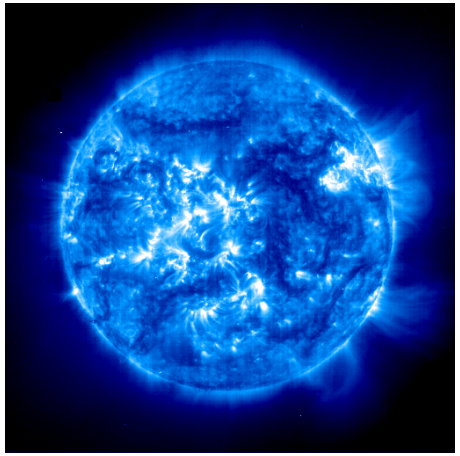
Climate and radiative properties of a tidally-locked planet around Proxima Centauri

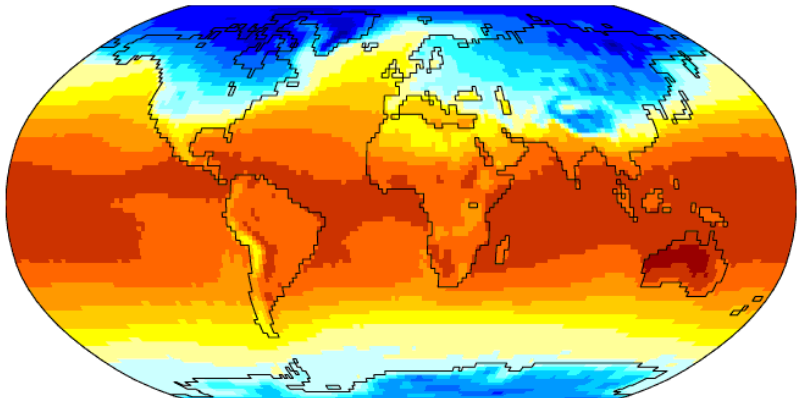
D. Galuzzo[1,2] F. Berrilli[1] C. Cagnazzo[2] L. Giovannelli[1] F. Fierli[2]

1 – Department of Physics, University of Rome 'Tor Vergata'

2 – Istituto di Scienze dell'Atmosfera e del Clima (ISAC), Centro Nazionale delle Ricerche (CNR)



Bordi, Berrilli & Pietropaolo, Ann. Geo., 2015



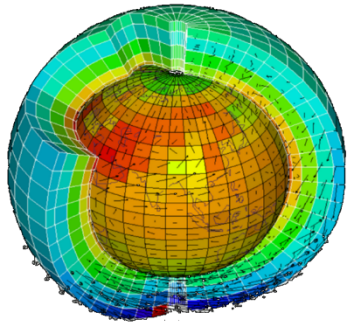
UV new proxies suitable for Str. O_3

Climate and possible role of stratospheric ozone

UV Color, Mg II, UV recons., O_3 (ML)

UV Color and fluxes in 3D GCM (DG)

Earth's thermosphere



UV Color Stellar Application

3D GCM + 1D RTM (exoplanets)

Lovric+, *J. Space Weather Space Climate*, 2017
Criscuoli+, *ApJ,* 2018

(Exo)planetary-Stellar Connection

Galuzzo+, *ApJ submitted,* 2018
Galuzzo+, *J. Climate in preparation,* 2018

Goals

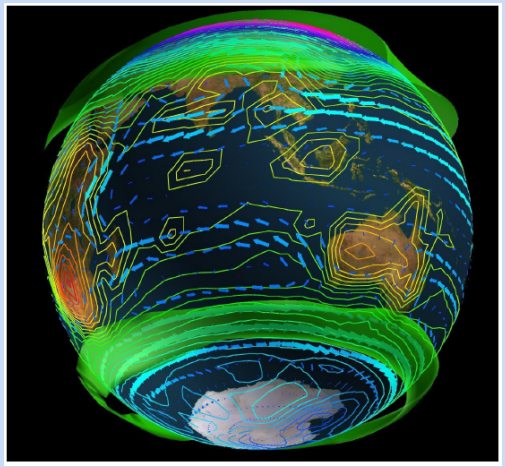
1. From solar and atmospheric physics to exoplanet climate and star/planet interactions;
2. Explore a wide range of parameters for habitability conditions;
3. Develop a procedure to assess space and ground based detection limits for exoplanets;
4. Supply a method to evaluate the required performances of future detectors.

Simulating an exoplanetary atmosphere: our tool

3D Intermediate Complexity GCM

Planet Simulator (PlaSim)

(*Fraedrich, K. et al., 2005*)



Keplerian parameters

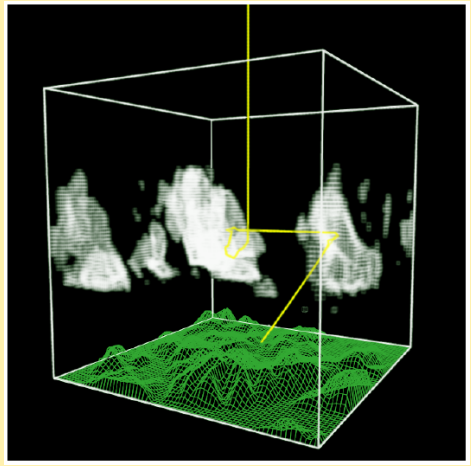
atmospheric composition

surface properties

1D RTM

Library for radiative transfer (libRadtran)

