



MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS



Composição química inicial em estrelas de tipo solar ante a presença de planetas e habitabilidade em planetas rochosos: grupo CNO e Tório

Rafael Bueno Botelho
André de Castro Milone

Estrelas - Classificação



Estrelas análogas e gêmeas solares

- Análogas $T_{\text{ef}} \pm 500$ K, $\log(g) \pm 0,60$ dex e $[\text{Fe}/\text{H}] \pm 0,33$ dex
- Gêmeas $T_{\text{ef}} \pm 100$ K, $\log(g) \pm 0,10$ dex e $[\text{Fe}/\text{H}] \pm 0,10$ dex

Temos dois grupo:

- HIDES - 42 estrelas análogas (Takeda et al 2005)
- HARPS - 53 estrelas análogas (Spina et al 2018)
- ...

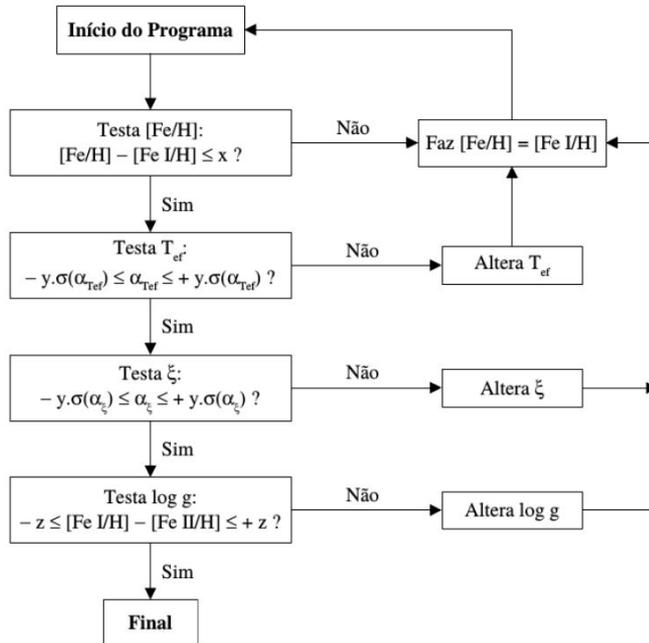
Parâmetros fotosféricos



- Temperatura efetiva
- Gravidade superficial
- Velocidade de microturbulência
- Metalicidade

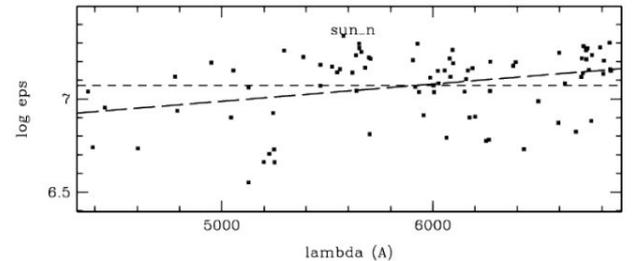
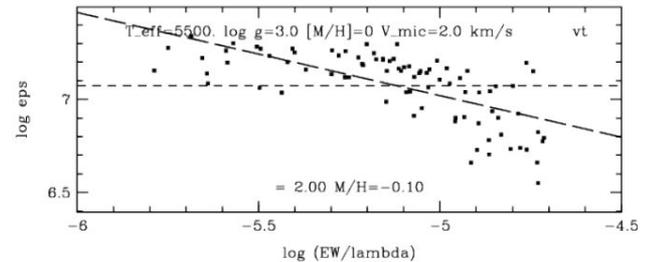
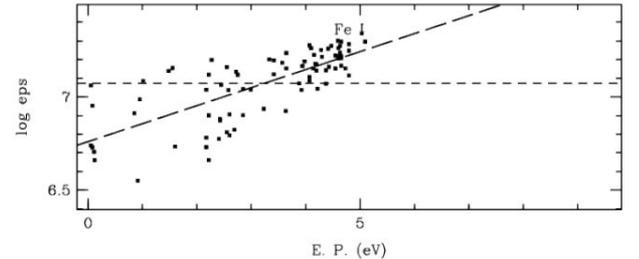
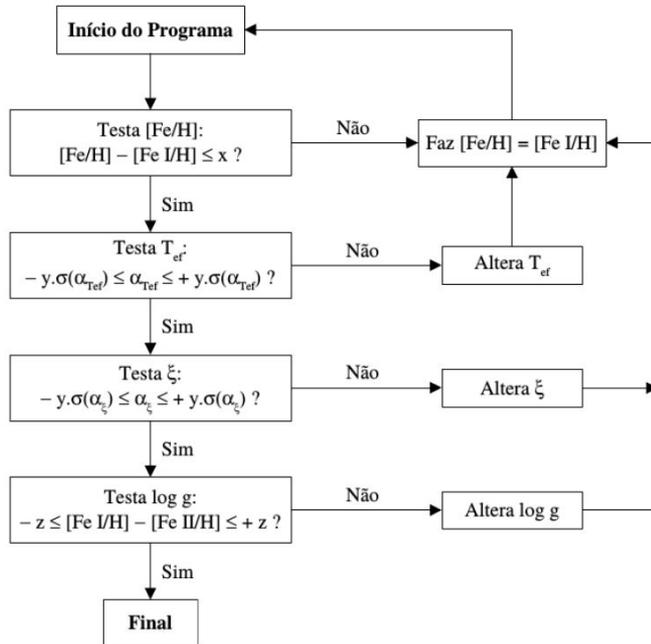
Parâmetros fotosféricos

