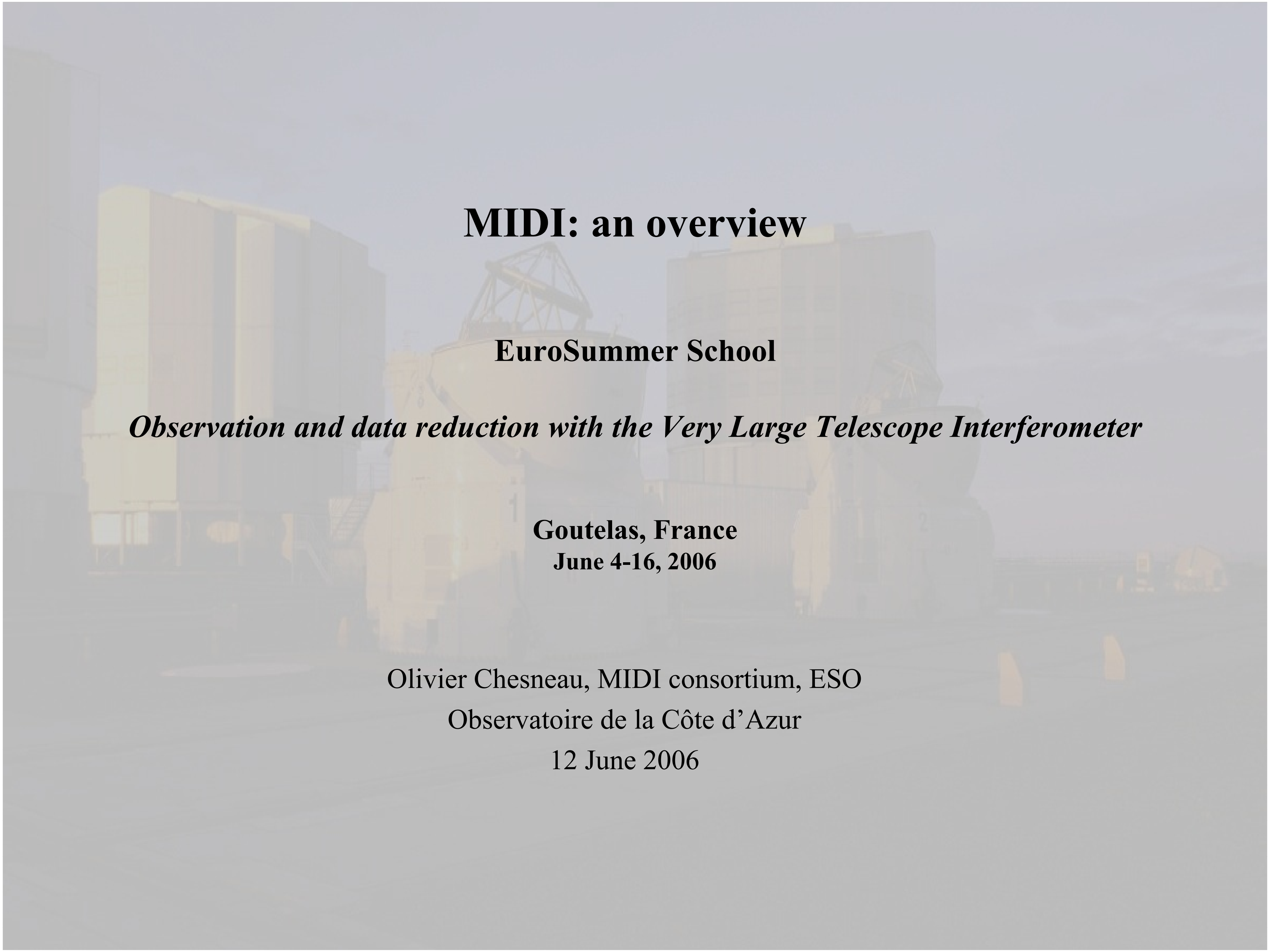


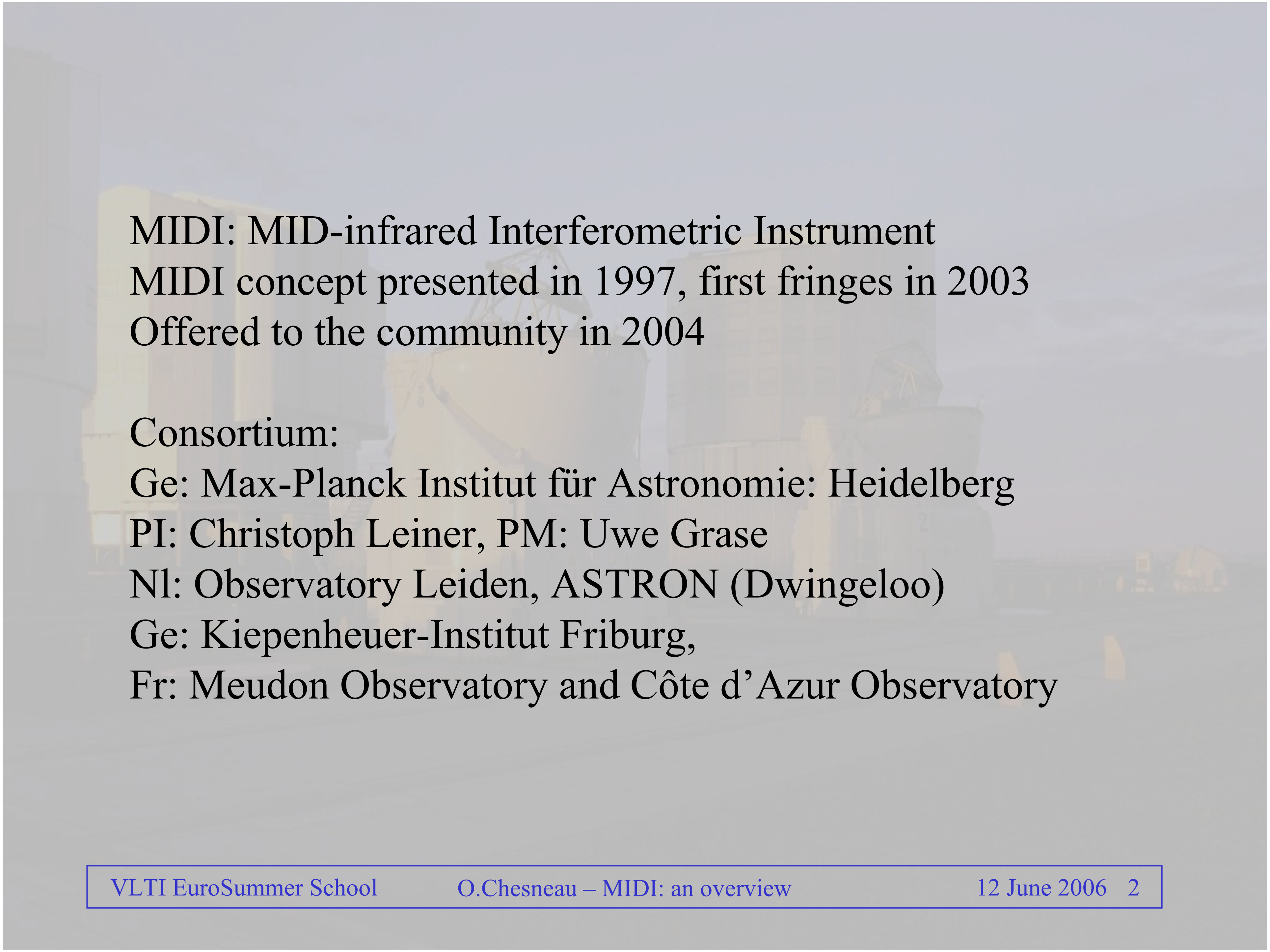
MIDI: an overview

EuroSummer School

Observation and data reduction with the Very Large Telescope Interferometer

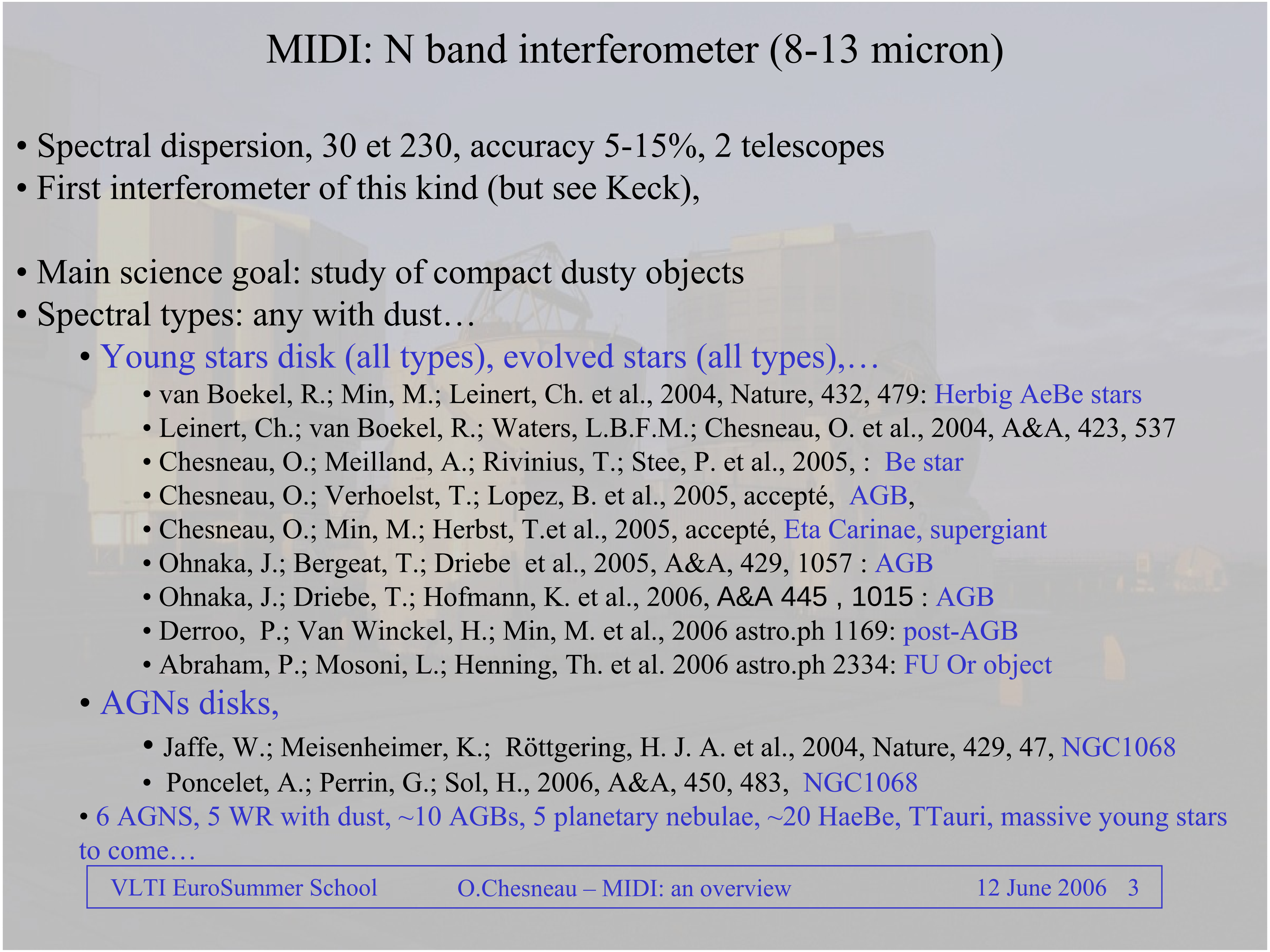
Goutelas, France
June 4-16, 2006

Olivier Chesneau, MIDI consortium, ESO
Observatoire de la Côte d'Azur
12 June 2006



MIDI: MID-infrared Interferometric Instrument
MIDI concept presented in 1997, first fringes in 2003
Offered to the community in 2004

Consortium:
Ge: Max-Planck Institut für Astronomie: Heidelberg
PI: Christoph Leiner, PM: Uwe Grase
Nl: Observatory Leiden, ASTRON (Dwingeloo)
Ge: Kiepenheuer-Institut Friburg,
Fr: Meudon Observatory and Côte d'Azur Observatory