(*Emde, C. et al., 2016*)



Host star

Geometry of incident radiation

Clouds properties

A case study: Proxima b

Proxima b: derived parameters from radial velocity (*Anglada-Escudé, G. et al., 2016*)

Parameter	Symbol	Value
Orbital period	T	11.186 Earth days
Orbital semi-major axis	a	0.0485 AU
Orbit eccentricity	e	<0.35
Planet minimum mass	m_P	1.27 $M_\oplus$
Eq. blackbody temperature	T_{eq}	234 K

Proxima b: Unknown planetary parameters (assumed in simulation)

Parameter	Symbol	Value
Mean density	ρ_P	$\rho_\oplus$
Radius	r_P	1.08 $R_\oplus$
Surface gravity acceleration	g_P	10.64 m/s^2
Axial tilt	α	0 deg
Rotation rate	ω_P	6.50×10^{-6} rad/s

Assumptions:

- Rotation period = Orbital period more likely orbit, tidally locked (*Ribas, I. et al., 2016*);
- Earth-like atmosphere with 360 ppm of CO_2 ;
- Aquaplanet with a slab thermodynamic ocean of 50 meters depth;

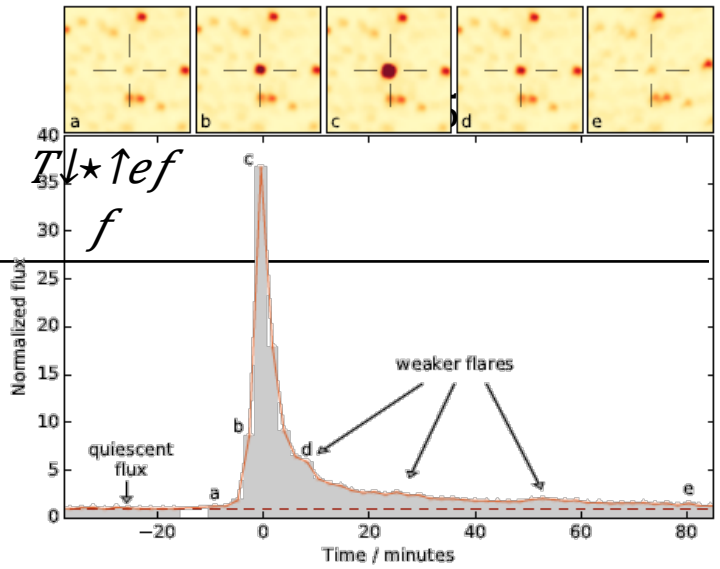
Host star properties

Stellar property	Symbol	Value
Spectral type	-	M5.5
Mass	$M\downarrow\star$	$0.120\ M\downarrow\odot$
Radius	$R\downarrow\star$	$0.154\ R\downarrow\odot$
Bolometric flux	$F\downarrow\star\uparrow bol$	$2.186\times10\uparrow-11\ \ W\ m\uparrow-2$
Irradiance at Planet b TOA	$F\downarrow\star\uparrow to$	$884.650\ W\ m\uparrow-2$
Effective temperature	$T\downarrow\star\uparrow ef\ f$	

