Ground-based optical instrumentation for stellar studies

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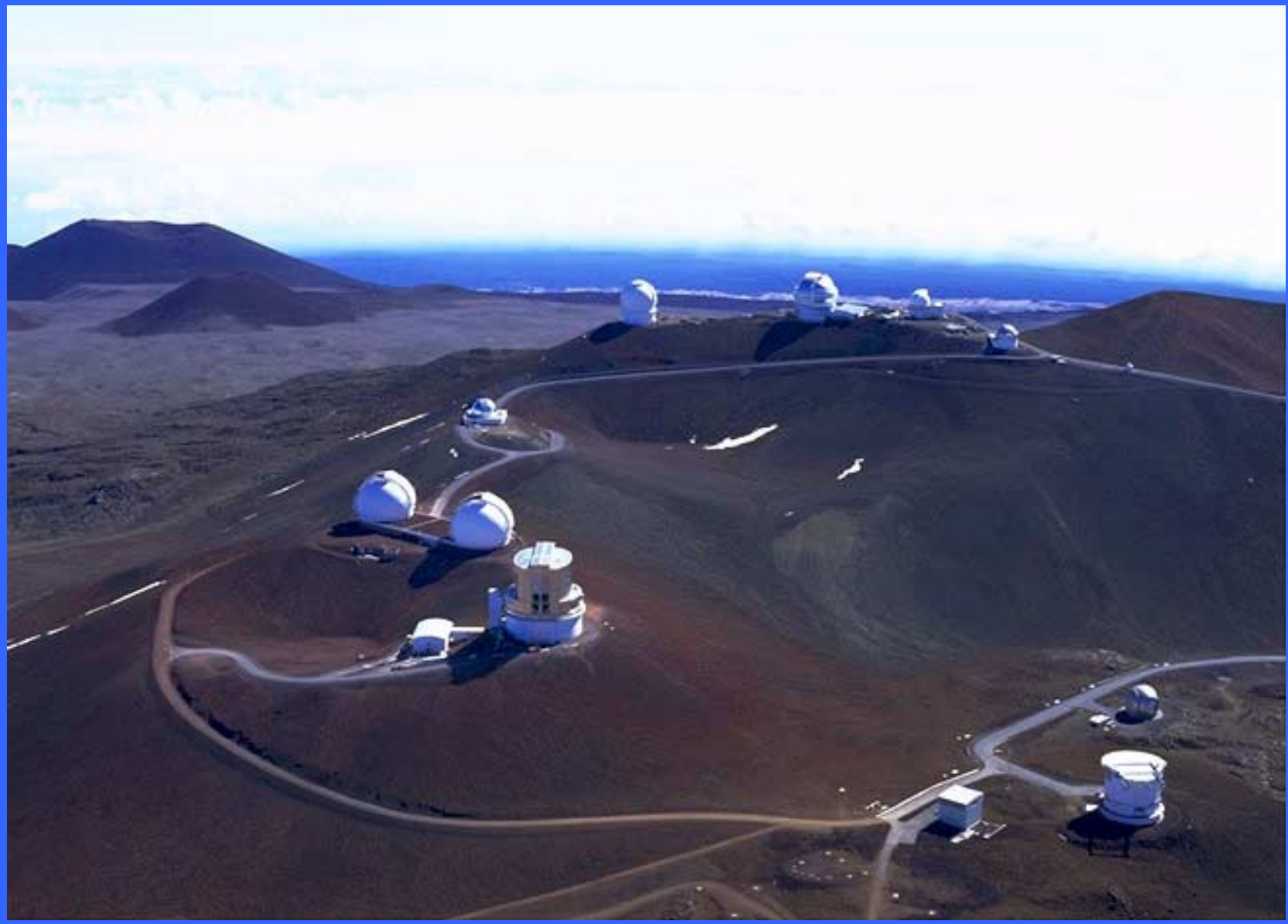
Year 2000: a crucial time

- advent of large 8-10m class telescopes throughout the world
- new role of 4m class telescopes
- renewed interest in small (1m class, robotic) telescopes
- new observing strategies needed

On top of La Silla, Chile

On top of Mauna Kea, Hawaii

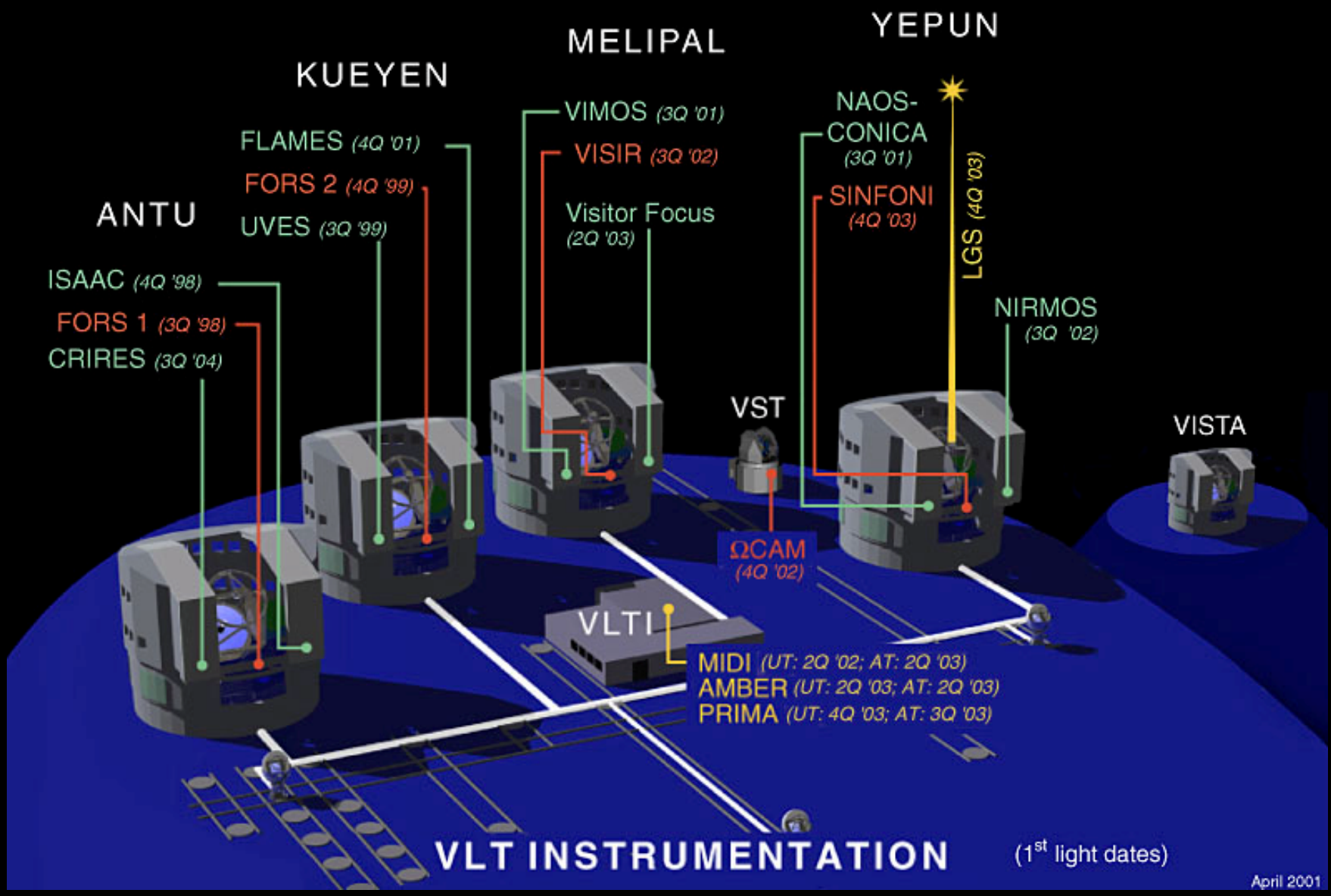


The VLT Array on the Paranal Mountain

ESO PR Photo 14a/00 (24 May 2000)