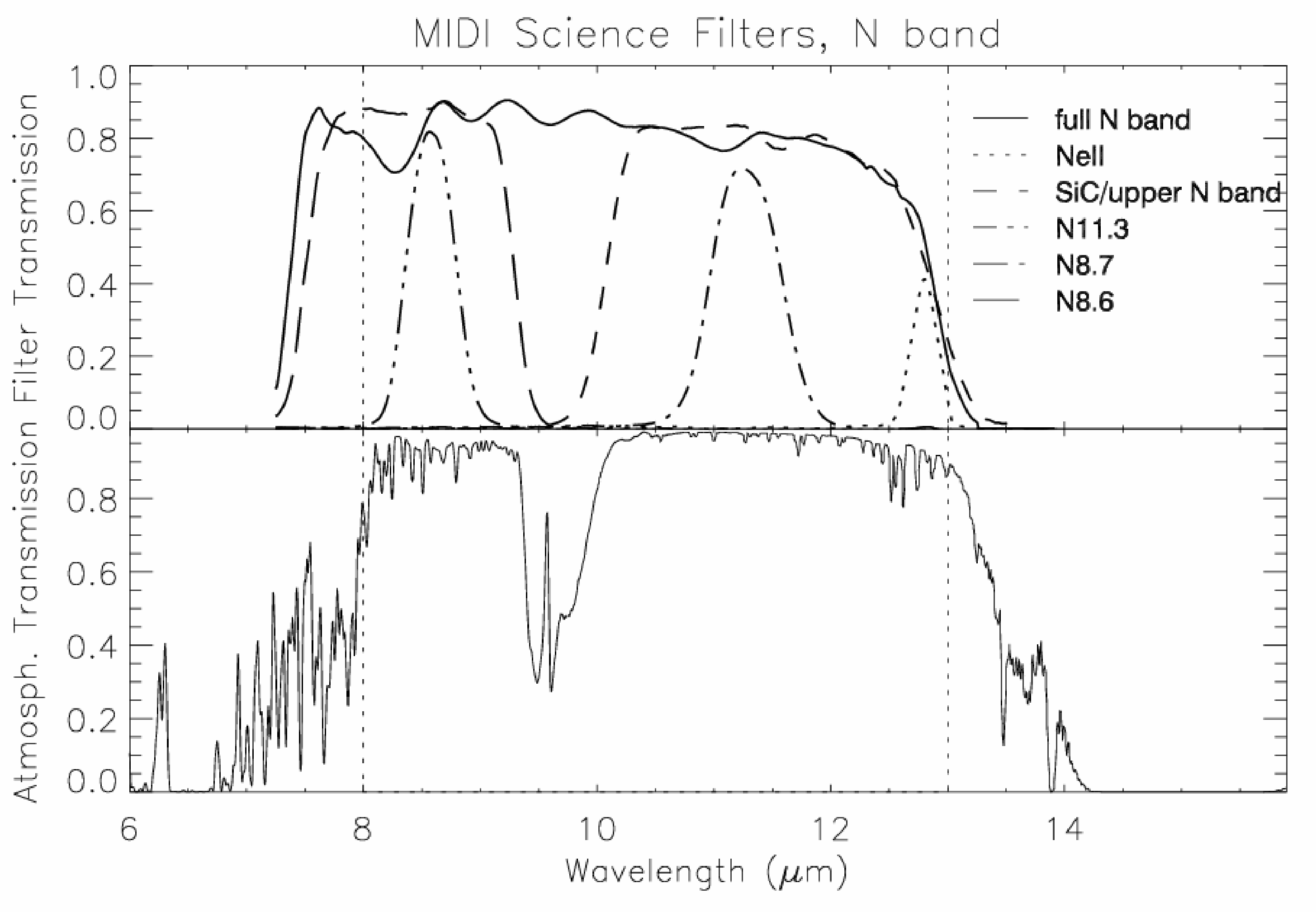


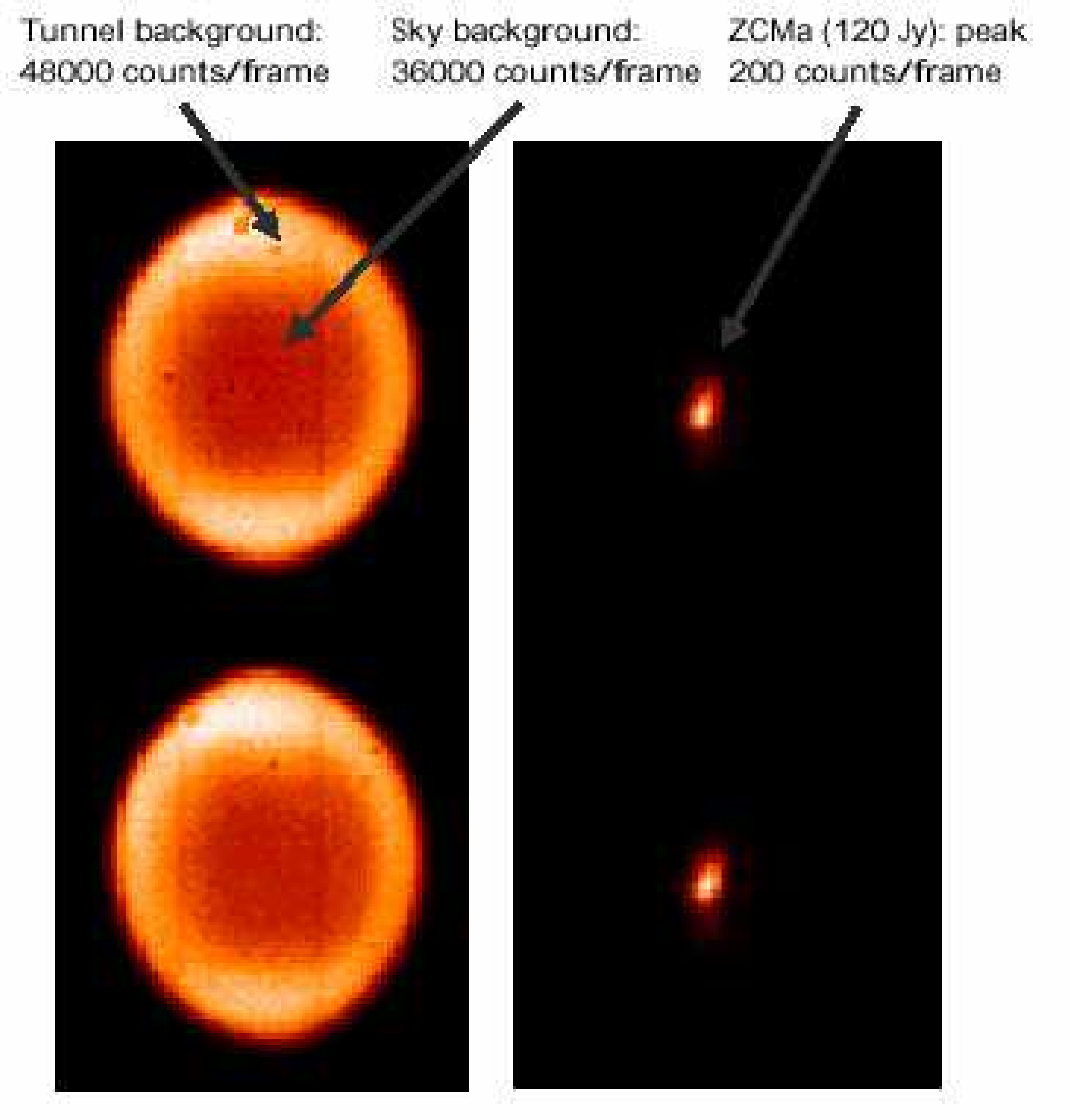
MIDI: N band interferometer (8-13 micron)

- Spectral dispersion, 30 et 230, accuracy 5-15%, 2 telescopes
- First interferometer of this kind (but see Keck),

- Main science goal: study of compact dusty objects
- Spectral types: any with dust…
    - Young stars disk (all types), evolved stars (all types),…
        - van Boekel, R.; Min, M.; Leinert, Ch. et al., 2004, Nature, 432, 479: Herbig AeBe stars
        - Leinert, Ch.; van Boekel, R.; Waters, L.B.F.M.; Chesneau, O. et al., 2004, A&A, 423, 537
        - Chesneau, O.; Meilland, A.; Rivinius, T.; Stee, P. et al., 2005, : Be star
        - Chesneau, O.; Verhoelst, T.; Lopez, B. et al., 2005, accepté, AGB,
        - Chesneau, O.; Min, M.; Herbst, T.et al., 2005, accepté, Eta Carinae, supergiant
        - Ohnaka, J.; Bergeat, T.; Driebe et al., 2005, A&A, 429, 1057 : AGB
        - Ohnaka, J.; Driebe, T.; Hofmann, K. et al., 2006, A&A 445 , 1015 : AGB
        - Derroo, P.; Van Winckel, H.; Min, M. et al., 2006 astro.ph 1169: post-AGB
        - Abraham, P.; Mosoni, L.; Henning, Th. et al. 2006 astro.ph 2334: FU Or object
    - AGNs disks,
        - Jaffe, W.; Meisenheimer, K.; Röttgering, H. J. A. et al., 2004, Nature, 429, 47, NGC1068
        - Poncelet, A.; Perrin, G.; Sol, H., 2006, A&A, 450, 483, NGC1068
    - 6 AGNS, 5 WR with dust, ~10 AGBs, 5 planetary nebulae, ~20 HaeBe, TTauri, massive young stars to come…

MIDI – Working in Mid-IR: the N band challenge




Tunnel background:
48000 counts/frame
Sky background:
36000 counts/frame
ZCMa (120 Jy): peak
200 counts/frame

In the infrared, as in the optical, the means of reporting source brightnesses and the units employed have varied considerably. In recent years, however, 'magnitude' systems have been used less frequently, and the most popular unit for expressing brightnesses, both for point source fluxes and surface brightnesses, is steadily becoming the Jansky.

Conversion between Fν and Fλ

1Jy is defined as 10-26Wm-2Hz-1, so it is a unit of measurement of the spectral flux density, Fν.

For Fν in Jy, use the following formula:

Fλ=βFν/λ2, where λ is the wavelength in microns (µm), and β is a constant chosen from

Table 1 and depending on the units of Fλ. (This is simply derived, using the fact that dν/

dλ=c/λ2.)

Band (µm)	S (Jy)	Flux (Wm-2 µm-1)
(8.7)	53.0	2.10e-12
(9.8)	42.3	1.32e-12
N (10.1)	39.8	1.17e-12
(11.6)	30.5	6.81e-13
(12.5)	26.4	5.07e-13

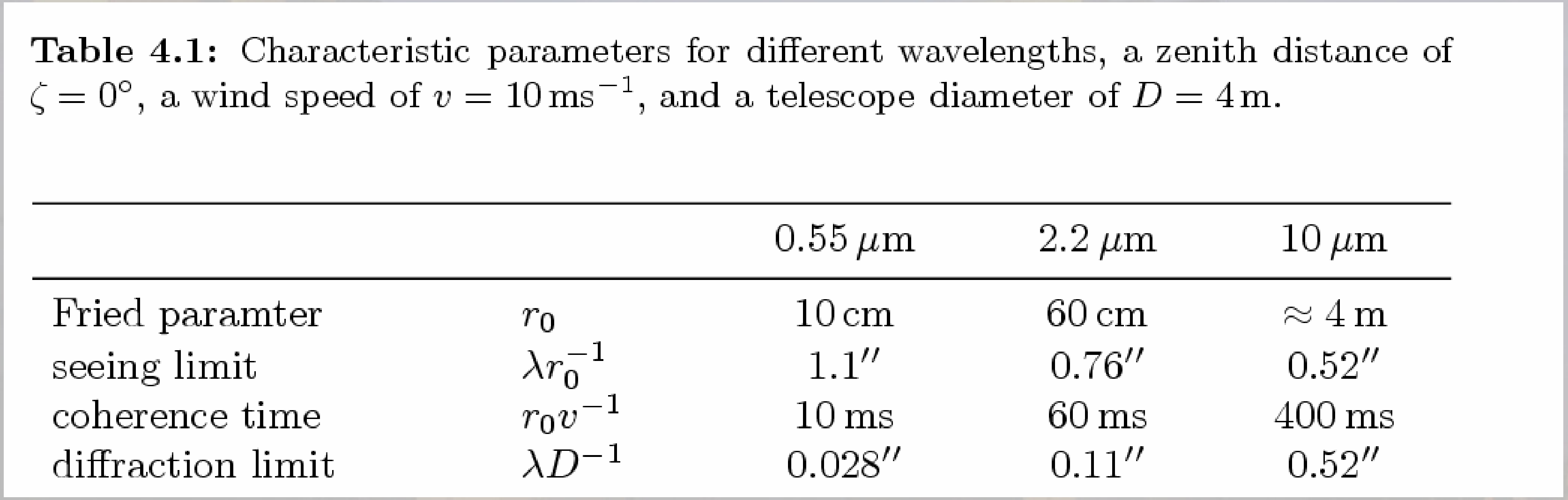
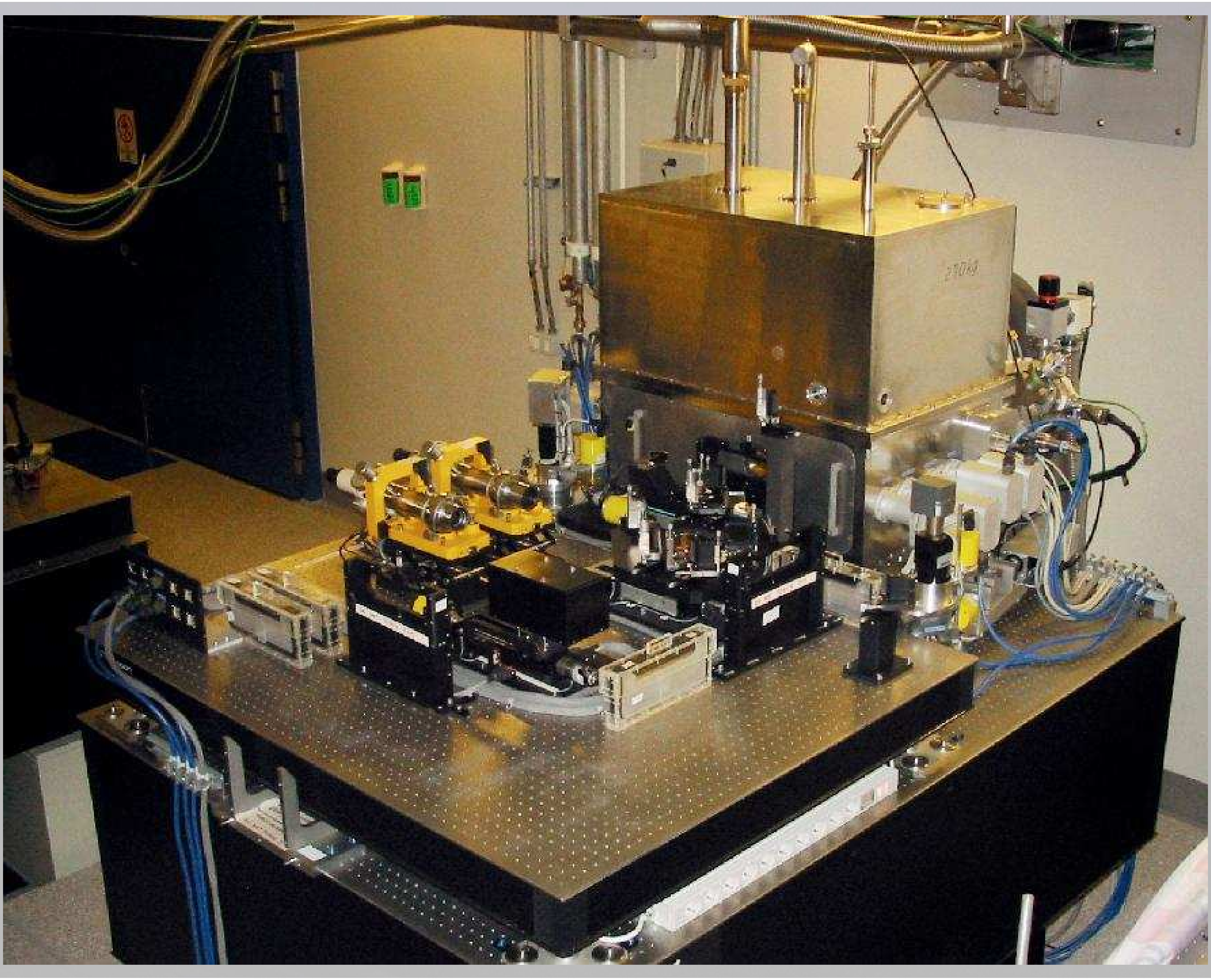
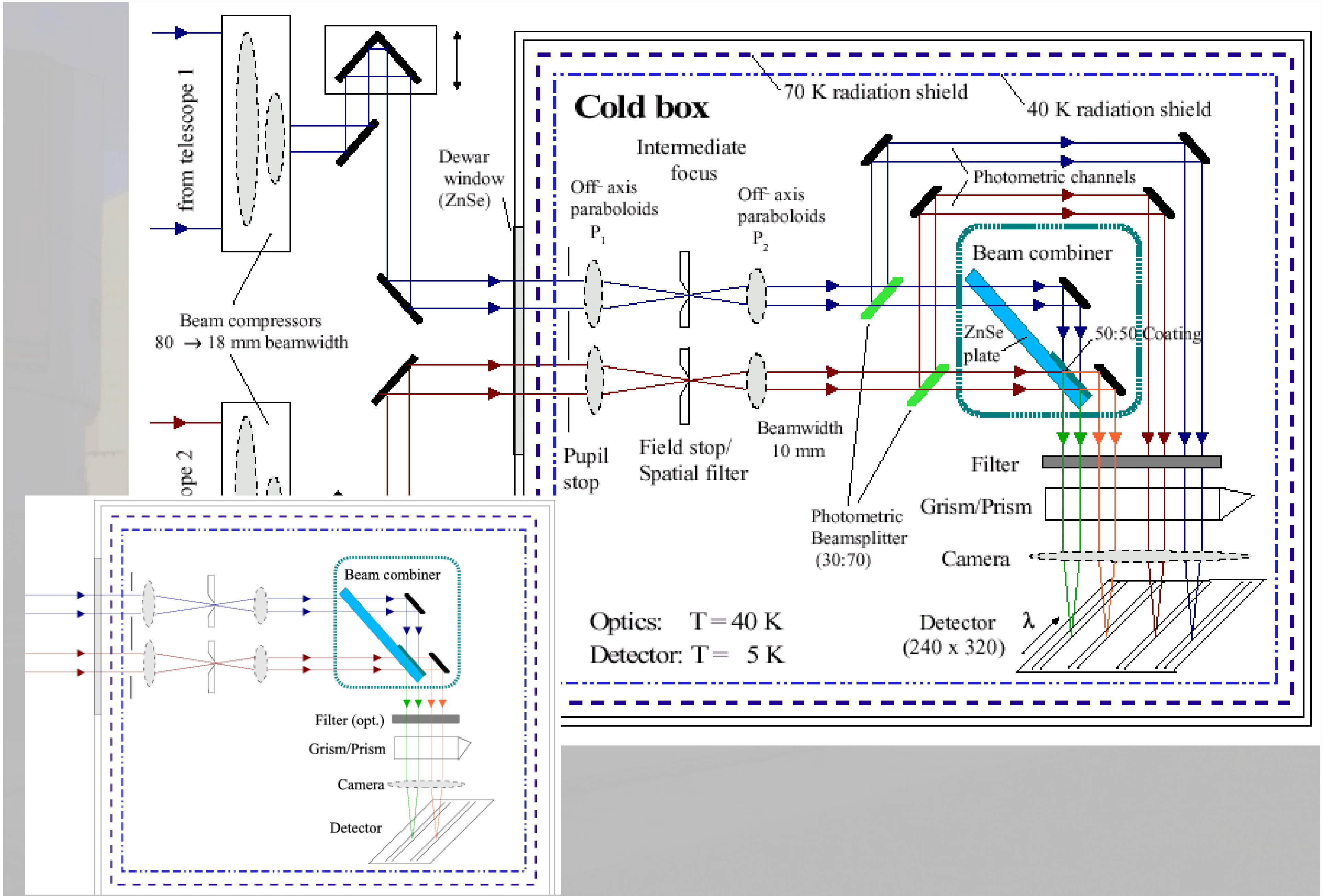


Table 4.1: Characteristic parameters for different wavelengths, a zenith distance of $\zeta = 0°$, a wind speed of $v = 10\,\mathrm{ms}^{-1}$, and a telescope diameter of $D = 4\,\mathrm{m}$.

