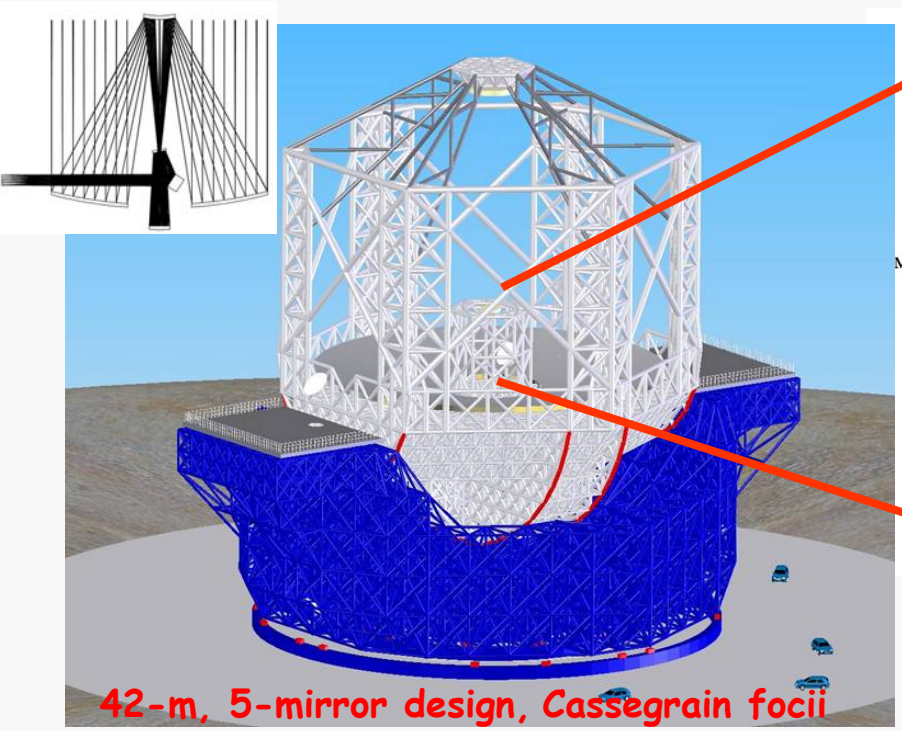
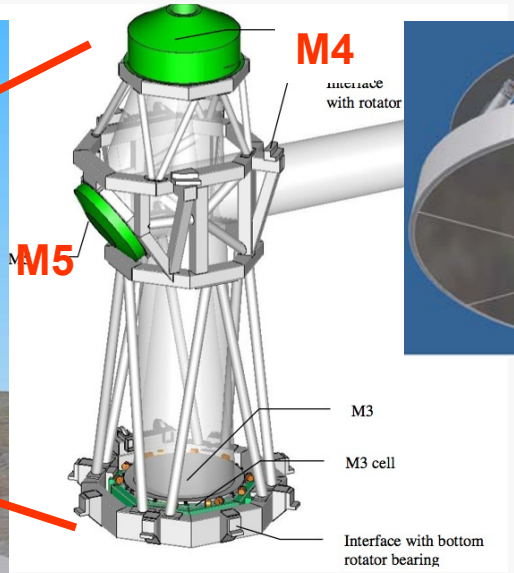
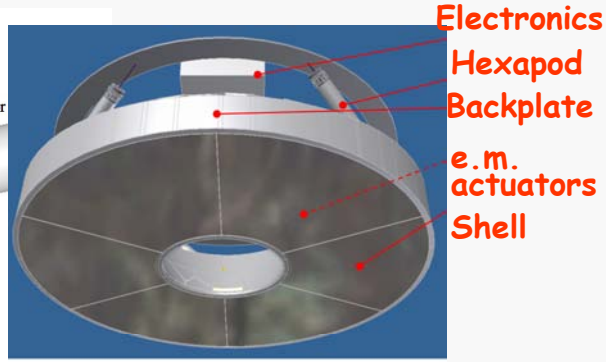
EPICS: A planet hunter for the European ELT

M. Kasper, C. Verinaud, J.L. Beuzit, N. Yaitskova, A. Boccaletti, S. Desidera, K. Dohlen, T. Fusco, N. Hubin, A. Glindemann, R. Gratton, N. Thatte

