Os elementos químicos : do *Big Bang* aos planetas rochosos

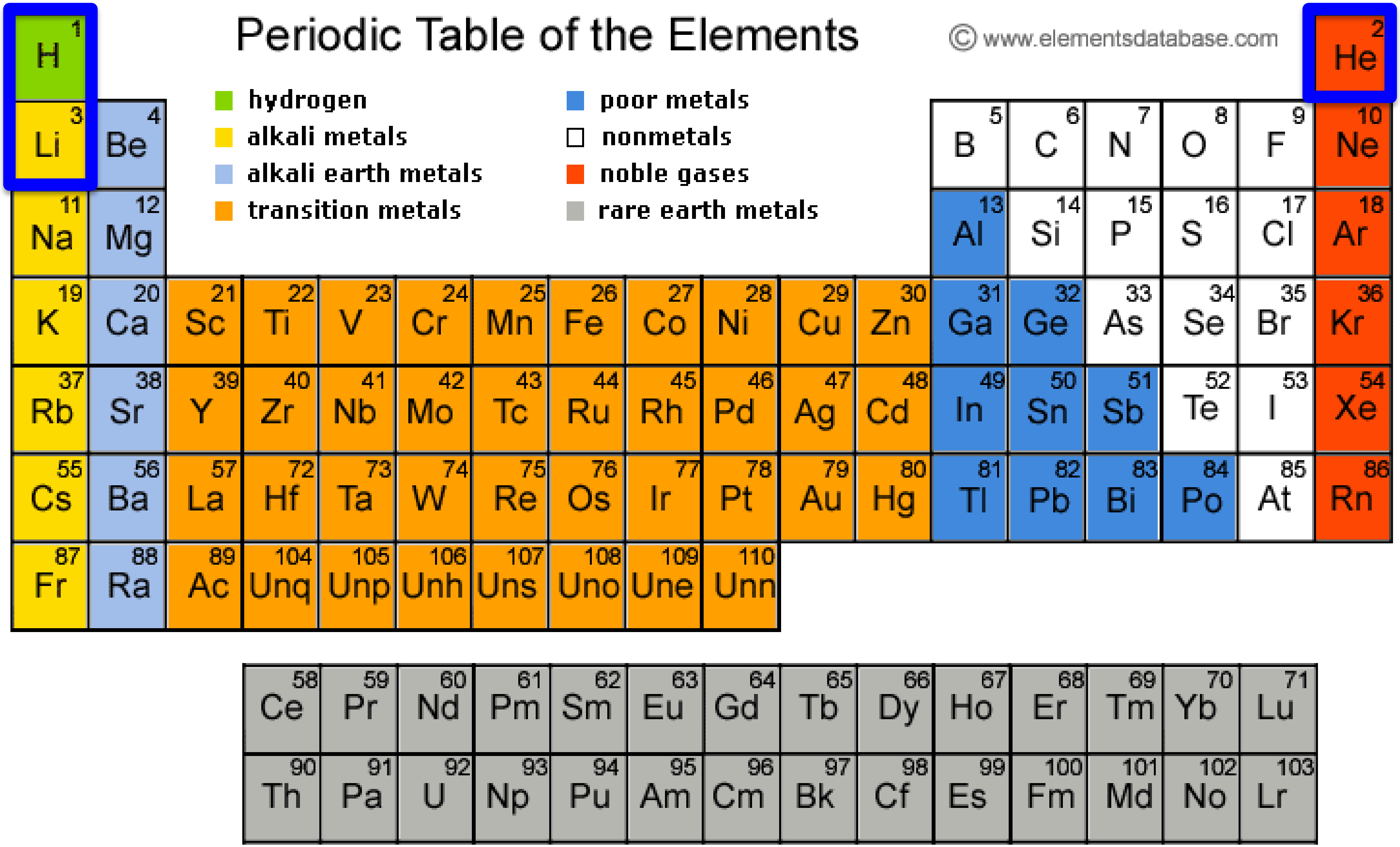
The chemical elements : from the Big Bang to terrestrial planets

Cr He C P Si Ba Be N S V Sc La F O Ti Fe H B Li Mg Ca Eu

Jorge Meléndez

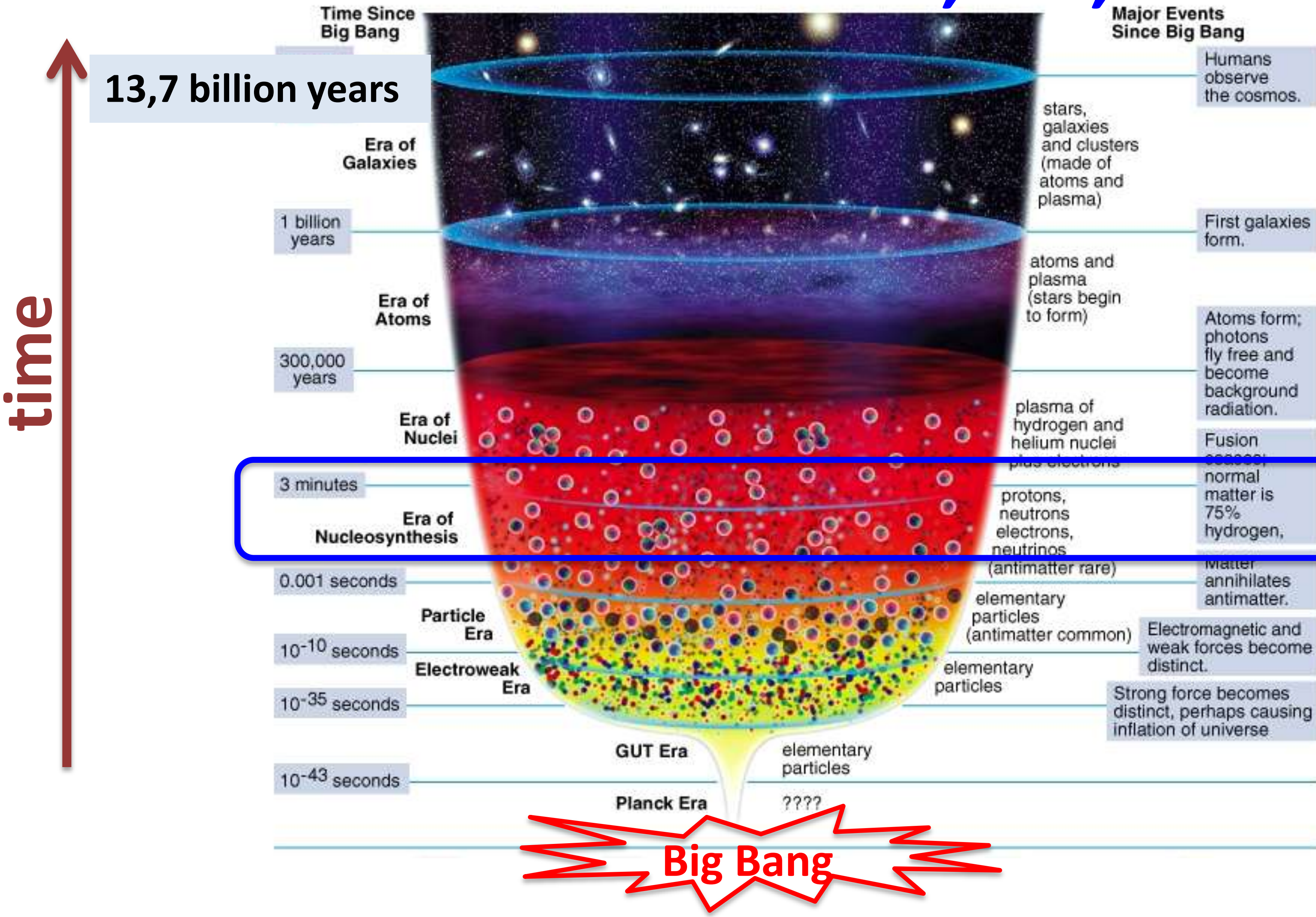
Departamento de Astronomia do IAG/USP

First elements in the universe:
H, He, Li



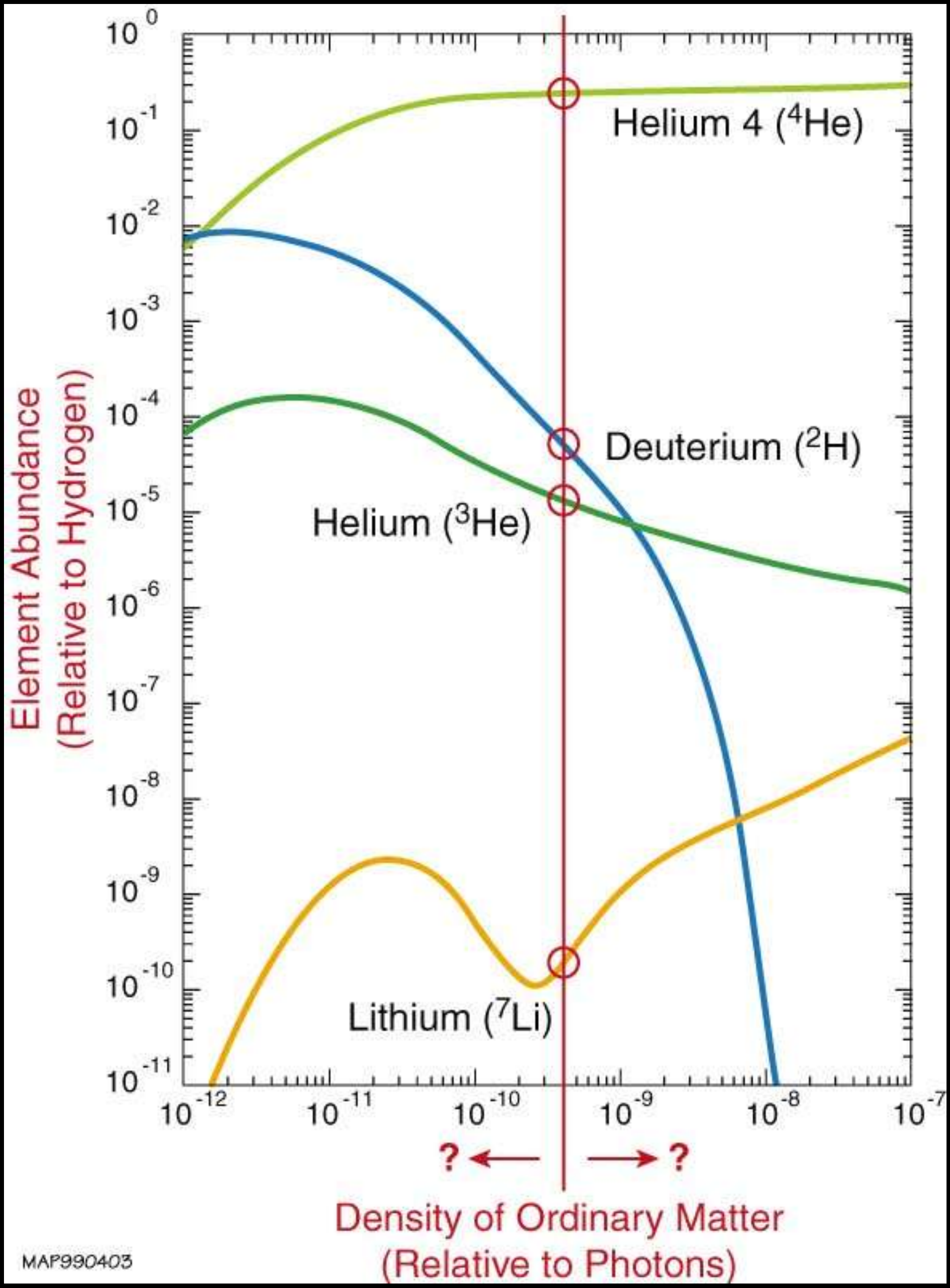
Evolution of our universe

First few minutes: H, He, Li



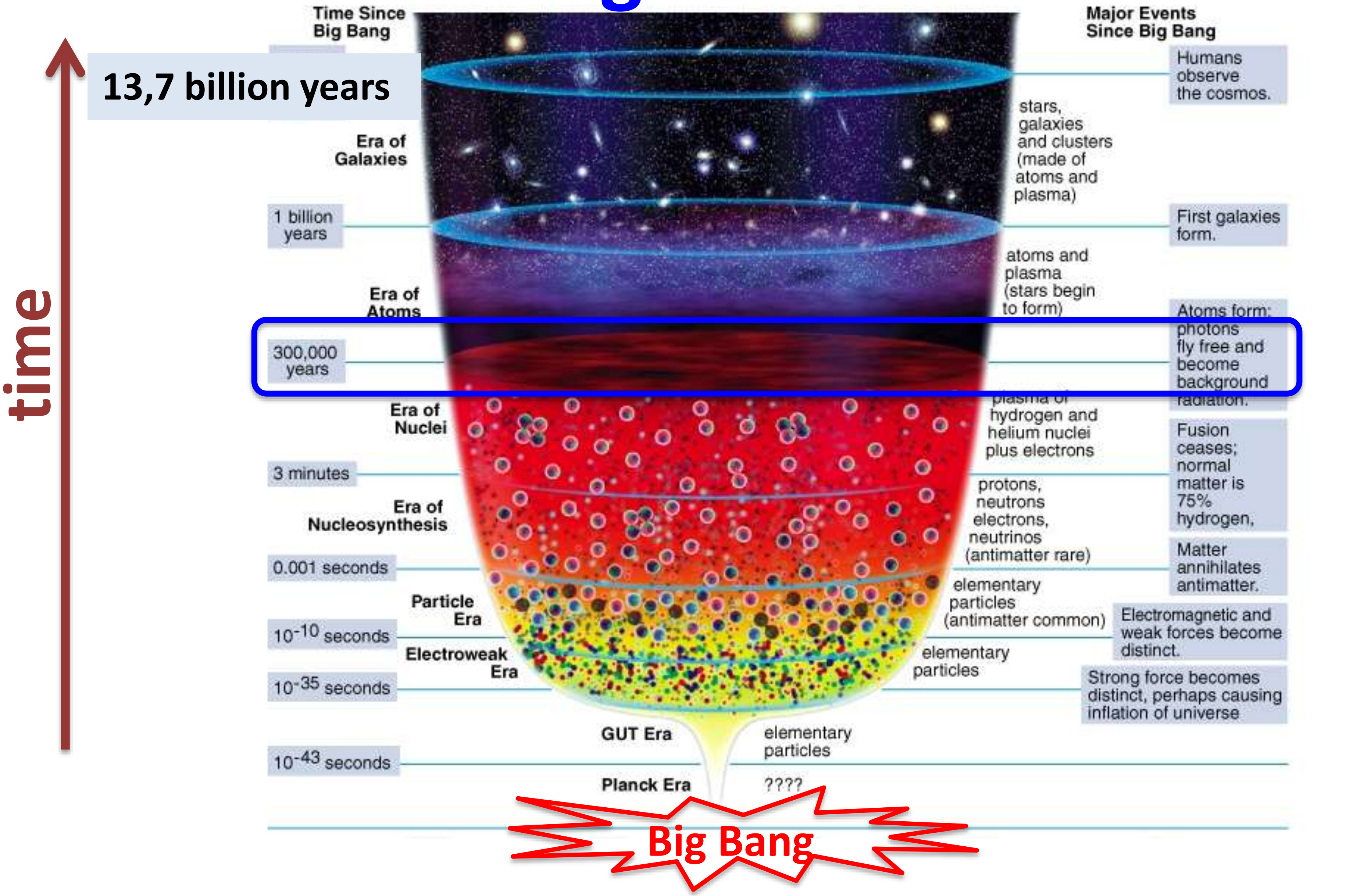
The abundances of the light elements (H, He, Li) formed a few minutes after the Big Bang depend only on η_{10}

(baryon-to-photon ratio)

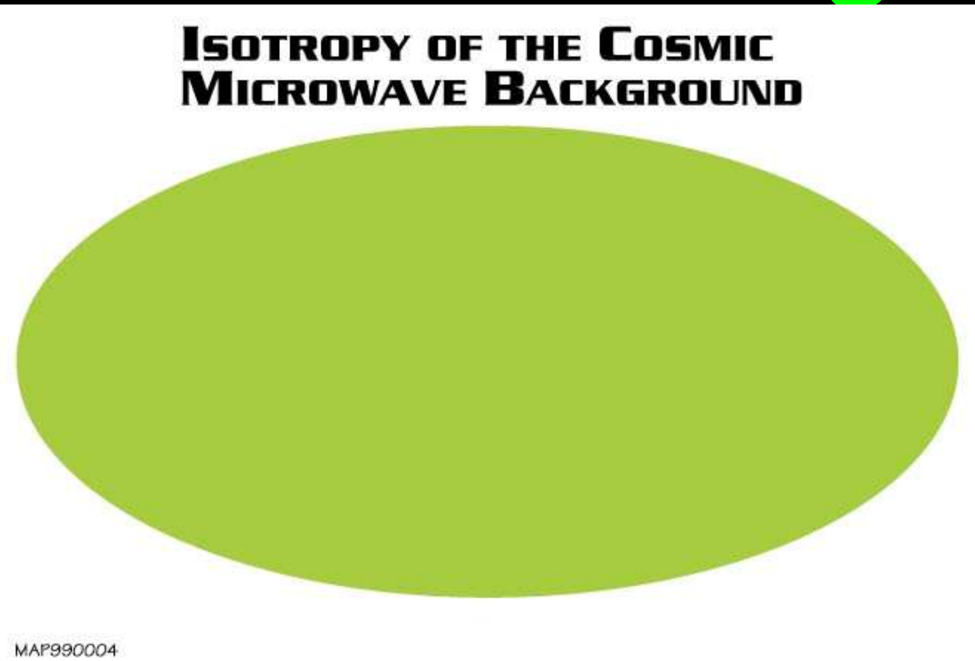


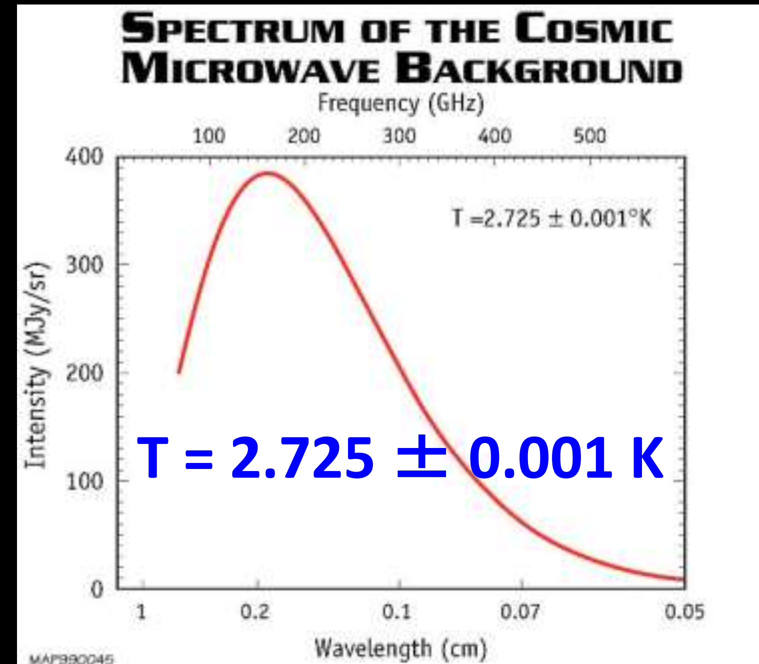
η_{10} *credits: NASA*

Evolution of our universe
Cosmic Background Radiation



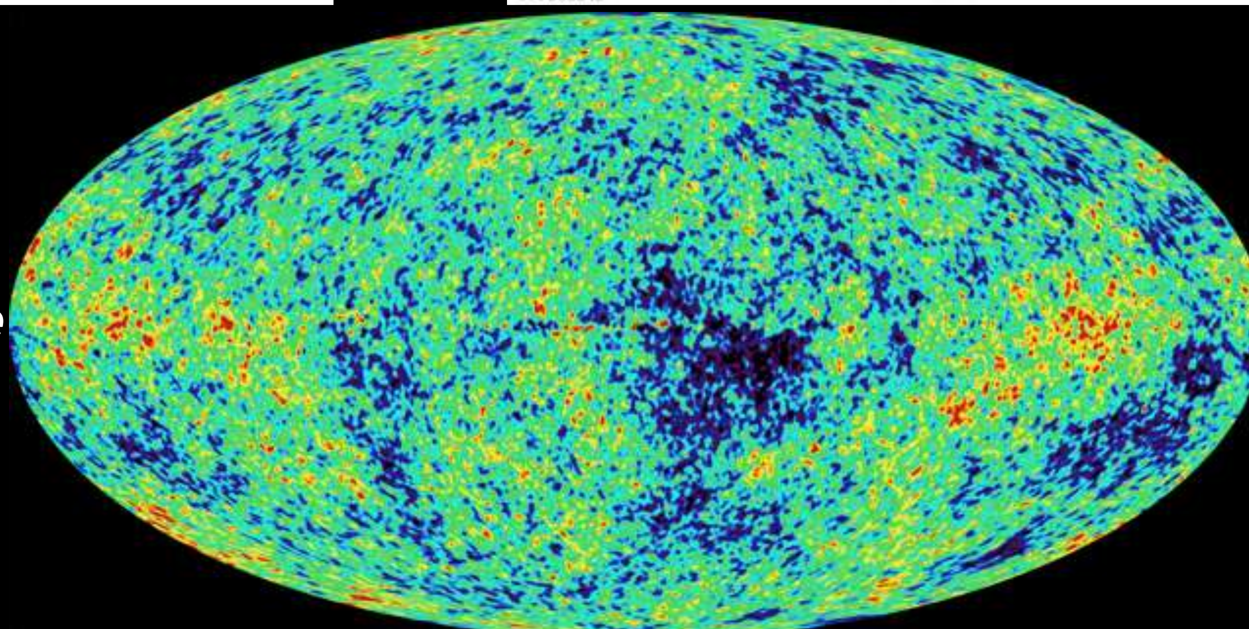
Cosmic Background Radiation





T = 2.725 ± 0.001 K

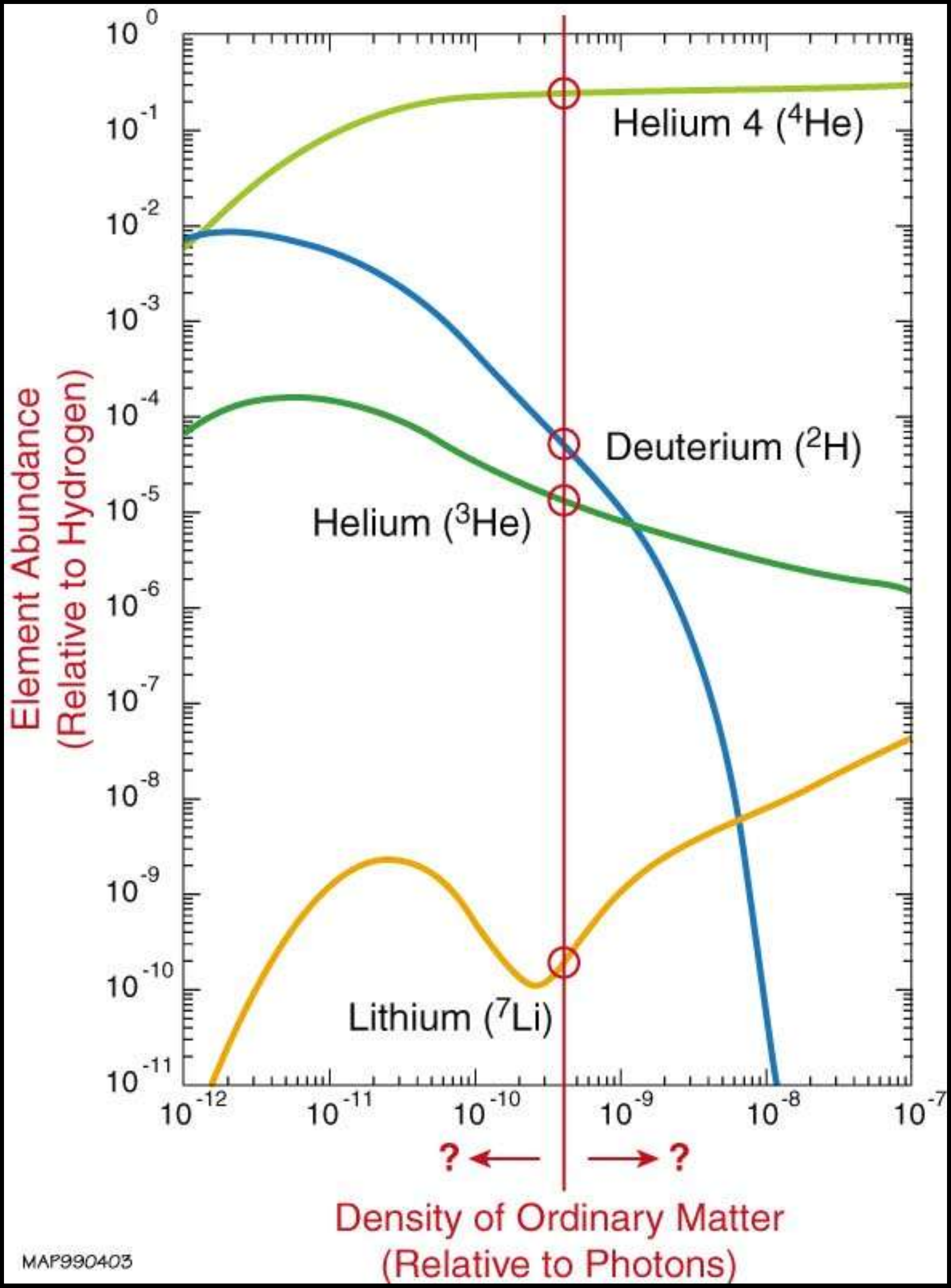
WMAP satellite



small fluctuations in the cosmic radiation → η_{10}

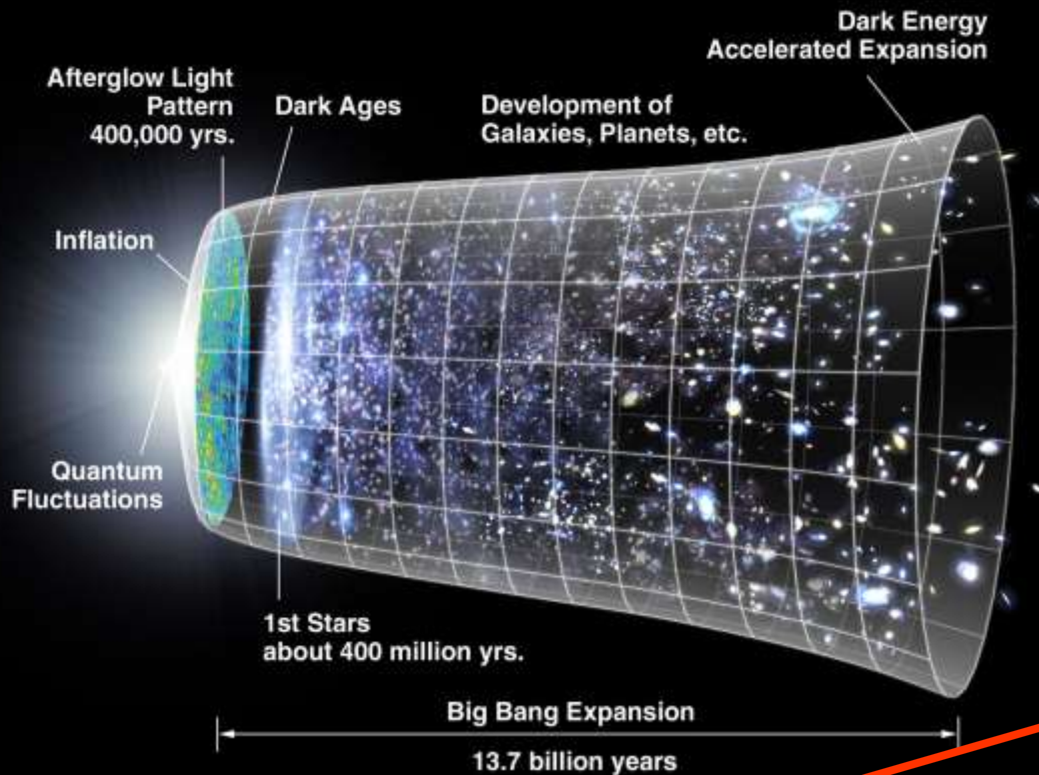
credits: NASA

The abundances of the light elements (H, He, Li) formed a few minutes after the Big Bang depend only on η_{10} (baryon-to-photon ratio)

