XUV-Driven Atmospheric Mass Loss of M Dwarf Planets due to Flaring

Laura Amaral[1,2,3,4], Rory Barnes[3,5], Antigona Segura[2,3], and Rodrigo Luger[3,6]

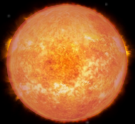
[1]School of Earth and Space Exploration, ASU (current)
[2]Instituto de Ciencias Nucleares, UNAM
[3]NASA Virtual Planetary Laboratory
[4]Consortium on Habitability and Atmospheres of M-dwarf Planets (CHAMPs)
[5]Departament of Astronomy, UW
[6]Center for Computational Astrophysics, Flatiron Institute

Sun-climate symposium | october 2023

48.6%

18 of the 20 planets with higher earth similarity index are around mdwarfs (PHL, 2023)

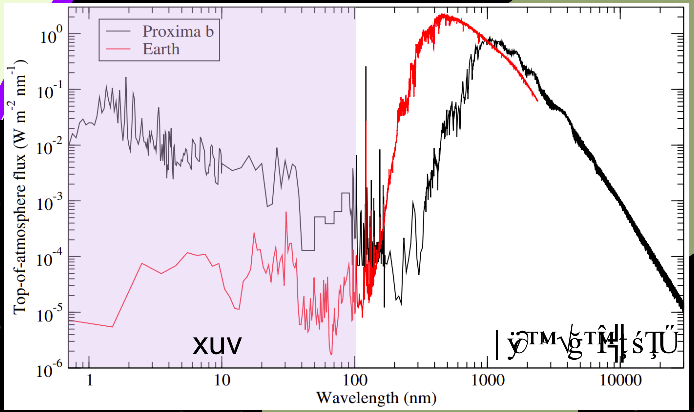
1. iron core And silicate mantle



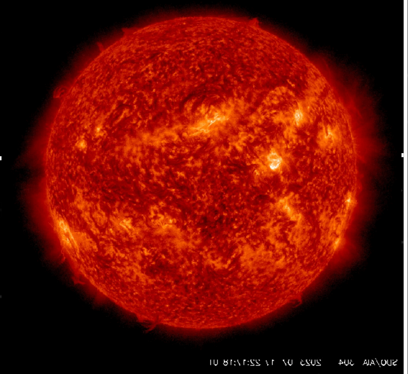
3. Habitable zone

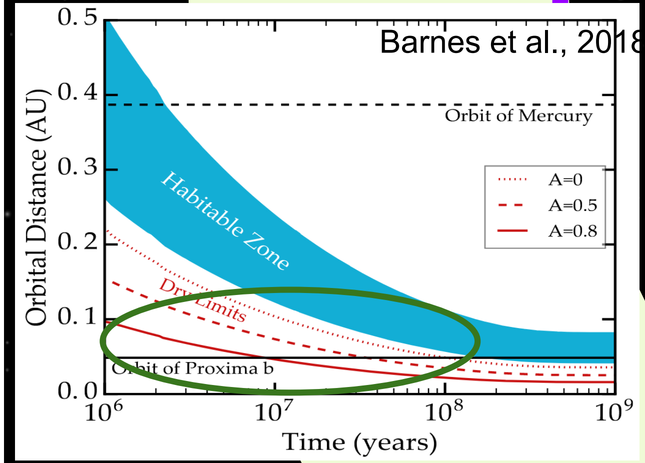
PRE-MAIN SEQUEN

INNER EDGE HZ

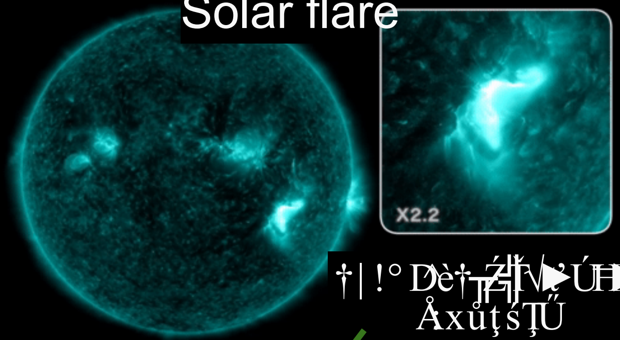


