The Galactic Habitable Zone: the effects of metals and dust

Astro-Ts 2017

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Outline

- The GHZ definition
- The probabilities of finding Earth-like planets around M and FKG stars
- Results computed through the chemical evolution model of the Milky Way (Grisoni’s talk): the GHZ map
- The role of the dust in the GHZ
- Conclusions

The GHZ definition

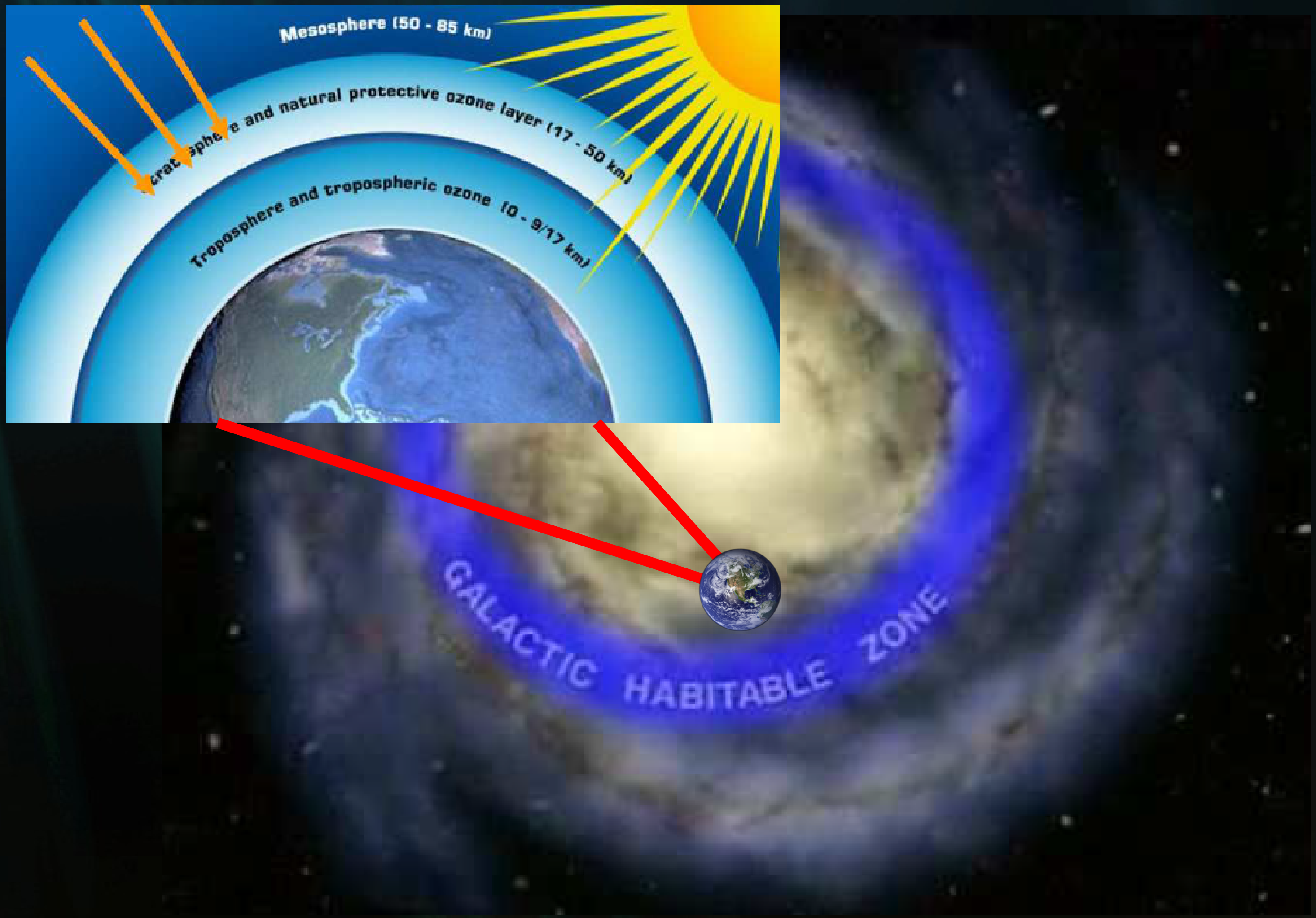
The Galactic habitable (GHZ) is defined as the region of the Galaxy with sufficiently high metallicity to form planetary systems in which Earth-like planets could be born and might be capable of sustaining life, after surviving to close supernova explosion events.

Gonzalez et al. (2001)

The GHZ definition

When a SN explodes, it emits STRONG RADIATION that may ionize the planets atmosphere, causing stratospheric ozone depletion.

THE ULTRAVIOLET FLUX from the planets host star can damage genetic material DNA, and
consequently the planet sterilization.
(Gehrels et al.2003)



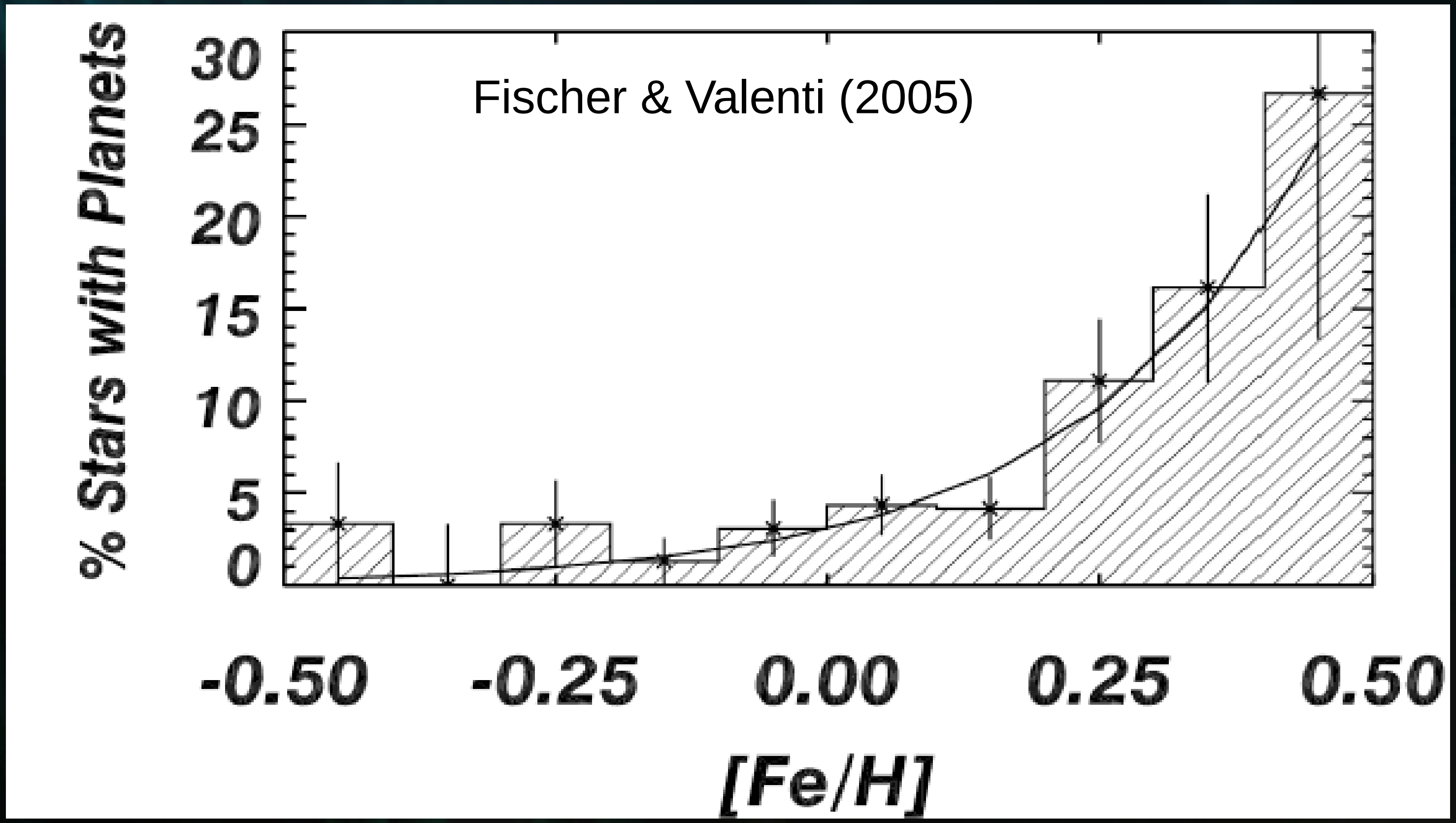
The GHZ definition

Lineveawer et al. (2004), Spitoni et al. (2014) identified the GHZ as an annular region between 7 and 9 kpc from the Galactic Centre.