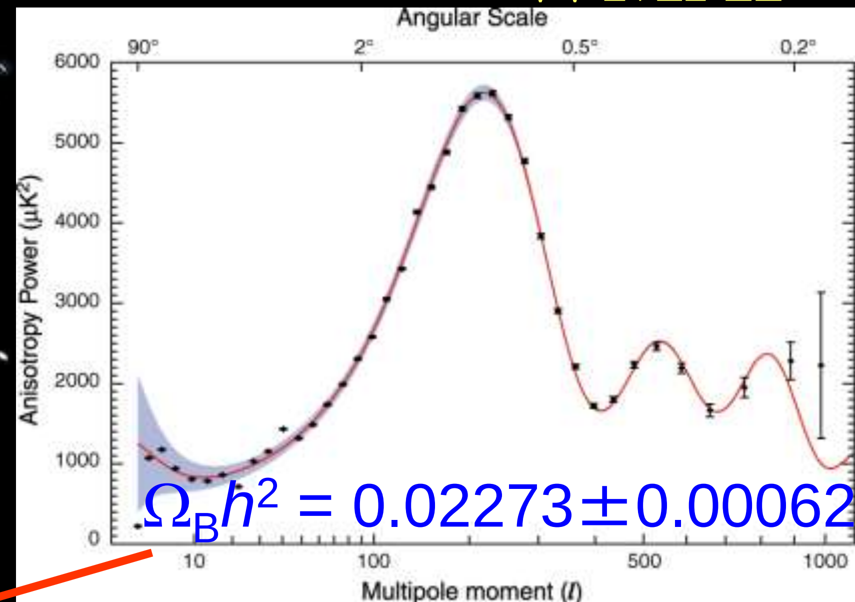


η_{10} *credits: NASA*

Cosmic Microwave Background



WMAP



$\Omega_B h^2 = 0.02273 \pm 0.00062$

credits: http://map.gsfc.nasa.gov

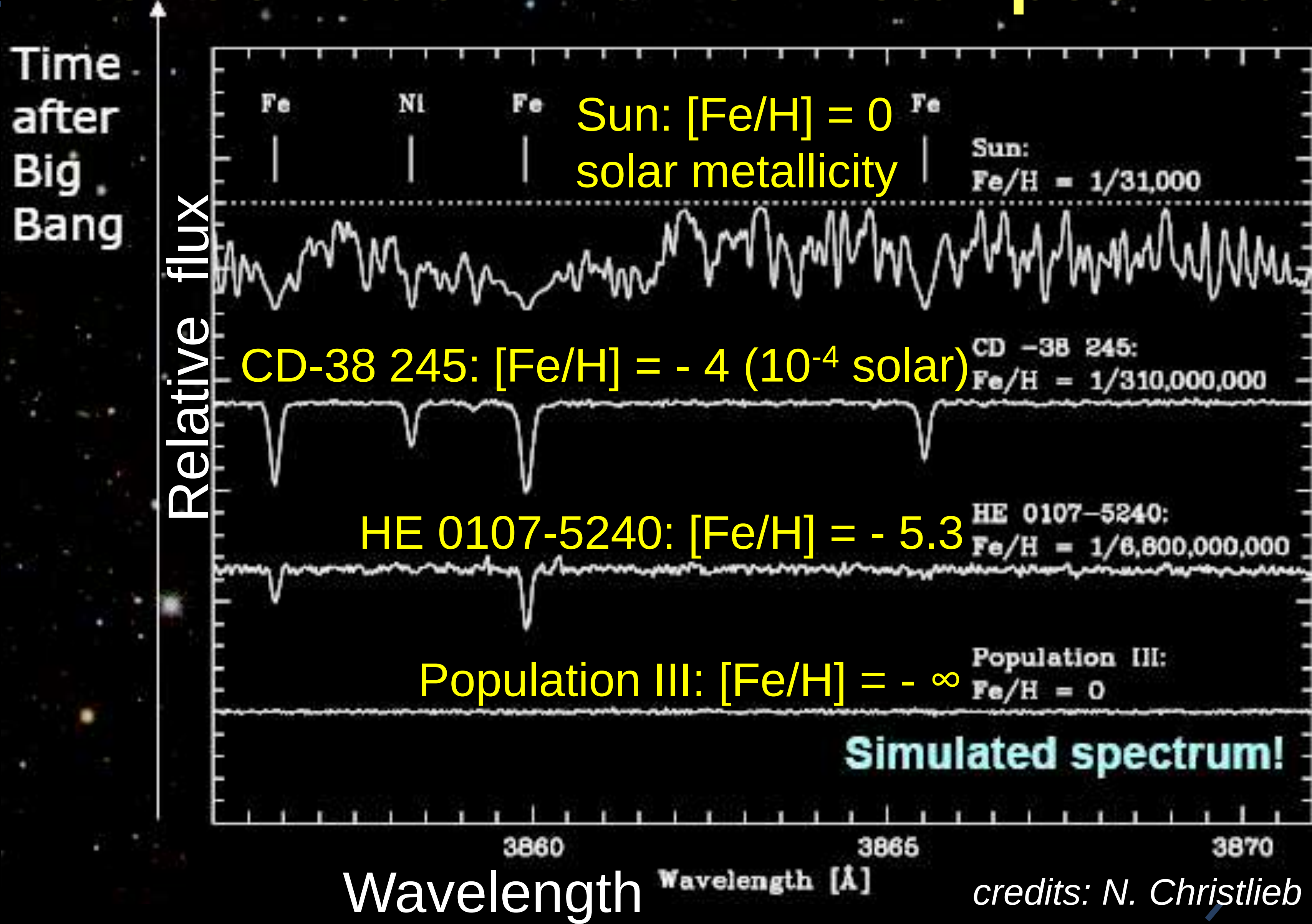
η_{10} = 6.226 ± 0.170 (Dunkley et al. 2009)

Predicted primordial lithium abundance:

A(Li) = 2.72 dex ⟶ Li/H = 5.2 10^{-10}

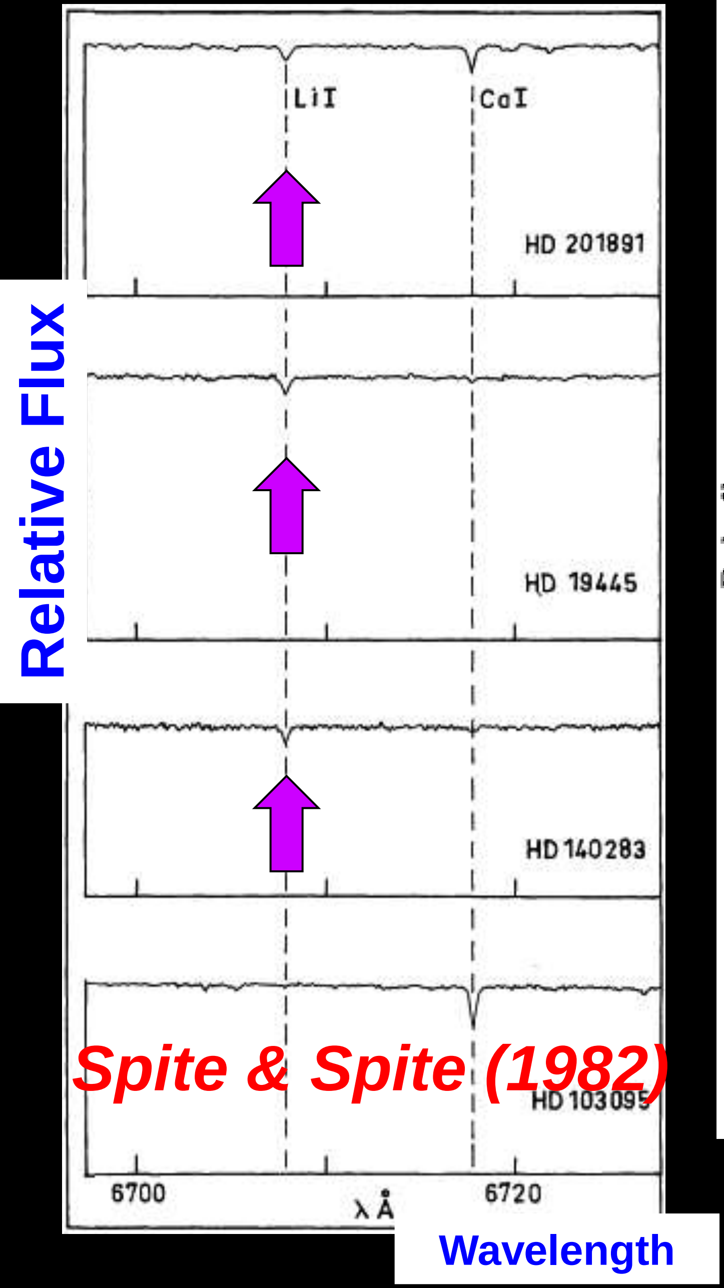
(Cyburt et al. 2008, see also Steigman 2009; Coc & Vangioni 2010)

To test Big Bang Nucleosynthesis we need to look back in time: metal-poor stars

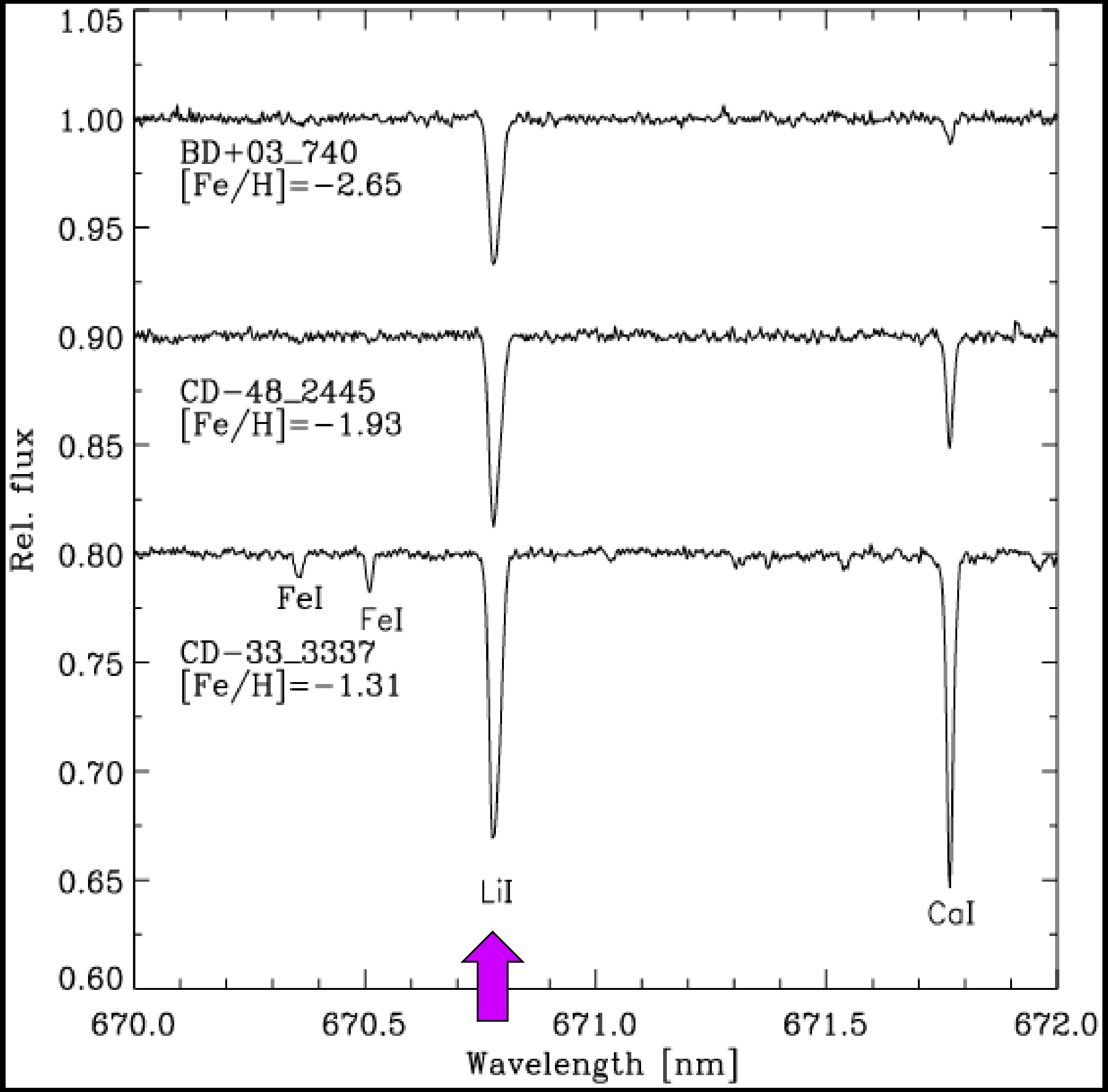


credits: N. Christlieb

Primordial Li in metal-poor stars !



Spite & Spite (1982)



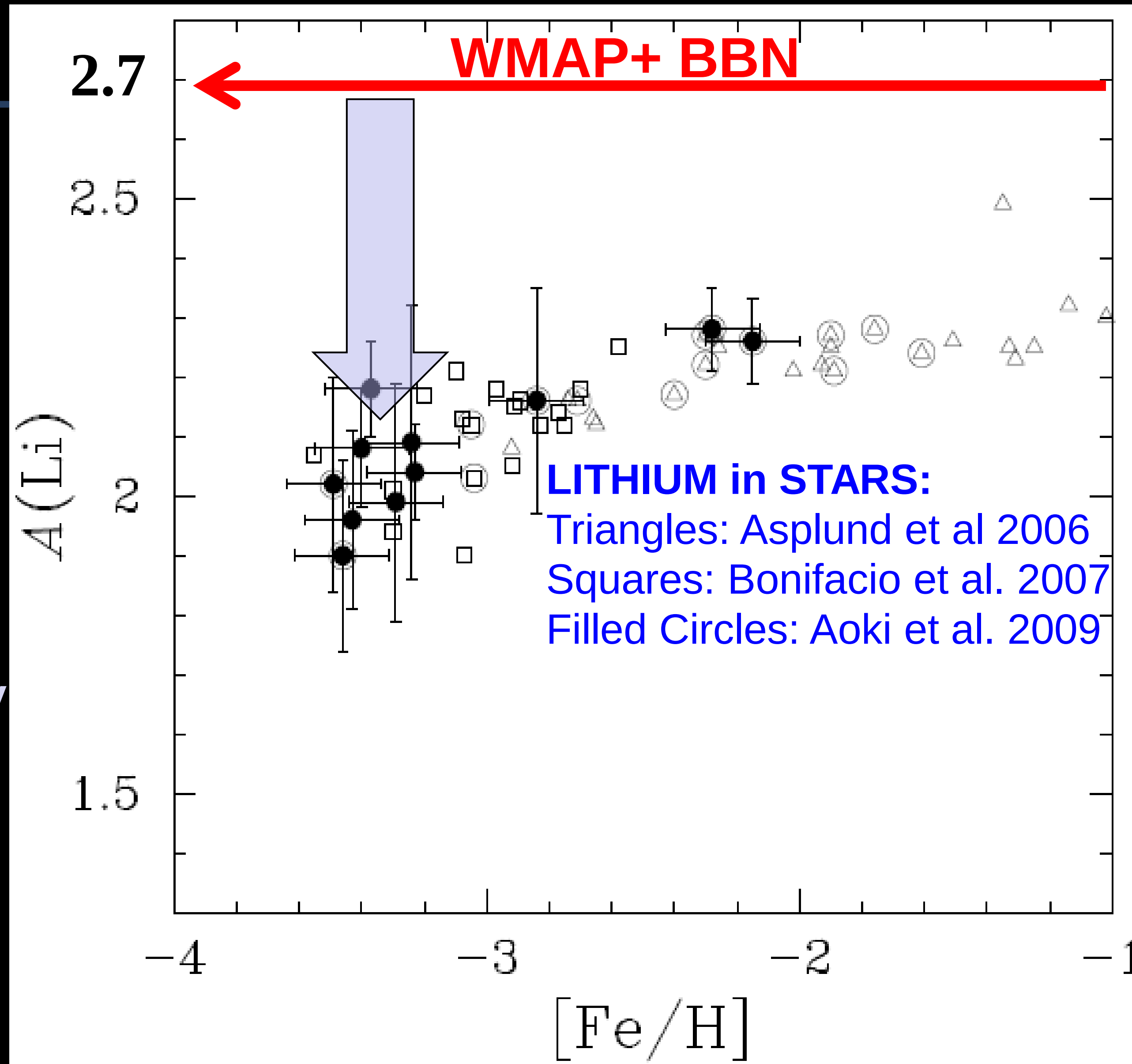
Asplund et al. (2006)

Cosmological lithium problem

WMAP+ BBN
(Li = 2.72)

Stars
(Li = 2.0 – 2.25)

0.7 dex (factor of 5) discrepancy at the lowest metallicities between BBN+WMAP and stars



Aoki et al. (2009)

The cosmological Li problem:

Li in stars is much lower (x 5) than the primordial Li predicted by BBN

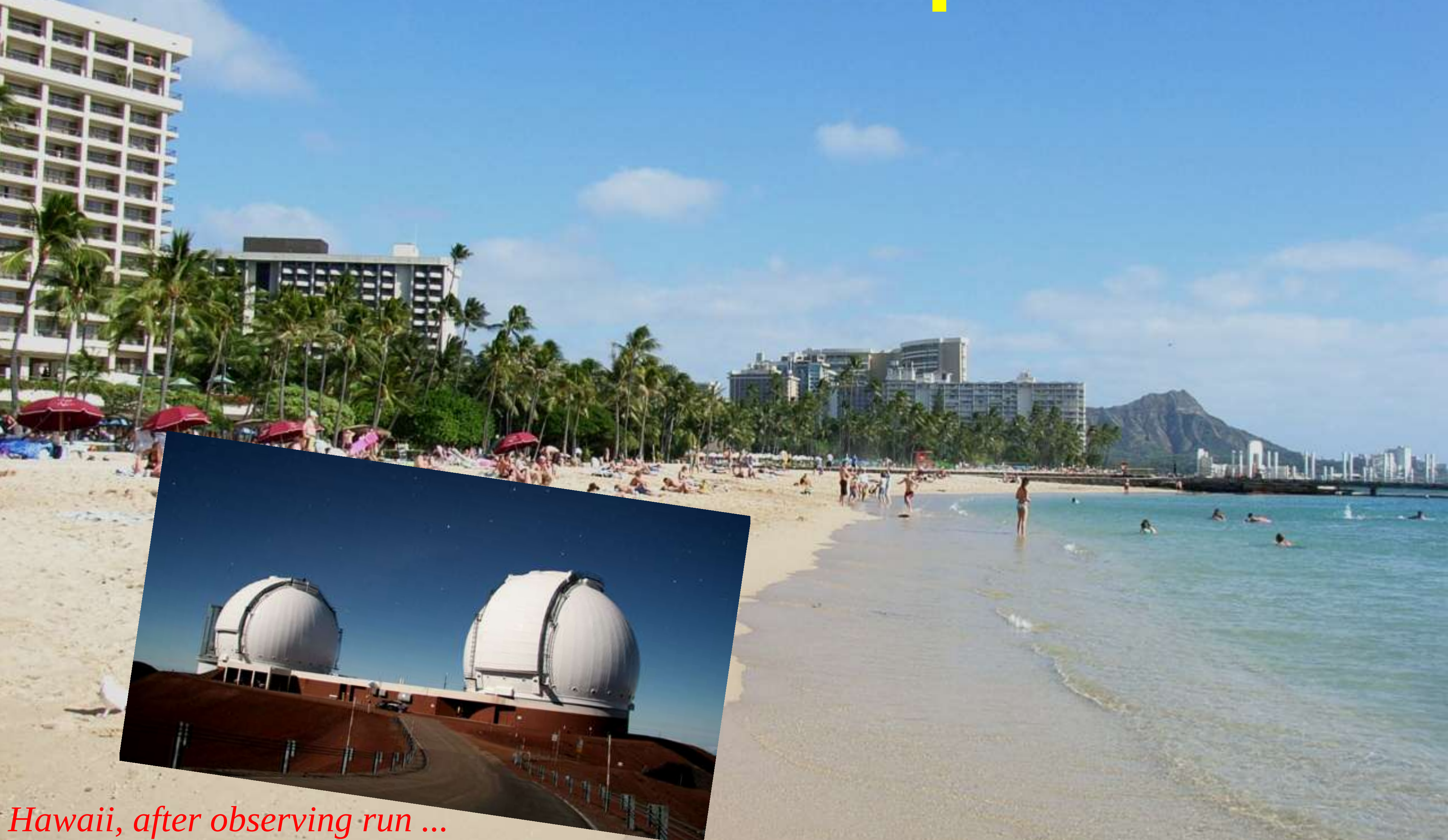
~~T_{eff} scale~~

~~Errors in nuclear reaction rates~~

New physics / cosmology ?

Li depletion in stars ?

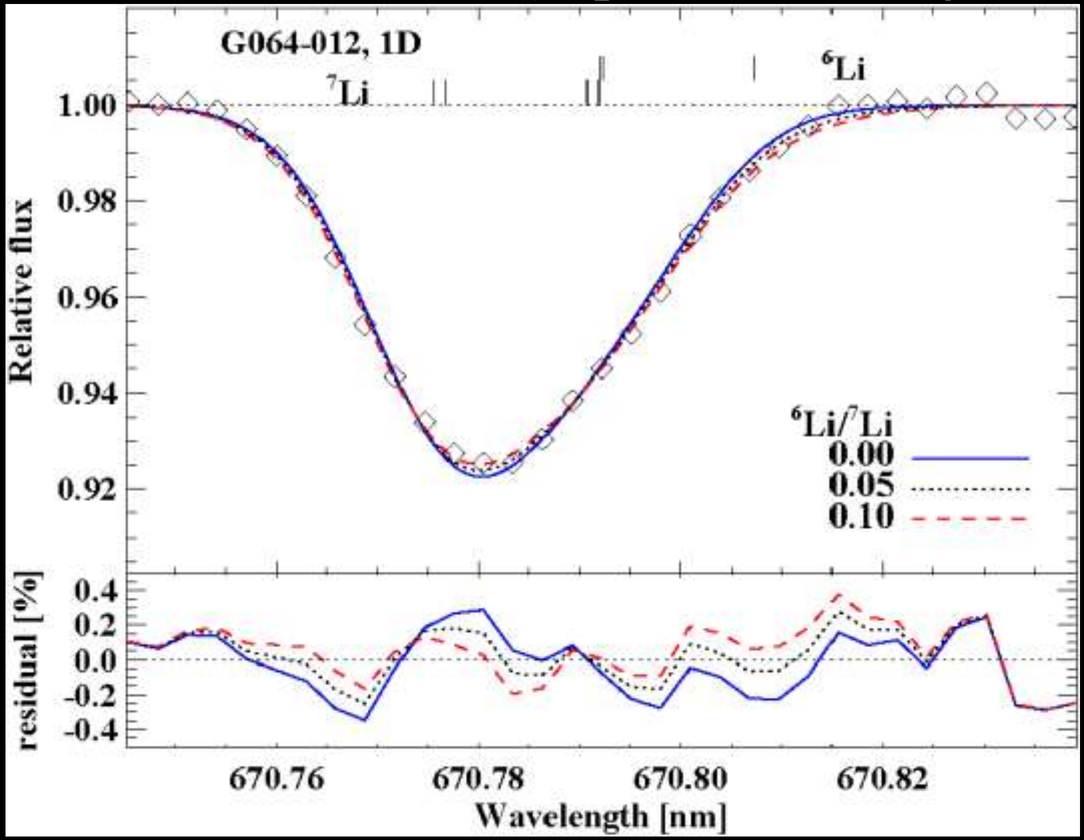
Ultra high precision analysis of lithium in metal-poor stars



Hawaii, after observing run ...