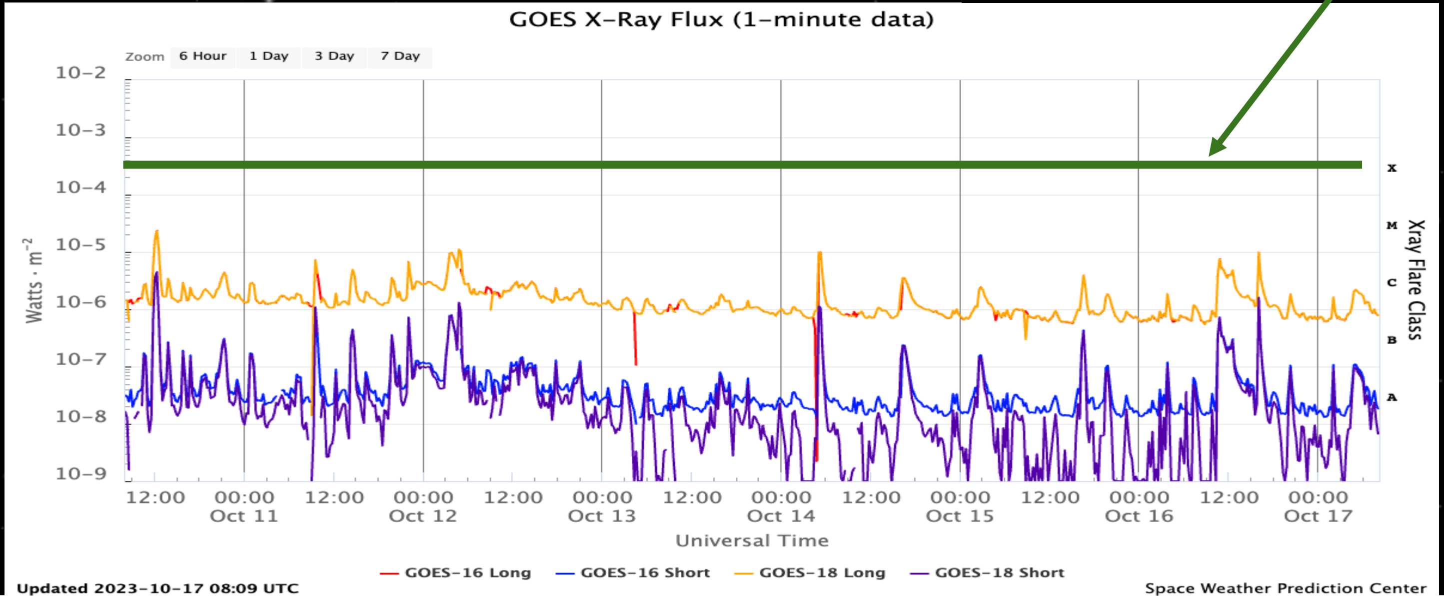
M DWAR ENVIRONME



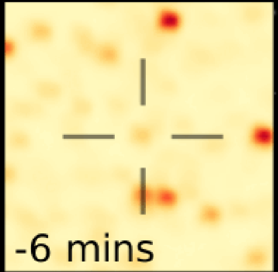


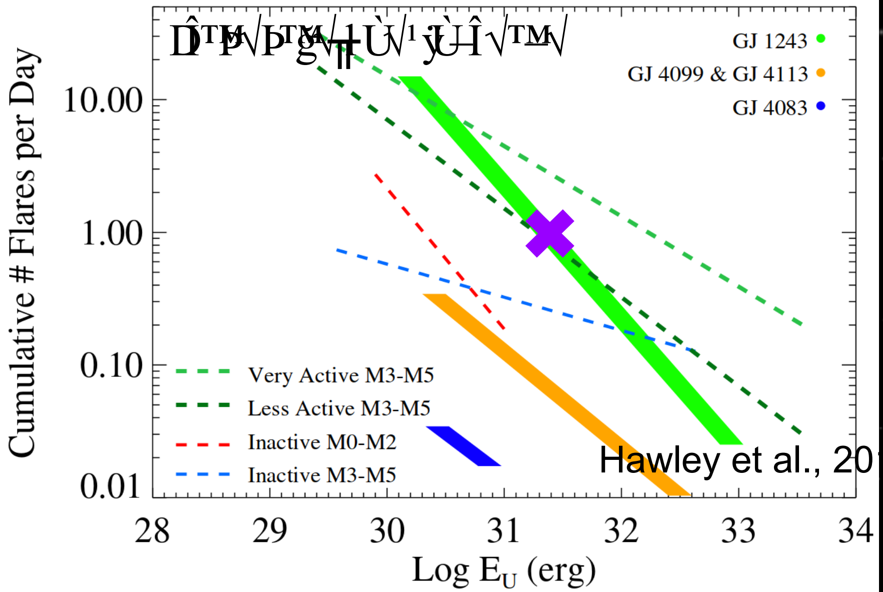
MAIN SEQUEN

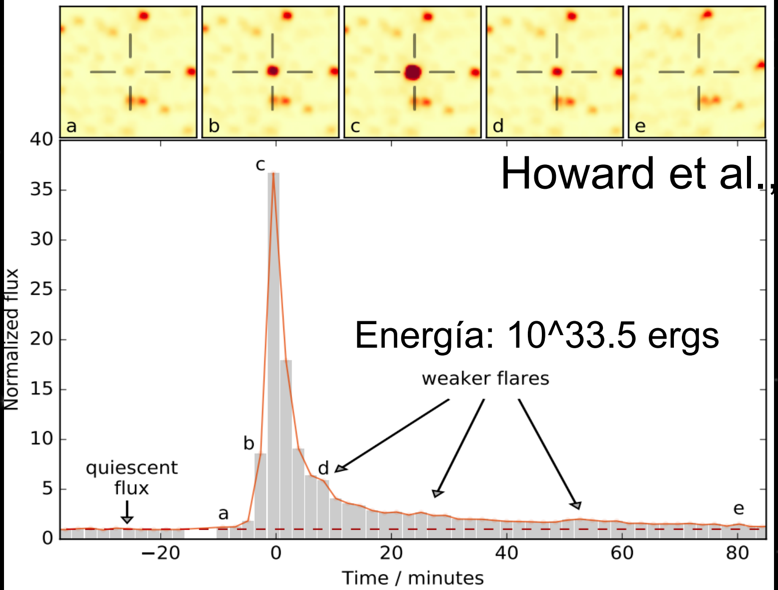

Solar flare
X2.2

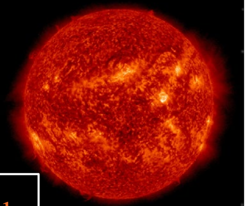

GOES X-Ray Flux (1-minute data)
Zoom 6 Hour 1 Day 3 Day 7 Day
10−2
10−3
10−4
10−5
10−6
10−7
10−8
10−9
Watts · m⁻²
X
M
C
B
A
Xray Flare Class
12:00
00:00 Oct 11
12:00
00:00 Oct 12
12:00
00:00 Oct 13
12:00
00:00 Oct 14
12:00
00:00 Oct 15
12:00
00:00 Oct 16
12:00
00:00 Oct 17
Universal Time
GOES-16 Long
GOES-16 Short
GOES-18 Long
GOES-18 Short
Updated 2023-10-17 08:09 UTC
Space Weather Prediction Center

M DWARF flare (PROXIMA CEN









FFD constant along
The stellar age

→ Add XUV by flares

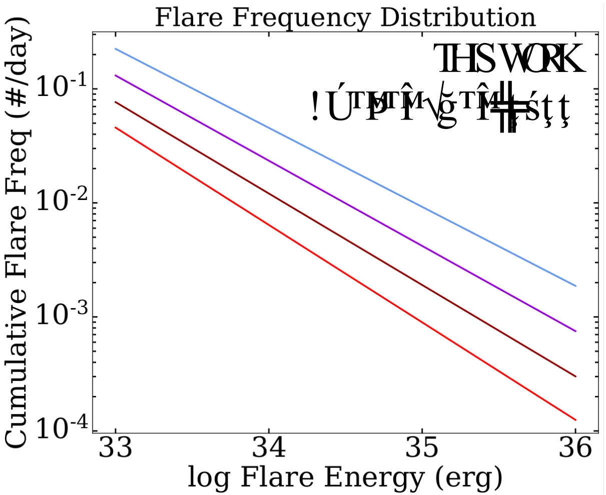
Flare module

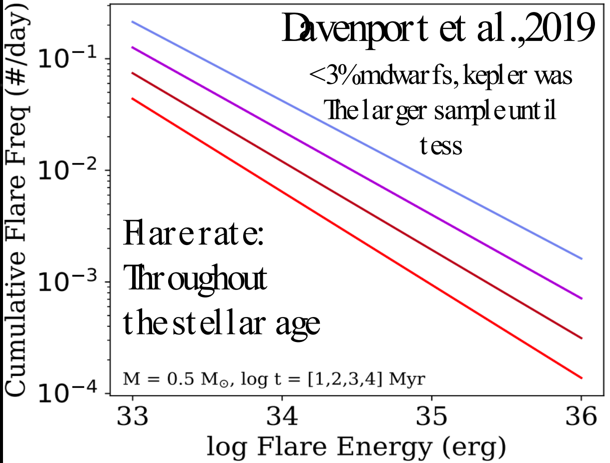
github.com/lauraamaral/WaterEscapeFlares