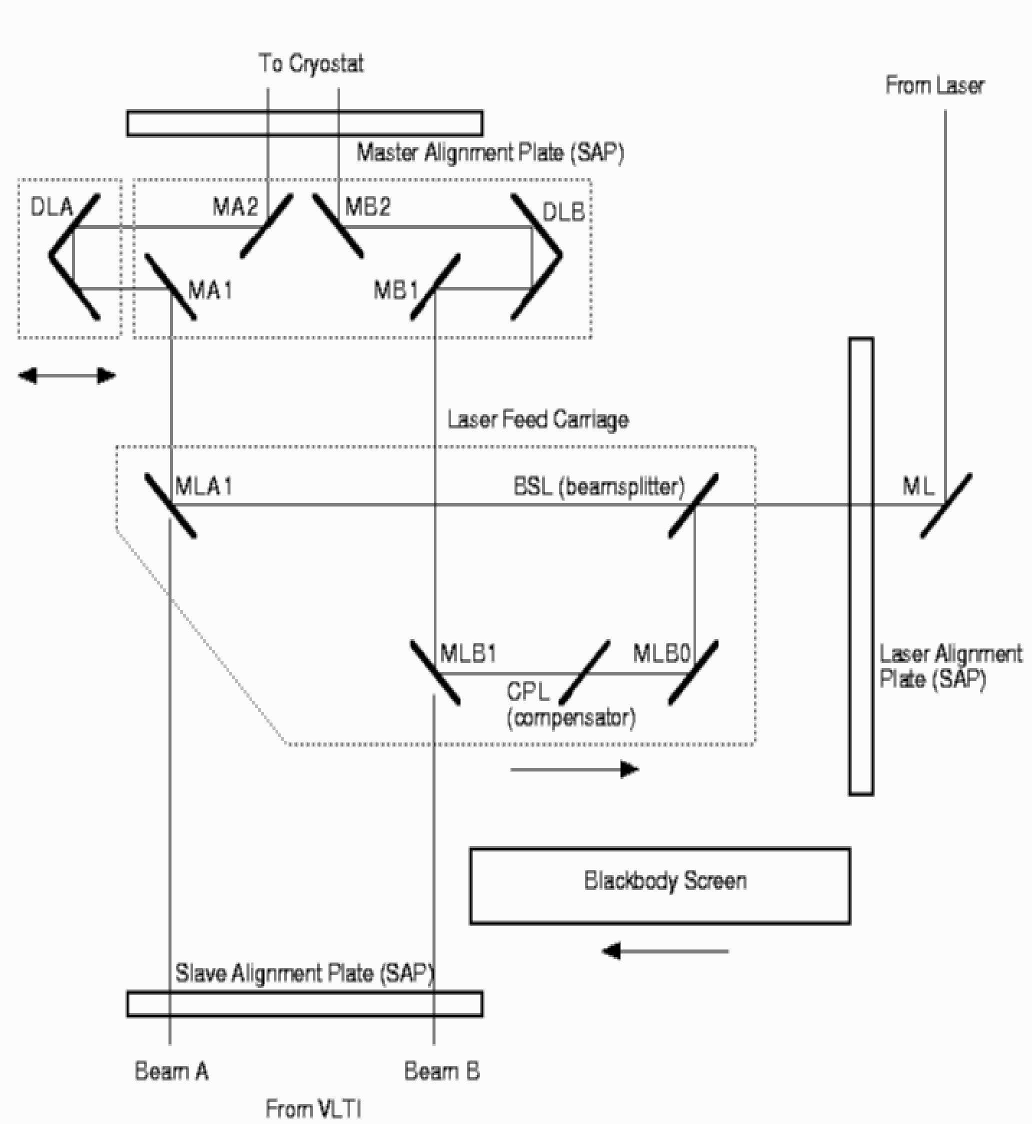
		0.55 μm	2.2 μm	10 μm
Fried paramter	r_0	10 cm	60 cm	≈ 4 m
seeing limit	λr_0^{-1}	1.1″	0.76″	0.52″
coherence time	$r_0 v^{-1}$	10 ms	60 ms	400 ms
diffraction limit	λD^{-1}	0.028″	0.11″	0.52″

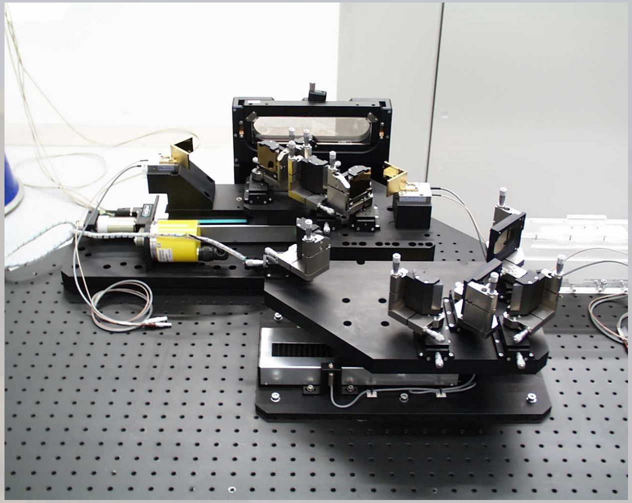
MIDI: no fibers, but good correction with adaptive optics

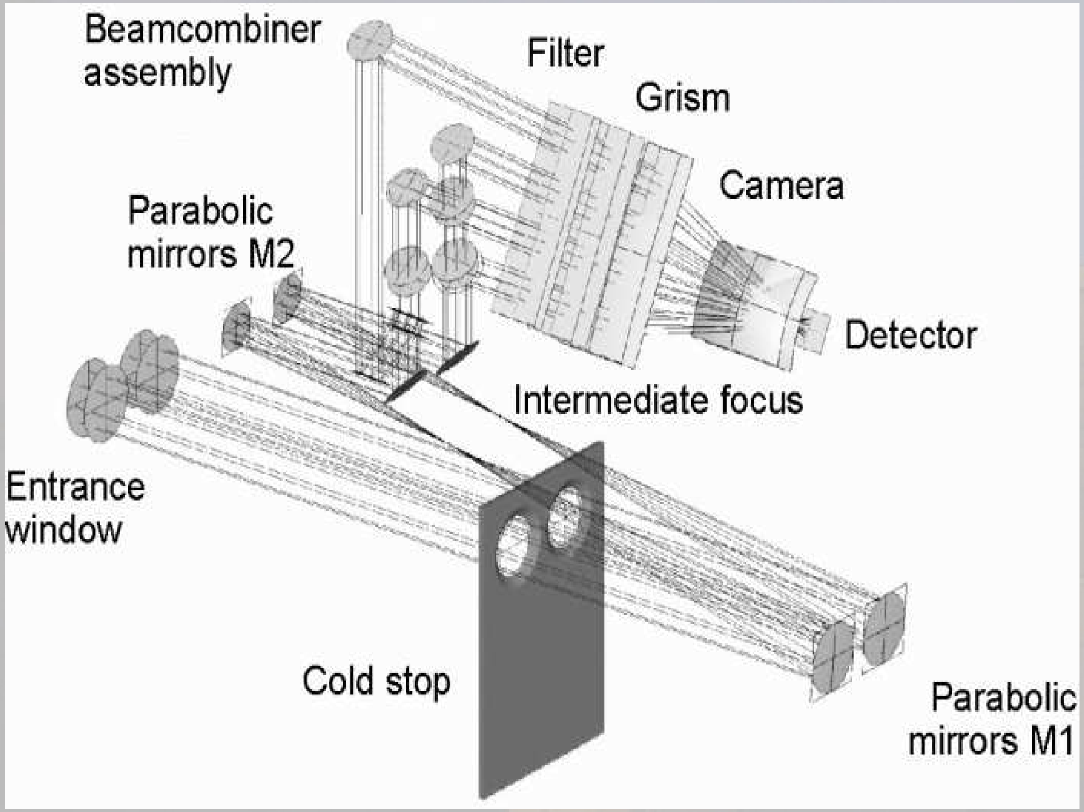



from telescope 1
ope 2
Beam compressors
80 → 18 mm beamwidth
Dewar
window
(ZnSe)
Cold box
70 K radiation shield
40 K radiation shield
Intermediate
focus
Off- axis
paraboloids
P_1
Off- axis
paraboloids
P_2
Photometric channels
Beam combiner
ZnSe
plate
50:50 Coating
Pupil
stop
Field stop/
Spatial filter
Beamwidth
10 mm
Photometric
Beamsplitter
(30:70)
Filter
Grism/Prism
Camera
Optics: T = 40 K
Detector: T = 5 K
Detector
(240 x 320)
λ
Beam combiner
Filter (opt.)
Grism/Prism
Camera
Detector

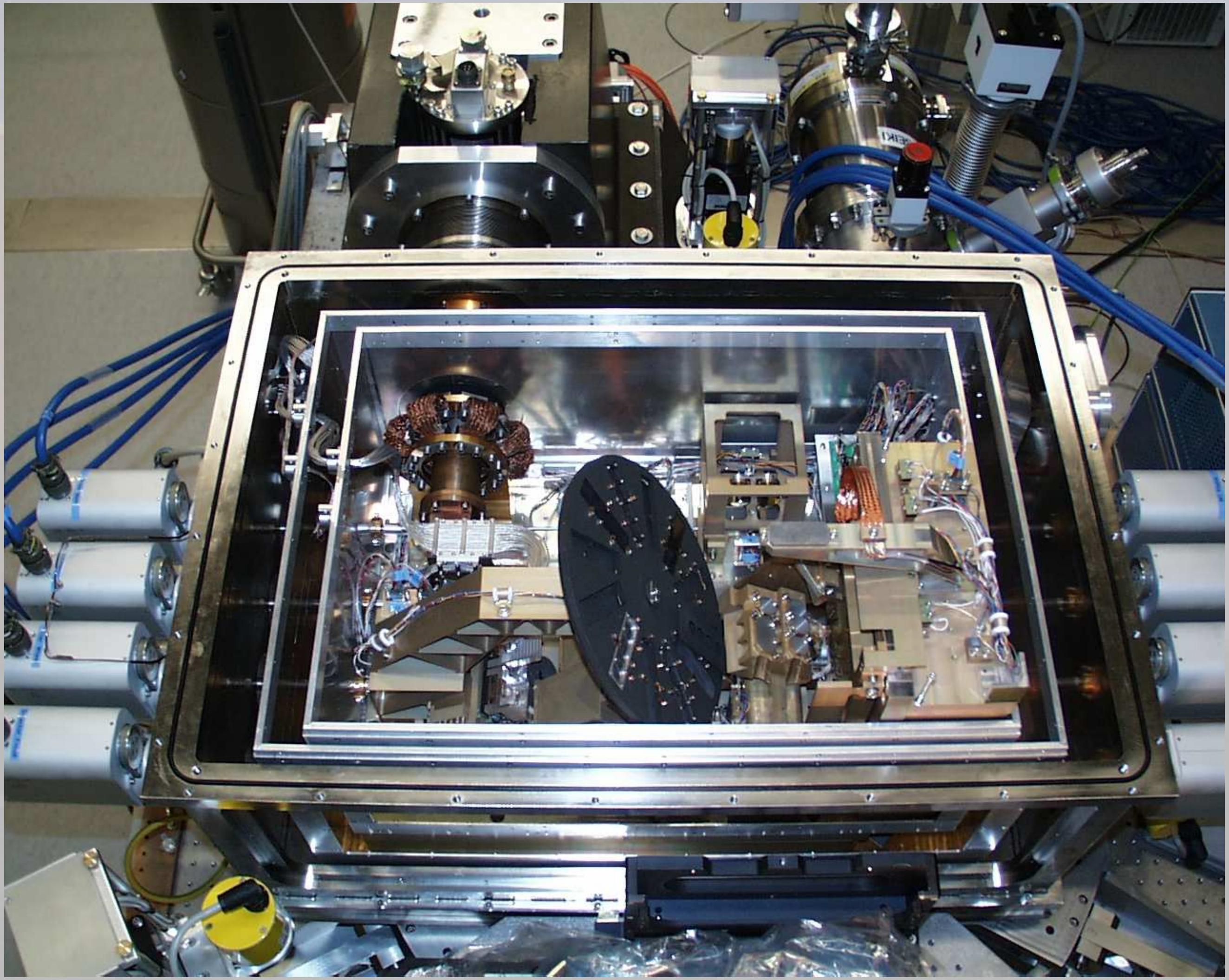
MIDI - Warm Optical Bench





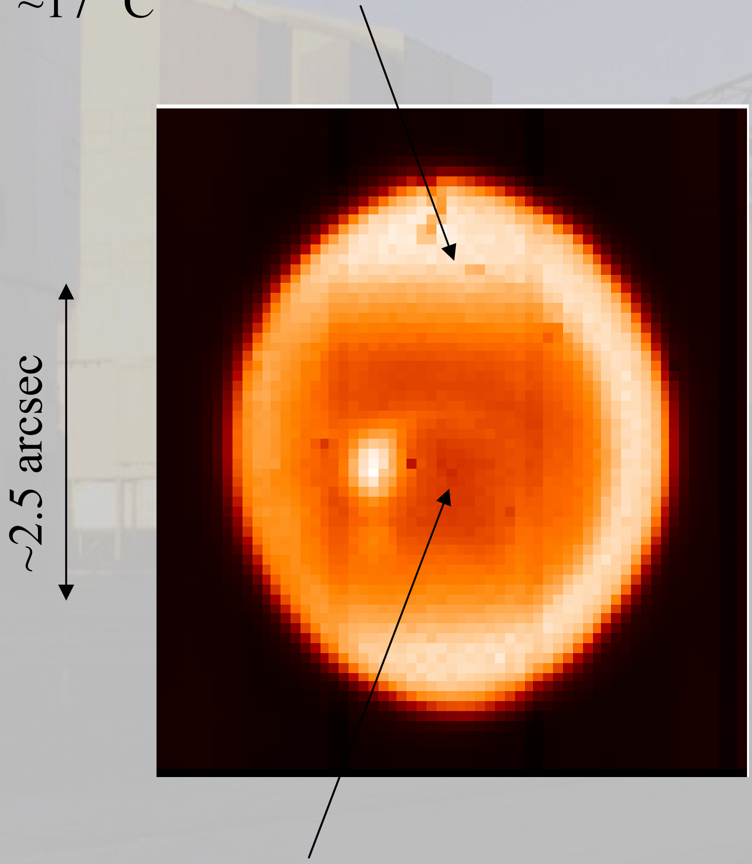


Inside the dewar



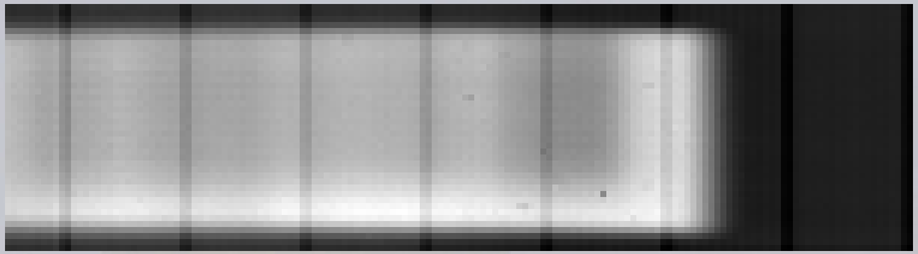
What sees MIDI?