Ultra high precision analysis of lithium in metal-poor stars using Keck and VLT data

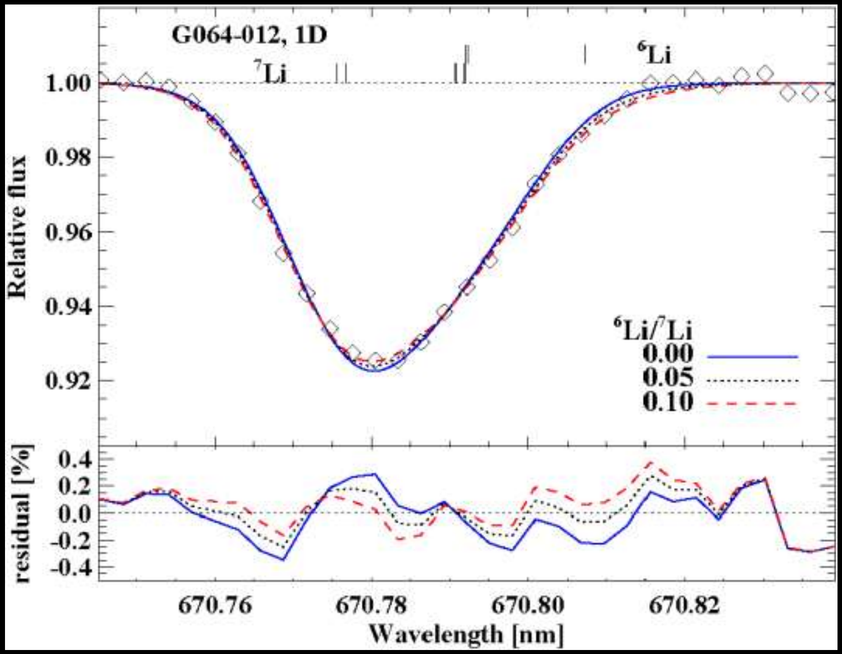
Stellar spectrum observed with Keck (exposure time of 5 hours)



Asplund & Melendez (2008)

Next steps in solving the Li problem @ IAG/USP

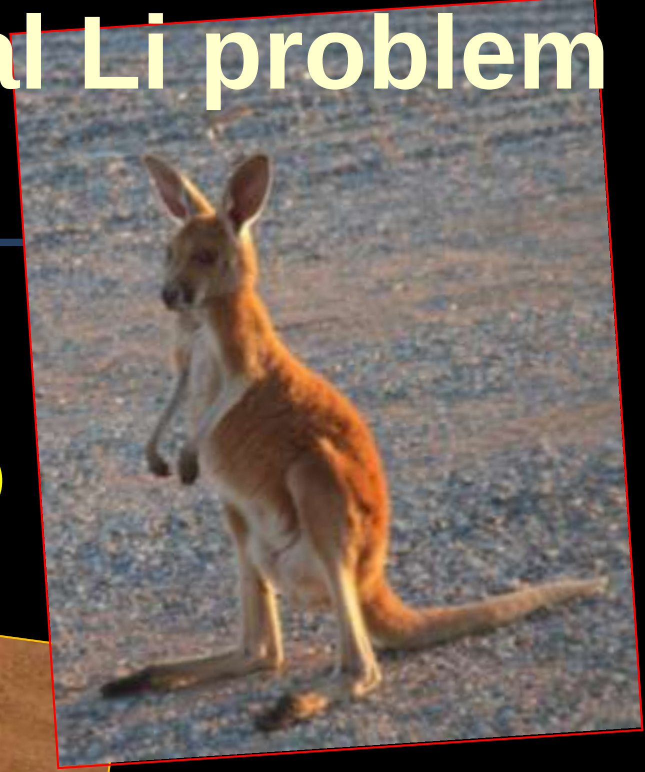
- Finish data reduction
- Accurate + precise stellar parameters
- Determination of Li and Be abundances
- Study of Li and Be depletion
- Li isotopes

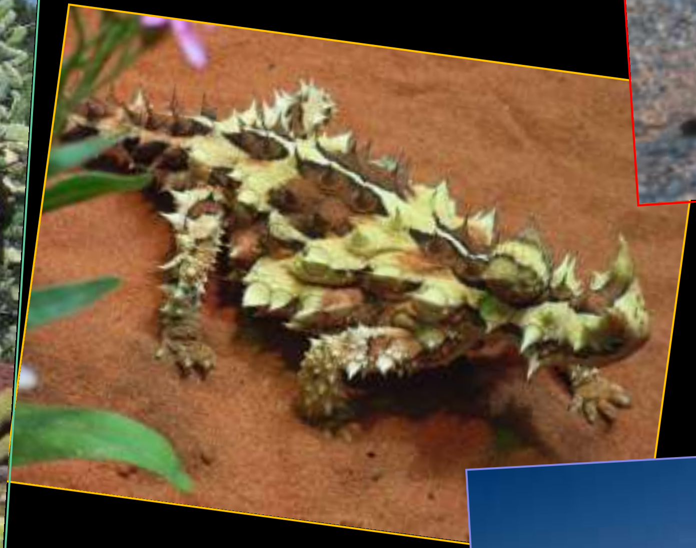


Solving the cosmological Li problem

Team :

- Jorge Melendez (IAG)
- Martin Asplund (Australia)
- Luca Casagrande (Australia)
- Ivan Ramirez (Carnegie, USA)





Help Welcome !

Periodic Table of the Astronomers ..

From H and He to "metals"

H 1

Periodic Table of the Elements

© www.elementsdatabase.com

He 2

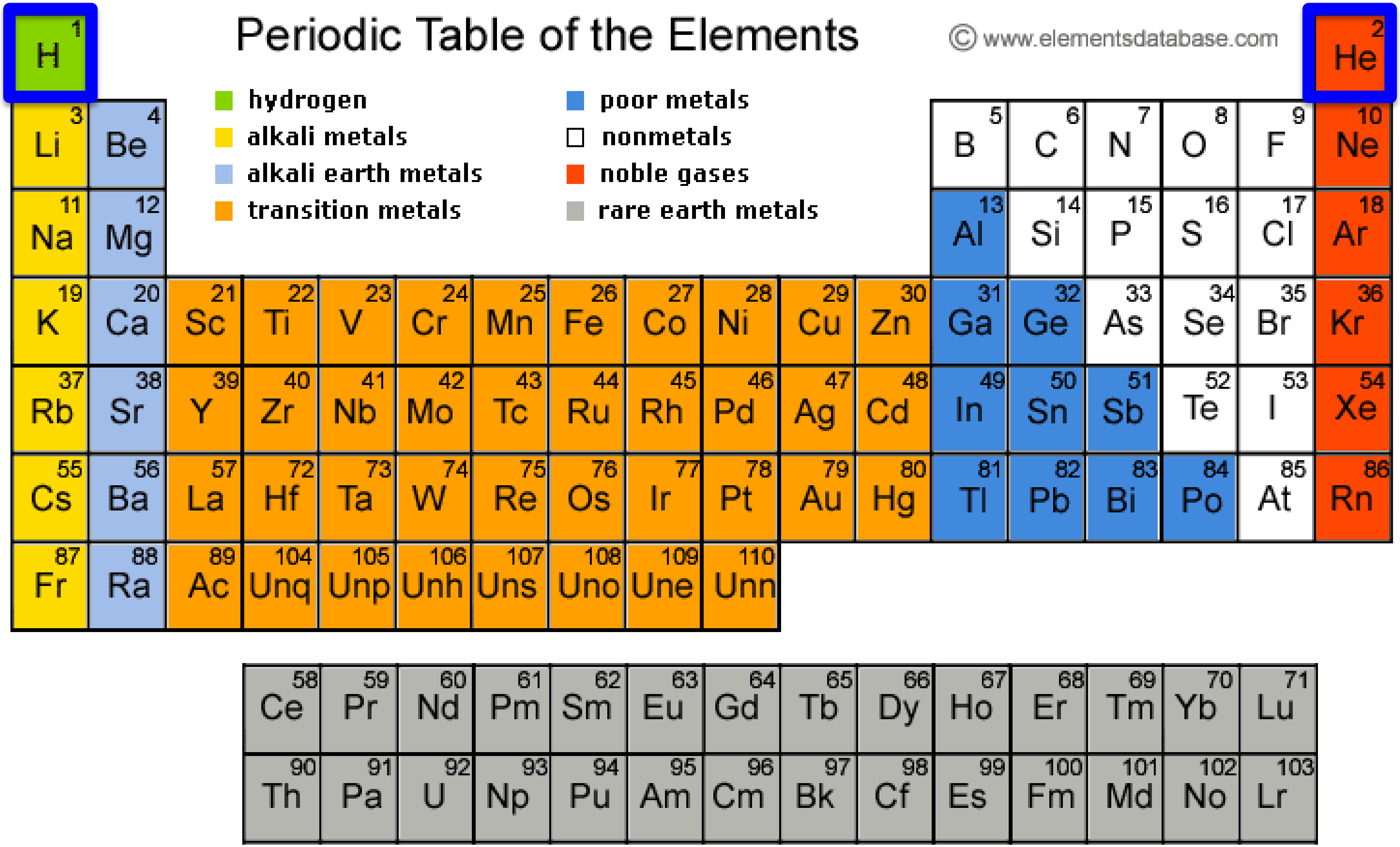
hydrogen

poor metals

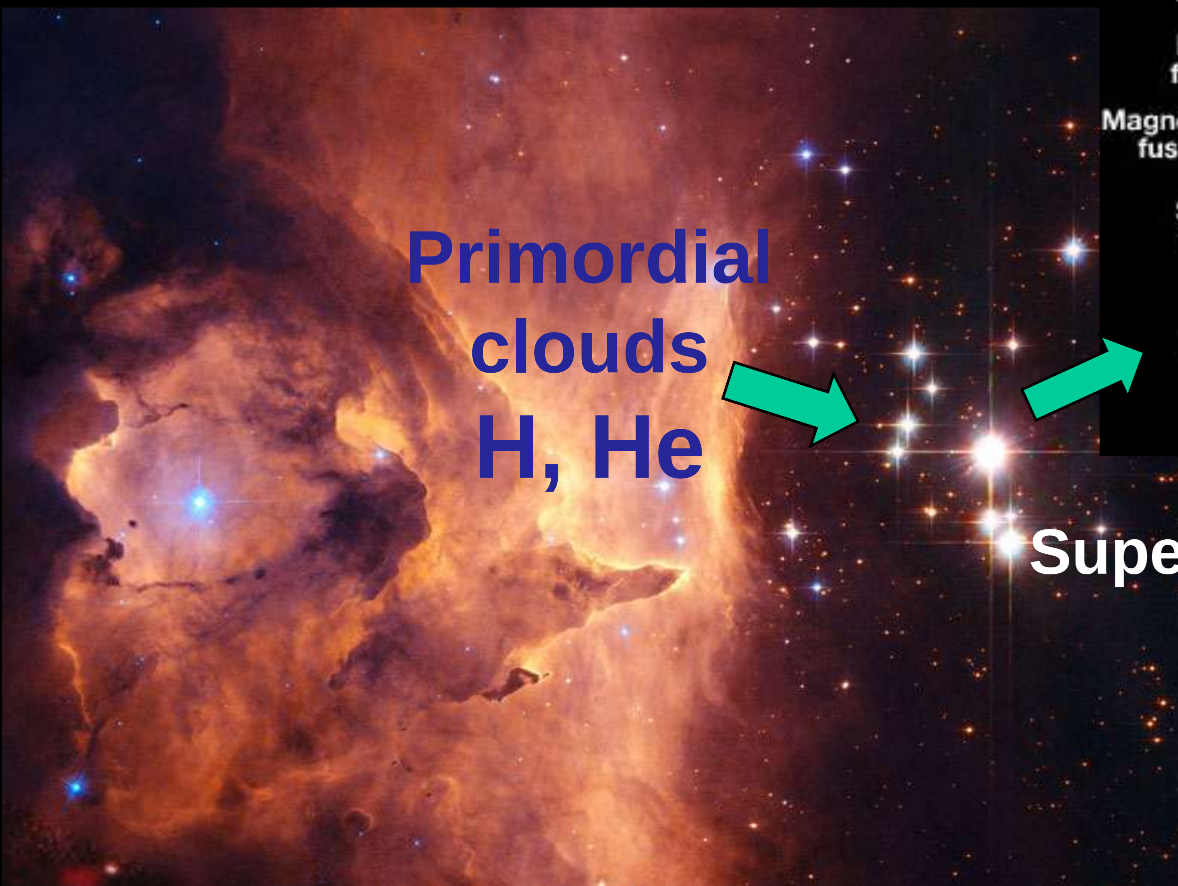
METALS

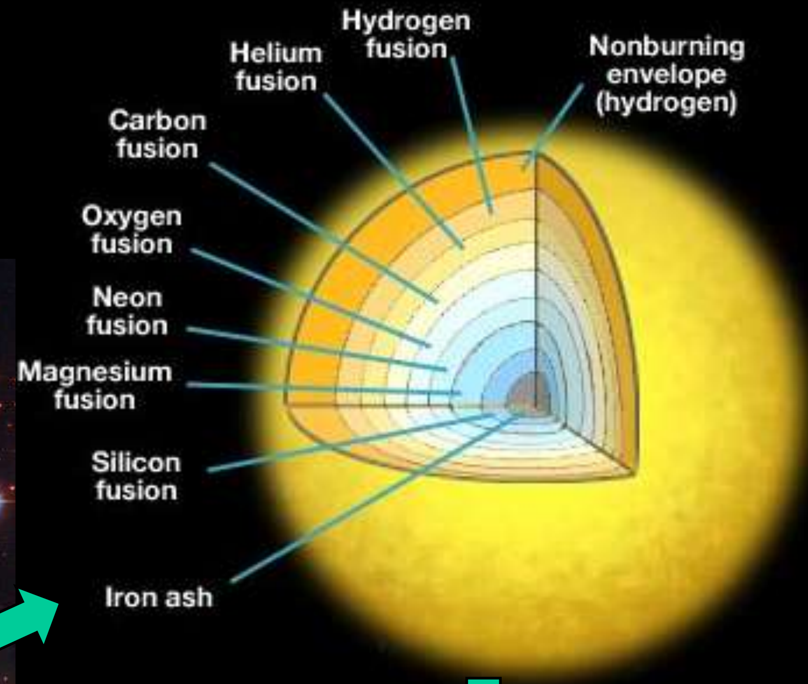
Chemical evolution of the elements

From H and He to “metals”

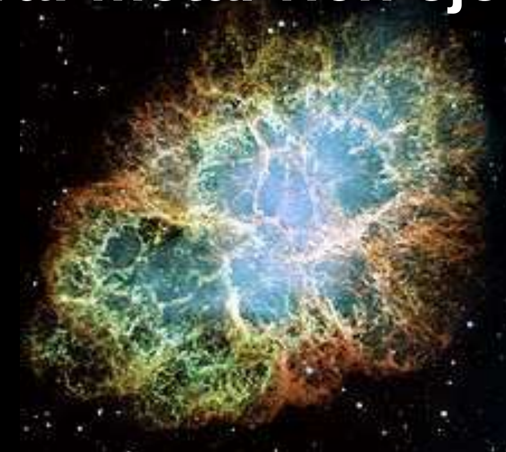


The first stars and the formation of metals (elements heavier than H & He)





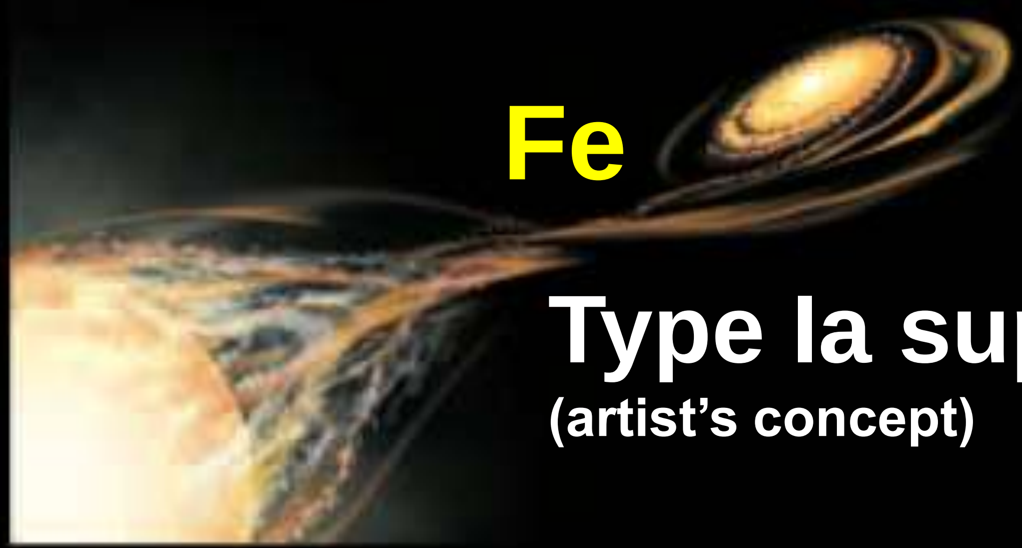
Supernova: metal-rich ejecta



Stellar Evolution

Type II supernova

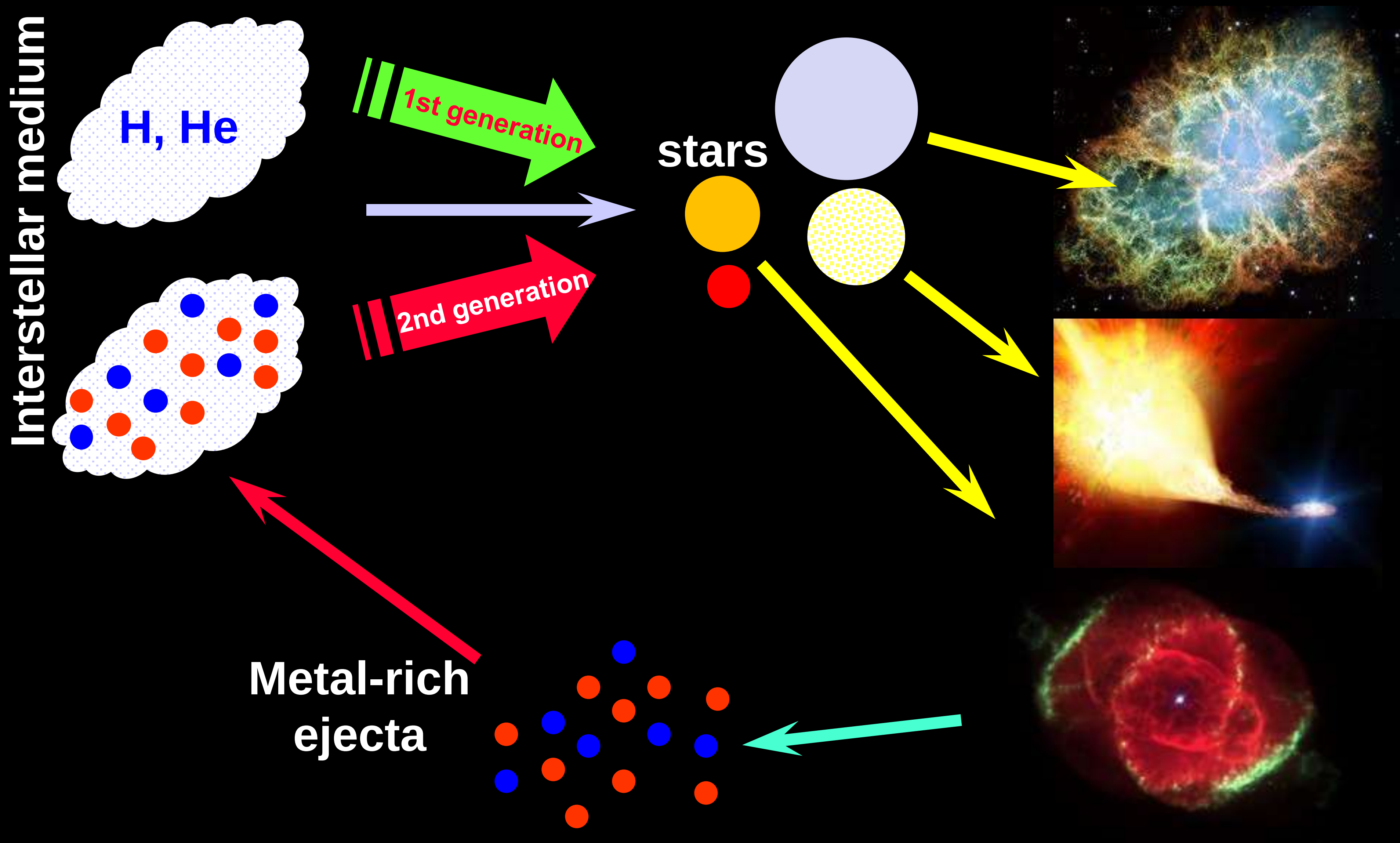
Planetary nebula



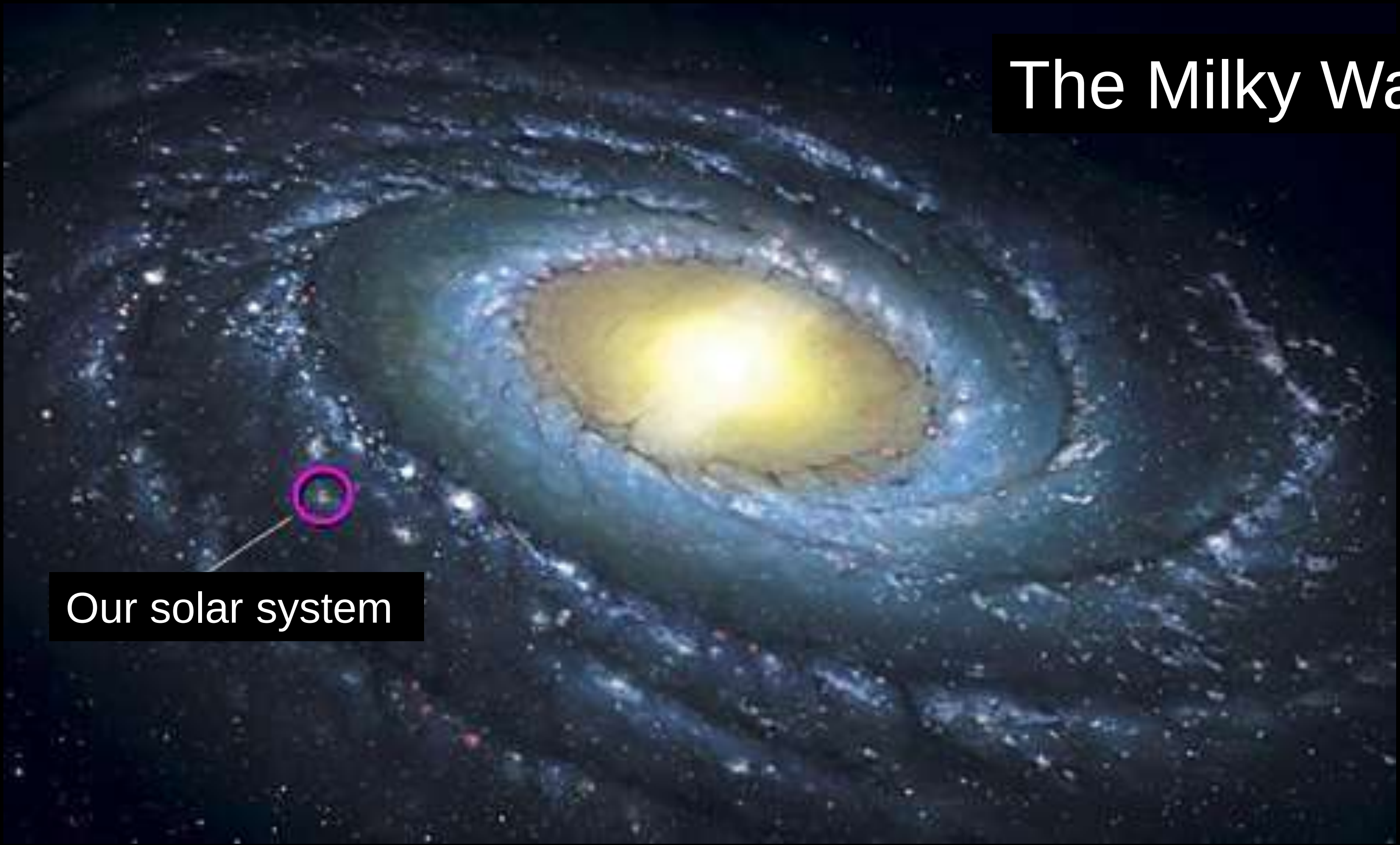
Type Ia supernova

(artist's concept)

