The METIS Times

EXOPLANET SPECIAL ISSUE

VOL. II ... No. I LEIDEN, MONDAY, DECEMBER 1, 2014 PAGE 1

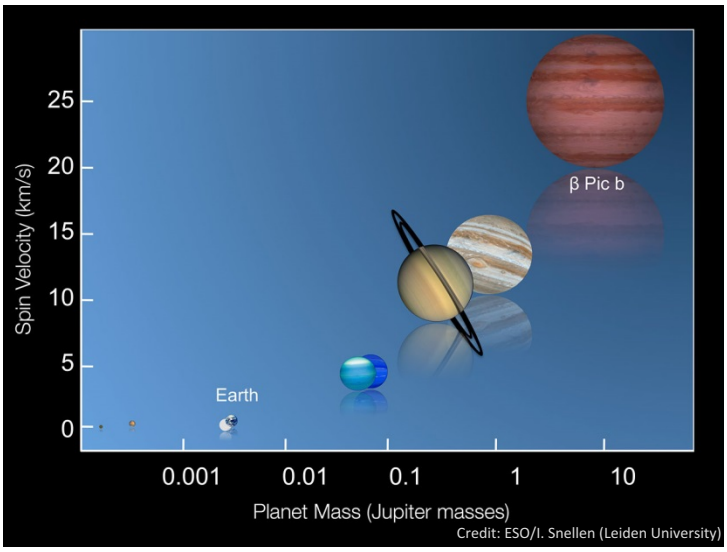
EDITOR's CORNER

Only about 20 years after their discovery, exoplanets have become one of – if not the – most exciting and vibrant areas of modern astronomy, driven by the societal interest in the search for other habitable worlds. Most major observatories worldwide have joined in the hunt for exoplanets, but are facing some of the biggest challenges in observational astronomy ever: the huge imaging contrast and sensitivity required for the detection and characterization of exoplanets. While dedicated instruments on 8-10m telescopes have just begun to scratch the surface of the discovery space, high expectations are raised for the next generation of extremely large telescopes (ELTs).

The mid-infrared E-ELT imager and spectrograph (METIS) will be a unique 1st generation instrument on ESO's leading observing facility. It will substantially add to the exoplanet discovery space spanned by the suite of planned E-ELT instruments. This special issue of the 'METIS Times' features the most relevant METIS news on the hunt for exoplanets for a general audience.

A unique competitive advantage

CERRO ARMAZONES – The two competing ELT projects – the Giant Magellan Telescope (GMT) and the Thirty Meter Telescope (TMT) – appear to follow a less aggressive approach concerning exoplanets. Their 1st light instruments are limited to wavelengths shortward of 2.5 μm, with only one exception: GMTNIRS, a 1-5 μm high resolution slit spectrograph. METIS offers a unique advantage to European astronomers.



METIS to measure exoplanets' spin

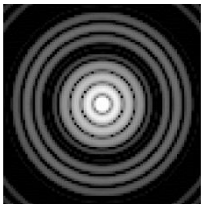
LEIDEN, HARVARD – Recently, a new observable has emerged that will help to constrain planet evolution – planetary spin. Observations with CRIRES at the VLT show that the exoplanet Beta Pictoris b spins with an equatorial velocity of almost 100.000 km per hour, implying an 8 hour day on this world. Interestingly, the fact that Beta Pictoris b spins so fast is well in line with the trend of spin rotation with planet mass seen for the solar system planets, and is likely a relic of the planet formation process during which mass and angular momentum are accreted. METIS will determine the rotation of dozens of gas giant exoplanets for a range of masses - an exciting new perspective for exoplanet science.

METIS to study 100s of exoplanets

SACLAY – METIS has an enormous potential to observe a vast number of exoplanets - probably in the hundreds to thousands. Planets so far detected by direct imaging are restricted to young gas giants on wide orbits. METIS' unparalleled spatial resolution and sensitivity provides access to both older, more evolved planets, which have cooled down further, and also smaller planets, which cool down faster. Simply scaling up the number of known detectable planets to the volume of the METIS discovery space indicates that hundreds to thousands of objects will be within the reach of METIS.