Technical developments

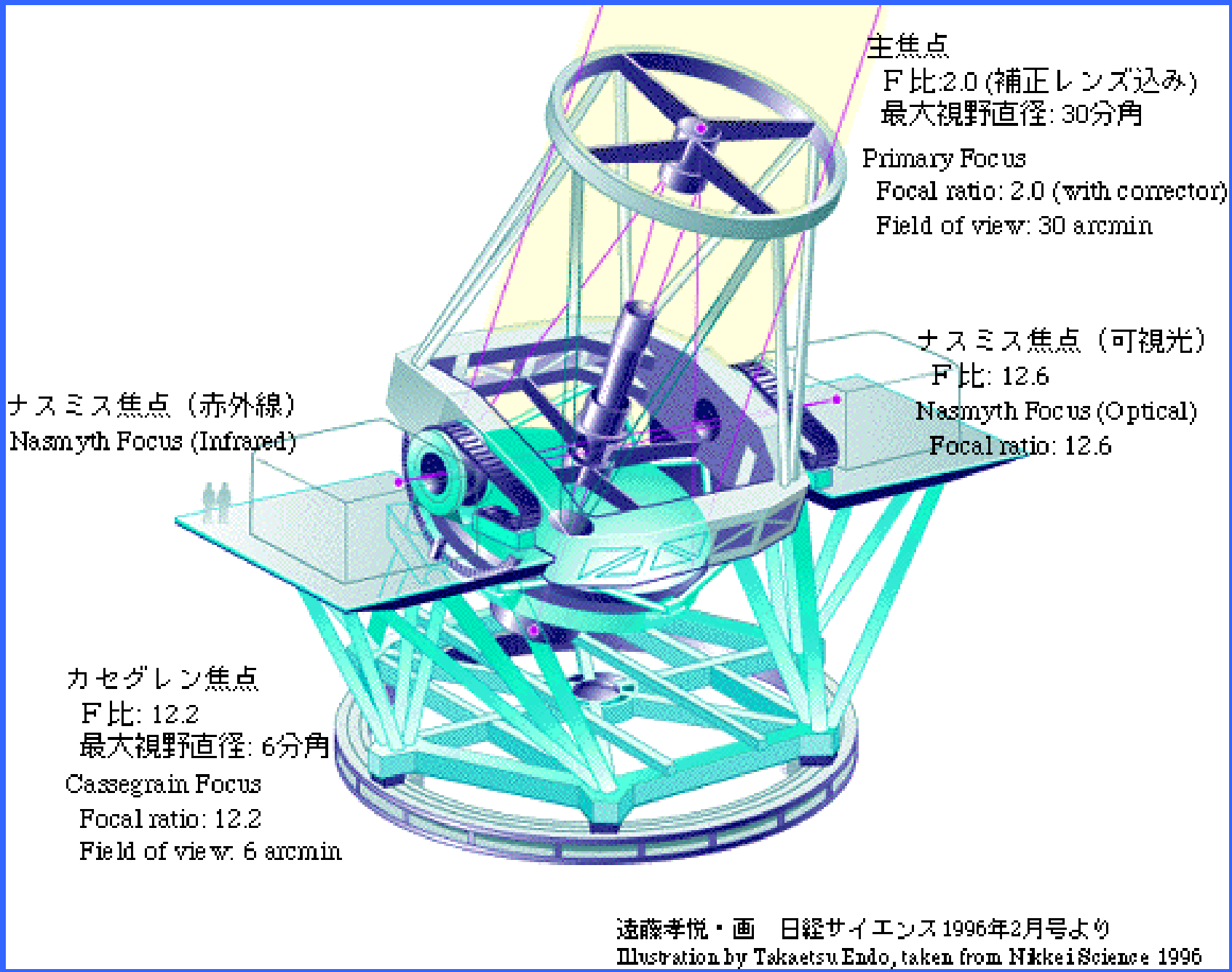
- new improved optical detectors
- fiber-feed, multi-object and IFU capabilities
- Adaptive Optics (AO) modules at all major telescopes
- coherent beam combination (interferometry)
- new IR detectors/instruments to complement optical instrumentation


MELIPAL
YEPUN
KUEYEN
VIMOS (3Q '01)
VISIR (3Q '02)
NAOS-
CONICA
(3Q '01)
FLAMES (4Q '01)
FORS 2 (4Q '99)
UVES (3Q '99)
Visitor Focus
(2Q '03)
SINFONI
(4Q '03)
LGS (4Q '03)
ANTU
ISAAC (4Q '98)
FORS 1 (3Q '98)
CRIRES (3Q '04)
NIRMOS
(3Q '02)
VST
VISTA
ΩCAM
(4Q '02)
VLTI
MIDI (UT: 2Q '02; AT: 2Q '03)
AMBER (UT: 2Q '03; AT: 2Q '03)
PRIMA (UT: 4Q '03; AT: 3Q '03)
VLT INSTRUMENTATION
(1st light dates)
April 2001

8-10m telescopes

- only two (Keck I and II) available in the 90's
- several available at the turn of the century (the 4 VLT units, Gemini North and South, Subaru, HET)
- others under construction (LBT, GTC, SALT)
- and plans already for 30-100m telescopes...

The SUBARU telescope at Mauna Kea



遠藤孝悦・画　日経サイエンス1996年2月号より
Illustration by Takaetsu Endo, taken from Nikkei Science 1996

6m class telescopes

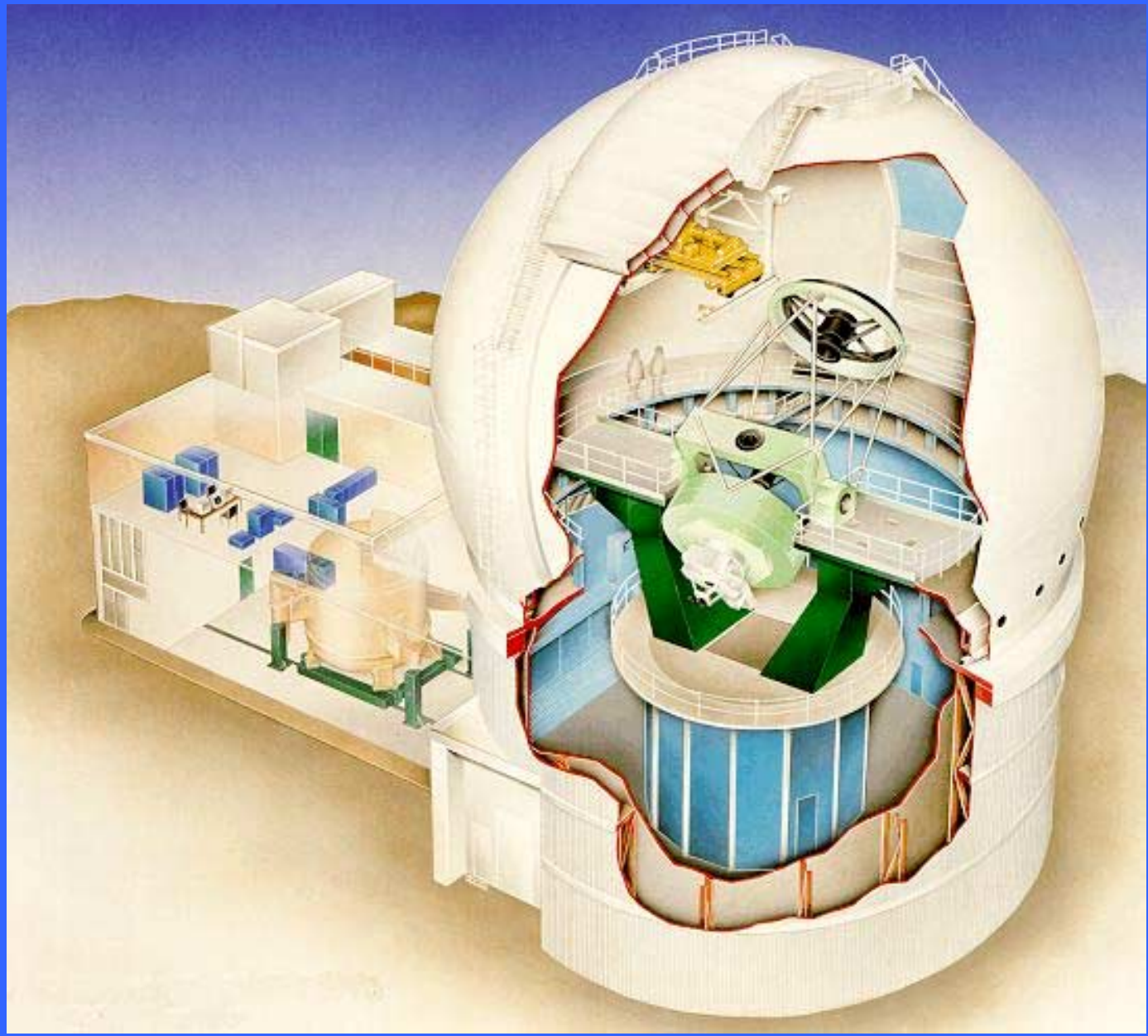
- Converted (monolithic) MMT (twin of Magellan and also test-bench for the LBT)
- Magellan I (and, in the future, Magellan II)
- in addition to the “venerable” ones (Palomar 5m and Bolshoy 6m telescopes)