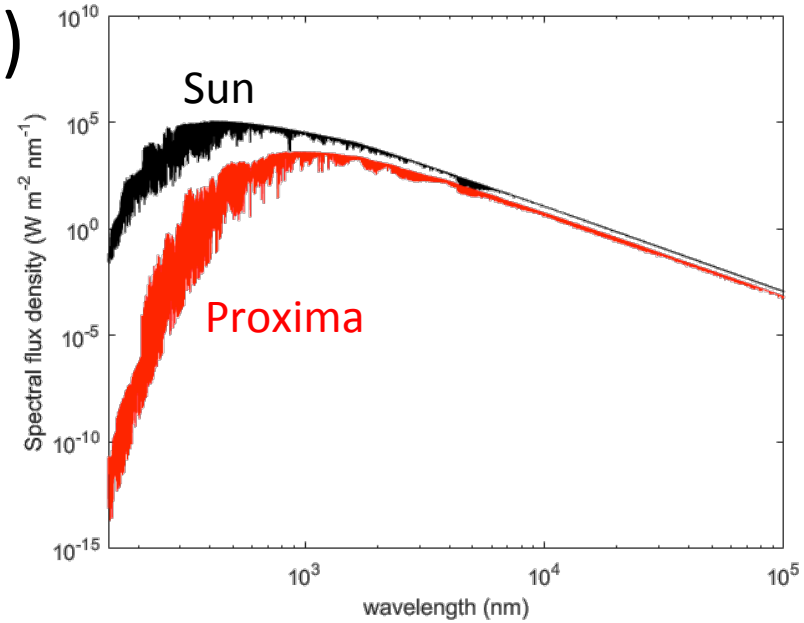
Ribas, I. et al., 2017

Howard, W. S. et al., 2018

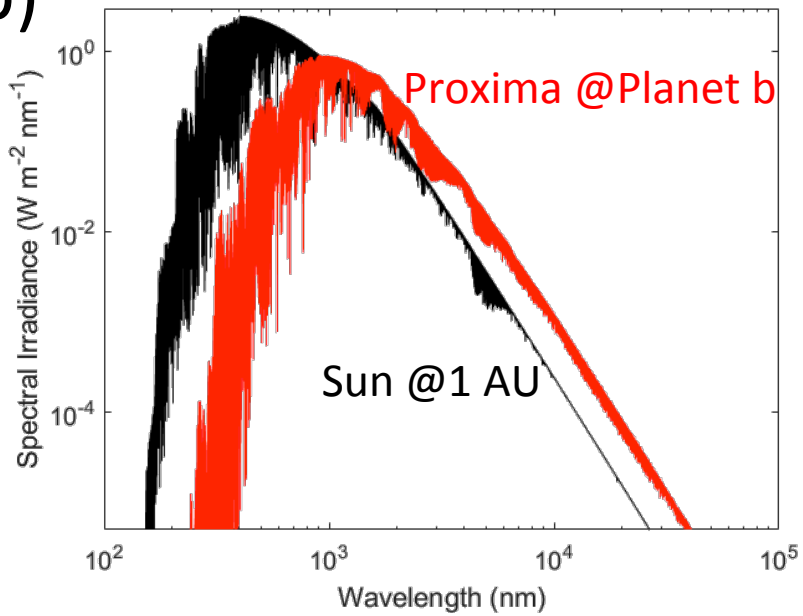
c)



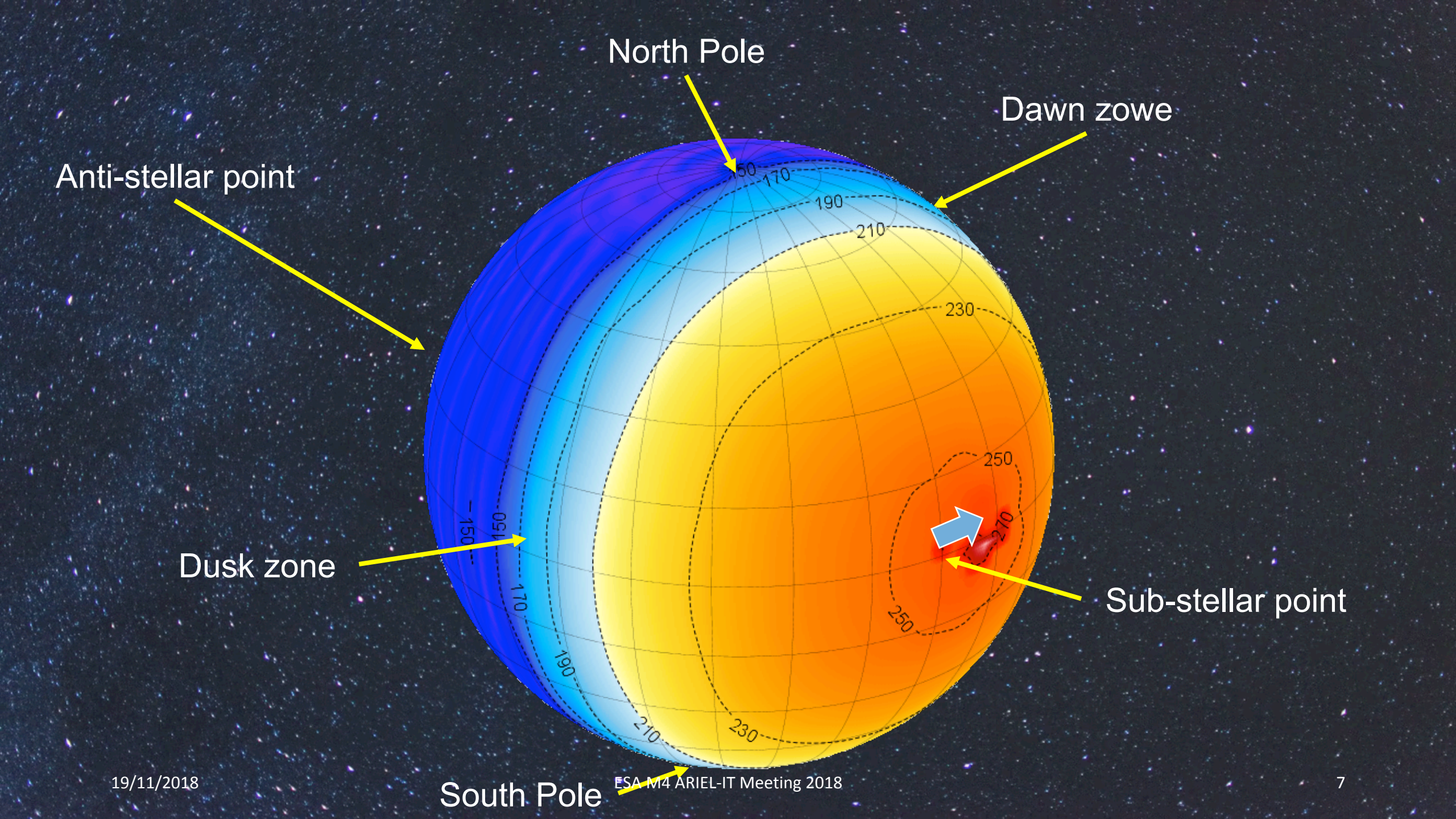
a)



b)

