What can we learn about present day oxygen abundances from the combined study of massive stars and HII regions?

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Many thanks to ...

Artemio Herrero
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Jorge García Rojas
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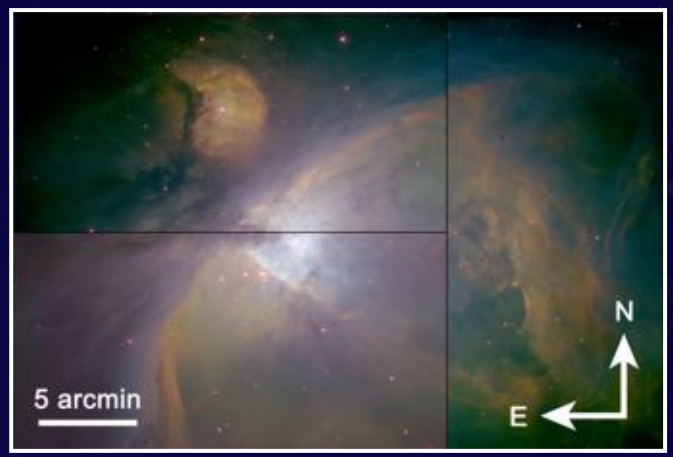
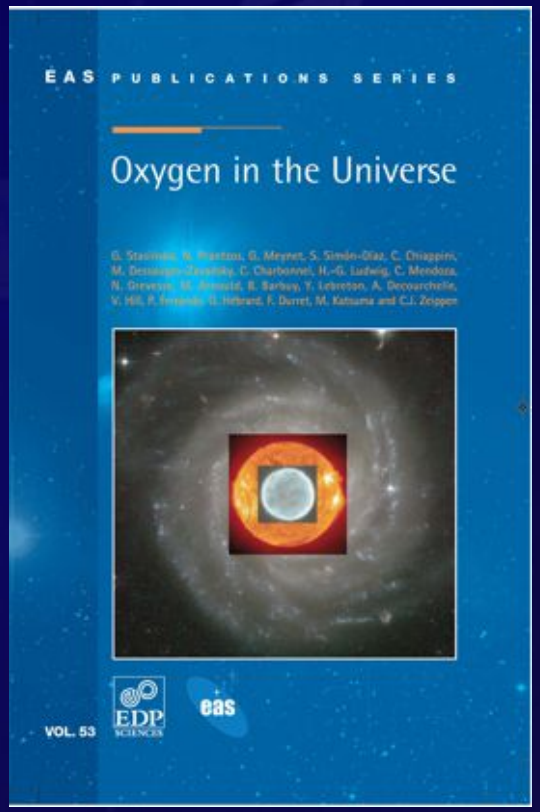


... for many discussions about abundances in massive stars and HII regions during the last 12 years

Some publicity ...



Oxygen in the Universe

G. Stasinska,
N. Prantzos, G. Meynet, S. Simón-Díaz,
C. Chiappini, M. Dessauges-Zavadsky, C. Charbonnel,
H.-G. Ludwig, C. Mendoza, N. Grevesse, M. Arnould,
B. Barbuy, Y. Lebreton, A. Decourchelle, V. Hill, P. Ferrando,
G. Hébrard, F. Durret, M. Katsuma and C.J. Zeippen

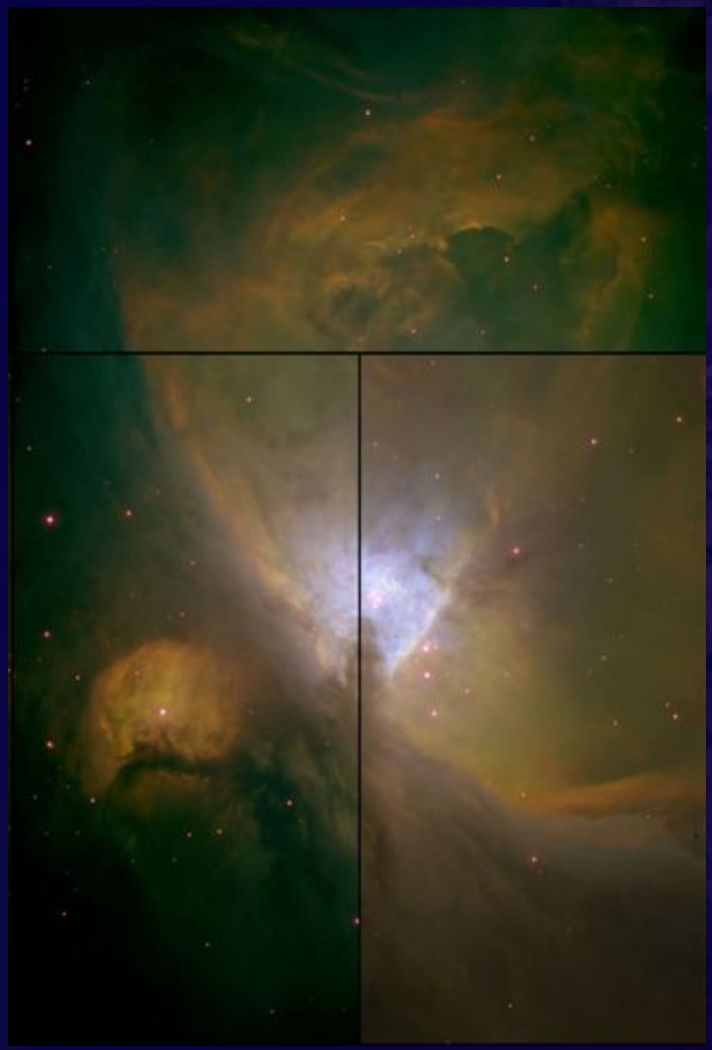
1. How to derive oxygen abundances
2. A panorama of oxygen in the Universe
3. Oxygen production and destruction
4. The evolution of oxygen in galaxies

A. The atomic physics of oxygen

... and then we start to talk about massive stars and HII regions

I challenge you to guess what these two images are ...

An Universe (as seen in optical wavelenghts) without massive stars !!!



M33 and M42

Massive stars and HII regions: born to live and die together

Massive stars (M > 8 Msun): Born from the ISM

O and B dwarfs (→ stellar evolution →) OBA Supergiants

O stars: Ionize the surrounding ISM and originate HII regions

Massive stars: Short lived (~10 Myrs)

Oxygen is generated in the interior of massive stars, but the photospheric abundance of O is only modified in their late evolutionary phases

Oxygen in OB-type stars and early-B Sgs = Oxygen in the nearby ISM (gas + dust !!) = Present day (local) oxygen abundance

Massive stars and HII regions: born to live and die together

The associated HII region dissapear as soon as the O stars dissapear (i.e. evolve to B Sgs, or die)

Massive stars and HII regions sample the same temporal and spatial O abundance distribution in galaxies

Without massive star we will not be able to measure present-day oxygen abundances

Massive stars and HII regions as tools to measure present-day oxygen abundances

Massive stars

Methods: Complex modelling

Observable at large distances

Critical: SNR, resolution, undetected binarity, normalization

Complex atomic model

No dust depletion

* Stellar parameter determination
* Microturbulence

HII regions

Methods: generally straightforward

Observable at large distances

Critical: [OIII]λ4363 (+ faint ORL), flux calibration, aperture and geometrical effects, scattered light

Atomic data: a few quantities

Only gas abundances - dust

* CEL/ORL discrepancy
* Strong line methods
* Metal rich regime

Oxygen abundances from Massive Stars and HII regions

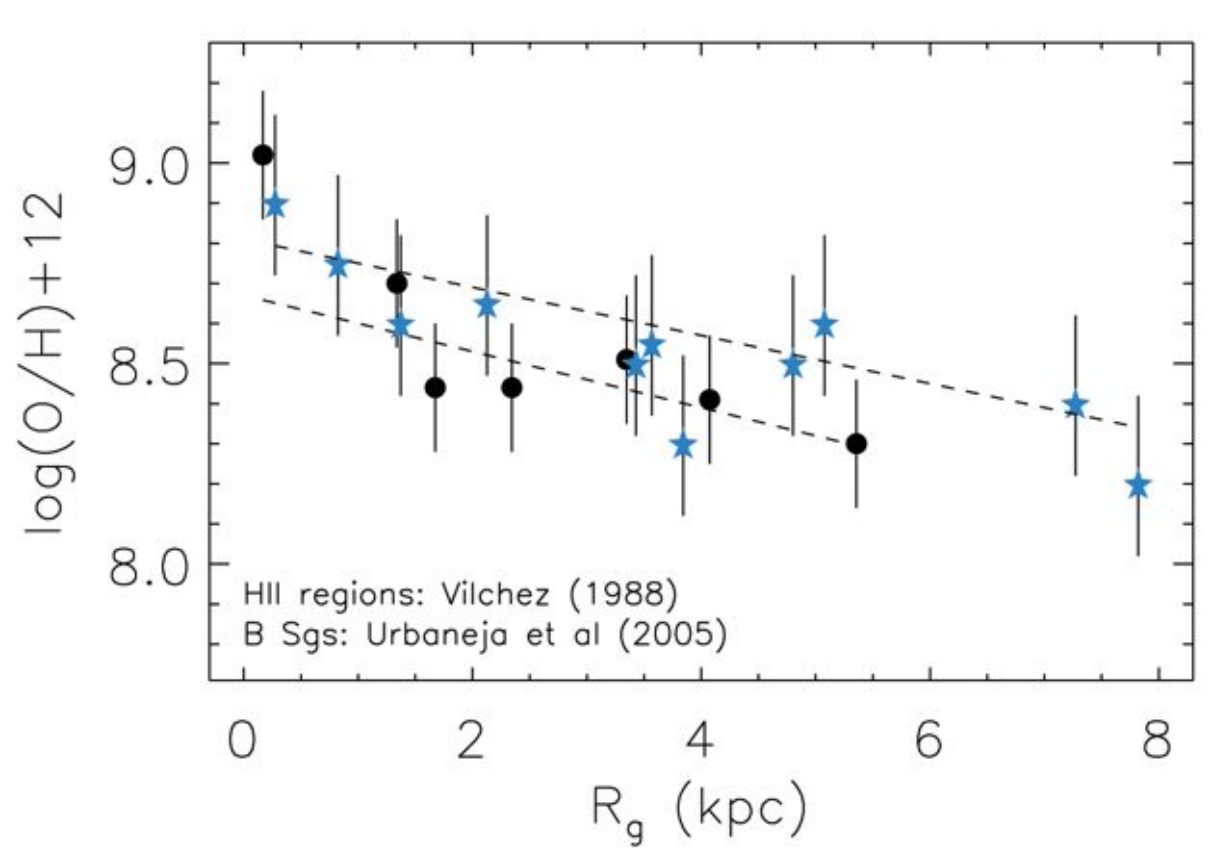
Do they agree?

