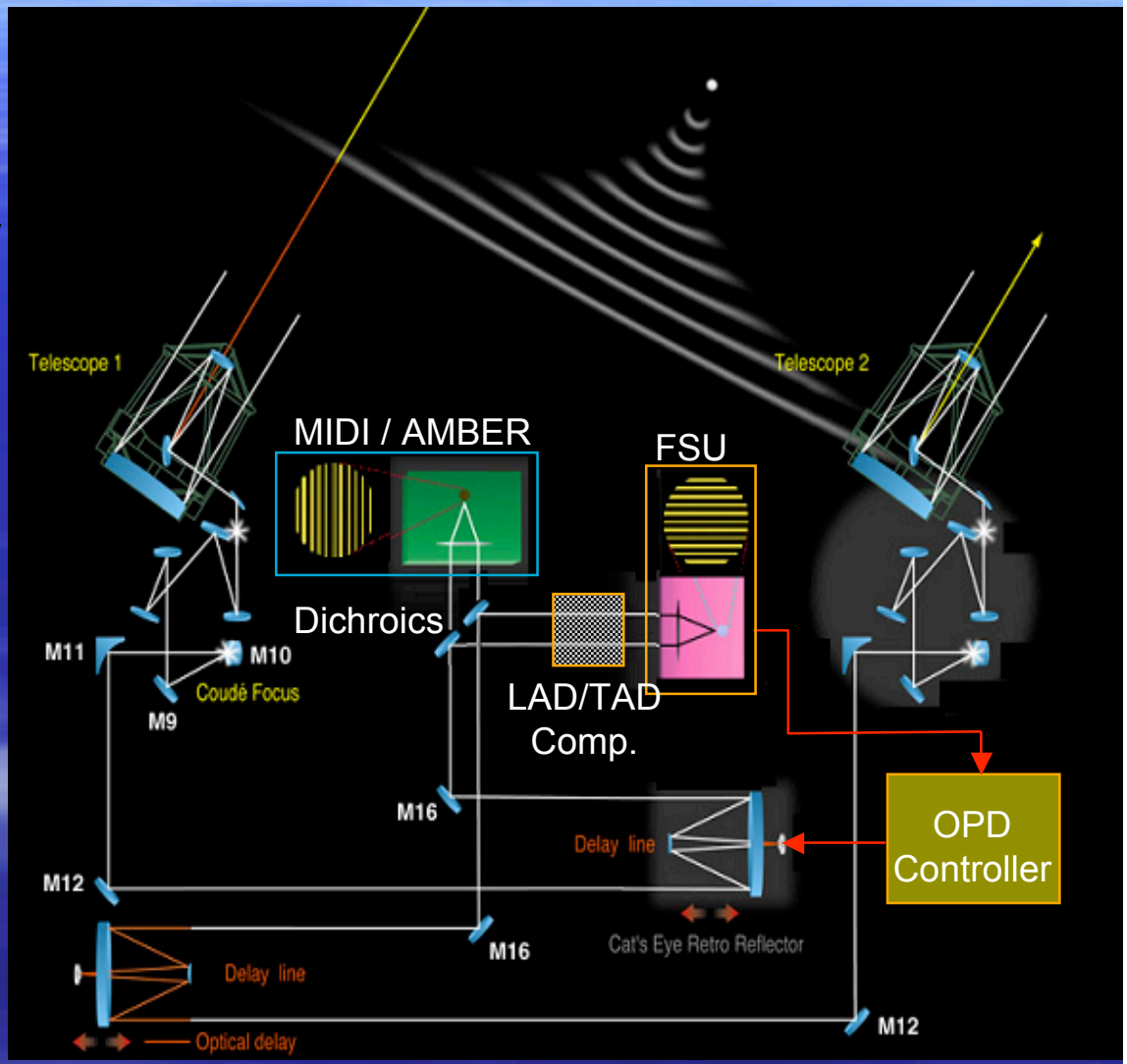
MIDI needs

- Exposure time limited by the background (~800ms)
- If no fringe tracking: need to find the 10 μm fringes in each frame =>
  - Limiting magnitude N = 5 (8) with the ATs (UTs)
- If external fringe detector: *coherent* frame addition in post-processing =>
  - Limiting magnitude N = 8 (11) with the ATs (UTs)
- If dual-feed and phase-referencing:
  - Aperture reconstructed imaging
  - Differential phase measurements
  - Access to objects with no near-IR counter-part

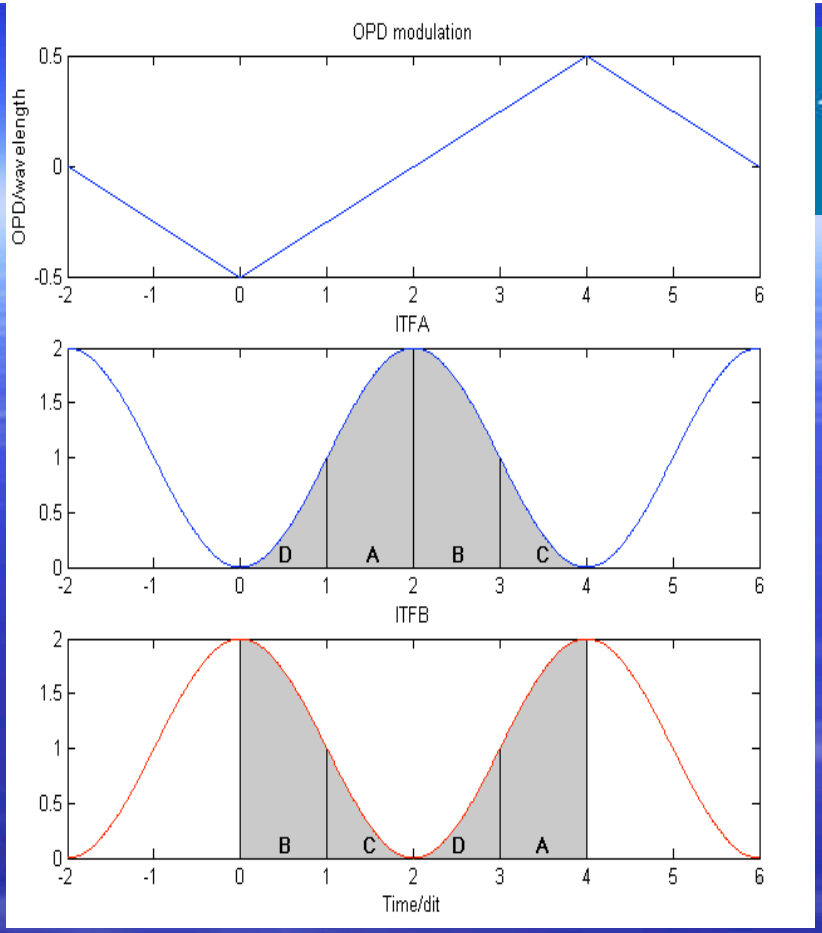
FINITO (1)

