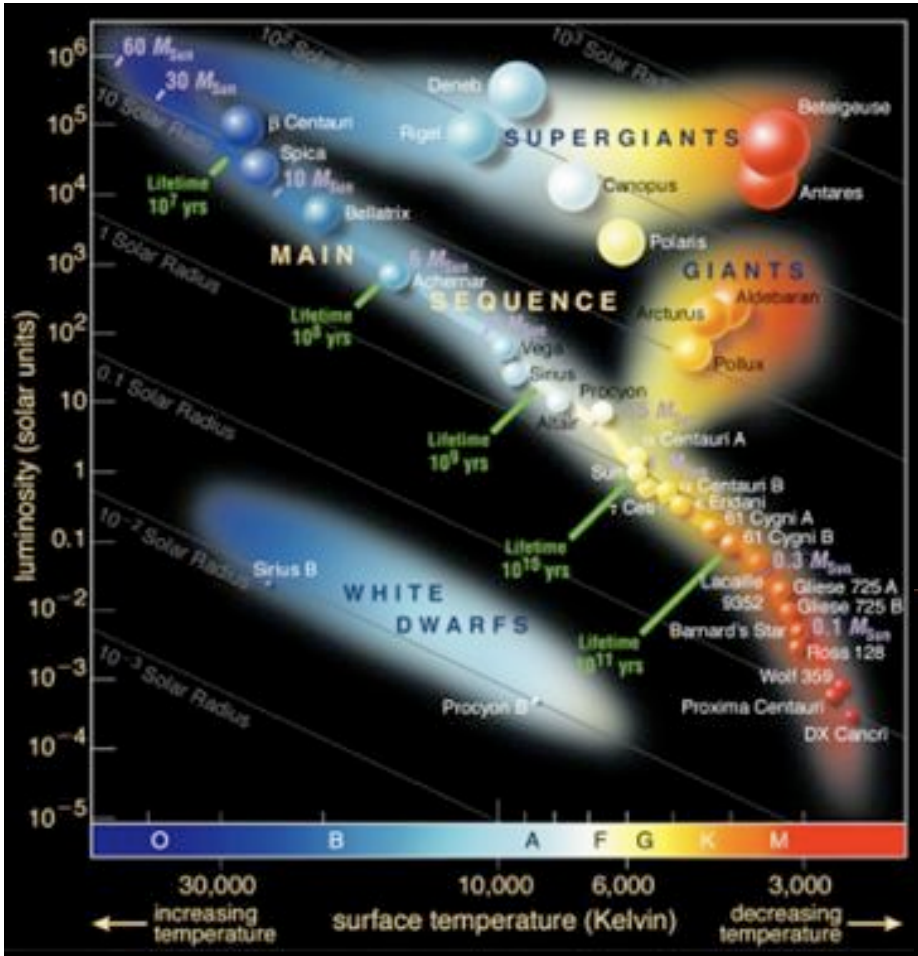
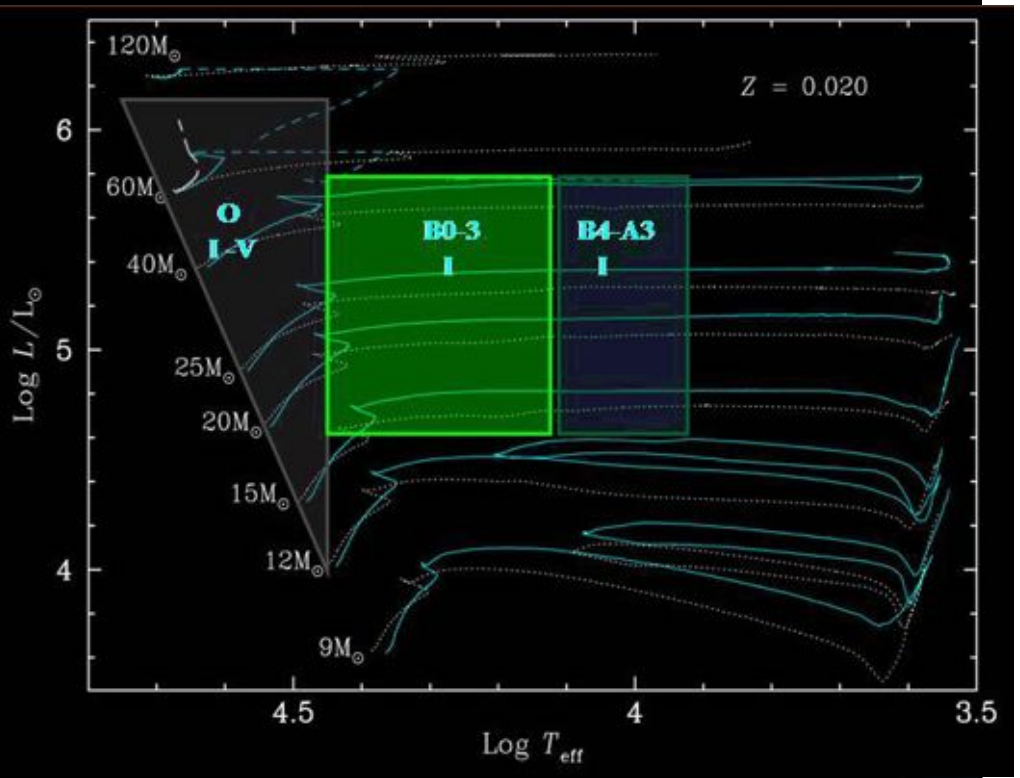
Oxygen abundance determinations in OB dwarf and supergiant stars - Methods & Uncertainties -

Miguel A. Urbaneja

Institute for Astronomy

OB-type Stars





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Mapping Oxygen in the Universe, 2012

OB-type Stars

- Massive and young objects
  - Short evolutionary time-scale
  - Associated with HII regions
- High luminosities
  - Visually brightest normal objects
- Agents of galaxy evolution
  - O, Mg, Si, S, Ti …
  - Mechanical energy
  - Huge radiation fields
- Optical spectra richly populated by metal lines
  - B Sgs : O, N, Si, Mg, C

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How

Observables

$O_\lambda = f(M,L,z)$

$S_\lambda = f(O_\lambda,D,A_v)$

Analysis Tools

$F_\lambda = f(\text{Teff}, \text{logg}, \{\varepsilon_i\})$

$O_\lambda \quad \Leftrightarrow \quad F_\lambda$

Physical properties

Teff, logg, mass ...

The Source...