Abundace gradients in Spiral galaxies

--- M33 ---

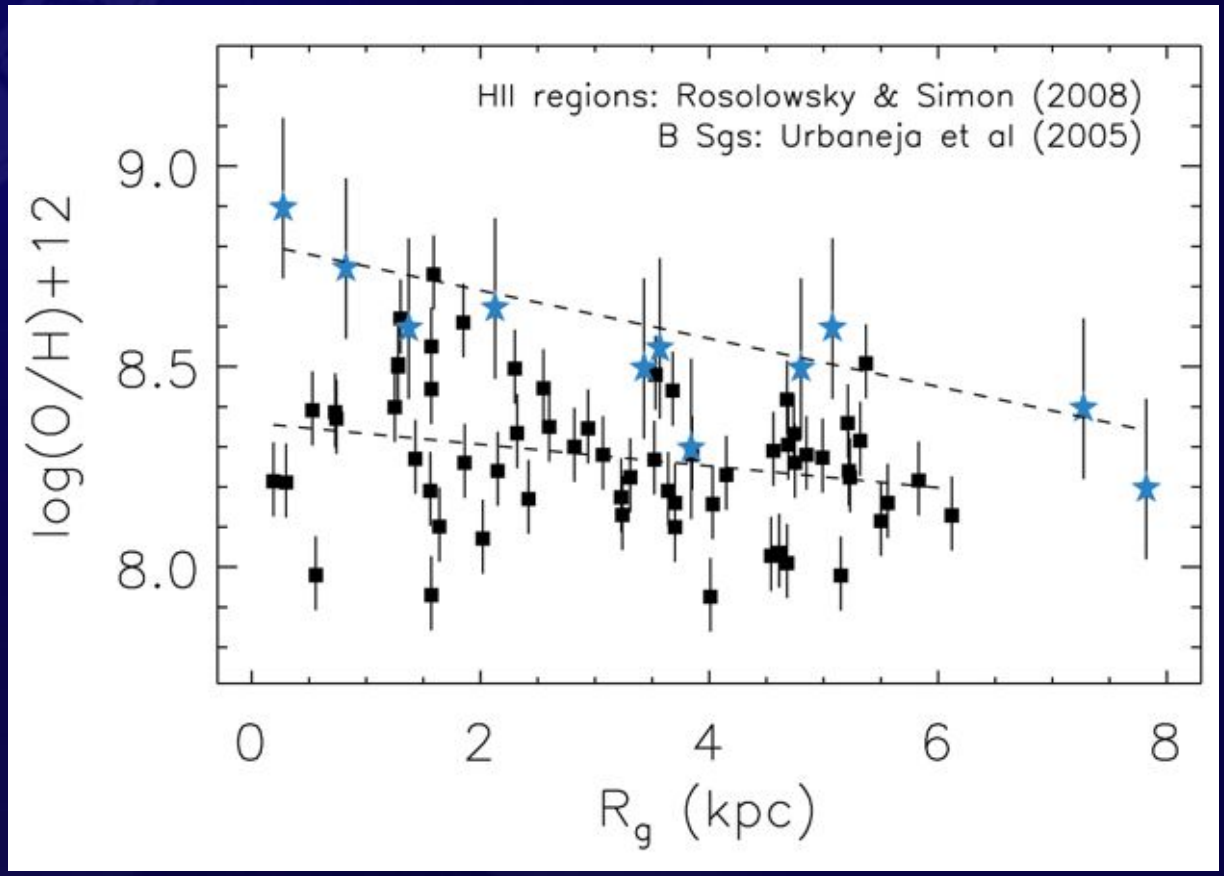
Oxygen abundances from Massive stars and HII regions: do they agree?

M33 *Urbaneja et al. (2005) vs Vilchez et al. (1998)*



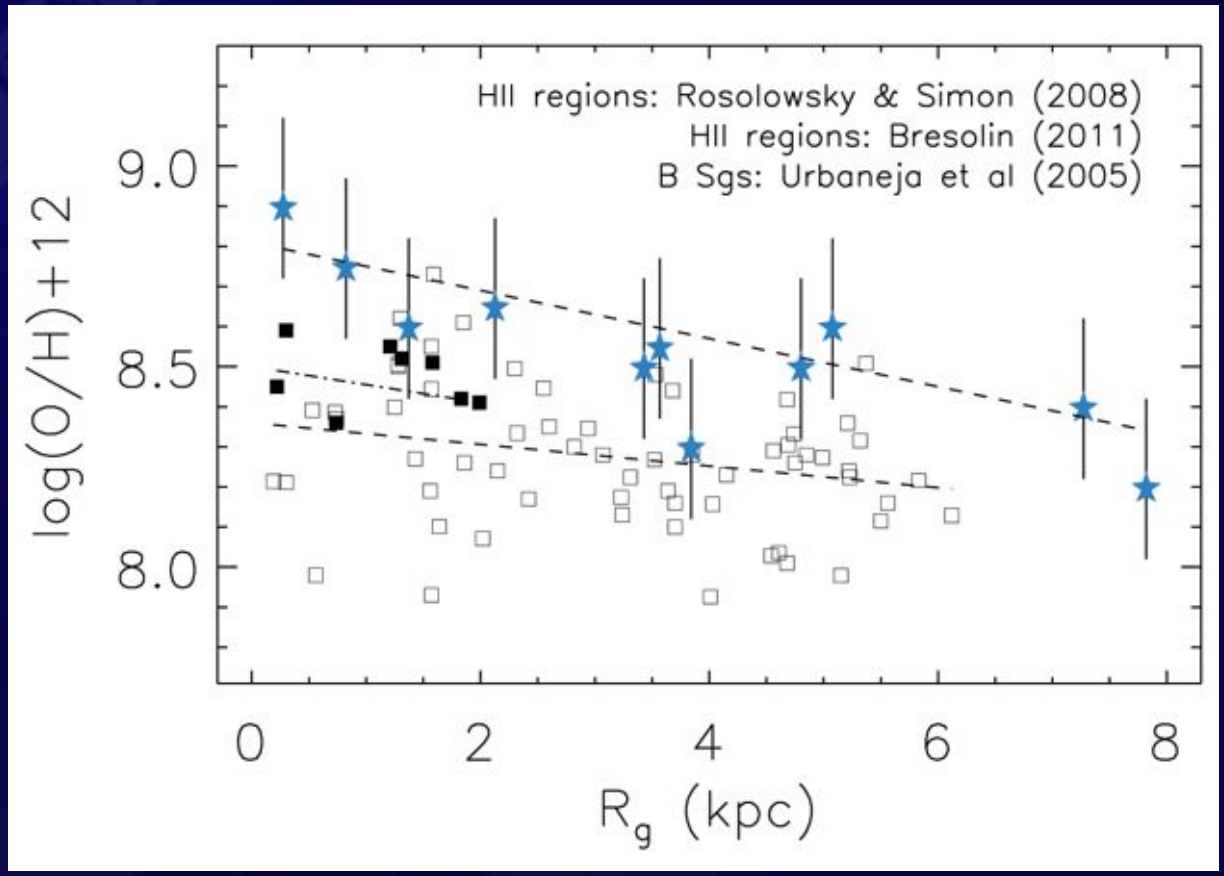
Oxygen abundances from Massive stars and HII regions: do they agree?

M33 *Urbaneja et al. (2005) vs Rosolowsky & Simon (2008)*



Oxygen abundances from Massive stars and HII regions: do they agree?