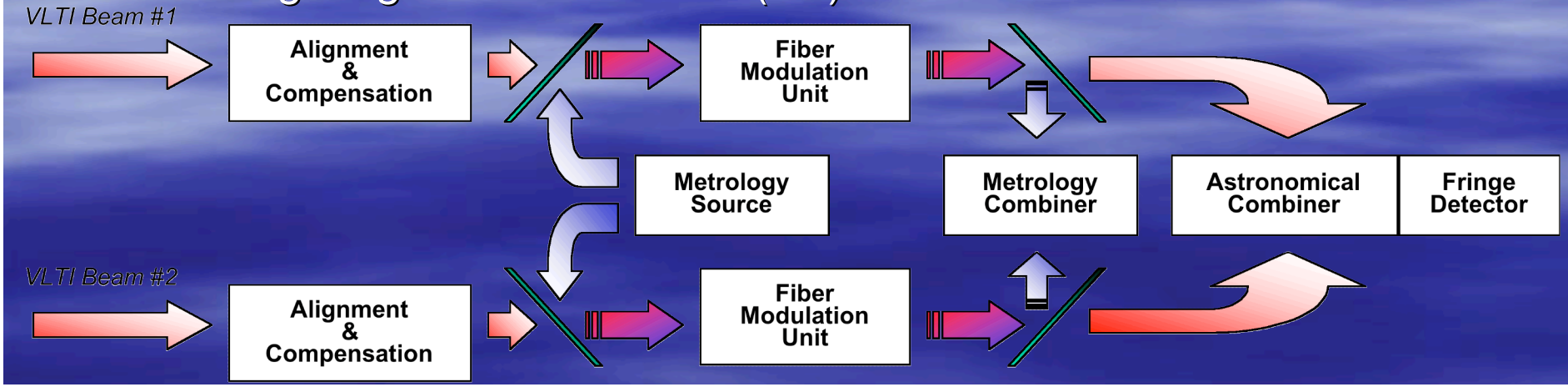
- On-axis fringe tracker
- H-band
- 3-way beam combiner
- LAD and TAD compensation
- No recording of delay
- Installed in Paranal
- Under commissioning
- OPD time scanning



FINITO (2)

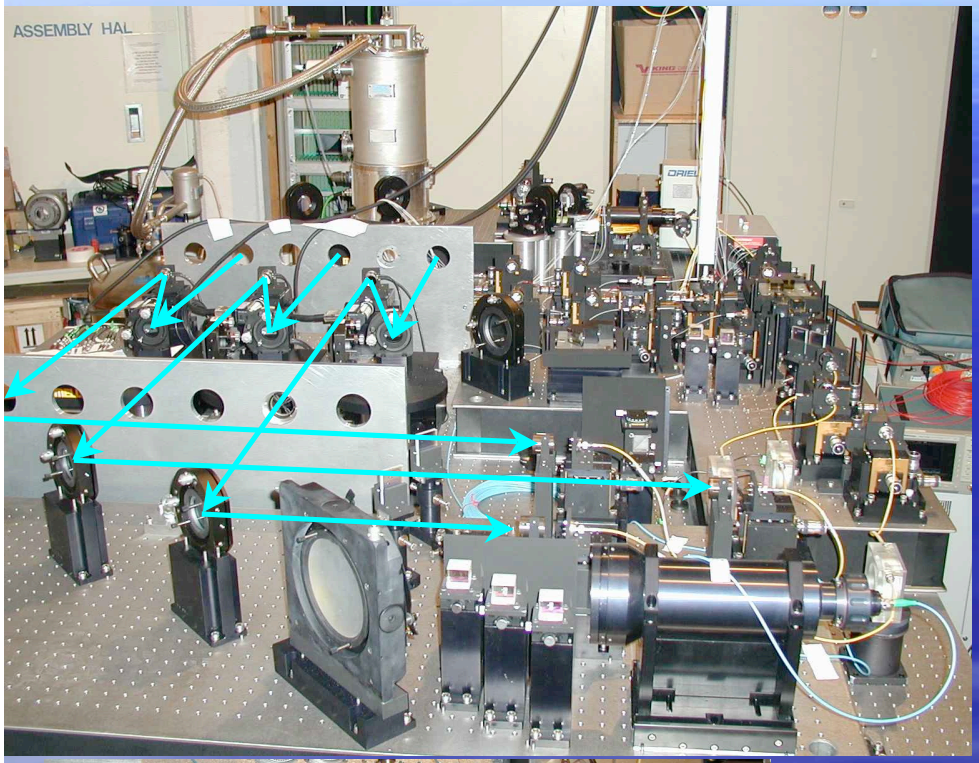
- Phase Delay = OPD mod □
  - High frequency (up to 2kHz)
  - Low noise
  - Small range (□)
- Group Delay or Coherence = "white" fringe position (LAD)
  - Low frequency (up to 50Hz)
  - Higher noise
  - Large range (10 □) for fringe jump detection & correction
- Limiting magnitude: H=9 to 11 (UT)