42-m E-ELT

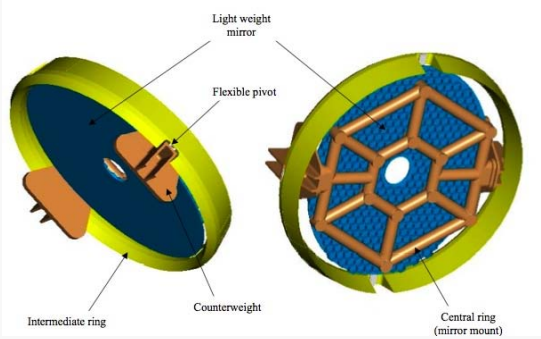






M4 specifications

- 2.5 m flat
- ~8000 actuators
- 30 mm pitch
- 1 ms response
- Stroke 25-90µm
- Inter act: 2-3µm



M5 specifications

- 2.7 m flat
- Field stabilization
- Monolithic
- Lightweight

Adaptive (integrated deformable mirror)

- Corrects for active optics residuals and ground layer
- Reduces DM stroke for post focal AO systems
- Makes instrumentation easier.

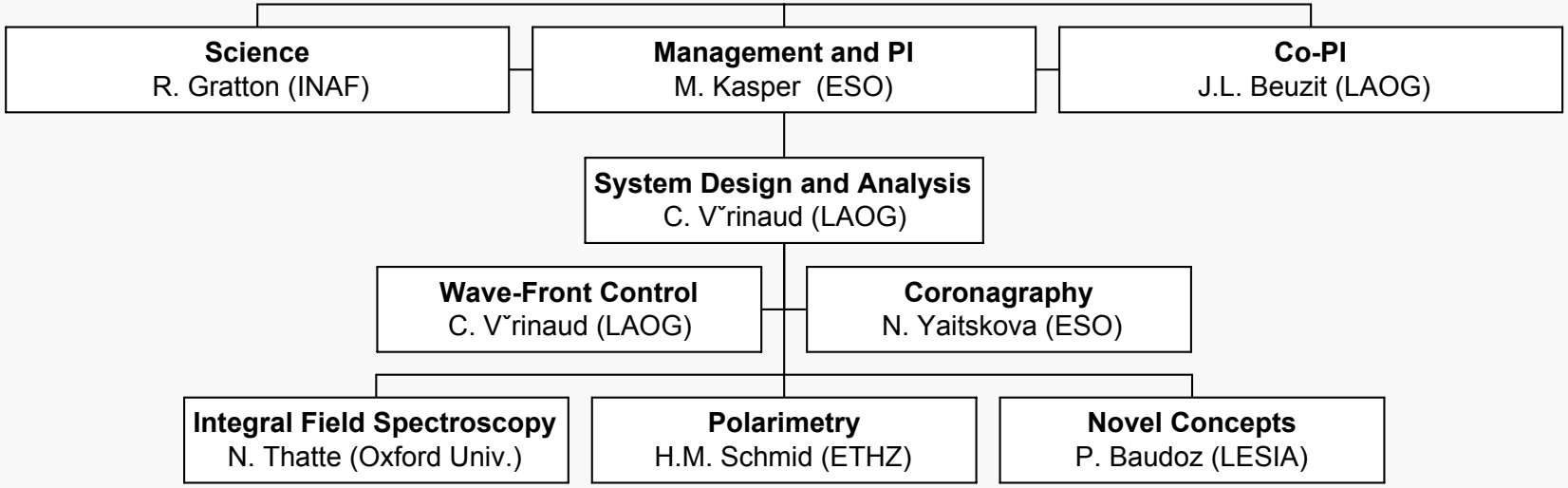
Multiple sodium LGS

In detailed study phase (phase B) until 2009

EPICS phase-A study

- Partners: ESO, LAOG, LAM, LESIA, LUAN, Oxford University, Padova University, ETH Zuerich, …
- 2-year phase-A study starts end of 2007, finish at the same time as E-ELT phase-B end of 2009
- Phase 1 (6 months): Simulations, Requirements, Concept
- Phase 2 (18 months): Conceptual design, analysis, feasibility studies, breadboard testing (FPWS, IFS incl. data processing, Coronagraphs, woofer/tweeter concept)