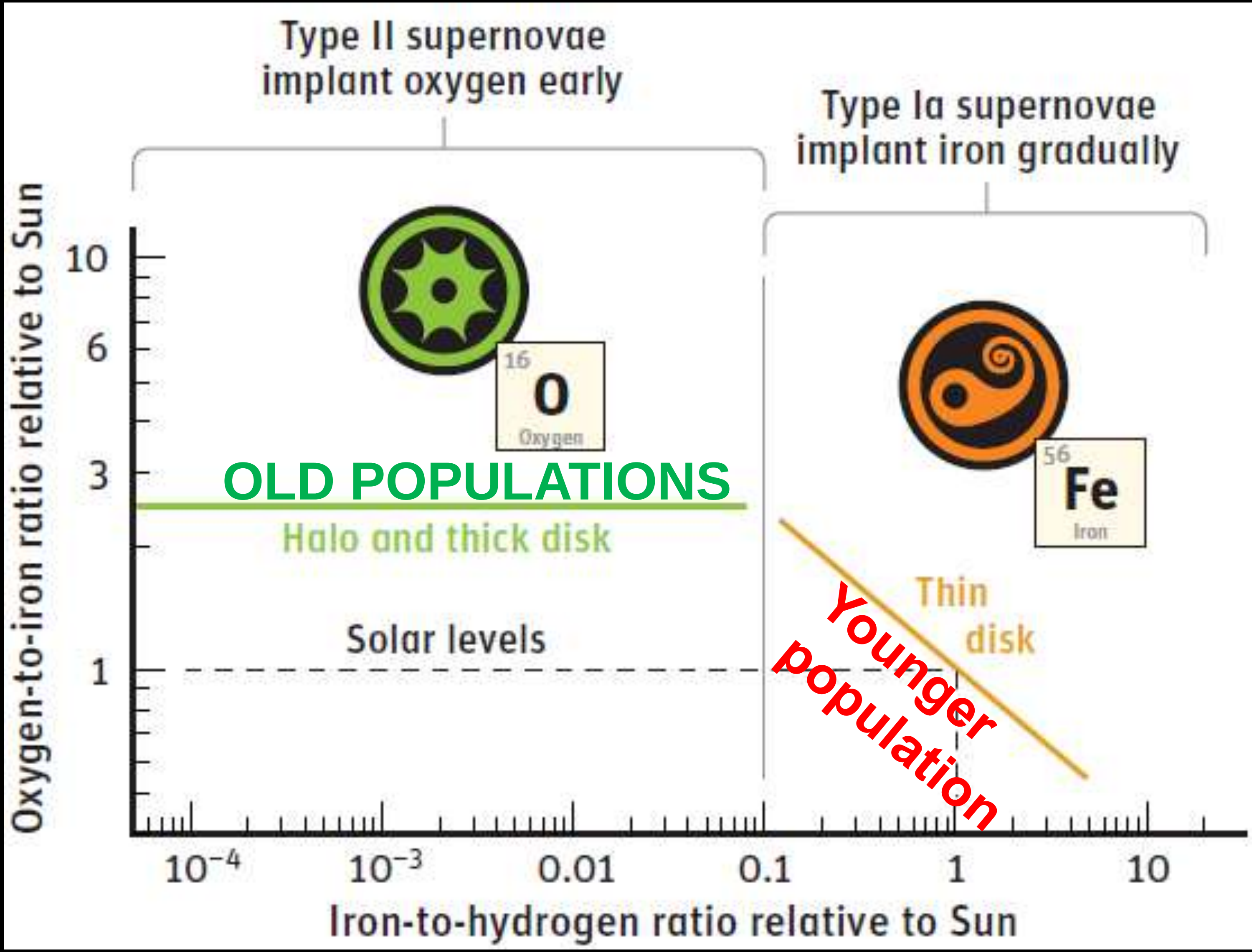
Galactic chemical evolution



After 12 billion years of *chemical evolution* in our Galaxy, stars have produced only 2% of "metals", the rest (98%) being H & He



Galactic archaeology



Galactic archaeology: disk(s)

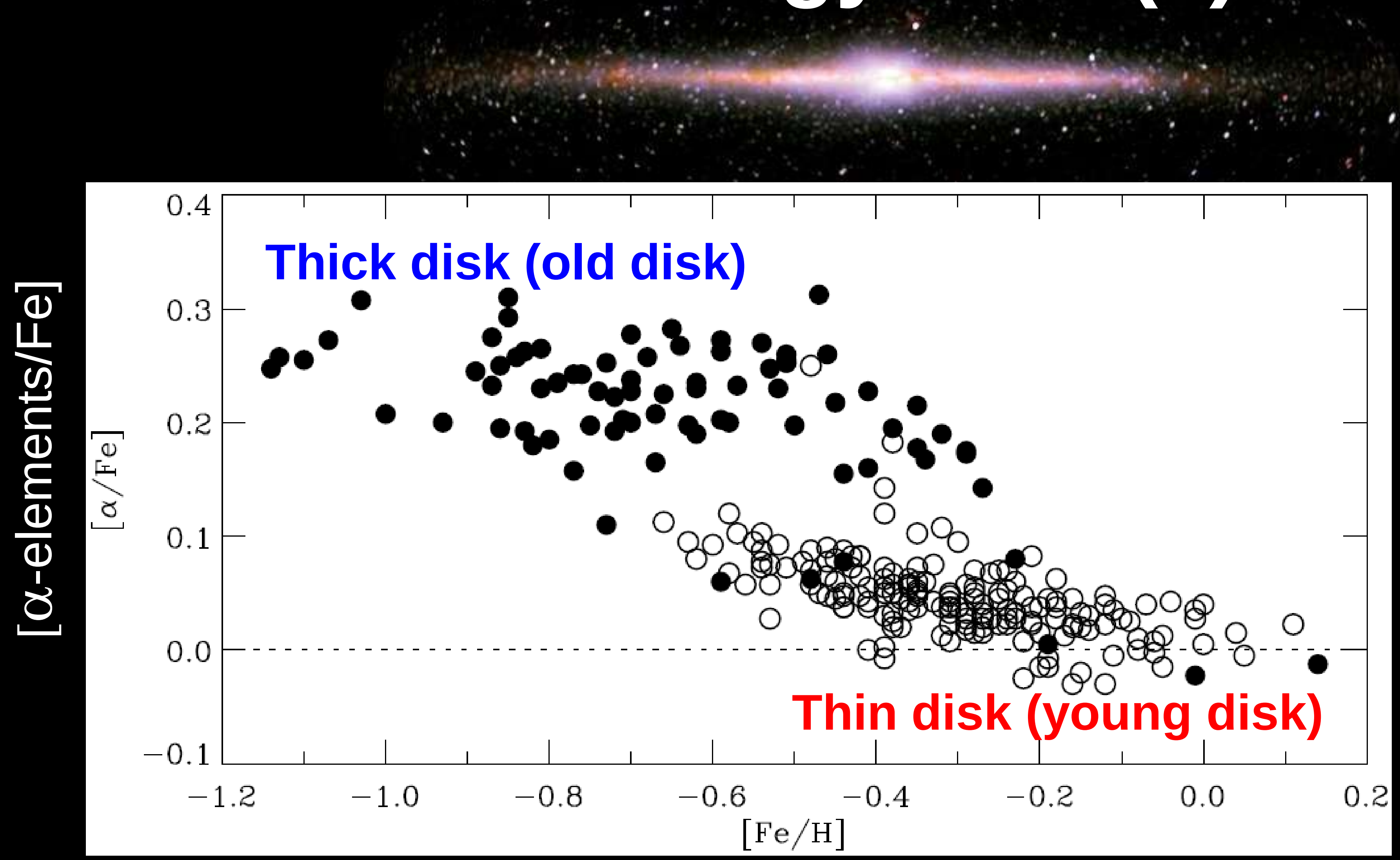
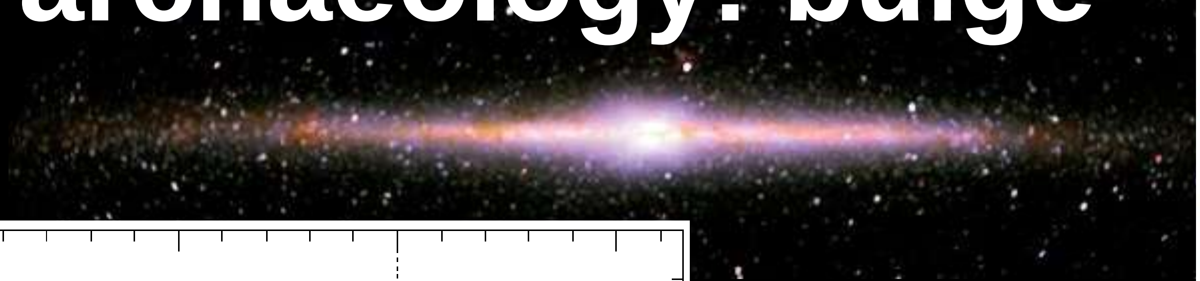
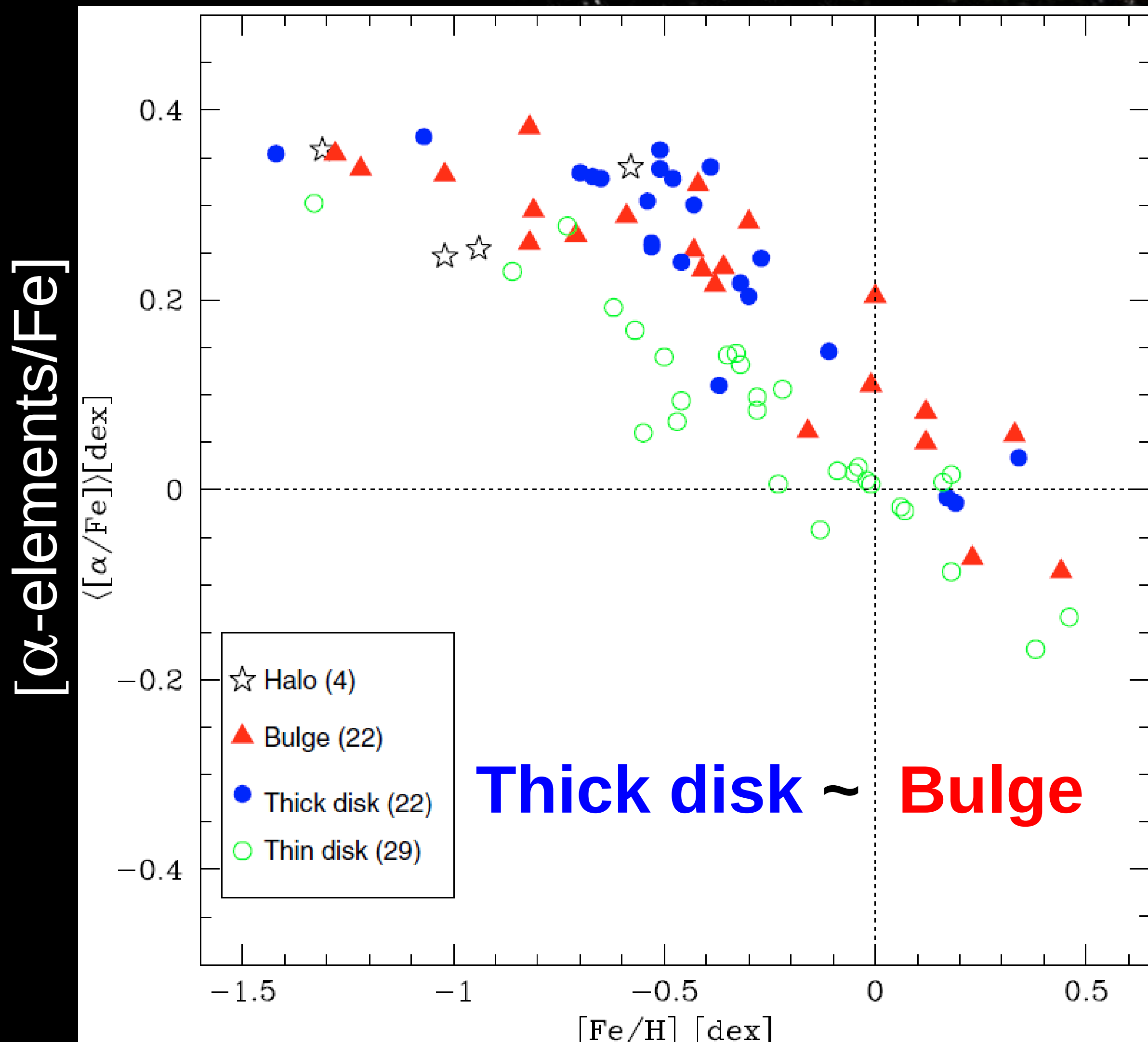


Fig. 7. [α/Fe] as a function of [Fe/H] according to Reddy et al. (2003, 2006). Stars indicated by open circles have a probability $P > 70\,\%$ of belonging to the thin disk, whereas stars represented by filled circles have $P > 70\,\%$ of belonging to the thick disk.

Galactic archaeology: bulge





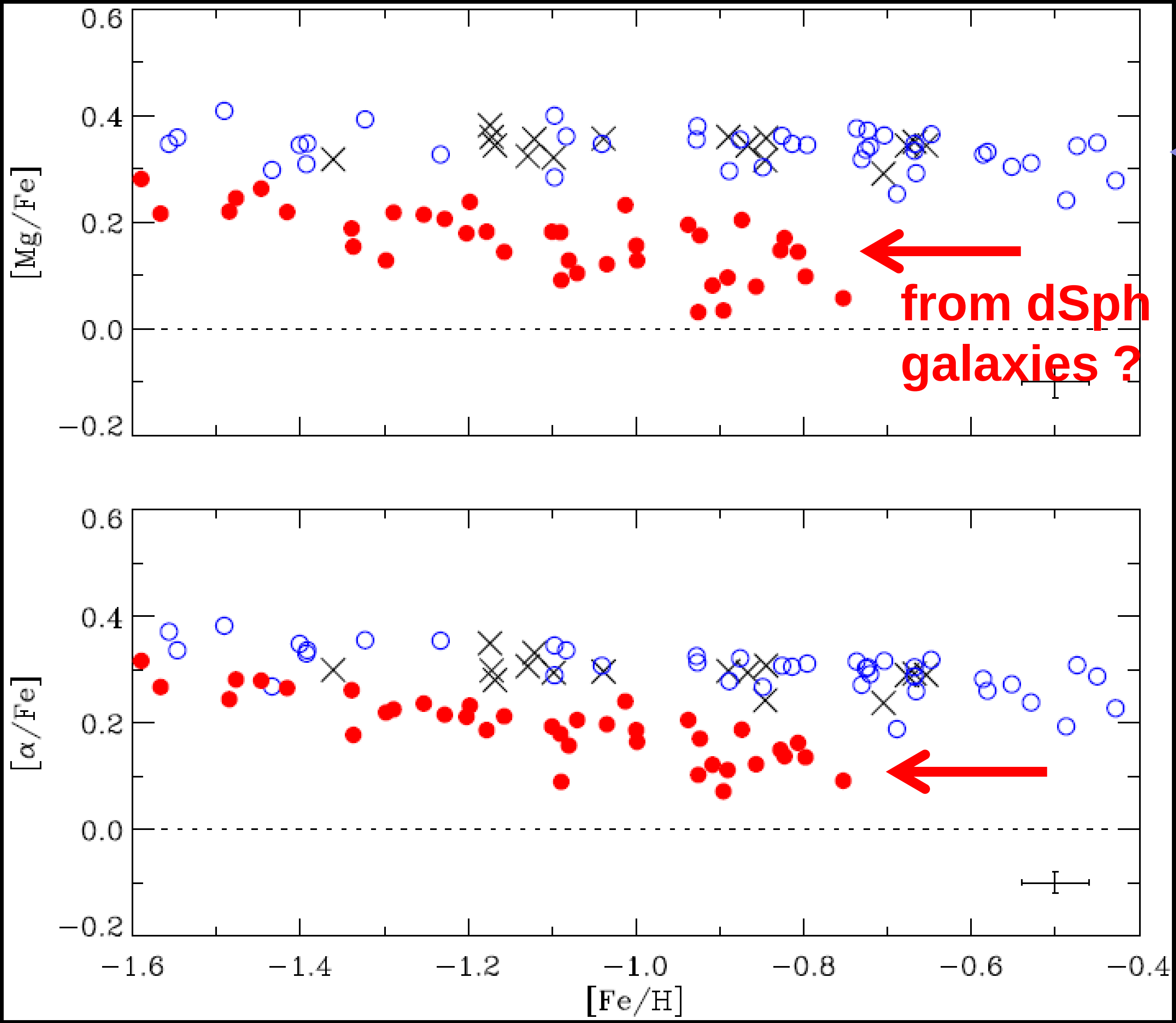
Chemical similarities between Galactic bulge and local thick disk red giants: O, Na, Mg, Al, Si, Ca, and Ti*

A. Alves-Brito[1,2], J. Meléndez[3], M. Asplund[4], I. Ramírez[4], and D. Yong[5]

A&A 513, A35 (2010)

Astronomy & Astrophysics

Galactic archaeology: halo(s)



"true" halo stars?

Nissen & Schuster 2010

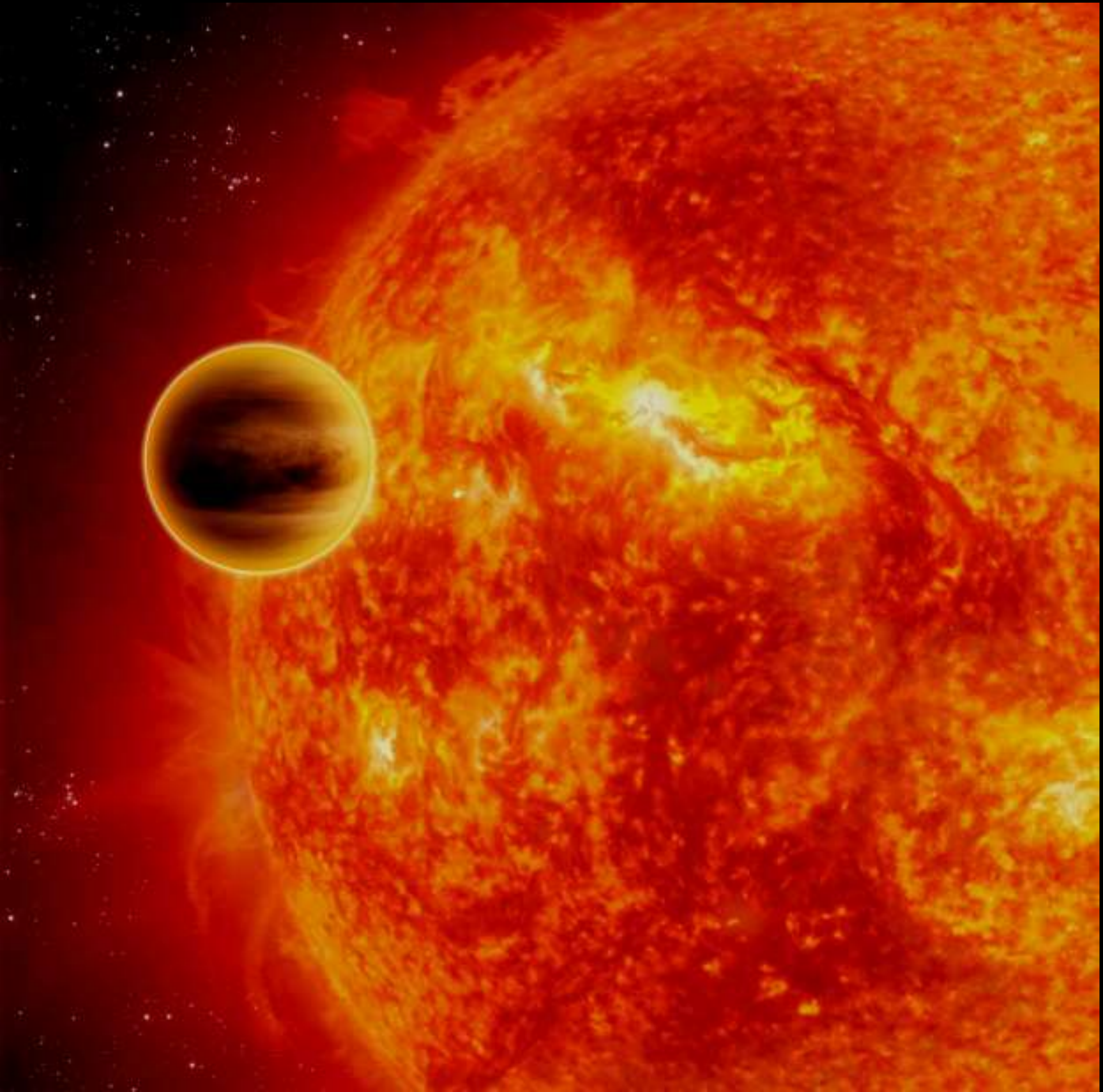
High precision chemical abundances in metal-poor stars @ IAG / USP

High resolution (R = 100, 000) high S/N spectra (300-1000) available to perform the highest precision study to date

HELP
WELCOME !

Sunset in Paracas, Peru
(c) www.flickr.com/photos/rodrigocampos/

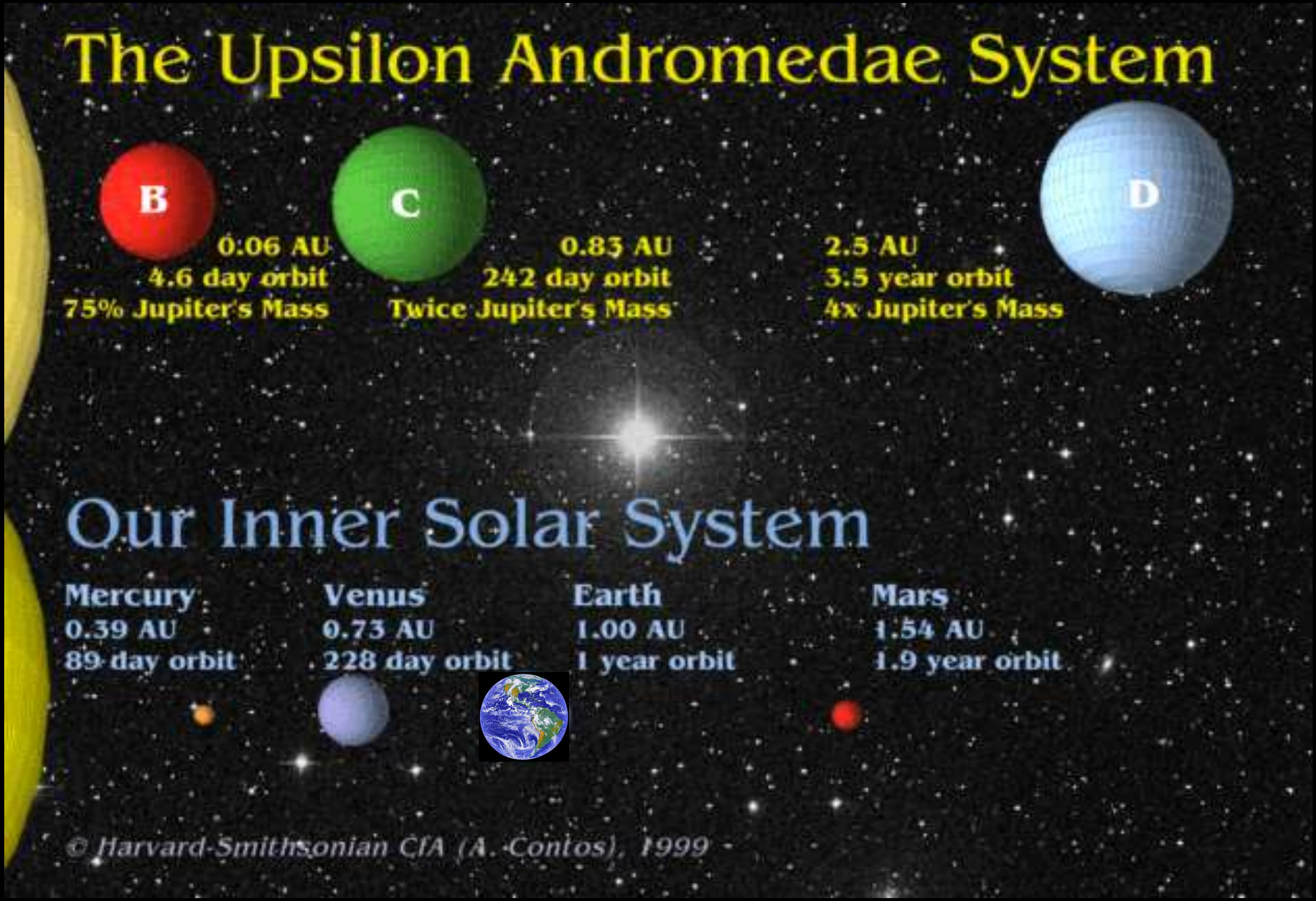
More than 500 planetary systems found until now



But ... most of them DO NOT resemble our own solar system

C. Carreau / ESA

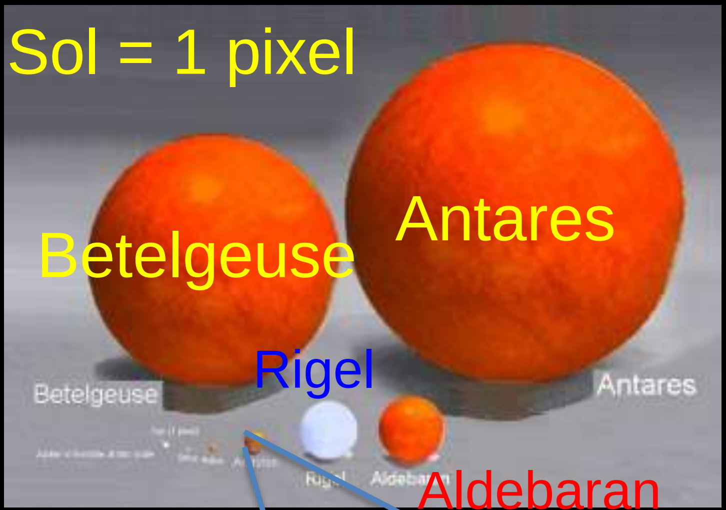
Most planetary systems found so far have inner **giant planets**, unlike the inner **rocky planets** of our solar system