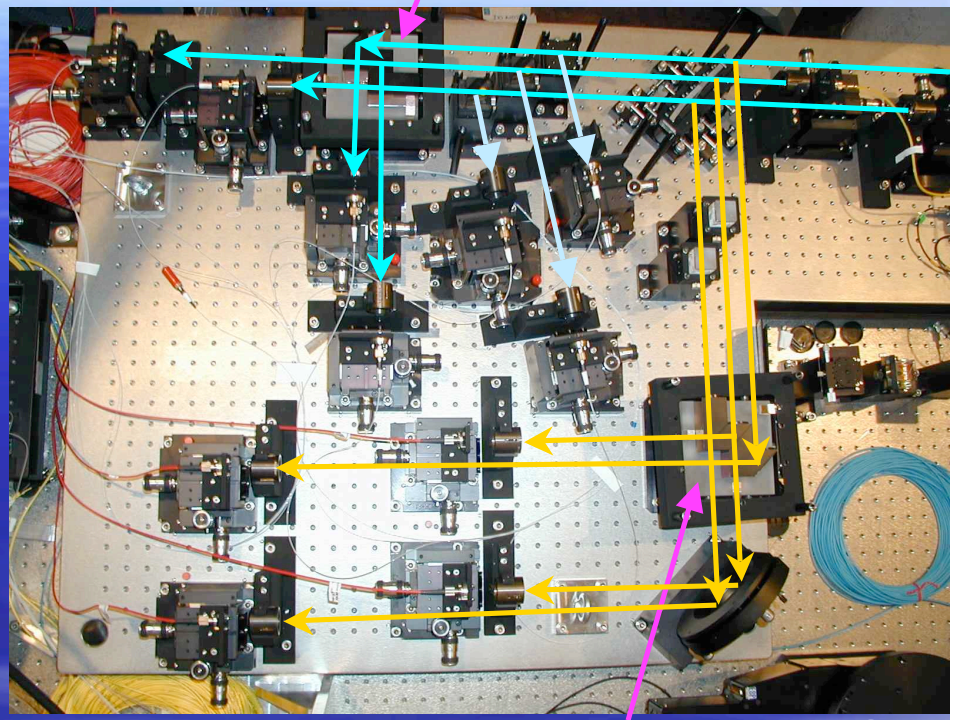




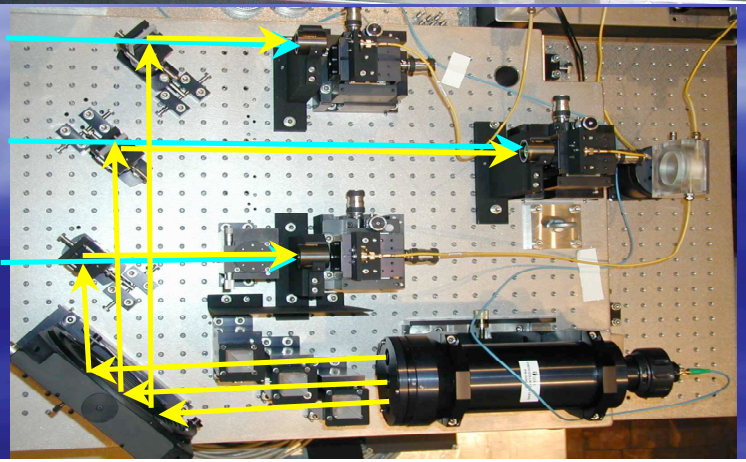
FINITO (3)

