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A2_2 The Detection Limits of the E-ELT on the Proxima Centauri System

R. Bradley-Evans, R. Gafur, R. Heath, M. Hough

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

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Abstract

The development of the European Extremely Large Telescope (E-ELT) allows for a more in-depth analysis of exoplanets. We explore the Proxima Centauri system as a potential target for the E-ELT. Our results show that the instrument would allow us to resolve the separation of the star and planet, thus making it possible to conduct spectral analysis on the atmosphere of the planet.

Introduction

In recent years, there has been a growing number of exoplanets discovered within the habitable zone; including an Earth-like planet orbiting Proxima Centauri 4.22 light years away [1]. In this paper we will explore what can be seen if the E-ELT was pointed at the system. The exposure will be obtained along with the angular and pixel resolutions. A simulation is made of the system which is passed through the SimCADO [2] Python package in order to simulate the optical train of the telescope.

Theory

Direct observations of exoplanets are rare [3]. However, the size and operational wavelengths of the E-ELT should make direct observations more frequent. The MICADO instrument on the 39 m E-ELT will be sensitive to near Infra-red wavebands at a native resolution of 1.5 milliarcseconds per pixel [4]. If you were to take a picture through a telescope looking at a star, the resulting visual would be an unresolved and blurry point of light. In this case, the same applies to exoplanets. By resolving the separation between the light coming from the planet and the star, we can analyse the planet's atmosphere using spectroscopy.

We can find its pixel resolution using the small angle approximation and converting to degrees using the following relation, where 57.29 is a conversion from radians to degrees:

$$angle = \frac{planet\ diameter}{distance} \cdot 57.29 \tag{1}$$

Then we can convert this into pixels based on the telescope′s stated resolution and by looking at the geometry of the system:

$$linear\ pixel\ resolution = \left(\frac{angle}{\frac{1.5\times10^{-3}}{60\cdot60}} \right) \tag{2}$$

The mass of the planet in question, Proxima Centauri b, is 1.3 times the mass of Earth [6]. Due to this, we approximate it to have the same radius as the Earth. This gives the planet a native resolution of 0.044 pixels. Proxima Centauri has a resolution of 0.684 pixels and the maximum apparent distance from the star to its planet is approximately 20.5 pixels (0.04 AU [6]).

The brightness of the star and exoplanet will determine what we see. The brightness is measured on a relative scale known as apparent magnitude which ranges from -27 (brightness of the Sun) to the visual limit (+6.5) and beyond [5]. Using the following relationships [5], the apparent magnitudes of the star and planet can be calculated.

$$m_s = 2.152 \ln \frac{(d_0)^2}{L_s} - 26.73 \quad (3)$$

$$m_p = 2.152 \ln \frac{(d_0)^2 \cdot (d_p)^2}{L_s \cdot p(\theta) \cdot a \cdot (r_p)^2} - 5.1598 \quad (4)$$

Where r_p is the planets radius, m_s and m_p are the apparent magnitudes of the star and planet respectively, d_0 and d_p are the distances between the telescope/planet and star/planet respectively, a is the planet's albedo and $p(\theta)$ is the phase of the planet. The luminosity of Proxima Centauri, L_s, is calculated to be 2031 W due to its apparent magnitude, $m_s = 11.13$ [6]. Therefore, the magnitude of the Proxima Centauri b, assuming the phase angle is 1 and the albedo is the same as the Earth (0.3), is 16.37. This falls within the detection limits of the E-ELT [4].

Results

Given that the star and planet are each less than one pixel, we can simulate them as point sources with the appropriate spectrum (A0V and M0V respectively [6]) and magnitudes. This is then passed through the SimCADO [4] package to run our simulation through the optical train of the telescope with an exposure time of 0.0115 seconds. The resulting image is displayed in Figure 1 where Proxima Centauri can be seen in the centre with diffraction effects generated from the lenses and atmosphere. Proxima Centauri b is shown with the aid of an arrow.

Conclusion

We conclude that the E-ELT will have enough resolving power to separate the light emanating from the planet and the host star. If this system was actually to be observed with the E-ELT, the light from Proxima Centauri b could be isolated and spectroscopy could be conducted - this can be done using the MICADO instrument. The spectrographic data can then be used to determine its atmospheric composition.

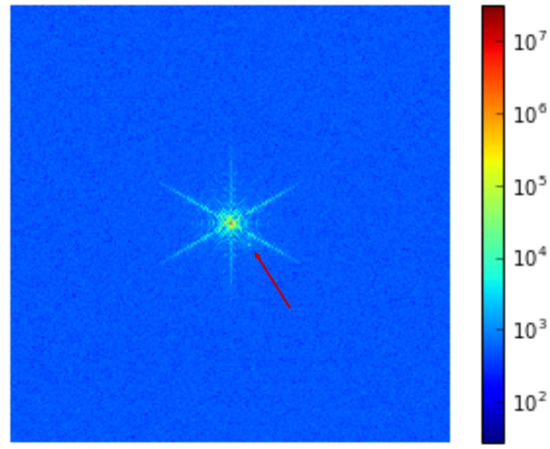

Figure 1: Resultant image of the SimCADO simulation. The colour map represents photon count over the 0.0115 second simulated exposure [4].

References

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