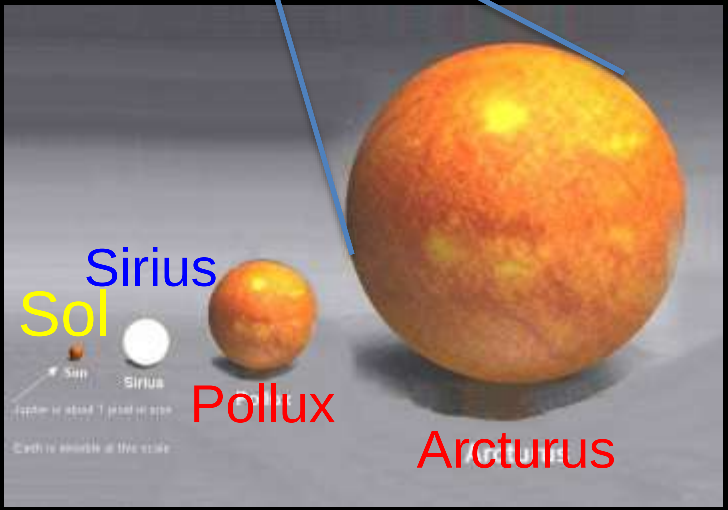


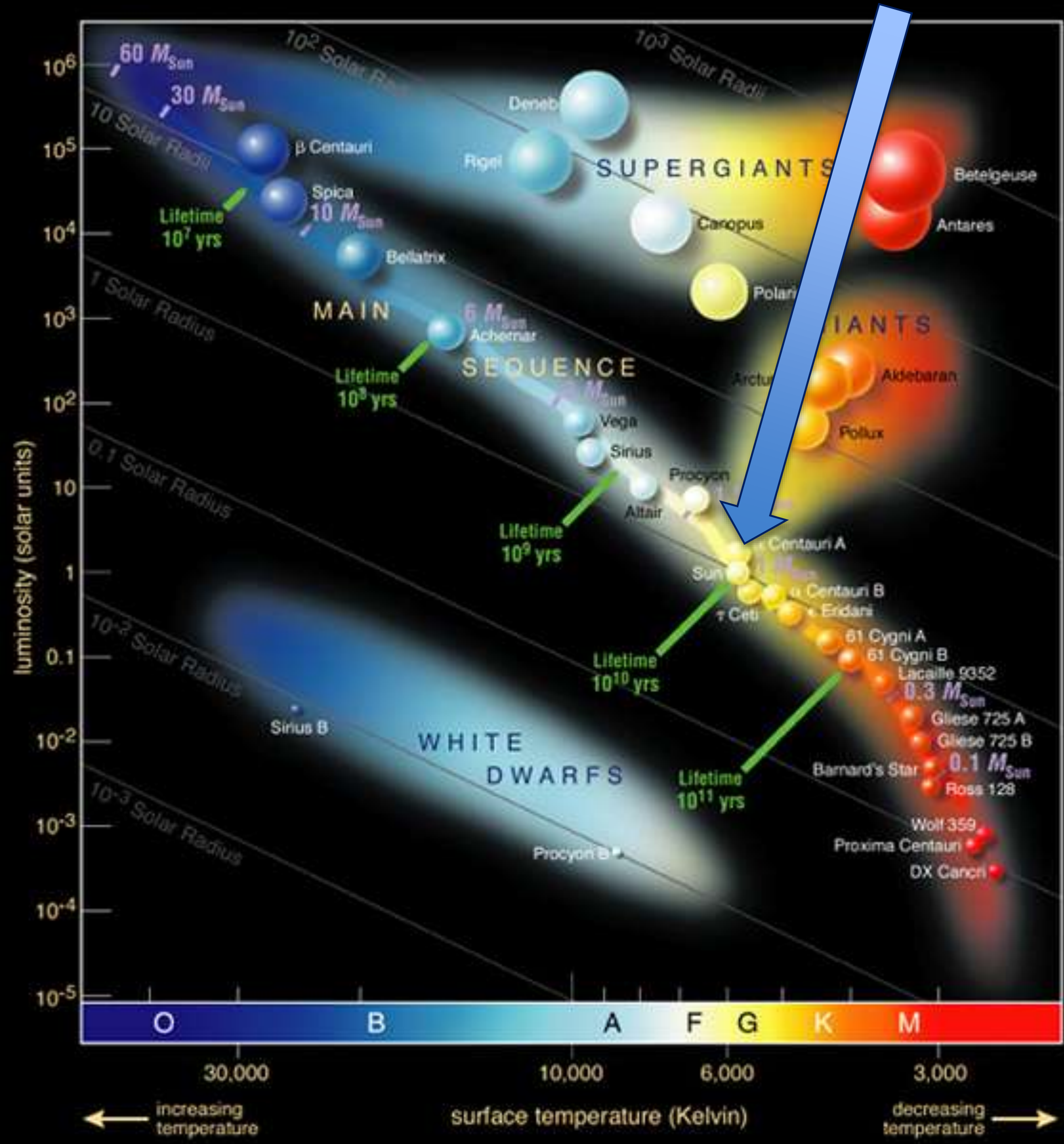
How to find a planetary system similar to our own?

Credits: Nasa

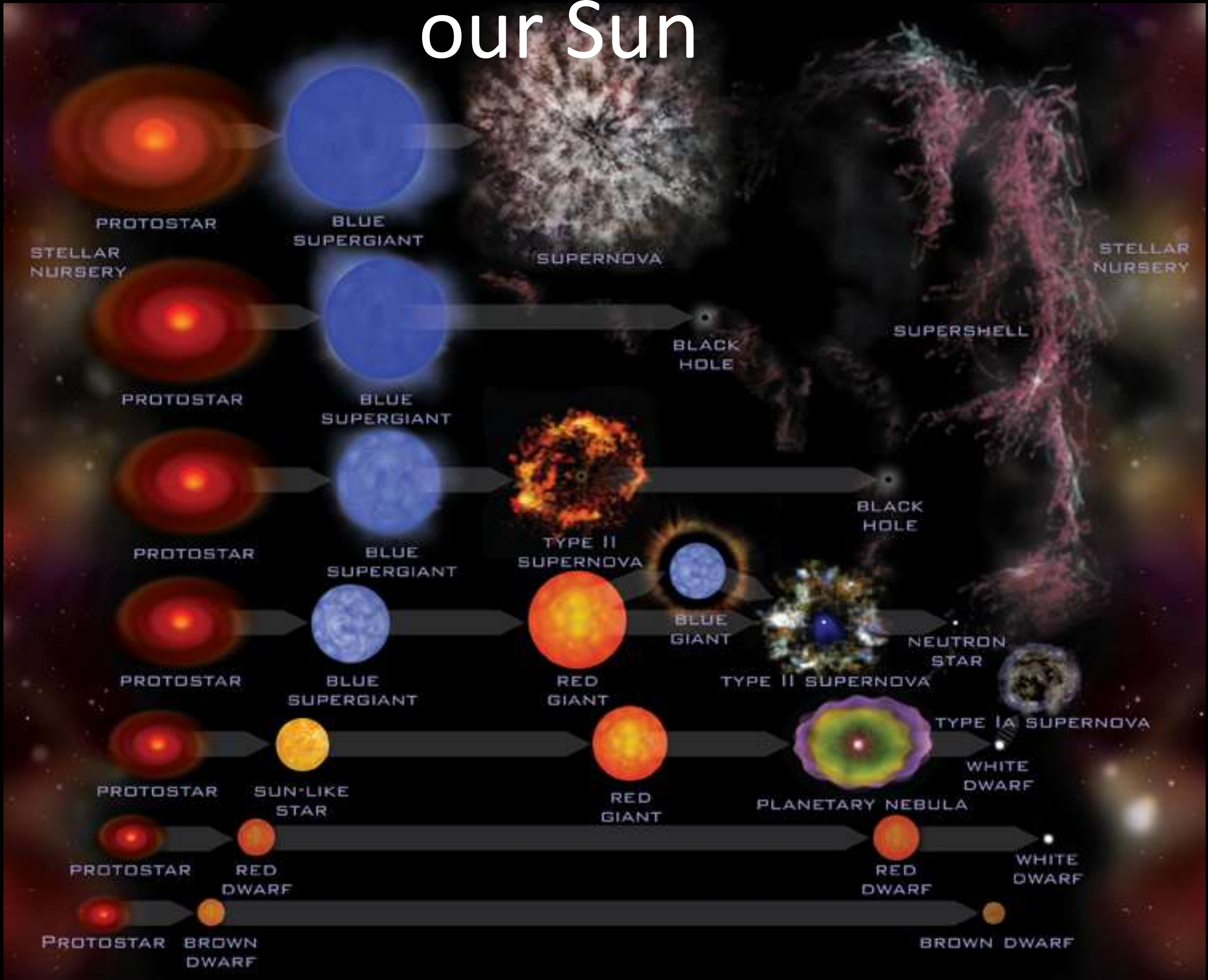
1. Search for stars similar to our Sun



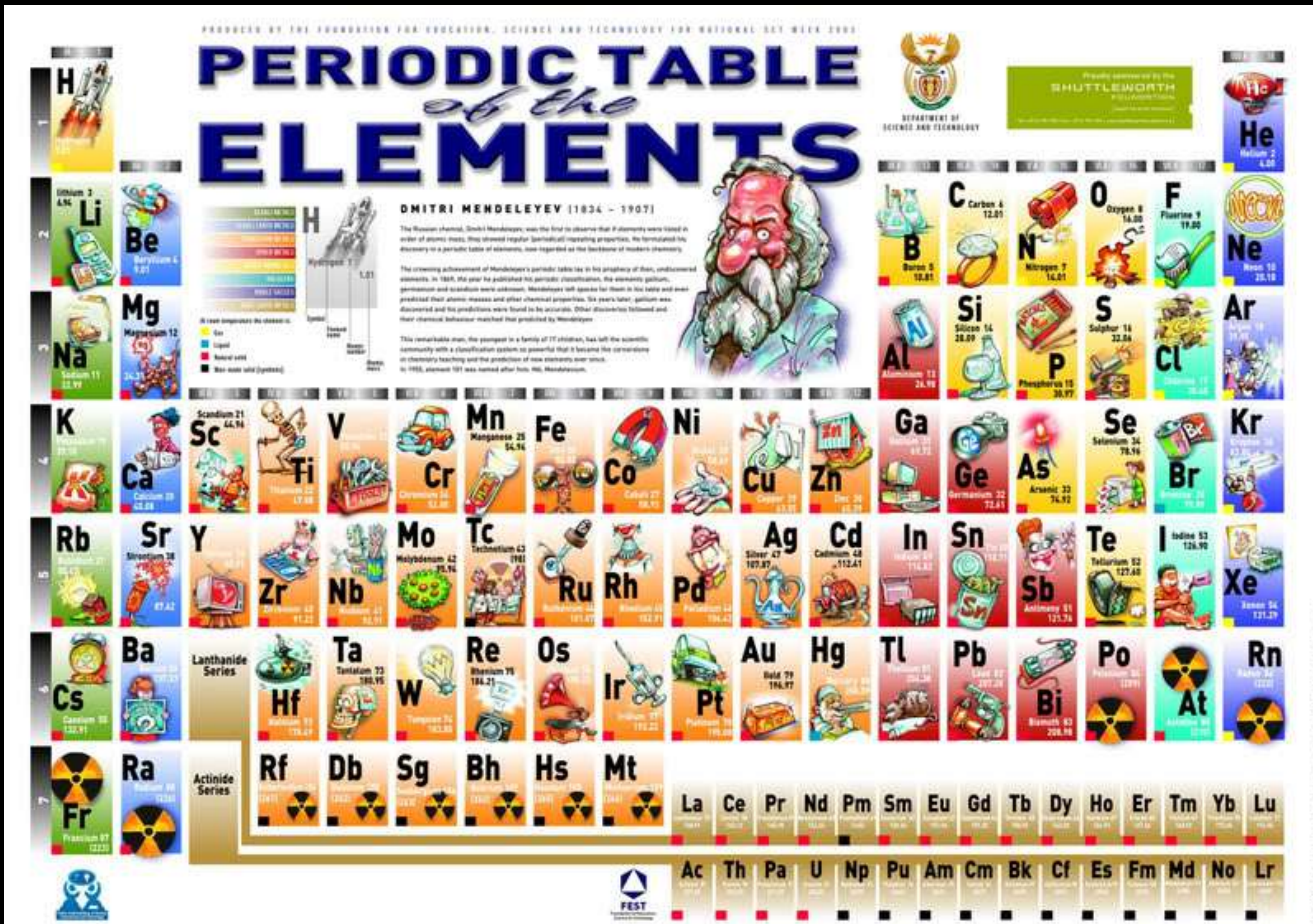




2. In the same evolutionary stage as our Sun

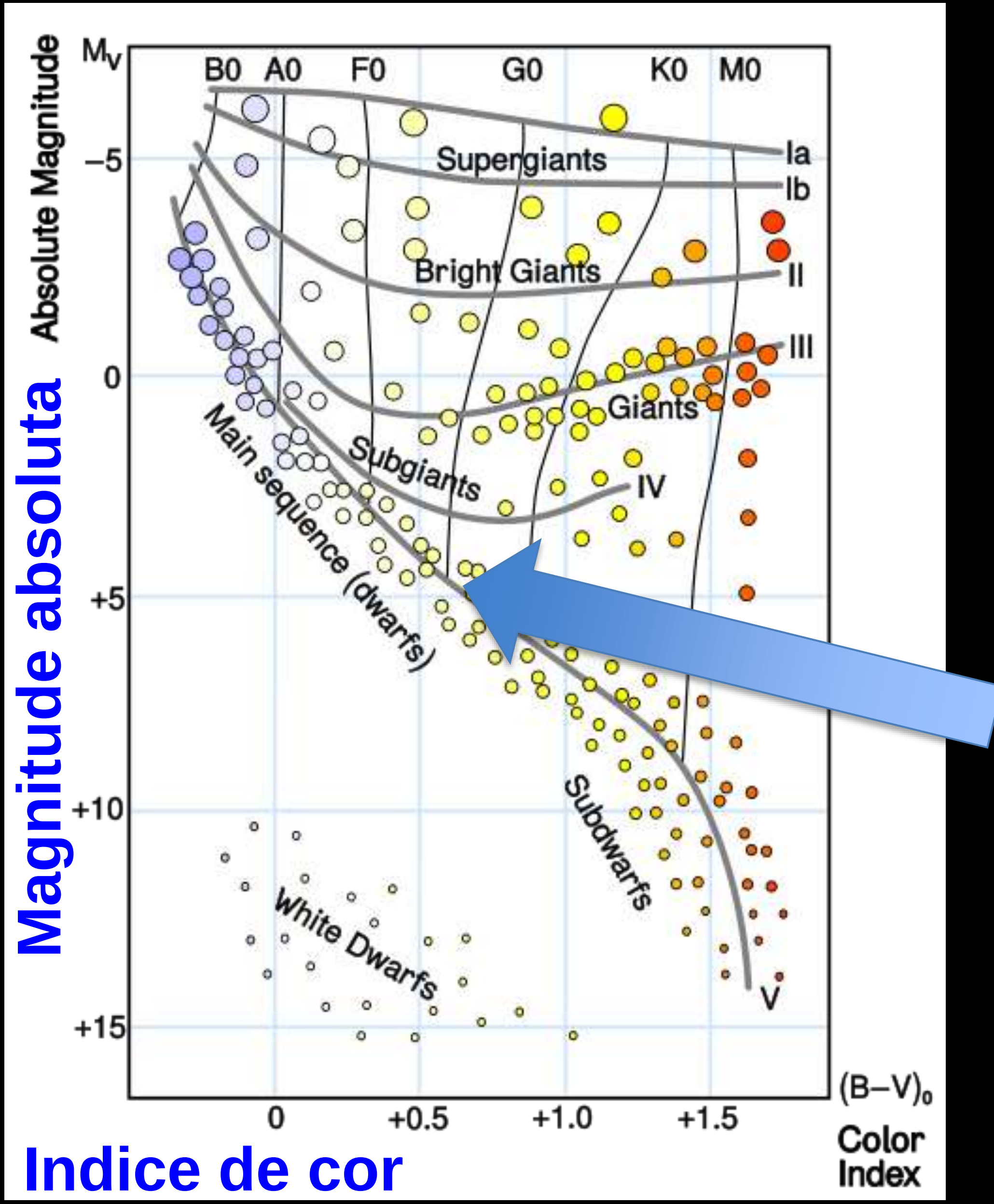


3. Chemical composition ~ solar?



But there are myriad stars in the sky … how can we find solar twins?

Diagrama H-R



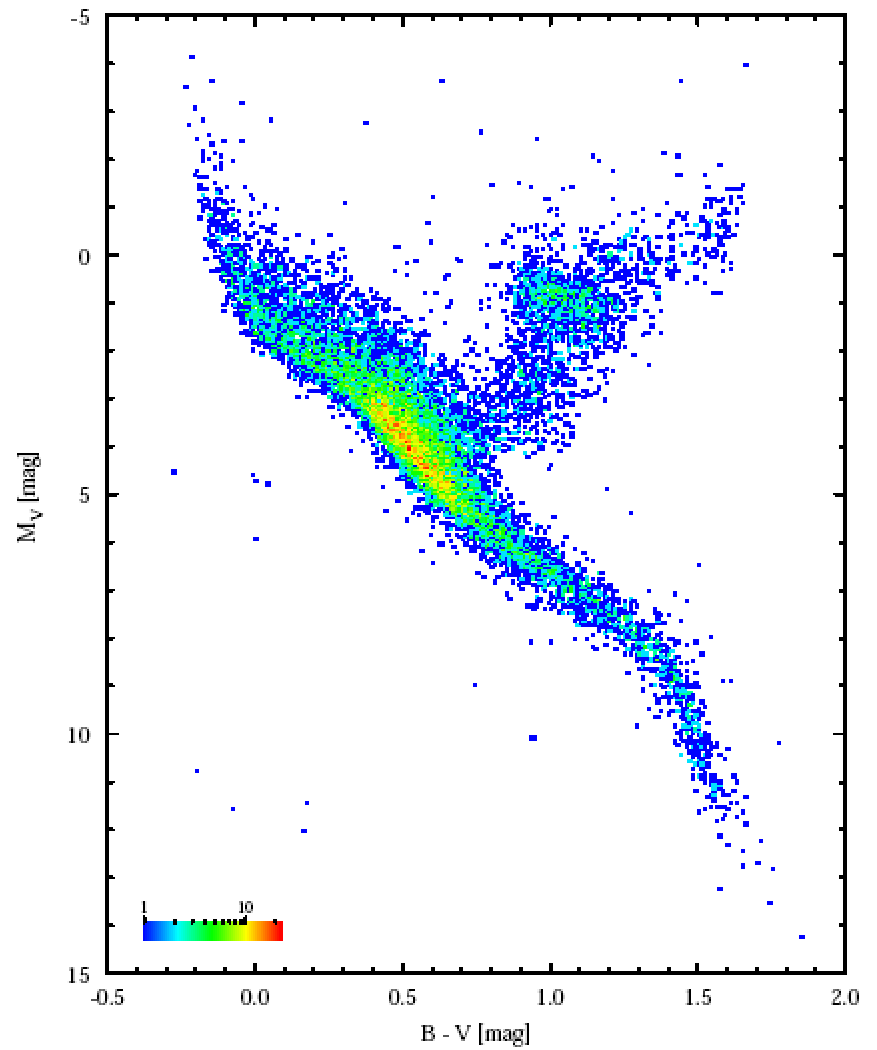
SOL

M_v = 4.82

B-V ~ 0.65

Procura por gêmeas solares usando o catálogo Hipparcos (+ Tycho)

- Cores B_T-V_T
- Magnitude absoluta V_T
  - Outras cores (optico e infravermelho), indicadores de idade



- Nos primeiros 25 anos de pesquisa não foi encontrada nenhuma gêmea solar (Cayrel de Strobel et al. 1996)

Astron. Astrophys. 63, 383—390 (1978)

The Sun among the Stars

I. A Search for Solar Spectral Analogs*

J. Hardorp

Astron. Astrophys. 94, 1–11 (1981)

In Search of Real Solar Twins

G. Cayrel de Strobel[1,2], N. Knowles[1], G. Hernandez[2], and C.

Astron. Astrophys. 274, 825–837 (1993)

In search of real solar twins. III.*

E. Friel[1], G. Cayrel de Strobel[1], Y. Chmielewski[2], M. Spite[1], A. Lèbre [1], and C. Bentolila[1]**

First solar twin discovered only in 1997: **18 Sco**

THE ASTROPHYSICAL JOURNAL, 482:L89–L92, 1997 June 10

HR 6060: THE CLOSEST EVER SOLAR TWIN?[1]

G. F. PORTO DE MELLO[2,3] AND L. DA SILVA[3]

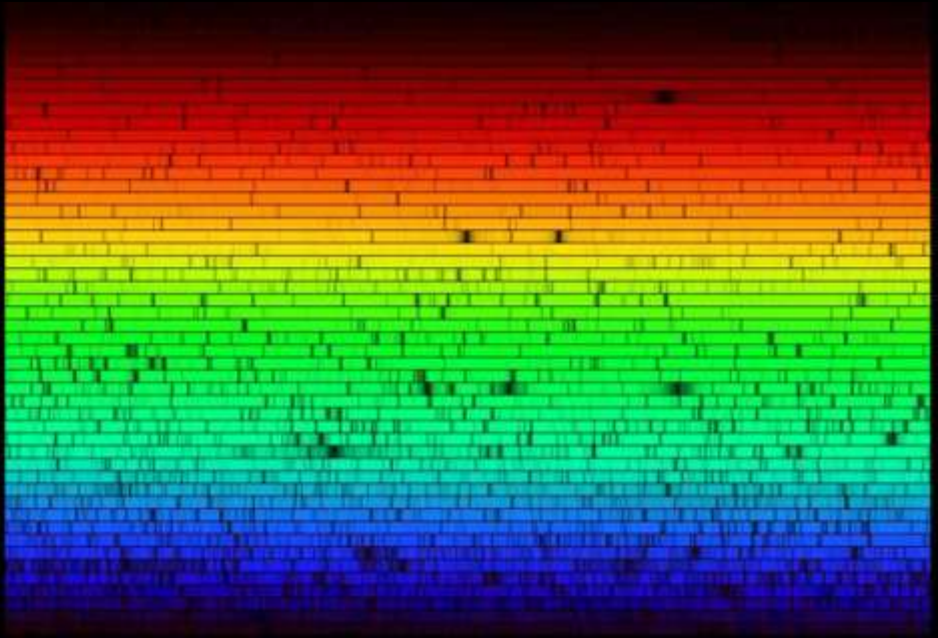
[2] Universidade Federal do Rio de Janeiro, Departamento de Astronomia, Observatório do Valongo, Ladeira do Pedro Antônio, 43, CEP 20080-090 Saude, Rio de Janeiro, Brazil; gustavo@ov.ufrj.br.

[3] CNPq/Observatório Nacional, Departamento de Astronomia, Rua General José Cristino 77, 20921-400 São Cristovão, Rio de Janeiro, Brazil; licio@on.br.