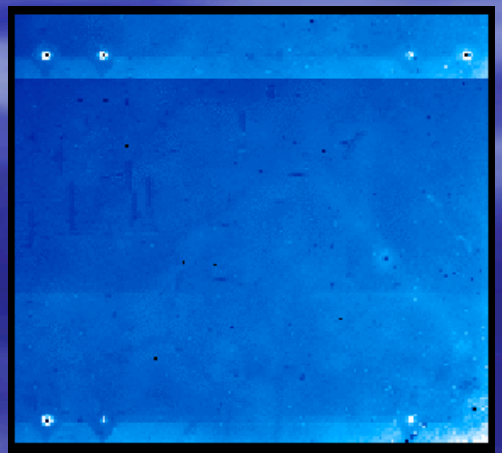
H-band 3-way beam-combiner

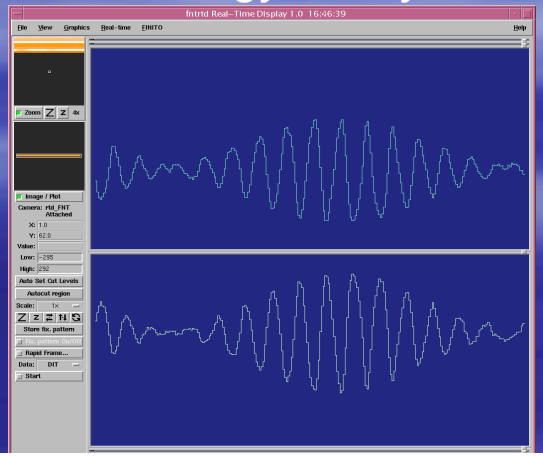




Metrology 3-way BC

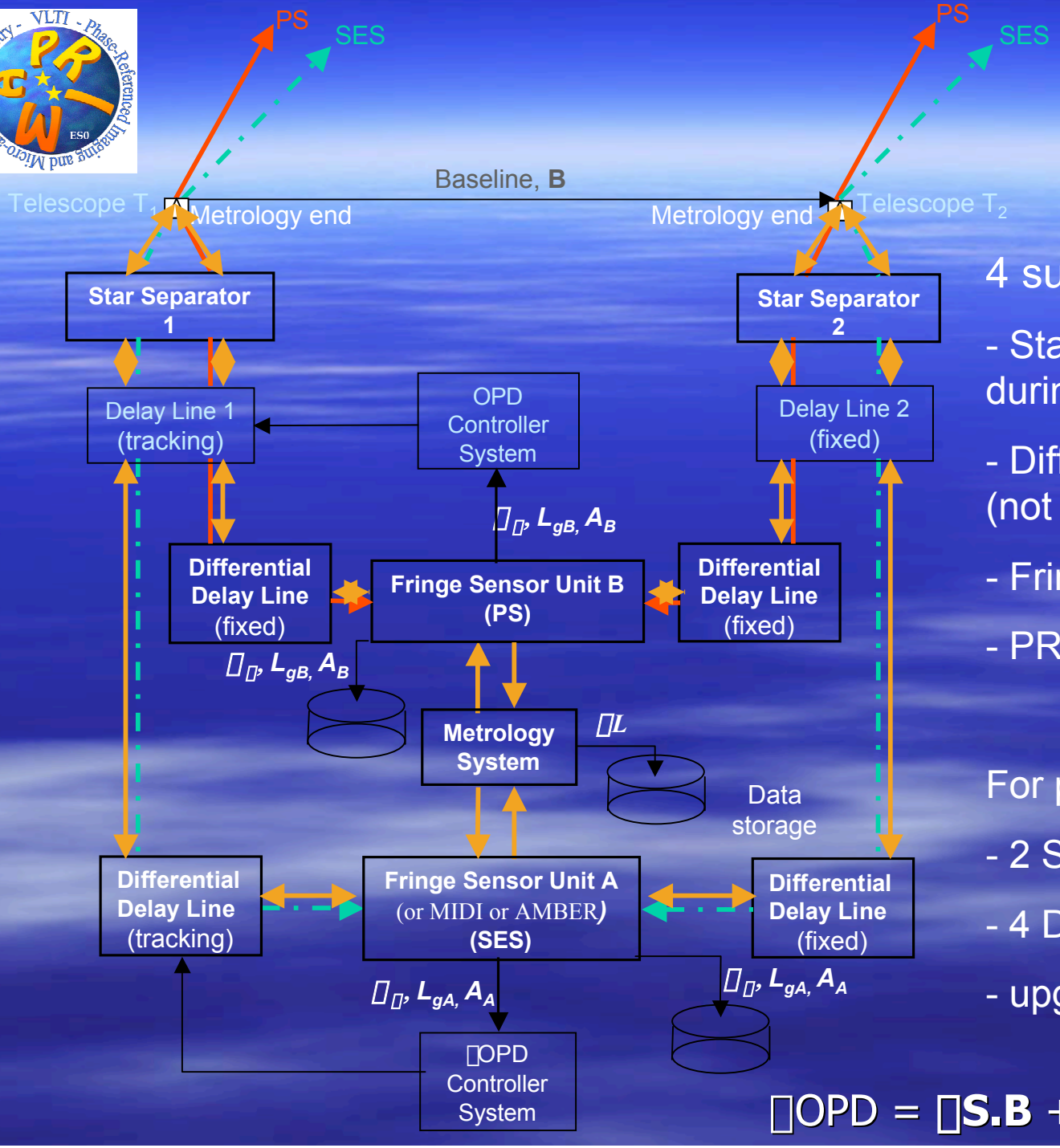






PRIMA (1)

- VLTI *Dual-Feed* facility => off-axis fringe tracking
- 3 aims:
  - faint object observation (by stabilising the fringes)
    - dual-feed / dual-field : 2' total FoV (2" FoV for each field)
    - K=13 (guide star) - K=20 (object), N=11 on UTs
    - K=10 (guide star) - K=16 (object), N=8 on ATs
  - phase-referenced imaging
    - accurate (better than 1%) measurement of the visibility modulus and phase
    - observation on many baselines
    - synthetic aperture reconstruction at 10 mas resolution (10 µm)
  - micro-arcsecond differential astrometry
    - very accurate extraction of the astrometric phase:
      - 1st phase ~ 2006 : 100 µas
      - 2nd phase ~ 2008 : 10 µas
    - 2 perpendicular baselines
    - 2 phase-reference stars (2D-movement of photocenter)



4 sub-systems:

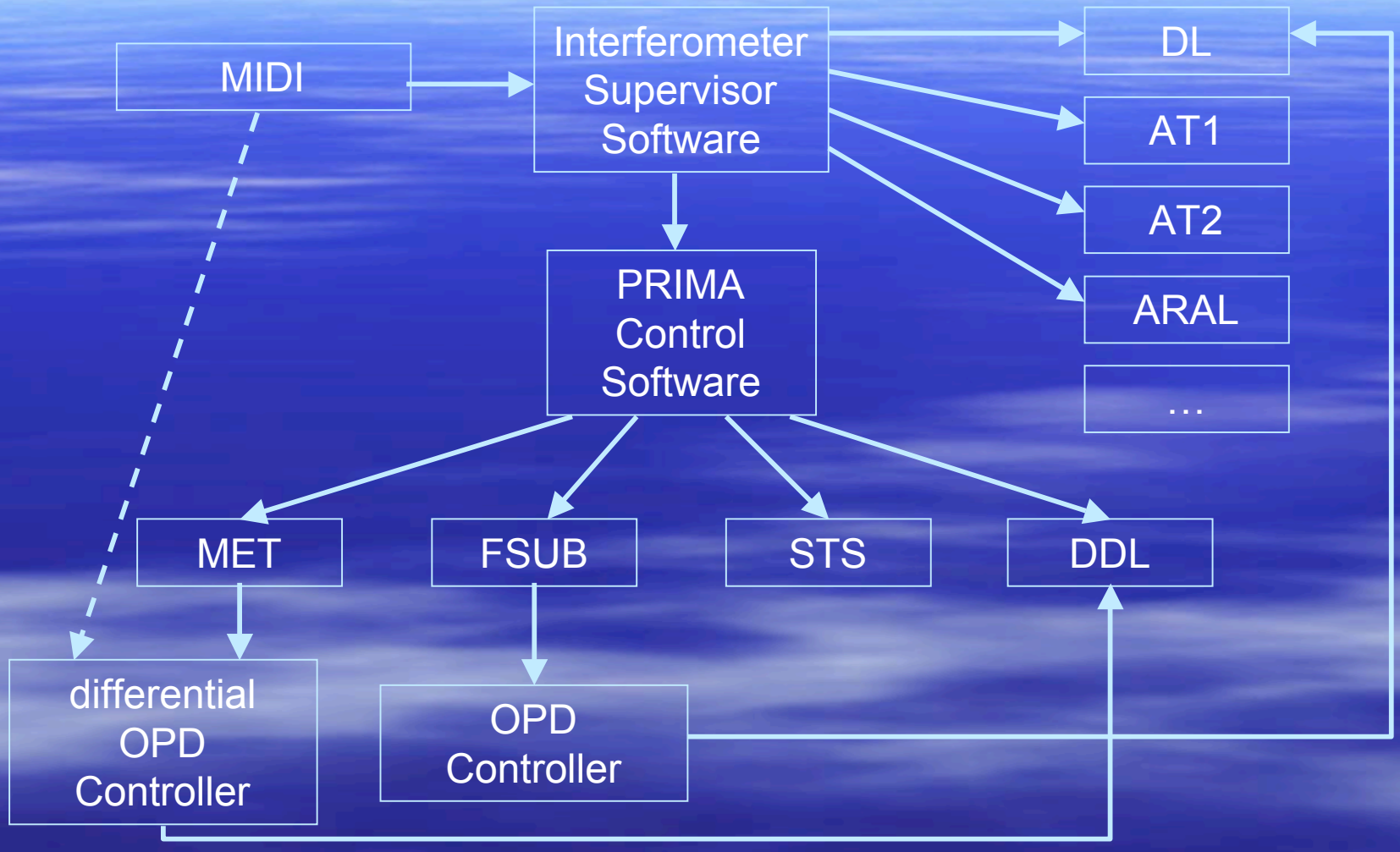
- Star Separators (2 on ATs during phase A)
- Differential Delay Lines (4) (not in phase A unless…)
- Fringe Sensor Unit(s) (2)
- PRIMA Metrology (1)