The probabilities of forming planets

Gas Giant planets

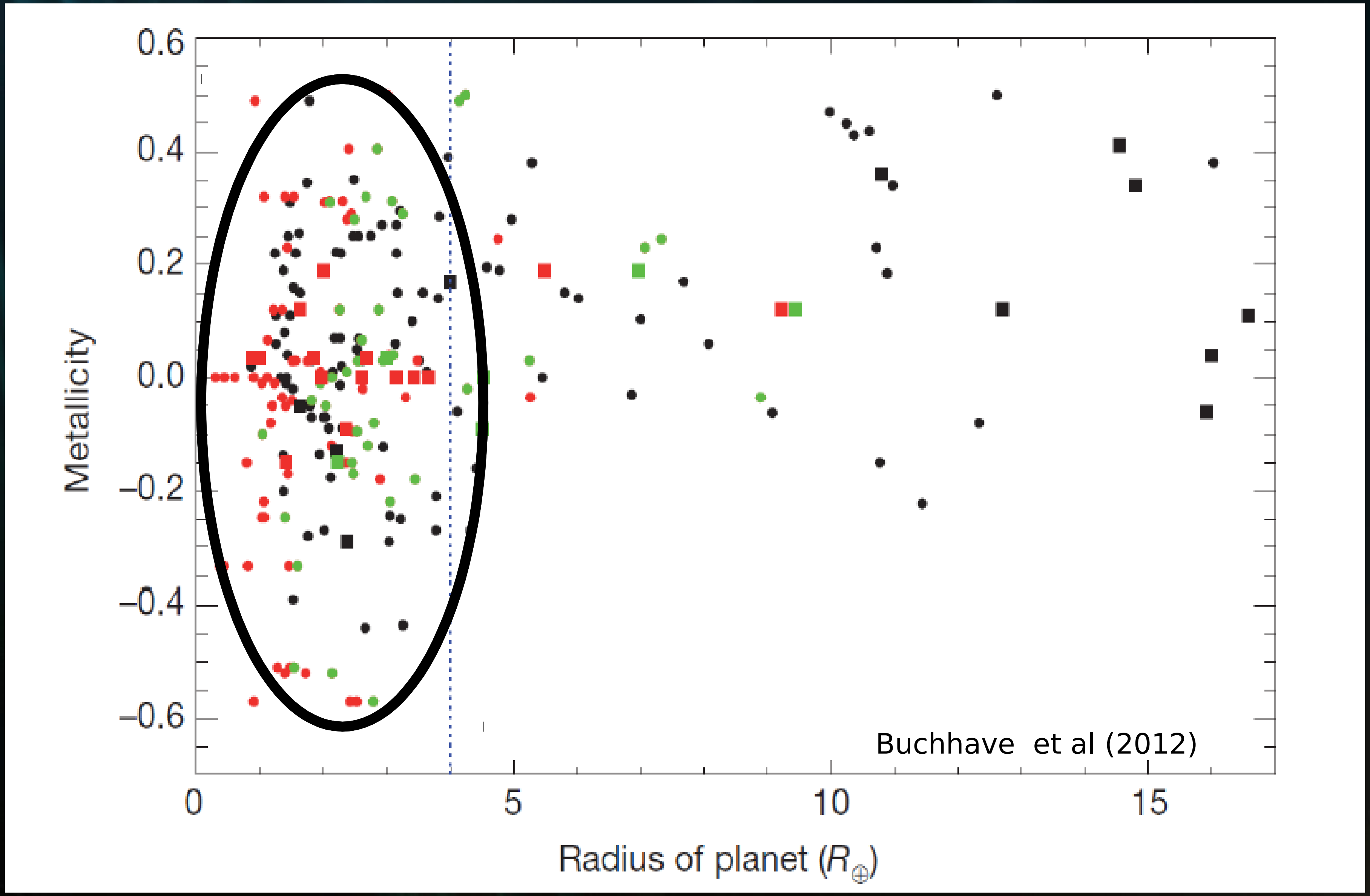
Planets are believed to form by the accumulation of dust and ice particles.
The metallicity of the host star represent the metallicity of the interstellar medium when the planet formed.
The frequency of the presence of gas giant planets increases with the metallicity of the host star.



$$P_{GGP}([\mathrm{Fe/H}]) = 0.03 \times 10^{2.0[\mathrm{Fe/H}]}$$

The probabilities of forming planets

The frequencies of the planets with **Earth-like sizes** are almost independent from the metallicity of the host star (Bucchave et al. 2012).



The probabilities of forming planets

New probabilities for gas giant planets as functions of [Fe/H] and dependent on stellar types. (Gaidos & Mann 2014 – Zackrisson et al. 2016)

FGK stars

$$P_{GGP/FGK}\left([\mathrm{Fe/H}], M_\star\right) = 0.07 \times 10^{1.8[\mathrm{Fe/H}]} \left(\frac{M_\star}{M_\odot}\right)$$

M stars

$$P_{GGP/M}\left([\mathrm{Fe/H}], M_\star\right) = 0.07 \times 10^{1.06[\mathrm{Fe/H}]} \left(\frac{M_\star}{M_\odot}\right)$$

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NEW!!!

Weighted on the IMF

Spitoni et al. (2017)

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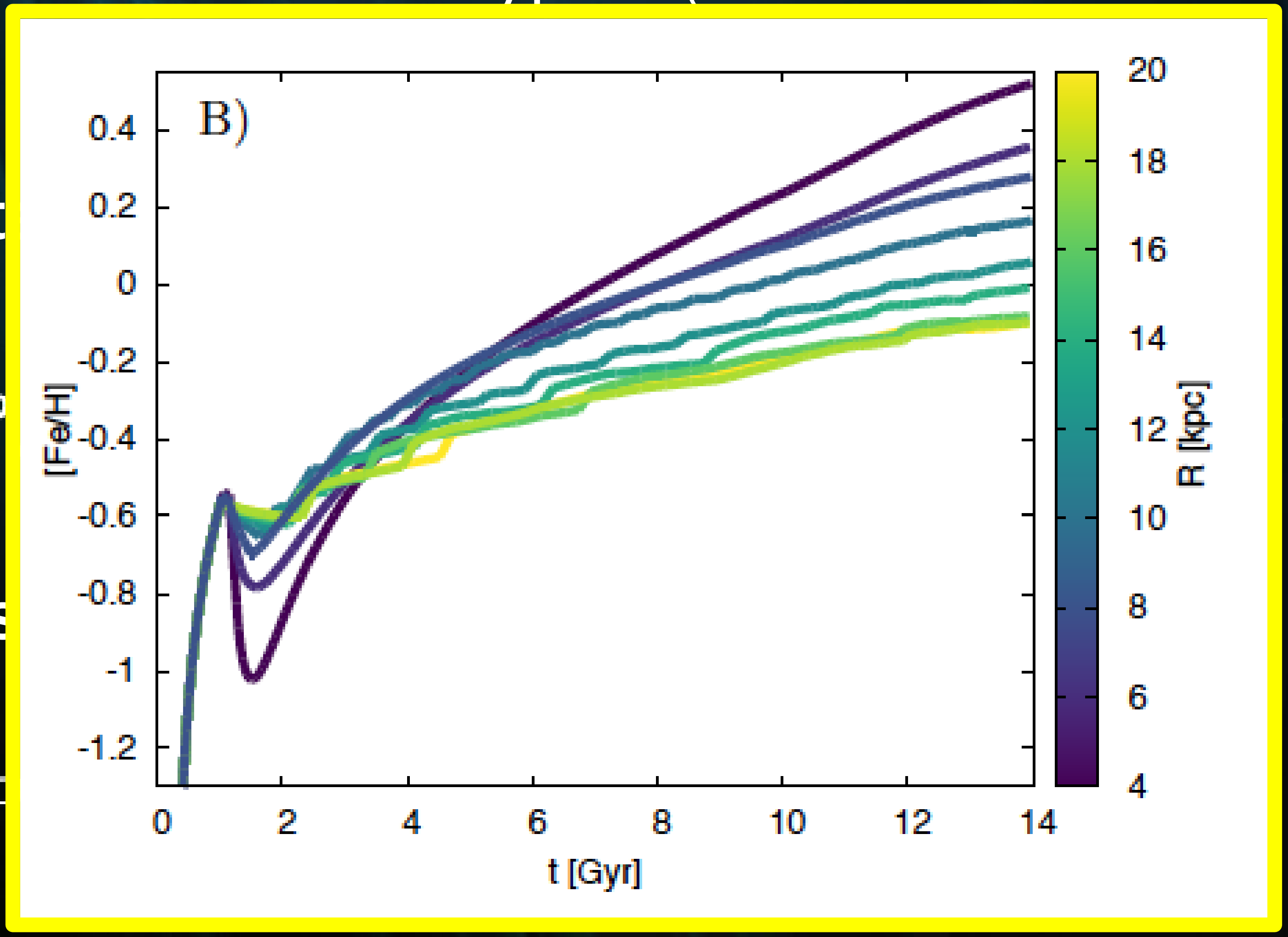


From the Galactic chemical evolution model

NEW!!!