- Temperatura efetiva
- Gravidade superficial
- Velocidade de microturbulência
- Metalicidade



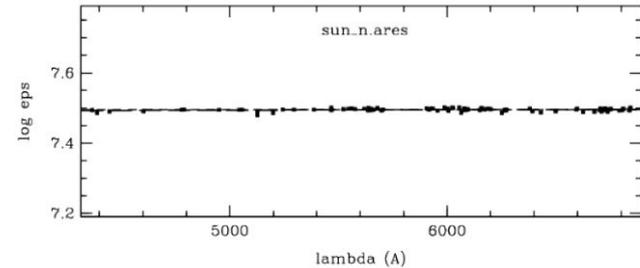
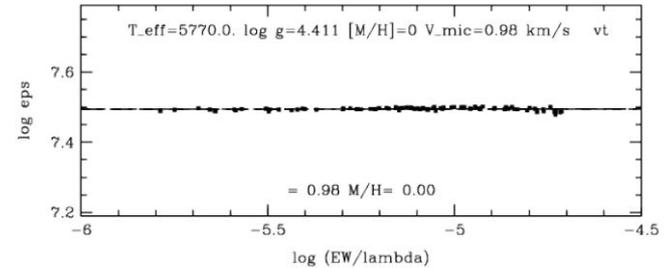
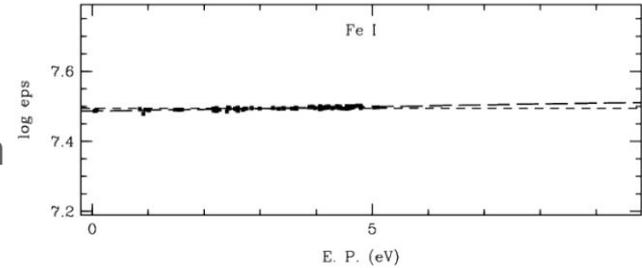
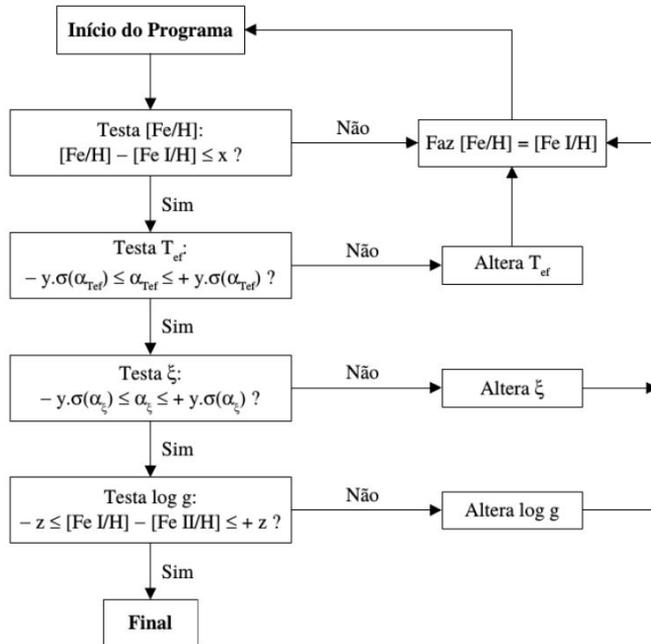
Parametros fotosféricos

- Temperatura efetiva
- Gravidade superficial
- Velocidade de microturbulência
- Metalicidade