- Observations
- Model assumptions
- Atomic data
- Analysis
- Incomplete understanding of the stars

- Signal-to-noise
- Metallicity, rotation, SpT
- LTE or non-LTE
- Atomic data
- Teff, logg
- Microturbulence
- Macroturbulence

Stationary, 1D models

- Classic LTE/non-LTE models
  - Plane-parallel, hydrostatic, radiative equilibrium, (UV) blanketing/blocking effects
    - ATLAS (Kurucz 1970)
    - TLUSTY (Hubeny 1988)
    - DETAIL/SURFACE (Butler & Giddings 1985)
- Unified models
  - Non-LTE, spherical geometry, mass outflow, blanketing
    - WM-basic (Pauldrach el al. 2001)
    - PoWR (Hamann & Graefener 2004)
    - CMFGEN (Hillier & Miller 1998)
    - FASTWIND (Puls et al. 2005)

- Atmospheric structure
  - ATLAS9
  - TLUSTY
  - CMFGEN
  - FASTWIND
- Occ. Numbers
  - DETAIL
  - TLUSTY
  - CMFGEN
  - FASTWIND

- Formal Solution
  - SURFACE
  - SYNSPEC
  - CMF_FLUX
  - FASTWIND

$$\sum_{j \neq i} n_i \left(R_{ij} + C_{ij}\right) = \sum_{j \neq i} n_j \left(R_{ji} + C_{ji}\right)$$

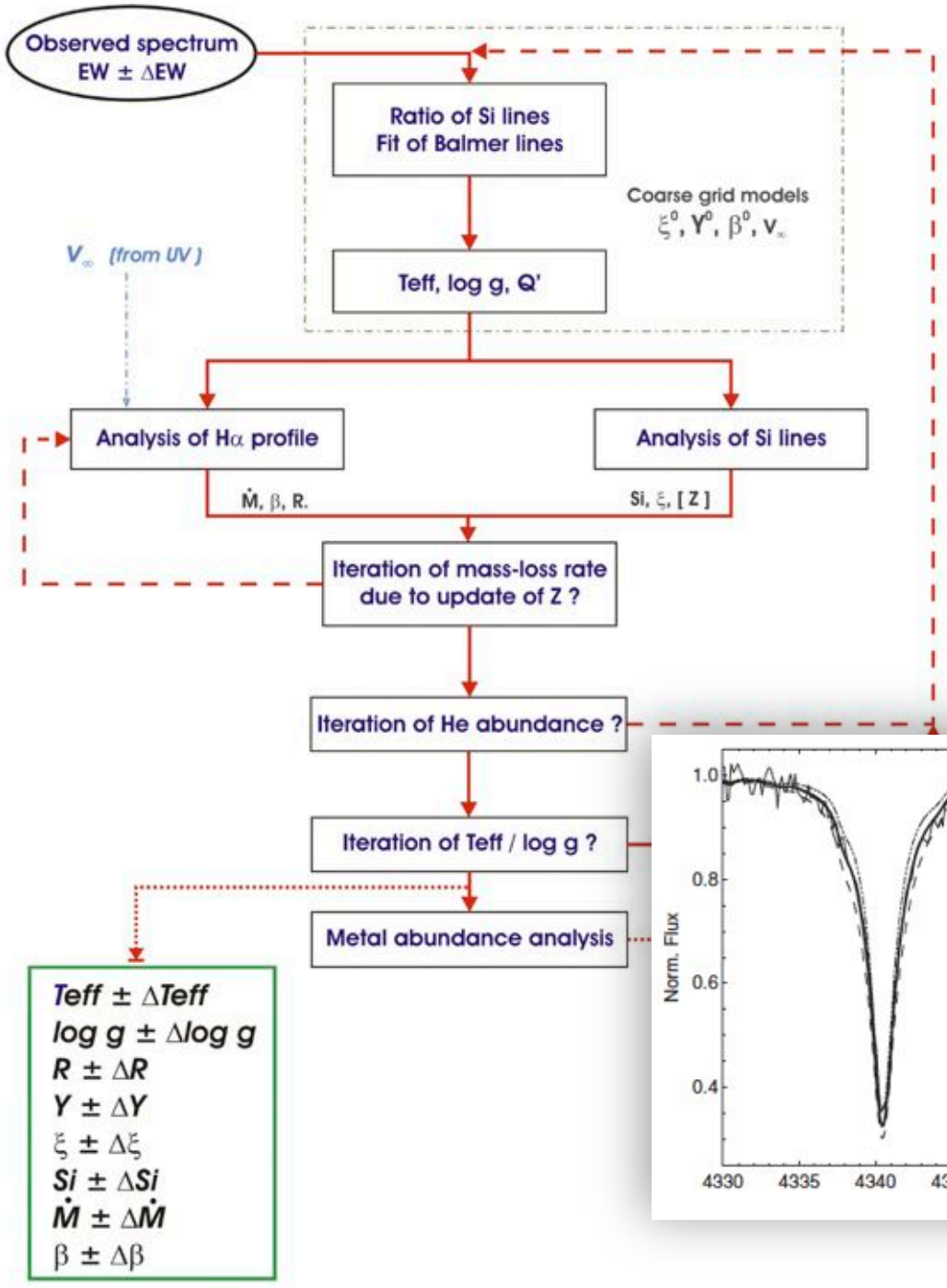
$$C_{ij} = n_e \int \sigma_{ij}(v) f(v) v dv$$

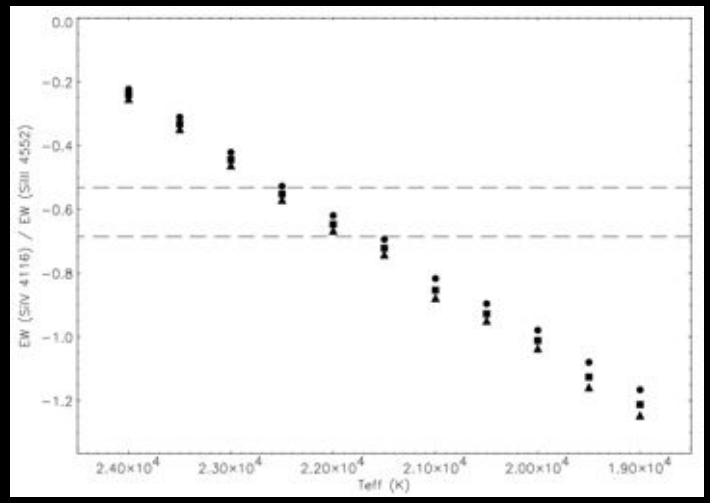
$$R_{ij} = 4\pi \int \sigma_{ij}(\nu) \frac{J_\nu}{h\nu} d\nu$$