Parameter	Sun	HR 2290	HR 6060 (**18 Sco**)	16 Cyg A	16 Cyg B
$\Delta T_{\rm eff}$ (K)	0	0	12 ± 30	8 ± 25	−17 ± 20
$\Delta \log g$	0	0.07 ± 0.20	0.05 ± 0.12	−0.16 ± 0.07	−0.09 ± 0.07
$L/L_\odot$	1.00	1.05 ± 0.27	1.05 ± 0.02	1.63 ± 0.03	1.28 ± 0.02
[Fe/H]........................	0	0.13 ± 0.04	0.05 ± 0.06	0.06 ± 0.04	0.02 ± 0.04
$(B-V)$	0.648	0.66	0.65	0.64	0.66
$(U-B)$	0.178	0.20	0.17	0.19	0.20
Spectral type	G2 V	G3 V	G2 Va	G1.5 V	G2.5 V

Searching for solar twins

- *Programa observacional desde 2005*
- Keck (Havaí, USA)
- McDonald (Texas, USA)
- Magellan (Chile)
- VLT/UVES (Chile)
- La Silla / HARPS (Chile)



Colaboração: Australia, França, Portugal, U.S.A., Brasil, Chile, México, Inglaterra, Alemanha

Second solar twin identified in 2006: HD 98618

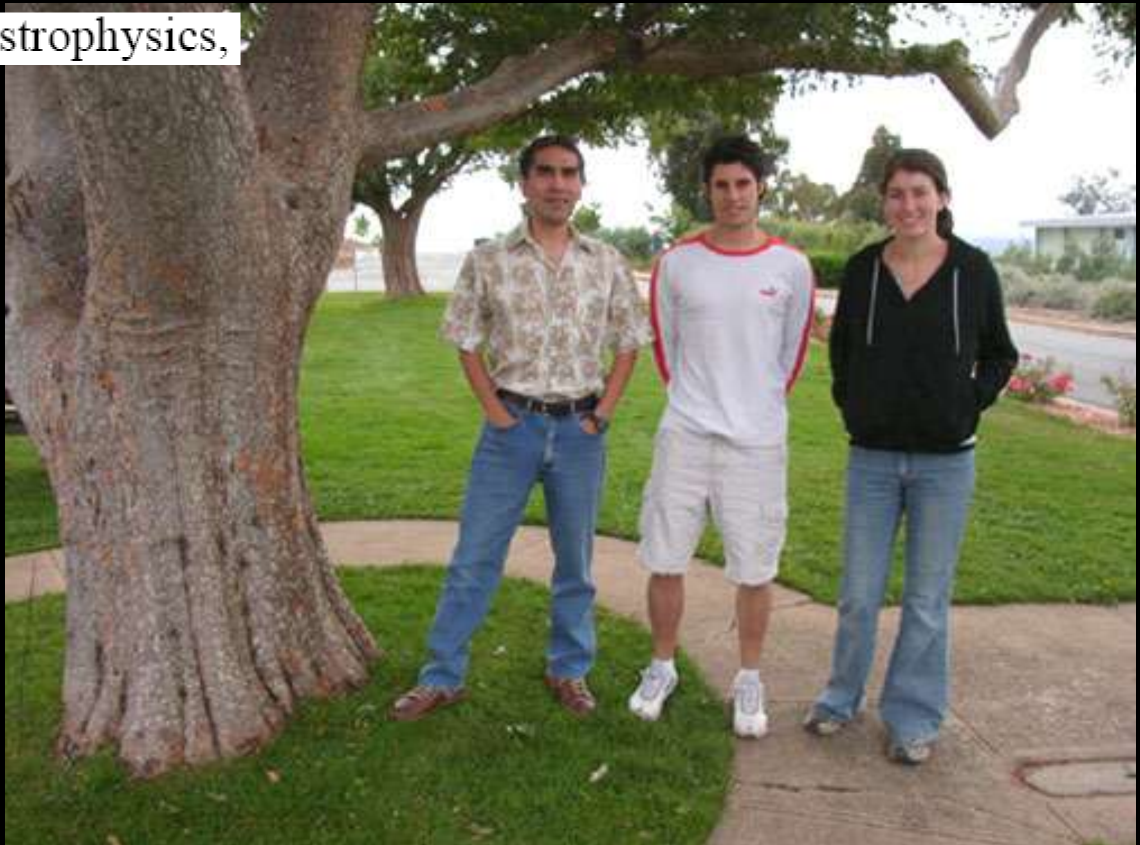
THE ASTROPHYSICAL JOURNAL, 641:L133–L136, 2006 April 20

HD 98618: A STAR CLOSELY RESEMBLING OUR SUN[1]

JORGE MELÉNDEZ,[2] KATIE DODDS-EDEN, AND JOSÉ A. ROBLES

Research School of Astronomy and Astrophysics,
Mount Stromlo Observatory

- Undergrad *summer* research project of Katie Dodds-Eden



HD 98618: Destaque na imprensa

A Solar Twin in t

By Ken Croswell

March 10, 2006

A yellow star in the Big Dipper's bo
scientists search the star for signs of

Solar twins are stars with the same
more light than the typical star in th
extraterrestrial intelligence.

Jorge Meléndez, Katie Dodds-E
high-resolution spectra of HD 98
126 light-years from Earth, almo

http://www.20minutos.es/noticia/107450/0/sol/estrella/astronomos/

Astrónomos australianos descubren una estrella idéntica al Sol

Se llama HD98618 y es prácticamente idéntica al Sol: tiene su misma edad, su mismo tamaño, su misma temperatura y su misma composición, según los científicos de la Escuela de Astronomía australiana.

El mellizo del
(Imagen: Web)

Los expertos esperan que este hallazgo ayude a

Guaranteed to be 100% genuinely produced in Australia and wholly Australian owned – since 1988

THE 'NEW' SKY & SPACE

www.SkyandSpace.com.au

Australia $7.40 New Zealand $8.75

News Update

with Dave Reneke

New solar twin sheds light on twin Earth

Astronomers at the Australian National University (ANU) have discovered a nearby solar twin which may shed light on the search for Earth-like planets capable of supporting life.

and to the other closest Sun twin, a star known as 18 Scorpii, which was discovered a decade ago.

The spin-offs of this discovery are tantalising. Solar twins are ideal for the absolute calibration of astronomical measuring instruments. They can provide data useful in modelling the solar phenomena that may affect climate change and will help settle the argument about the uniqueness or otherwise of our Sun and Solar System.

With a number of sample stars to study, HD 98618 was one of the last on the list to be analysed. Team members were quite surprised when they discovered how it stood out from the other candidates along with 18 Scorpii. "It was very exciting – I had to blink twice to be sure I wasn't imagining it," Ms Dodds-Eden said.

The researchers made the discovery using the largest telescope in the world, the 10metre Keck I telescope on the summit of Hawaii's dormant Mauna Kea volcano. A paper detailing this amazing discovery is expected to be published shortly.

Source: ANU

A colour-enhanced close-up around the newly discovered HD 98618, one of the most Sun-like stars

New 'earthly' planet found in our galaxy

A ground-breaking discovery in the search for planets that may support life in our galaxy has been made by an international team of astronomers with much critical data provided b

WEEKLY | NEWS IDEAS INNOVATION

NewScientis

8 April 2006 No2546 Australia $6.50 (Inc GST) New Zealand NZ$6.95 (Inc GST) Print Post Approved 230009/00015

SUN'S TWIN IS STRONG CANDIDATE FOR LIFE

Astronomers have found a twin of the sun, the first such star to be spotted in a decade and only the second ever. They say that these stars are our best bets for finding Earth-like planets with life on them.

Jorge Meléndez, Katie Dodds-Eden and José Robles of Mount Stromlo Observatory near Canberra, Australia,

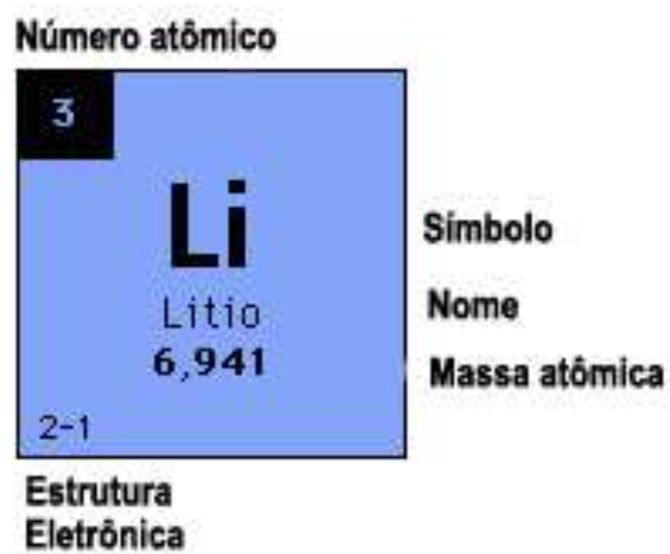
have roughly the same concentratio of heavy elements as the sun. These elements are crucial to the formation of Earth-like planets and the emergence of life (www.arxiv.org/astro-ph/060321 Another cause for optimism is the absence of "hot Jupiters", massive gas giants orbiting close to each star whose gravity could destabilise the orbits of

Mas 18 Sco e HD 98618 não são gêmeas solares perfeitas ...

FUNDAMENTAL PARAMETERS Estrela - Sol

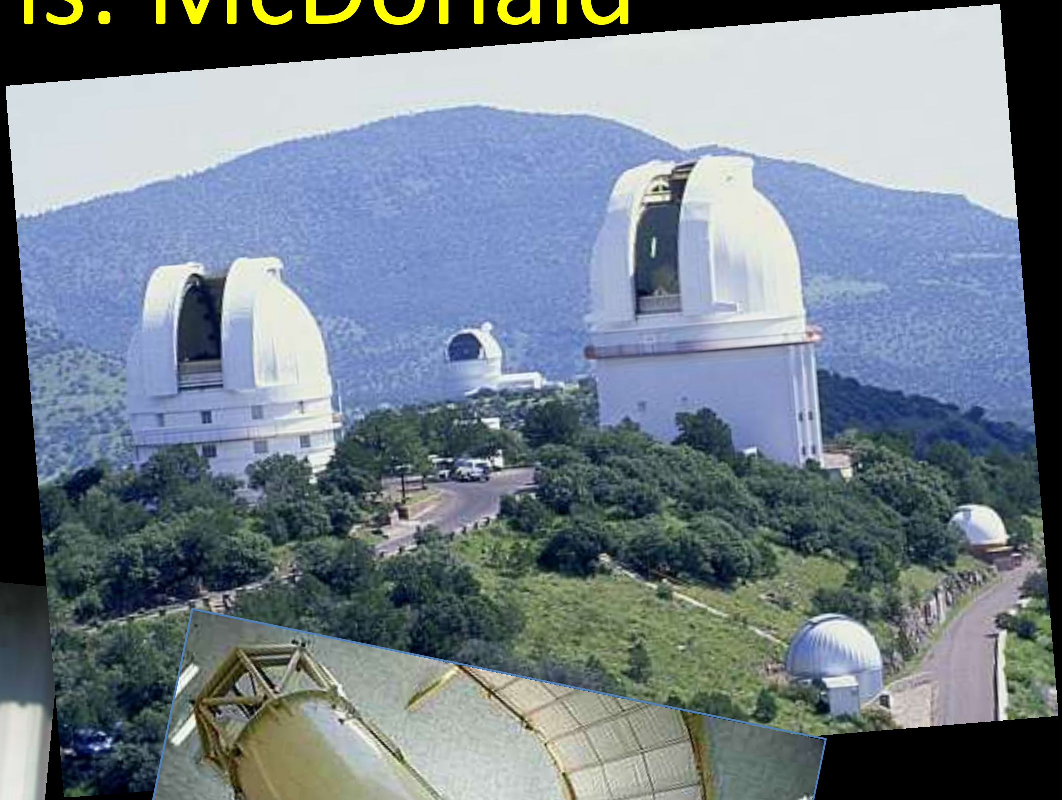
Parameter (Star − Sun)	18 Sco	HD 98618
Δv_t (km s^{-1})	+0.08 ± 0.15	+0.09 ± 0.15
ΔT_{eff} (K)	+40 ± 30	+66 ± 30
$\Delta \log g_{spec}$ (dex)	+0.01 ± 0.04	+0.01 ± 0.04
$\Delta \log g_{Hip}$ (dex)	+0.01 ± 0.02	+0.01 ± 0.03
$\Delta \log g_{adopted}$ (dex)	+0.01 ± 0.02	+0.01 ± 0.03
ΔL_{spec} ($L_\odot$)	+0.02 ± 0.06	+0.04 ± 0.06
ΔL_{Hip} ($L_\odot$)	+0.03 ± 0.03	+0.08 ± 0.07
$\Delta L_{adopted}$ ($L_\odot$)	+0.03 ± 0.02	+0.06 ± 0.05
[Fe/H] (dex)	+0.02 ± 0.03	+0.05 ± 0.03
[O/H] (dex)	−0.03 ± 0.05	0.00 ± 0.04
[Li/H] (dex)	+0.53 ± 0.09	+0.47 ± 0.09
Δ mass ($M_\odot$)	+0.02 ± 0.03	+0.02 ± 0.03
Δ $age_{isochro}$ (Gyr)	−0.8 ± 1.5	−1.1 ± 1.5
Δ $age_{chromos}$ (Gyr)	-0.3^a	$+0.7^a$
Δ $age_{rotation}$ (Gyr)	−1.1	−0.4
Δ $age_{adopted}$ (Gyr)	−0.7 ± 0.4	−0.3 ± 0.9
Δ rotation period (days)	-2.5^b, -1^a	-1^a
$\Delta \log R'_{HK}$ (dex)	0.0^a	-0.05^a
ΔM_V (mag)	−0.04 ± 0.04	−0.09 ± 0.07
$B-V$	0.65	0.64
Distance (pc)	14.0	38.7

- Abundancias de lítio são muito altas, um fator de 3 maior que no Sol !



Continuing the search for **perfect** solar twins: McDonald

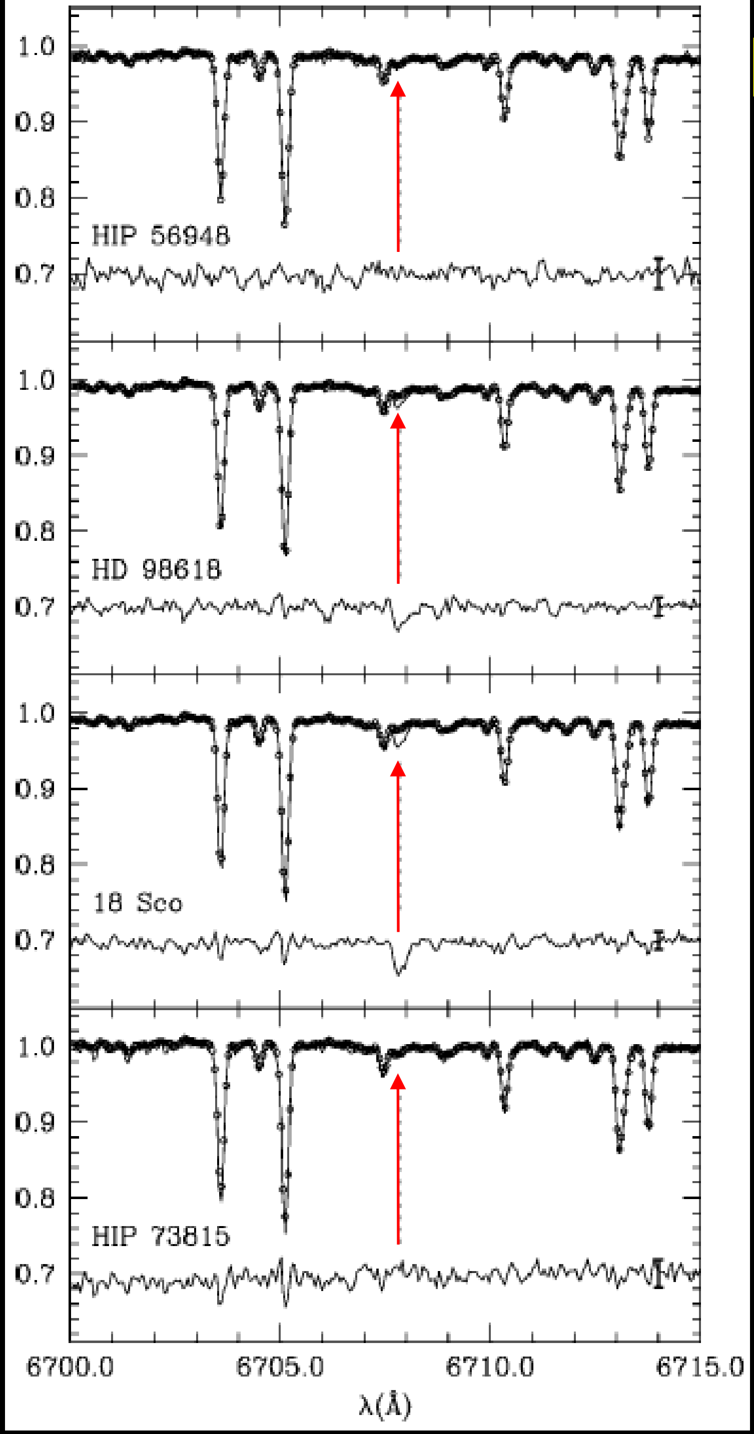
- 2.7-m tel. + 2dcoudé
- Observações em Abril, Out, Nov 2007
- **P.I.: Iván Ramírez**



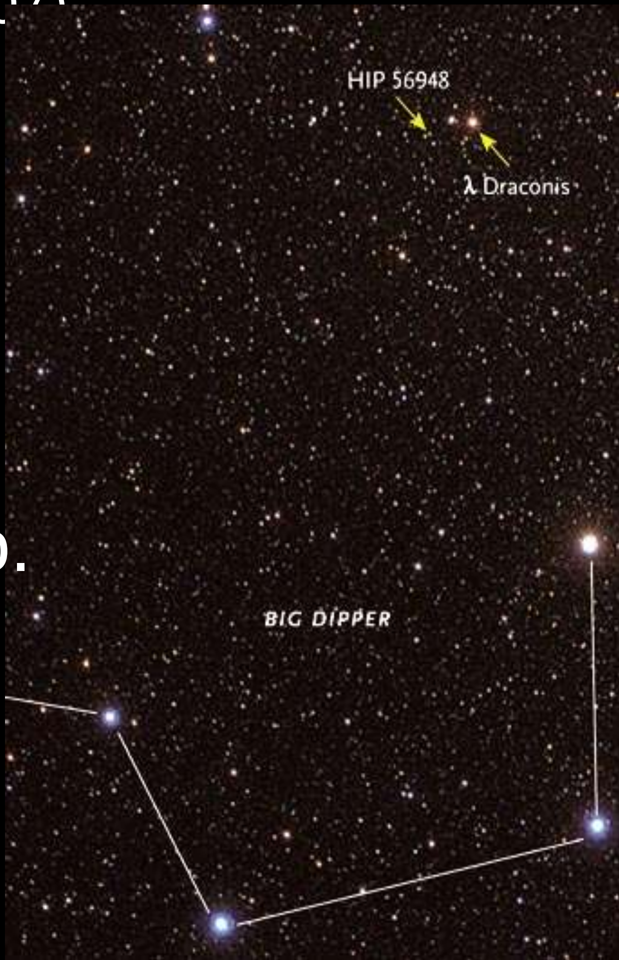
McDonald solar twin survey

Novas gêmeas solares HIP 56948 & HIP 73815 tem baixo Li (~1.0)! Muito parecido ao Sol !

(Melendez et al. 2006;Melendez & Ramirez 07)



HIP 56948 é a melhor gêmea solar, quase identica ao Sol, inclusive no lítio.



HIP 56948: destaque na imprensa

Subscribe | Renew | About S&T | Archive | Almanac | E-Newsletters | Shop

SKY® & TELESCOPE

THE ESSENTIAL MAGAZINE OF ASTRONOMY

IN THE JANUARY 2008 ISSUE — Table of Contents

- Hot Products for 2008
- Total Eclipse Preview
- Extrasolar Planets Examined
- Subscribe Today!

SUBSCRIBE
Sky & Telescope

NEWS
S&T News Highlights
All S&T News Blogs
Wire-Service Stories

OBSERVING
Observing Highlights
All S&T Observing Blogs
This Week's Sky at a Glance
Let's Go Stargazing
Celestial Objects
Observing Projects
Sky Tour Podcasts
Interactive Sky Chart
Interactive Observing Tools

COMMUNITY
Sky Blogs
Photo Gallery

EMAIL THIS > PRINT THIS > SAVE THIS > RSS >

NEWS by Kelly Beatty

Our Sun's Twin

Every now and then someone tries to trip me up with that old trick question, "What's the closest star to Earth?"

"Hmm," I reply in mock contemplation. "Is it the Sun?"

This little exchange underscores how we've come to regard old Sol as a one-of-a-kind star. But now two astronomers think they've found the closest thing yet to the Sun's twin. It's not some long-lost, separated-at-birth companion, but rather a 9th-magnitude blip in the constellation Draco that's about 200 light-years away.

Work by Peter Hänggi of the University of Augsburg in Germany and his collaborators contradicts those early calculations. The group's one-dimensional models of particles in a gas show that the same temperature will be observed regardless of the observer's speed. The team admits, however, that this may not be true of two- or three-dimensional gases, and believes that further study is needed.

CLIMATE CHANGE

Irreducible sensitivity

PLANETARY SCIENCE

Identical twins

Astrophys J. 669, L89–L92 (2007)

Astronomers have identified a star that is in many ways indistinguishable from the Sun.

Peruvian astronomers Jorge Meléndez of the Australian National University, and Iván Ramírez at the McDonald Observatory of the University of Texas in Austin report that the parameters of HIP 56948, one of four 'solar twins' they have been studying, are exactly the same as the Sun's, within the constraints of observational accuracy. Unlike previous solar twins, this star — which resides 200

Medicine, California, USA

A systems biologist encourages modelling by the millions.

In a typical modelling study, we write down equations, solve them, and see whether they account for known data. If they do, we claim to understand some bit of biology. One huge caveat is that many other models might have matched the data just as well.

Researchers from Peking University in Beijing and the University of California,

NewScientistSpace

Search

Go

Home

Stories

Chinese lunar orbiter to begin observations

Sun may be smaller than thought

Deflected asteroids may keep coming back

Mars rover hobbled as instruments show their age

Is Comet Holmes bigger than the Sun?

ARTICLE

Sun's 'twin' an ideal hunting ground for alien life

05:07 03 October 2007
NewScientist.com news service
David Shiga

Astronomers have found the most Sun-like star yet, and they say it is an ideal place to hunt for alien civilisations.

The star, called HIP 56948, lies a little more than 200 light years from Earth. Its size, mass, temperature, and chemical makeup are all so similar to the Sun's that no measurable differences could be found in high-resolution observations made by the 2.7-metre telescope at the McDonald Observatory in Texas, US.

The analysis was carried out by Jorge Melendez of Mount Stromlo Observatory in Weston Creek, Australia, and Ivan Ramirez of the University of Texas in Austin, US.

Portada > Ciencia

POR MASA, TAMAÑO, TEMPERATURA Y COMPOSICIÓN QUÍMICA

Expertos peruanos en EEUU descubren una estrella 'gemela' de nuestro Sol

Actualizado jueves 04/10/2007 10:44 (CET)

ÁNGEL DÍAZ

MADRID.- A medida que se construyen mayores telescopios y se crean mejores sistemas de observación, los científicos siguen afanados en hallar, en algún recóndito rincón del cosmos, un espejo perfecto de nuestro mundo, cuya lejana luz pueda mostrarnos que no estamos tan solos como parece. Como no habría vida sin planetas como la Tierra, ni planetas como la Tierra sin su Sol, el **hallazgo de una estrella idéntica a la nuestra**, llamada HIP 56498, podría suponer un gran avance en esta dirección.

El gemelo del Sol se encuentra a 200 años luz de

HIP 56948: destaque na imprensa

The New York Times

TierneyLab

Putting Ideas in Science to the

NOVEMBER 13, 2007, 12:52 PM

Name This Solar Twin

By JOHN TIERNEY

The Sun's twin, unfortunately...

Digitized S...

Русский Newsweek

8 - 14 октября 2007 г. № 41 (165) » НАУКА

АСТРОНОМИЯ

ДВОЙНИК СОЛНЦА

Астрономы обнаружили звезду, по своим характеристикам практически неотличимую... Солнца. Объект, получивший название HIP 56948, находится на удалении 200 световы... лет от Земли. Его размер, масса, температура и химический состав настолько напомин... наше светило, что сколько-нибудь существенные отличия не в состоянии выявить даж... —рассказал Newsweek один из авторов

Astronomers find the sun's long-lost twin

Happy reunion unlikely, as the star is about 200 light-years away

By Dave Mosher

SPACE.com

updated 11/9/2007 7:04:06 PM ET

Share |

Somewhere out there, astronomers knew th... long-lost relative aimlessly drifting through... they've found it.

Although a happy reunion is unlikely, as the... about 200 light-years away, it is now consid... "solar twin" out of four known candidates.

The wayward star challenges the idea that our... a unique composition, as it has a similarly low... element lithium — a lightweight byproduct of t... reactions that power stars.

Polski Portal Astronomiczny

ASTRONOMIA.PL

Pod patronatem Polskiego Towarzystwa Miłośników Astronomii

2007-11-12

Peruwiańczycy odkryli "bliźniaka" Słońca

Peruwiańscy astronomowie Jorge Melendez University i Ivan Ramirez z University of Texas teleskopu Obserwatorium McDonalda w Teksa bliźniaczo podobna do naszego Słońca.

ECUADOR CIENCIA

Científicos peruanos descubren nuevo sol

Publicado: Viernes, 14/12/2007 - 15:2

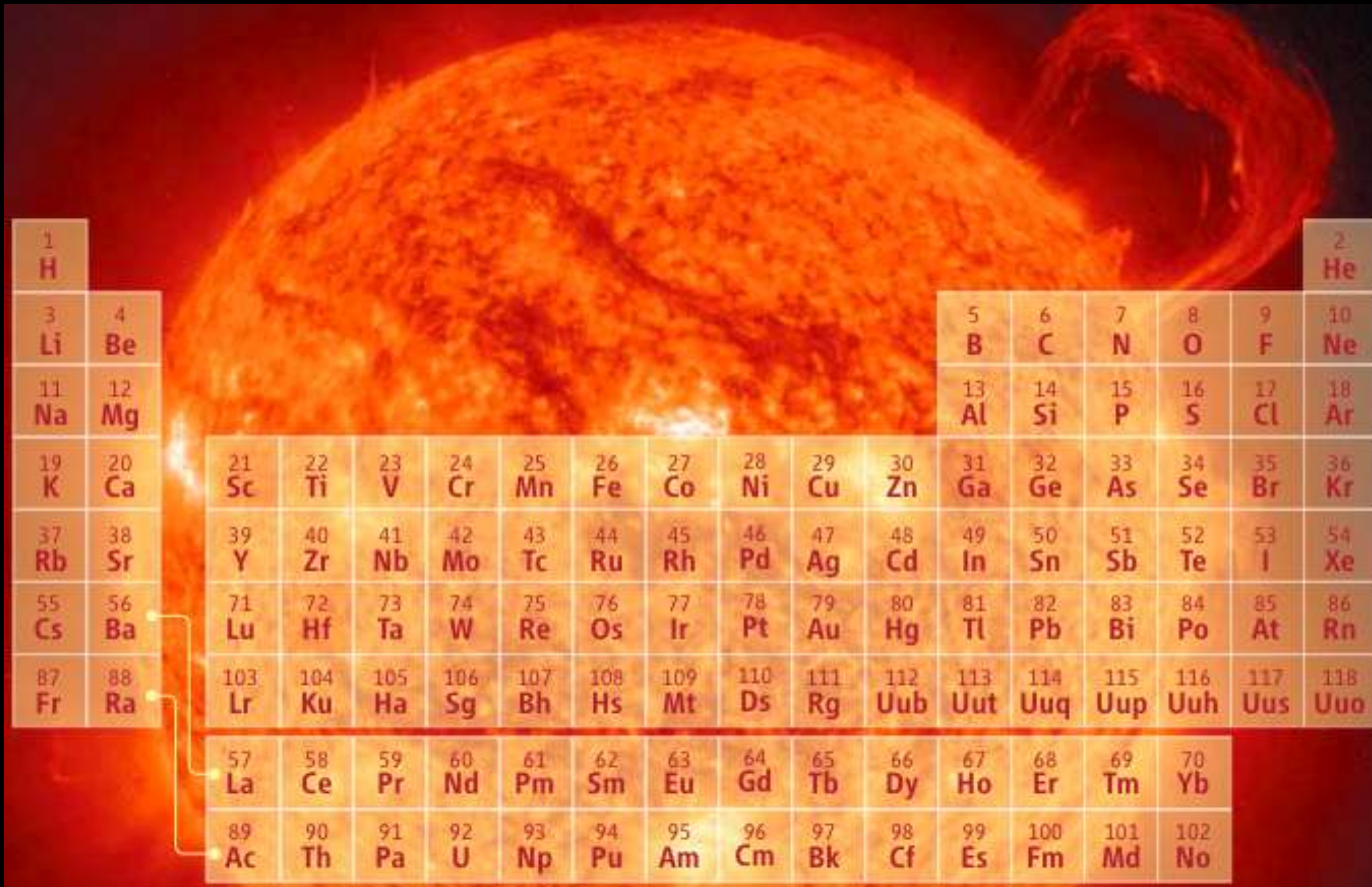
Al parecer tiene todas las condiciones para albergar planetas similares a la Tierra con agua y aire.