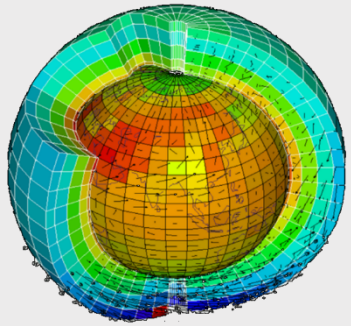


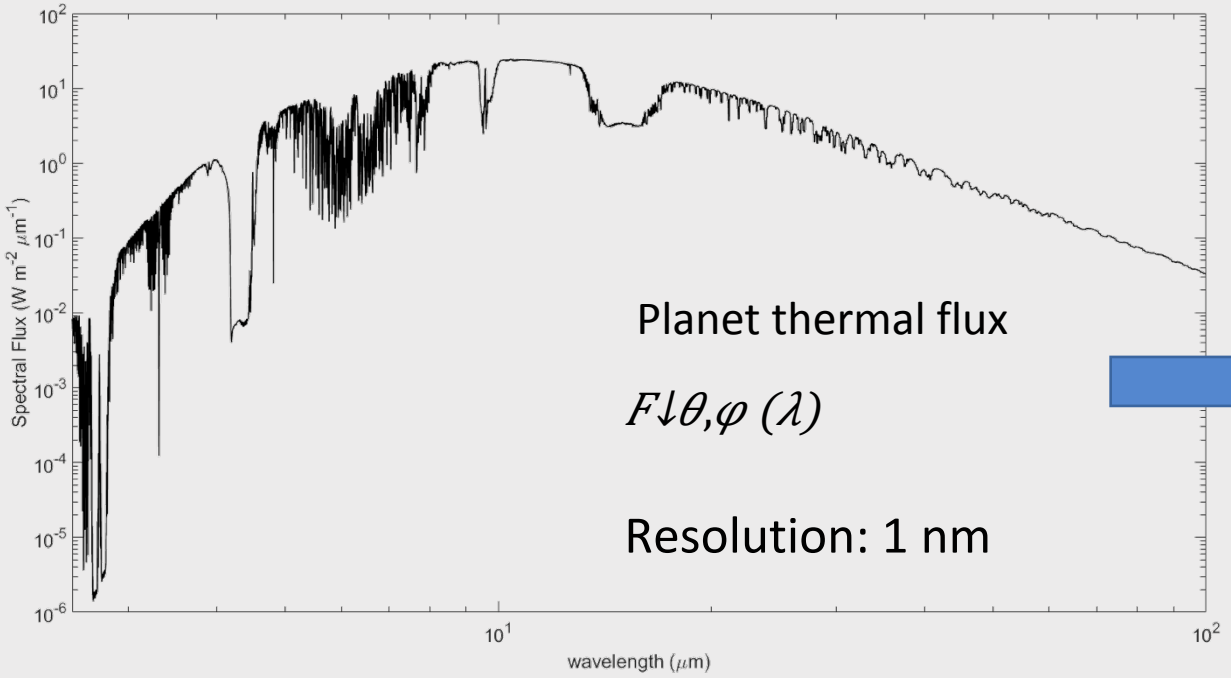
Proxima data from https://archive.stsci.edu/prepds/muscles/.


North Pole
Dawn zowe
Anti-stellar point
Dusk zone
Sub-stellar point
South Pole
150
170
190
210
230
250
270