M33 *+ Bresolin (2011)*



Oxygen abundances from Massive Stars and HII regions

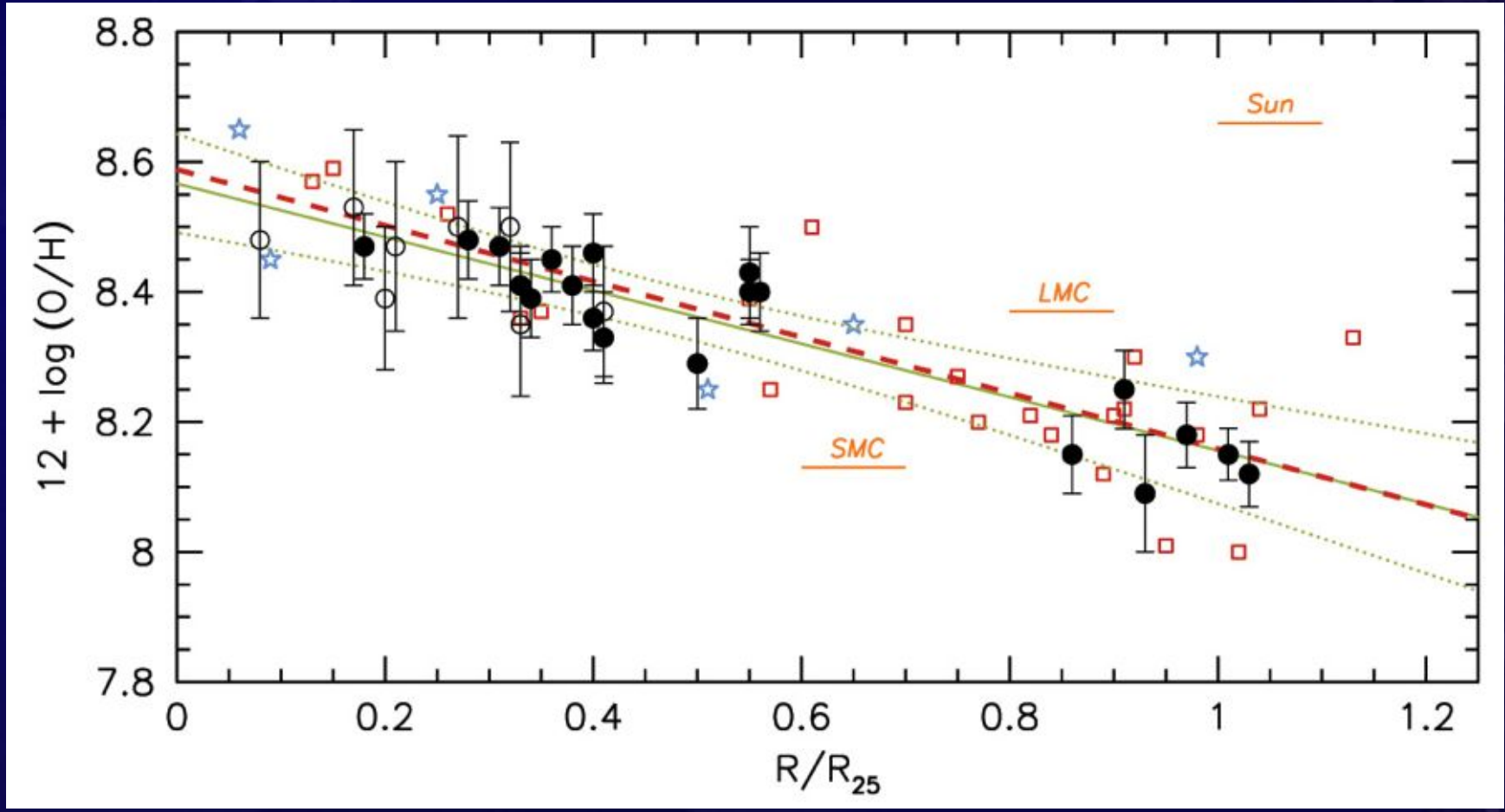
Do they agree?

Abundace gradients in Spiral galaxies

--- NGC300 ---

Oxygen abundances from Massive stars and HII regions: do they agree?

NGC300 *Bresolin et al. (2009)*



Oxygen abundances from Massive Stars and HII regions

Do they agree?

Abundace gradients in Spiral galaxies

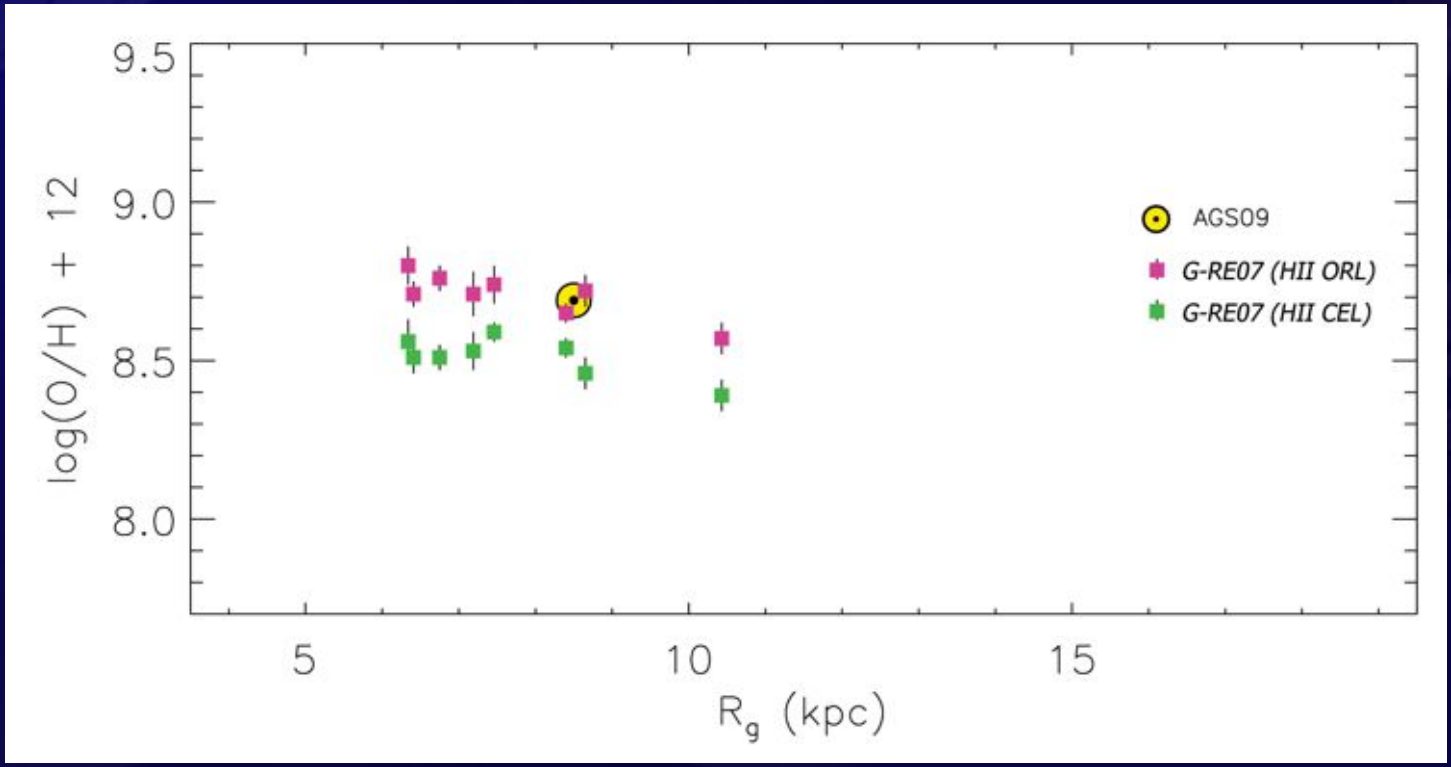
--- Milky Way (as for 2007) ---

Oxygen abundances from Massive stars and HII regions: do they agree?

Milky Way

Data from García-Rojas & Esteban (2007)

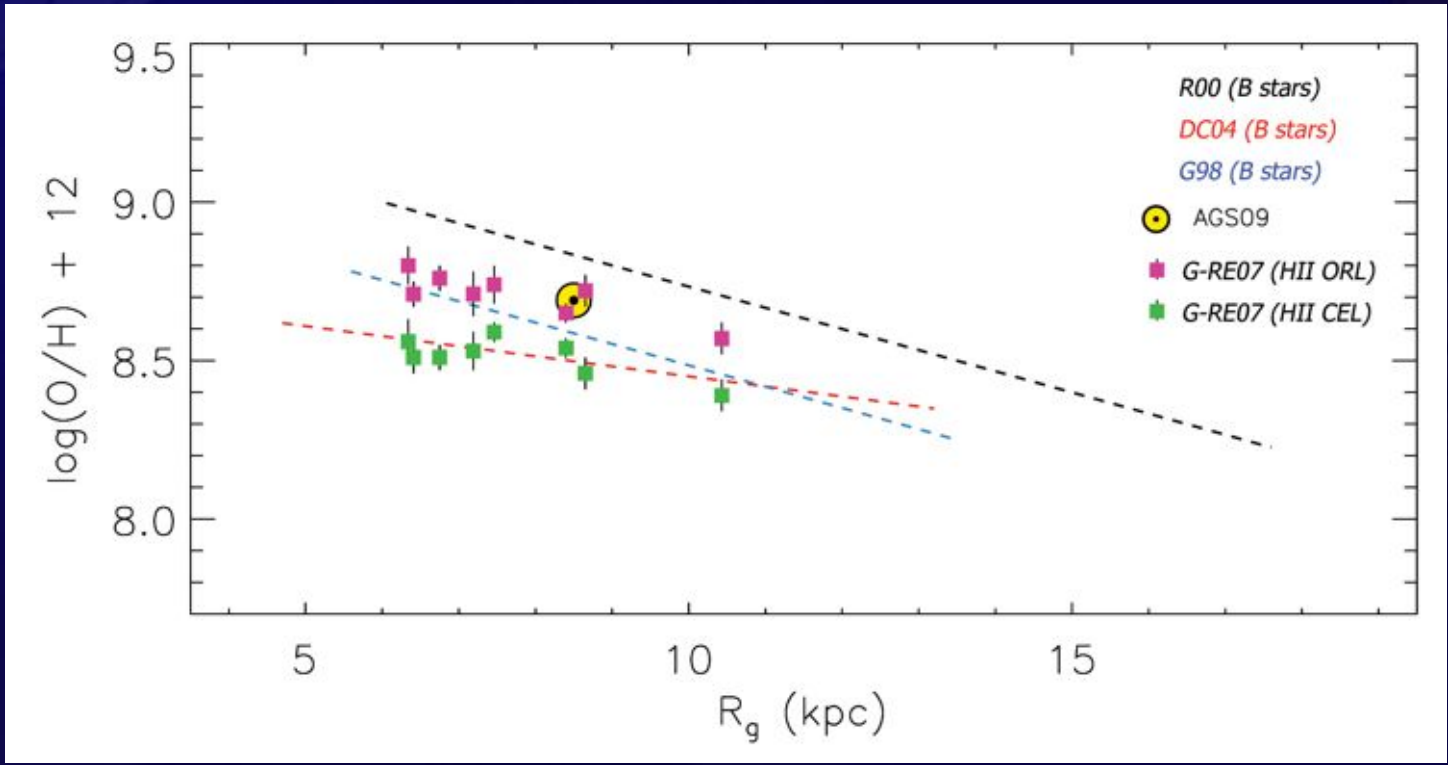
HII regions (CEL // ORL)



Oxygen abundances from Massive stars and HII regions: do they agree?