Dos astrónomos nacionales han hecho un descubrimiento que abonaría a la tesis de que la Tierra no es el único planeta del univer... donde existe vida.

Jorge Meléndez, del Observatorio Stromlo de Australia, e Iván Ramírez, del Observatorio Mc Donald en Texas (EEUU), son los compatriotas que descubrieron la existencia de una estrella que, p... sus características, podría ser considerada gemela del sol y que, ... parecer, tiene todas las condiciones para albergar planetas como... Tierra.

Is the Sun a normal solar-type star?

Are there any anomalies in the Sun’s chemical composition?



Por quase um seculo e meio o Sol foi considerado ”normal” na sua composição química

- Secchi (1868): Sol é tipico de estrelas de tipo solar

- Payne (1925): composição solar é universal

- Bent Gustafsson (1998, 2008): não sabemos devido às grandes incertezas (**0.05-0.10 dex**)

- Carlos Allende Prieto (IAU Symp 265 [Aug09] revisão sobre o disco fino): devemos melhorar nossas abundancias: <**0.05 dex (accuracy)**

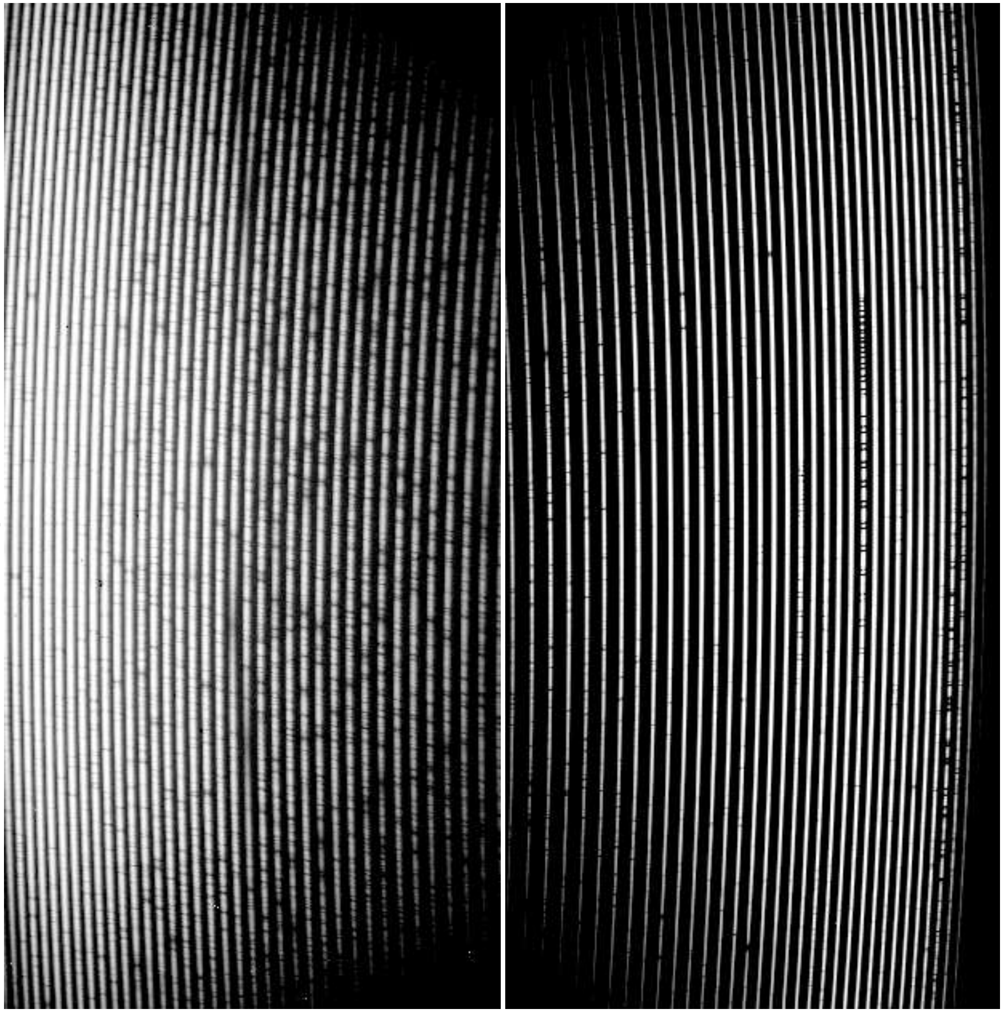
High precision chemical abundance study of solar twins: Magellan (Clay 6.5m)

Jorge Meléndez (CAUP/Portugal), Martin Asplund (Max Planck), Bengt Gustafsson (Uppsala), David Yong (Stromlo)

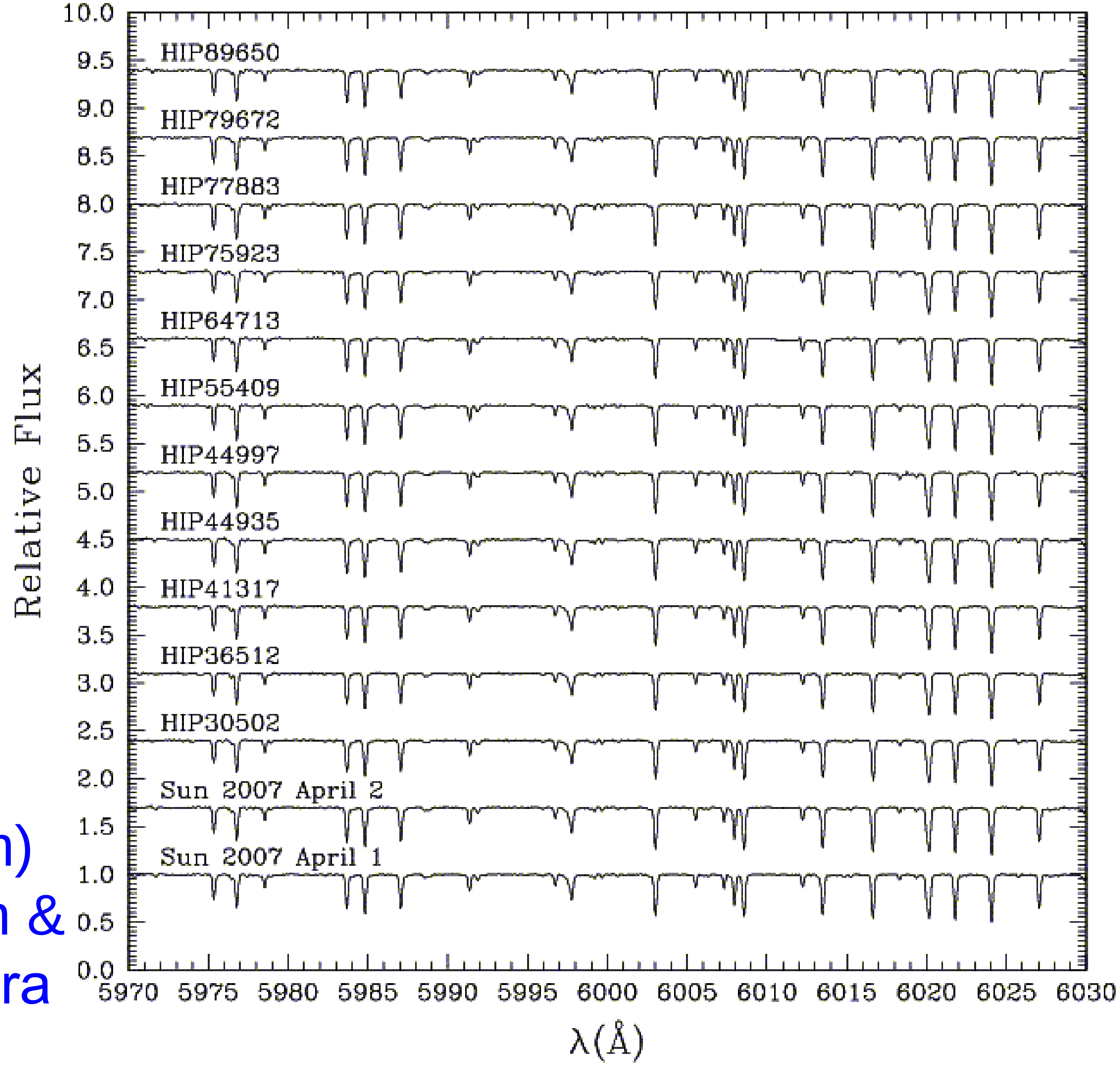
Observações espectroscópicas

Observações da gêmea solar 18 Sco

-Magellan 6.5m Clay Telescope
& Mike spectrometer
- R = $\lambda/\Delta\lambda$ = 65,000
- S/N = 450 per pixel
- coverage 340 – 1000 nm
- Solar spectrum:asteroid Vesta
- 3 nights of observations.



BLUE frame **RED frame**

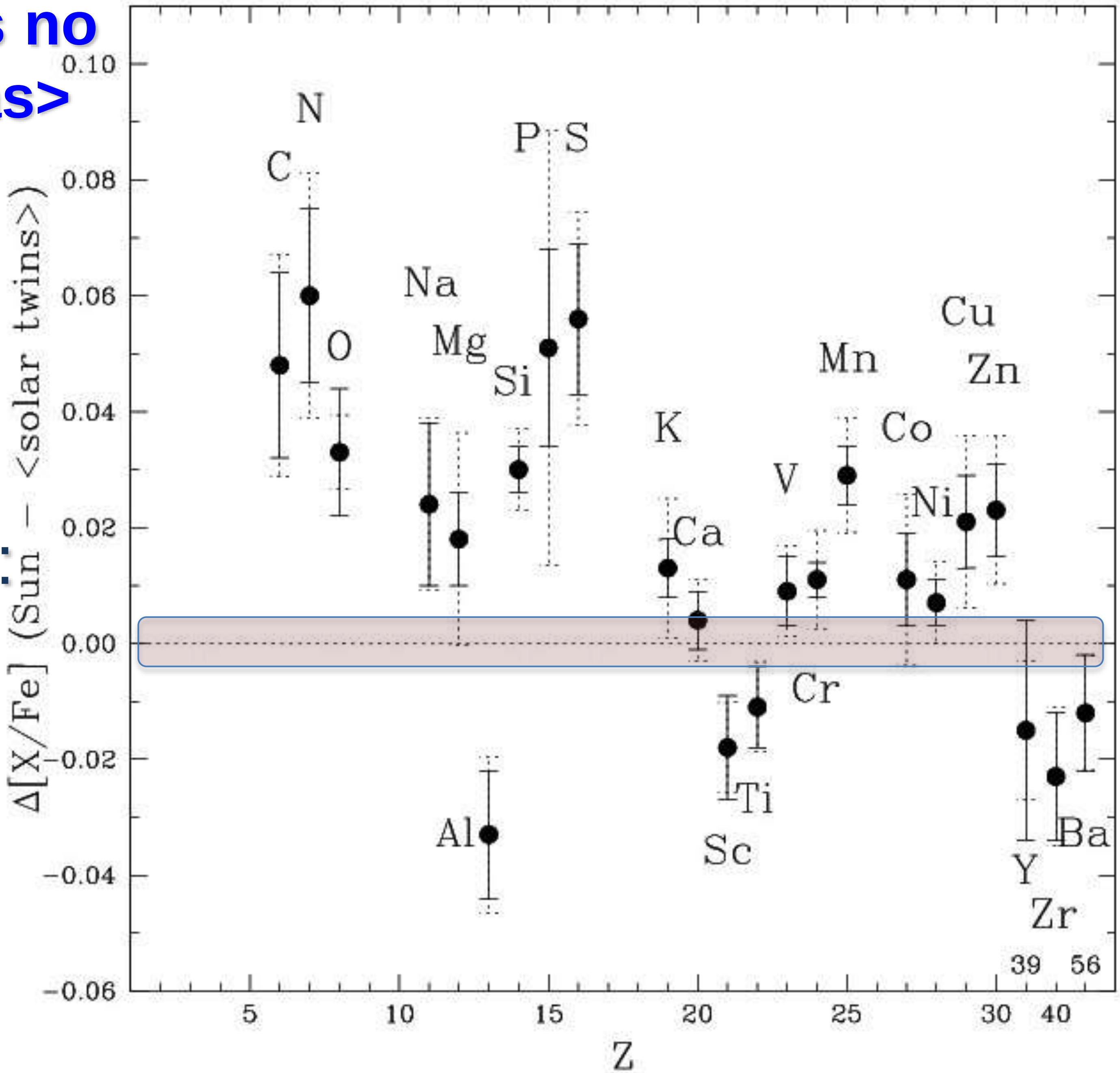


Small part (597-603nm) of solar twin & Sun's spectra

Abundancias no Sol - <gêmeas>
vs. número atómico Z

Sol típico:
Δ = 0
Sol anormal:
Δ ≠ 0

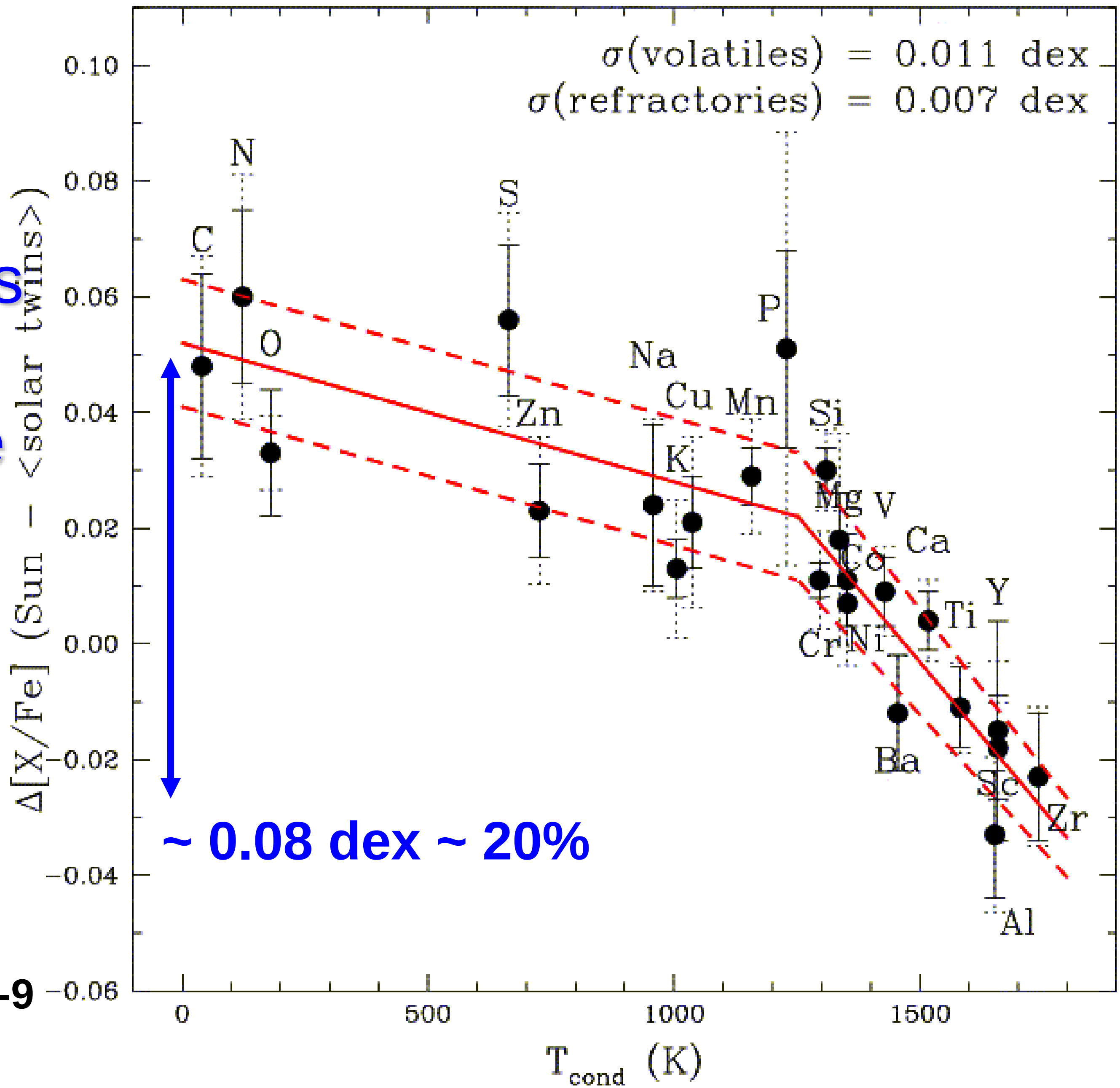
Our Sun is abnormal !



Are the anomalies in the Sun's composition related to the formation of our planetary system ?

The Sun & the Andes from the windows of Machu Picchu *http://www.flickr.com/photos/oscarpacussich*

Anomalias no Sol são fortemente correlacionadas com a temperatura de condensação (T_{cond}) dos elementos!

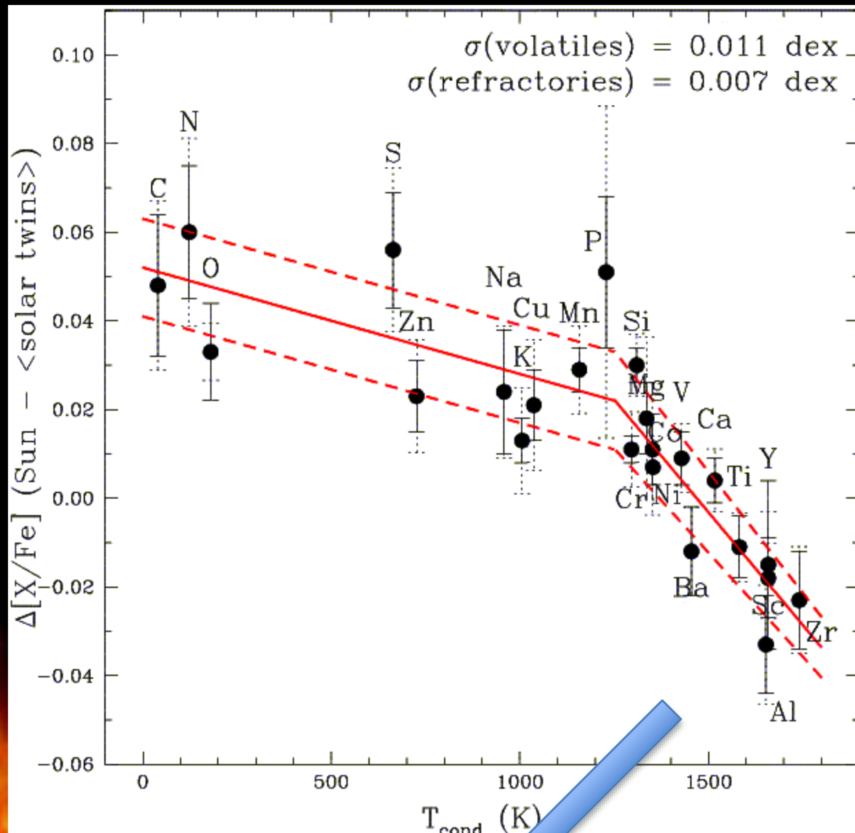


Correlação é altamente significativa

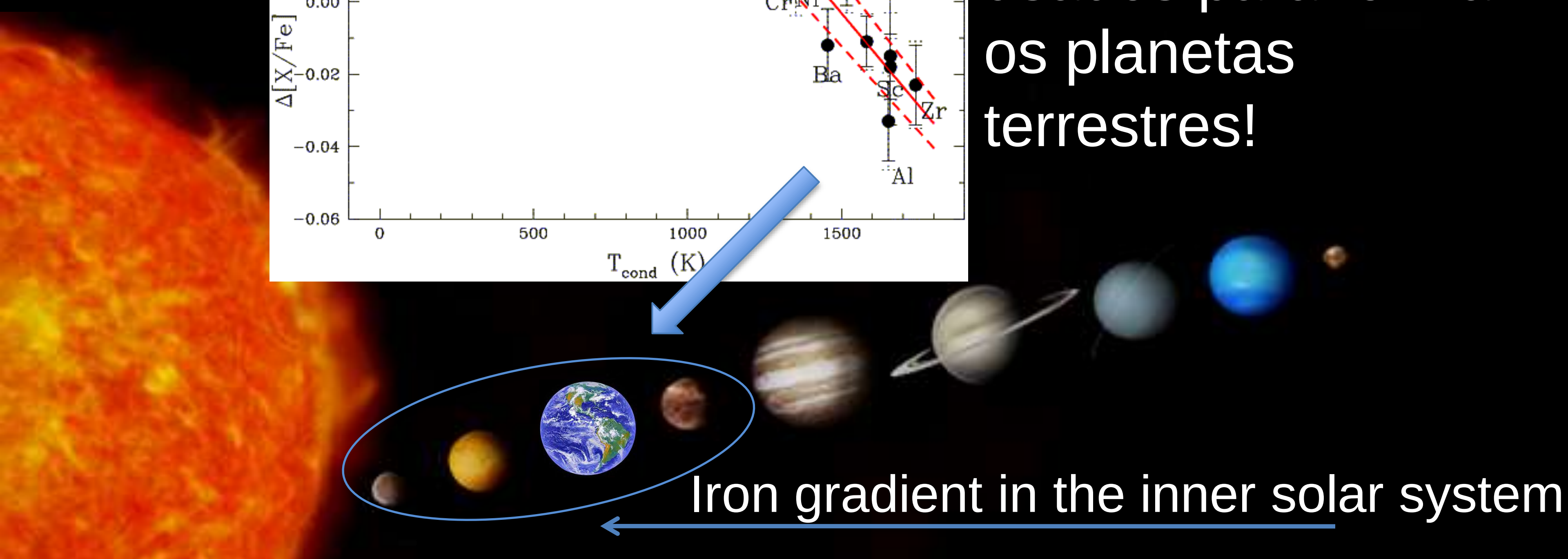
probabilidade ~10^{-9} de acontecer por acaso

Somente os elementos refractarios (e.g. Fe, Al, Sc) podem ter se condensado no sistema solar interno, *forming dust, planetesimals and finally rocky planets*

As camadas externas do Sol acretaram material deficiente em refractarios



O Sol é deficiente em refratarios porque esses elementos foram usados para formar os planetas terrestres!