Results: Synthetic spectra

From LibRadTran
each atmospheric column

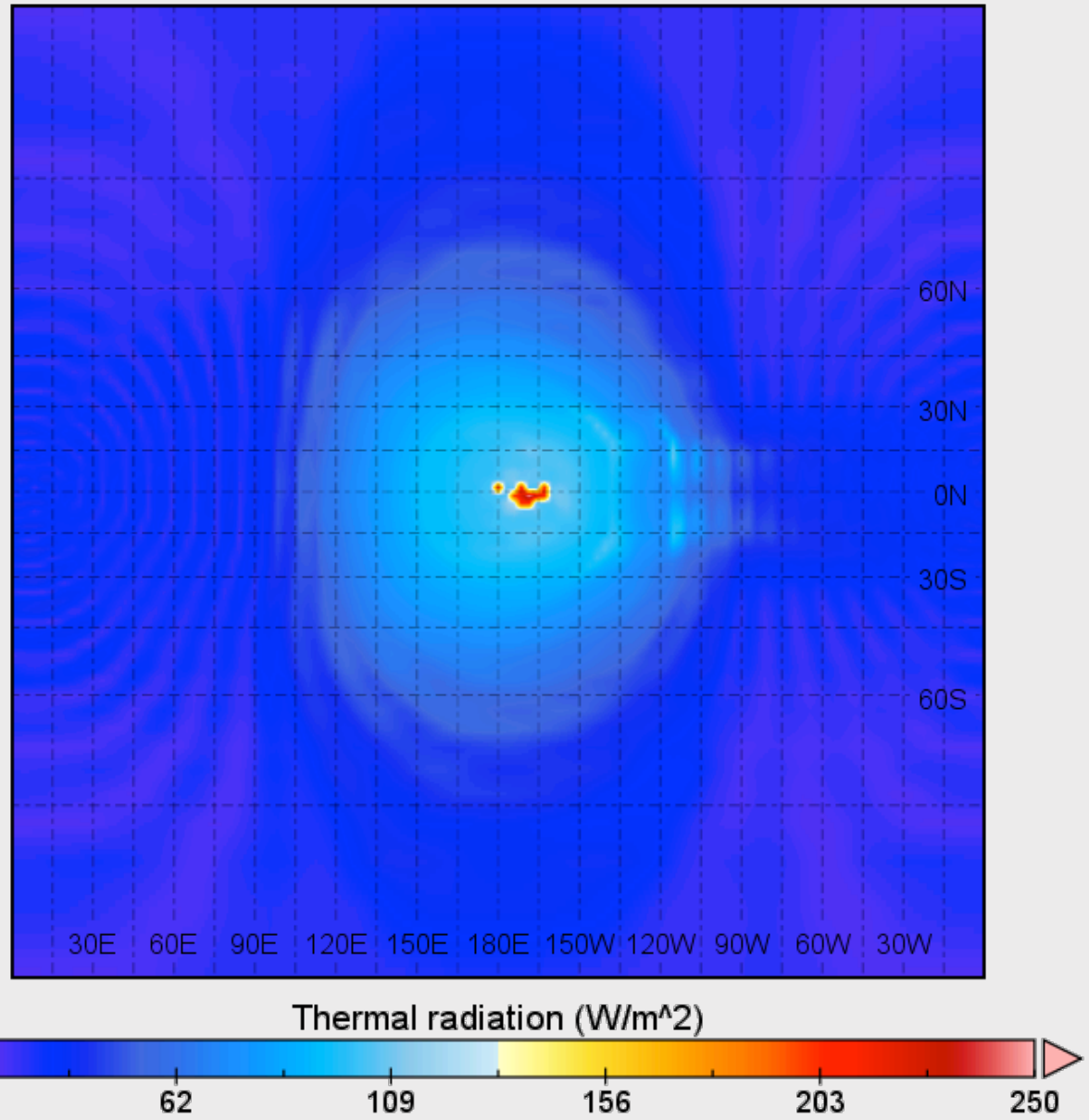




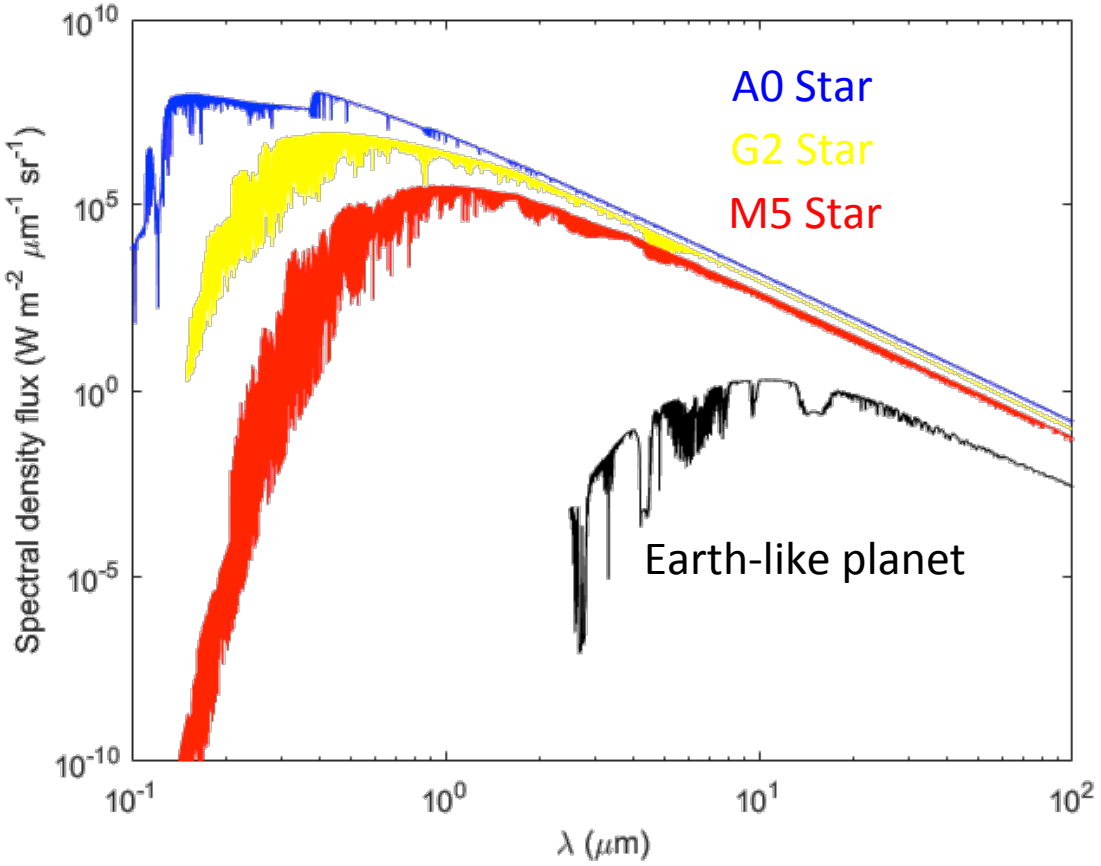
Planet thermal flux

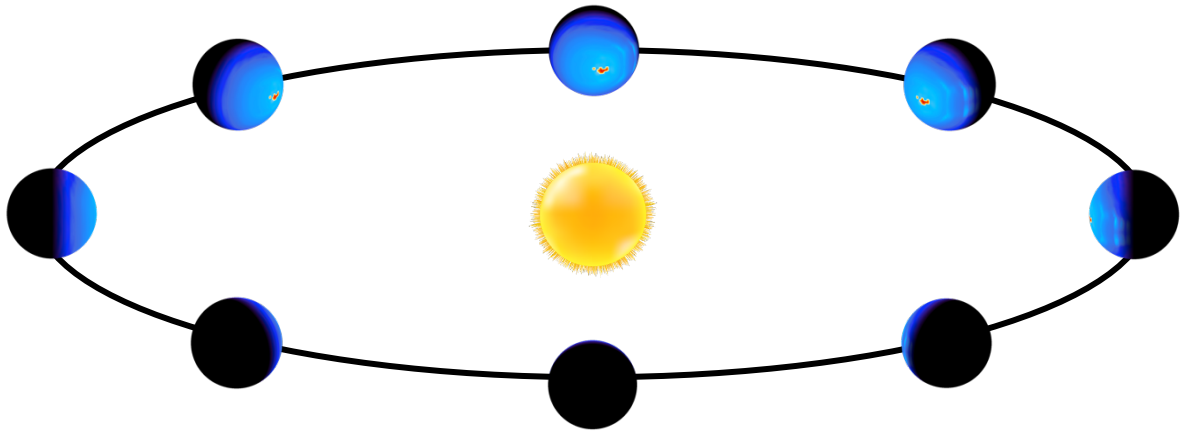
$F\downarrow_{\theta,\varphi}(\lambda)$

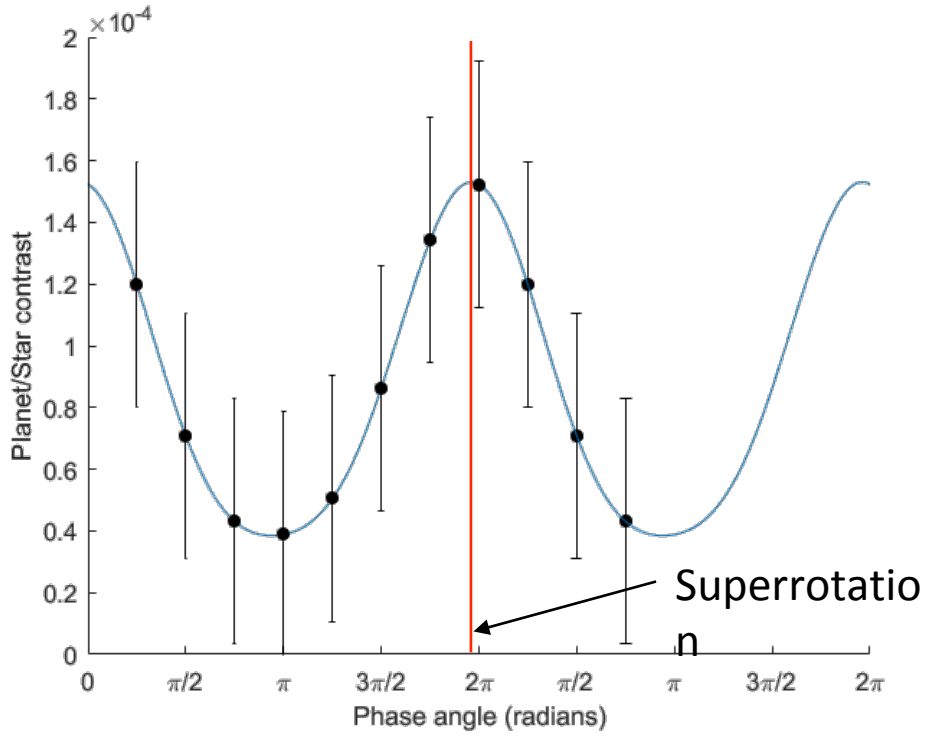
Resolution: 1 nm



Results: Atmosphere/climate detectability