Milky Way

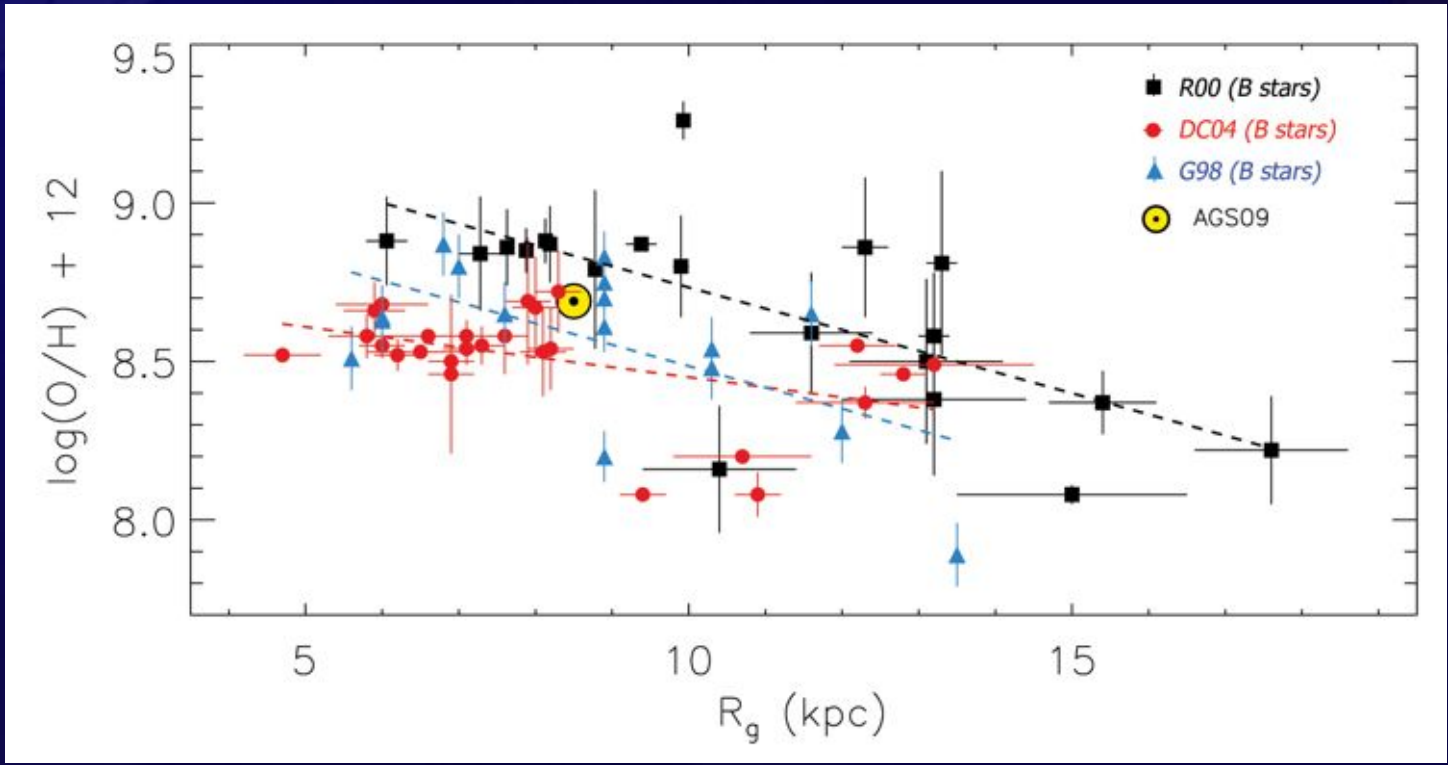
Data from García-Rojas & Esteban (2007)
+ Rolleston et al. (2000)
+ Daflon & Cunha (2004)
+ Gummersbach et al. (1998)



Oxygen abundances from Massive stars and HII regions: do they agree?

Milky Way

B-type stars (as for 2004)
Rolleston et al. (2000)
Daflon & Cunha (2004)
Gummersbach et al. (1998)



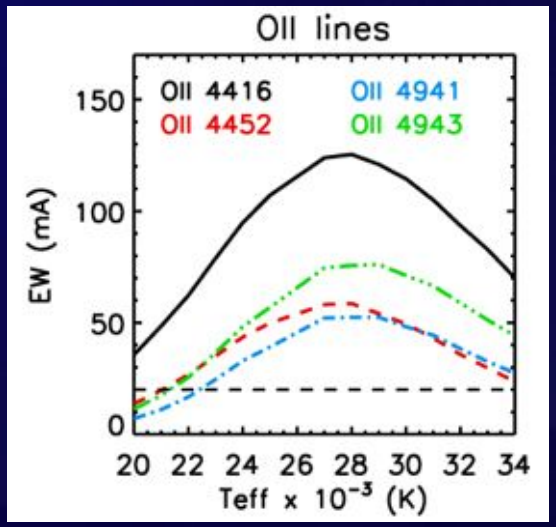
Oxygen abundances in B-type stars
One VERY important step: the stellar parameters determination

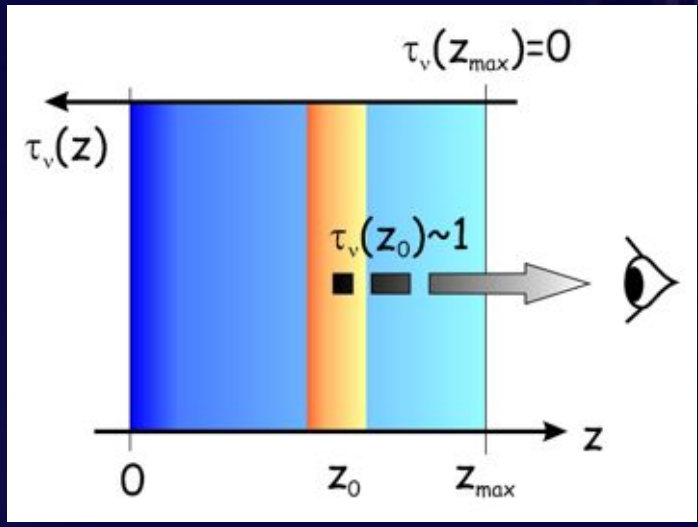
Use of photometric calibrations vs. **Self-consistent spectroscopic approach**

e.g. Lester, Gray & Kurucz (1986)

$[c_1] = c_1 - 0.20\ (b\text{-}y) = f(T_{eff}, \log g)$
Based on Kurucz's (1979) models

T_{eff}, log*g*, ... are determined by using synthetic lines resulting from the same stellar atmosphere code that will be used for the abundance analysis





Oxygen abundances from Massive Stars and HII regions

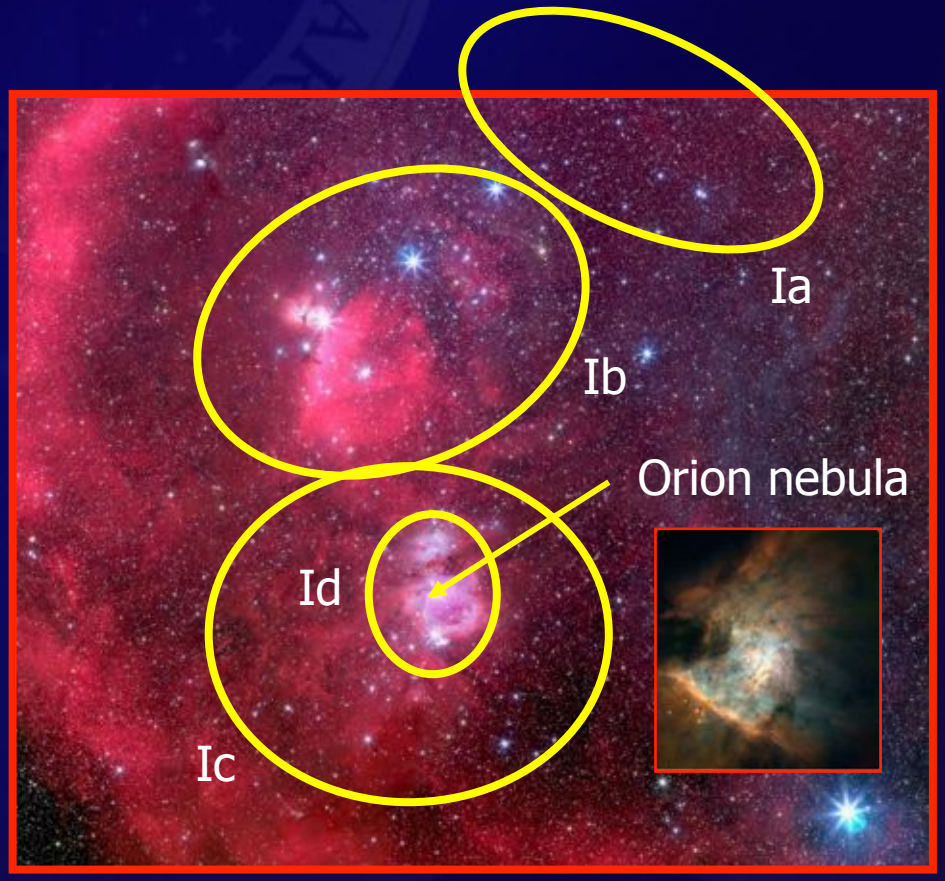
Do they agree?