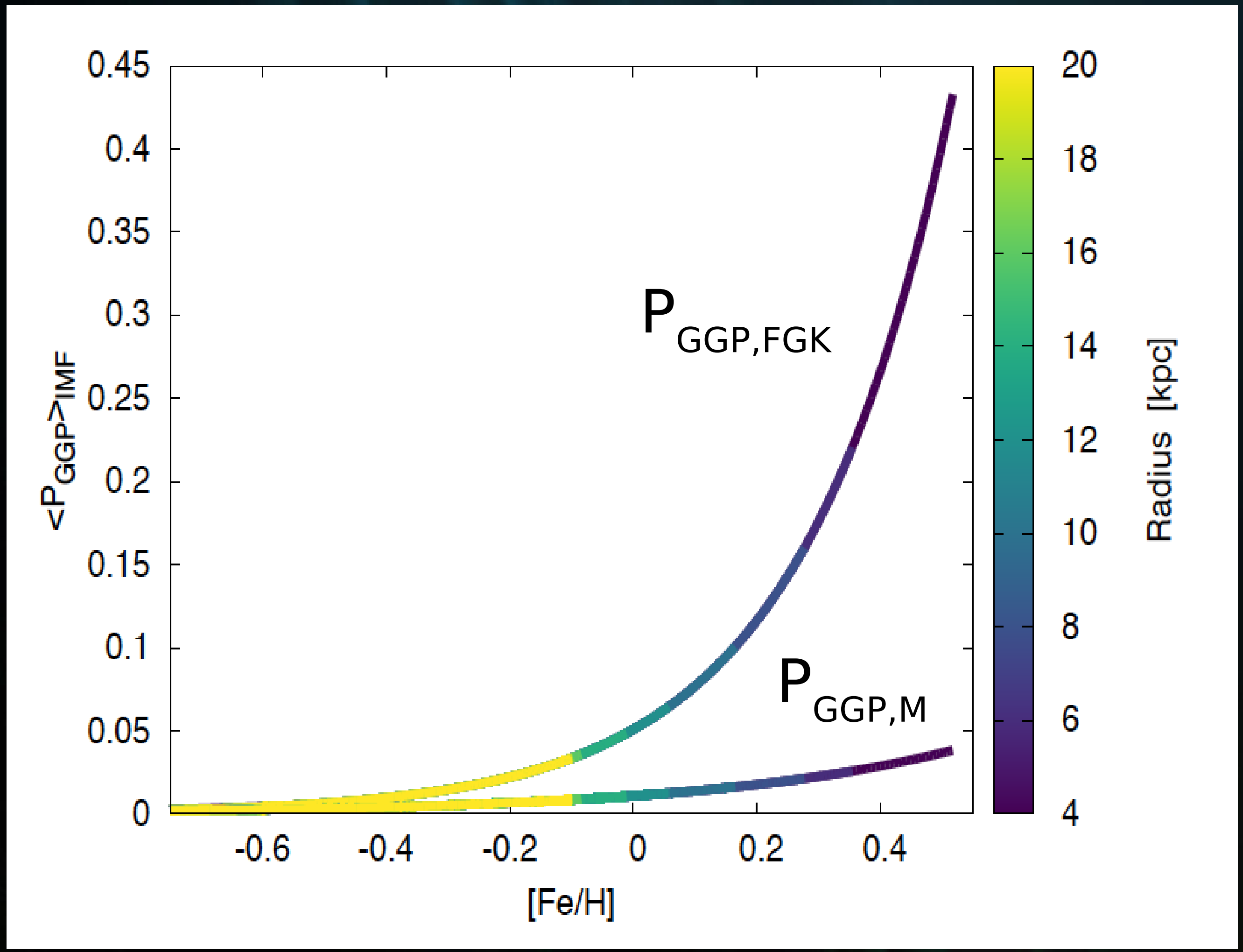
Weighted on the IMF

Spitoni et al. (2017)

Probability predictions through the MW chemical evolution model

Gas Giant Planets around FGK and M stars

P_{GGP}



Spitoni, Gioannini & Matteucci (2017)

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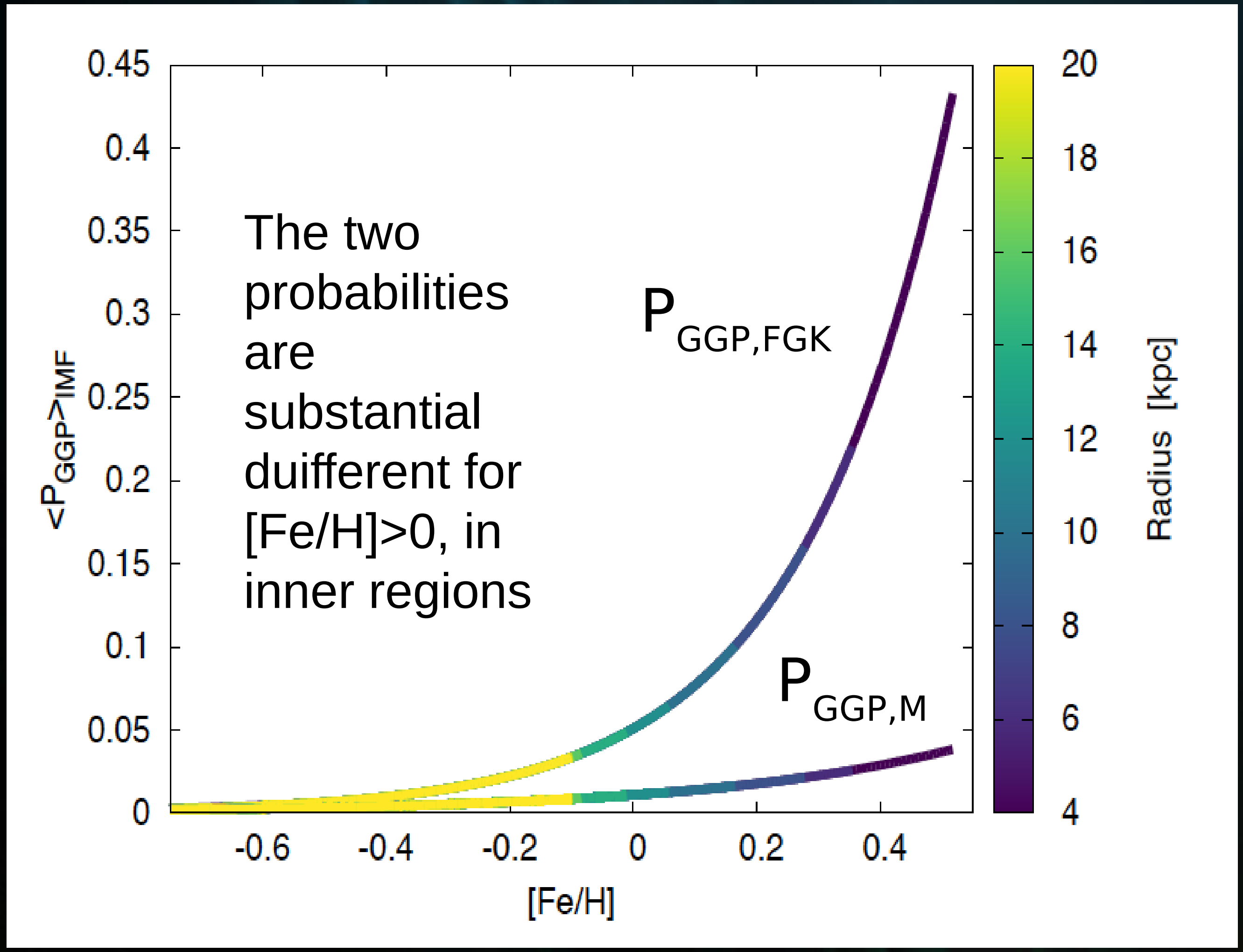

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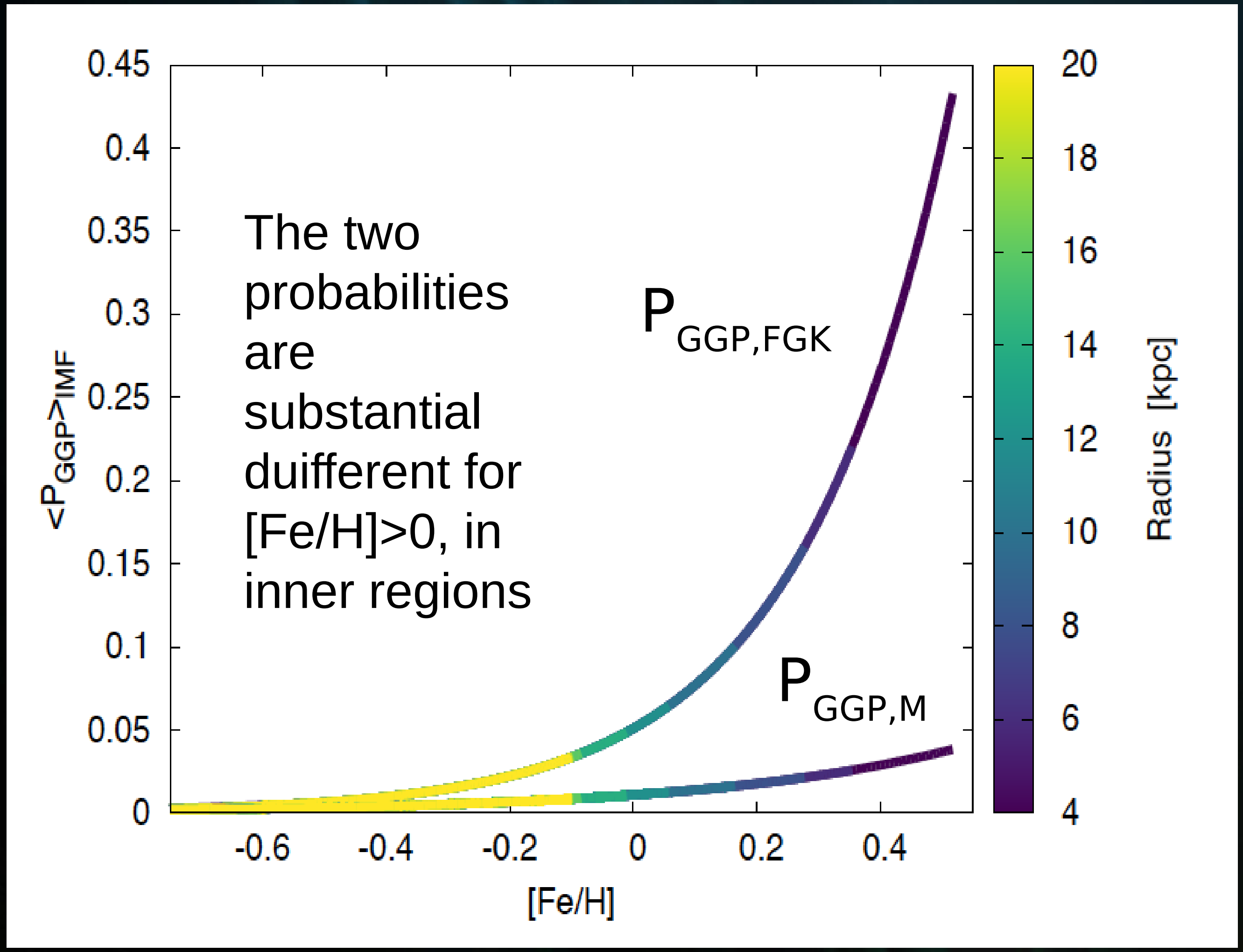

