Stellar Oxygen in M33

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Mapping O in the Universe
Puerto de la Cruz, 18 May 2012
Artemio Herrero

Stellar O in M33 -- Motivation

- Why Oxygen?
  - Personal reasons

Average time a person can live without…	
Food	1 week
Water	3 days
Sex	Highly controversial
Oxygen	5 minutes

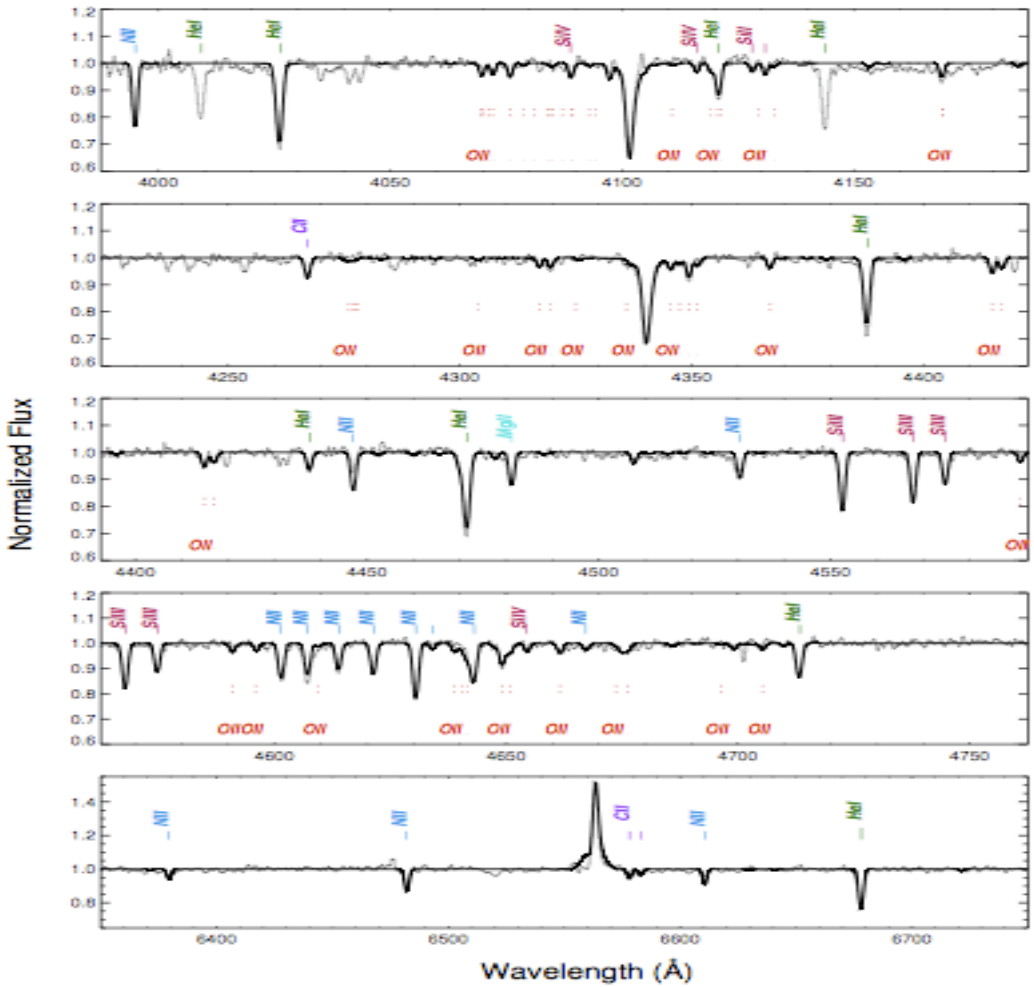
  - Astrophysical reasons
    - Oxygen is the ideal element for comparison to HII regions and their ionizing stars
    - Oxygen is a fundamental element in the evolution of massive stars
    - It reveals the presence of advanced stages of stellar evolution
    - Together with iron, it is a tracer of the Star Formation History