Contrast impact of the M1 central hole

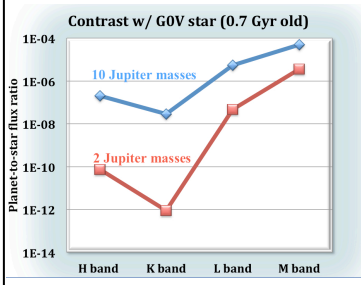
LEIDEN – In order to keep the construction of the E-ELT in line with the available funding it has been proposed that the primary mirror M1 will have a larger central obscuration at 1st light, which affects the PSF.



"While the contrast in the inner 2 – 3 Airy rings is about 35% lower, it gets actually better in rings 4 – 5. In any case, the METIS APP mask can compensate for this effect" explains AO expert Remko Stuik.

L and M band: The place to be for exoplanet imaging

ZURICH – Even though the first generation of dedicated high-contrast exoplanet imagers on 8m telescopes works mainly in the red and near-infrared wavelength regime, there is growing interest in going to the 3-5 micron range. This is mainly driven by significantly less stringent contrast requirements to actually detect thermal emission from a planet – in particular for older and lower mass planets. In addition, superior AO performance and higher Strehl ratios at longer wavelengths increase the effectiveness of coronagraphs and other high-contrast techniques.



Mid-IR instruments a 'must' for an ELT

HEIDELBERG – "For very large telescope apertures *D*, the highest gain in ground-based observations is at longer wavelengths opening up completely new discovery space", explains Roy van Boekel, METIS Instrument Scientist. While the gain in sensitivity increases only linearly with the collecting area ($\sim D^2$) in the photon noise limited regime, observations in the background limited regime benefit over-proportionally from going from an 8-m to a 39-m telescope: Here, for instruments working at the diffraction limit - like METIS -, the time to detect point sources with a given signal-to-noise decreases with $\sim D^4$.

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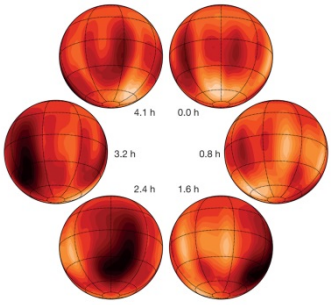
New technique to map alien worlds

HEIDELBERG – One decade ago, astronomers believed that it would take a space interferometer of several kilometers in size to resolve structures on exoplanets - beyond the dreams of even the largest optimists. However, recent work with CRIRES at the VLT indicated that Doppler-imaging, a technique regularly used to map stars and now also a brown dwarf, can be applied with METIS to make 2D images of exoplanet atmospheres.