EPICS Consortium OrganisationChart



SPHERE science

- Directly detect photons from extrasolar giant planets (0.5 M_J) around
  - Young nearby stars (age 5-50 Myr)
  - Young active F-K stars (age 0.1–1 Gyr)
  - Nearby (mostly late type) stars
- Explore the mass-period distribution (1-20 Mjup, 1-1000 years)
- Survey an extended number of stars
- First order characterisation of the atmosphere (Clouds, dust content, Methane, water absorption, Effective temperature, radius, dust polarization)

➔ Understand the **planetary system origins**

Main TLR for AO guide stars V<9:

	5σ contrast at 0.1″	**5σ contrast at 0.5″**
IRDIS	5e-5 (goal 1e-5)	5e-6 (goal 5e-7)
IFS		1e-6 (goal 1e-8)

EPICS science

- Detection and 1st order characterization of **terrestrial planets and super-Earths** for very nearby stars (≤ 10pc), ultimately located in the HZ (for M-dwarfs)
- **Young self-luminous gas giants** in star forming regions or young associations
  - Good resolution achieved even for star forming regions at ~100pc, young planets at separation > 3 AU can be detected, very important observations to understand planet formation (talk Jang-Condell)
- **Mature gas giants** at orbital distances between ~5 and 15 AU in the solar neighbourhood (≤ 20 pc)
  - Not an easy observation
  - Determine frequency and mass distribution of giant planets
- **Warm Jupiters** that have been discovered by radial velocity searches
  - Fairly easy, spectral characterization
  - Understand giant planets' atmosphere composition and structure