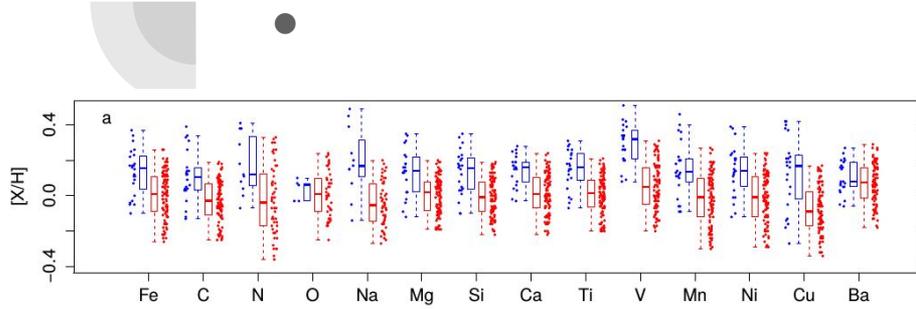


Parâmetros fotosféricos

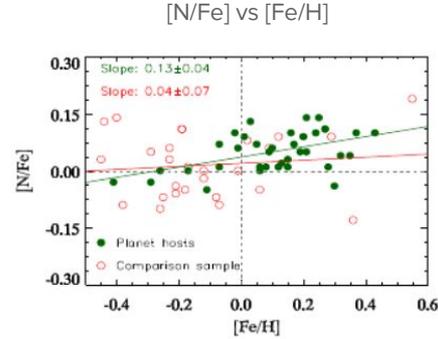
- Temperatura efetiva
- Gravidade superficial
- Velocidade de microturbulência
- Metalicidade



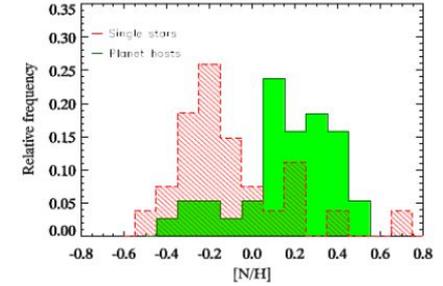
Determinação das abundâncias CNO



(Silva et al. 2015)

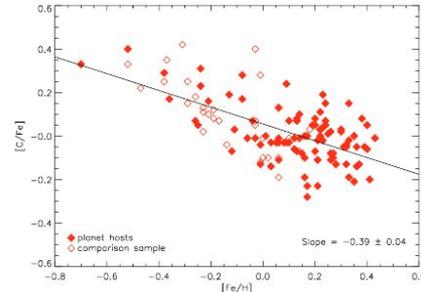
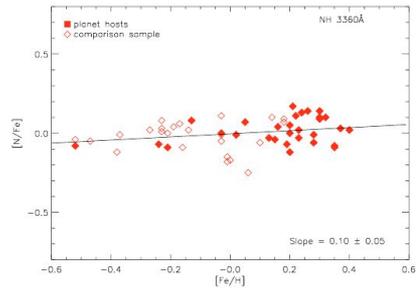


(Suárez-Andrés et al. 2016)



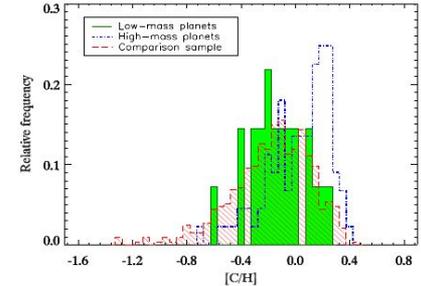
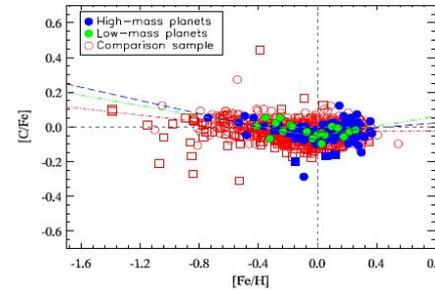
$[N/Fe]$ vs $[Fe/H]$

$[C/Fe]$ vs $[Fe/H]$



Ecuivillon et al. (2004a,2004b)