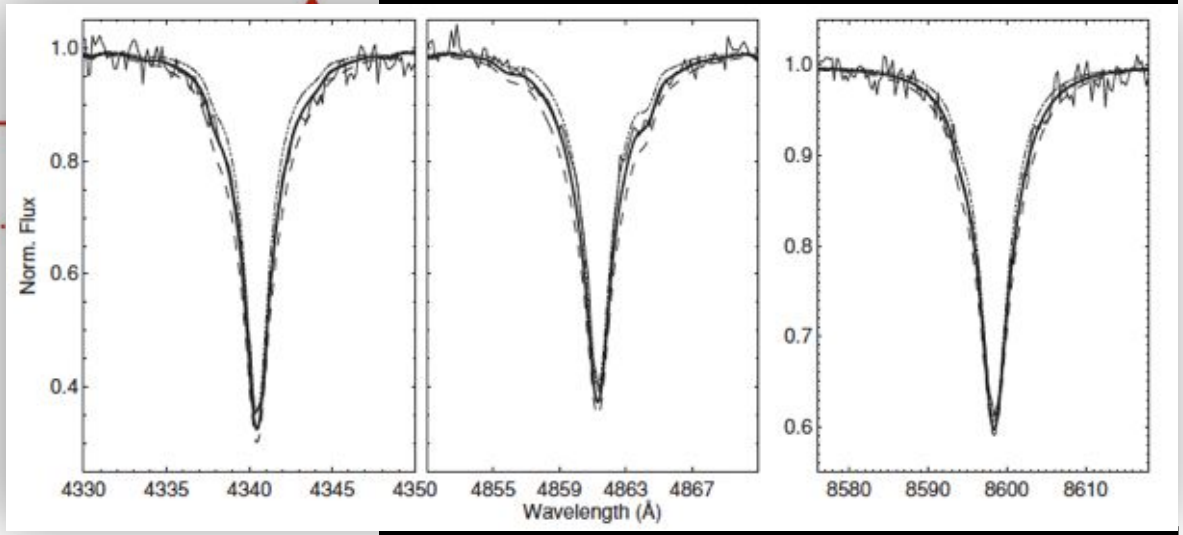
- Accurate determination of level populations implies:
  - Local temperature and particle densities
  - Non-local radiation field
  - Cross-sections
  - All relevant transitions have to be accounted for

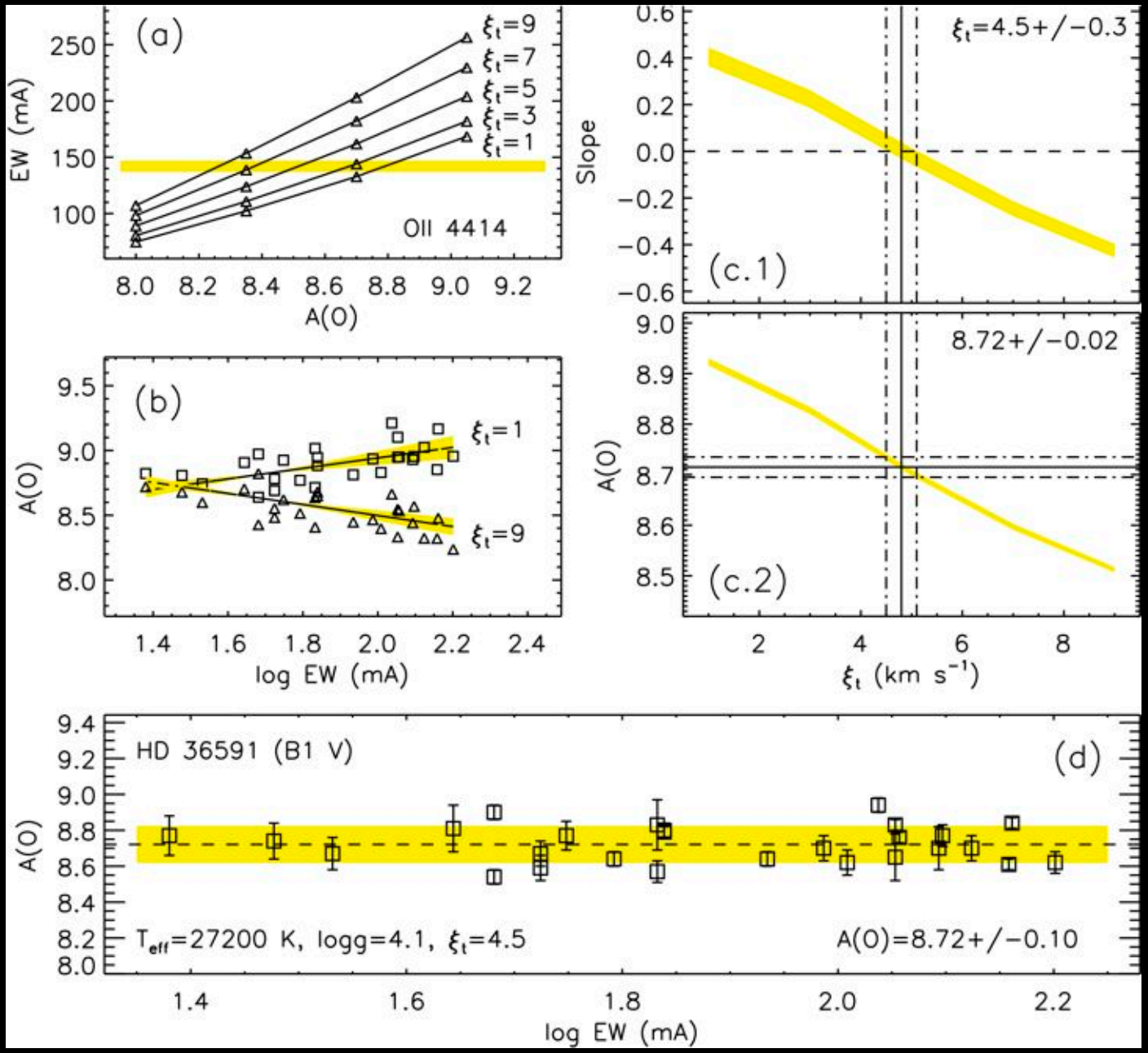
- Atomic physics (microscopic physics)
  - Radiative bound-bound
  - Radiative bound-free: ionizations/recombinations
  - Collisional ionization/recombination (electrons)
  - Collisional bound-bound (electrons)
  - Dielectronic recombination
  - Charge-exchange reactions
  - …