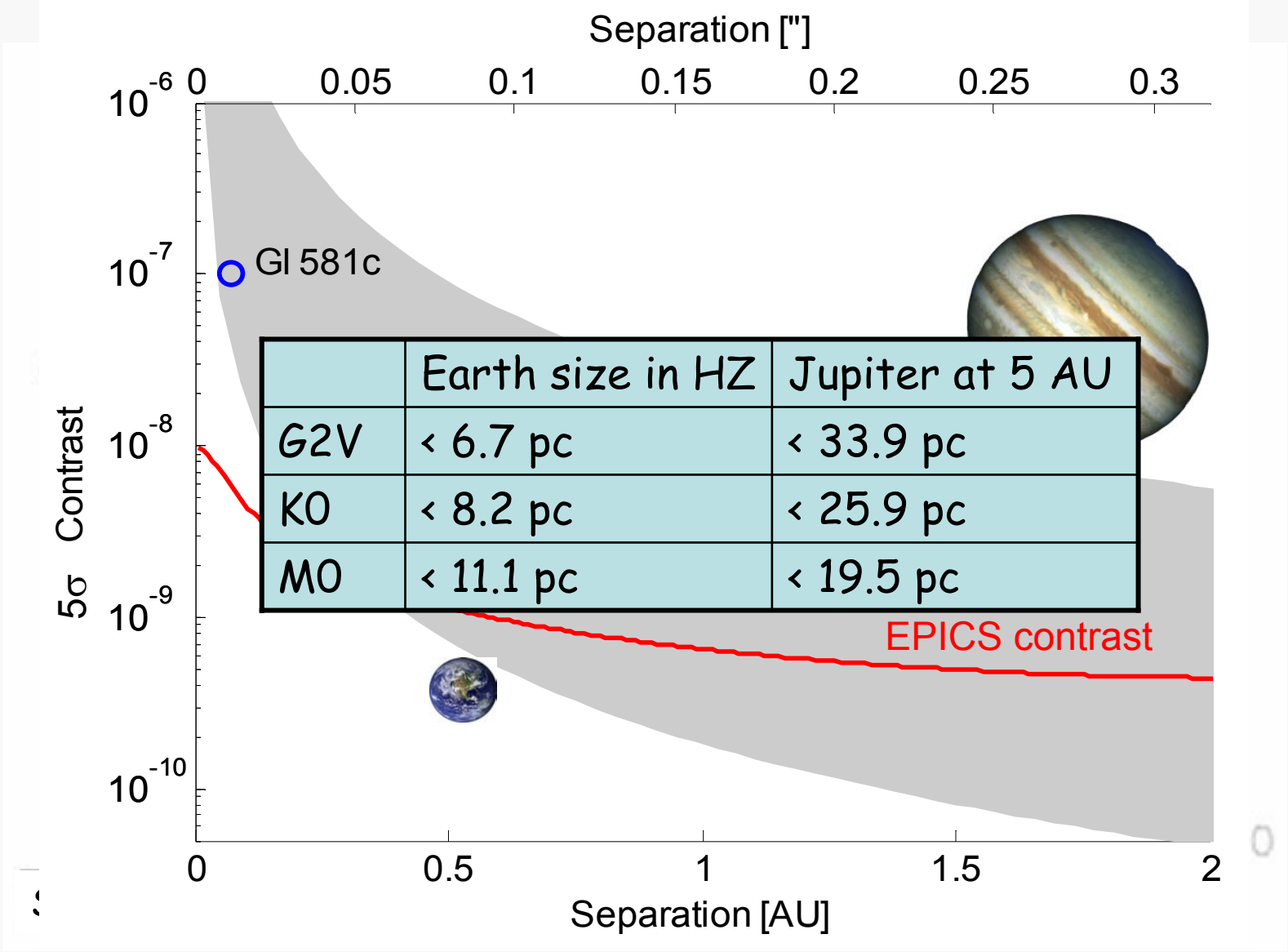
EPICS TLR

- XAO: SR=90% in H band, ~200x200 act (for 42-m), Starlight Halo Rejection (→ contrast)
- IFS spectro-imaging: Y-H band, R ~ 50
- Polarimetry: 600-900 nm
- Inner Working angle: 20 mas
  (central blind spot of 5 λ/D @ H)
- FoV: 4" diameter
- Contrast (J, H) for I < 8 mag (AO NGS) :
  - 30 mas – 100 mas: 10^{-8}
  - 100 mas – 800 mas: 10^{-9} → goal: 10^{-10}
- Contrast (J, H) for I < 10 mag. :
  - 30 mas: 10^{-7}

Photon Noise Limit

- Seeing: 0.6″, 10h on-source integration (same performance as with 30h in 1″)
- XAO system,
  - Pyramid WFS,
  - 0.2-m actuator spacing (~25.000 actuators),
  - 3 kHz,
  - I band for WFS (small chromatic errors)
- Perfect coronagraph (no diffraction residuals)
- Perfect speckle subtraction (only photon noise residuals)
- Transmission to science detector: 10%
- Observation: J-band with 100nm bandwidth (all planet photons supposed to contribute to detection),
- NO INSTRUMENT AND TELESCOPE ERRORS (perfect optics and detectors)
- ONLY PHOTON NOISE originating from AO residuals

Ultimate performance



	Earth size in HZ	Jupiter at 5 AU
G2V	< 6.7 pc	< 33.9 pc
K0	< 8.2 pc	< 25.9 pc
M0	< 11.1 pc	< 19.5 pc

Challenge, quasi-static speckles

Aberrations in front of coronagraph

$$\left\langle \left| I_1 - I_2 \right| \right\rangle \approx \left| \hat{\phi}_{common} \right| \left| \hat{\phi}_{dif,shift} \right|$$