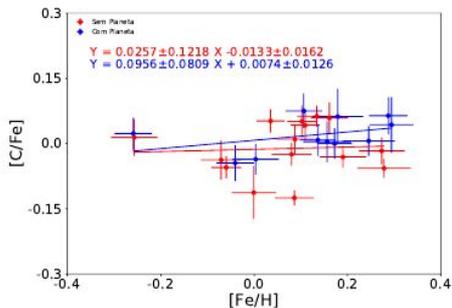
$[C/Fe]$ vs $[Fe/H]$



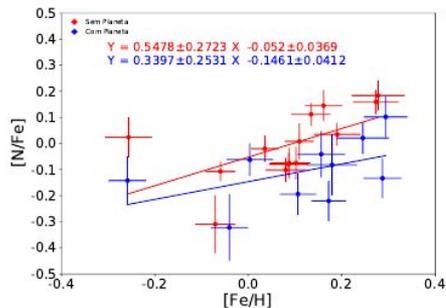
(Suárez-Andrés et al. 2017)

Determinação das abundâncias CNO

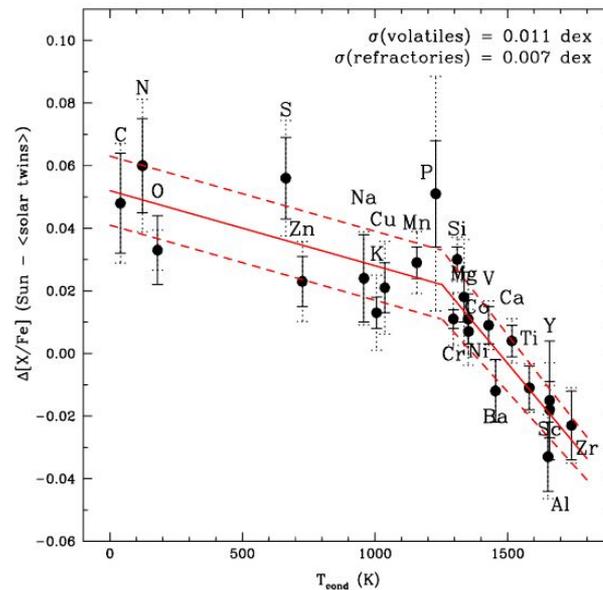
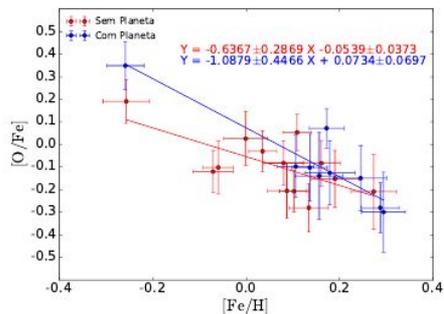
- Amostra de estrelas de Takeda et al (2005)



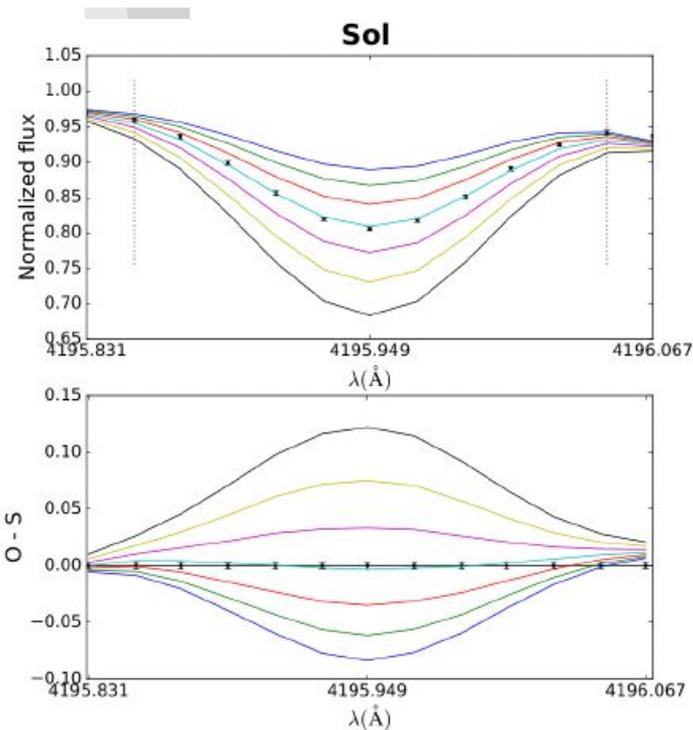
(a)