Tunnel background
~17 °C

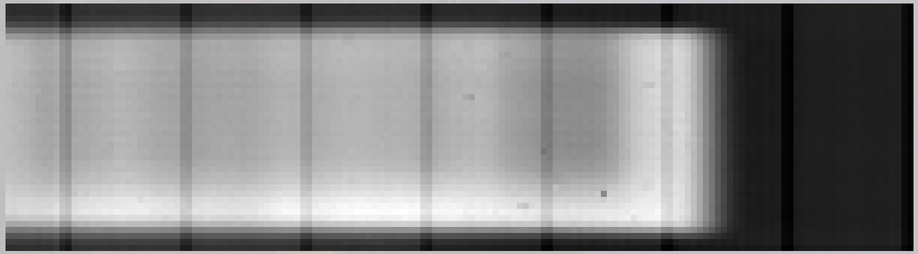


Sky background
~5-10 °C

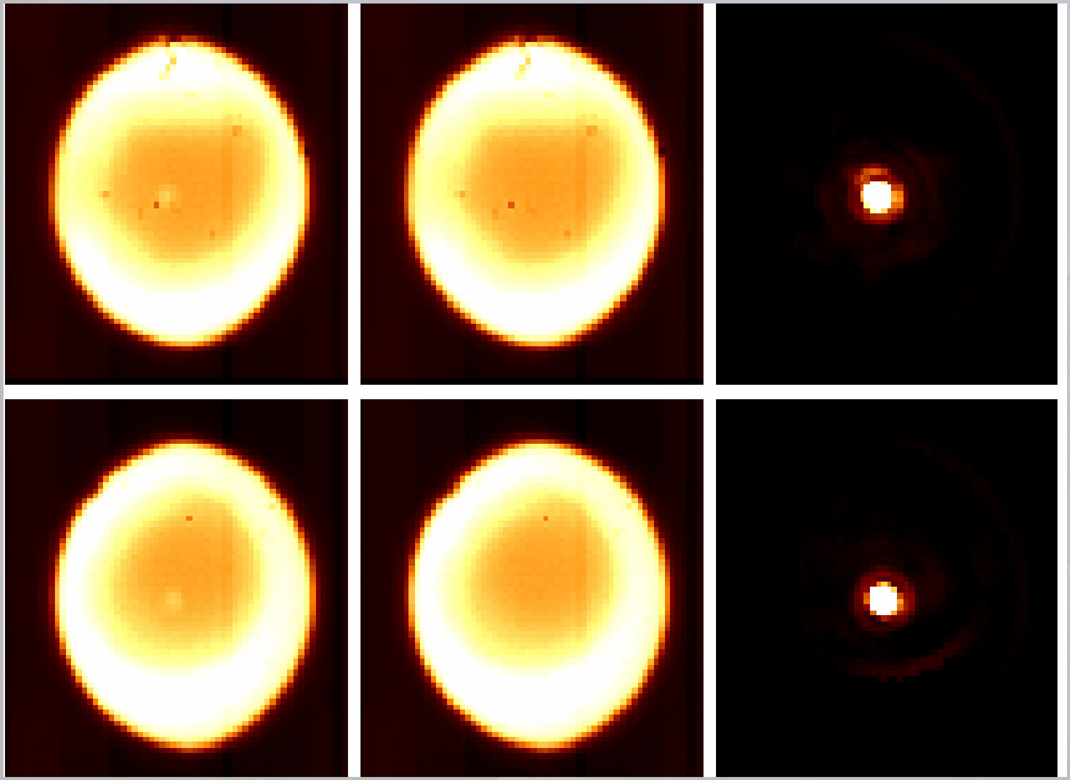
Sky exposure

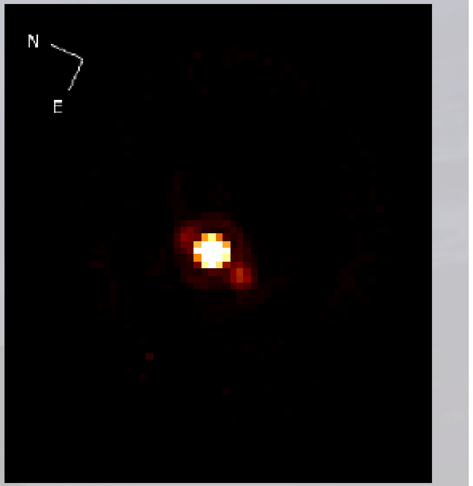


On source exposure



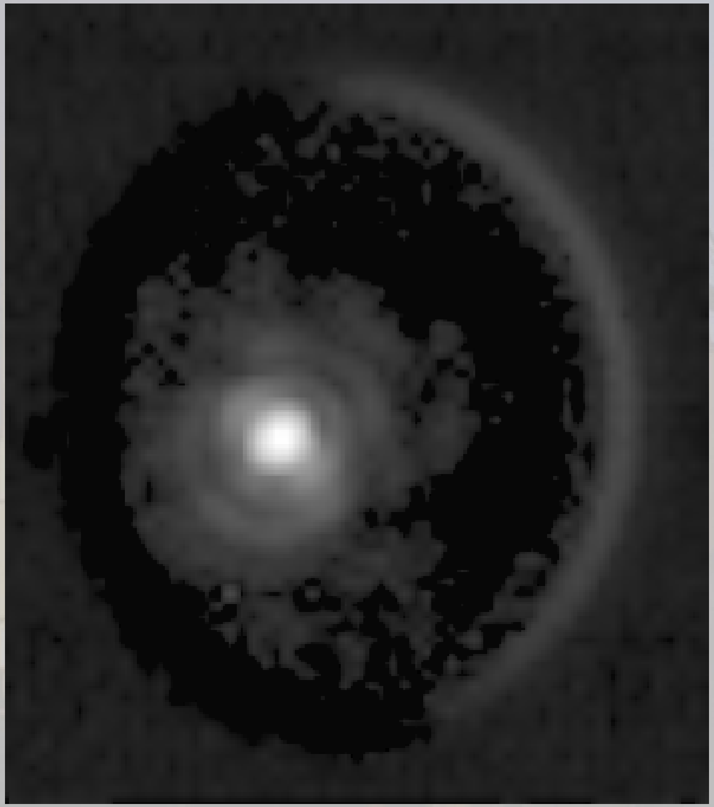
Chopped spectrum



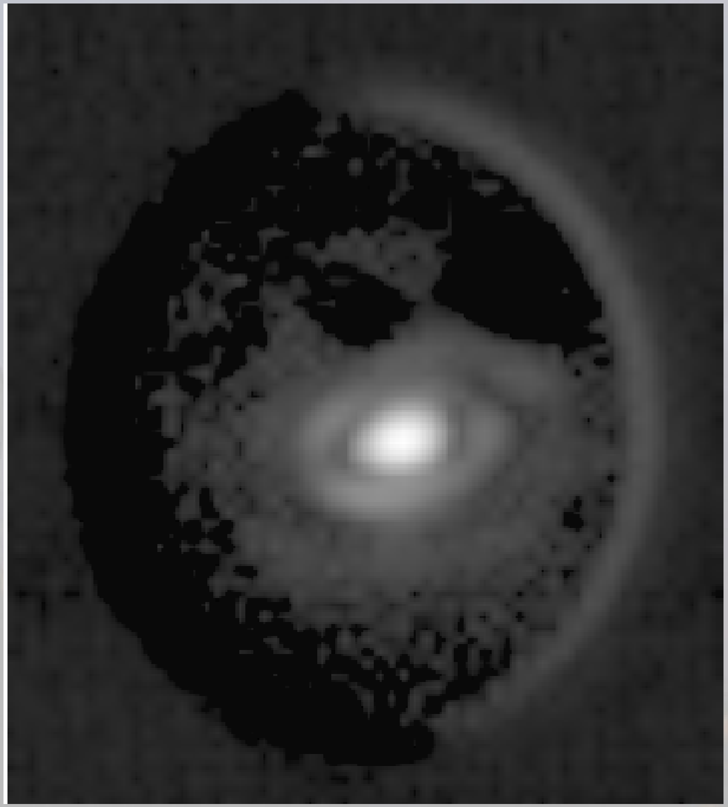


Binary Fu Orionis

Z CMa



Z CMa$^{1/4}$ Beam B

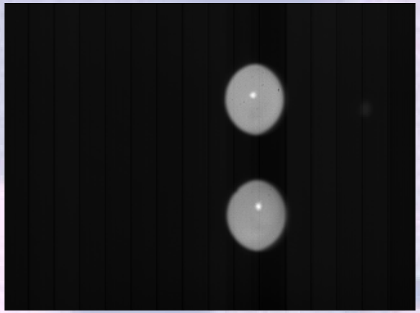


Z CMa$^{1/4}$ Beam A

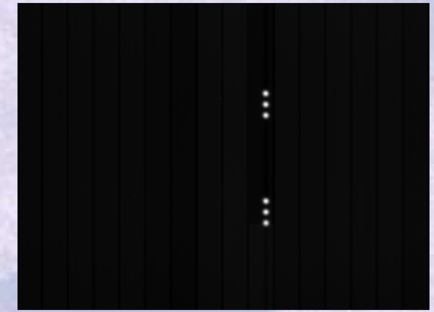
MIDI - Detector

Detector: 320 x 240 pixels

Acquisition (Field Camera)

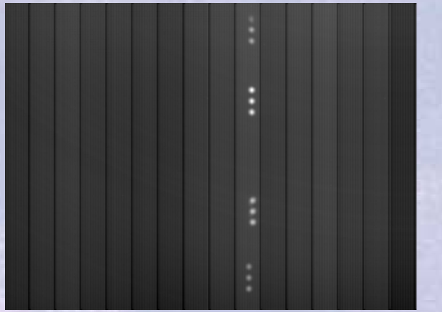


High-Sens Mode



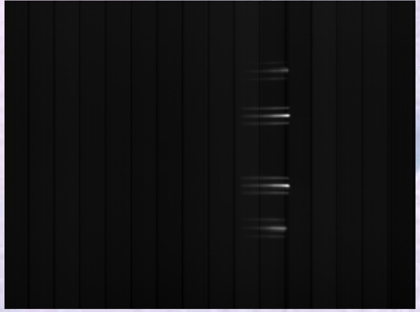
Typical exposure time: 4ms

Sci-Phot Mode



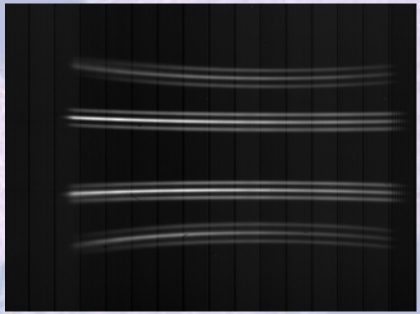
70% Interferom., 30% Photom.

Dispersion with Prism

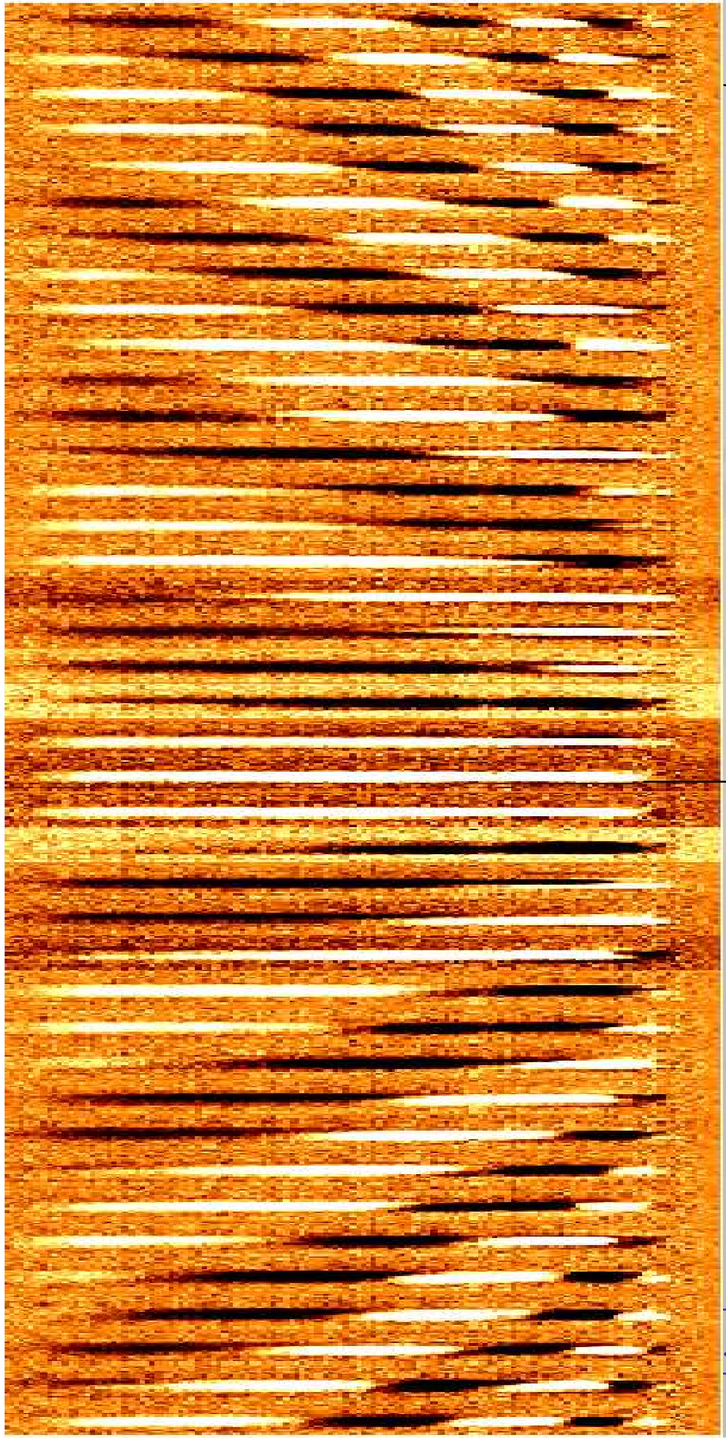


λ= 8 - 13.5µm, R = ~ 25
Typical exposure time: 15-20 ms

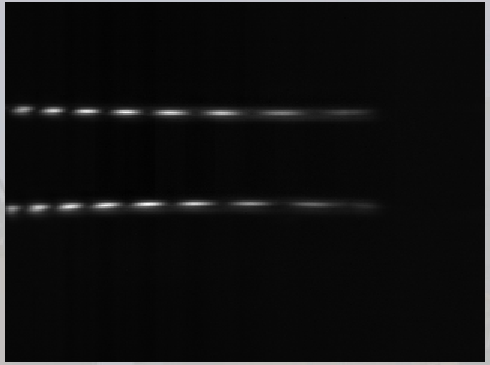
Dispersion with Grism



λ= 8 -13.75 µm, R = 230
Typical exposure time: 30-40 ms



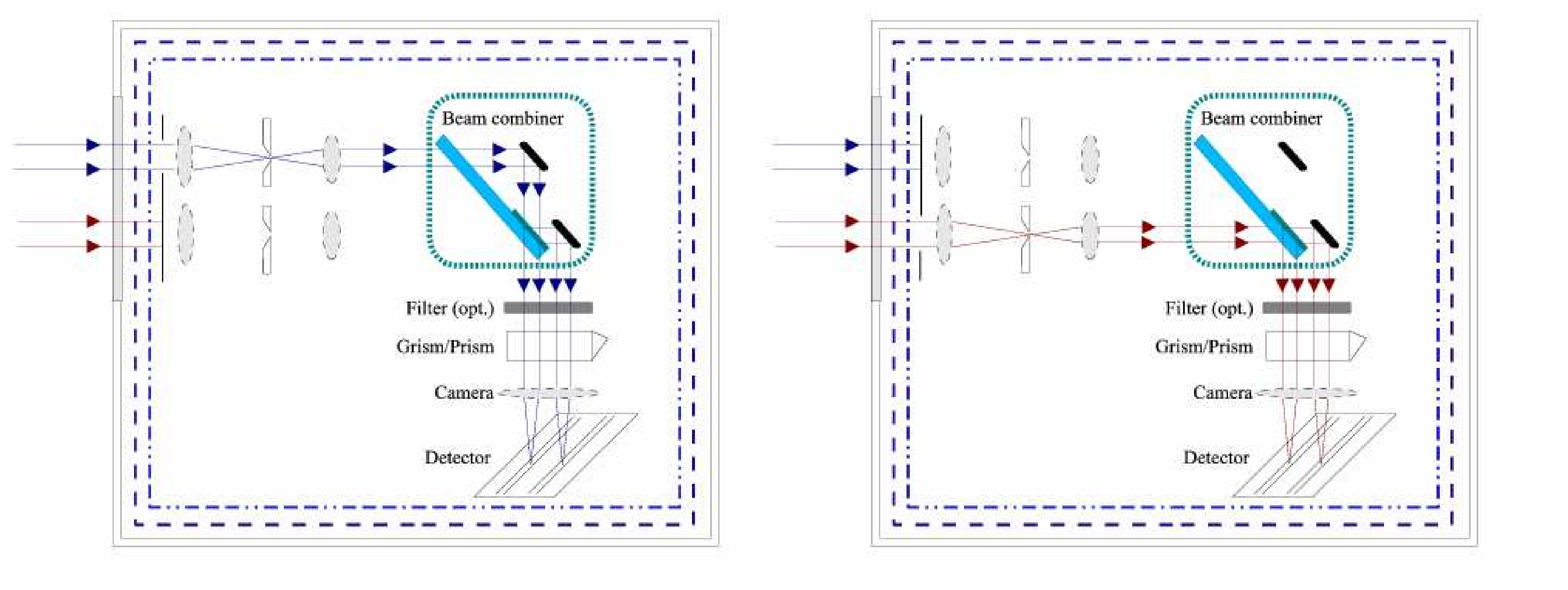
Limit of the scan



Zero OPD: white fringe at all wavelengths

From PhD of Thorsten Ratzka

Delayed Photometric Calibration



High Sens mode: the photometric calibration is done afterwards
Beam A (PA) and beam B (PA): a few minutes later