Oxygen abundance in the same site

--- Orion OB1 ---

Oxygen abundance in the same site: Orion OB1 + M42

Oxygen abundance in the same site: Orion OB1 + M42



(One of) the closest star forming region

Orion OB1 association

Blaauw (1964): Four subgroups with different ages and location in the sky

Brown et al. (1994):

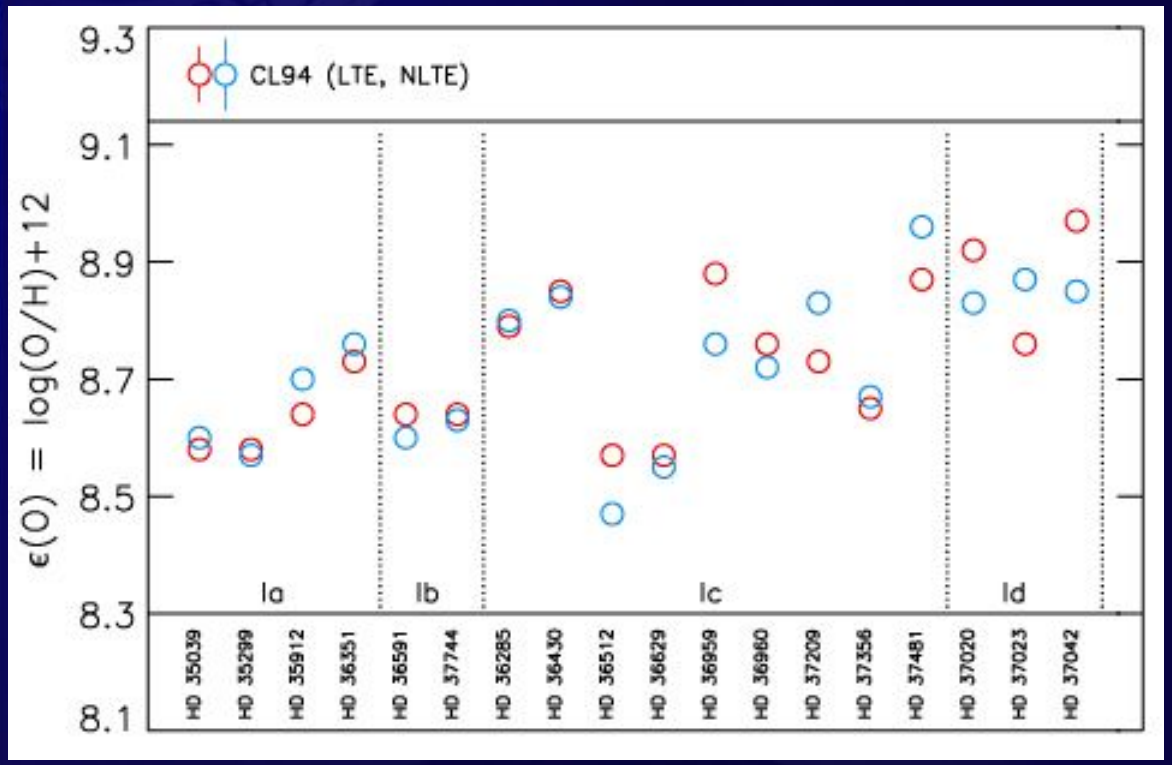
Ia:	380(90) pc	11.4(1.9) Myr
Ib:	360(70) pc	1.7(1.1) Myr
Ic:	400(90) pc	4.6(2) Myr
Id:	400(50) pc	< 1 Myr

Several SN events features

The Orion nebula (M42)

Abundances in B-type stars in the Orion Association

Cunha & Lambert (1994) : C, N, O, Si and Fe abundances of 18 B-type main sequence stars from the four subgroups comprising the Orion association

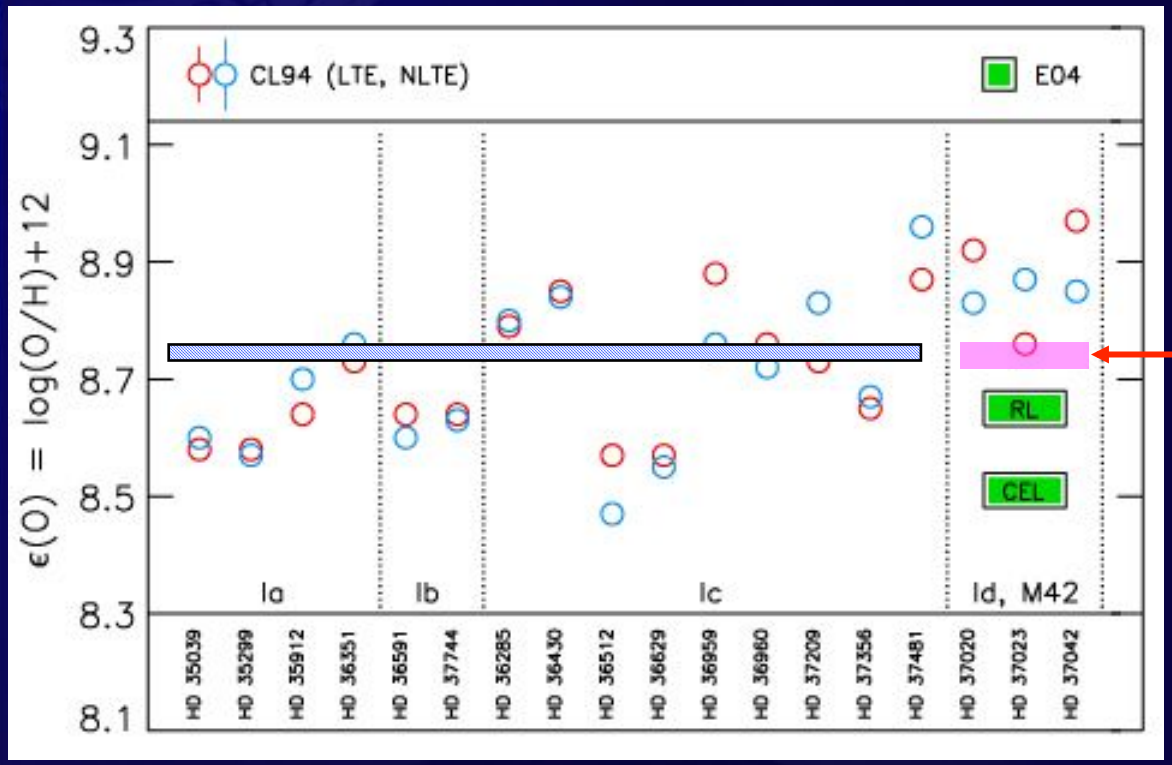


The higher values of the O abundances were found for the stars in the youngest groups (Id and some Ic)

Contamination of the new generation of stars by SN type-II ejecta (O, Si, Mg ...)

Orion OB1: B-type stars vs nebular (M42) abundances

Photospheres of early type, main sequence stars are expected to share the same chemical composition as the ISM where they were born



ORL + DUST
(Esteban et al. 2004)

Orion OB1: B-type stars vs nebular (M42) abundances

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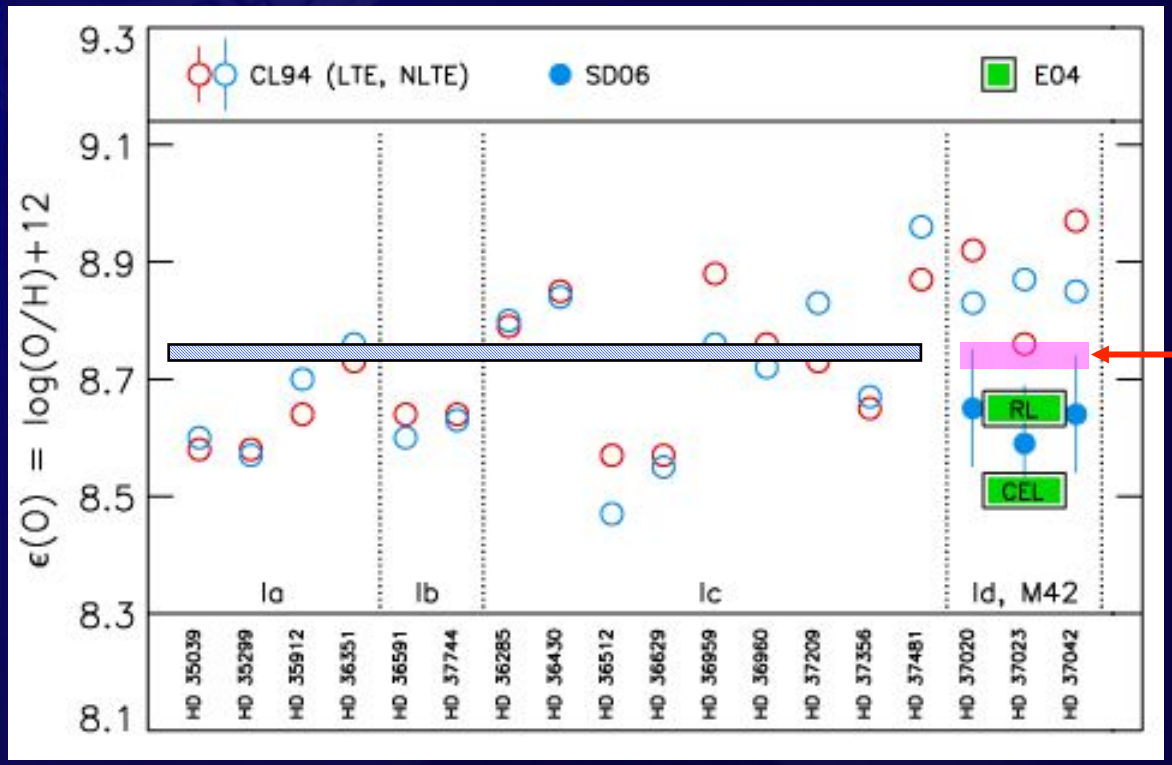


But ...