4m class telescopes

- the “classical” ones (Mayall at Kitt Peak, Blanco at CTIO, ESO 3.6m at La Silla, CFHT at Mauna Kea, AAT in Australia, WHT at La Palma, Calar Alto in Spain)
- the “new technology” ones (ESO NNT at La Silla, WIYN at Kitt Peak, TNG at La Palma, ARC at Apache Point)
- and those under construction (SOAR at Cerro Pachon, LAMOST in China)

The William Herschel Telescope (WHT) at La Palma

The William Herschel Telescope (WHT) at La Palma



A matter of perspective

- until the end of the ‘90s, 4m class telescopes were the “giant ones” for the average user
- now they are big, but not as “big” as before, with strong impact on the smaller/older ones
- “small” telescopes (< 1m) being closed down at many largest observatories
- role of small telescopes must be reassessed

ESO

New Technology Telescope (NTT)

La Silla, Chile

The Italian National Telescope Galileo (TNG) at La Palma is very similar to NTT

TSU/SAO 0.8m Automatic Photoelectric Telescope

One of several automatic telescopes operated by Tennessee State University at Fairborn Observatory in Southern Arizona

Other considerations

- “private” vs “public” telescopes
- “national” vs “international” telescopes
- “Northern” vs “Southern” telescopes
- “specialized” vs “general purpose” instruments
- instrument complexity (and cost) increasing with telescope aperture
- competition with extragalactic work also increasing with telescope aperture

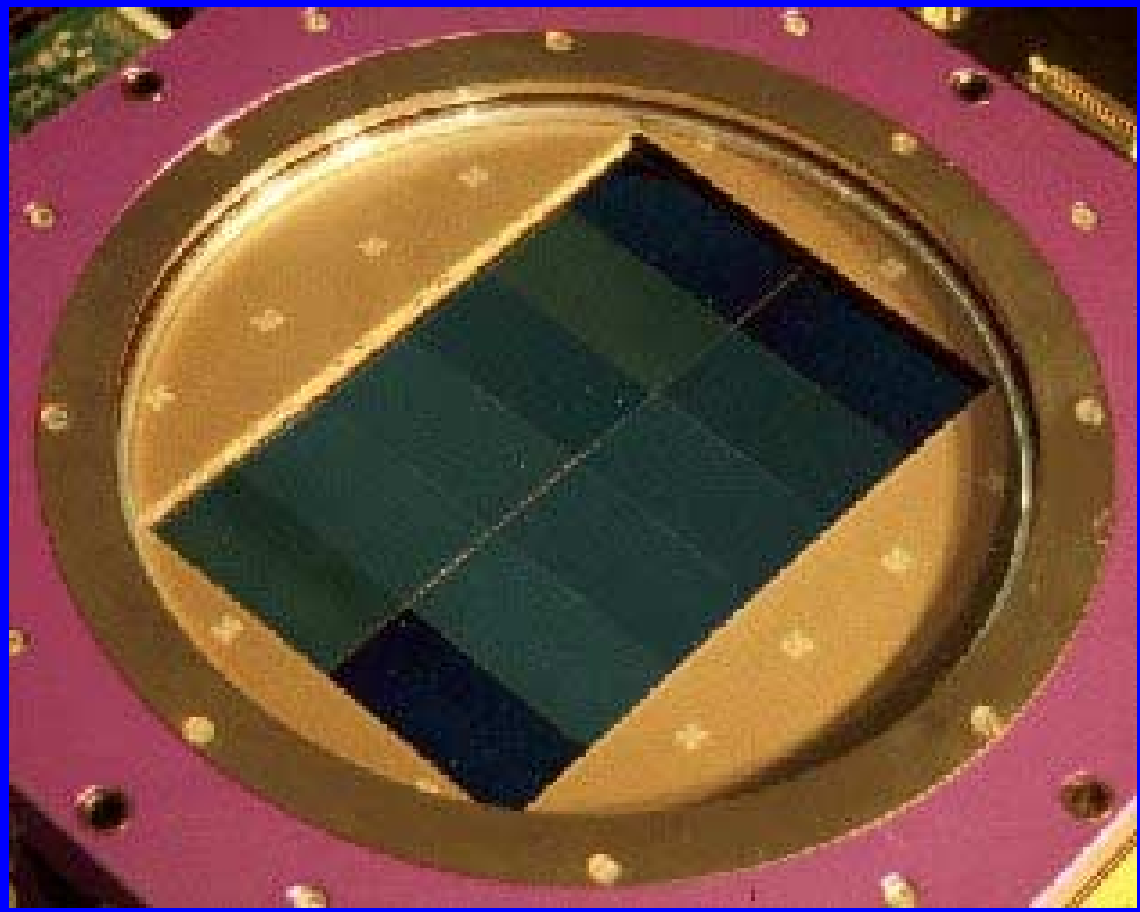
Advances in optical instrumentation
(from a "stellar" point-of-view)

- wide field imaging
- high-resolution spectroscopy
- multi-object (and IFU) spectroscopy
- accurate radial velocities
- interferometry

Wide Field Imaging

- Science: accurate photometry of stellar clusters (open and globular), star forming regions, Local Group galaxies, C-M diagrams, stellar evolution
- present facilities: CFHT12K, AAT WFI, INT WFC, Kitt Peak MOSA, ESO 2.2m & EIS public survey
- future facilities (CFHT MegaCam, VST OmegaCam and VISTA at ESO, Subaru Suprime-Cam, MMT Megacam, LBT PFC)