What about terrestrial planets?

The probability is constant, independent from the metallicity of the host star (Prantzos 2008, Spitoni et al. 2014, Spitoni et al. 2017).

The presence of gas giant planets may destroy smaller planets in the inner orbits (orbit instabilities, planet migration). Rice & Armitage (2003)

Spitoni, Gioannini & Matteucci (2017)

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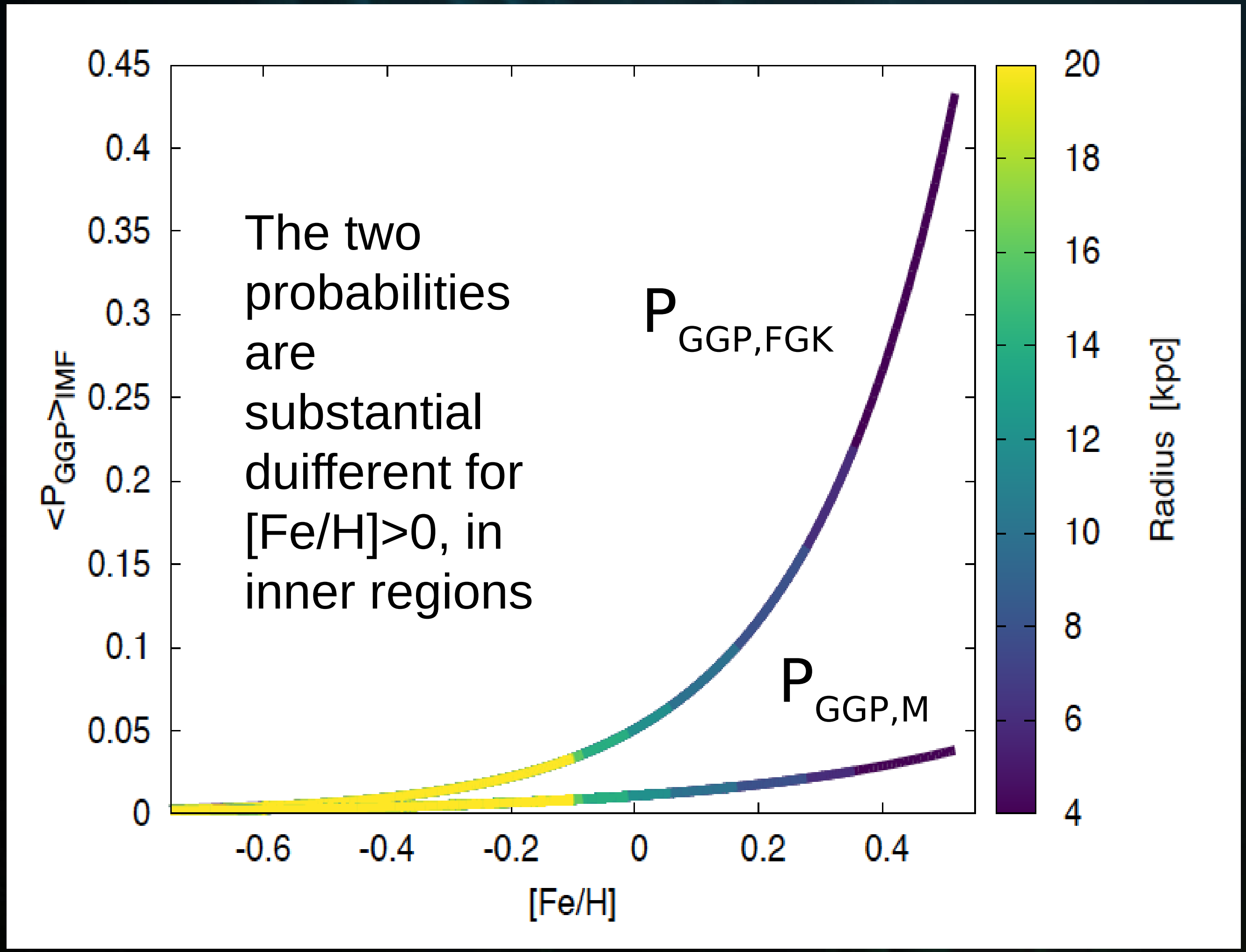
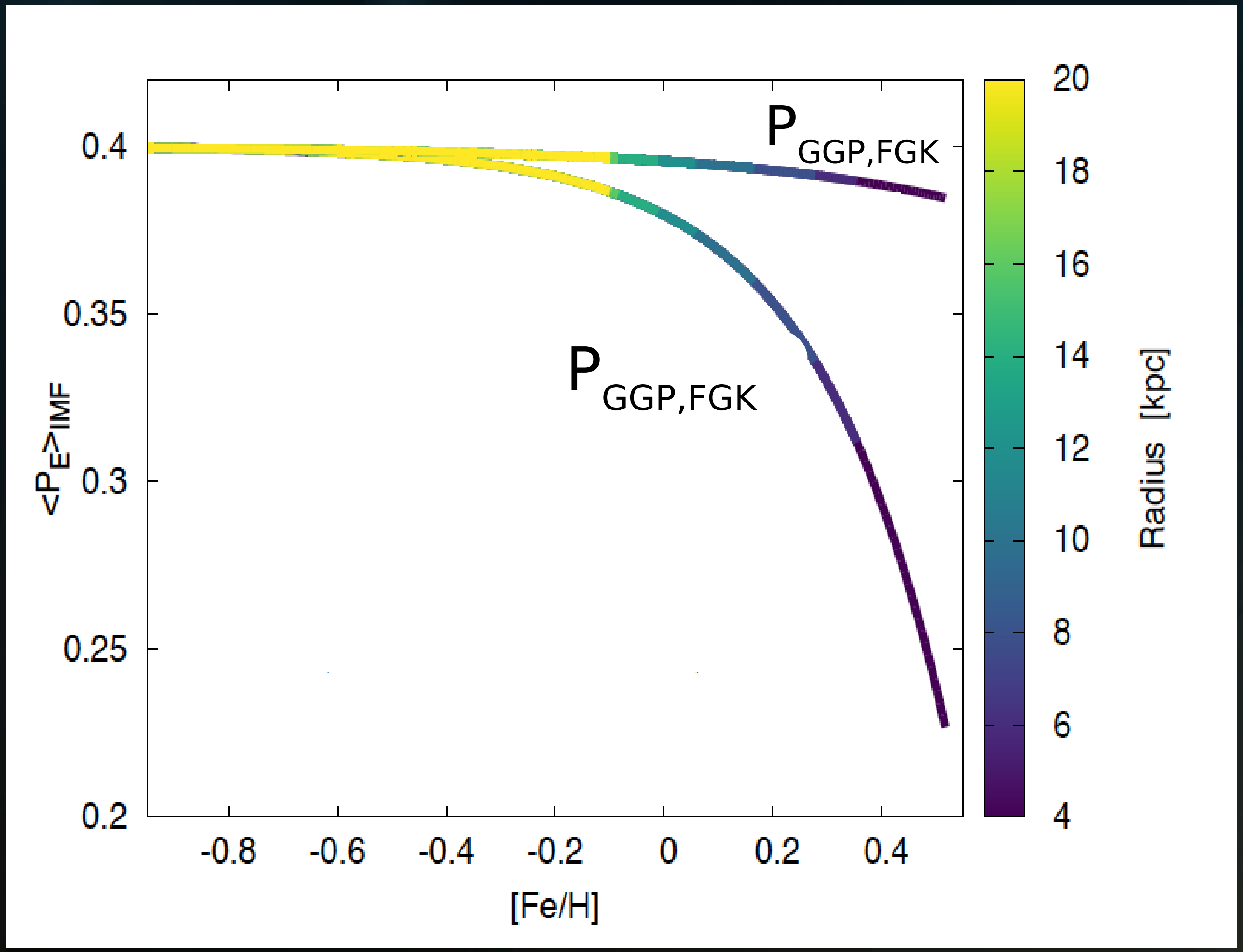