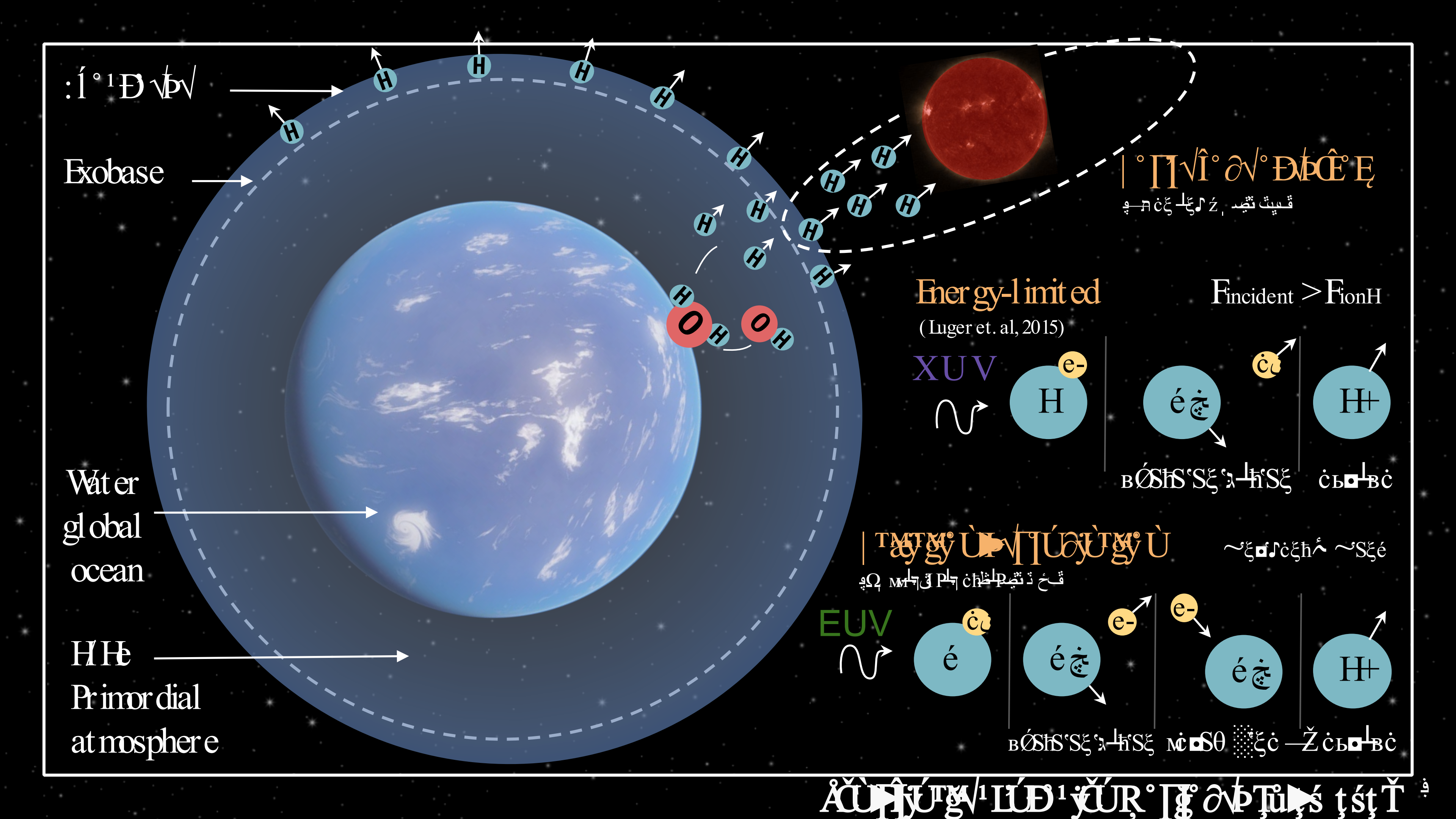
VPLanet

github.com/VirtualPlanetaryLaboratory

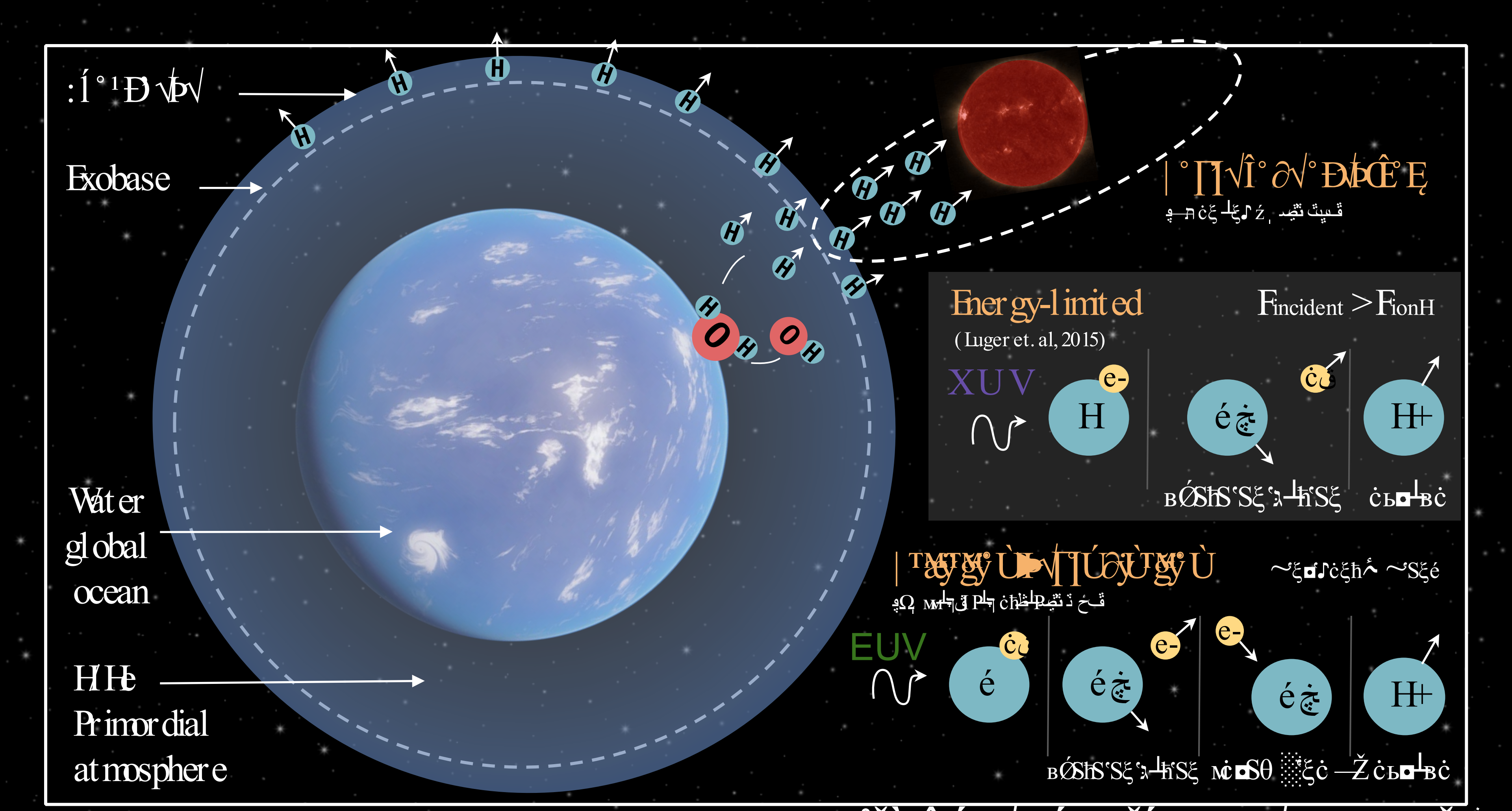
Barnes et al., 2020







Exobase
Water
global
ocean
H/He
Primordial
atmosphere
Energy-limited
(Luger et. al, 2015)
Fincident > FionH
XUV
H
e-
H+
EUV
e-
H+



Exobase
Water global ocean
H He Primordial atmosphere
Energy-limited
(Luger et. al, 2015)
$F_{incident} > F_{ionH}$
XUV
H
e-
H+
EUV
e-
H+

PARAMETERS

Planetary mass
0.5-5 Mearth

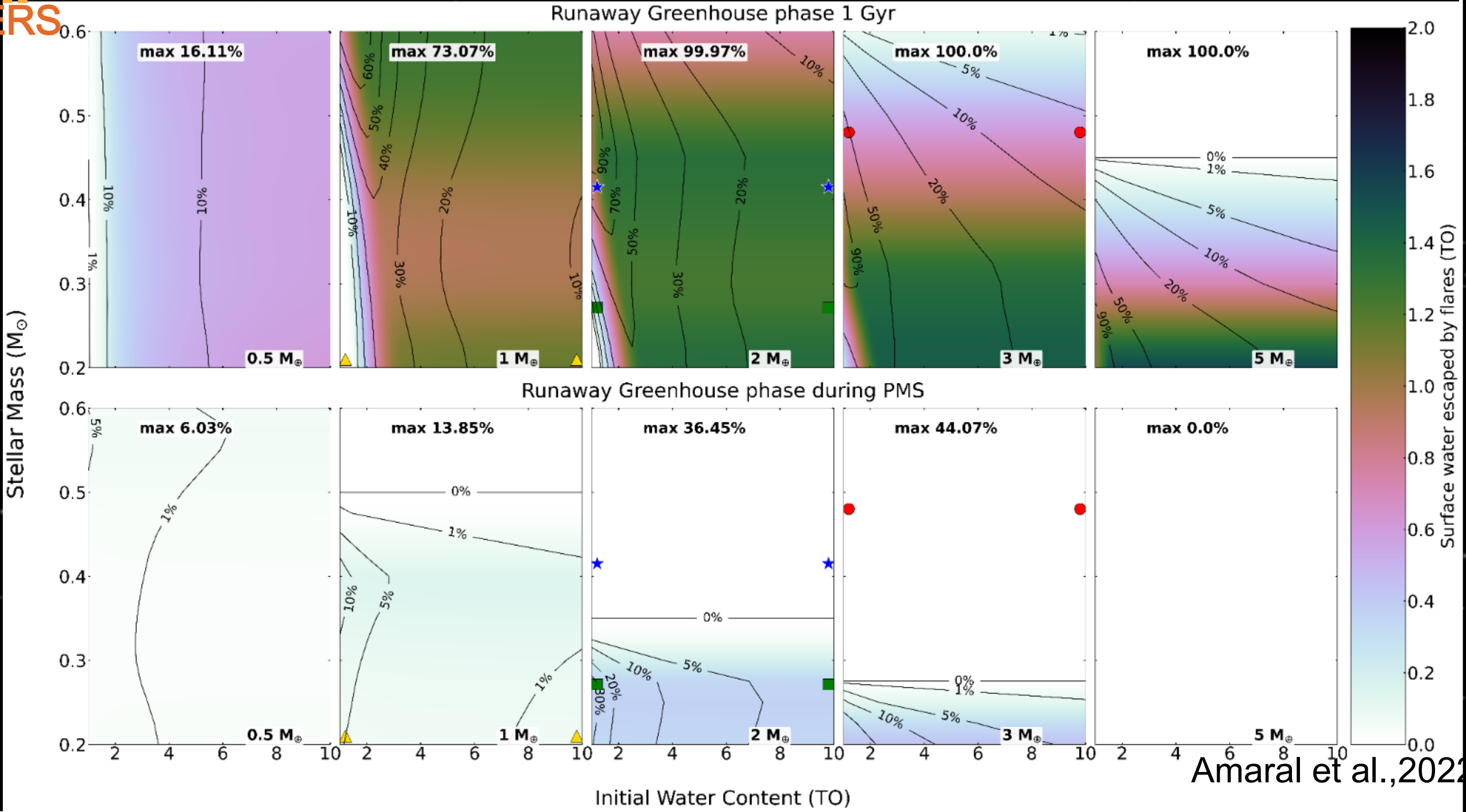
Stellar mass
0.2-0.6 Msun

Flare energy
10^{33} - 10^{36} ergs

Initial surface water
1-10 TO

Distance
1 AU eq.
(0.07- 0.3 AU)