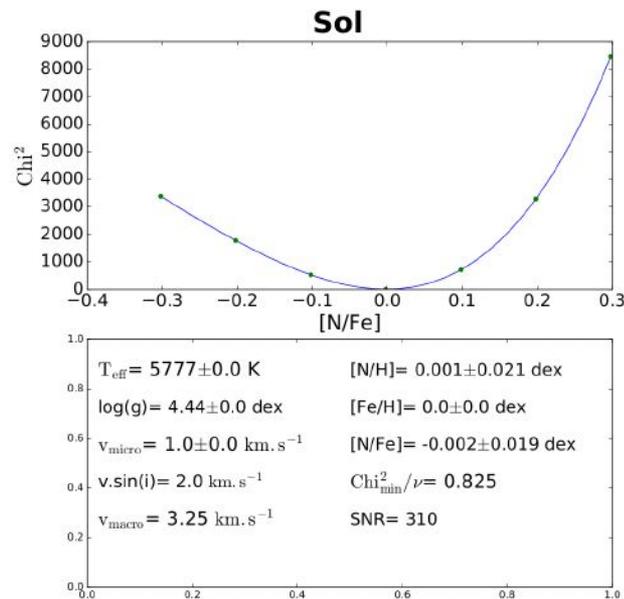
(b)



Determinação de abundância elemental via síntese espectral



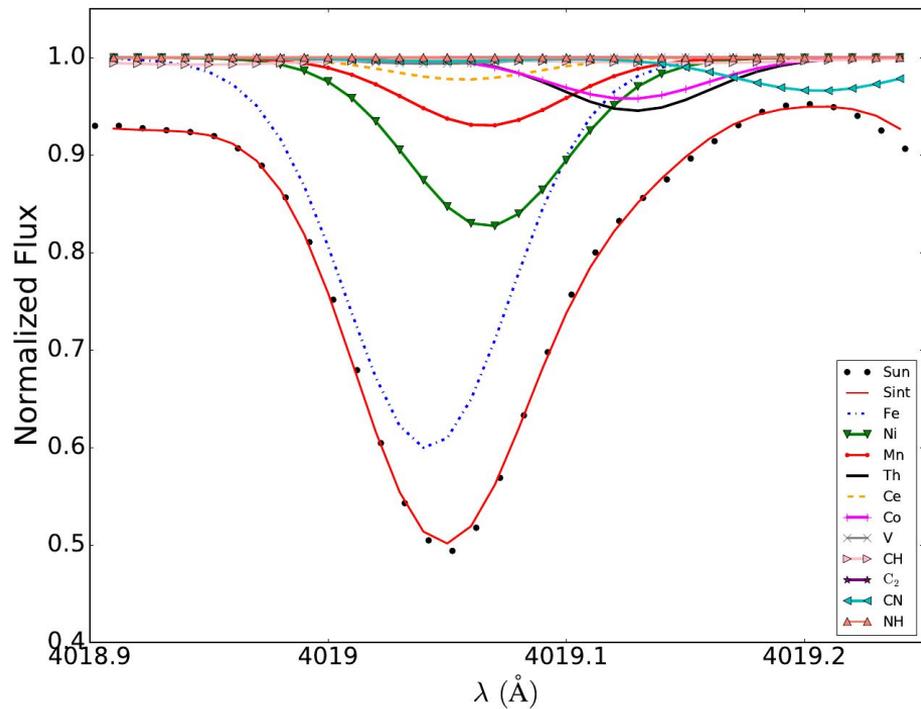
$$\chi^2 = \sum_{i=1}^N \frac{(f(\text{ sint})_i - f(\text{ obs})_i)^2}{\left(\frac{f(\text{ obs})_i}{SN}\right)^2}$$