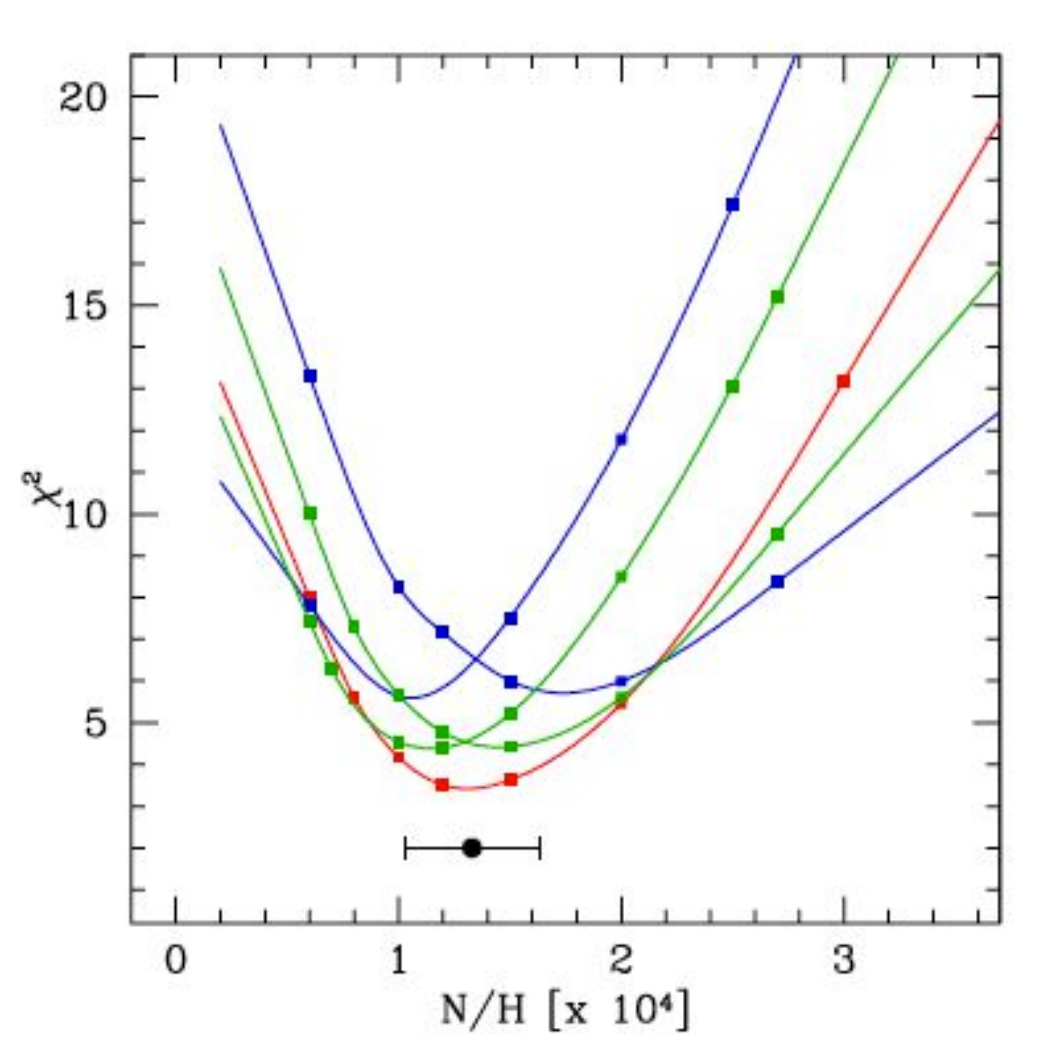
- Teff → ionization equilibrium: He I/II, Si III/IV, O II/III, N II/III, C II/III …
  - Δ Teff < 4-5% (even better when multiple IE available)
- Gravity → H Balmer lines
  - Δ logg ~ 0.10 dex
- Chemical abundances
  - Only a handful of elements show spectral features in the optical spectrum
    - He, C, N, O, Mg, S, Si (Al, Fe)
  - Superb objects for O abundances in distant galaxies
    - Many strong and un-blended O lines
    - Δ log (O/H) < 0.2 dex (dwarfs: ~0.05 dex)


Observed spectrum
EW ± ΔEW
Ratio of Si lines
Fit of Balmer lines
Coarse grid models
ξ⁰, Y⁰, β⁰, v∞
V∞ (from UV)
Teff, log g, Q'
Analysis of Hα profile
Analysis of Si lines
Ṁ, β, R.
Si, ξ, [Z]
Iteration of mass-loss rate due to update of Z ?
Iteration of He abundance ?
Iteration of Teff / log g ?
Metal abundance analysis
Teff ± ΔTeff
log g ± Δlog g
R ± ΔR
Y ± ΔY
ξ ± Δξ
Si ± ΔSi
Ṁ ± ΔṀ
β ± Δβ


EW (SiIV 4116) / EW (SiIII 4552)
Teff (K)


Norm. Flux
Wavelength (Å)