Earth-like planets around FGK and M stars

$P_E = P_{FE}(1-P_{GGP})$



Spitoni, Gioannini & Matteucci (2017)

$$P_{GHZ}(FGK/M, R, t) = \frac{\int_0^t SFR(R,t')P_{E/FGK,M}(R,t')P_{SN}(R,t')dt'}{\int_0^t SFR(R,t')dt'}$$

Prantzos (2008),
Spitoni et al. (2014;2017)

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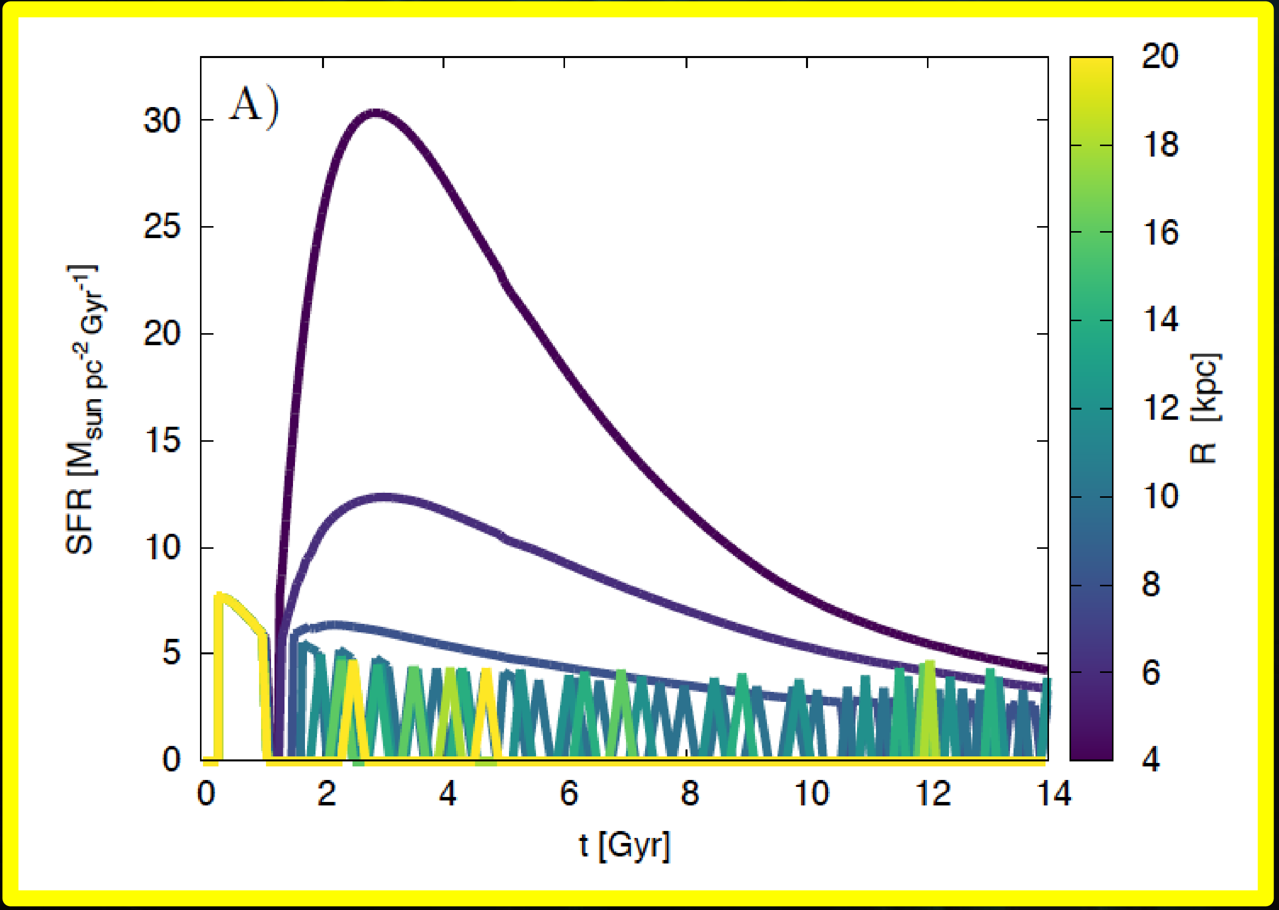

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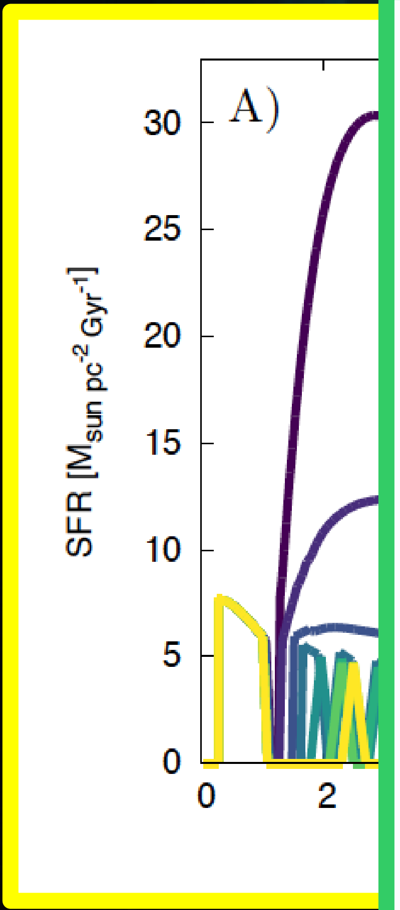