Simulated time
1 Gyr



|:Åè^âÅ x:|/:fâ!F:1DÅè|D/:õ!â:|^1Åâ-°D!|:Å

x!|!d:â:|Å

Planetary mass
0.5-5 Mearth

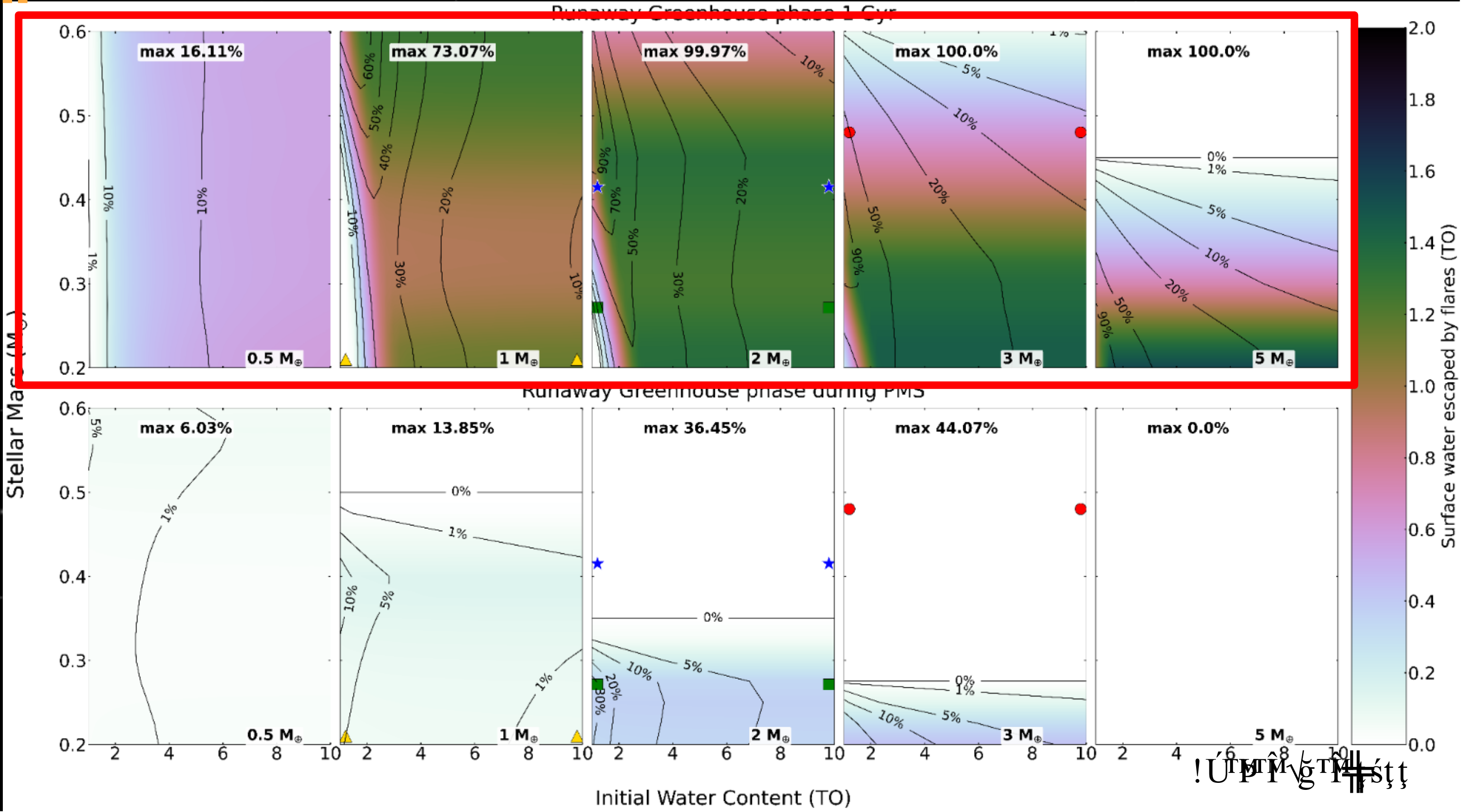
Stellar mass
0.2-0.6 Msun

Flare energy
10^{33} - 10^{36} ergs

Initial surface water
1-10 TO

Distance
1 AU eq.
(0.07 - 0.3 AU)