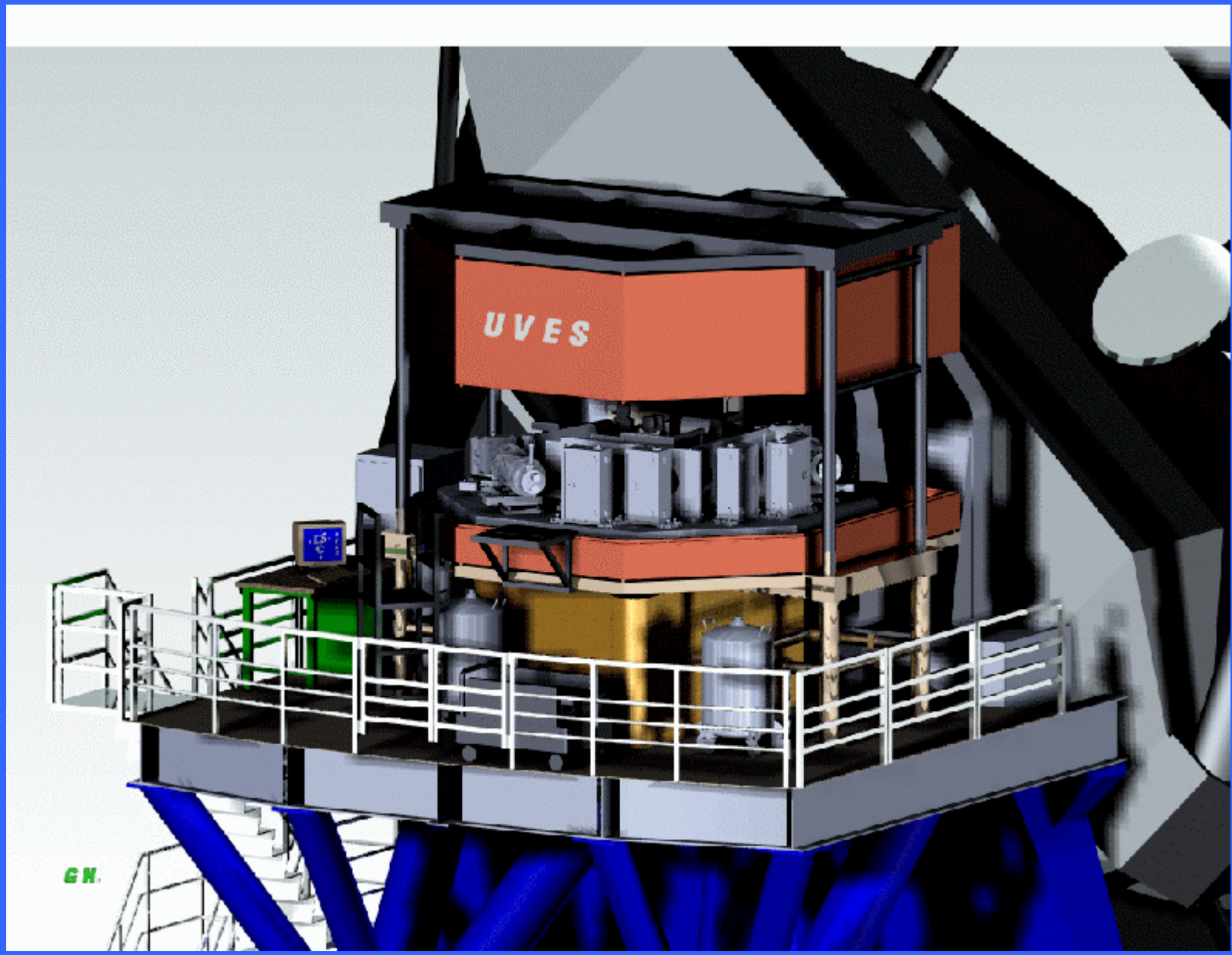
CFHT12K: a 12Kx8K CCD camera at CFHT



High Resolution Spectroscopy

- Science: chemical abundances, line profiles, convection and rotation, stellar atmospheres, radial velocities, stellar activity, Doppler imaging
- HR spectrographs on ≤ 4m telescopes (UCLES at AAT, UES at WHT, SARG at TNG, FEROS at ESO 1.5m + Kitt Peak, Cerro Tololo, CFHT, etc.)
- HR spectrographs on 8-10m class telescopes (HIRES at Keck, UVES at VLT, HRS at HET, HDS at Subaru, HROS at Gemini South)

The UVES spectrograph at the VLT

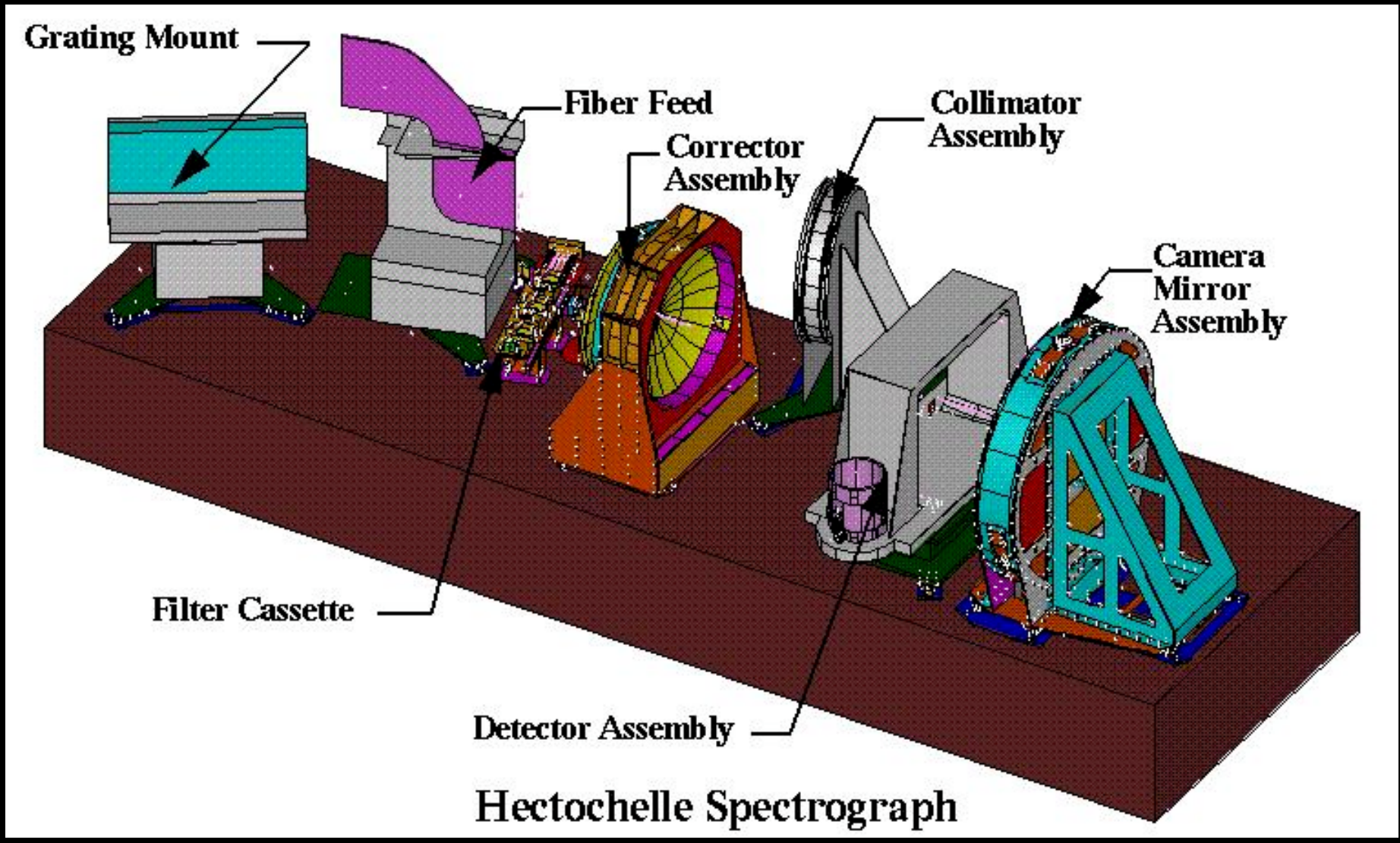


Multi-object spectroscopy

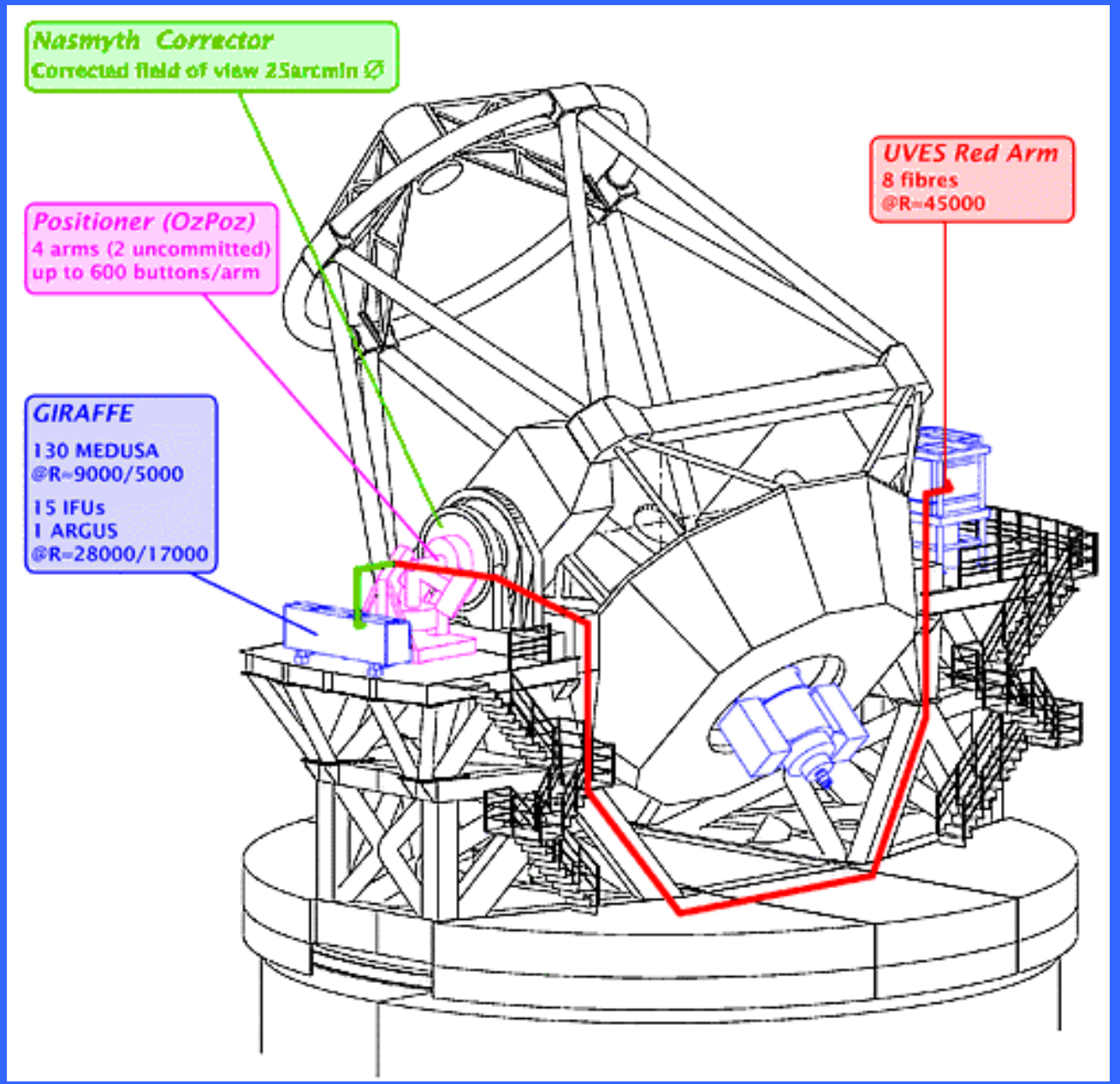
- *low-resolution* multi-slit spectrographs, mostly for extragalactic work, available or being developed (LRIS at Keck, VIMOS at ESO, GMOS at Gemini, LRS at HET, OSIRIS at GTC, MODS at LBT)
- fiber-feed multi-object spectrographs being developed also for stellar work (*at moderate resolution*: 2dF at AAT, WYFFOS at WHT, HECTOSPEC at MMT; *at higher resolution*: HYDRA at WYIN and CTIO, HECTOCHELLE at MMT, FLAMES at VLT)