Aberrations behind coronagraph

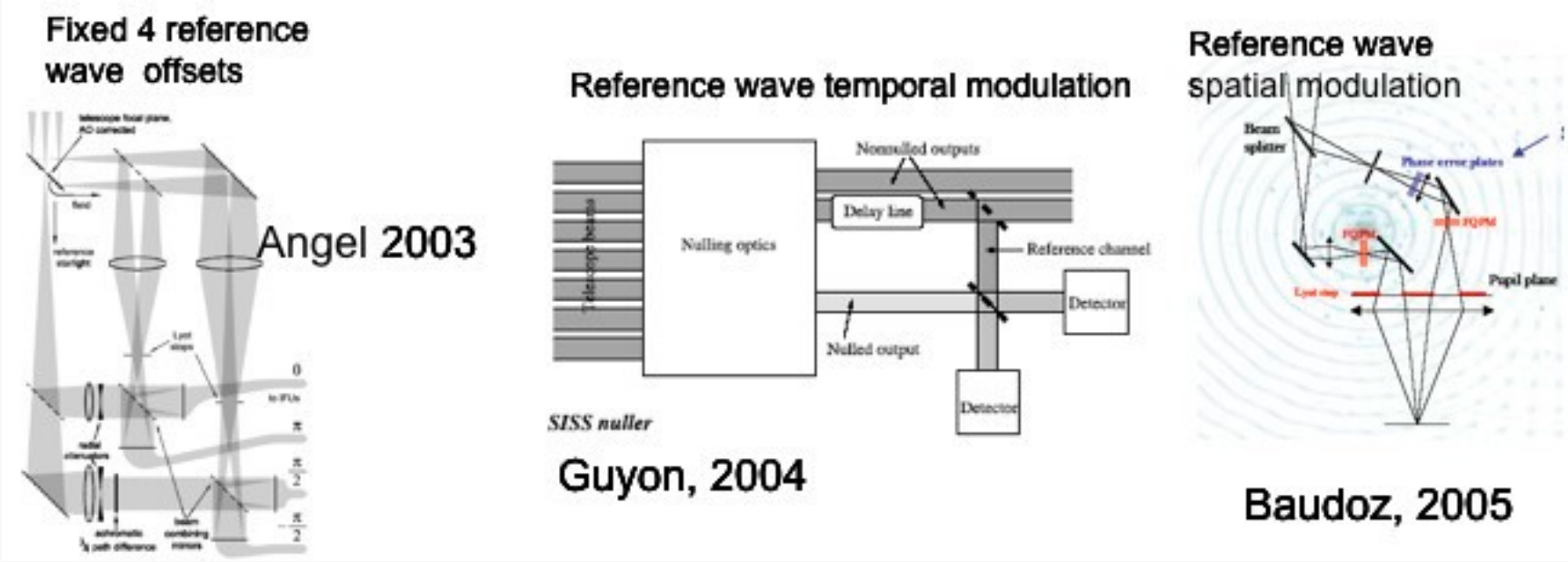
$$\left\langle \left| I_1 - I_2 \right| \right\rangle \approx \left| \hat{\phi}_{common} \right|^2 \cdot \sigma_{dif,ins}$$

Cavarroc et al., 2006

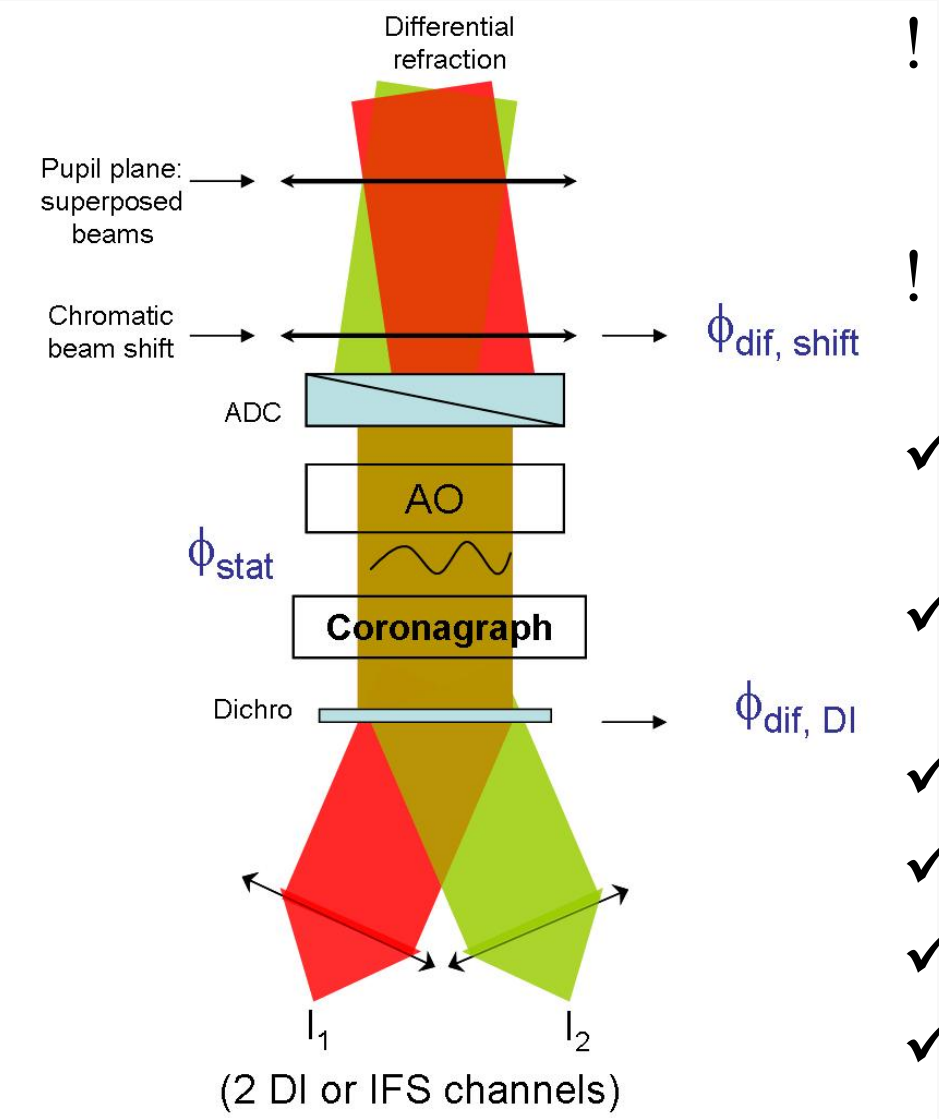
! Static aberrations must be controlled at nm level by DM