For phase B & C:

- 2 Star Separators on UTs
- 4 Differential Delay Lines
- upgrade Metrology

$$\Delta OPD = \Delta S.B + \Delta + OPD_{turb} + OPD_{int}$$

PRICS: Control S/W



14 control loops working in parallel

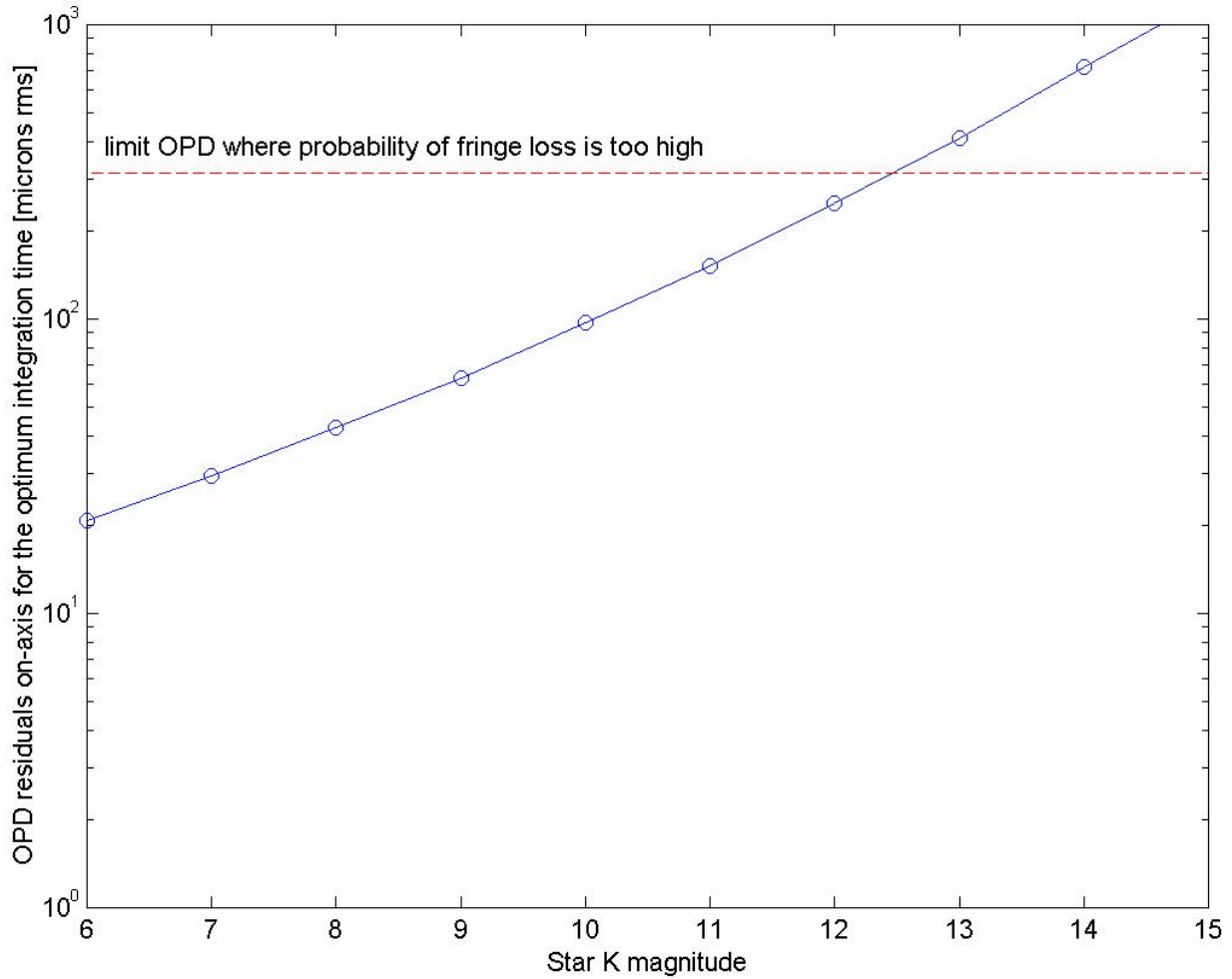
PRIMA performance

- Fringe tracking in K-band:
  - Phase delay:
    - Measurement frequency up to 8 kHz (closed loop residuals 70nm rms)
    - OPD measurement noise on the ATs =
      - 70 nm rms at K=7 (0.25 ms)
      - 140 nm rms at K=11 (2 ms)
    - Maximum allowable closed loop residuals ~ 370 nm rms (fringe jumps)
  - Group delay:
    - Measurement frequency up to 200 Hz
    - GD measurement noise on the ATs =
      - 900 nm rms at K=7 (5 ms)
      - 1900 nm rms at K=13 (200 ms)
      - 2300 nm rms at K=16 (2 s)
- Incremental Metrology at 1.3 □m:
  - Resolution = 1nm
  - Accuracy on 30 min = 5nm <=> 0.05% on phase in N-band
  - Measurement frequency = 200 kHz
- OPD, GD, metrology are stored at max 8 kHz