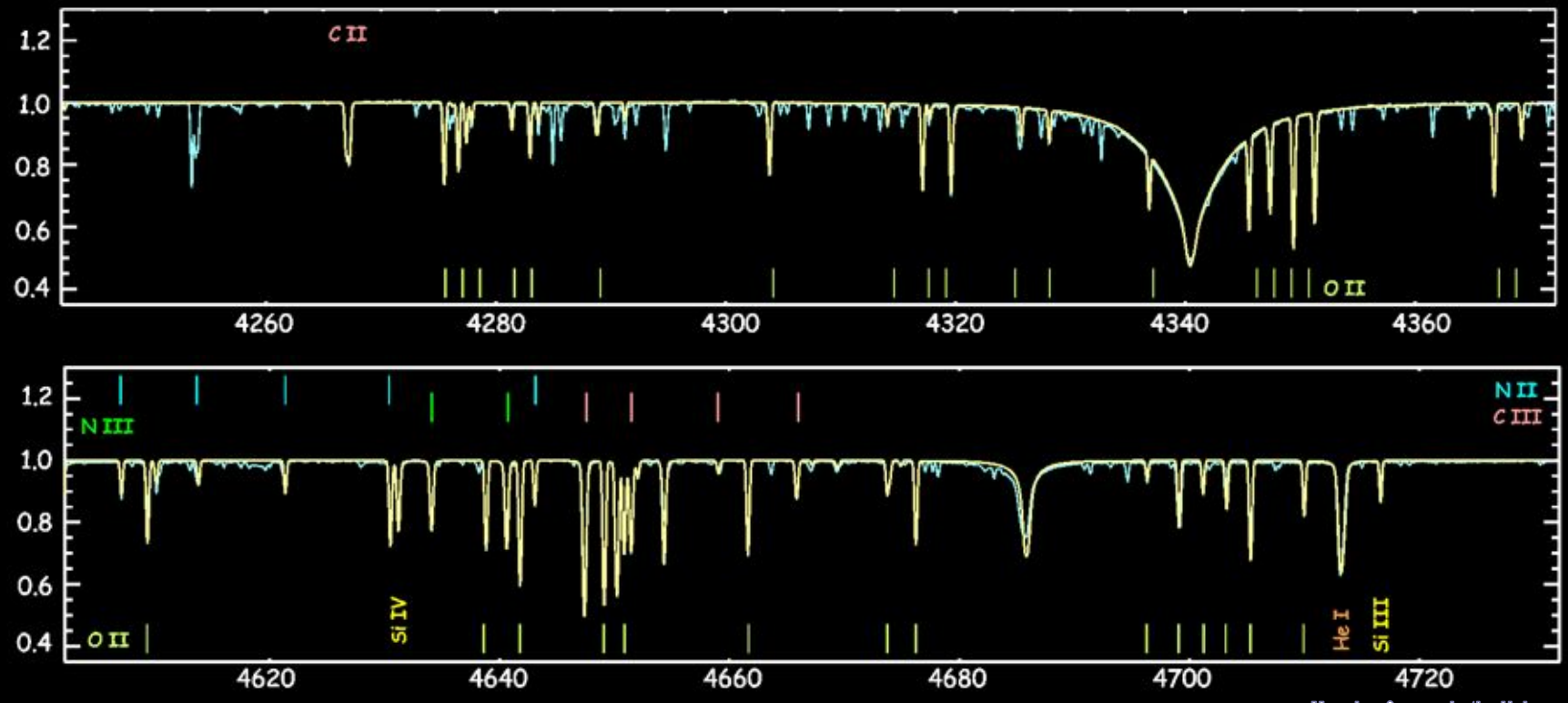

(a)
EW (mA)
A(O)
OII 4414
ξt=9
ξt=7
ξt=5
ξt=3
ξt=1
(b)
A(O)
log EW (mA)
ξt=1
ξt=9
Slope
(c.1)
ξt=4.5+/−0.3
(c.2)
A(O)
8.72+/−0.02
ξt (km s−1)
(d)
HD 36591 (B1 V)
Teff=27200 K, logg=4.1, ξt=4.5
A(O)=8.72+/−0.10
log EW (mA)

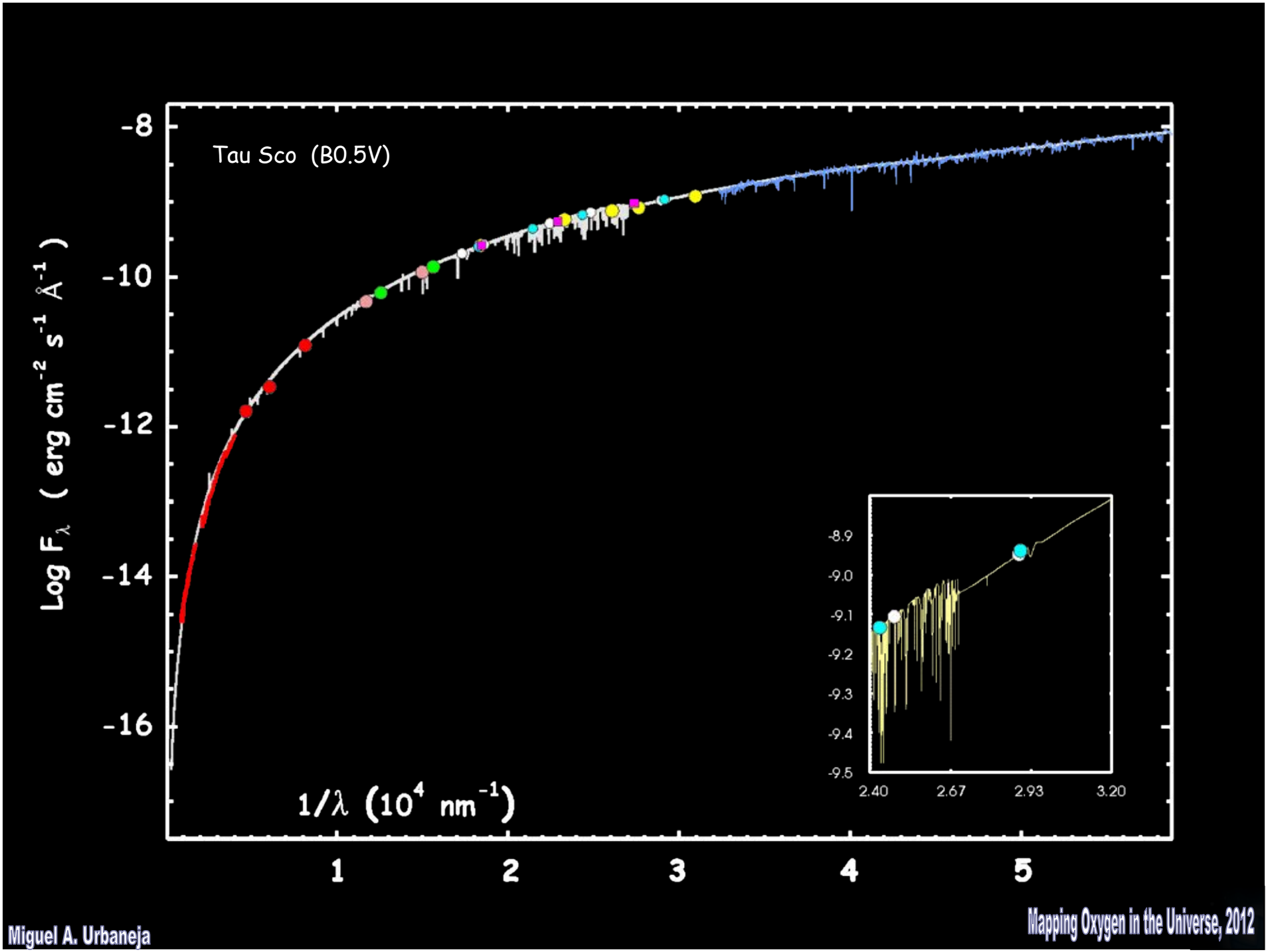


Martins et al. (2012)

Tau Sco

Teff	Log g	Micro	Log(O/H)+12	Comment
32000.	4.30	5.0	8.77 +/- 0.08 [51]	ADS – Przybilla et al. (2008)
31500.	4.05	2.0	8.62 +/- 0.20 [34]	ADS – Hubrig et al. (2008)
32000.	4.00	8.7	8.60 +/- 0.10 [14]	FASTWIND – Simon-Diaz et al. (2006)
31400.	4.10	5.0	8.69	CMFGEN – Najarro (el tio sentado ahÍ)