Simulated time
1 Gyr



Planetary mass
0.5-5 Mearth

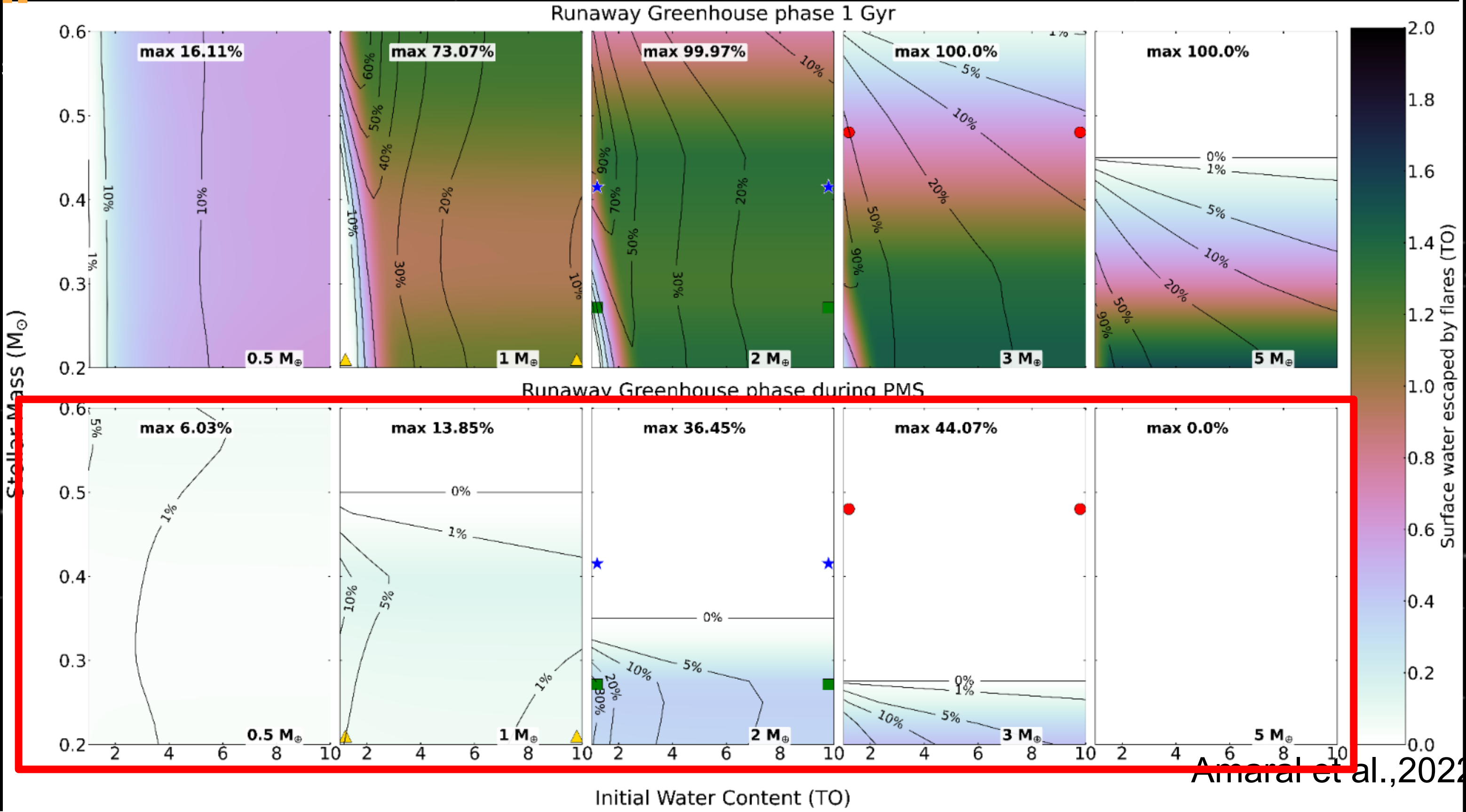
Stellar mass
0.2-0.6 Msun

Flare energy
10^{33} - 10^{36} ergs

Initial surface water
1-10 TO

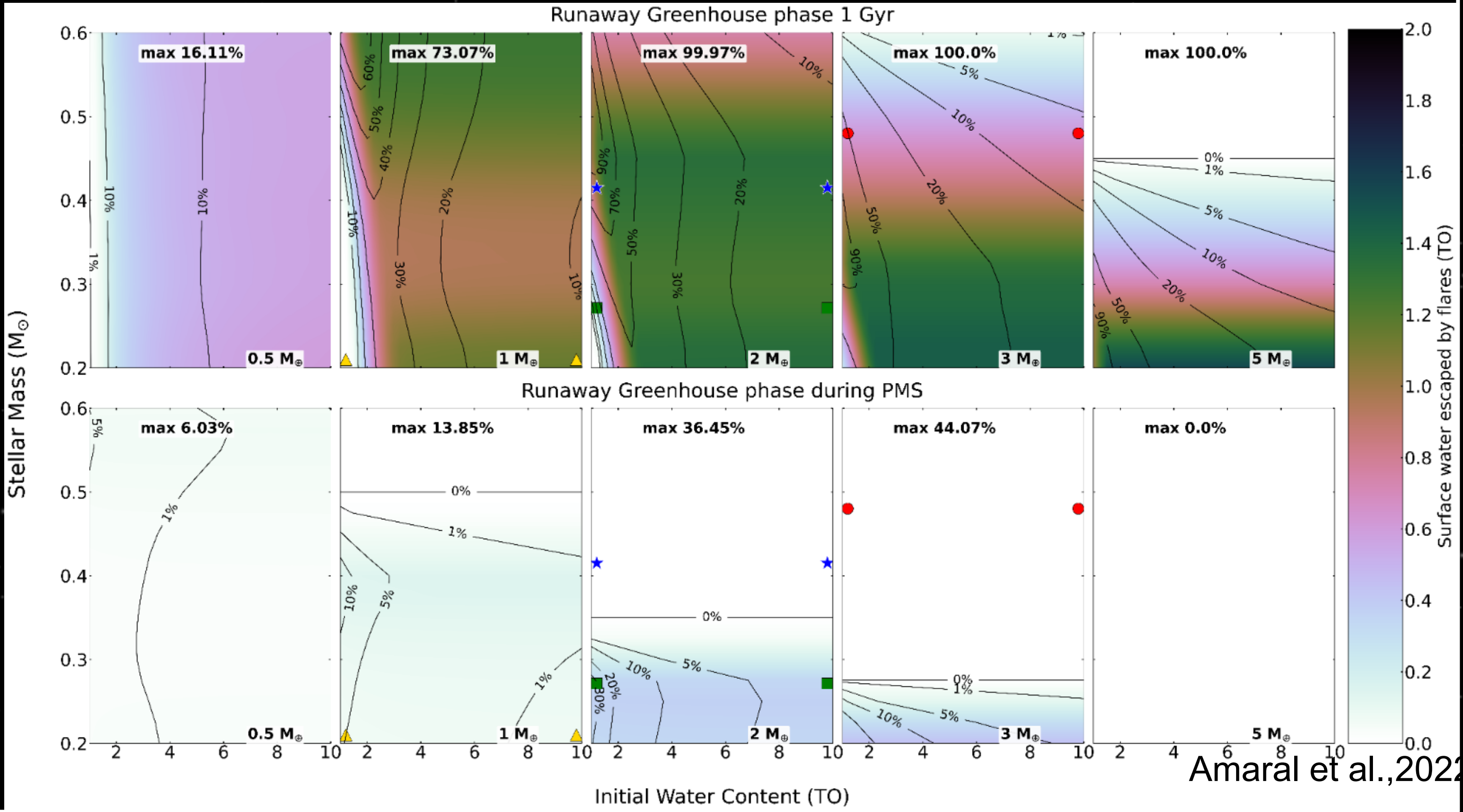
Distance
1 AU eq.
(0.07- 0.3 AU)