PRIMA Performances

FSU B – Limiting Magnitude

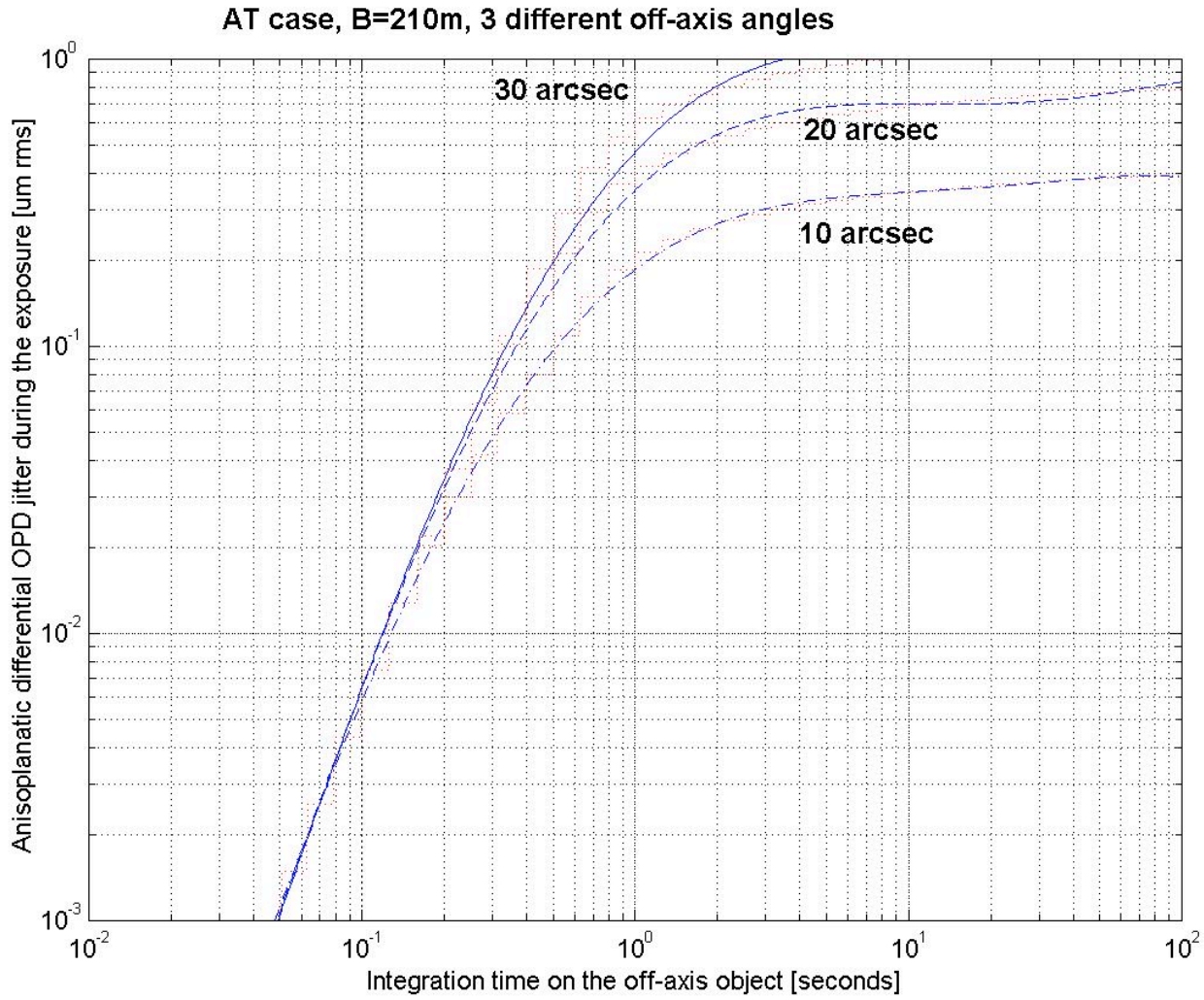
AT case



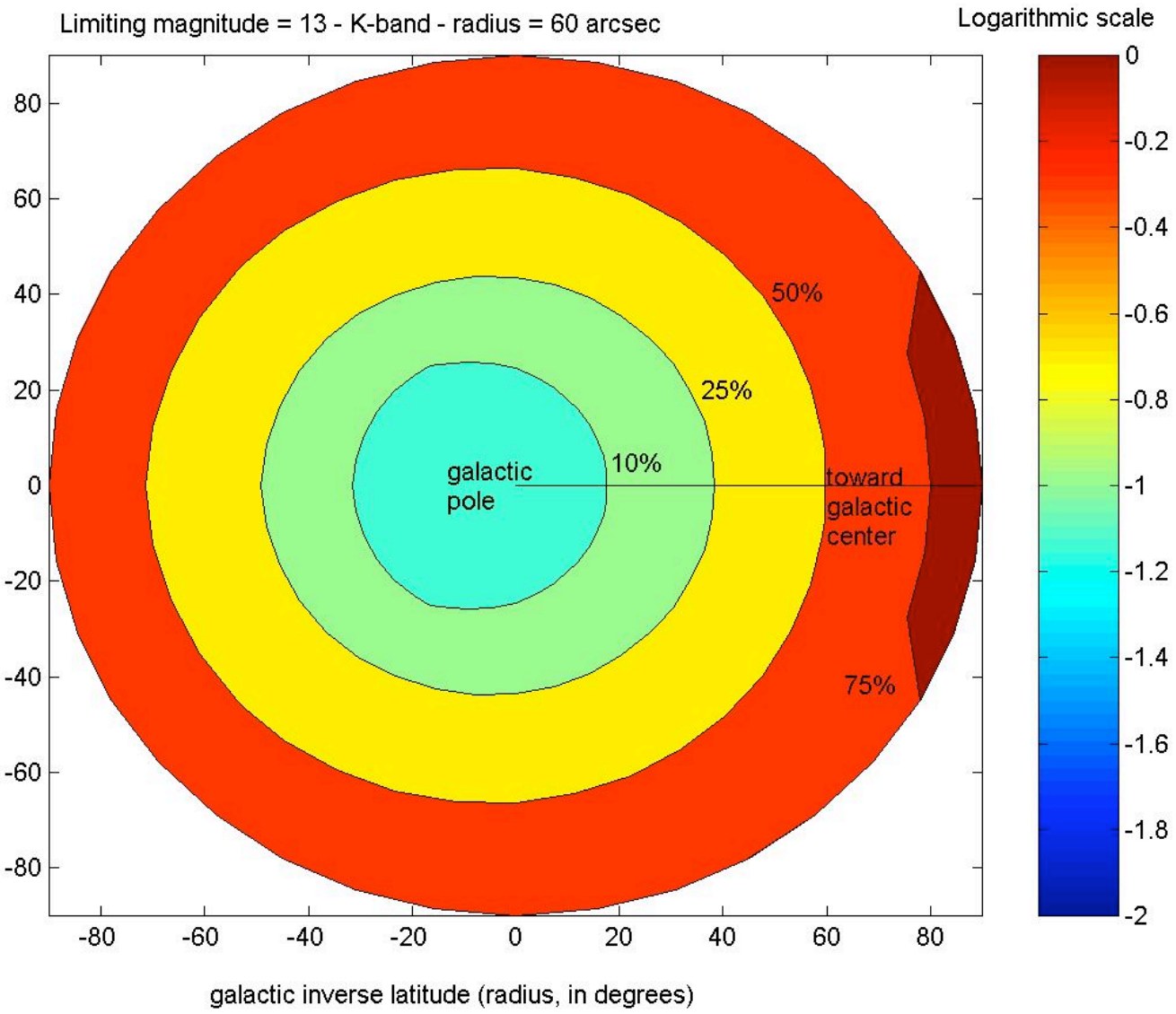