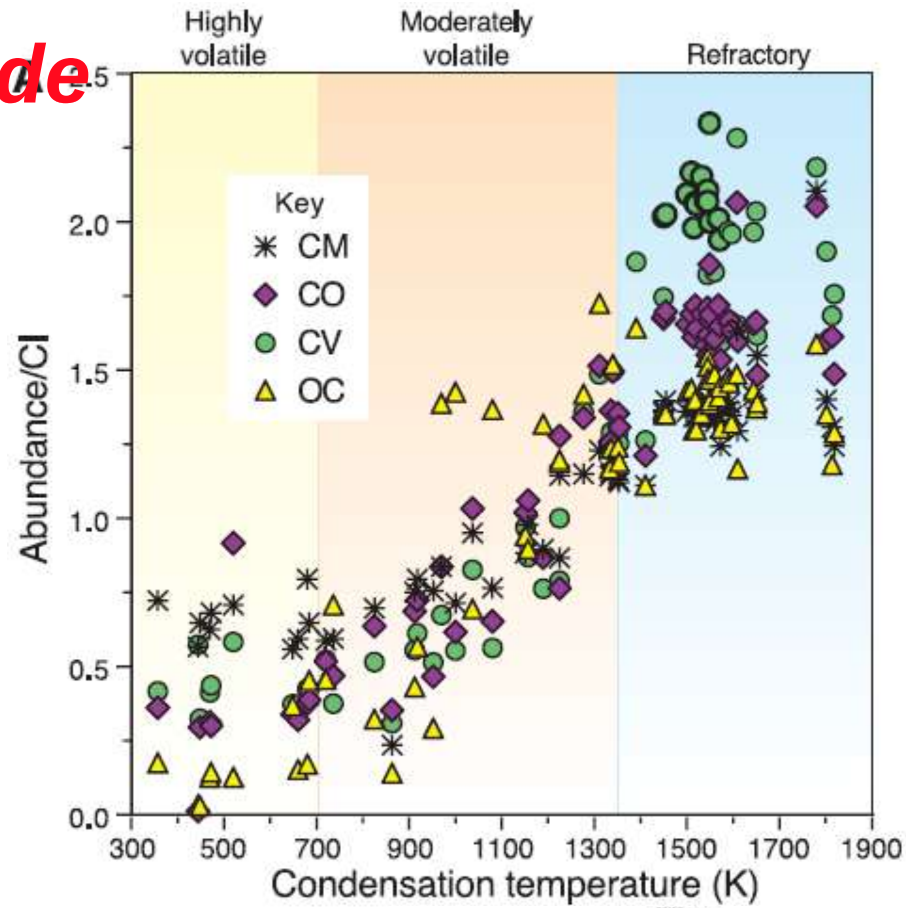


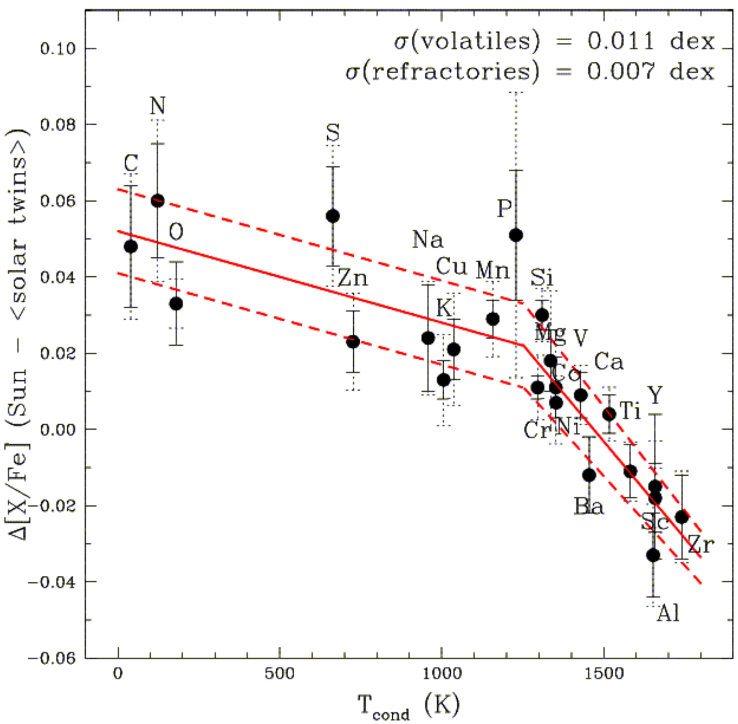
Iron gradient in the inner solar system

Relação com formação de planetas terrestres: meteoritos

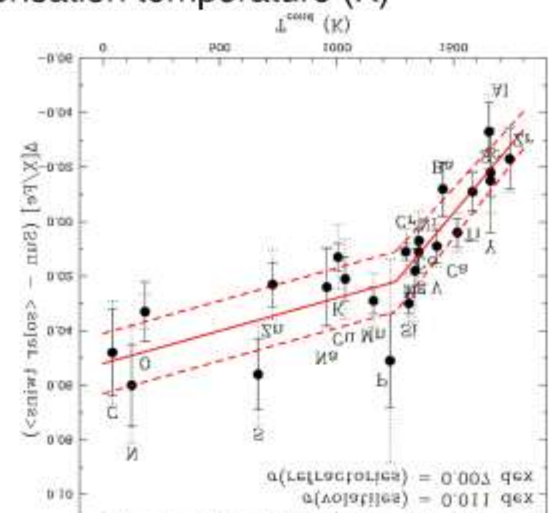
Alexander et al. (2001)

Fig. 2. (**A**) The CI chondrite normalized elemental abundances in bulk carbonaceous (CM, CO, and CV) and ordinary chondrites (OC) (*53*) versus their 50% condensation temperatures (*54*). The correlation between abundance and condensation temperature (volatility) is striking. The elements are divided into refractory (>1350 K), moderately volatile (700 to 1350 K), and highly volatile (<700 K). The common





O comportamento do Sol é uma imagem espelho do seguido por meteoritos!



A quantidade de material que falta no Sol é da mesma ordem que a requerida para formar os planetas terrestres + asteroides

How much dust-cleansed gas is required to affect the Sun in this way?

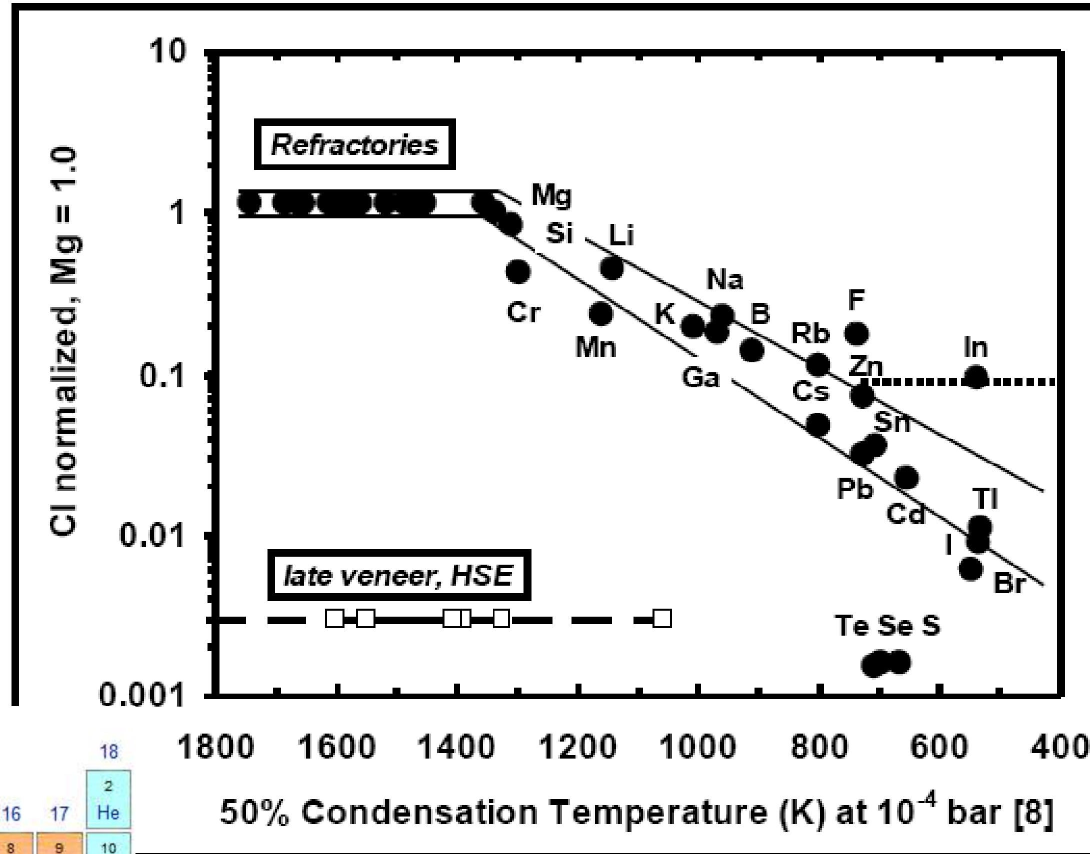
Assume gas accretion until solar convection zone reached ~ present size (~0.02 M_{sun}):

Refractories depleted in the Sun: ~2*10^{28} g ≈ 4 $M_{\oplus}$

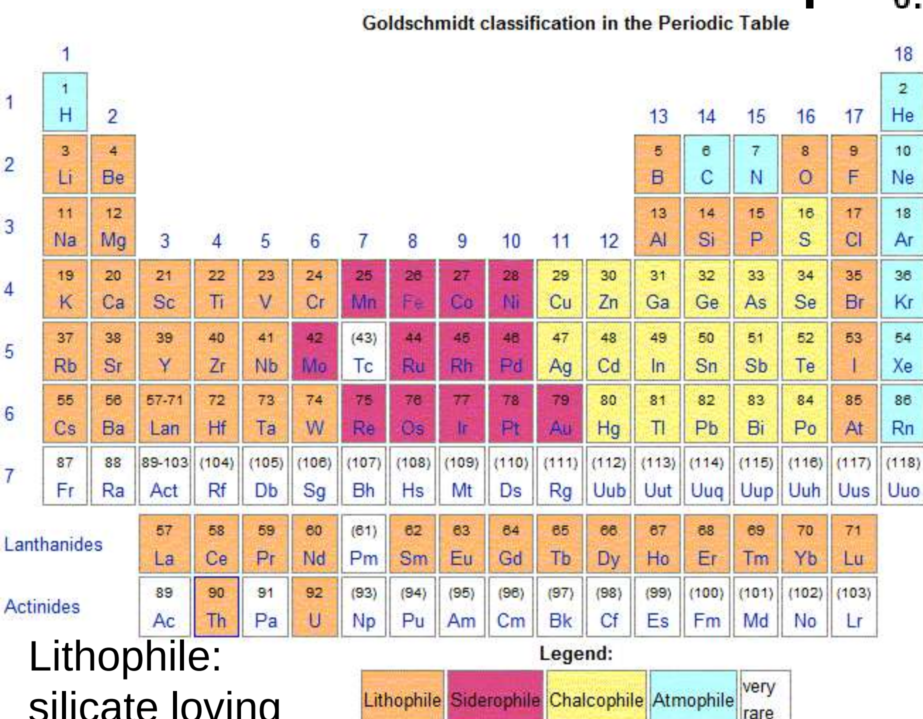
Refractories locked-up in terrestrial planets: ~8*10^{27} g ≈ 1.3 $M_{\oplus}$

O manto terrestre também mostra abundancias compativeis com o nosso cenario

volatile elements in Earth's mantle are depleted !



Witt-Eickschen et al. (2007)



Lithophile: silicate loving

Depletion trend of volatiles in Earth's mantle probably reflects primary nebular depletion in the Earth making material (Witt-Eickschen et al. 2007).

Earth-making material was poor in volatiles, and the Sun rich in refractories !

O Sol é unico ?

Não, o Sol é peculiar mas não é unico: ~ 10-20% de estrelas de tipo solar tem uma composição química similar ao Sol, e tal vez possam possuir planetas como a nossa Terra (e tal vez vida !)

$$N = R^{*} \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

Destaques na imprensa sobre a composição peculiar do Sol

elcomercio.com.pe — 06 de agosto del 2009

Astrónomo peruano halla forma de descubrir sistemas planetarios similares

16:28 | Se trata de Jorge Meléndez, quien el 17 de a
descubrimiento en la Biblioteca Nacional

IOP A website from the Institute of Physics

physicsworld.com

Home News Blog Multimedia In depth Jobs Events

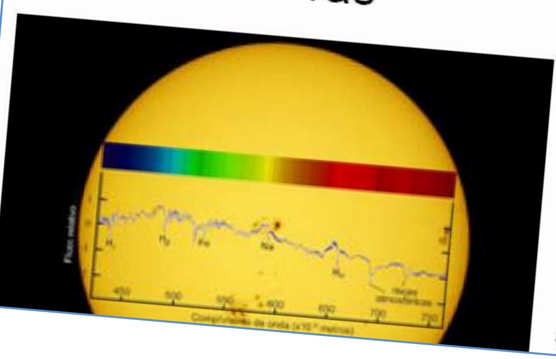
Chemical signature could help locate Earth-like planets

Oct 16, 2009 3 comments

Centro de Astrofísica da Universidade do Porto

Astronotícias

Composição do Sol fornece pistas para a descoberta de outras Terras



21 Setembro 2009

A equipa liderada por Jorge Meléndez, astrónomo do Centro de Astrofísica da Universidade do Porto (CAUP), descobriu uma relação entre a composição química do Sol e a presença de planetas rochosos. Este resultado poderá ser essencial para a descoberta de planetas semelhantes à Terra, à volta de estrelas

Destaques na imprensa sobre a composição peculiar do Sol

RARE SOLAR SYSTEM, RARE SUN

Print this ShareThis

12/14/2009
by Dr. Hugh Ross

The first discovered extrasolar planet was found in 199
Pegasi.[1] This finding persuaded many astronomers a
conclude that Carl Sagan was right—our Milky Way Ga
billions of planets, most of which would prove to be a
solar system. Sagan concluded that this, in turn, wou
present on several million of them. The subsequent
extrasolar planets before the end of the twentieth cen
would be able to "explore strange new worl
before."

Victor Stenger laments that
advanced life might exist.[2]

er Jorge Meléndez, has
[3] Meléndez has devoted much
the Sun, in the sense that the
ne existence of advanced life on
rried out in the last few decades.

a plan
solar twin has been found

DISCOVER

Science, Technology, and The Future

Subscribe

Health & Medicine | Mind & Brain | Technology | Space | Human Origins | Living World | Environment

Space / New Planets

Astronomers Discover 2 Shortcuts for Locating Earth-Like Planets

Stars orbited by planets are a little bit different than other stars, and scientists can use that to quickly home in on new planets.

by Andrew Moseman

From the March 2010 issue; published online March 23, 2010

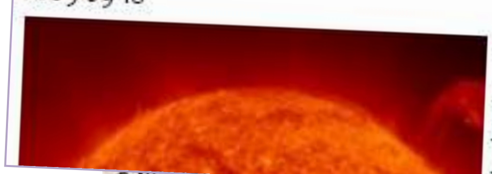
Jorge Meléndez, an astronomer at the University of Porto in Portugal, has turned up a different indicator of planets
Meléndez identified 15 elements that are more abundant in sun-size stars with giant planets orbiting very close to
the stars. But these elements are scarce in our sun, which hosts distant giants and small, rocky inner planets. A
chemical signature like the sun's could be a clue to finding Earth-like worlds that could potentially support life.

CiênciaHoje

Composição do Sol fornece pistas sobre outras «Terras»

Estudo publicado na Astrophysical Journal Letters

2009-09-18

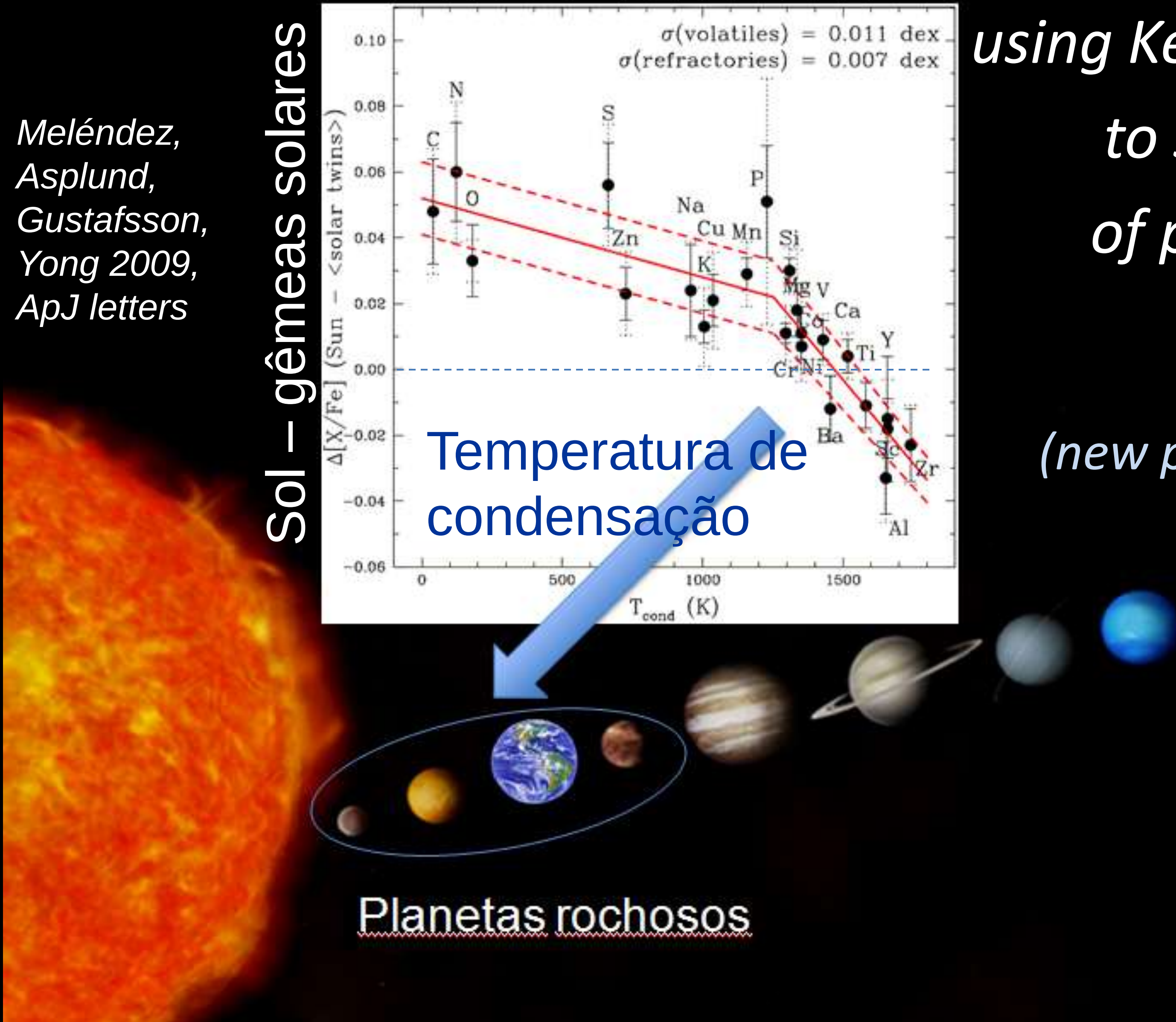


Um estudo publicado na revista ***«Astrophysical Journal Letters»****, da equipa liderada por Jorge Meléndez, astrónomo do*

Solar twins @ IAG/USP

Extremely high precision abundance analysis using Keck and VLT data to study signatures of planet formation

Meléndez, Asplund, Gustafsson, Yong 2009, ApJ letters



Tala Monroe

(new postdoc @ IAG/USP)

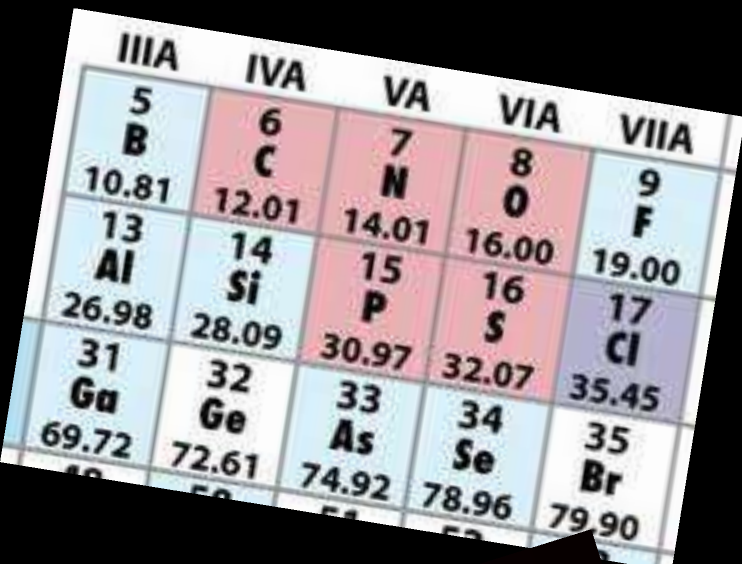
Solar twins @ IAG/USP

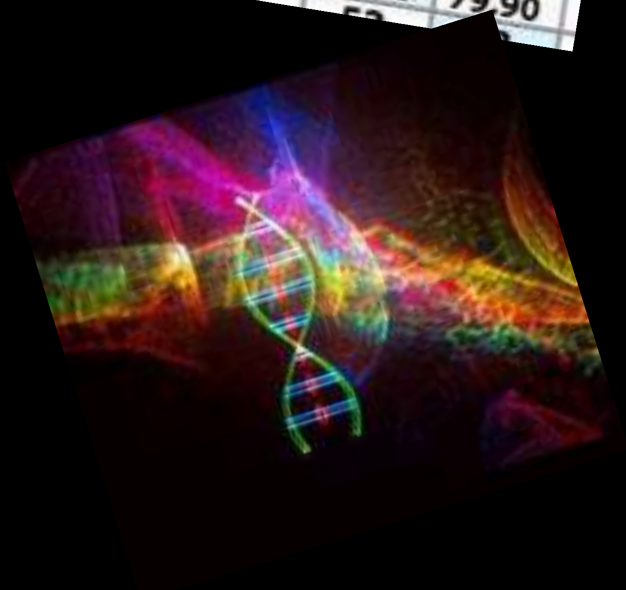
Biogenic elements :

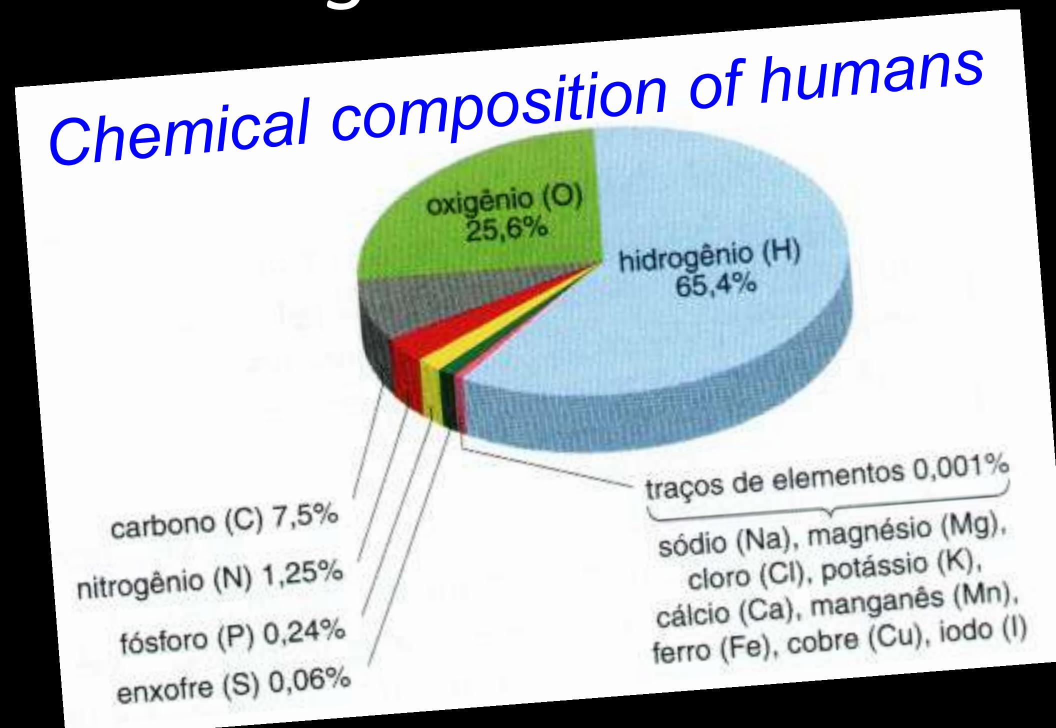
C, O, N, P, S

(Basic building blocks of life)

using VLT CRIRES data







Procura de planetas ao redor de gêmeas solares: 88 noites no HARPS/ESO

FOLHA.com

29 DE SETEMBRO DE 2011 - 02:34 SP

VEJA O TEMPO EM MAIS CIDADES 14ºC

NOTÍCIAS PODER MUNDO MERCADO COTIDIANO ESPORTE ILUSTRADA F5 CIÊNCIA TEC FOLHA D

AMBIENTE BICHOS BLOGS CELEBRIDADES COLUNISTAS COMIDA EQUILÍBRIO E SAÚDE FOLHATEEN FOLHINHA

HORÓSCOPO TRÂNSITO FOLHAINVEST INDICADORES GUIA E-MAIL FOLHA ASSINANTES ERRAMOS TV F

EM CIMA DA HORA PUBLICIDADE: Bluetec5. Conheça a nova tecnologia Mercedes-Benz para motores de ônibus

ciência

Maior | Menor Enviar por e-mail Comunicar erros Link http://folha.com/no959

15/08/2011 - 09h02

Brasil participará de monitoramento de planetas 'gêmeos' da Terra

SALVADOR NOGUEIRA
COLABORAÇÃO PARA A FOLHA

Recomendar 114 +1 5

Atualizado às **14h15**.

Um grupo liderado por um astrônomo do Brasil pode desvendar o que leva certas estrelas, como o Sol, a abrigar planetas como o nosso, rochosos e pequenos. De quebra, trata-se da primeira grande investida brasileira na busca por mundos extrassolares com telescópios em solo.

Help most welcome

O estudo se viabilizou graças ao acesso recém-obtido pelo Brasil às instalações do ESO (Observatório Europeu do Sul). O governo assinou no fim do ano passado o acordo que torna o país o mais novo membro do consórcio. Embora o acerto ainda careça de aprovação do Congresso para entrar em vigor, o ESO já trata o Brasil como parceiro, concedendo o direito de solicitar tempo de observação nos telescópios da organização.

Foi por conta disso que a equipe de **Jorge Meléndez**, peruano que trabalha no **IAG** (Instituto de Astronomia, Geofísica e Ciências Atmosféricas) da USP, conseguiu aprovação num projeto que pode finalmente revelar alguns dos segredos mais bem guardados sobre os exoplanetas.

CONCLUSIONS

Very exciting research @ IAG/USP related to the chemical composition of stars:

- Big Bang nucleosynthesis
- Galaxy formation and evolution
- Stellar evolution
- Planet formation
- Uniqueness of our Sun and our solar system
- *Others: M dwarfs, isotopic ratios, stellar clusters, molecular spectroscopy, giant stars with planets, stellar parameters, interstellar extinction, archaeoastronomy...*