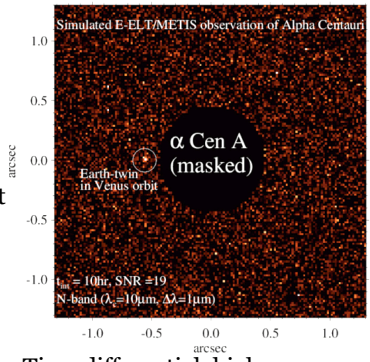


METIS to study clouds and chemistry

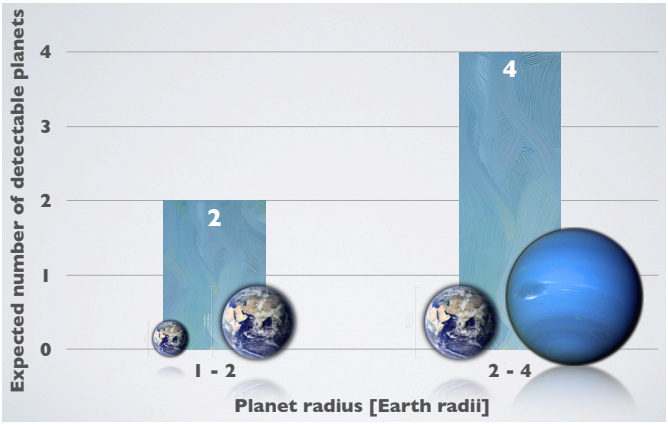
VIENNA – Broad wavelength coverage is key to understand exoplanet atmospheres. The L and M band provide crucial information regarding cloud properties and potential disequilibrium carbon chemistry. Studying the atmospheric composition of dozens of cool giant planets is required to draw stringent conclusions on their formation and evolution and to compare them to Hot Jupiters.

METIS - The first image of a rocky planet?

SACLAY – With all space-based missions to image Earth-like planets and characterize their atmospheres being put on hold or cancelled, ground-based projects have to step-in. Small, warm planets around the nearest stars emit enough thermal emission and are sufficiently separated from their hosts for METIS to detect them. "The Kepler mission has shown us that small planets are abundant. Based on the statistics from Kepler, we expect METIS to directly image ~6 warm planets (T ~ 200-600 K) with a radius between 1-4 Earth radii around the nearest stars", says Sascha Quanz, METIS Project Scientist. "This is a challenging, but not an impossible goal, and at the moment I do not see any other approved instrument or mission that can challenge METIS in achieving this landmark result." In addition, there is an enormous unexploited potential in the novel combination of existing techniques, which for the first time, will be fully utilized by METIS.



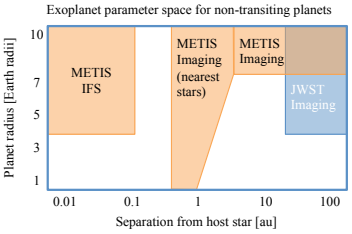
Time differential, high-dispersion spectroscopy has already shown to separate out planet signals in the time and spectral domain at the 10^{-4} level. High-contrast direct imaging spatially separates planets at even more extreme contrast levels. "Simulations show that the METIS IFU can combine these techniques and detect and characterize planets simultaneously in the time, spectral and spatial domain - reaching contrast levels of 10^{-9} or better - bringing characterization of rocky planets around nearby stars within reach", concludes Ignas Snellen, member of the METIS exoplanet team.



METIS reveals mass-luminosity relation for cool, giant planets

ZURICH – Mass and luminosity are fundamental physical properties of celestial objects. Yet up to now, not a single cool extrasolar gas giant has combined empirical measurements for both quantities. METIS is capable of directly imaging more than 20 of the currently known radial velocity detected gas giant planets on wide orbits. Dozens of additional – and better – targets are expected to be available in the future from continuing RV surveys and in particular from the GAIA space mission. "METIS will really open up a completely new research field in characterizing cool, distant gas giant planets with dynamical mass constraints", concludes Michael R. Meyer member of the METIS Science Team.

METIS and JWST are each unique!



EDINBURGH – A common misconception is that JWST will skim the cream of exoplanet science, starting in 2018. In practice, however, JWST and METIS complement each other perfectly, probing very different and unique parameter spaces: While JWST will be untouchable in terms of sensitivity and wavelength coverage, METIS will be superior in terms of spatial and spectral resolution. Together, both facilities can detect and study a wide range of exoplanets.

METIS employs state-of-the-art coronagraphy

LIEGE – METIS will provide a variety of coronagraphic concepts and masks to enhance the contrast, including an apodizing phase plates (APP), and angular groove phase masks (AGPM) vortex vector coronagraphs. Examples of these technologies are already installed at various mid-infrared instruments on 6-8m telescopes all over the world. "The combination of these concepts allows us to get the best performance under the given boundary conditions, ranging from the highest possible starlight suppression under stable conditions to being limited by residual jitter and telescope vibrations" according to the coronagraphy experts Matthew Kenworthy and Olivier Absil.