From PhD of Thorsten Ratzka

The two observing modes of MIDI

High Sensitivity mode:
Fringe tracking: exclusively on the source, no chopping
2 windows
Photometry of telescope A: shutter B, beam combiner inserted, chopping
2 windows located at the same place in the detector
Advantage: simple data sets in the same detector position
Drawback: Photometry performed at 2-5 minutes intervals. The accuracy on the visibility is typically 7-15% under good to medium atmospheric conditions,

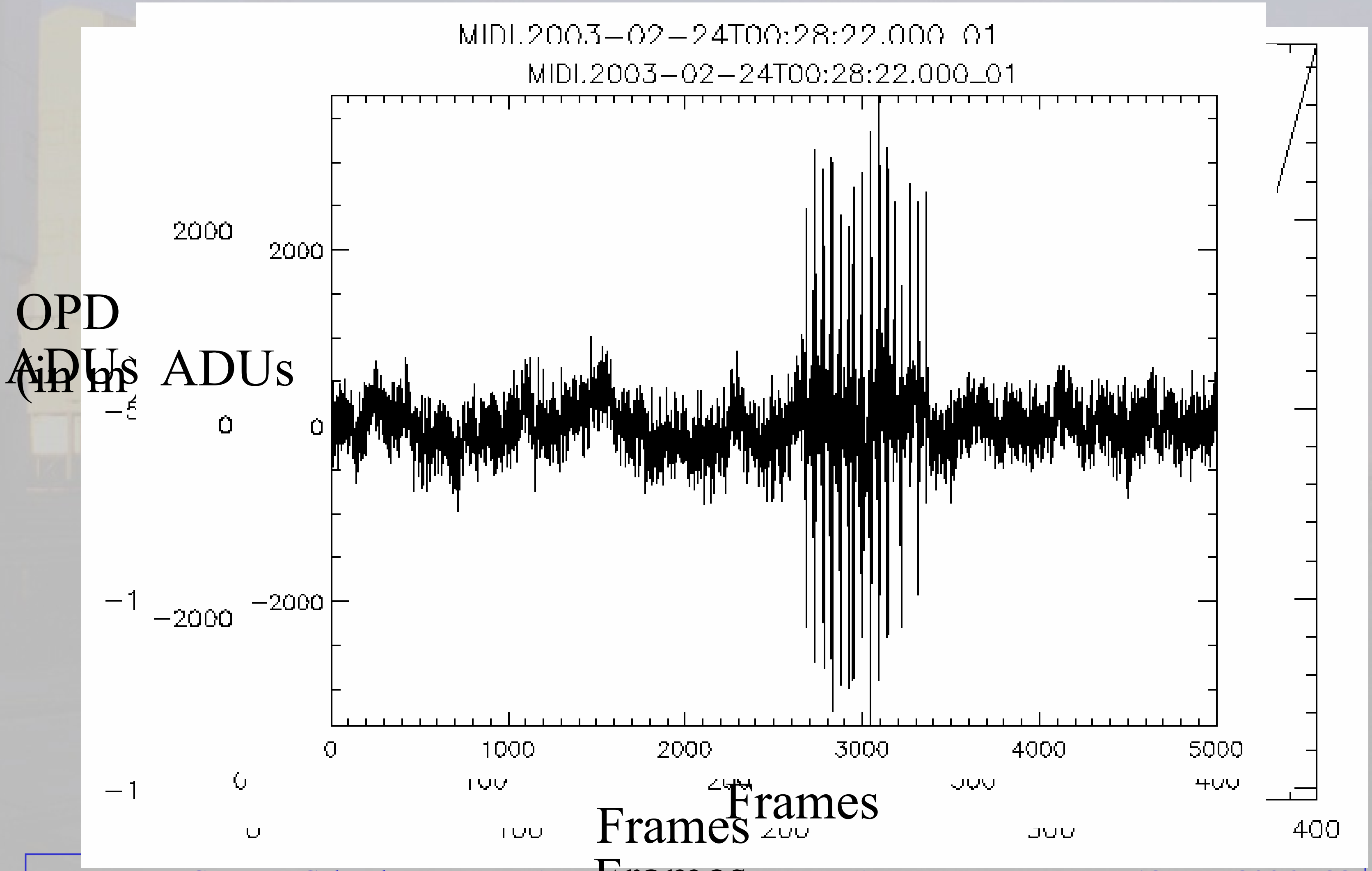
Science Photometry mode
Fringe tracking: chopping working at a frequency which is an integer mulitplier scanning of the scanning frequency
4 windows: 2 interferometric, 2 photometric
Advantage: simultaneous photometry
Drawbacks: chopping simultaneously with scanning, heavy real time control
: distorsion of the photometric beams, added detector noise

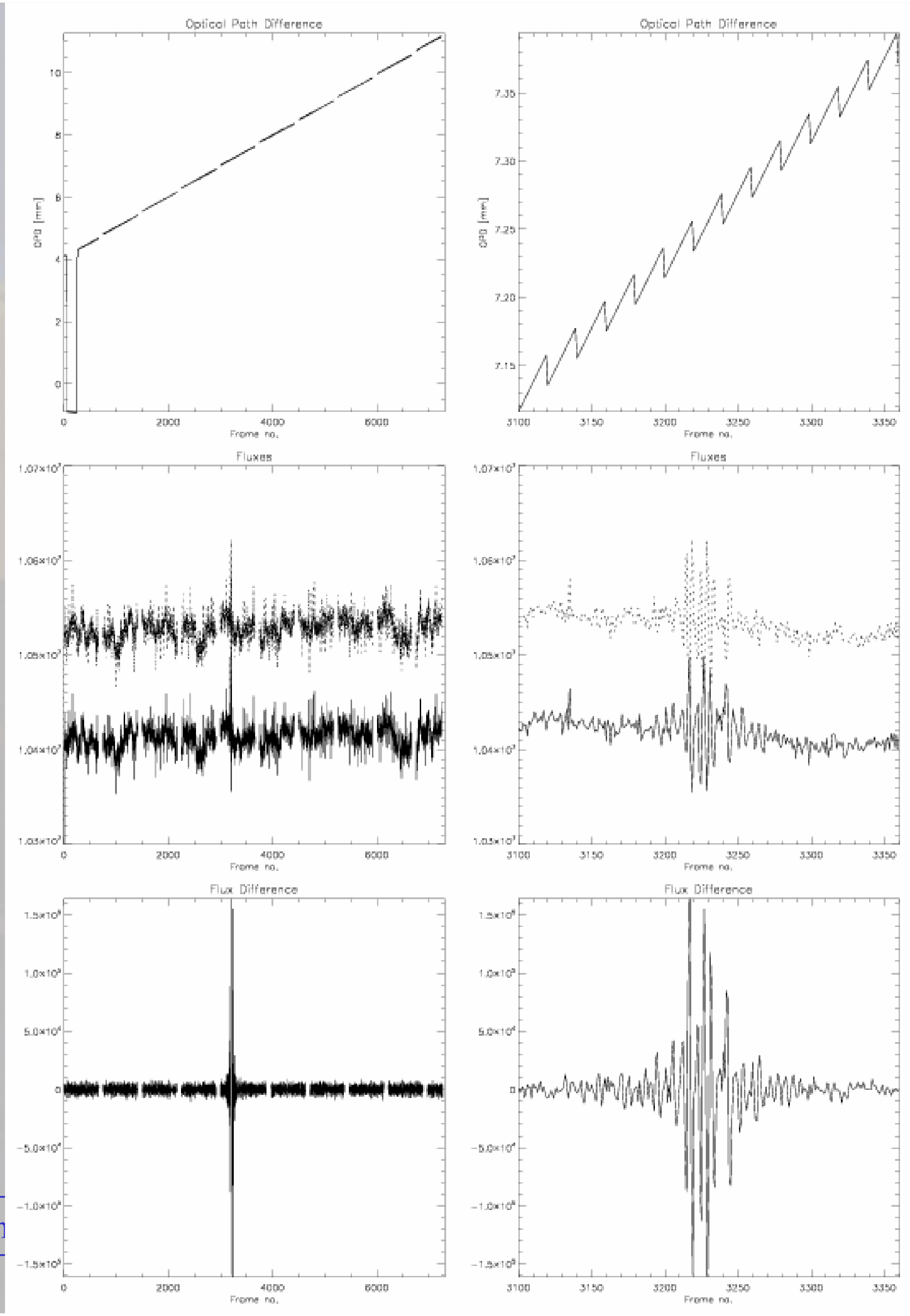
Unknow: coupling coefficients: is MIDI stable?

Fine Acquisition

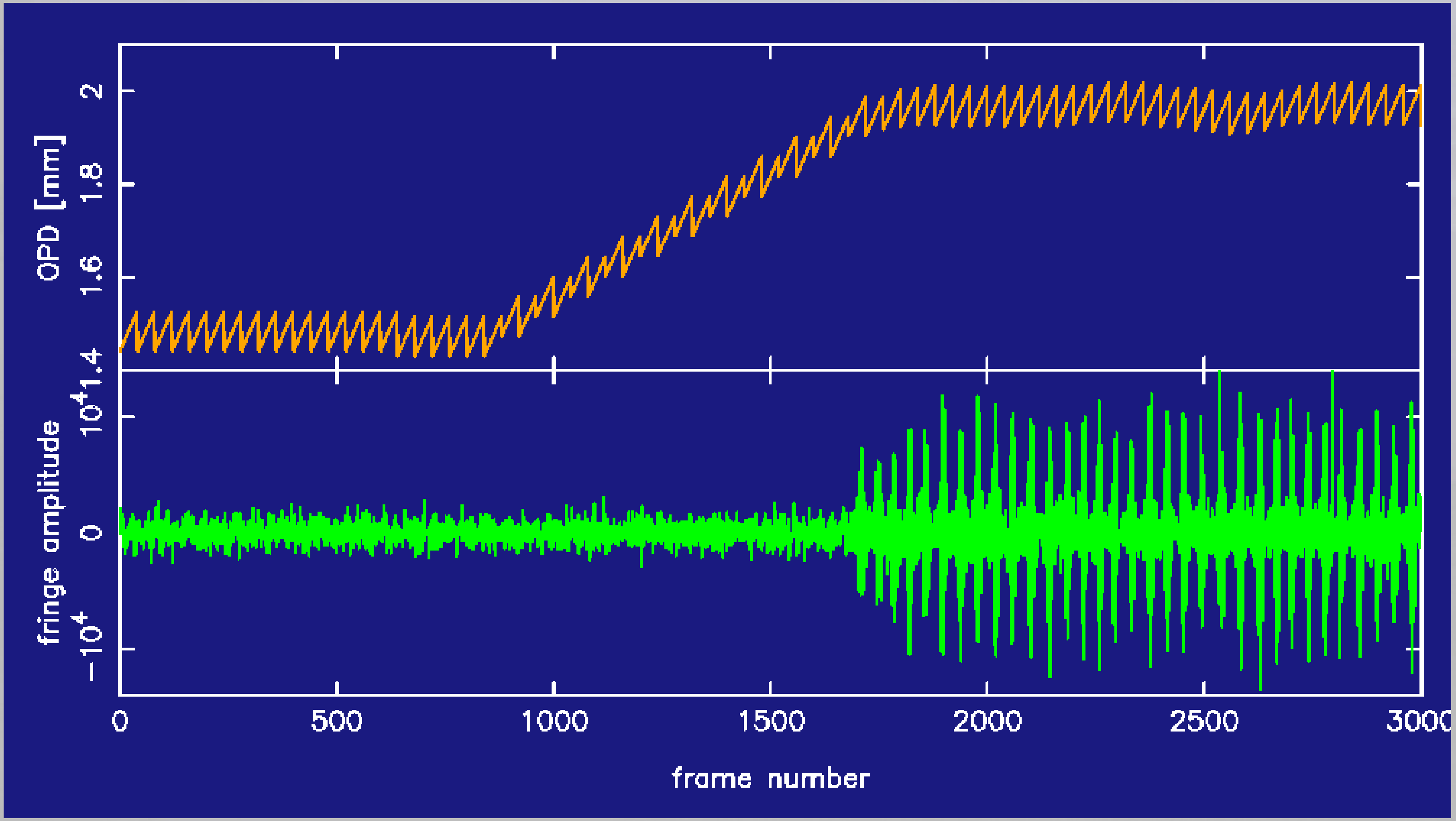
Fine Acquisition: about 5 min

Fringe Search

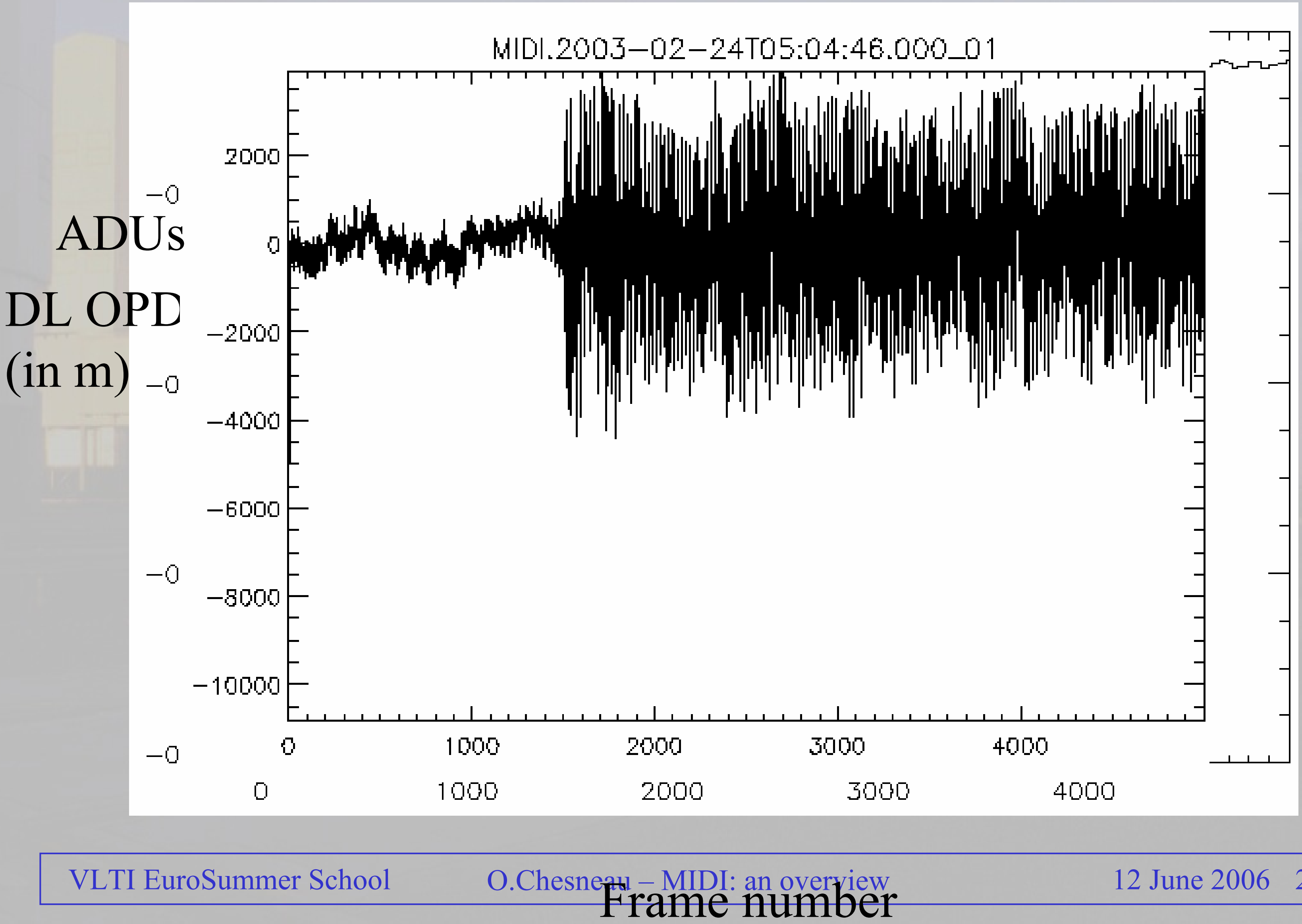



Optical Path Difference
OPD [mm]
0
2
4
6
8
10
0
2000
4000
6000
Frame no.
Optical Path Difference
OPD [mm]
7.15
7.20
7.25
7.30
7.35
3100
3150
3200
3250
3300
3350
Frame no.
Fluxes
1.03×10⁷
1.04×10⁷
1.05×10⁷
1.06×10⁷
1.07×10⁷
0
2000
4000
6000
Frame no.
Fluxes
1.03×10⁷
1.04×10⁷
1.05×10⁷
1.06×10⁷
1.07×10⁷
3100
3150
3200
3250
3300
3350
Frame no.
Flux Difference
1.5×10⁵
1.0×10⁵
5.0×10⁴
0
−5.0×10⁴
−1.0×10⁵
−1.5×10⁵
0
2000
4000
6000
Frame no.
Flux Difference
1.5×10⁵
1.0×10⁵
5.0×10⁴
0
−5.0×10⁴
−1.0×10⁵
−1.5×10⁵
3100
3150
3200
3250
3300
3350
Frame no.