2dF multi-object facility at AAT

2dF fibre positioner



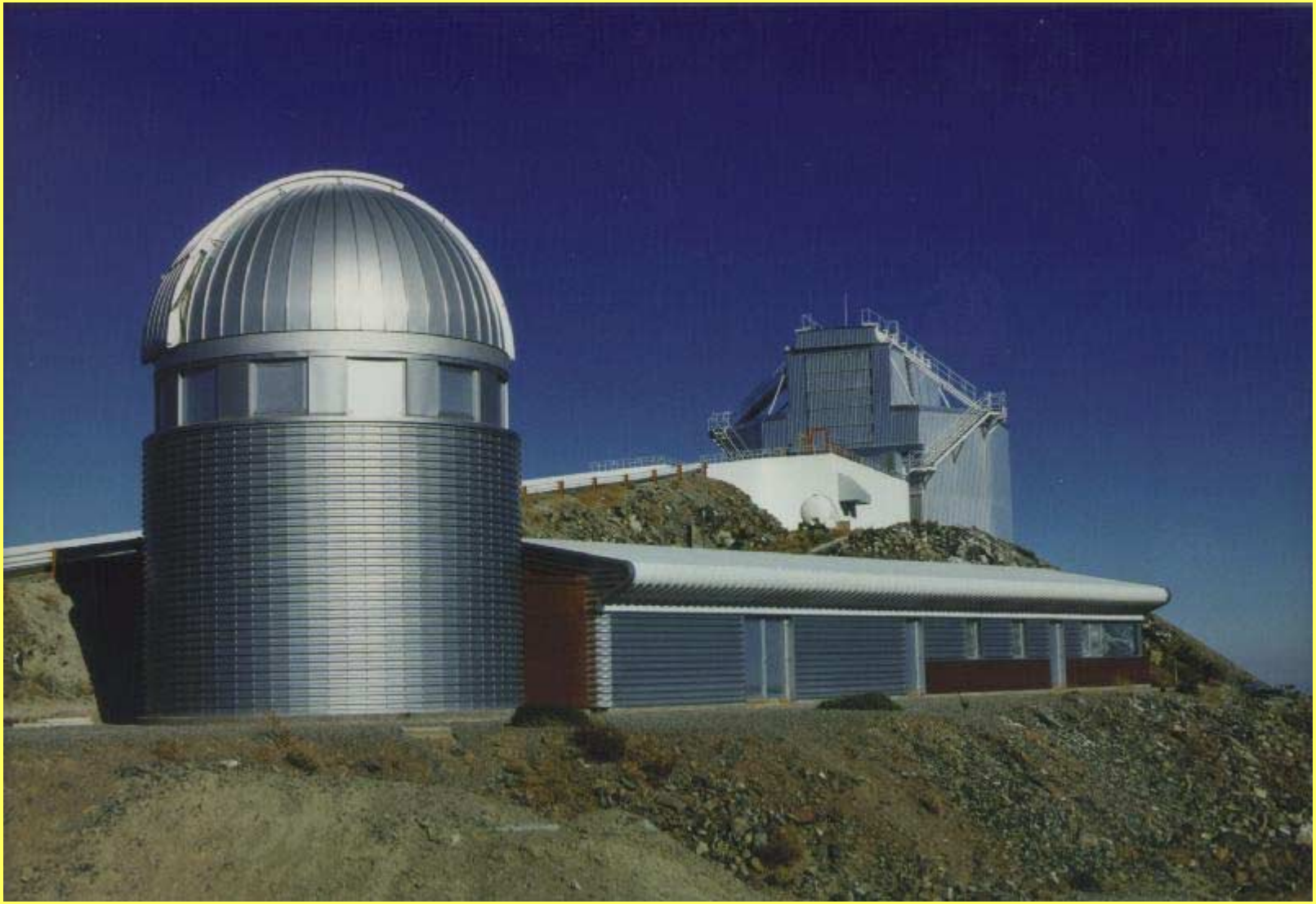
Hectochelle Spectrograph


Nasmyth Corrector
Corrected field of view 25arcmin Ø
Positioner (OzPoz)
4 arms (2 uncommitted)
up to 600 buttons/arm
GIRAFFE
130 MEDUSA
@R=9000/5000
15 IFUs
1 ARGUS
@R=28000/17000
UVES Red Arm
8 fibres
@R=45000