- *Simón-Díaz et al. (2006)*

ORL + DUST
(Esteban et al. 2004)

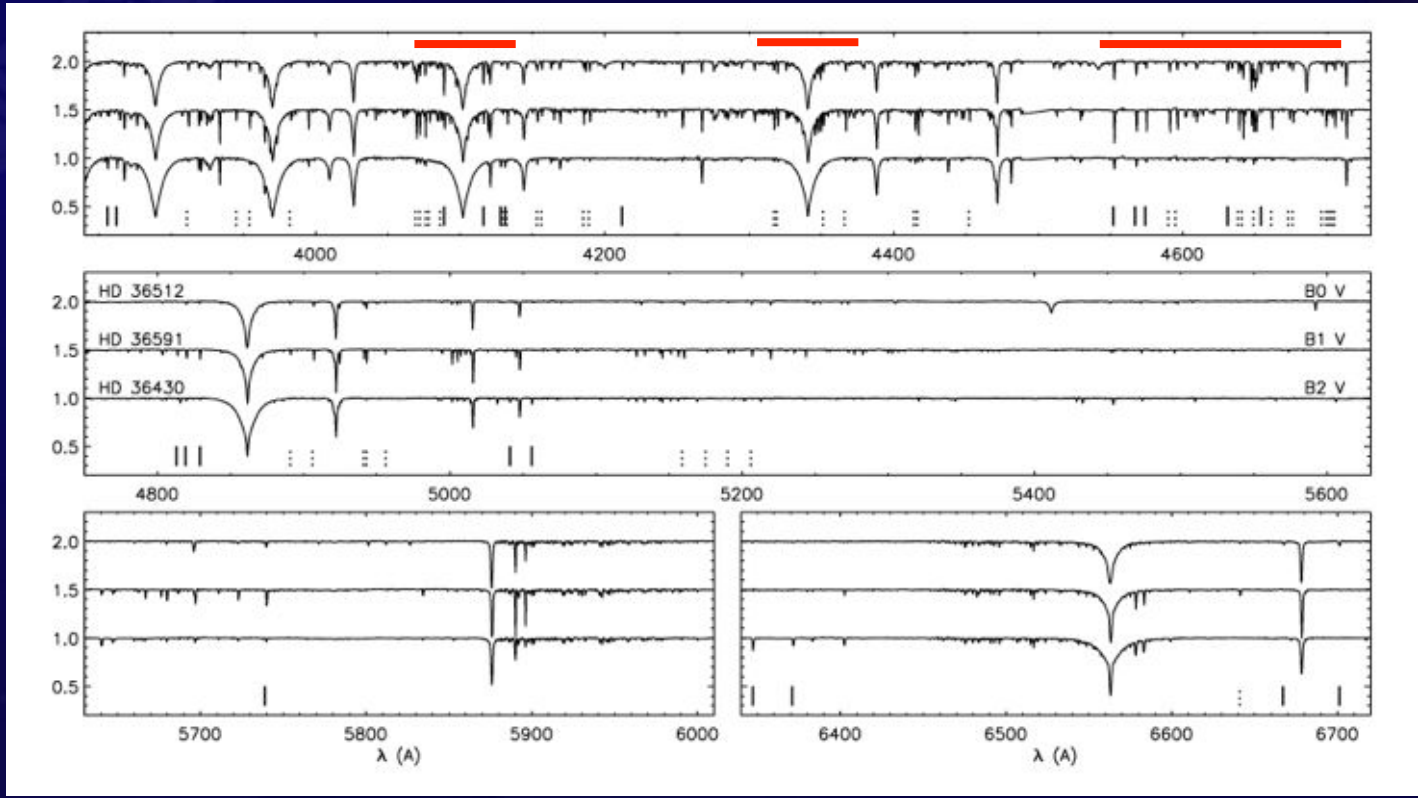
SNII contamination?

Stellar/nebular abundances comparison (+ dust?)

A new analysis of the B-type stars in Ori OB1 *(Simón-Díaz 2010)*

NEW observational data-set

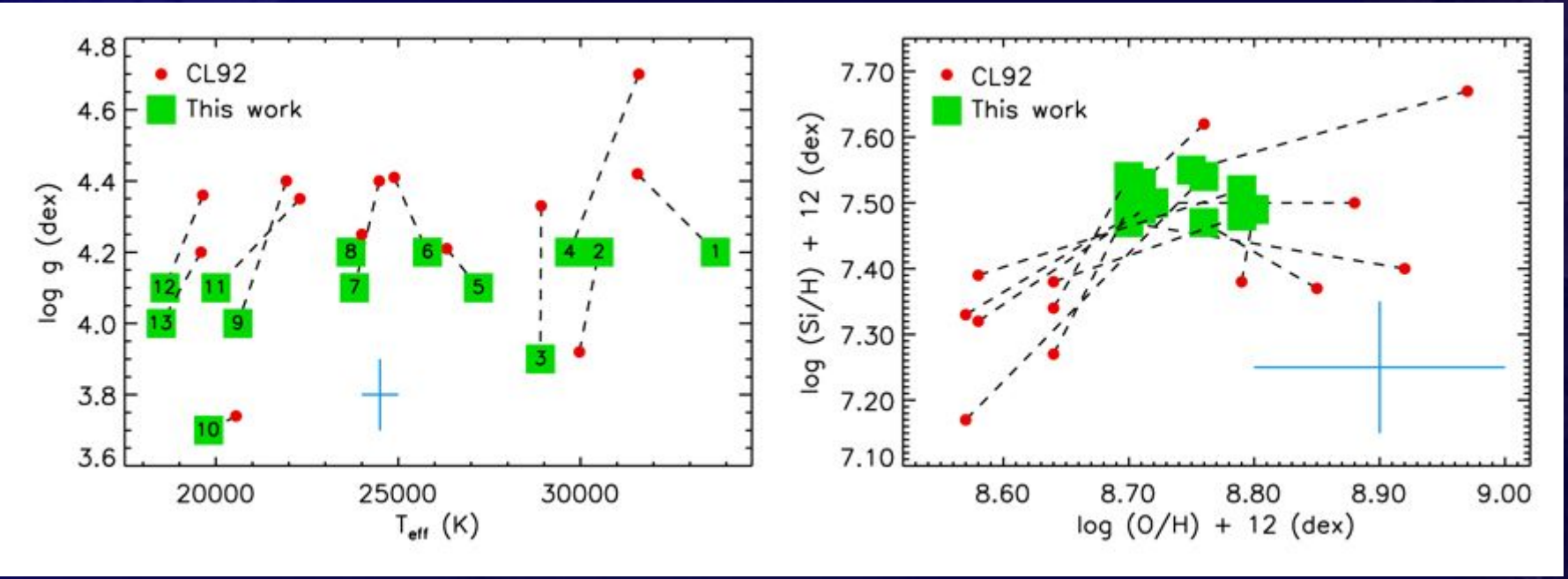
+ Self-consistent spectroscopic approach (FASTWIND)