Simulated time
1 Gyr



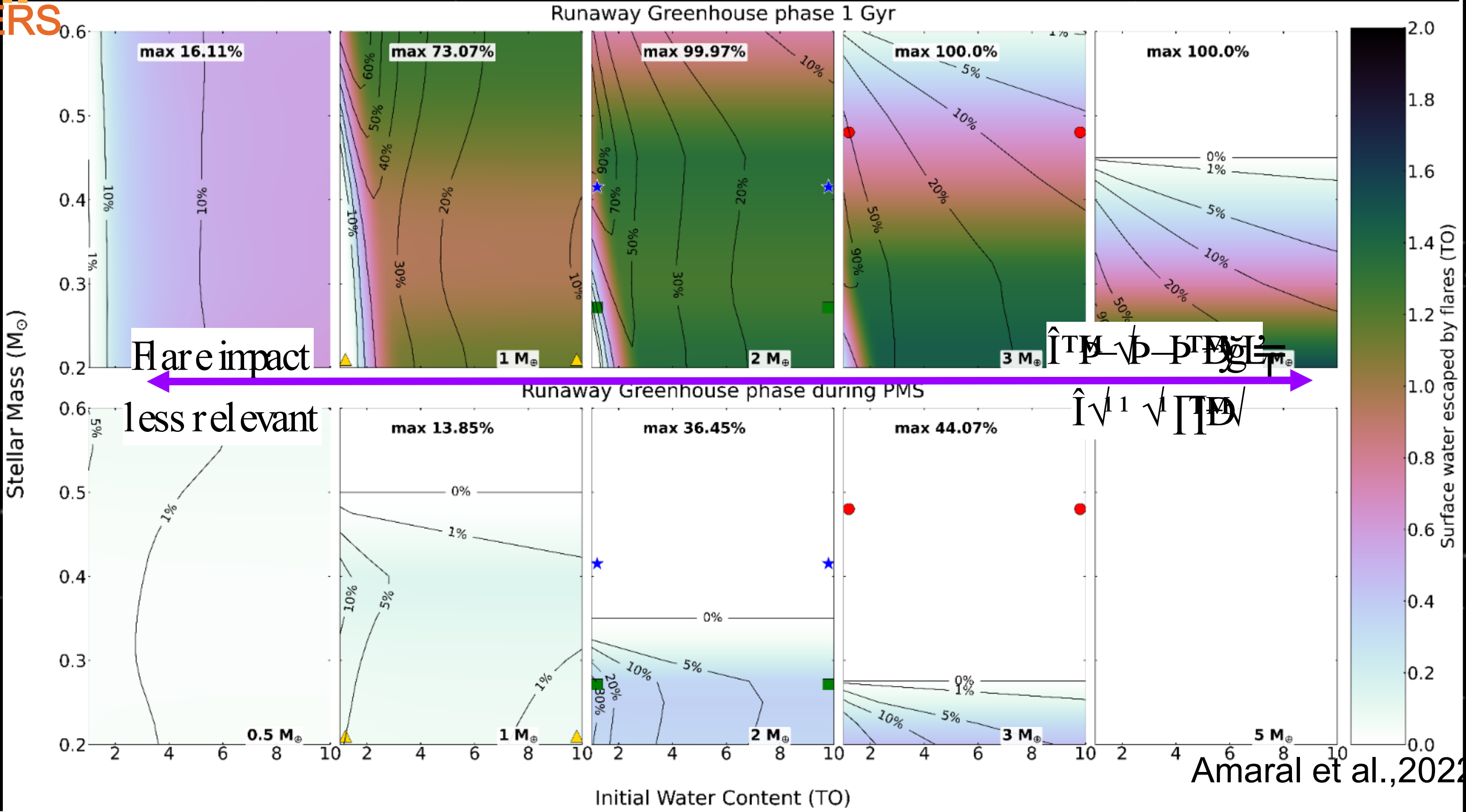
Amaral et al.,2022

RESULTS: PERCENTAGE OF SURFACE WATER L



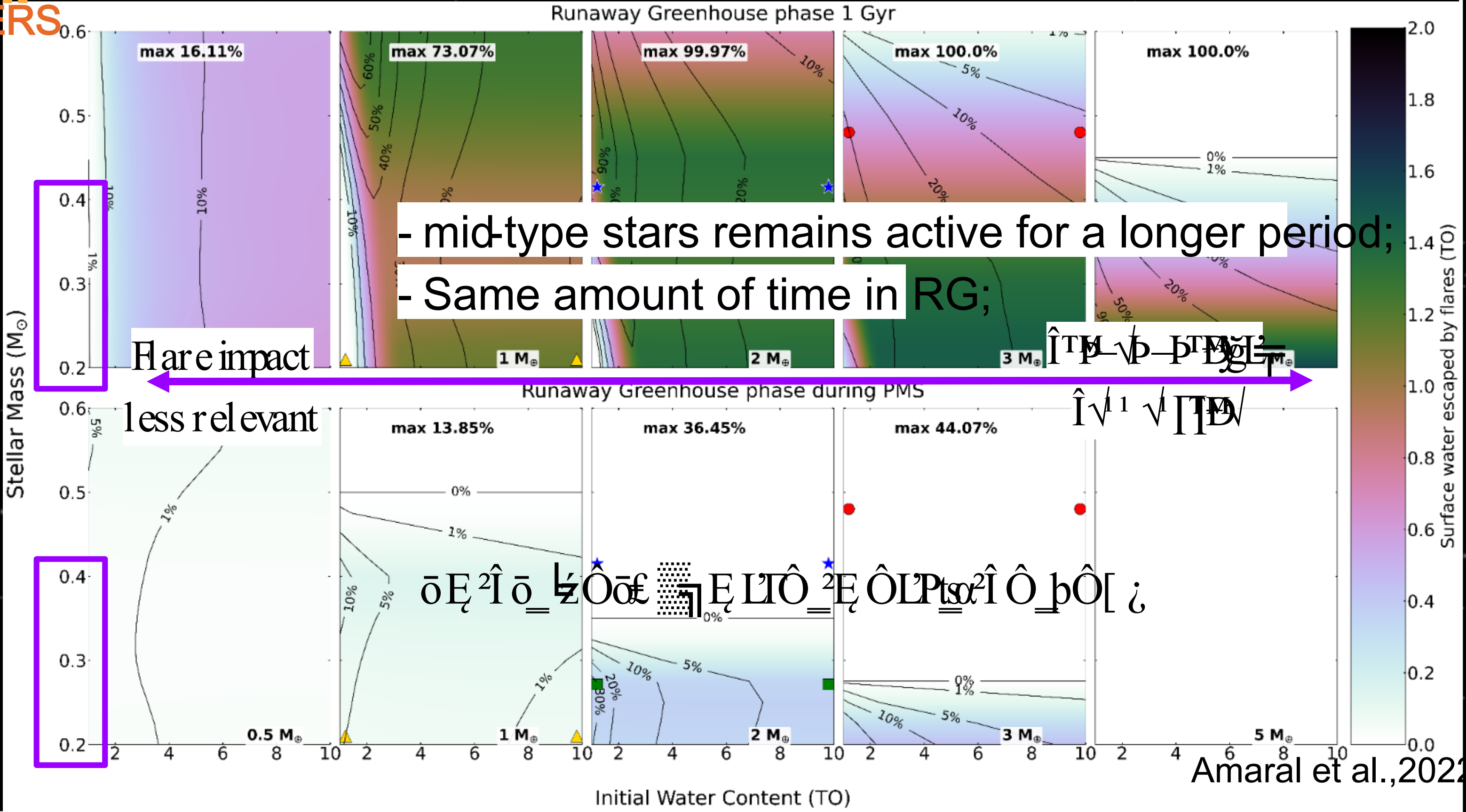
Amaral et al.,2022

PARAMETERS



Amaral et al.,2022

PARAMETERS

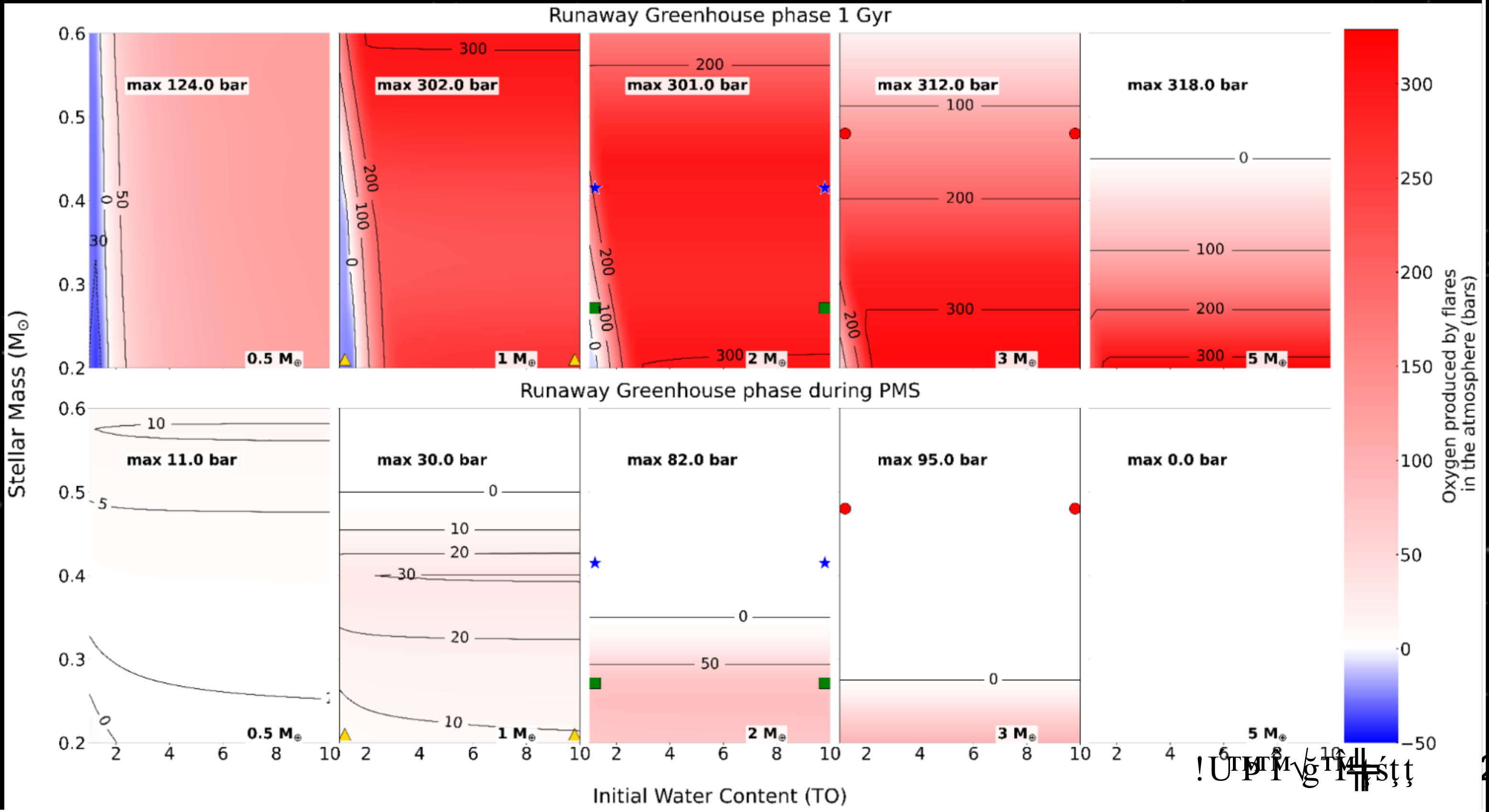


- mid-type stars remains active for a longer period;
- Same amount of time in RG;