PRIMA Performances (2)

Instrument integration time - anisoplanatic differential OPD

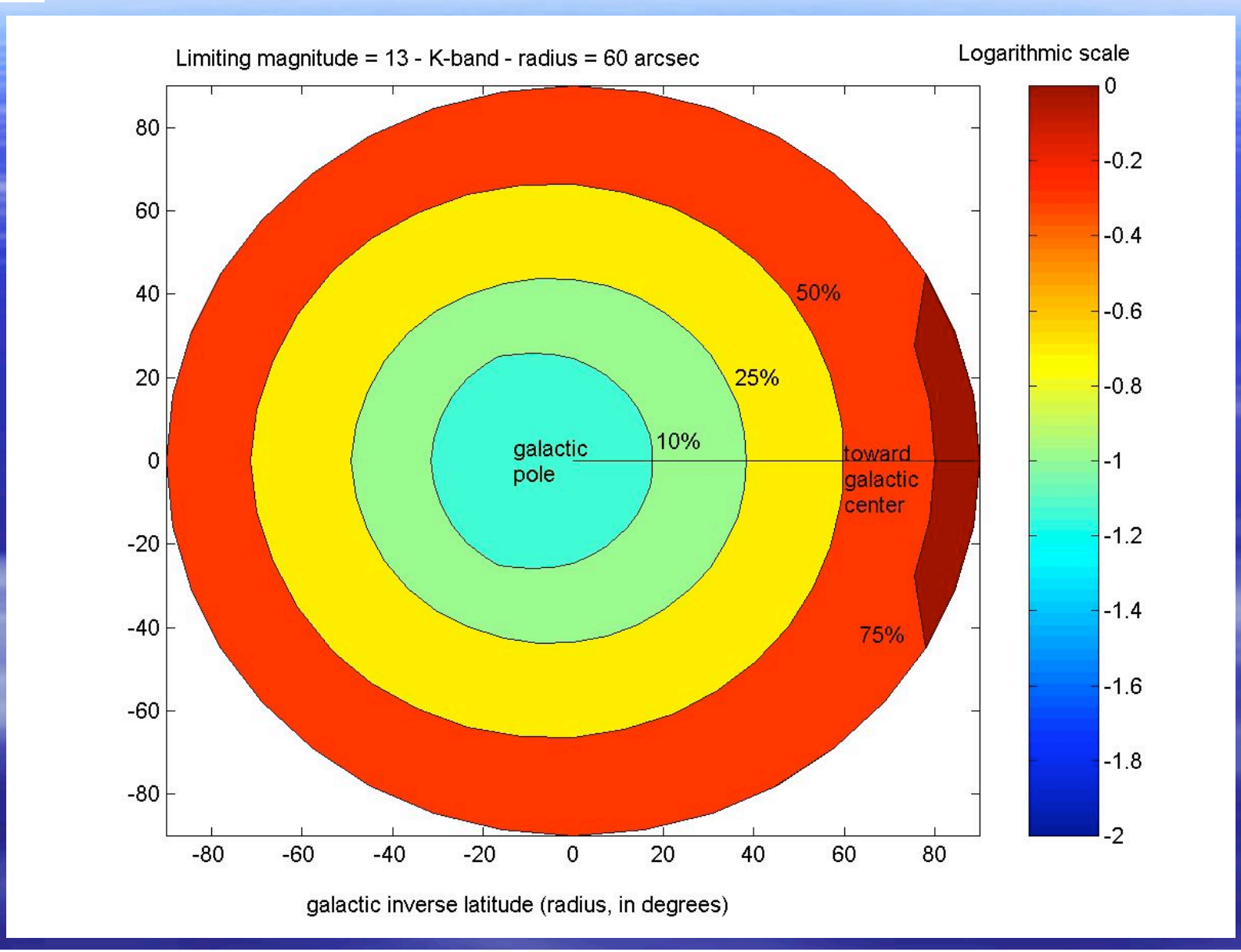
AT case



Sky coverage (1)