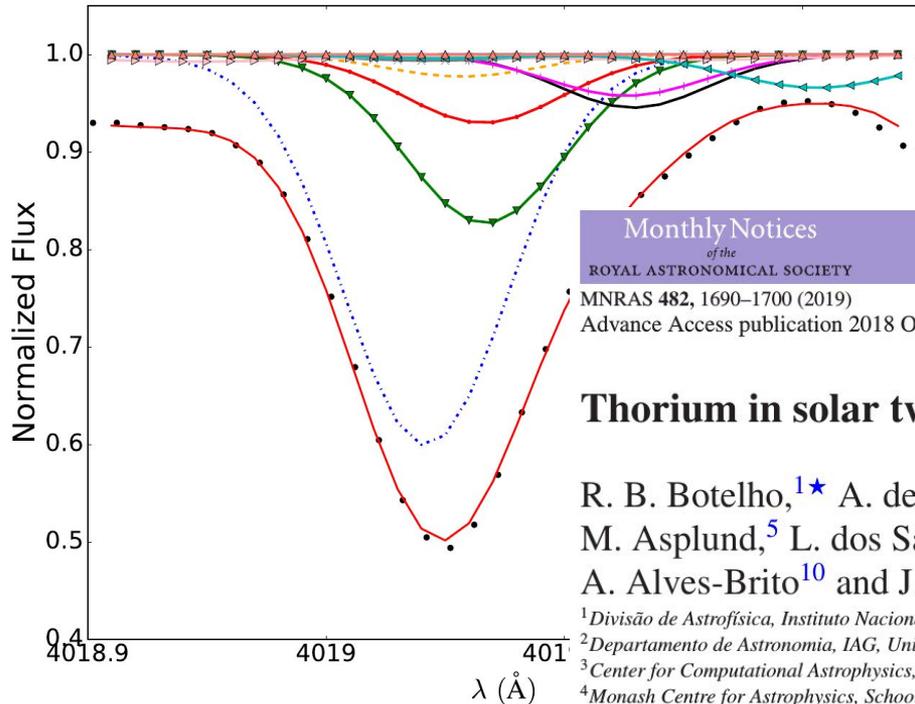
$$Erro_{[X/Fe]} = \sqrt{(\Delta[X/Fe]_{T_{\text{eff}}})^2 + (\Delta[X/Fe]_{\log g})^2 + (\Delta[X/Fe]_{v_{\text{mic}}})^2 + (\Delta[X/Fe]_{[Fe/H]})^2 + (\Delta[X/Fe]_X)^2}$$

(3.15)

Tório



Tório



Monthly Notices
of the
ROYAL ASTRONOMICAL SOCIETY

MNRAS 482, 1690–1700 (2019)
Advance Access publication 2018 October 17

doi:10.1093/mnras/sty2791



Thorium in solar twins: implications for habitability in rocky planets

R. B. Botelho,¹★ A. de C. Milone,¹★ J. Meléndez,² M. Bedell,³ L. Spina,⁴
M. Asplund,⁵ L. dos Santos,⁶ J. L. Bean,⁷ I. Ramírez,⁸ D. Yong,⁵ S. Dreizler,⁹
A. Alves-Brito¹⁰ and J. Yana Galarza²

¹Divisão de Astrofísica, Instituto Nacional de Pesquisas Espaciais, Av. dos Astronautas 1758 São José dos Campos, 12227-010, Brazil

²Departamento de Astronomia, IAG, Universidade de São Paulo, Rua do Matão 1226 São Paulo, 05509-900, Brazil

³Center for Computational Astrophysics, Flatiron Institute, 162 5th Ave, New York, NY 10010, USA

⁴Monash Centre for Astrophysics, School of Physics and Astronomy, Monash University, VIC 3800, Australia

⁵Research School of Astronomy and Astrophysics, The Australian National University, Cotter Road, Canberra, ACT 2611, Australia

⁶Observatoire de l'Université de Genève, 51 chemin des Maillettes, CH-1290 Versoix, Switzerland

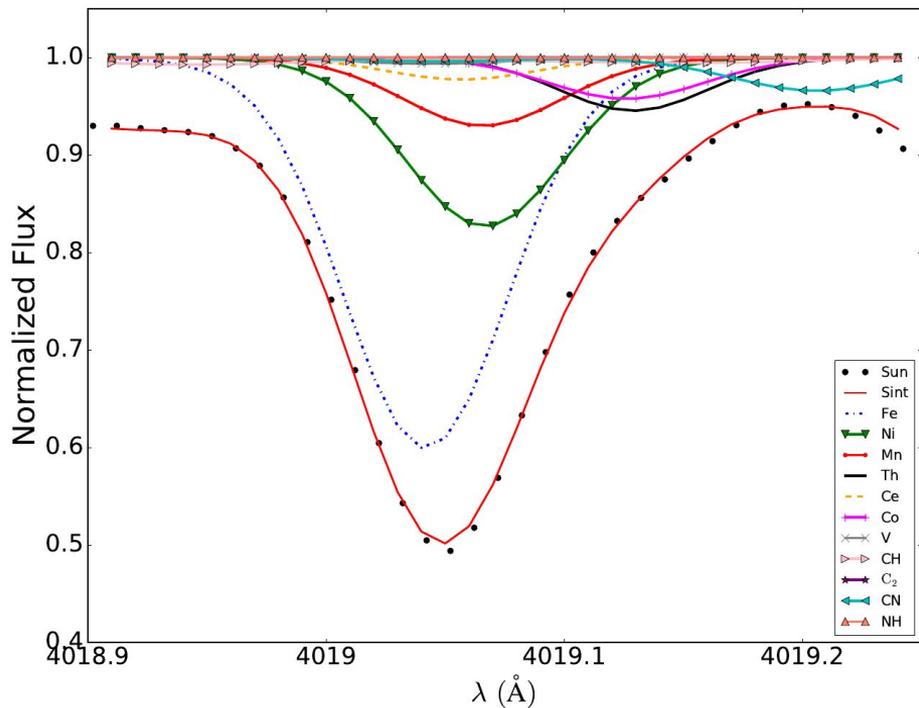
⁷Department of Astronomy & Astrophysics, 5640 S. Ellis Ave, Chicago, IL 60637, USA