FIES@NOT2.5m: R=46000, Spectral range = (3700-7300 A), SNR > 250

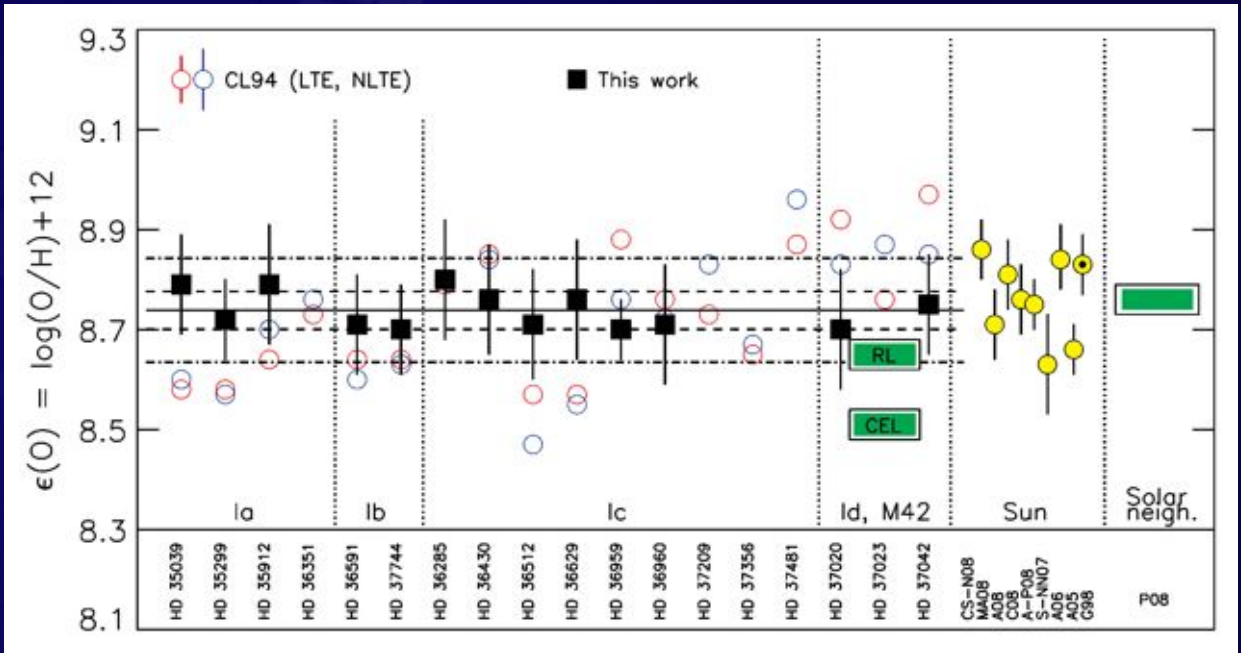
A new analysis of the B-type stars in Ori OB1 *(Simón-Díaz 2010)*

Simón-Díaz (2010) vs Cunha & Lambert (1992)



A new analysis of the B-type stars in Ori OB1 *(Simón-Díaz 2010)*

Summary of main results regarding oxygen abundances



Orion OB1
Simón-Díaz (2010)
ε(O) = 8.73 +/- 0.04

Solar neighbourhood
Przybilla et al (2008)
Nieva & Przybilla (2012)
ε(O) = 8.76+/-0.05

BA-Sgs < 1Kpc
Przybilla et al.
ε(O) = 8.78 +/- 0.03

- Homogeneous set of oxygen abundances
- Scatter (0.04) < intrinsic uncertainties (0.10)
- Newly formed stars contaminated by SN II?
- Same mean value and scatter as in the rest of the Solar neighbourhood

A new analysis of the B-type stars in Ori OB1 *(Nieva & Simón-Díaz 2011)*

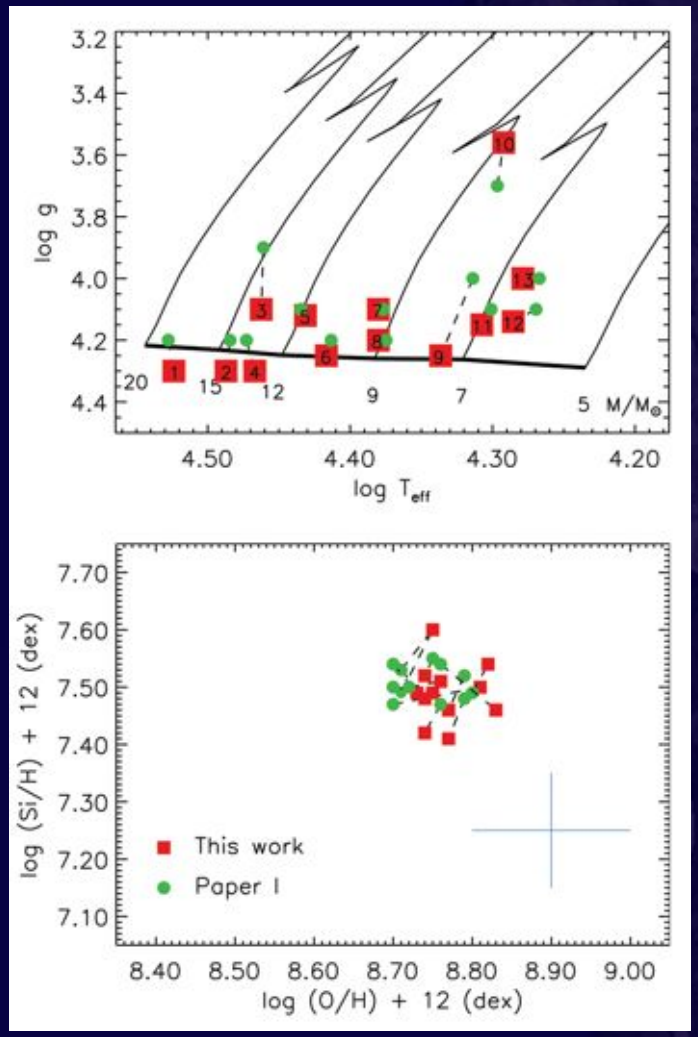
Simón-Díaz (2010)

* O and Si abundances
* Spectroscopic approach: FASTWIND
* Curve of growth
* To investigate oxygen depletion onto dust grains: Mg and Fe abundances are also needed

Nieva & Simón-Díaz (2011)

* C, N, O, Ne, Si, Mg, Fe abundances
* Spectroscopic approach: ATLAS+DETAIL+SURFACE
* Spectral synthesis

	ϵ(X)		ϵ(X)
C	8.35 ± 0.03 (0.09)	Si	7.51† ± 0.03 (0.08)
N	7.82 ± 0.07 (0.09)	Mg	7.57 ± 0.06 (0.03)
O	8.74† ± 0.04 (0.10)	Fe	7.50 ± 0.04 (0.10)
Ne	8.09 ± 0.05 (0.09)		

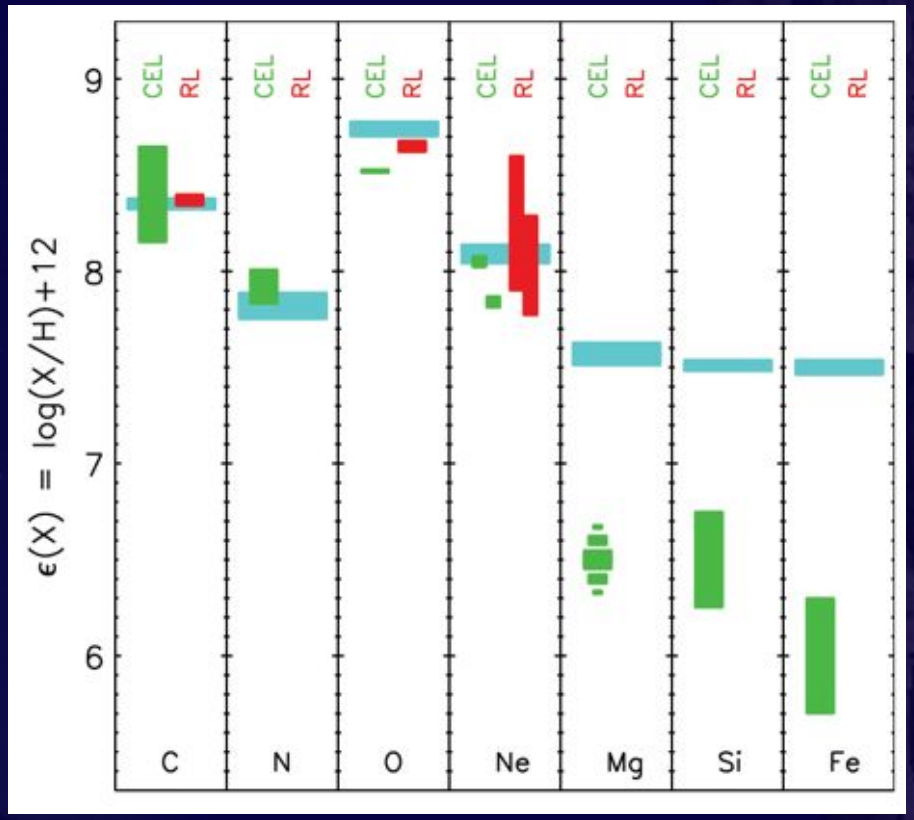


Orion OB1: B-type stars vs nebular (M42) abundances *(Simón-Díaz & Stasinska 2011)*

M42: *Esteban et al. (2004) + own reanalysis*
+ Rubin et al. (1993)
+ Baldwin et al. (1991)
+ Rodriguez & Rubin (2005)

	ϵ(X)		ϵ(X)
C	8.35 ± 0.03 (0.09)	Si	$7.51^{\dagger}$ ± 0.03 (0.08)
N	7.82 ± 0.07 (0.09)	Mg	7.57 ± 0.06 (0.03)
O	$8.74^{\dagger}$ ± 0.04 (0.10)	Fe	7.50 ± 0.04 (0.10)
Ne	8.09 ± 0.05 (0.09)		

A	ϵ(A)	data
C	8.40±0.25	CEL: C III]1907,09
	8.37±0.03	RL: C II
N	7.92±0.09	CEL: [N II]6584
O	8.52 ±0.01	CEL: [O III]5007, [O II]3727
	8.65±0.03	RL: O II
Ne	8.05±0.03	CEL: [Ne III]3869
	7.84±0.03	CEL: [Ne III]3869
	8.25±0.35	RL: Ne II
	8.03±0.26	RL: Ne II
S	6.87±0.06	CEL: [S III]9069
Ar	6.39±0.03	CEL: [Ar III]7135
Mg	6.50 ::	CEL: Mg II 2798
Si	6.50±0.25	CEL: Si III]1883,92
Fe	6.0±0.3	CEL: [Fe II], [Fe III], [Fe IV]



Orion OB1: B-type stars vs nebular (M42) abundances *(Simón-Díaz & Stasinska 2011)*

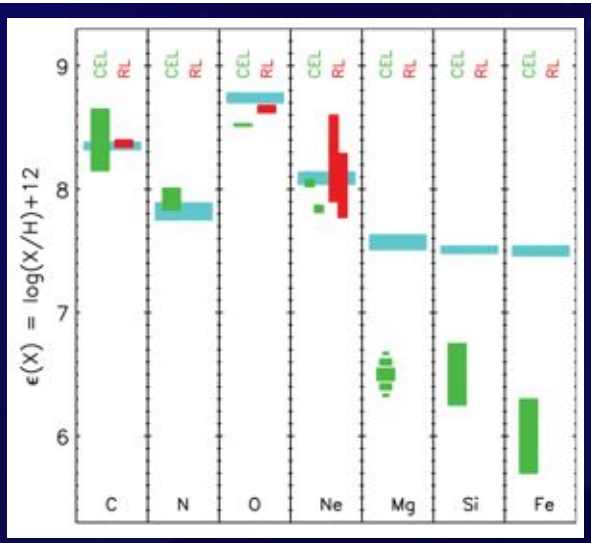
Taking care of dust ...