Fringe track



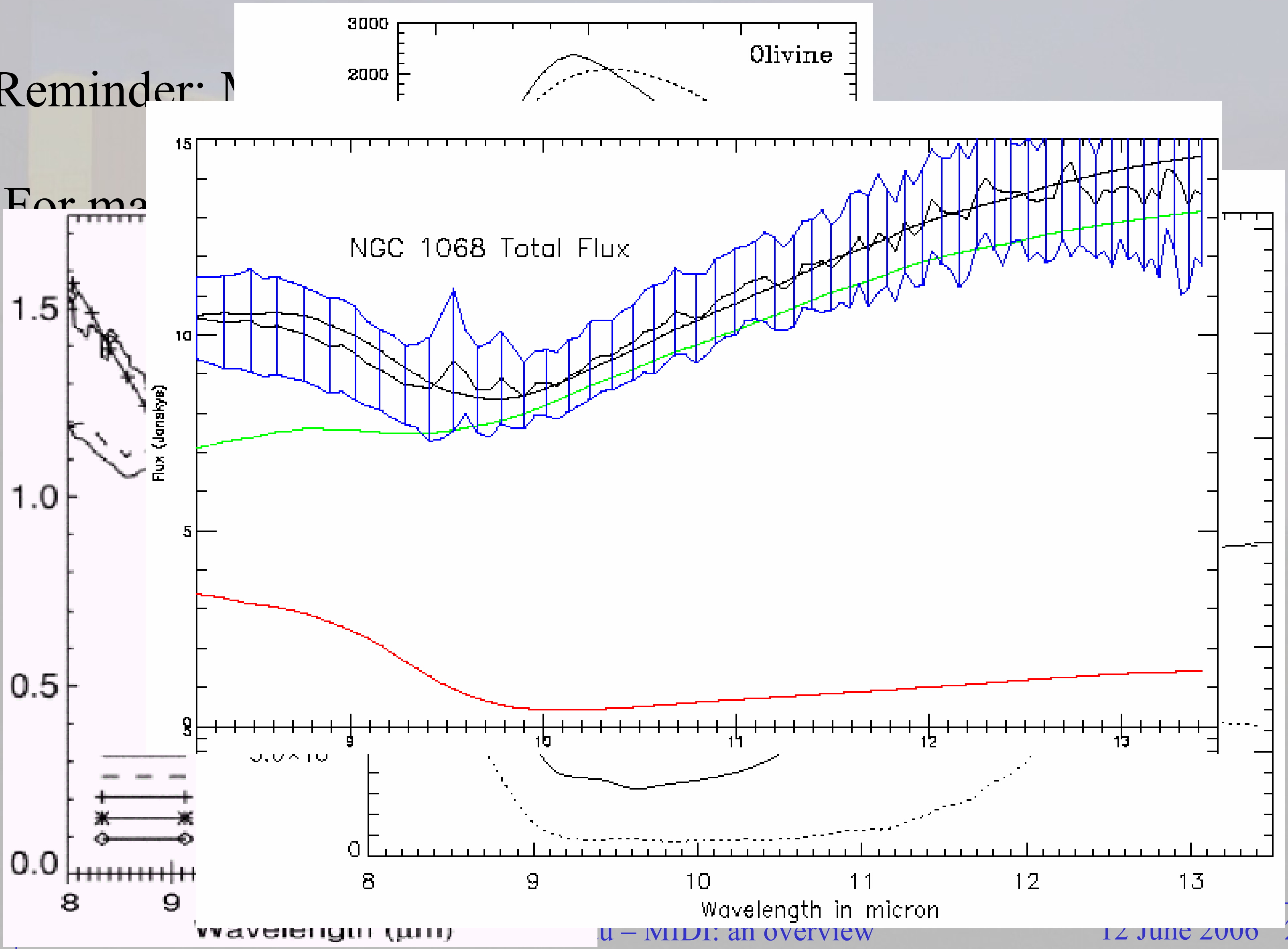
Fringe track About 3-5 min



Do you know the spectral structure of your objects?

Reminder: N

For ma



Other kind of spectra

Carbon chemistry with PAHs features

Emission lines:
[NeII]12.8 micron
[SiIV]10.5 micron
and others

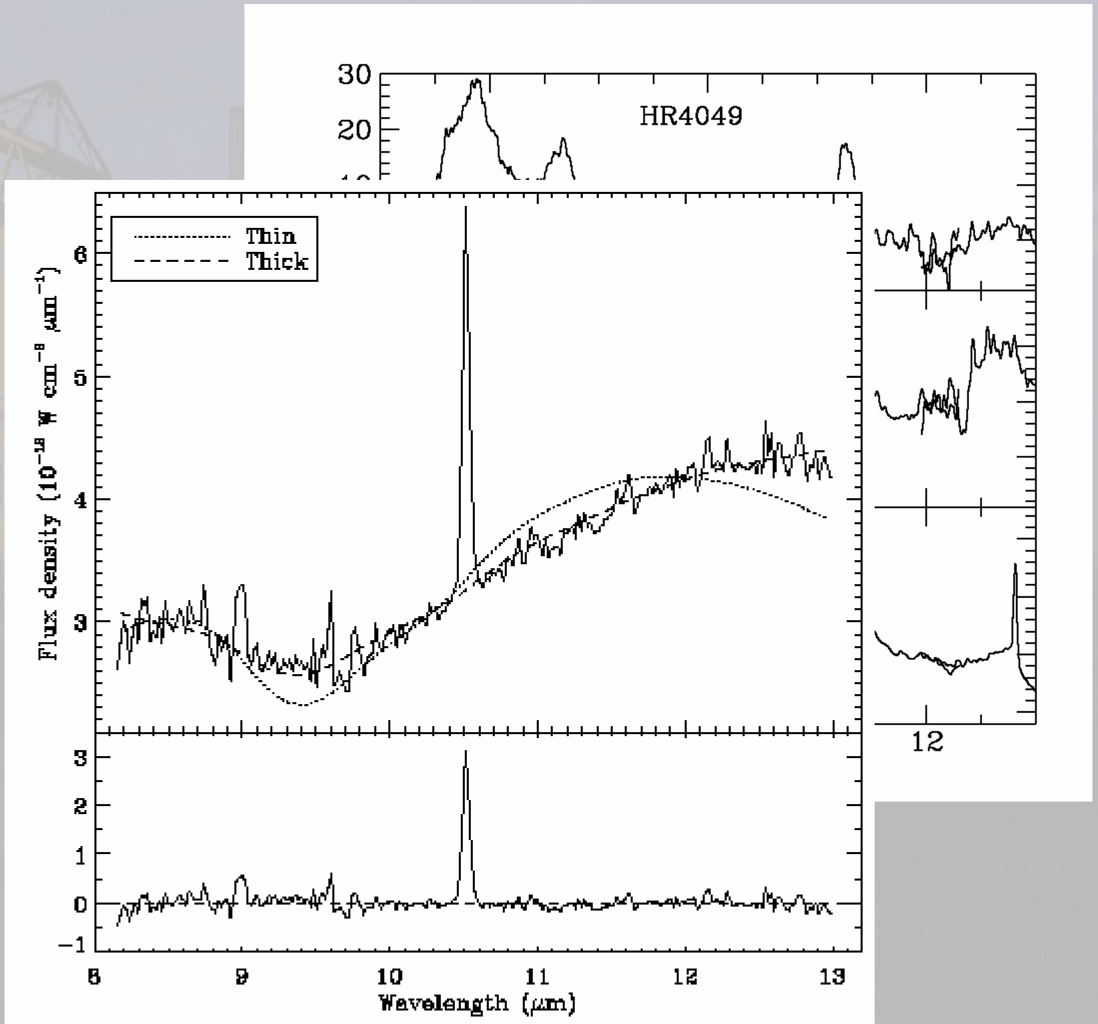


Fig. 3 – TIMMI2 *N*-band spectrum of NGC 5253–C2

Do you have an idea the shape of your object?

MIDI is a 2-Telescope interferometer

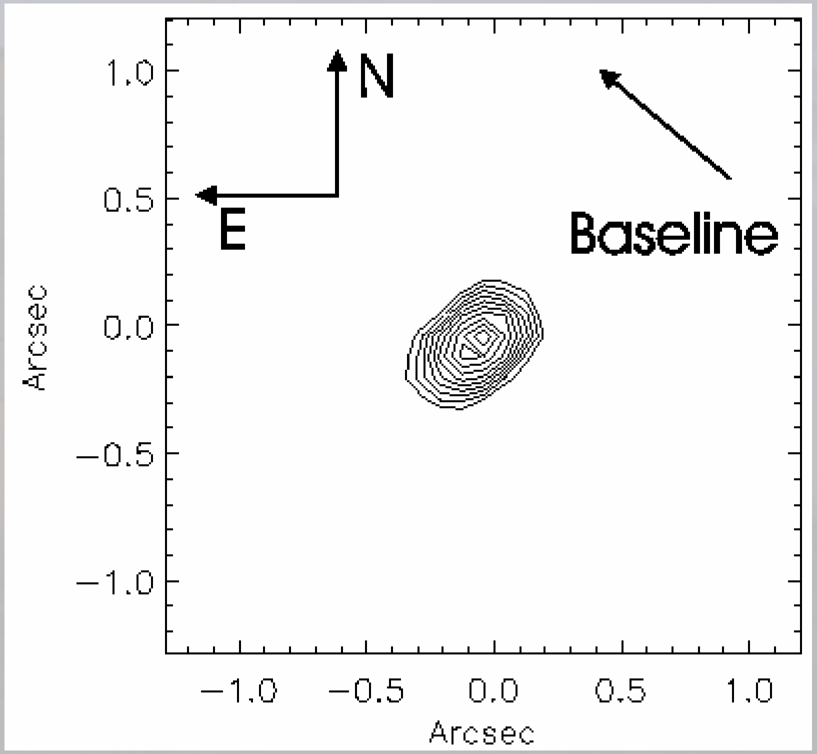
The object studied depart often from spherical symetry

When you expect a disk-like structure,
do you know its main direction?

Great help: radio observations,

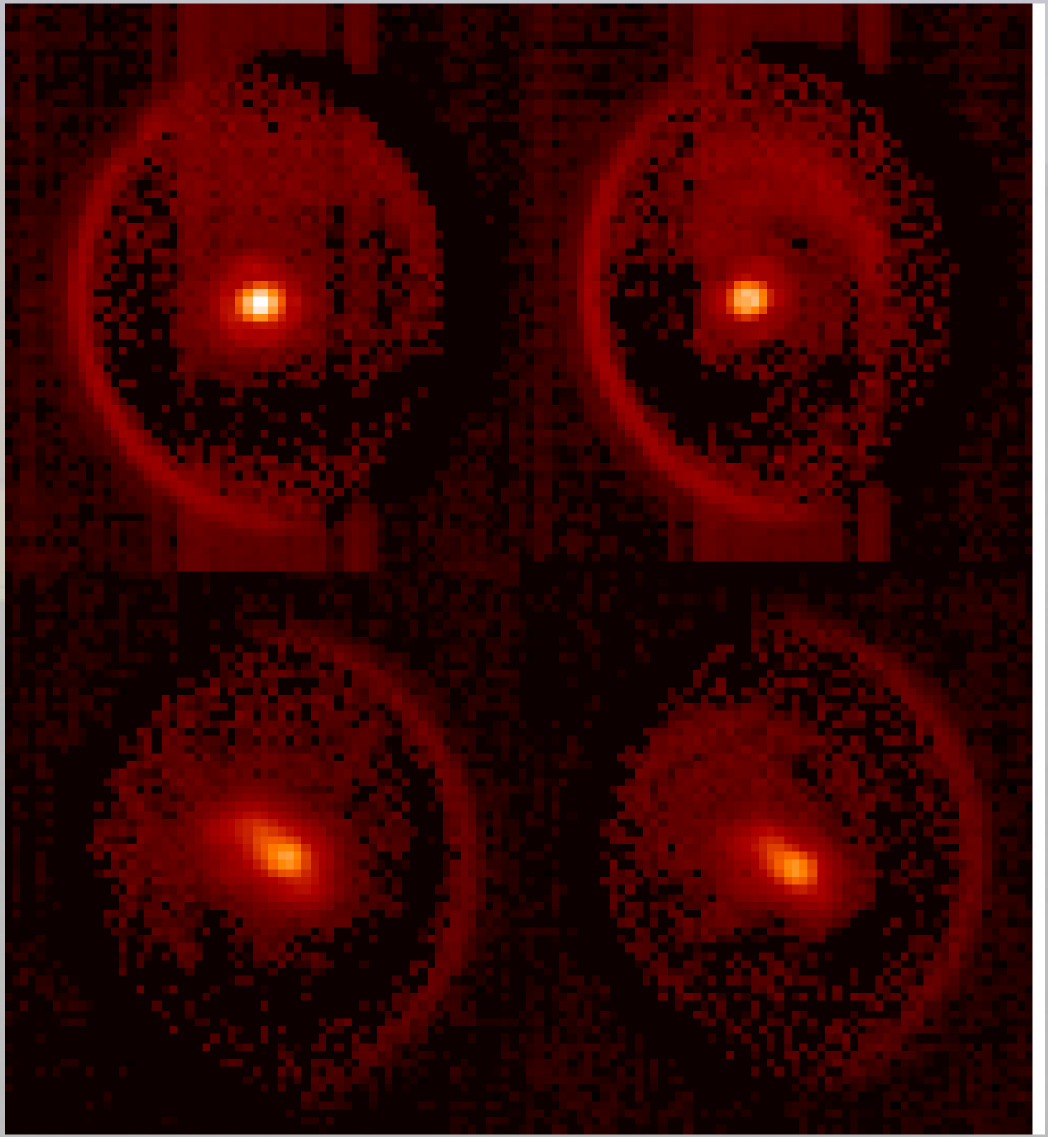
Best tool: polarimetry!