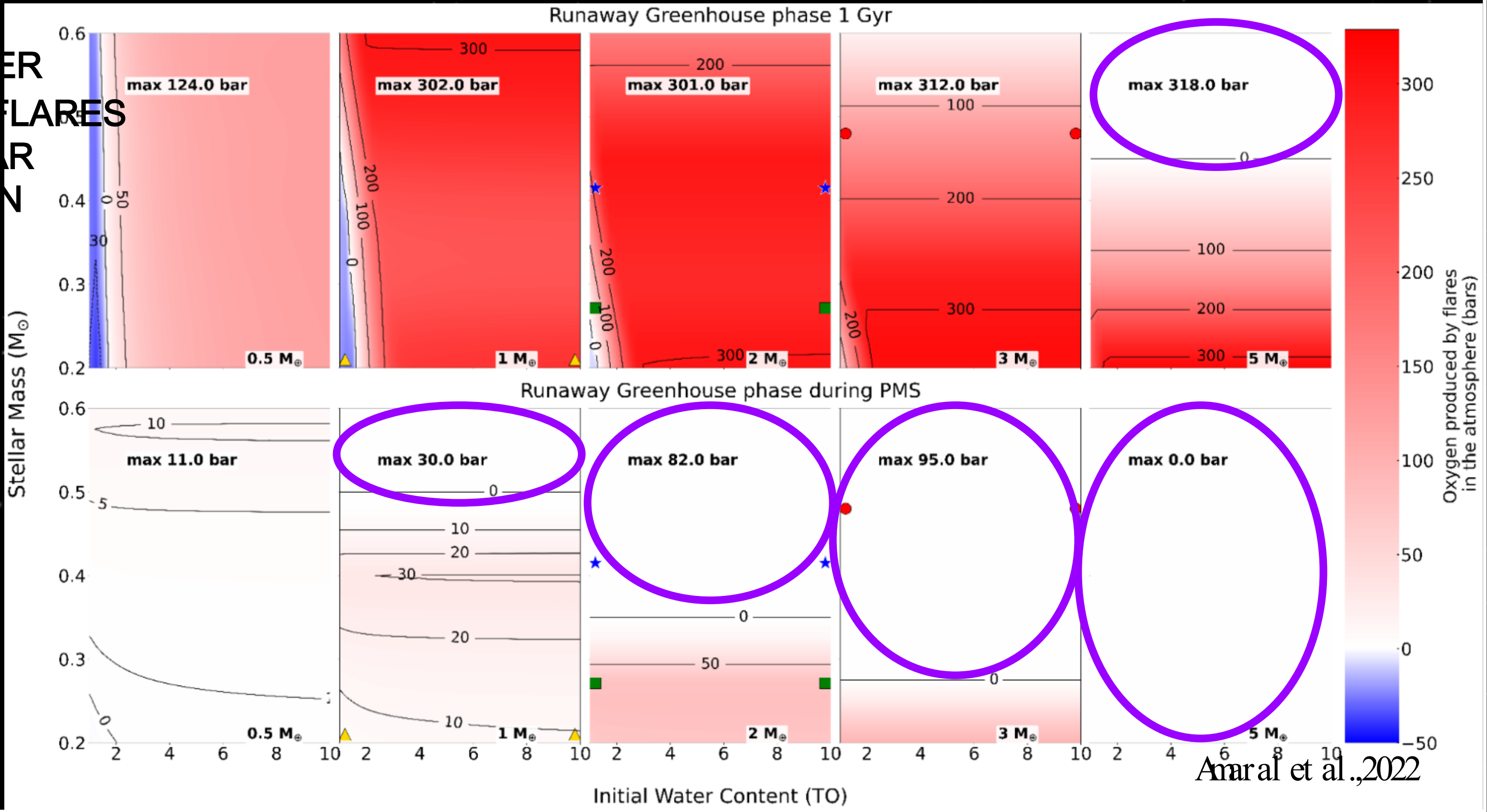
Flare impact less relevant

Amaral et al.,2022

RESULTS: EFFECT OF FLARES ON ATMOSPHERE

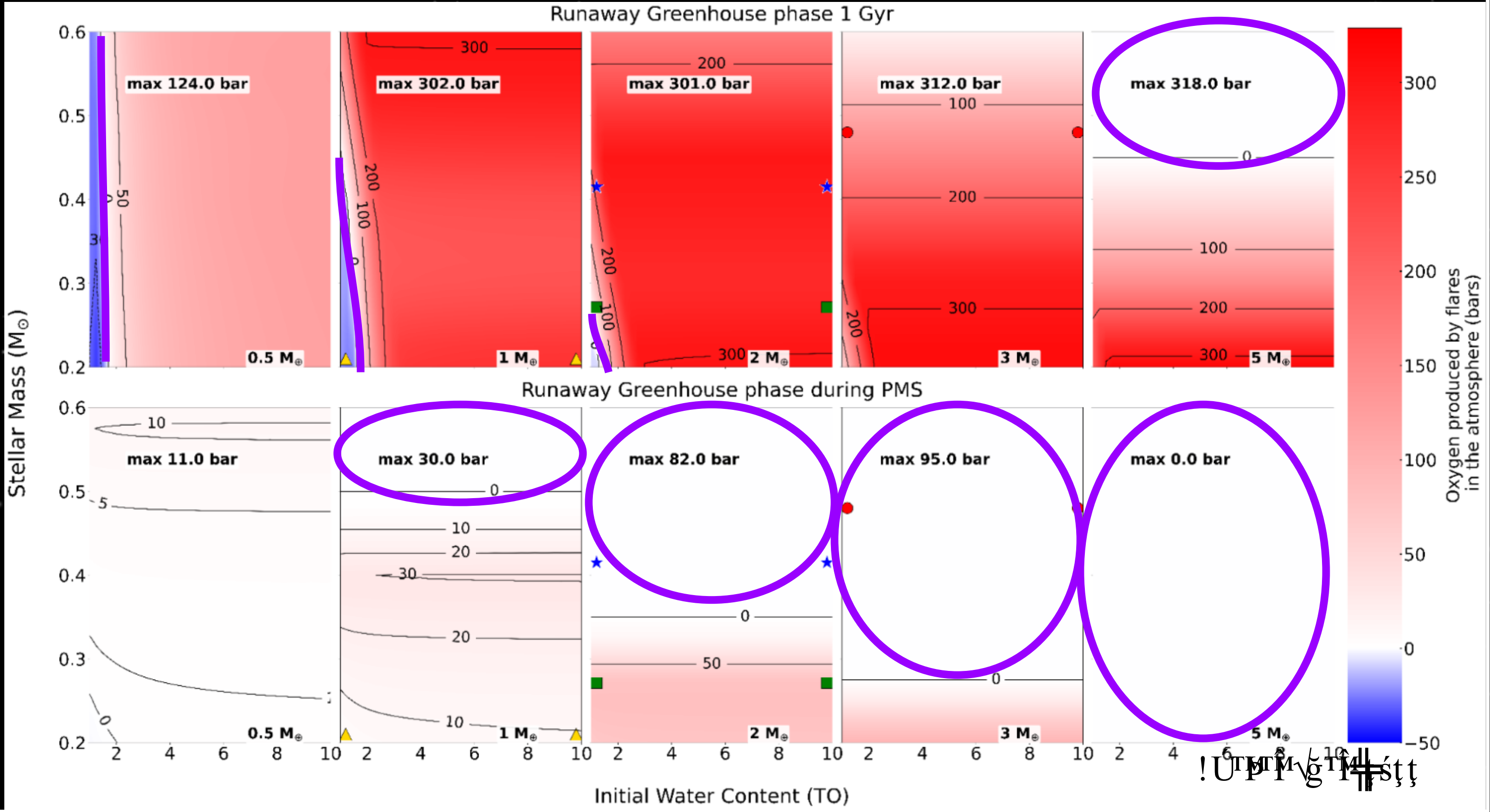


1 NO WA ER
ESCAPE BY FLARES
OR STE AR
EVOLU N



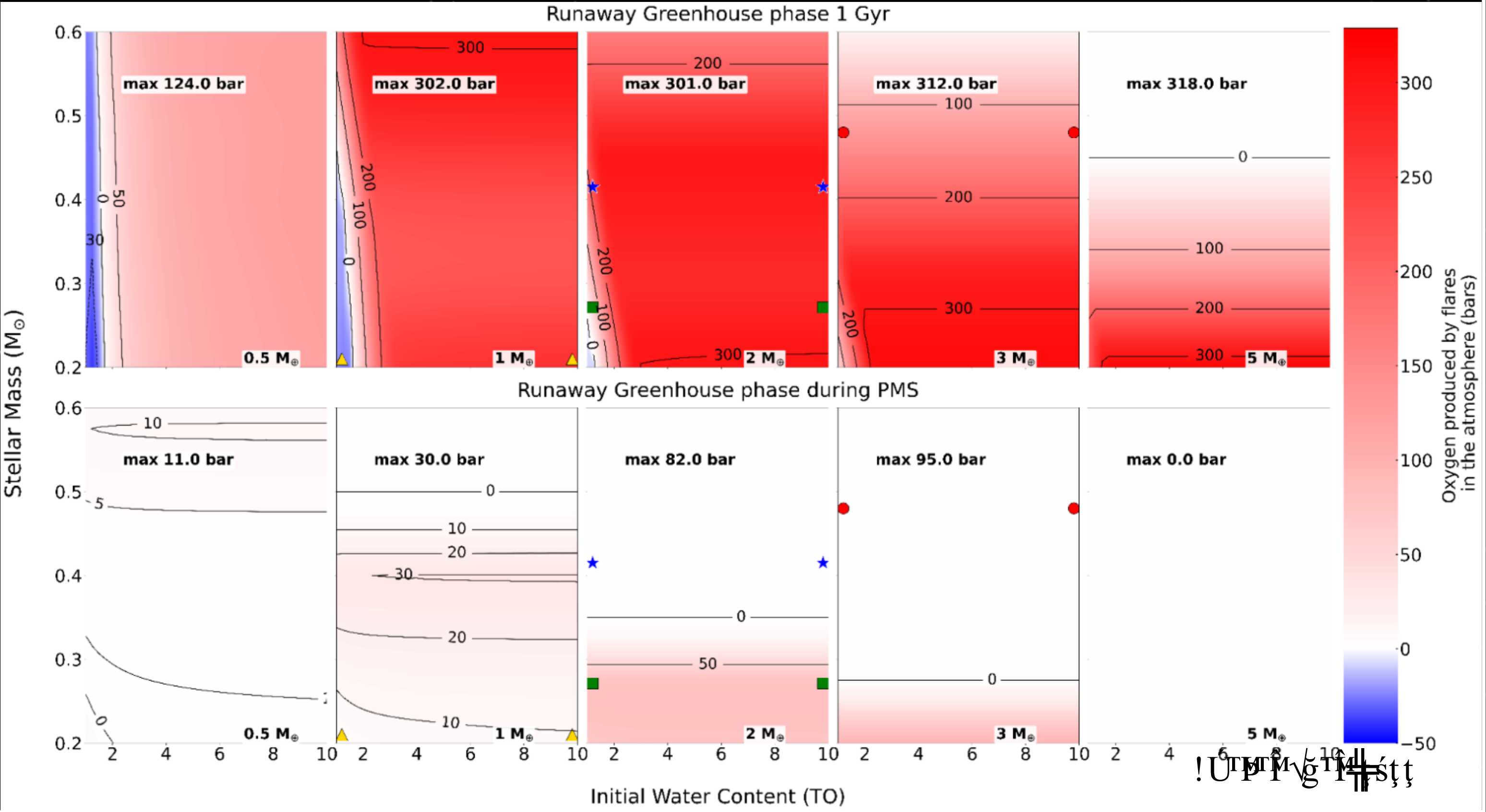
Amaral et al.,2022

RESULTS: EFFECT OF FLARES ON ATMOSPHERE

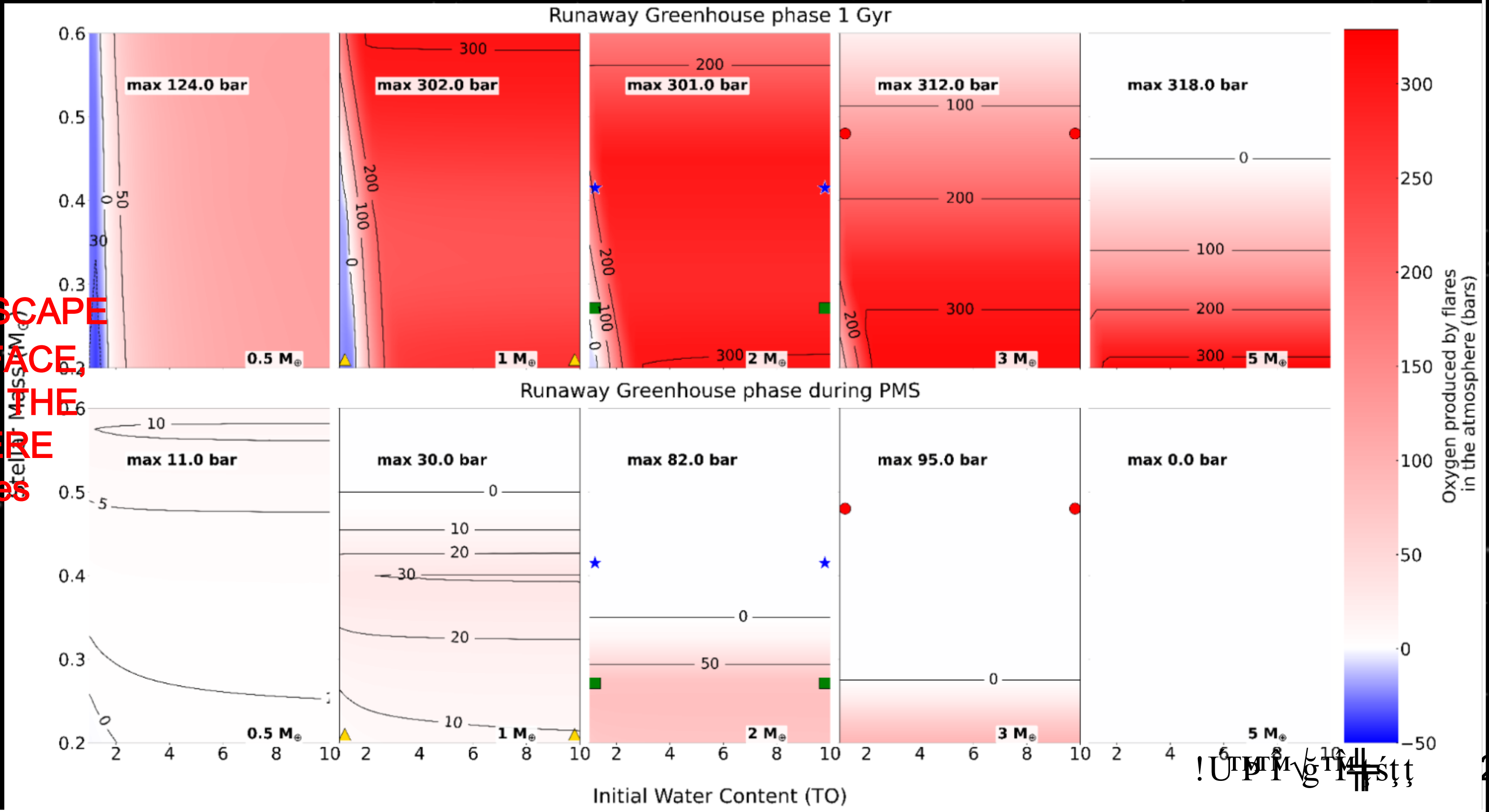


RESULTS: EFFECT OF FLARES ON ATMOSPHERE

1 NO WA
ESCAPE BY
OR STE
EVOLU

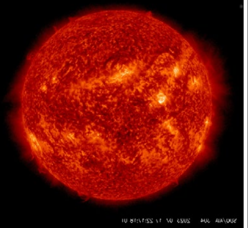


RESULTS: EFFECT OF FLARES ON ATMOSPHER



2 WATER ESCAPE FROM SURFACE, OXYGEN IN THE ATMOSPHERE (Positive values

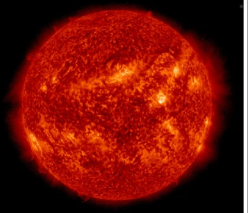
SUMMARY



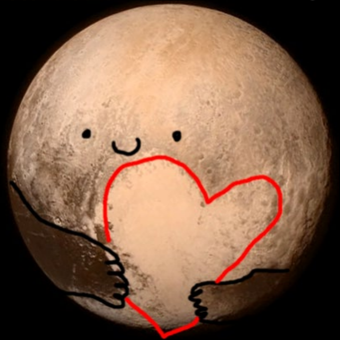
The flaring relevance in the water escape increases with the planetary mass, since to less massive ones, the XUV from the quiescent evolution of the star is enough to drive the loss.

Considering the results in this work, we should focus in looking for water on planets around early-type M dwarfs, since these stars provide a better environment for water retention.

To consider in the future



- Update the results with TESS data, Kepler has only a few M dw (If do you have the TESS flare data, please let me know!);
- Expand the study for late-type M dwarfs (Amaral et al. in prep) and K dwarfs (~3-15x less X-ray in the HZ, see Richey-Yowell et al. 2023);
- This are upper results because we considered superflares;
- Considering planetary interior process in the model;
- Add a secondary atmosphere.



Especial thanks to the organiz

invited and choose me to re

Thomas Metcalf Trave