Precise radial velocities

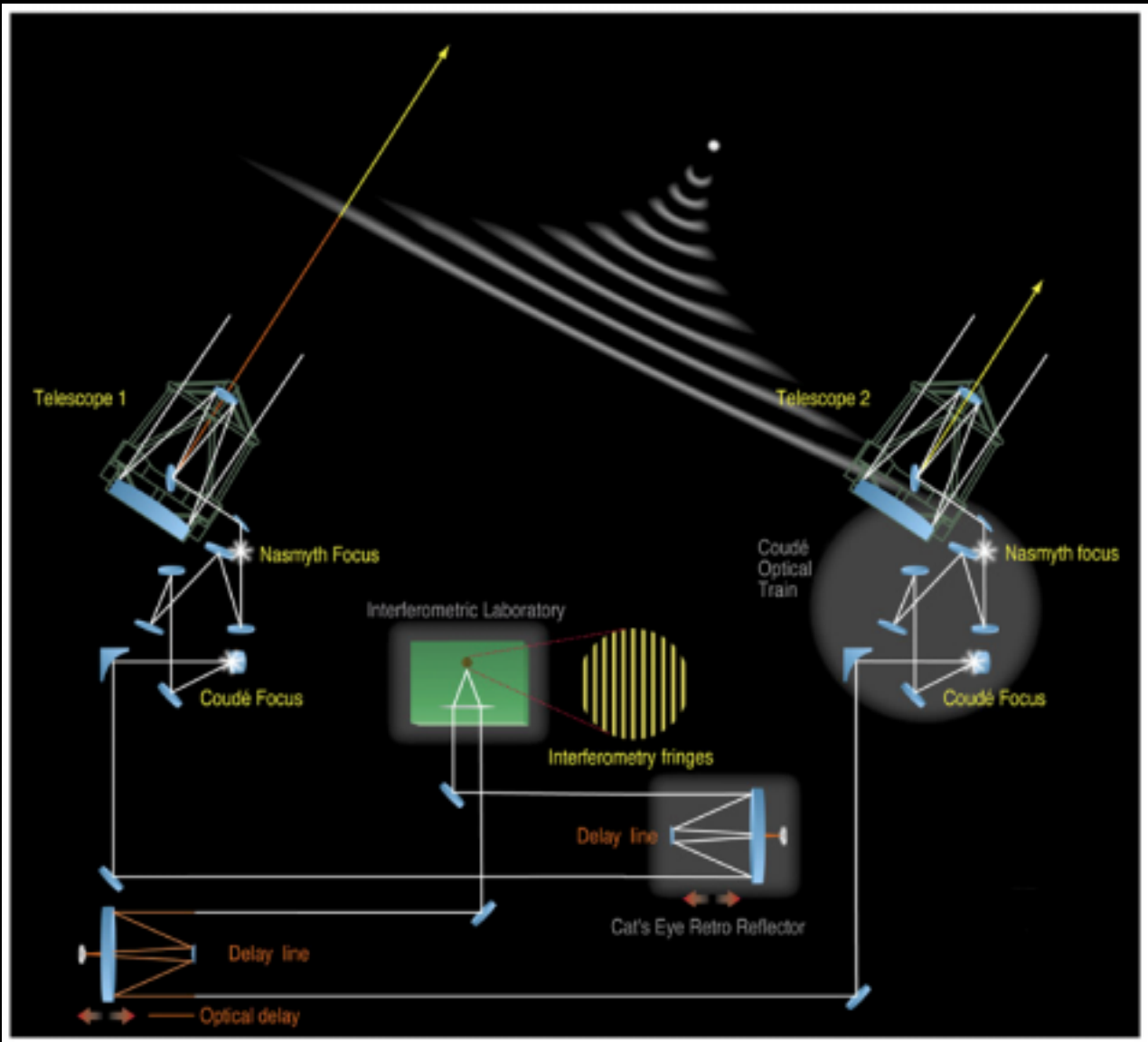
- science: search for planets around nearby stars, velocity fields in stellar atmospheres
- several RV survey programmes for extrasolar planets currently underway (Lick, AAT, HIRES at Keck, Elodie at HPO, Coralie at ESO)
- projects under development: HARPS (1m/s accuracy) at the ESO 3.6m telescope at La Silla
- require accurate determination of velocity fields in stellar atmospheres (convection, pulsations, etc.)

Extrasolar planet search at ESO La Silla



Interferometry

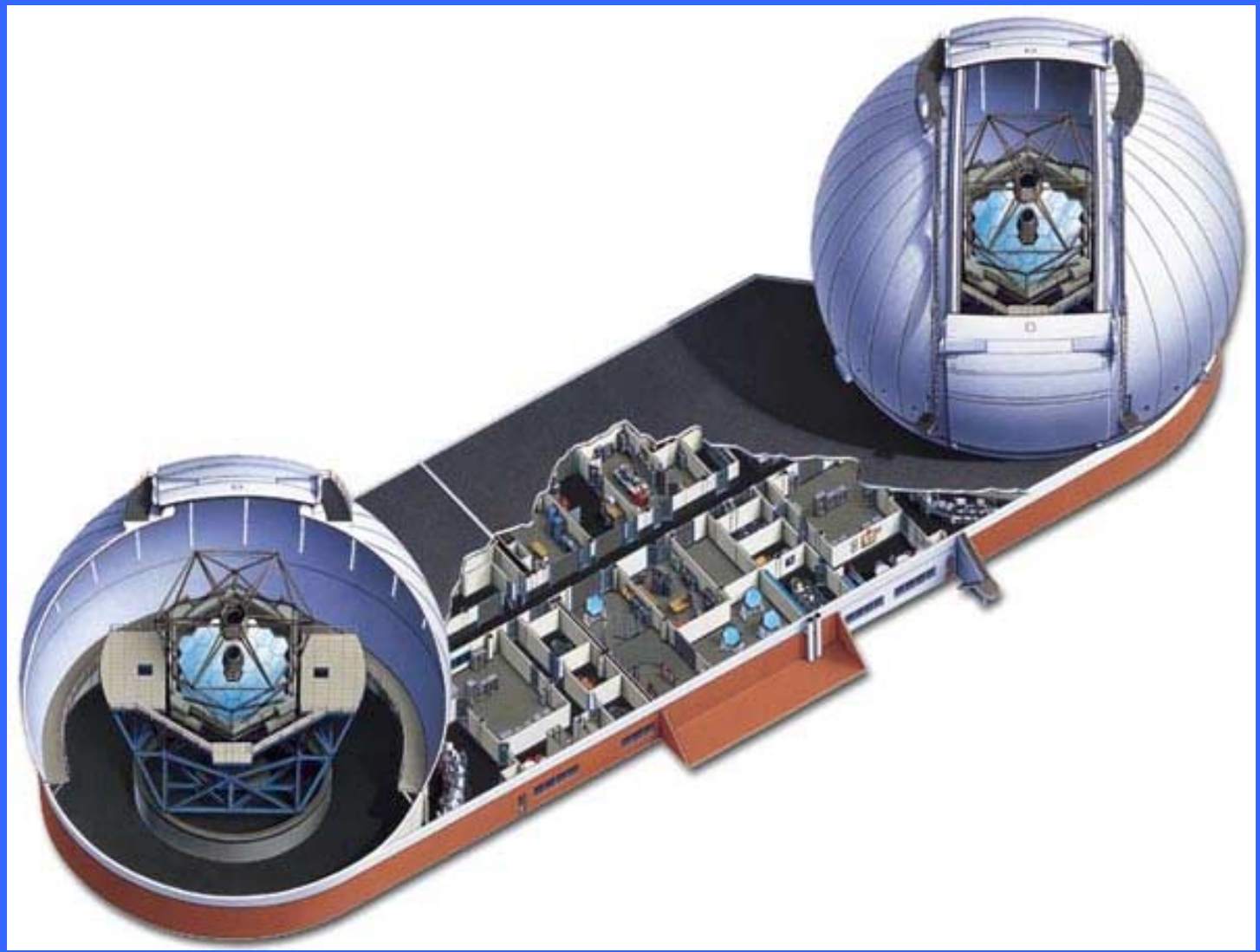
- Science: detection of extrasolar planets, close binary stars, pre-main sequence stars, surface structures, circumstellar envelopes
- technique developed and used so far on small (< 1m) telescope arrays
- programmes under development at large (8-10m class) telescopes with or without auxiliary telescopes (Keck I+ II, VLTI, LBT, Magellan)



Overview of the VLT Interferometer

ESO PR Photo 10c/01 (18 March 2001)