⁸Tacoma Community College, 6501 South 19th Street, Tacoma, WA 98466-7400, USA

⁹Institut für Astrophysik, Georg-August Universität Göttingen, Wilhelmsplatz 1, D-37073, Göttingen, Germany

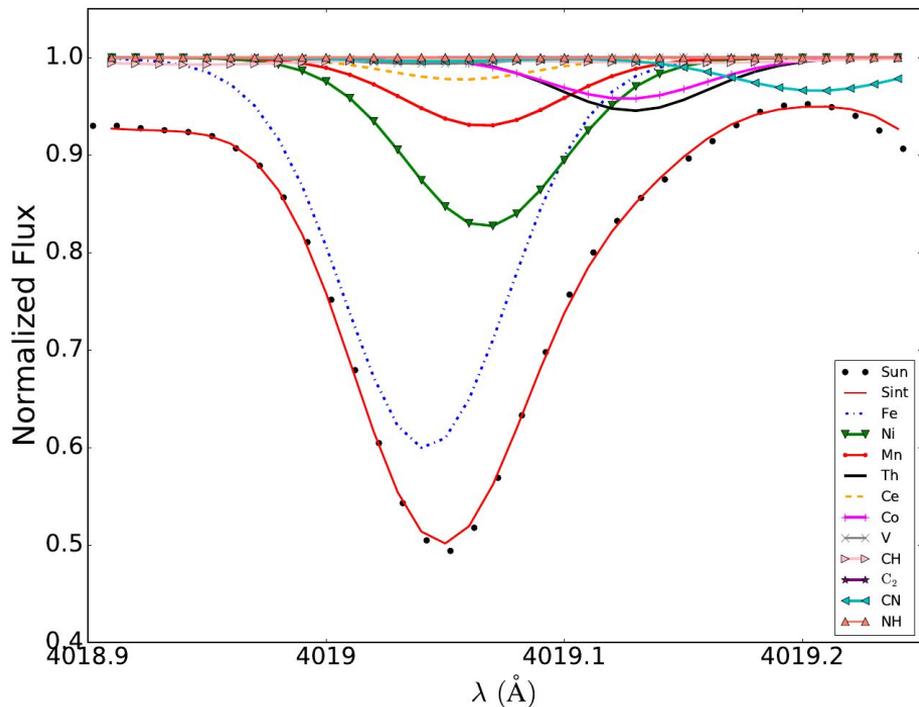
¹⁰Universidade Federal do Rio Grande do Sul, Instituto de Física, Av. Bento Gonçalves 9500, Porto Alegre, RS, Brazil

Tório

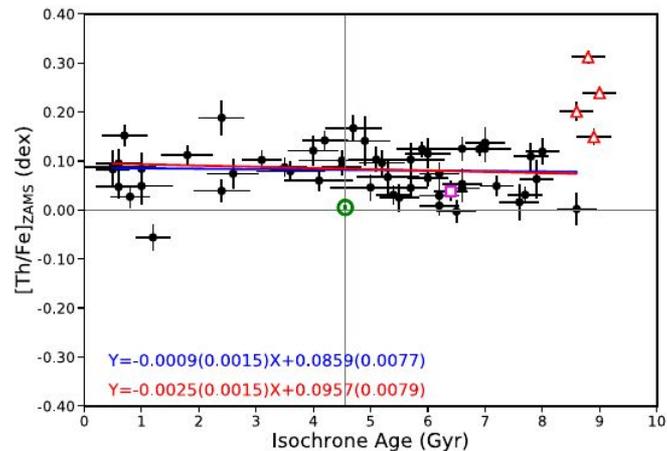
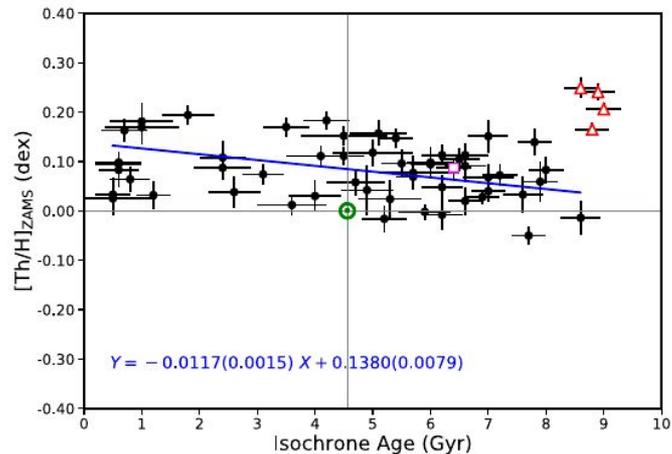