Tau Sco (B0.5V)
Log F_λ (erg cm^{-2} s^{-1} $Å^{-1}$)
-8
-10
-12
-14
-16
$1/\lambda$ (10^4 nm^{-1})
1
2
3
4
5
-8.9
-9.0
-9.1
-9.2
-9.3
-9.4
-9.5
2.40
2.67
2.93
3.20
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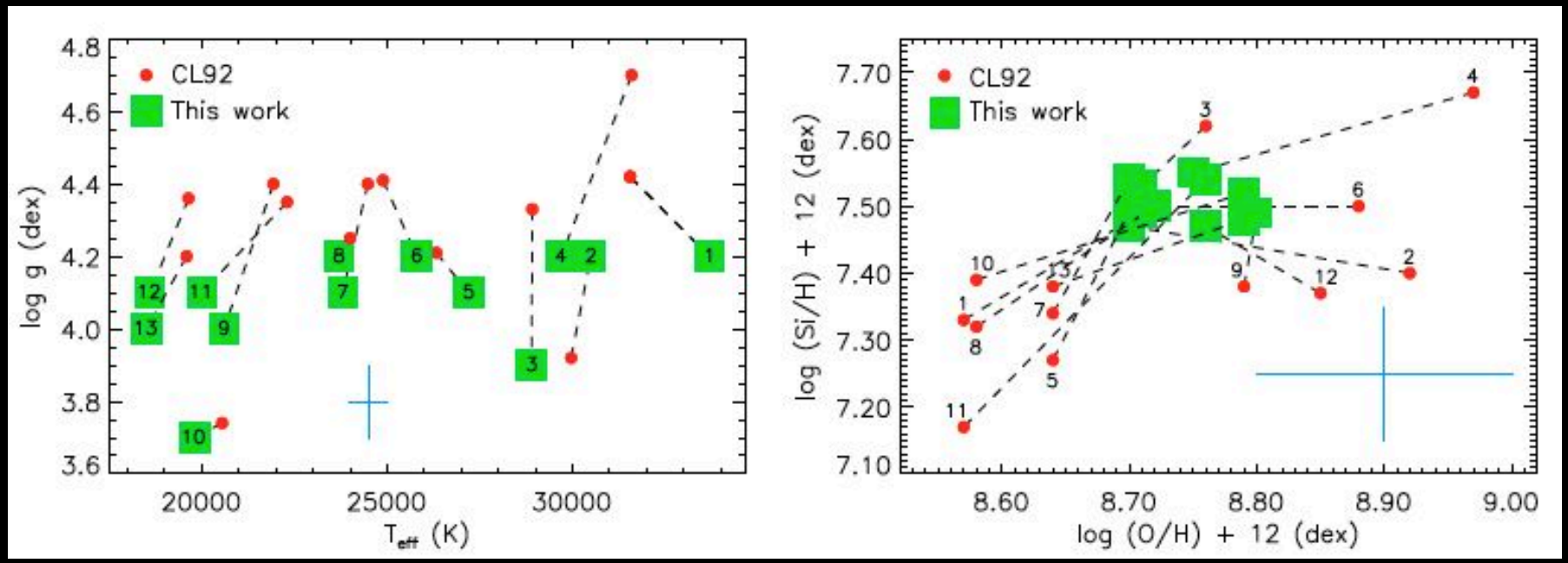
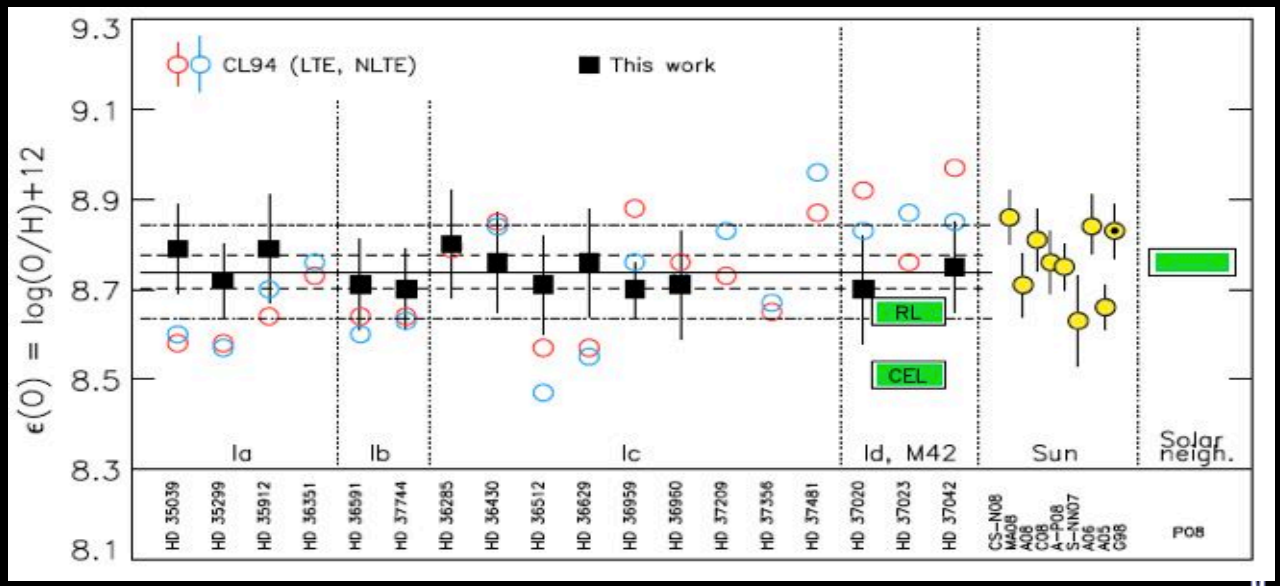
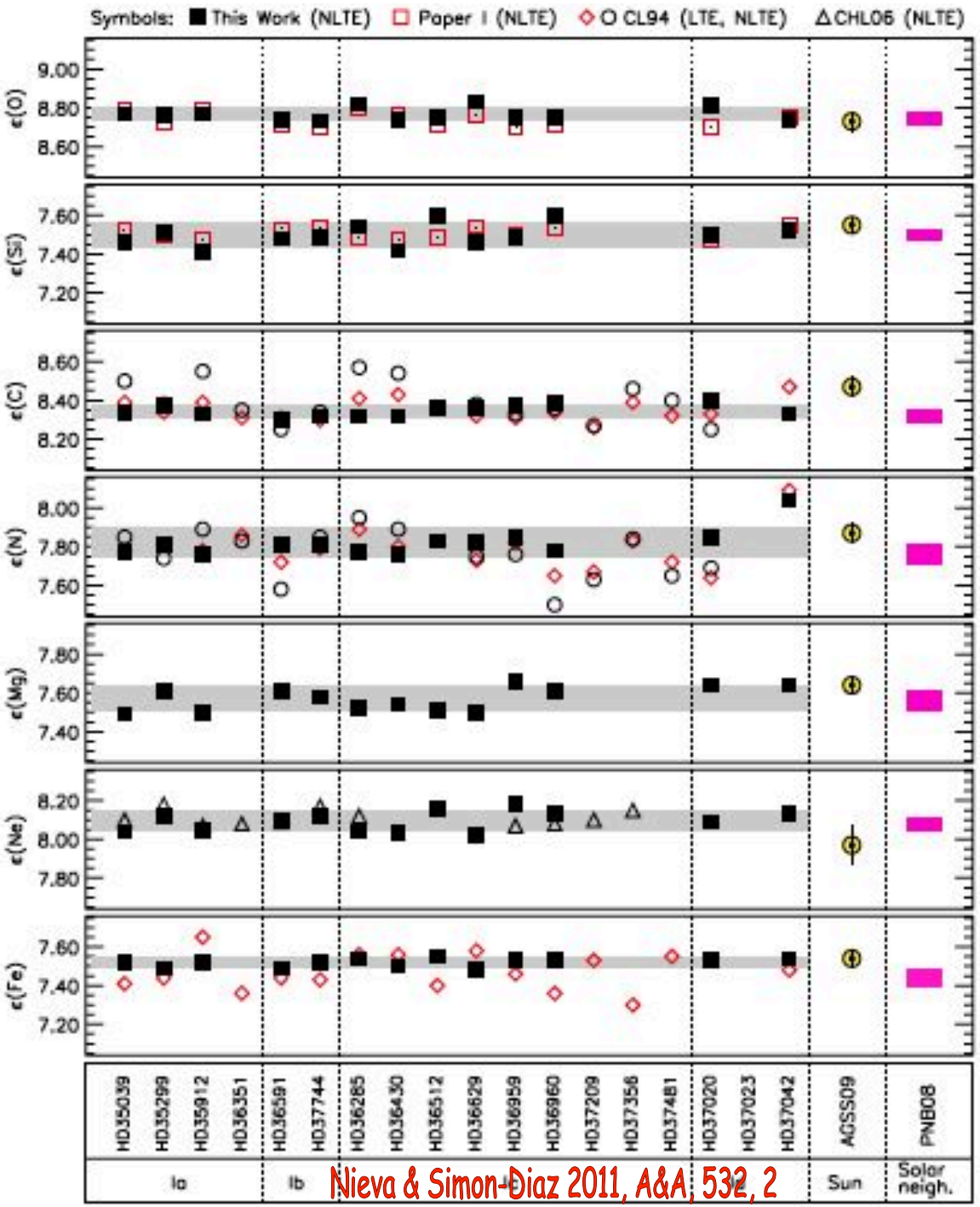