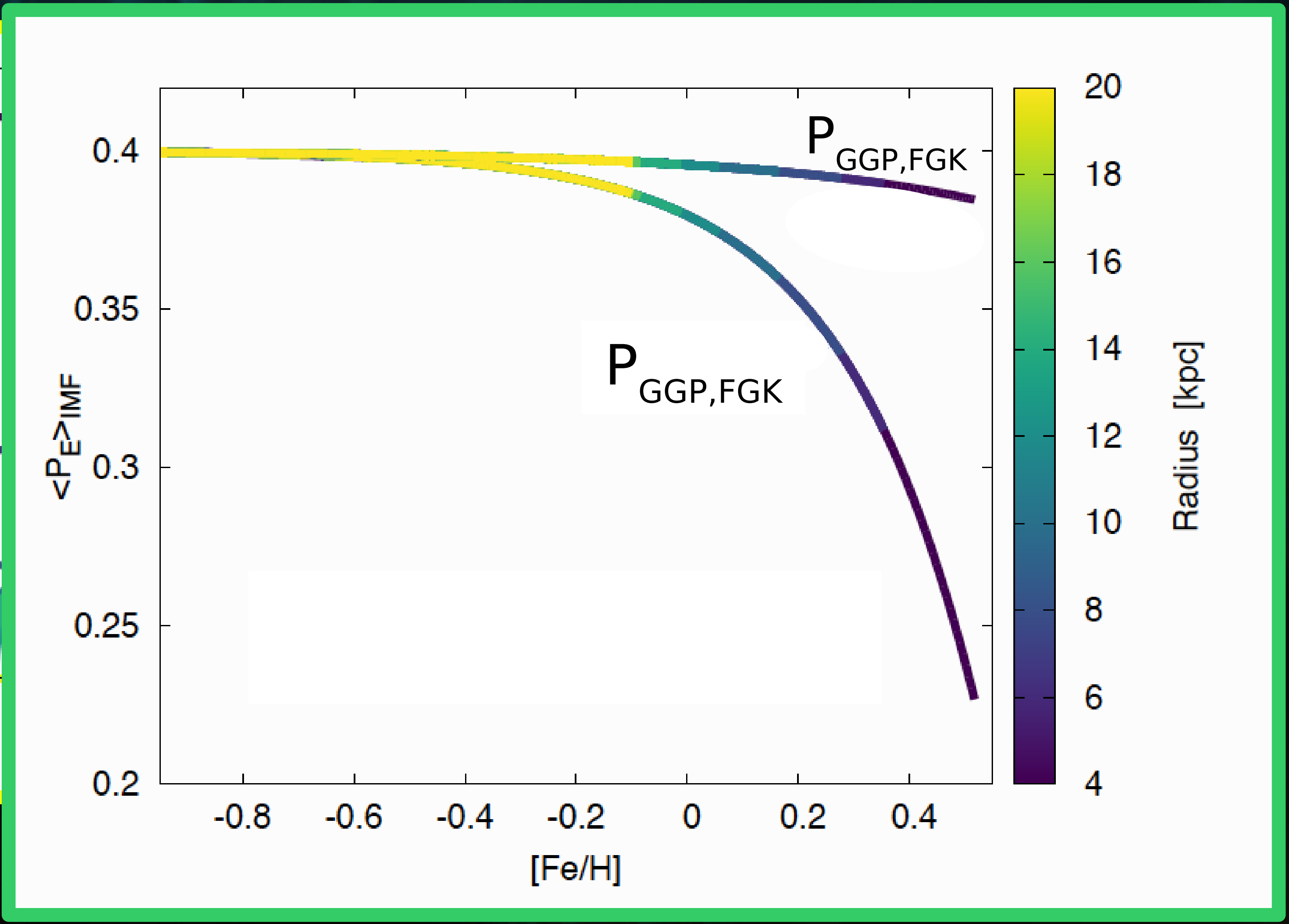

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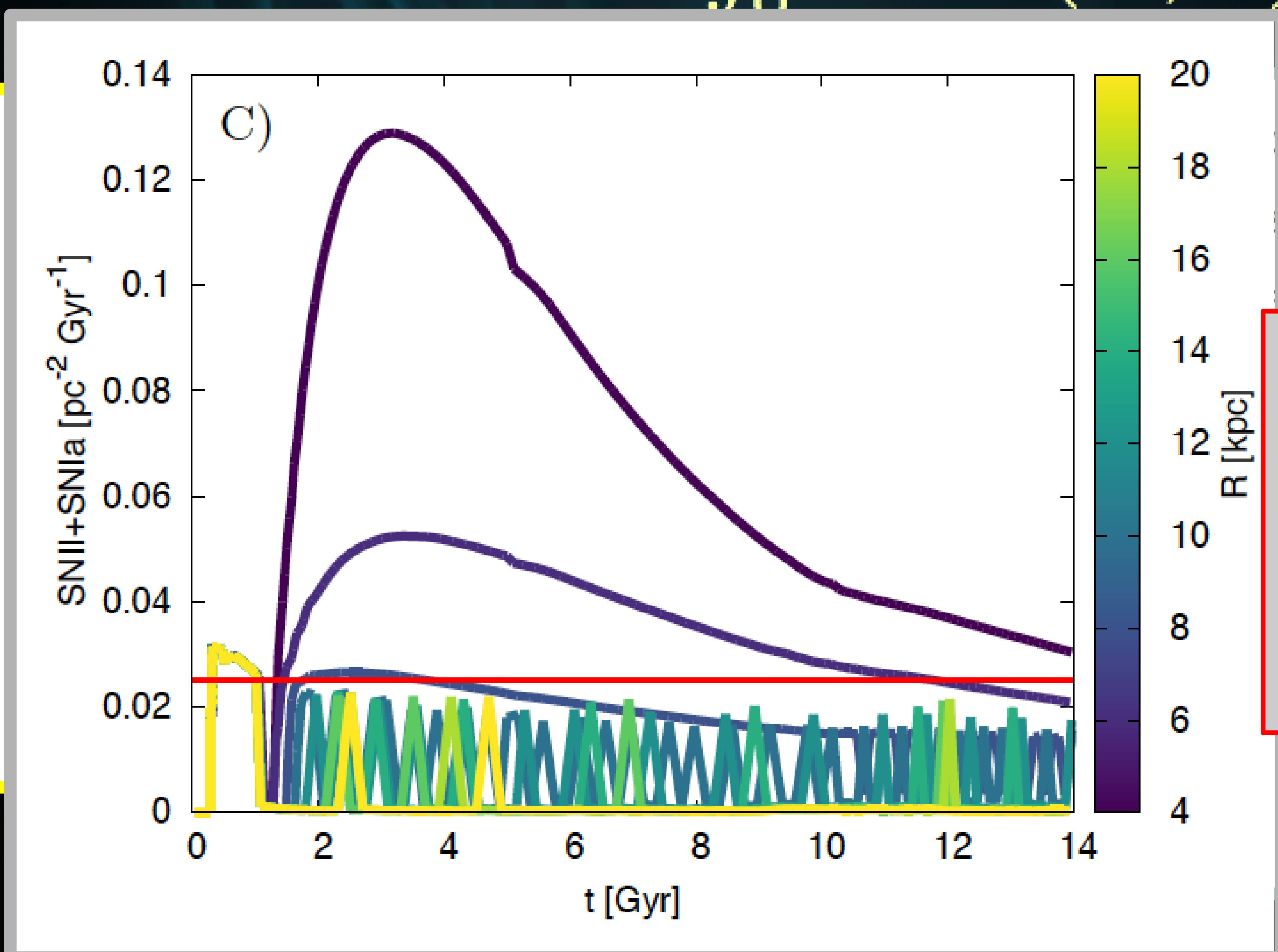


If the Supernova rate (SNR)

$SNR > 2 \langle SNR_{solar\ neigh.} \rangle$

Then:

$P_{SN}=0$ else,

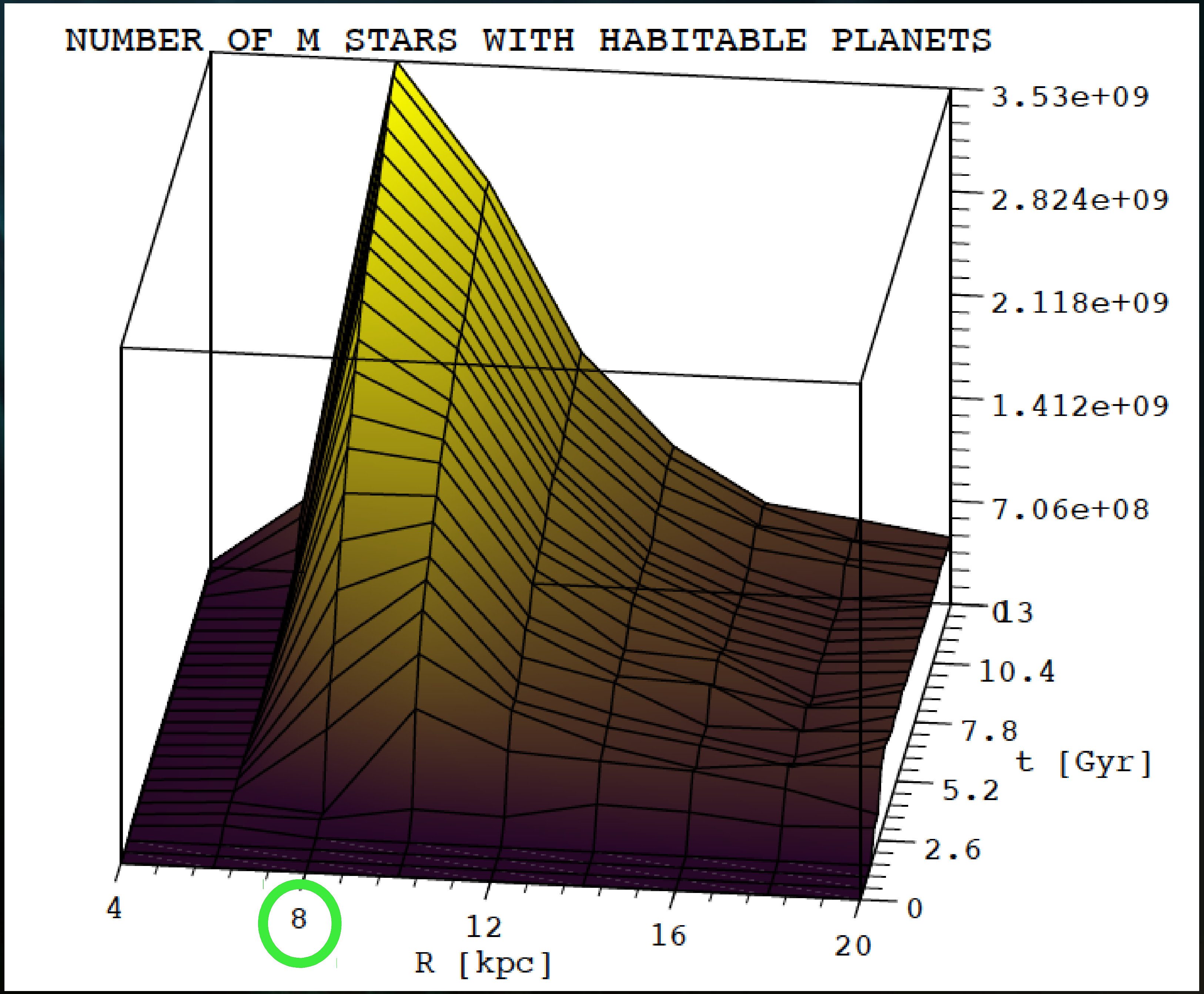
$P_{SN}=1$

Spitoni et al. (2017)