$$[X/H]_{\text{ZAMS}} = [X/H] + \frac{\ln(2) \log(e)}{t_{1/2}} (t_* - t_{\odot})$$

Tório

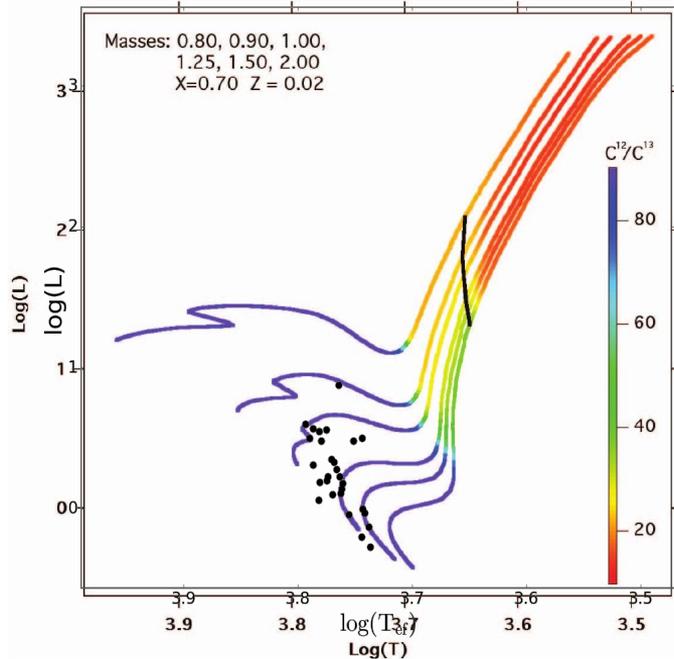


$$[X/H]_{\text{ZAMS}} = [X/H] + \frac{\ln(2) \log(e)}{t_{1/2}} (t_* - t_{\odot})$$

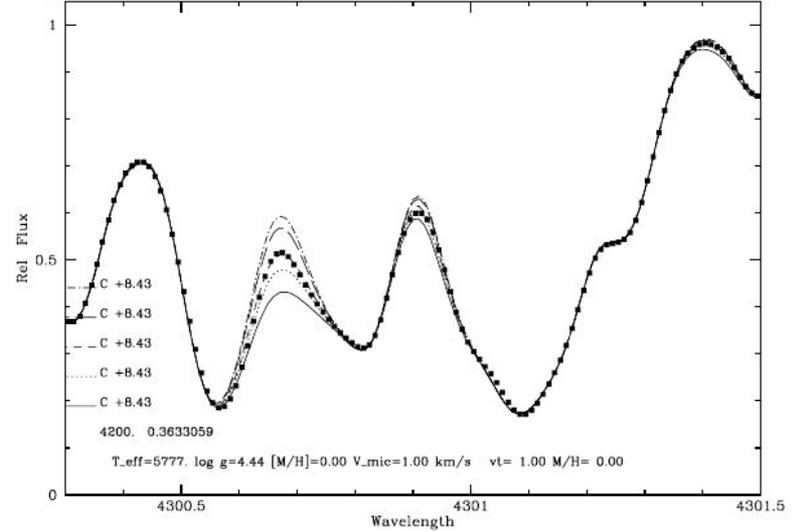


Razão isotópica

- $^{12}\text{C}/^{13}\text{C} \rightarrow 7$ Regiões
- $^{14}\text{N}/^{15}\text{N} \rightarrow 5$ Regiões



106.00112: 1.02/1.01/1.01/1.01/1.00/ 106.00113: 51.0/71.0/90.4/151./201./
smoothing=r V sini= 2.0 L.D.C.=0.60 Vmacro= 3.2 FWHMgauss= 0.039





Obrigado