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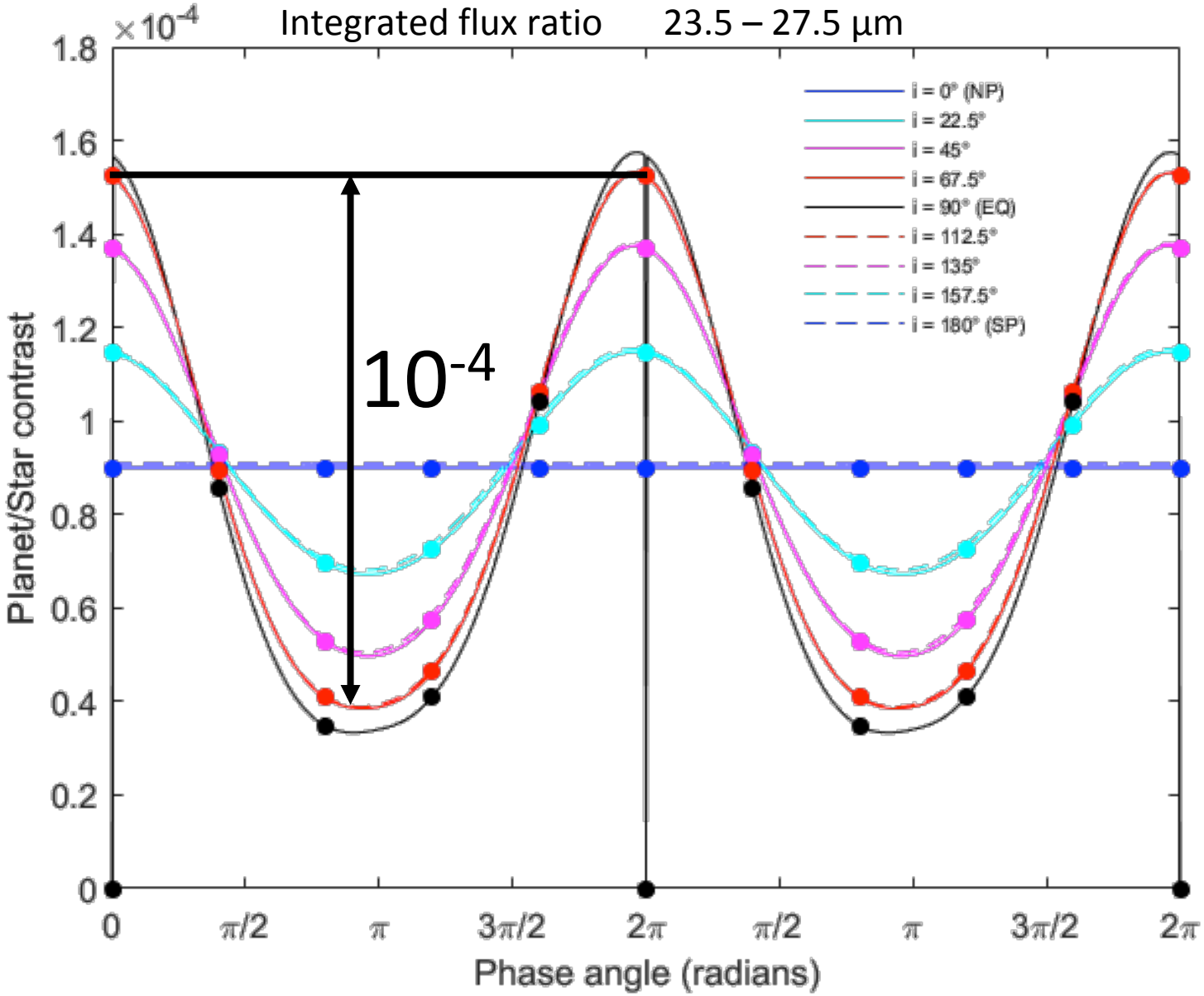
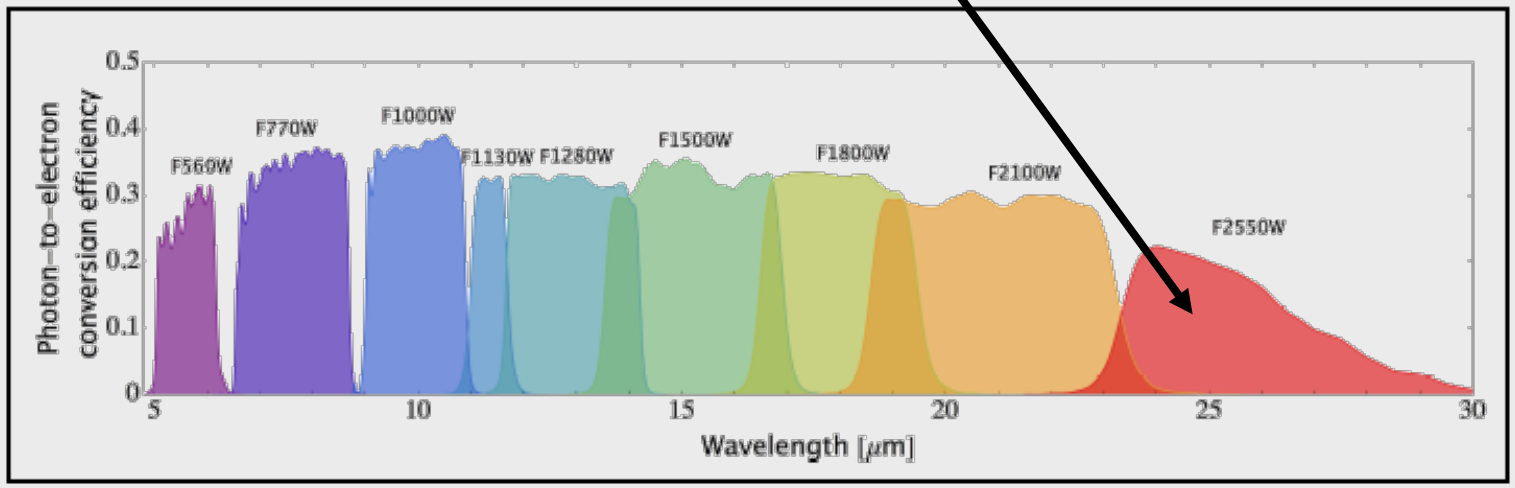
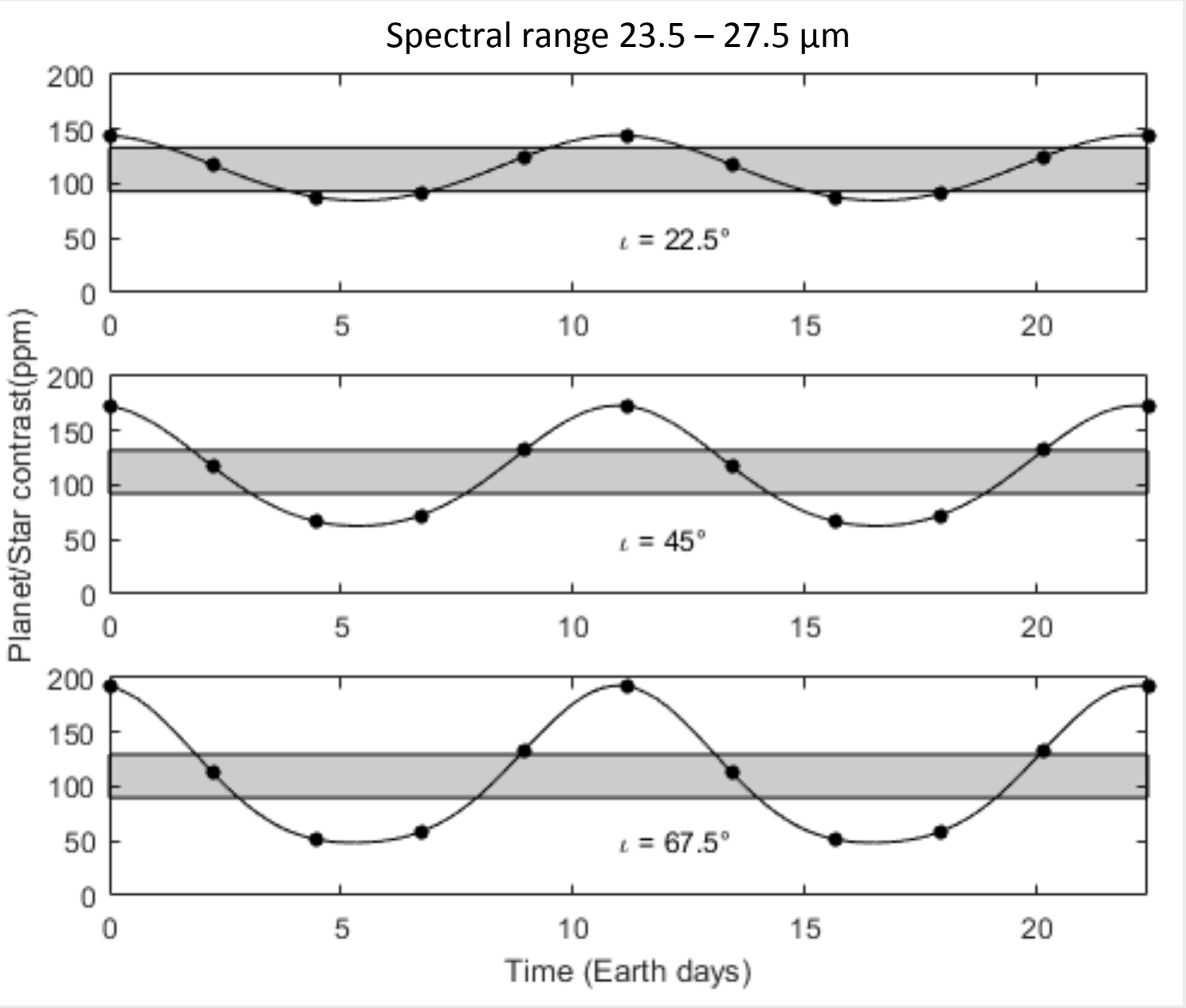


Feasibility of detecting Proxima b thermal emission with JWST

- Using the Mid-Infrared Imager on the James Webb Space Telescope
- Imaging mode
- 5 hours integration time





James Webb Space Telescope Exposure Time Calculator

https://jwst.etc.stsci.edu/

Orbital period

11.186 Earth's days

Exposure Time

5 hours

CONCLUSIONS AND PERSPECTIVES

- 3D GCM can be used to evaluate the instrumental observation limits for exoplanets;
- Exoplanet climatic conditions can be inferred by fitting model results to observational data;
- Ongoing collaboration between UniToV, ISAC-CNR, UniCal and INAF-IAPS to develop a 3D radiative, magnetic and particles model for planet/star interaction;
- **Model output: spectral retrieval (high resolution) , dynamical properties of the atmosphere, exoplanet climate features**

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