Simon-Diaz 2010, A&A, 510, 22





Nieva & Simon-Diaz 2011, A&A, 532, 2

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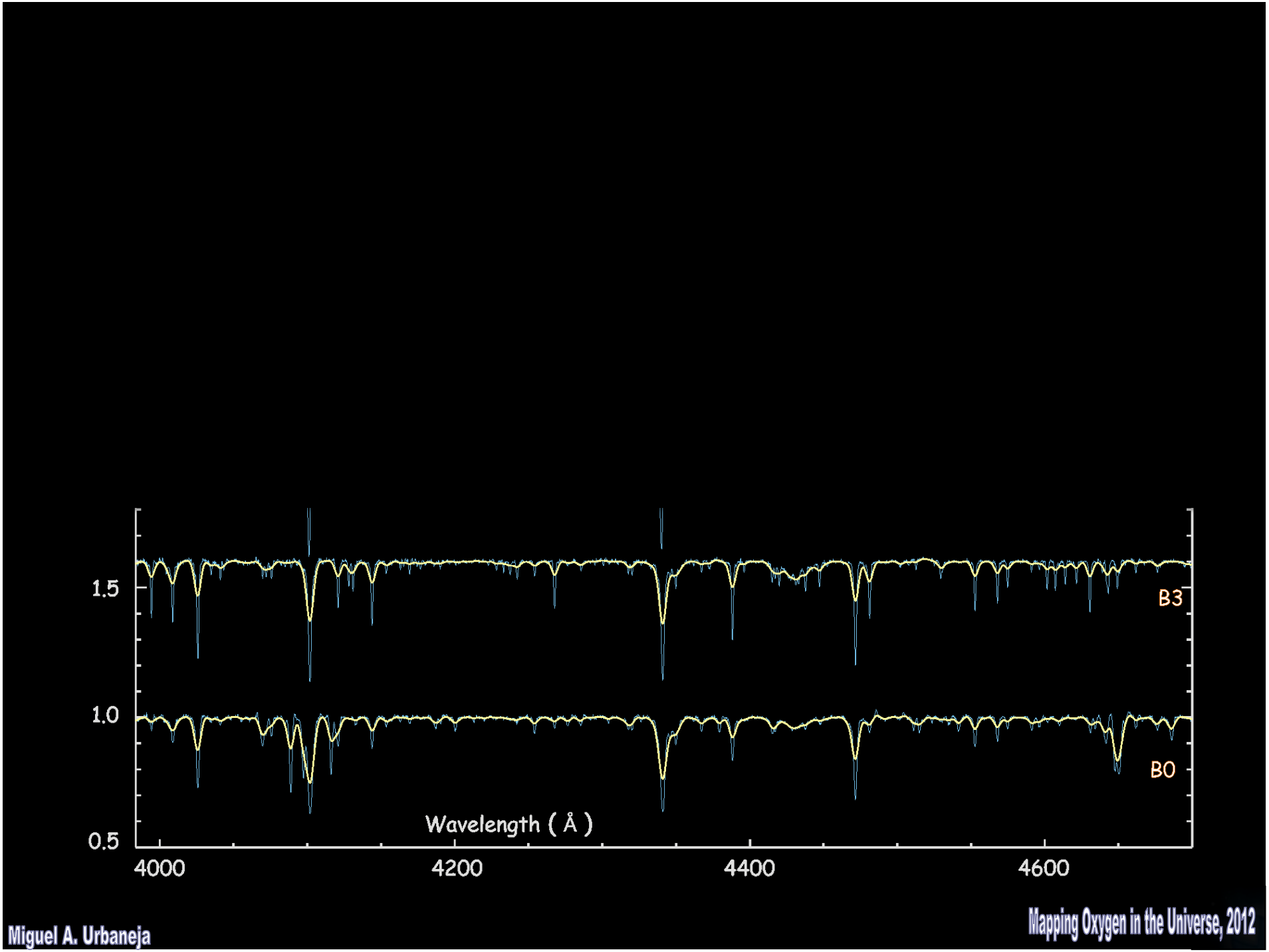
Mapping Oxygen in the Universe, 2012

- Intrinsically bright targets Mv ~ -8.0^{mag}
  - D ~ 1 Mpc m_V ~ 18.0^{mag} M 33
  - D ~ 7 Mpc m_V ~ 22.0^{mag} M 101
  - D ~ 10 Mpc m_V ~ 30.0^{mag} M 74
- MOS feasible with 10m-class telescopes
  - Low / intermediate spectral resolution
    - DEIMOS / Keck II $\Delta\lambda$ ~ 1.5 Å fwhm
    - FOCAS / SUBARU $\Delta\lambda$ ~ 2 Å fwhm
    - IMACS / MAGELLAN $\Delta\lambda$ ~ 2 Å fwhm
    - FORS2 / VLT $\Delta\lambda$ ~ 5 Å fwhm
    - LRIS / Keck I $\Delta\lambda$ ~ 5 Å fwhm
  - Wide spectral coverage
    - High / mid res 400 – 700 nm
    - Low res 360 – 700 nm