Sky coverage (2)



MIDI Performances with Fringe Tracking

- With FINITO
  - Available in 2004
  - H-band
  - Fringe stabilisation at 100nm (370) rms on-axis (closed loop)
  - Needs star brighter than H=6 (8) on ATs
  - Blind adding of stabilised frames in post-processing
  - Fringe visibility loss =
    - 0.2% (0.5%) on-axis
  - Increase of MIDI limiting magnitude by 3 magnitudes

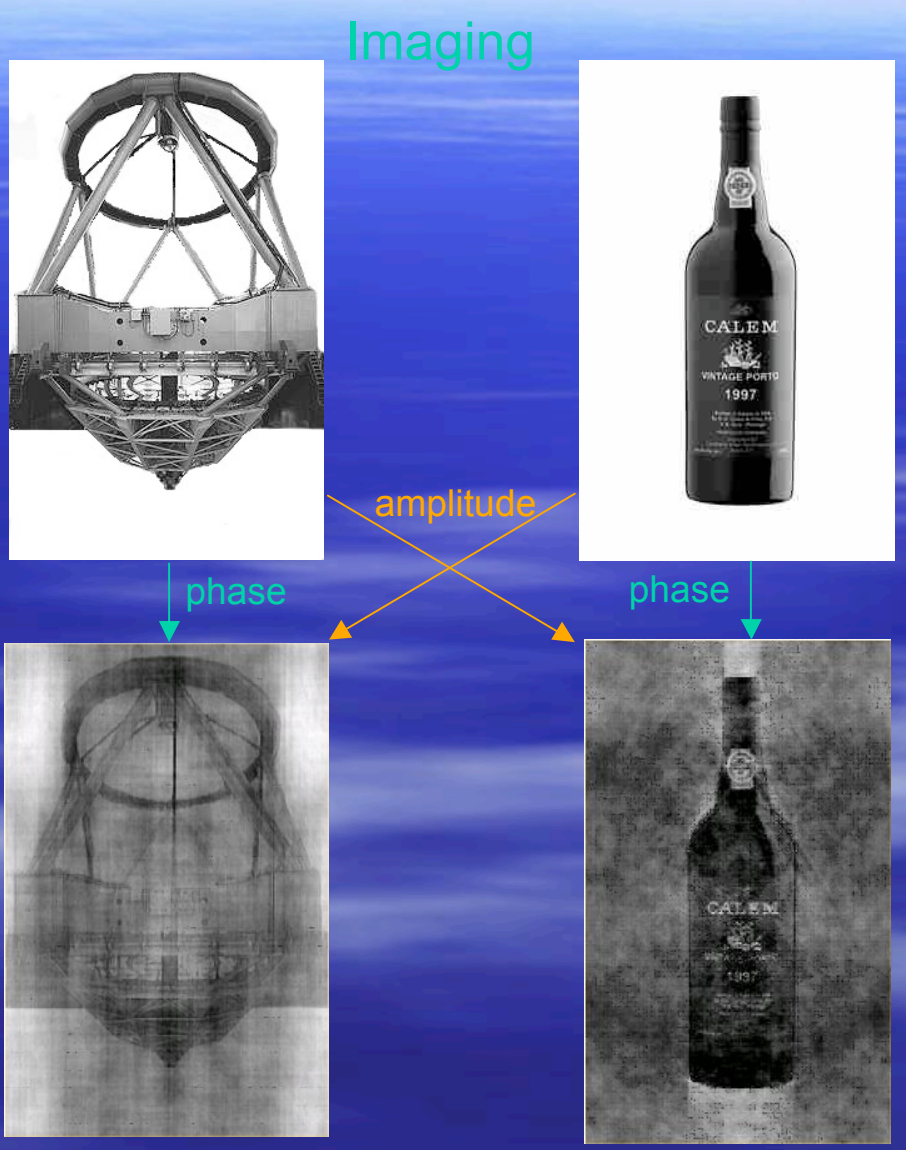
- With the FSU
  - Available mid-2005
  - K-band
  - Fringe stabilisation at 70nm (370) rms on-axis or off-axis
  - Needs star brighter than K=8 (12.5) on ATs
  - Coherent adding of frames in post-processing (slight improvement)
  - Fringe visibility loss =
    - 0.1% on-axis
    - + 3% at 10”
    - + 80% at 60”
  - Increase of MIDI limiting magnitude by 3 magnitudes + of near-IR counter-part

Imaging with MIDI

- Imaging dynamic range D is given by:

$$D \sim \frac{\sqrt{M}.\sqrt{N_{baselines}}}{\Delta\Phi + \Delta V}$$

  - Where
    - M = number of observations
    - $N_{baselines}$ = nb of independent baselines
    - $\Delta\Phi$ = error on phase
    - ΔV = error on visibility modulus
- Very important:
  - Increase the number of independent baselines
  - Well distribute the baselines (not especially uniform)
  - Keep a very good accuracy on the phase (1% error on visibility modulus <=> 0.01 rad error on phase)



Potential risks & limitations

- FINITO
  - Use not possible on siderostats (photometric variations too high)
  - Current absence of an IR tip-tilt tracker in the lab (IRIS)
  - Larger detector noise than expected (=> limiting magnitude)
  - To be commissioned soon => then the performances will be known
- PRIMA & FSU
  - Currently only for the ATs in PRIMA mode (on-axis with the UTs is allowed)
  - IRIS should be installed and running by 2005
  - Detector noise at longer T_{int}
  - Group Delay bias long term stability is critical for phase-referencing (large number of baselines = long observation programme) => FSU calibration is essential
  - Still to be built and installed but thorough modeling

The accurate knowledge of the atmospheric dispersion (LAD-TAD) will probably be essential to reach the ultimate accuracy