Mem. S.A.It. Suppl. Vol. 9, 439

Memorie della
Supplementi

A planet finder for VLT

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Abstract. In the framework of the 2^{nd} generation VLT instruments we have developed the design of an instrument, called CHEOPS, to detect and characterize faint objects (Jupiter-like planets) very close to a bright star. It consists of a high order adaptive optics system, at least an order of magnitude more sensitive in terms of giant planet detection with respect to the present VLT Adaptive Optics facility NACO plus Simultaneous Differential Imager. The adaptive optics system provides the necessary Strehl Ratio for the differential polarimetric imager (ZIMPOL) and an Integral Field Spectrograph (IFS).

Key words. Planets: exoplanets – Planets: Direct Imaging – Methods:Differential photometry – Methods: Integral Field Spectroscopy

The main goal of a Planet Finder for VLT is the detection of planetary systems similar to our own, with giant planets in the outer regions, possibly at distances not much larger than the typical size of the Solar System. In fact, stars with giant planets in such external orbits may be good candidates for harbouring terrestrial planets in the habitable zone. If this aim is achieved, the PF would be very useful for the selection of targets for future space missions aimed at the detection and characterization of Earth–like planets (e.g *Darwin* or *TPF*), currently planned for the next decade.

This kind of instrument may discover giant planets in different regions and phases of their evolution. We exclude ROASTER because they are so close to the host star that they can not be separated from parent star even for 8 m class telescope with the exception of the nearest stars. Cold/old giant planets shine in reflected light, hence the contrast is essentially independent from wavelength but it depends on the square of the distance from the parent star. On the contrary for young and therefore bright planets contrast is independent of separation but is a strong function of the wavelengths because of the lower temperature of the planet. The primary scientific goals for CHEOPS are the following:

- Detect planets of a few M_J around solar like stars (∼ Gyr)
- Detection of planets in habitable zones around nearby stars

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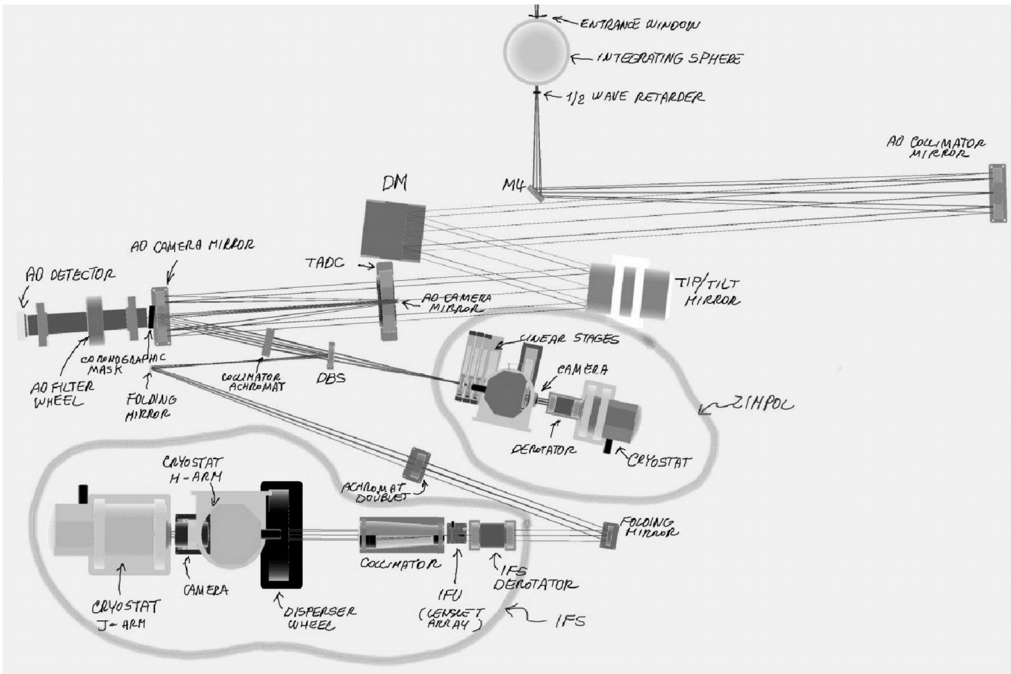

Fig. 1. The scheme of CHEOPS. Two different scientific arms are fed by the AO system, the polarimeter ZIMPOL and the Integral Field Spectrograph

- Determination of the relevant timescales for the formation and early evolution of planets ($\sim 10^7$, $\sim 10^8$, $> 10^9 yr$)
- Connection between disks and planets
- Constrain the models of planet evolution
- Spectral and polarimetric characterization of the atmosphere
- Detect planets or disks in old systems of potential interest for Darwin / TPF

On the other hand, CHEOPS could be utilized for several other interesting astronomical objects that needs both high spatial resolution and high contrast capability. One can easily envisage the utilization of CHEOPS for brown dwarfs, young stellar objects and debris disks, evolved stars, novae and active galaxies.