The GHZ map

The total number of stars hosting potential habitable planets:

$$N_{\star\, life}(R,t) = P_{GHZ}(R,t) \times N_{\star tot}(R,t)$$



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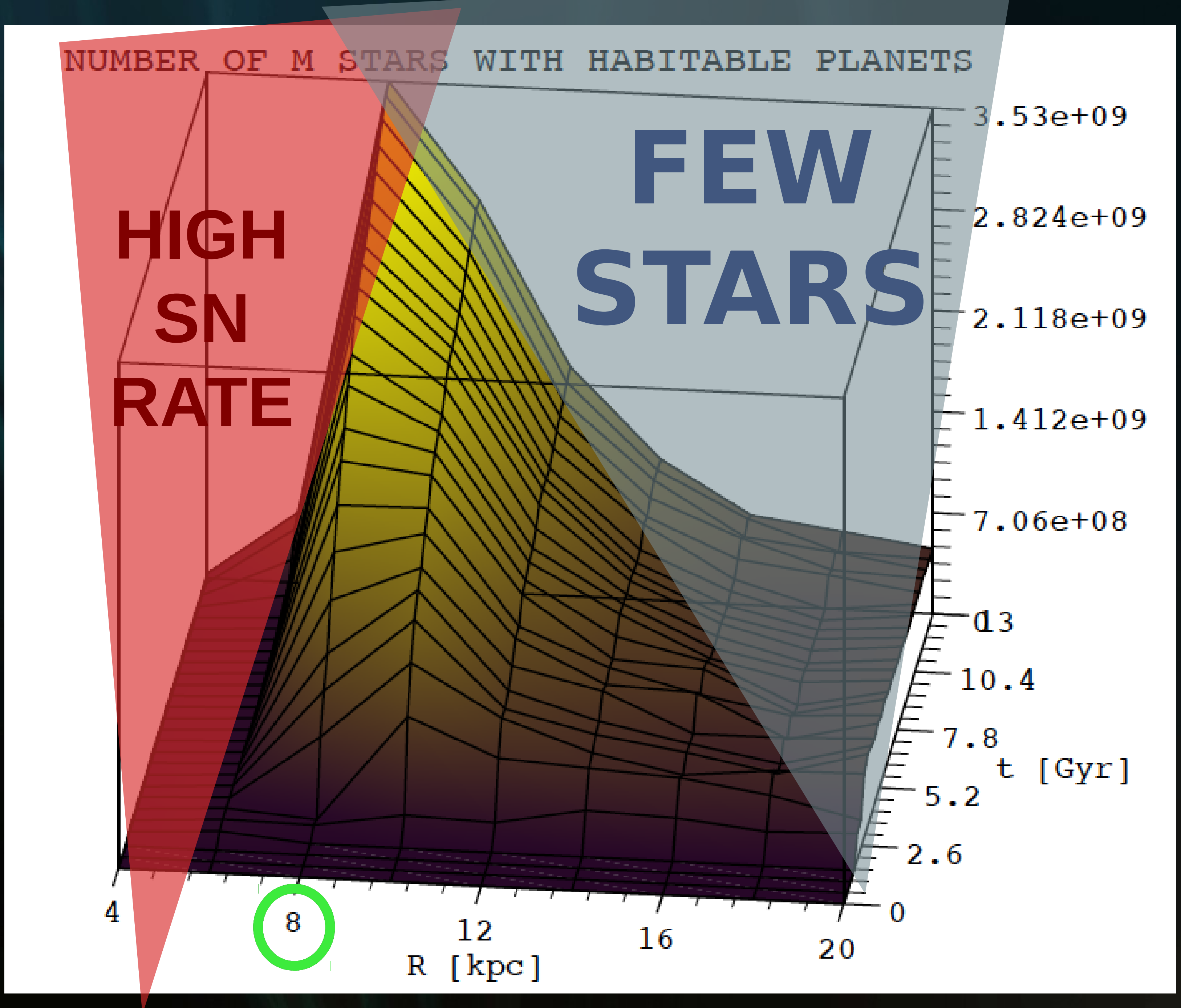

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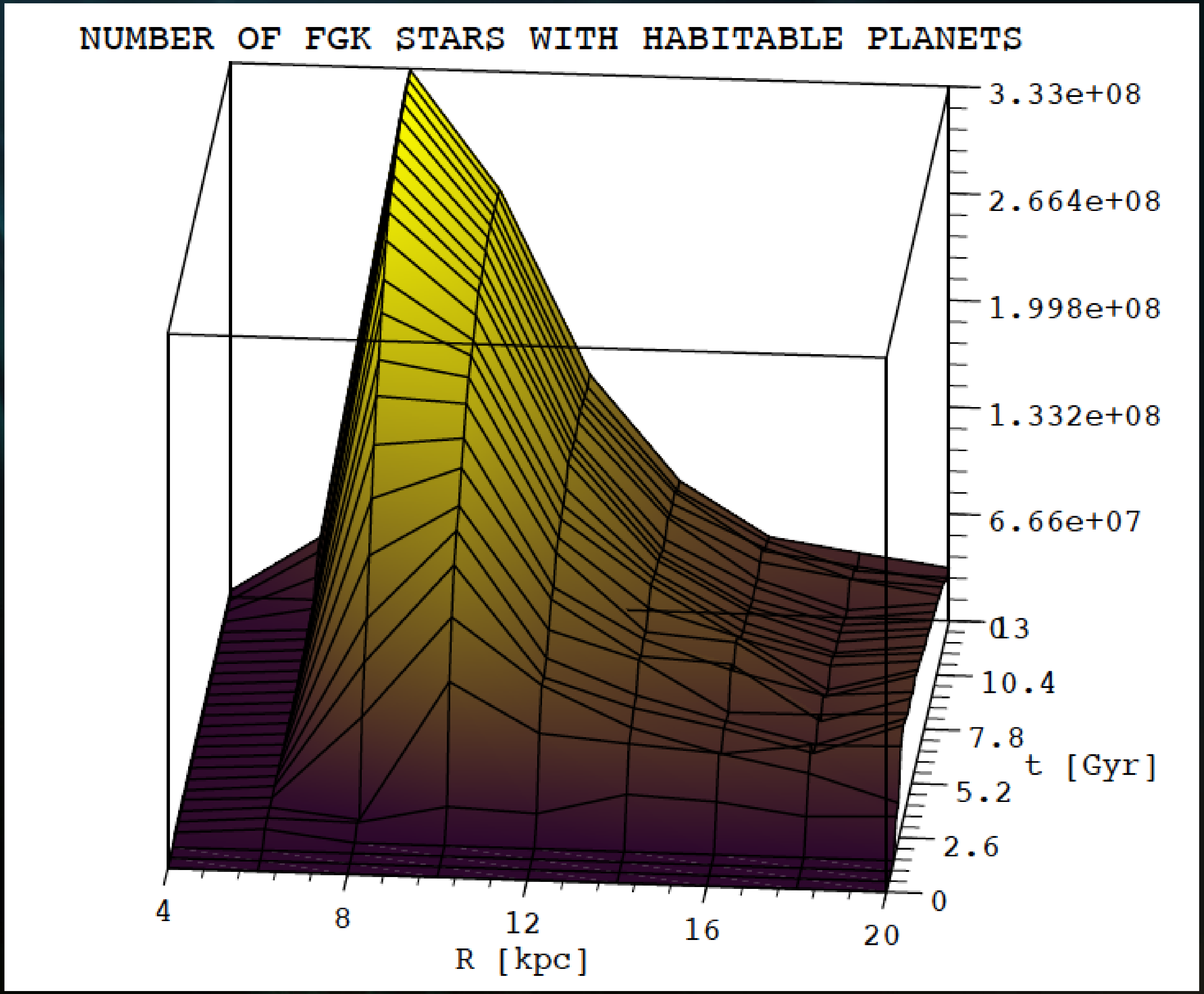

At the peak (8 kpc, at the present day)

$$\frac{N_{\star\, M,life}}{N_{\star\, FGK,life}} = 10.60$$

Spitoni et al. (2017)

The role of the dust

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The metallicity of stars, which is observationally related to the probability of the presence of hosted planets

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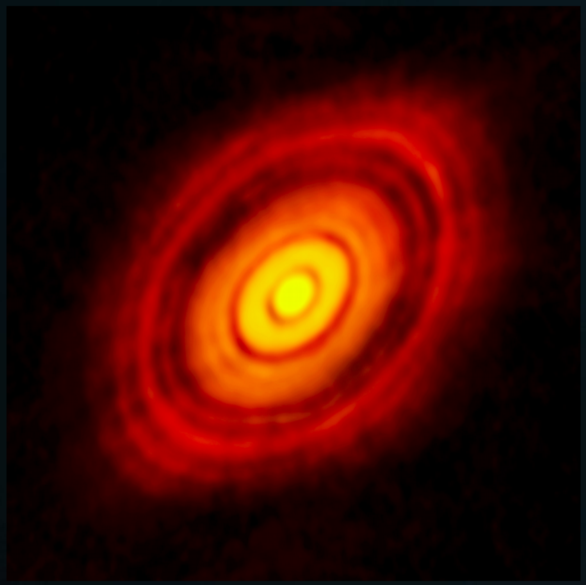