Example: HD 100546, Herbig AeBe star,
almost resolved by a single UT (300mas)
The direction coincide to millimetric observations and
the polarimetry of the object



FWHM=90/160 mas

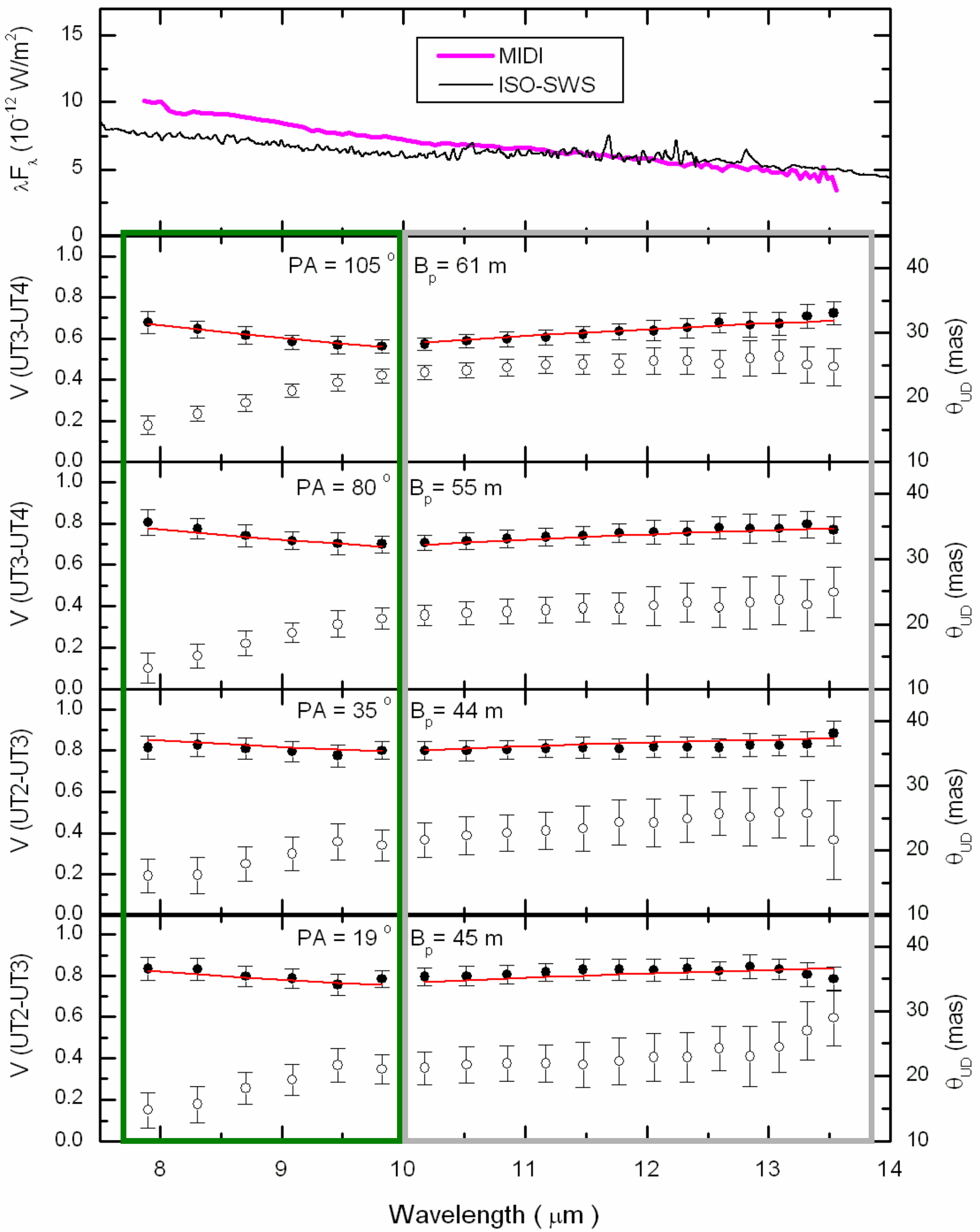
The AGN NGC 1068



Calibrator

NGC 1068

VLTI/MIDI spectrum and visibilities



Domiciano de Souza, Driebe, Chesneau et al. 2006 A&A (astro-ph/0510735)

B[e] supergiant star CPD-57° 2874

Gaussian models:

$2a = (10.1\pm0.7) + (2.6\pm0.4)\,(\lambda - 8\mu m)$ mas

Axial ratio $2b/2a = 0.76 \pm 0.11$

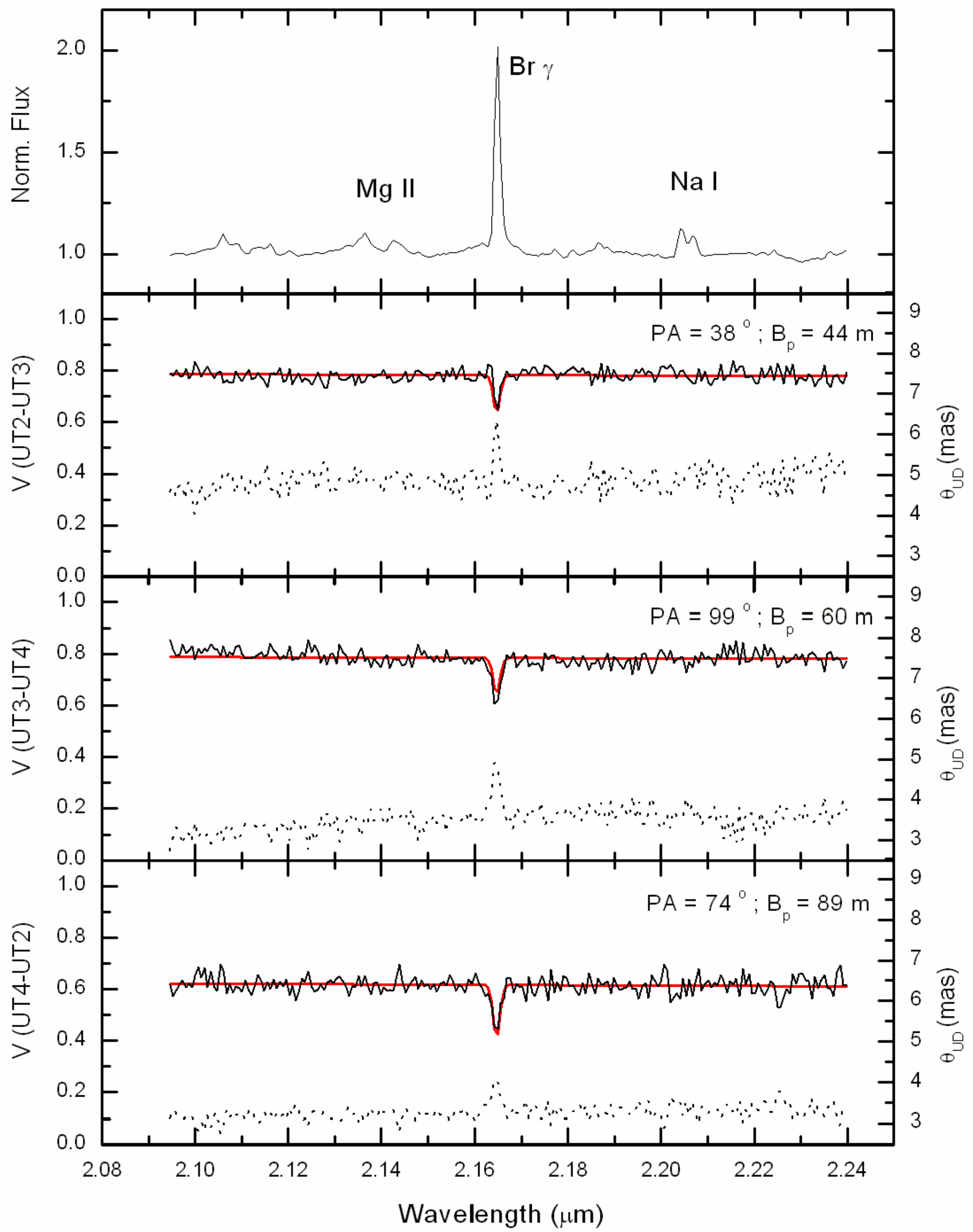
Position angle PA = 145° ± 6°

$2a = (15.3\pm0.7) + (0.45\pm0.22)\,(\lambda - 12\mu m)$ mas

Axial ratio $2b/2a = 0.80 \pm 0.10$

Position angle PA = 143° ± 6°

VLTI/AMBER spectrum and visibilities



Gaussian models:

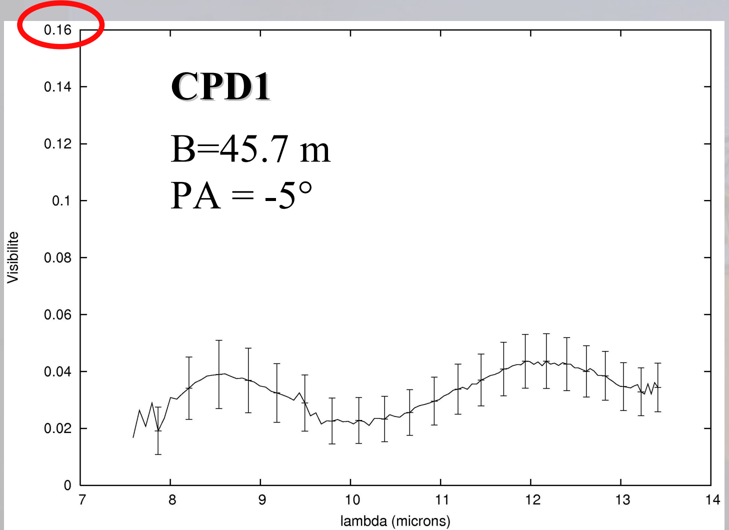
2a = (3.4±0.2) + (1.99±0.24) (λ-2.2μm) mas

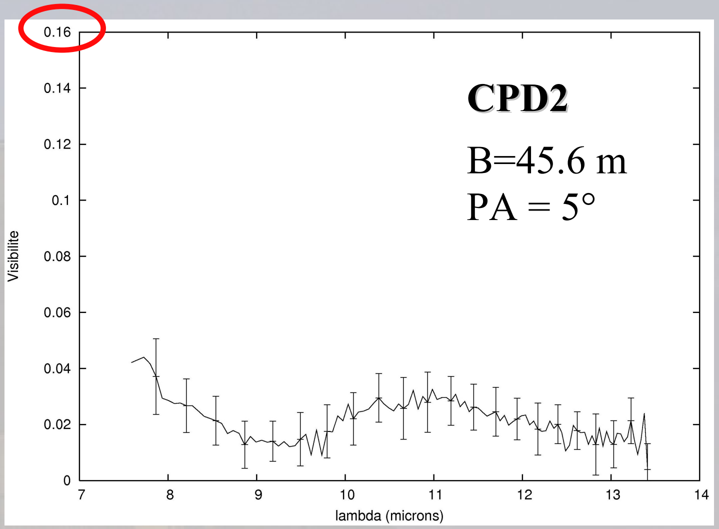
Axial ratio 2b/2a = 0.53 ±0.03

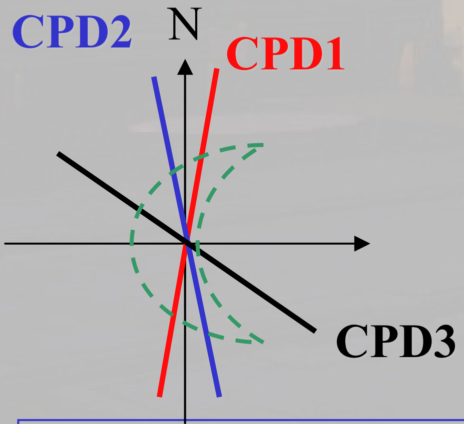
Position angle PA = 173° ± 9°

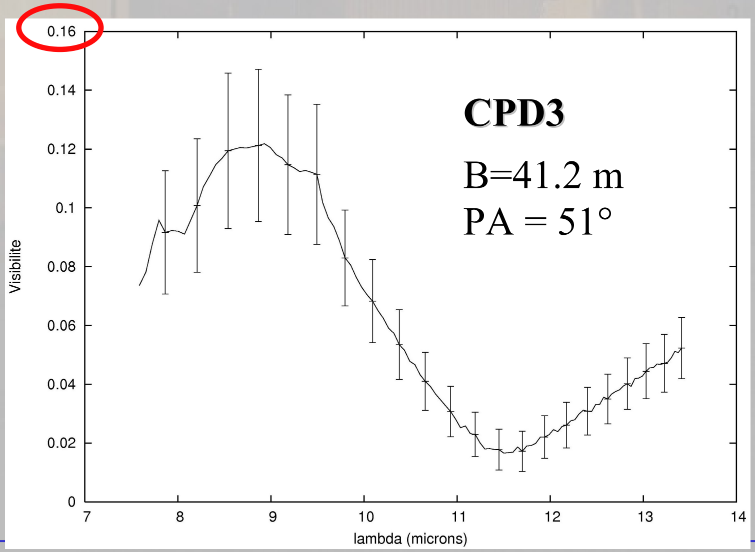
Brγ ➔ 2a = 4.5±0.3 mas ; Δλ=1.8 ±0.2 10^{-3} μm

MIDI data on CPD-56°8032



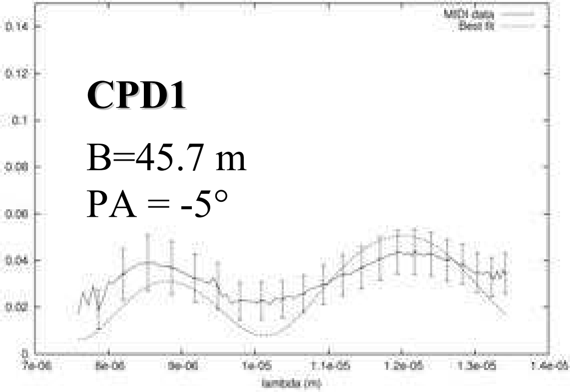






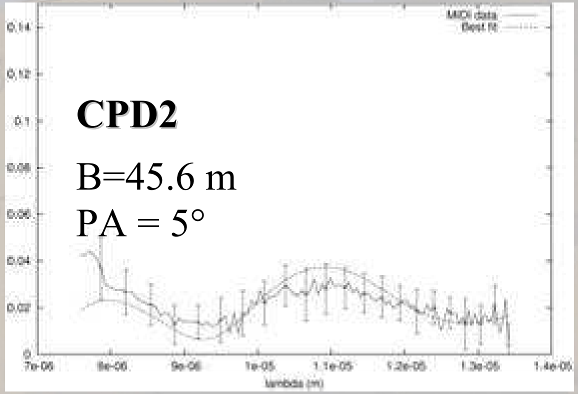
Résolution
36 mas à 8 µm
60 mas à 13.5 µm

Best geometrical model for CPD-56°8032 ?



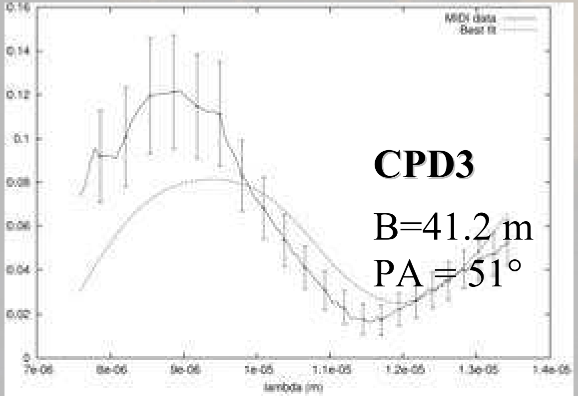
CPD1

B=45.7 m
PA = -5°



CPD2

B=45.6 m
PA = 5°

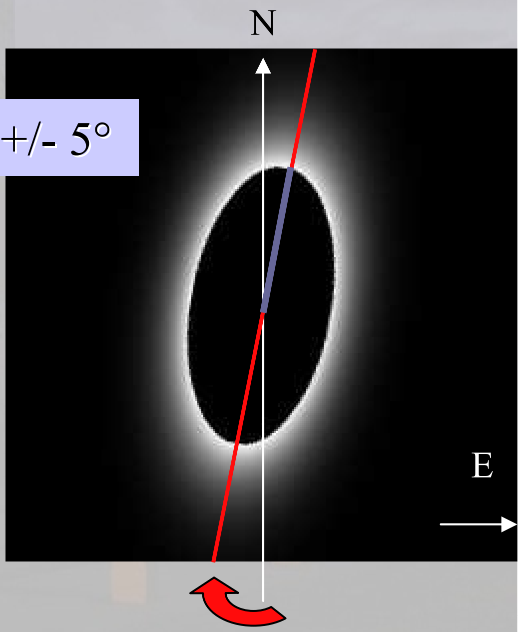


CPD3

B=41.2 m
PA = 51°

R = 72 +/- 3 mas
(110 +/- 5 UA)