1. The *CHEOPS* Concept

CHEOPS (see Figure 1) consists of an adaptive optics system feeding two science arms by means of a dichroic mirror. The entire instrument will be placed on a fixed optical bench located on a Nasmyth platform of the VLT. This set up guarantees the same attitude against gravity for the whole instrument. The optical part of the beam will end up in a polarimetric I-band imager using the ZIMPOL technique. The NIR beam feeds an integral field spectrograph optimized for the J and H bands. Both paths will provide a large contrast enhancement through differential measurements, either looking for a strong spectroscopic signal from a planetary atmosphere or for a polarimetric one. The use of both arms simultaneously will allow the detection of a Jupiter twin at 5 pc at a SNR of almost 10 within one night of integration time.

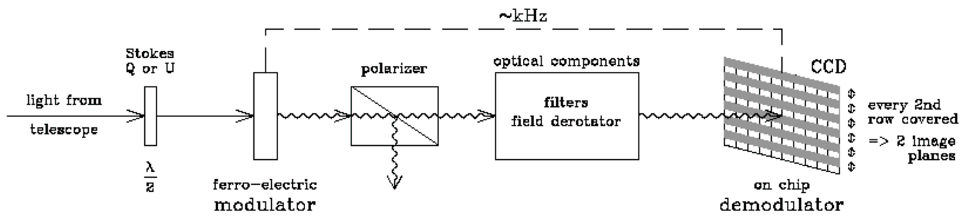

Fig. 2. Basic principle of the ZIMPOL technique for measuring linear polarization. From the left there is first a $\lambda/2$ plate for choosing between the Stokes Q and U parameters, then comes the polarization modulator and the polarizer. The modulator is synchronized with the CCD demodulator. Between the polarization optics and the detector any static optical component can be inserted without affecting the polarization measurement (adapted from Schmid et al 2002). In CHEOPS/ZIMPOL the second beam from the polarizer (beam splitter) goes to a second camera system

2. Diffractive IFS

The concept of the integral field spectrograph is based on the TIGER design Bacon et al. (1995).

Our current concept is to optimize the integral field unit to work between 0.9 μm and 1.7 μm using two different arms, one for J band and the other for H band. This wavelength range offers valuable diagnostics to discern planetary features in the proximity of the central star, while at the same time, it saves the hassle of adding cold optics to a fairly large part of the instrument. Table 1 gives a summary of the IFS baseline characteristics

Table 1. Summary of the IFS characteristics.

Range (μm)	0.90-1.70
Width absorption bands (μm)	0.030
J spectra length (px)	14.43
H spectra length (px)	14.43
R	15
detector size	$2 \times (2k \times 2k)$
N_{Lens}(n_{px} apart)	254×254
FoV (arcsecs^2)	3.5×3.5
IFU geometry	hexagonal
magnification	1
array size (mm^2)	38.1×38.1
coll/camera focal length (mm)	375

3. ZIMPOL

Light reflected from a planet is polarized, mainly due to Rayleigh scattering. This raises the possibility of detecting extra-solar planets by using its polarization signal. The best technique for high precision imaging polarimetry currently available is ZIMPOL (see Figure 2), the Zurich Imaging Polarimeter (Schmid et al. 2002). Advantages of the ZIMPOL technique are that a photon noise limited accuracy can be achieved up to a signal to noise level of 10^5 or even more, and that the polarimetry is not affected by seeing noise. These are key properties for detecting a small signal of polarized light from an extra-solar planet in the strong seeing halo of a bright star.

4. Conclusion

Our study demonstrates the feasibility of a high contrast instrument at the Nasmyth focus of one VLT telescope for direct detection of extrasolar planets.

References

Bacon et al. 1995, A&A Suppl., 113, 347

Schmid et al. 2002, in: Scientific drivers for ESO future VLT/VLTI instrumentation, J. Bergeron, G. Monet (eds.) ESO, Astrophysics Symposia, Springer, p.231