The initial dust-to-gas ratio of the protoplanetary discs

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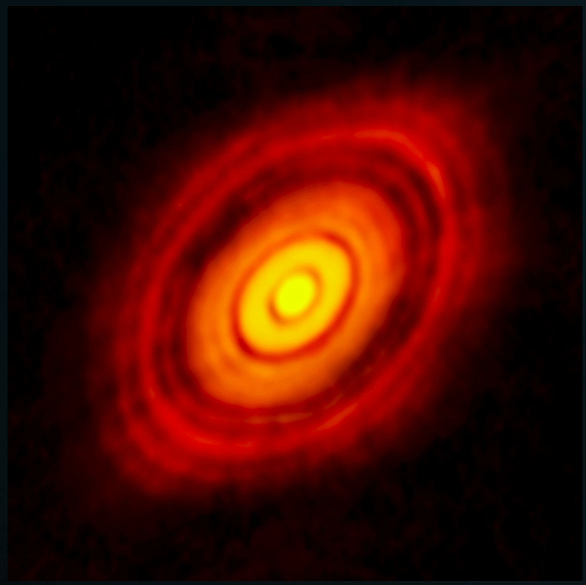
The metallicity of stars, which is observationally related to the probability of the presence of hosted planets

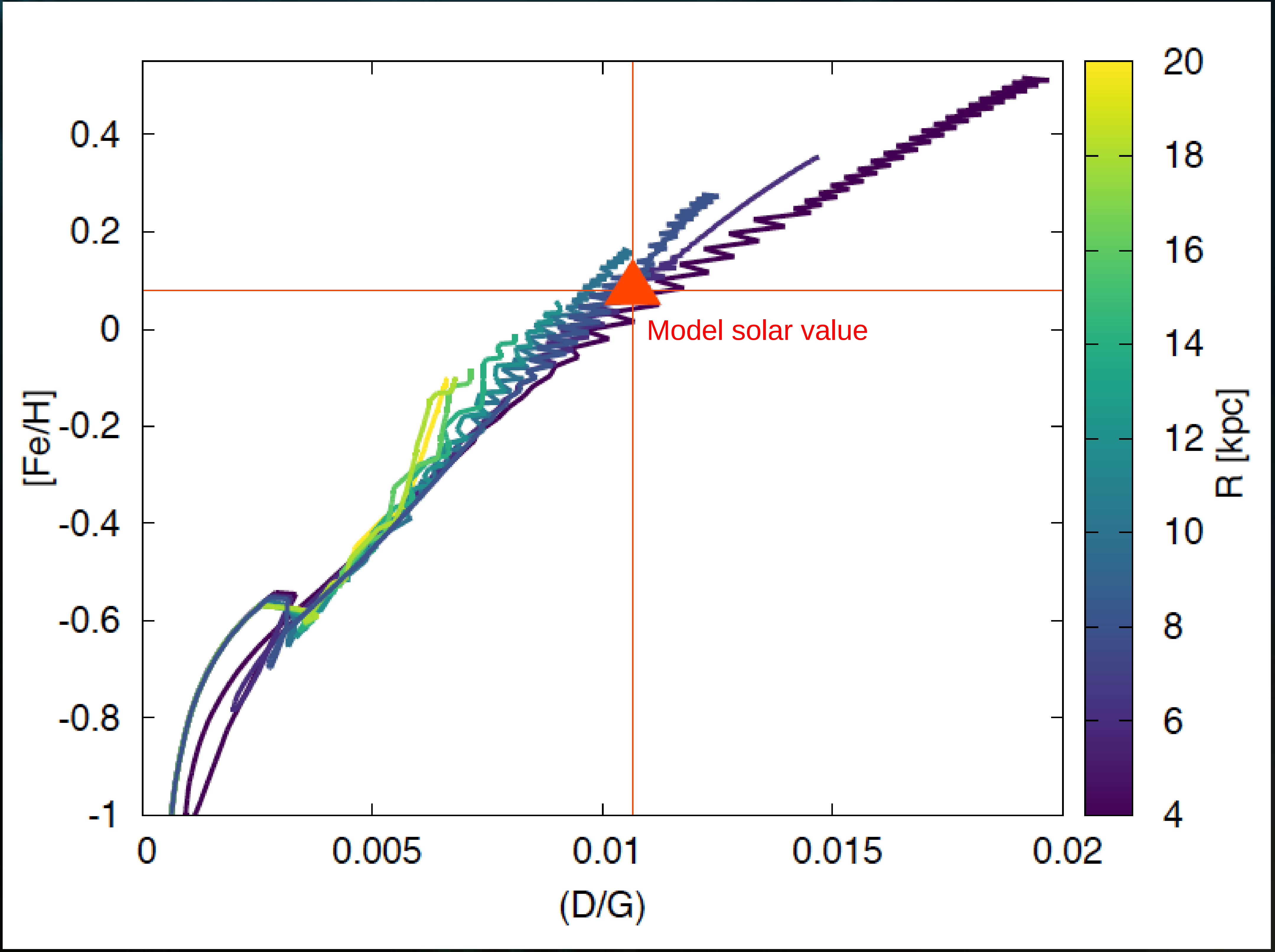


The initial dust–to–gas ratio of the protoplanetary discs

[Fe/H] versus the dust-to-gas ratio

Model of Gioannini et al. (2017)

The role of the dust



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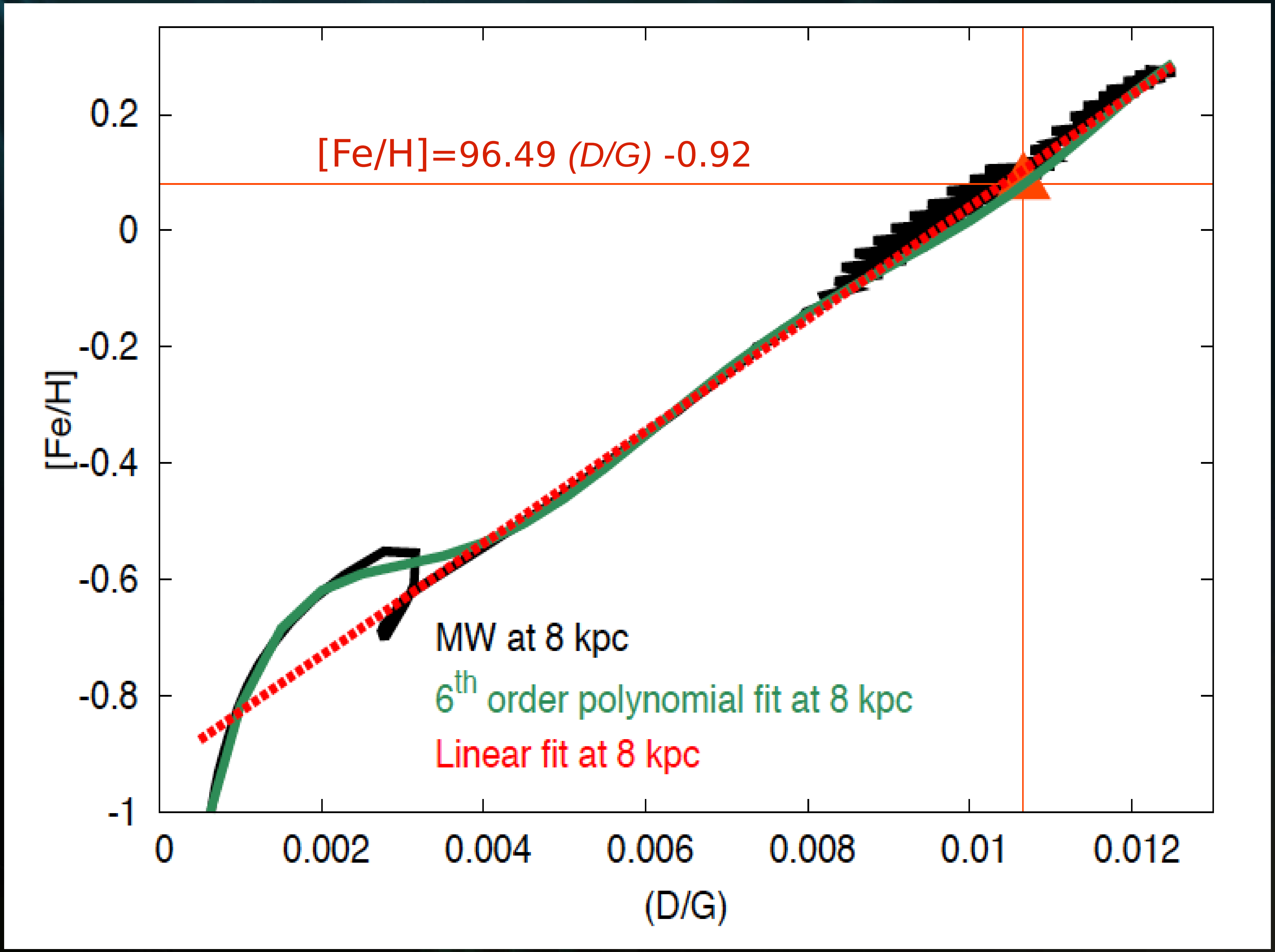

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Conclusions

- Updated study of the GHZ by using new probabilities which depend on stellar types (FGK and M stars).
  Spitoni, Gioanini, Matteucci (2017)

- The peak of the GHZ at 8 Kpc at the present time, in agreement with previous work (Lineweaver et al. 2004, Spitoni et al. 2014).

- The GHZ map:
  The $N_{*,life}$ of M type is about 10 times larger than FGK stars,
  according to their relative fraction in a Scalo IMF.

- We considered in our model the presence of dust (Gioannini et al. 2017):
  we linked the dust-to-gas ratio (D/G) to the metallicity and we expressed the probabilities for the presence of planets in term of the D/G.