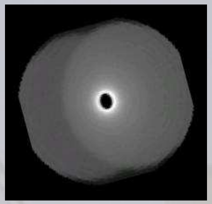
i = 29 +/- 5°

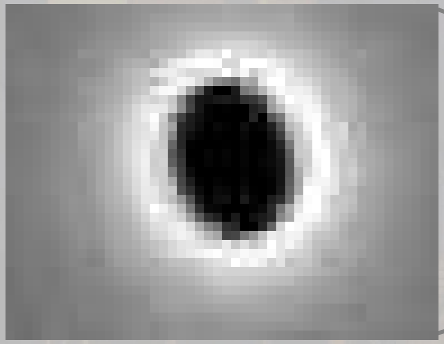


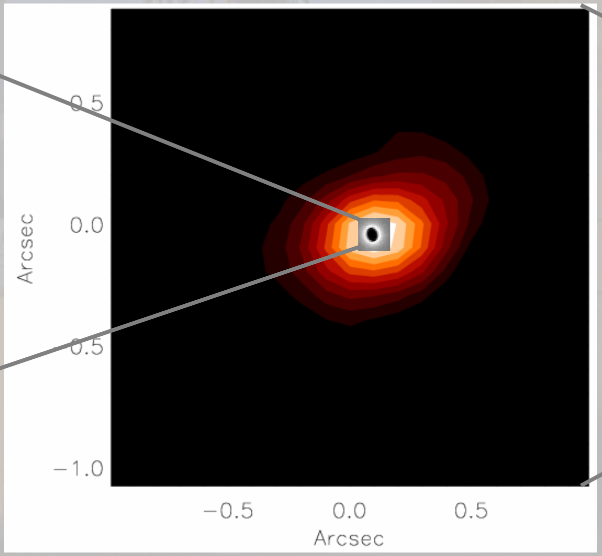
-15 +/- 5°

High-Resolution view of CPD-568032

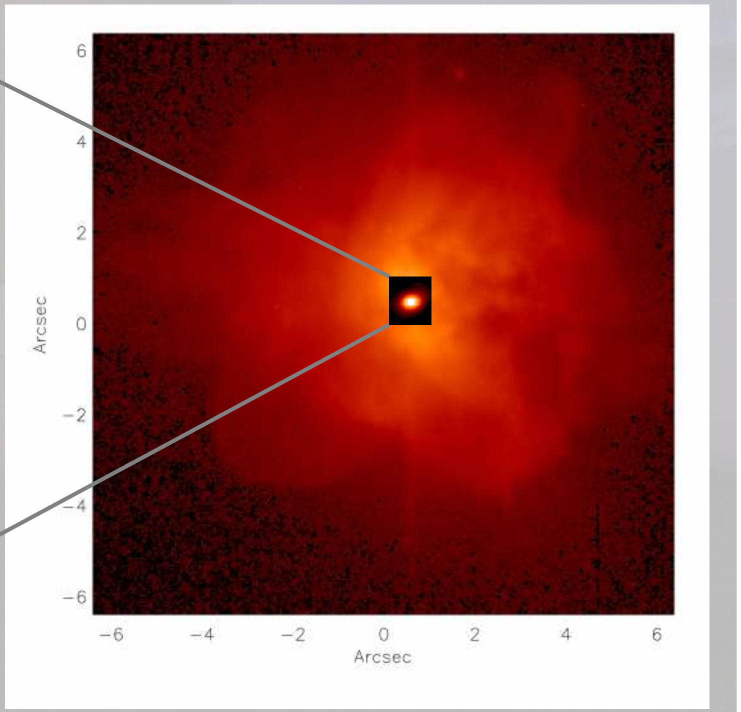
10 µm image







8.7 µm image (30% PAHs)

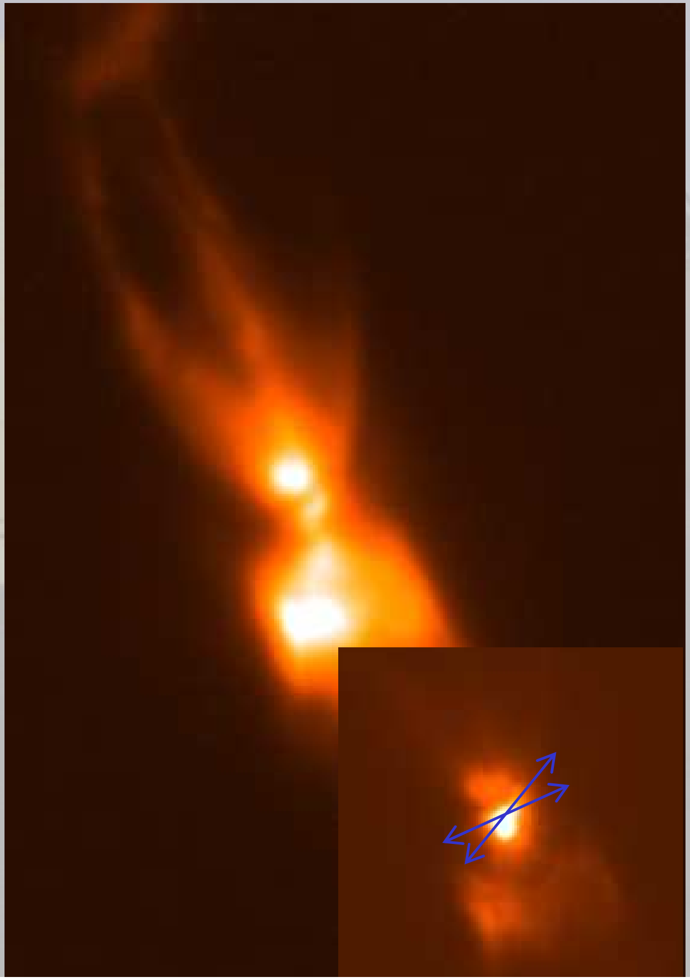


HST image
(complex object…)

Chesneau, O., Collioud, A., de Marco, O., et al., 2006, accepted

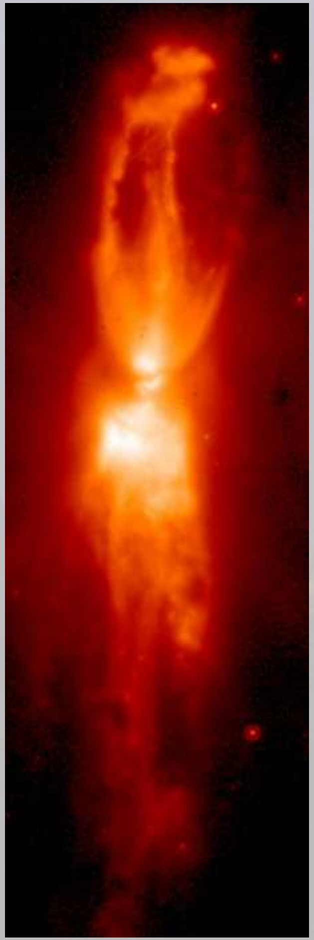
Other objects: QX Pup (OH231.8+4.2)

NACO 2.12



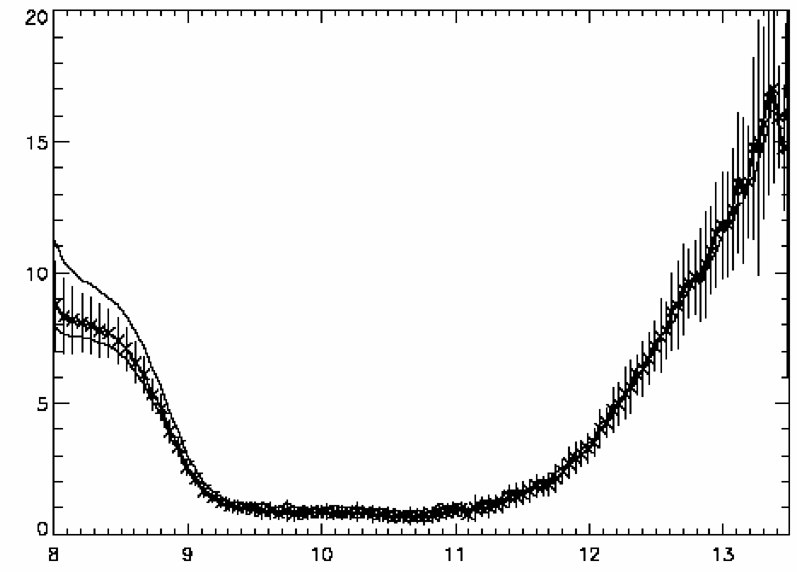
HST optical

HST Nicmos

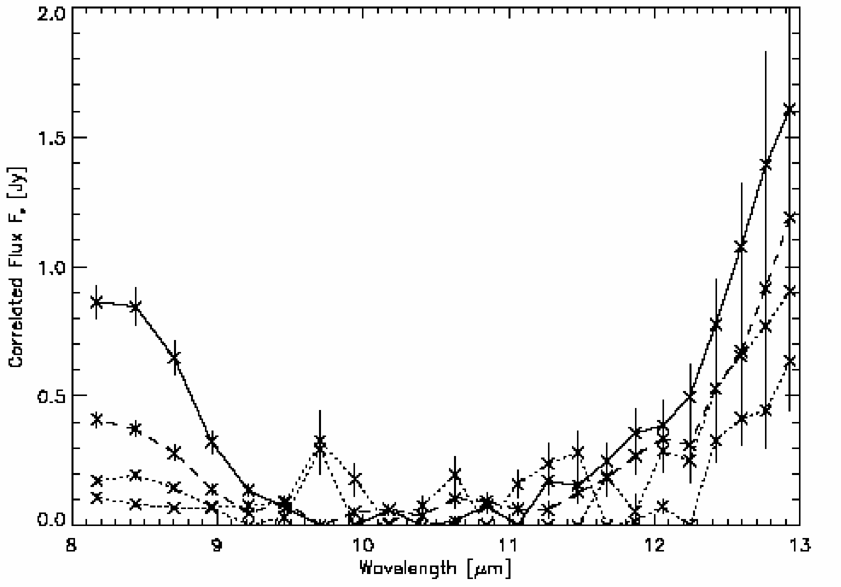


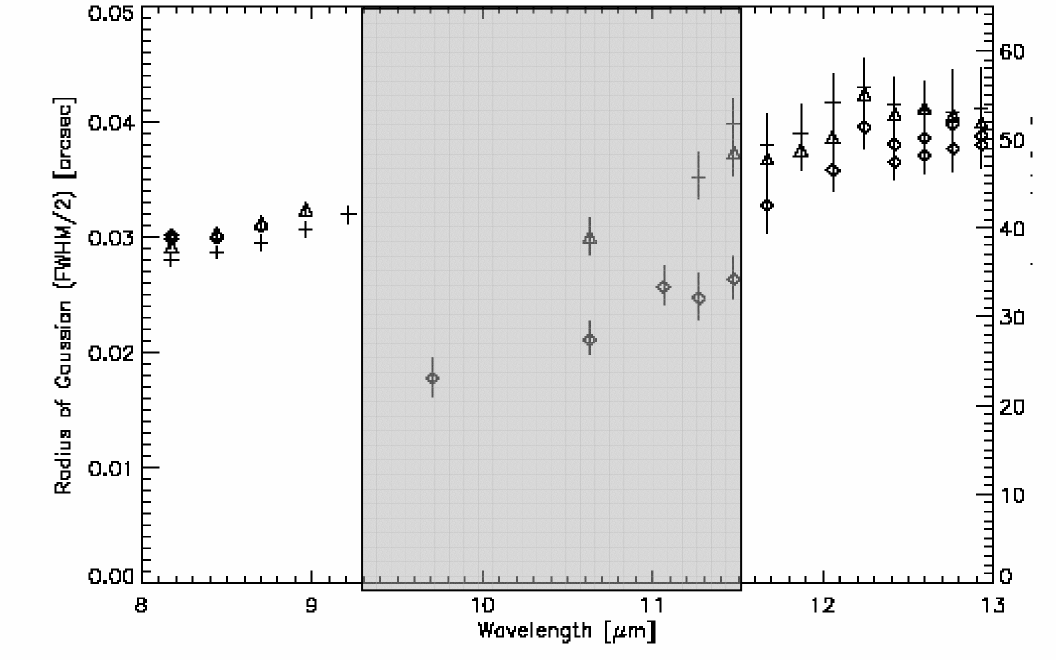
Matsuura, M, Chesneau, O., Zijlstra, A et al., 2006, accepted

MIDI spectrum



MIDI correlated flux



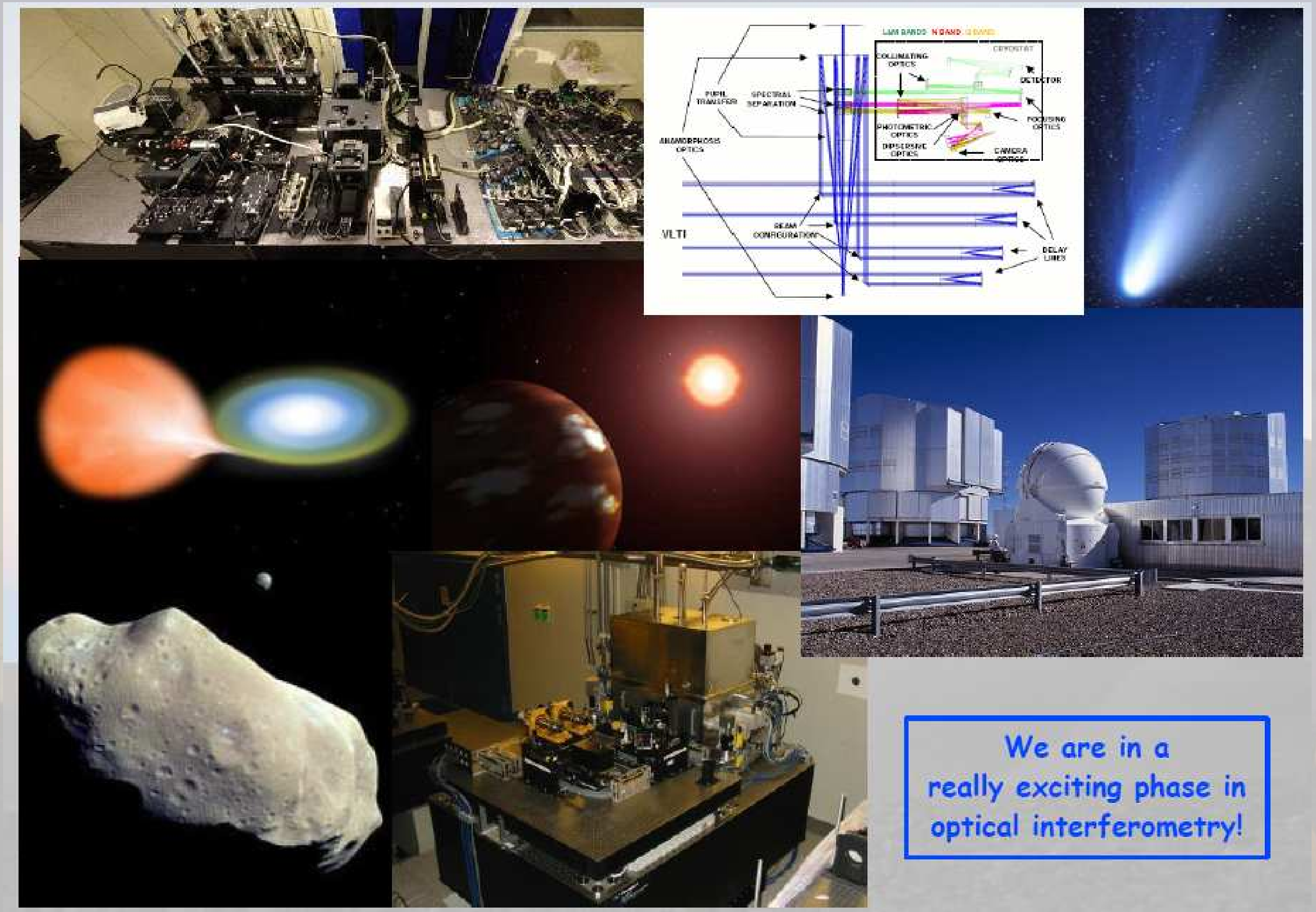


Typical extensions:
(Gaussian model)

- Low Mass (T Tauri) Stars:
  - RY Tau — A. Schegerer et al. (2006, in prep.)
  - T Tau — Th. Ratzka et al. (2006, in prep.)
  - VV CrA — Th. Ratzka et al. (2006, in prep.)
  - FU Ori — S. P. Quanz et al. (2006, ApJ, accepted)
  - V1647 Ori — P. Abraham et al. (2006, A&A, 449, L13)
- Intermediate Mass (Herbig Ae/Be) Stars:
  - HR 5999 — T. Preibisch et al. (2006, in prep.)
  - R CrA — H. Zinnecker et al. (2006, in prep.)
- Massive Stars:
  - M8E IR — H. Linz et al. (2006, in prep.)

- Symbiotic Systems and Planetary Nebula:
  - HM Sge — S. Sacato et al. (2006, in prep.)
  - CPD-56°8032 — O. Chesneau et al. (2006, A&A, accepted)
  - QX Pup — M. Matsuura et al. (2006, accepted)
- Carbon Stars:
  - RY Sgr — J. R. S. Leao et al. (2006, in prep.)
  - Hen 38 — K. Ohnaka, K. et al. (2006, A&A, 445, 1015)
  - HR 4049 — J.-L. Menut et al. (2006, in prep.)
- Hot Stars:
  - WR 31b, WR 95, WR 106, WR 122

    K. Rajagopal et al. (2006, in prep.)



We are in a
really exciting phase in
optical interferometry!

AGNs: see talk of Konrad Tristam

Asteroids: two asteroids detected by MIDI (Turin Observatory)

Novae: to come..