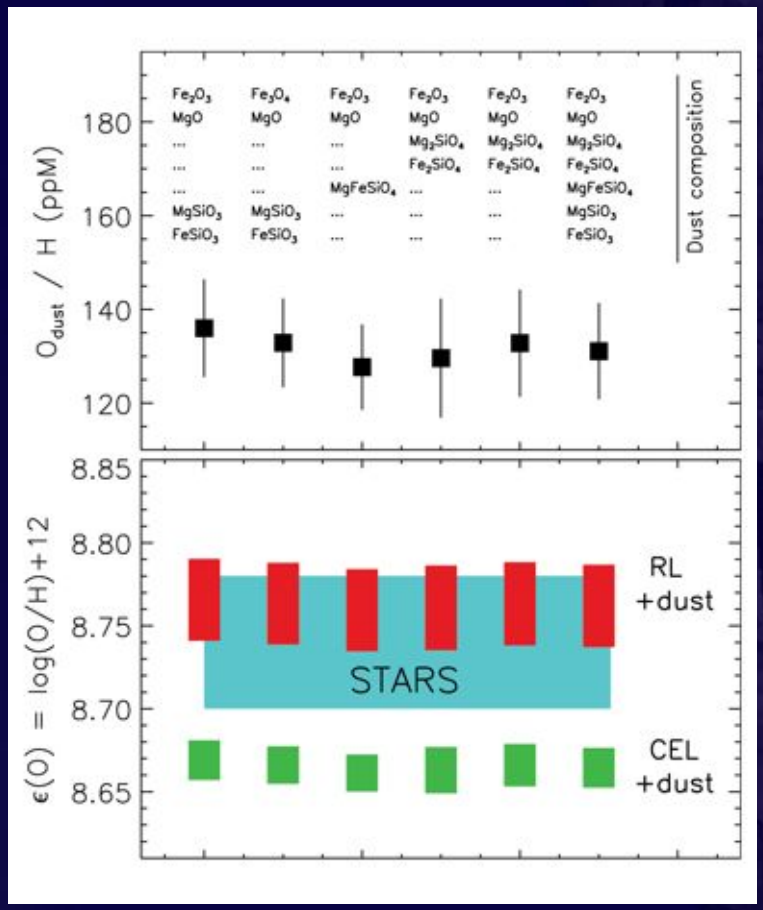
Dust correction (oxygen) = 0.08 dex

Draine (2003)

Table 3: Dust composition possibilities considered in this study

Silicates	Composition
A	$(x)MgSiO_3$, $(1\text{-}x)FeSiO_3$
B	$MgFeSiO_4$
C	$(x)Mg_2SiO_4$, $(1\text{-}x)Fe_2SiO_4$
Others	A+B, A+C, B+C, A+B+C
Mg oxides	**Composition**
	MgO
Fe oxides	**Composition**
	$(x)FeO$, $(y)Fe_2O_3$, $(1\text{-}x\text{-}y)Fe_3O_4$





Oxygen abundances from Massive Stars and HII regions

Do they agree?

Abundace gradients in Spiral galaxies

--- Milky Way (last update) ---

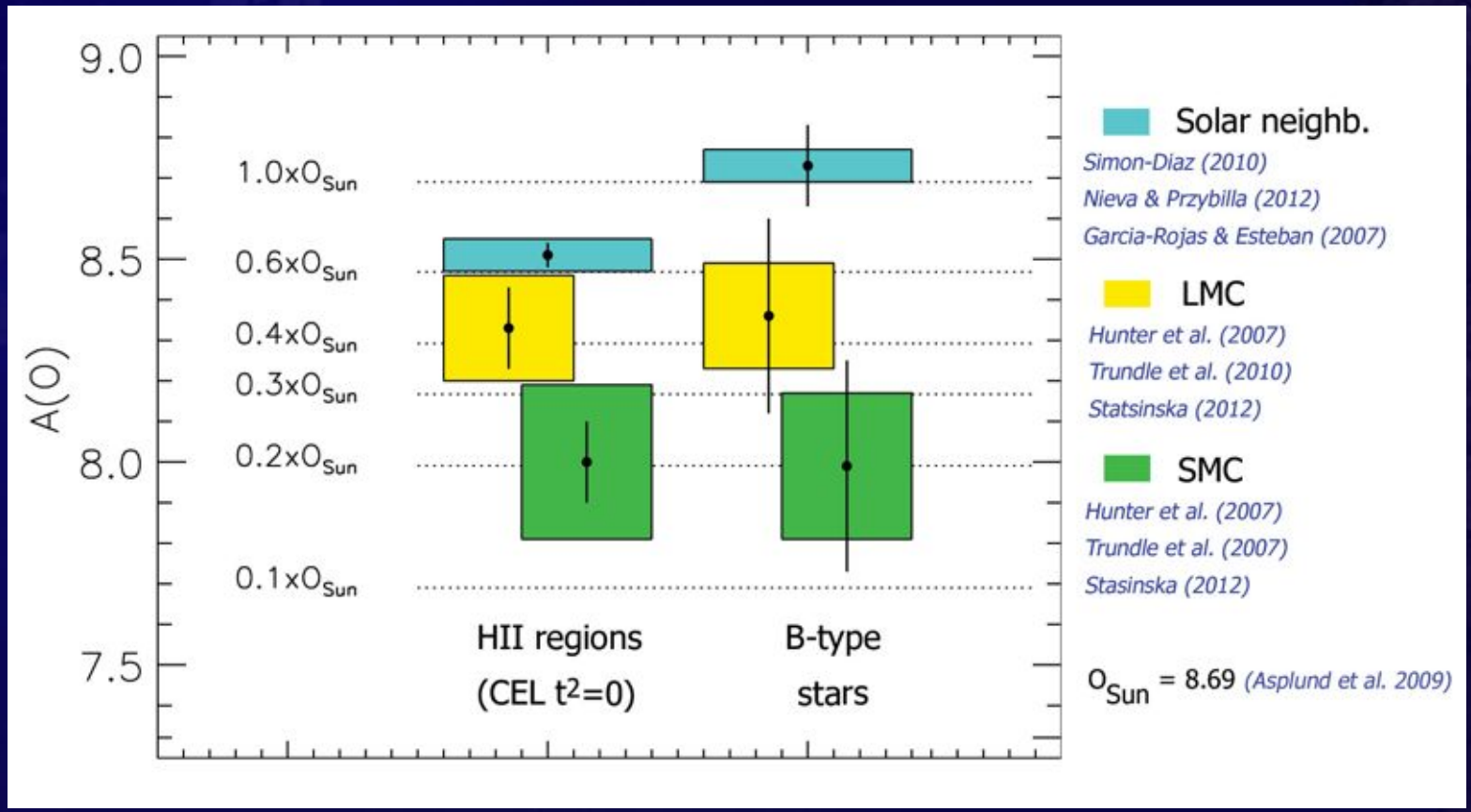
Oxygen abundances from Massive Stars and HII regions

Do they agree?

Oxygen abundance in the

Magellanic Clouds

Oxygen abundances from Massive stars and HII regions: do they agree?



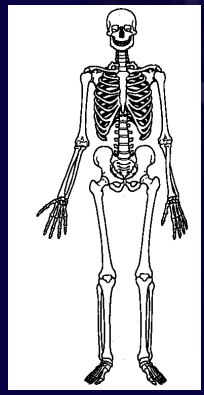
\+ *Tsamis et al. (2003)* find ADF(O^{2+}) > 0.3 dex in the SMC and LMC

Final (personal) notes

Massive stars and HII regions are very valuable tools to measure present-day oxygen abundances across the Universe

We have improved A LOT in the last decades on the reliability of oxygen abudances as derived from OB-type stars. Possible sources of uncertainties and systematics are now controlled

As an outsider, I would say that oxygen abundaces derived from CEL in HII regions seem to be in a problem (but I'm sure this will no be the last word), and this can be a real problem ...



To be continued ...

Discussion session I (Today, 21:00-22:00)

How well do we need to know oxygen abundance? How important is an absolute scale? (*led by Leticia Carigi*)

Discussion session II (Wednesday, 21:00-22:00)

Tracking the biases: comparison of abundances in the same site from various indicators (*led by Grazyna Stasinska*)

Discussion session III (Friday, 14:30-15:30)

Oxygen abundance gradients in galaxies: are they well understood (*led by Richard Henry*)