The two Keck telescopes at Mauna Kea

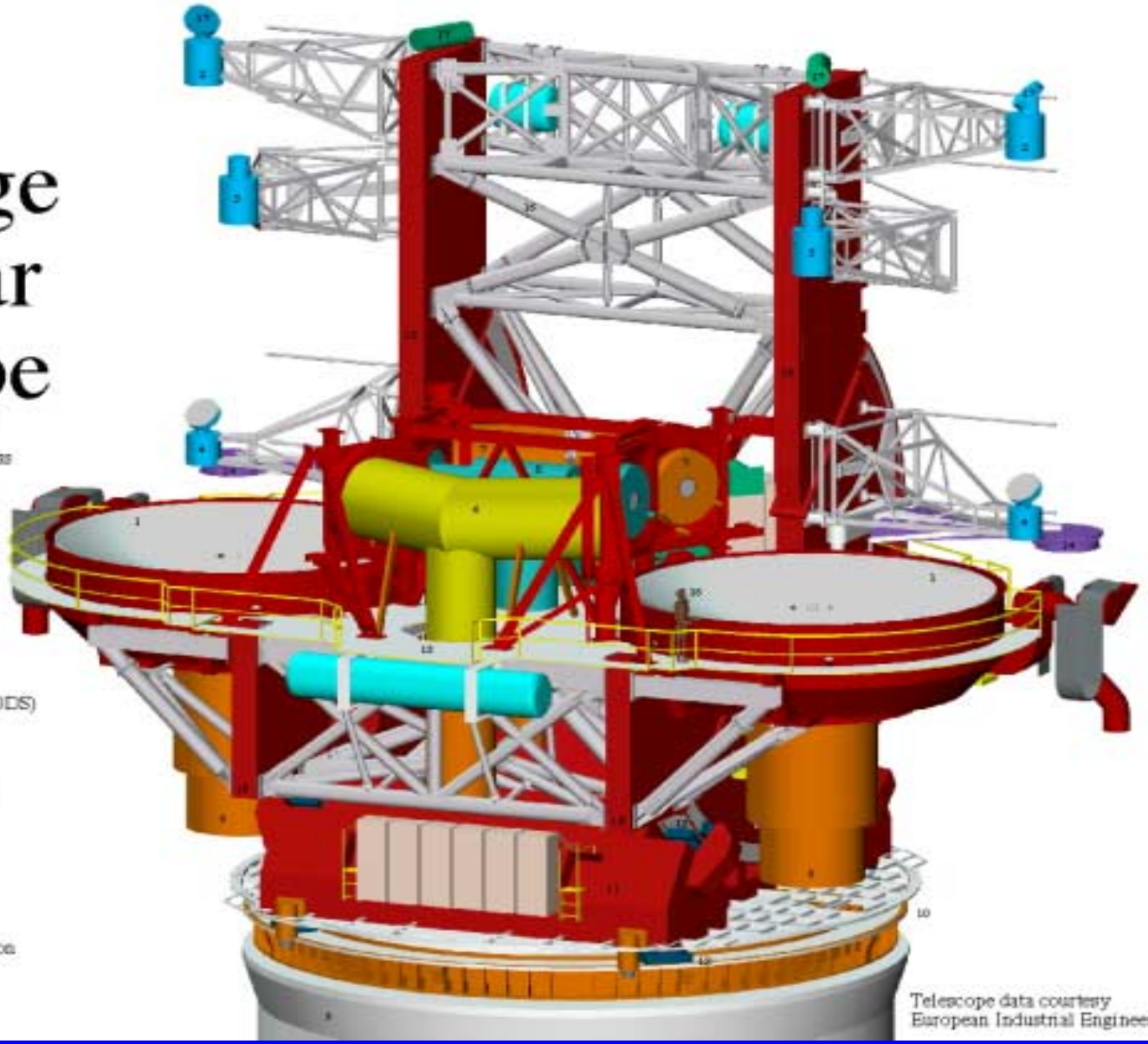


LBT

The Large Binocular Telescope

1. Twin, 8.4 meter, f/1.1 borosilicate glass honeycomb primary mirrors
2. f/15 adaptive Gregorian secondary mirrors (retracted)
3. Prime focus cameras
4. Tertiary mirrors (retracted)
5. On-axis interferometric beam-combiner
6. Forward bent beam-combiner
7. Twin near-infrared spectrographs (LUCIFER)
8. Twin UV / Visible spectrographs (MODS)
9. Telescope pier (21 m tall)
10. Azimuth track (13 m diameter)
11. Azimuth platform
12. Hydrostatic bearings for alt-az motion
13. Instrument platform
14. Mirror covers (retracted)
15. C-rings (17 m tall)
16. Wind bracing
17. Laser guide-star launch optics

18. Scale comparison. 1.8 meter tall person



Telescope data courtesy
European Industrial Engineering S.r.l.

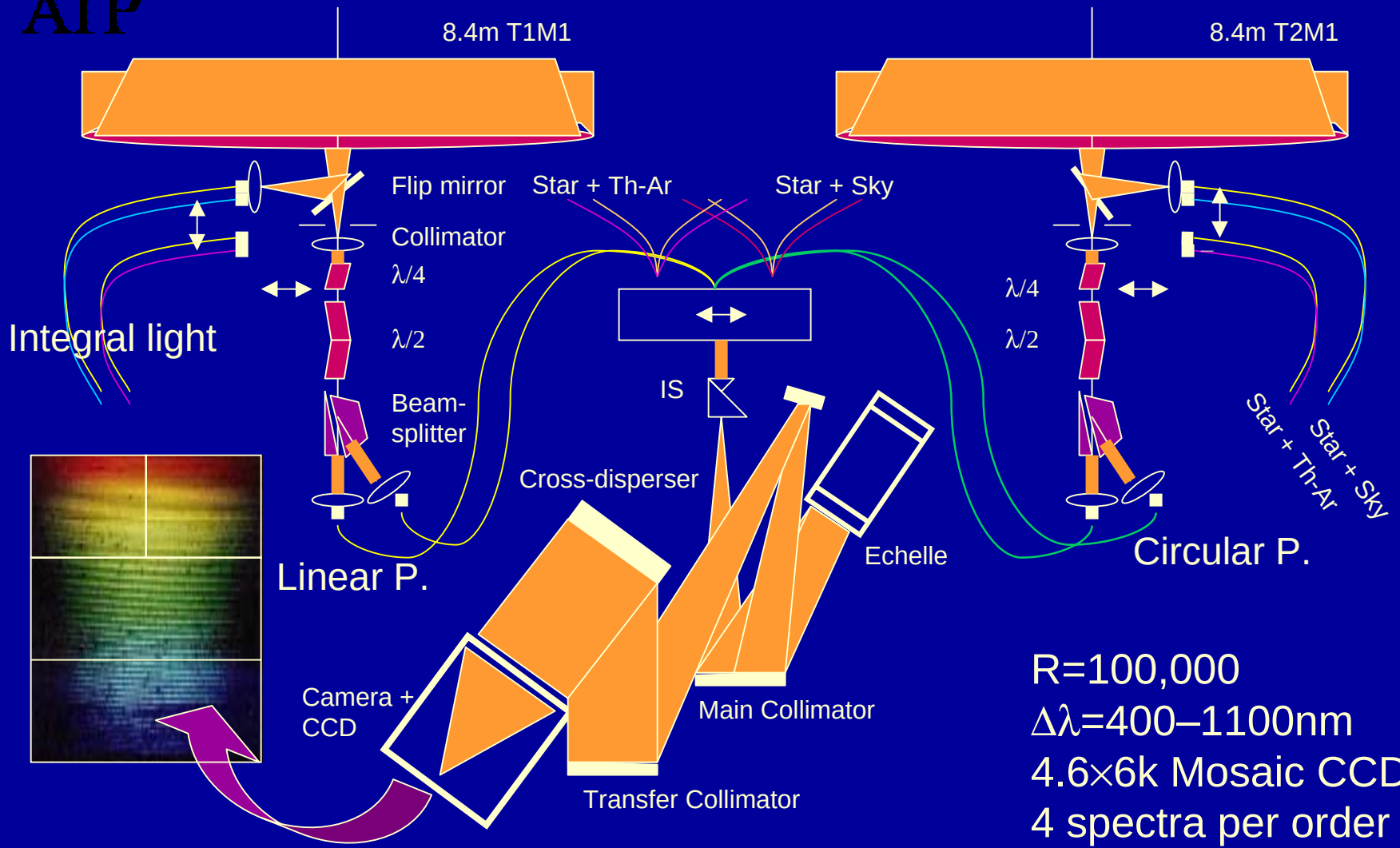
What is missing on large telescopes

- VHR (R= 200,000 - 400,000) spectroscopy (available only with the UHRF at the AAT, proposed but not yet approved for Gemini, the VLT and the LBT)
- Polarimetry (under development at CFHT, proposed for the LBT as PEPSI and for Gemini as a possible future upgrade of HROS)
- Faint object/AO medium-resolution spectroscopy (ESI at Keck, proposed for the VLT as AVES)