✓ Focal Plane Wavefront Sensor for ϕ_{common}

✓ IFS or differential polarimetry for $\phi_{dif,ins}$



Challenges, Chromatic effects



! Spectral differential aberrations already in common path

! AO residual error

✓ Keep optics close to pupil plane

✓ ADC as early as possible in optical design

✓ Observe close to zenith

✓ $\lambda_{WFS} \approx \lambda_{Science}$

✓ Dedicated AO algorithm

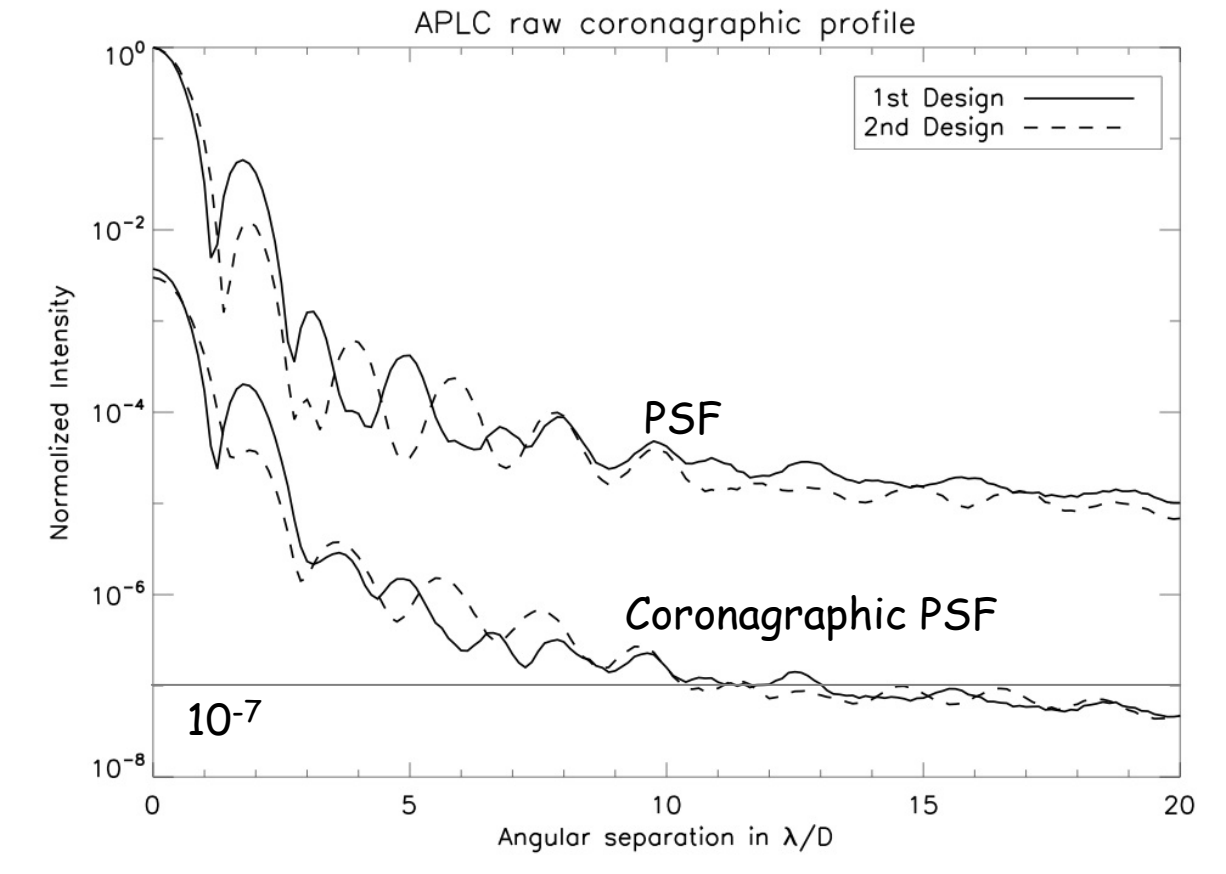
✓ Spectral deconvolution

Challenges, Diffraction suppression

- ! Similar effect as static aberrations
- ! Cannot be beat down by long integrations
- ! High rejection required, PSF contrast < 10^{-7}