1.5
1.0
0.5
B3
B0
Wavelength (Å)
4000
4200
4400
4600

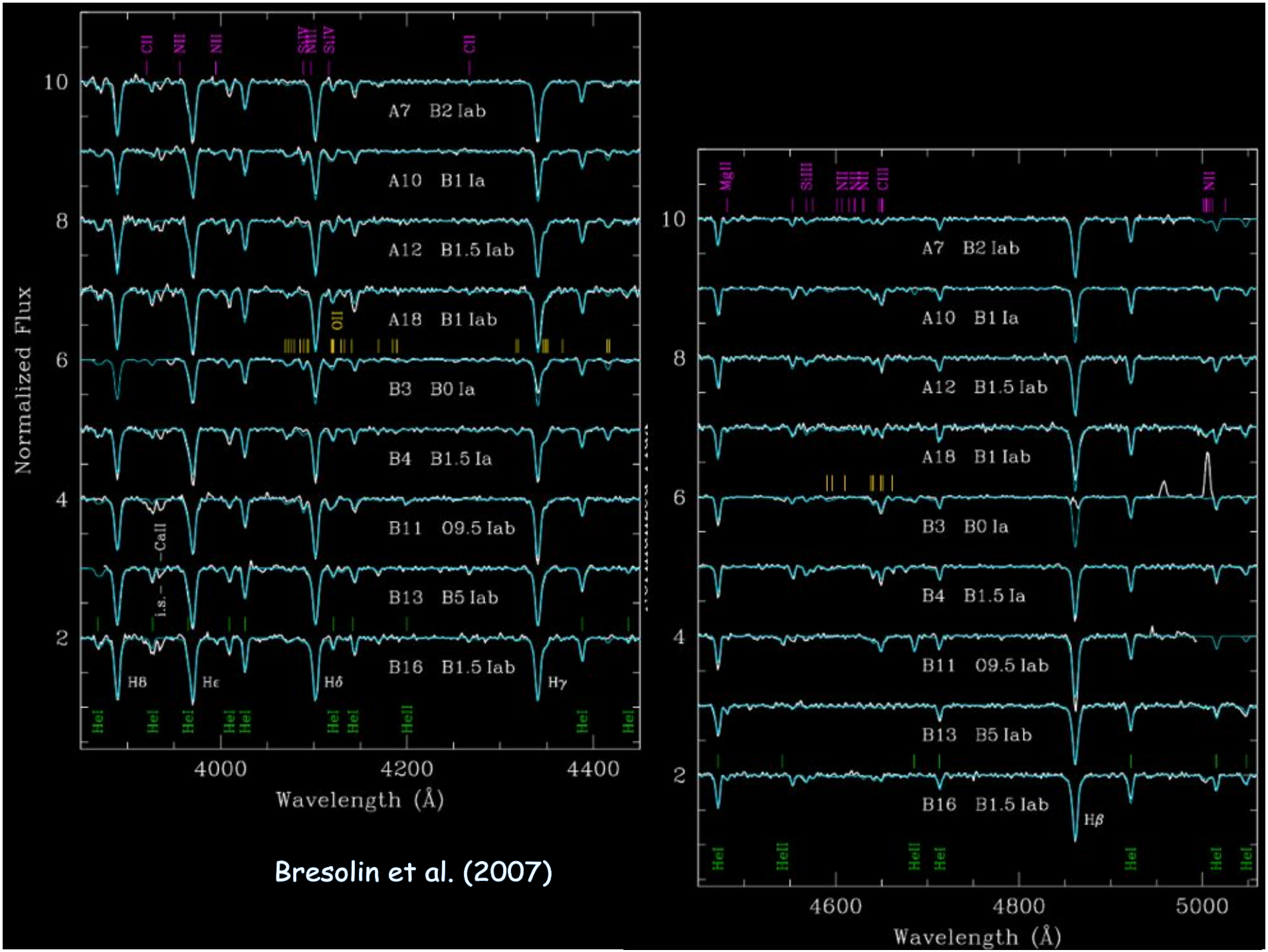
Some O results in OB stars in nearby systems

- LMC/SMC: Hunter et al. (2007)
- SMC: Trundle et al. (2004), Trundle & Lennon (2005), Dufton et al. (2006)

- IC1613 (0.7 Mpc): Bresolin et al. (2007)
- WLM (0.9 Mpc): Bresolin et al. (2006), Urbaneja et al. (2008)

- NGC 3109 (1.3 Mpc): Evans et al. (2007)

- M33 (0.8 Mpc): Urbaneja et al. (2005), U et al. (2009)
- NGC 300 (1.9 Mpc): Urbaneja et al. (2003,2005), Kudritzki et al. (2008)
- NGC 55 (1.9 Mpc): Castro et al. (2012)
- M81 (3.7 Mpc): Kudritzki et al. (2012)



Bresolin et al. (2007)

OB Sgs: Low Res Uncertainties

Table 5. Abundance uncertainties as a function of different stellar parameters for star 22

Element	Upper limit[a]	Lower limit[b]	v_{turb} [−5 kms^{-1}]	ΔHe [+0.2 dex]	ΔHe [−0.2 dex]	ΔZ [+0.2 dex]	ΔlogQ [+0.2 dex]	σ [c]
N	−0.10	−0.01	−0.08	−0.06	−0.03	−0.06	−0.06	0.16
O	−0.02	−0.08	−0.08	−0.08	−0.03	−0.05	−0.05	0.16

Table 6. Abundance uncertainties as a function of different stellar parameters for star 37

Element	Upper limit[a]	Lower limit[b]	v_{turb} [−5 kms^{-1}]	ΔHe [+0.2 dex]	ΔHe [−0.2 dex]	ΔZ [+0.2 dex]	ΔlogQ [+0.2 dex]	σ [c]
N	−0.05	−0.08	−0.09	−0.08	−0.02	−0.05	−0.05	0.17
O	0.04	−0.14	−0.09	−0.09	−0.01	−0.03	−0.05	0.20
Mg	−0.10	0.05	−0.11	−0.04	−0.02	−0.03	−0.03	0.16
Si	0.08	−0.13	−0.13	−0.08	0.04	0.00	−0.04	0.22

Urbaneja et al. 2005, ApJ, 622, 862
Evans et al. 2007, ApJ, 659, 1198

Questions to be answered

- Microturbulence
- Macroturbulence (supersonic)
- Model atoms: collisions, missing x-sections
- B-type supergiants: do we understand them?
- 3-D effects?
- If there are magnetic fields, would they affect in any way?