PEPSI proposal

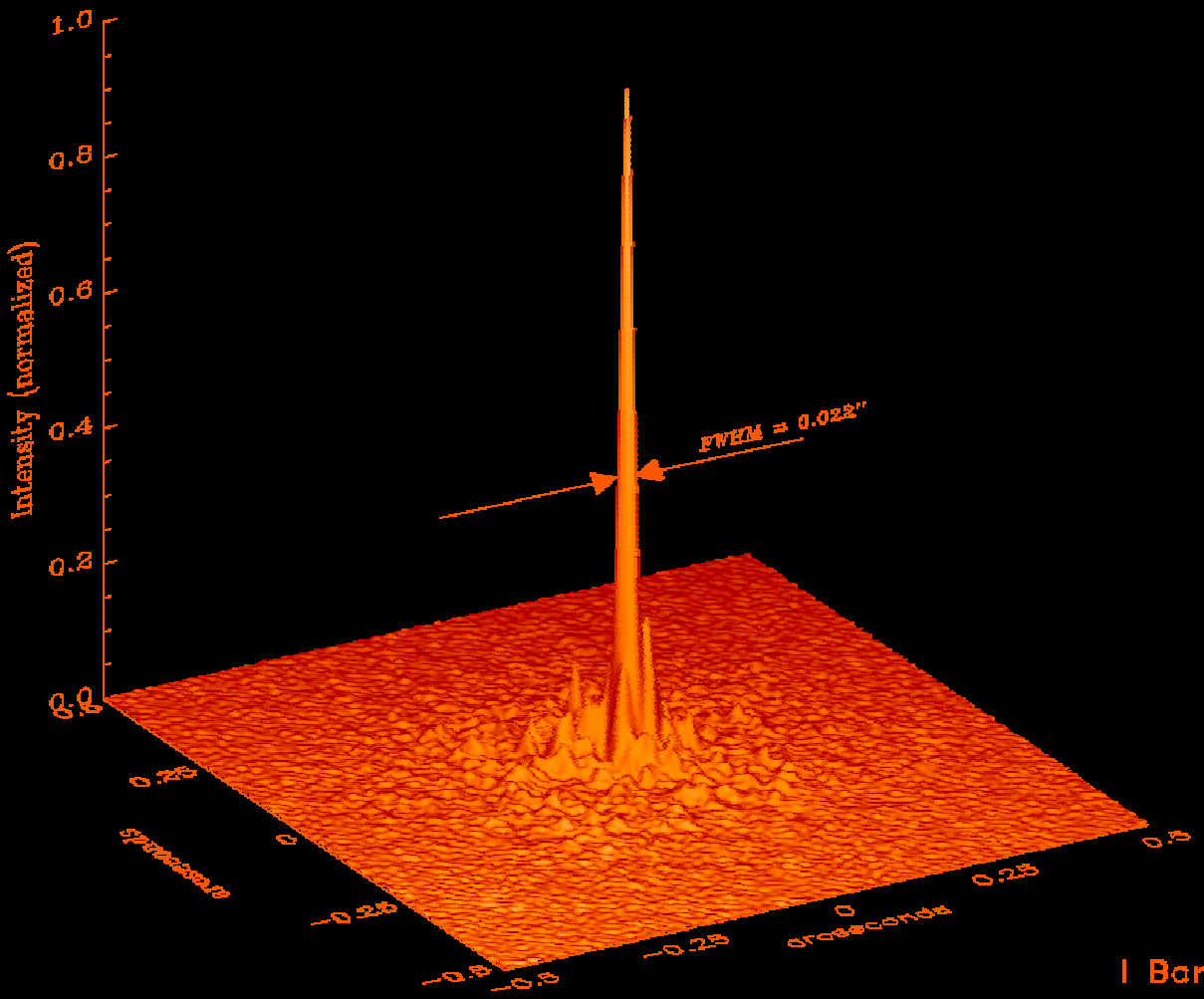
The **P**otsdam **E**chelle **P**olarimetric and **S**pectroscopic **I**nstrument for the LBT

AIP



R=100,000
Δλ=400–1100nm
4.6×6k Mosaic CCD
4 spectra per order

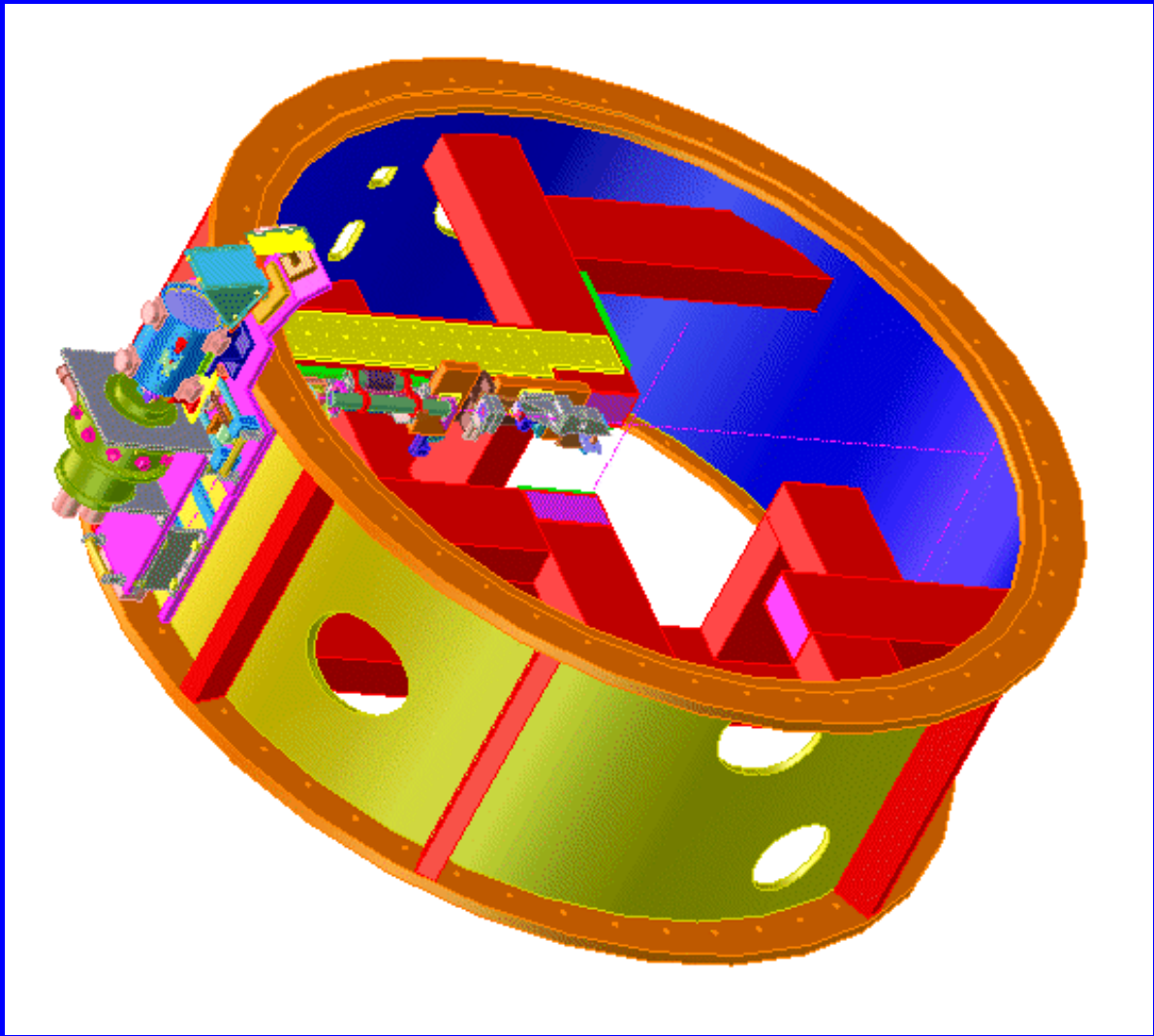
KECK Adaptive Optics



Strehl = 6%

I Band
850 nm (+/−10)

AVES-IMCO mounted on NAOS



Role of 2-4m class telescopes

- whenever larger apertures are not needed
- for preparatory work & surveys (e.g. VST, VISTA and the EIS survey at ESO)
- for dedicated programmes/instruments (e.g. 2dF at AAT, SLOAN survey, WIYN at Kitt Peak)
- for training new generations of young astronomers at national/institutional level)

Dolores and SARG at Telescopio Nazionale Galileo

Role of 1m-class telescopes

- small (1m class) telescopes are virtually disappearing at all major international observatories
- they are ideally suited for long-term programmes (mostly photometric but also spectroscopic) on relatively bright nearby stars (for monitoring stellar variability and activity)
- robotic telescopes appear to be the most effective way to satisfy this increasing demand

CONCLUSIONS (I)

- the advent of large (8-10m) class telescopes equipped with novel instruments is opening up tremendous opportunities for cool star research (e.g. for very faint nearby stars and brown dwarfs as well as for stars in distant clusters and Local Group galaxies)
- 2-4m class telescopes will continue to play an important role in the next several years for both preparatory/survey work and for dedicated programmes (e.g. open clusters, extrasolar planets)

CONCLUSIONS (II)

- Small aperture (1m class) robotic telescopes (both photometric and spectroscopic) will play a unique role for stellar activity studies, long-term monitoring and stellar variability
- AO will be crucial for imaging and spectroscopy not only at IR wavelengths but also in the optical
- Interferometry will have a tremendous impact on HR imaging of stars and extrasolar planet detections