✓ many promising concepts

✓ cascade
- ➢ 4-QPM (Baudoz talk)
- ➢ APLC (Soummer)
- ➢ …

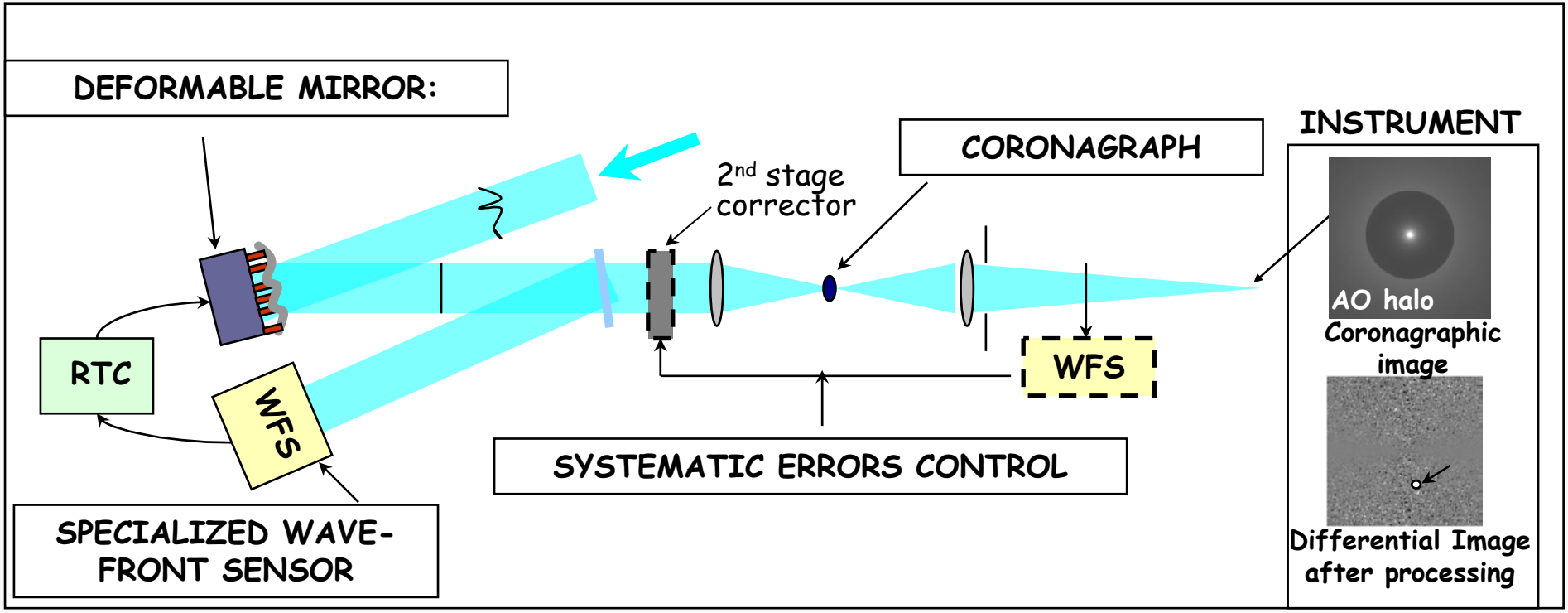


Martinez et al., 2007

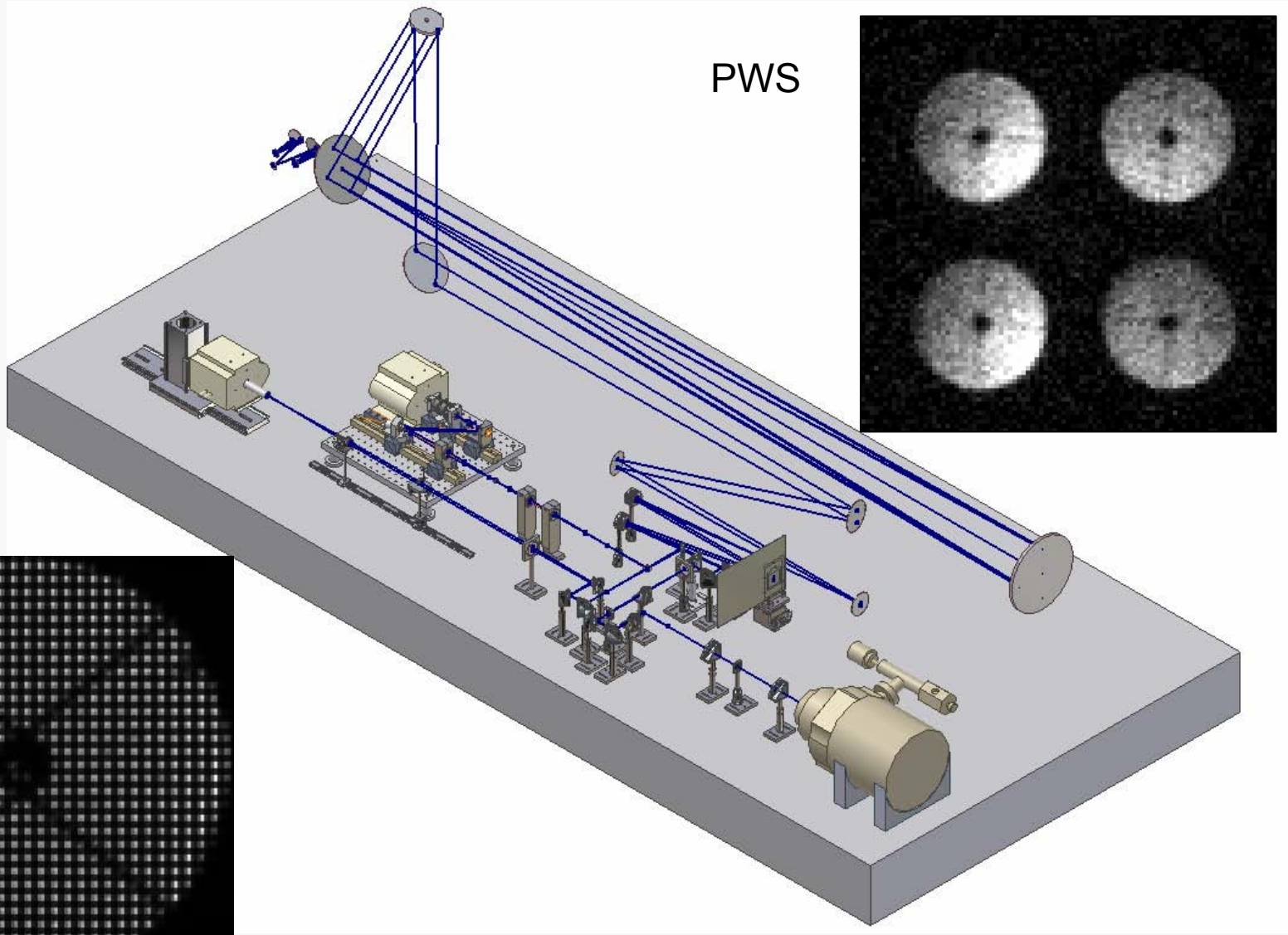
Other challenges

- Amplitude errors introduced by optics
  - ✓ Keep optics clean, additional corrector (phase/ampl)
- Gaps between telescope mirror segments
  - ✓ Optimize segment size, fancy apodization
- Dust introducing scattering
  - ✓ Keep optics clean (especially when close to image plane), high spatial frequencies
- Ghosts
  - ✓ Minimize number of transmissive optics, wedged surfaces, optimized coatings,…
- Technological: DM, detectors, real-time computer, optical polishing, …

Instrument outline



HOT



SHS