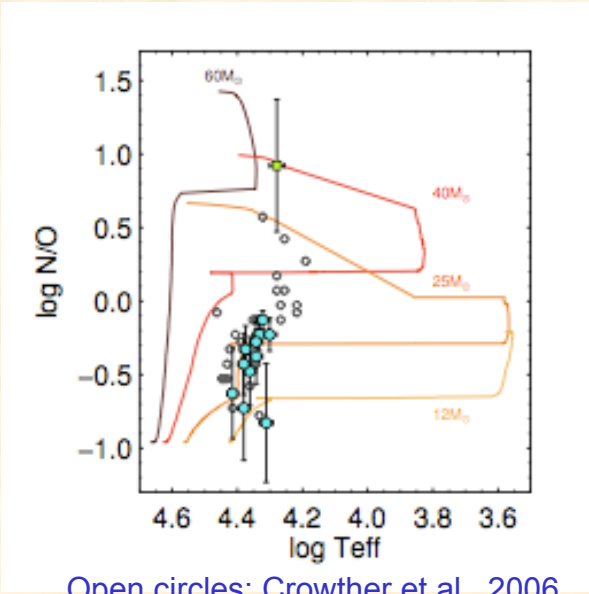
Motivation

- Why M33?
  - Astrophysical reasons
    - M33 is a nearby spiral galaxy seen nearly face-on
    - M33 is a typical spiral galaxy (the number of spiral galaxies with the same mass is very large)
      - We can use it as a proxy for many galaxies in the Universe
    - It has a gradient
      - We can use it to study stars of different metallicities at the same distance
    - We can find peculiar evolutionary states, not easily seen in our Galaxy, at a known distance

UIT005: a case of advanced stellar evolution in M33

- UIT005: B supergiant star with a very weak O spectrum (Urbaneja et al., 2010)





Open circles: Crowther et al., 2006 (Galactic stars)

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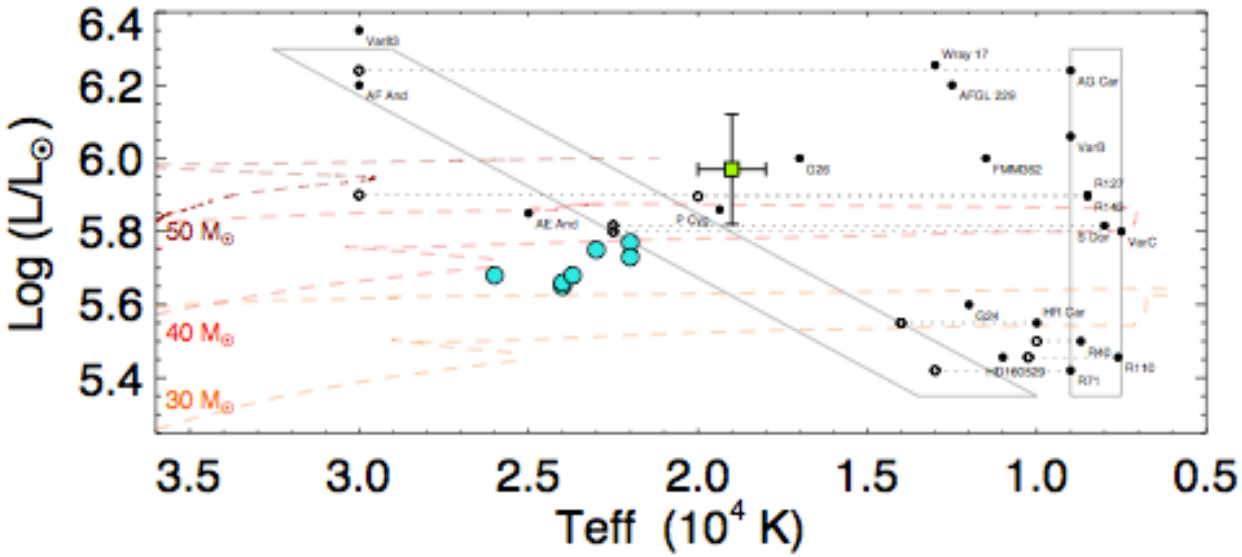

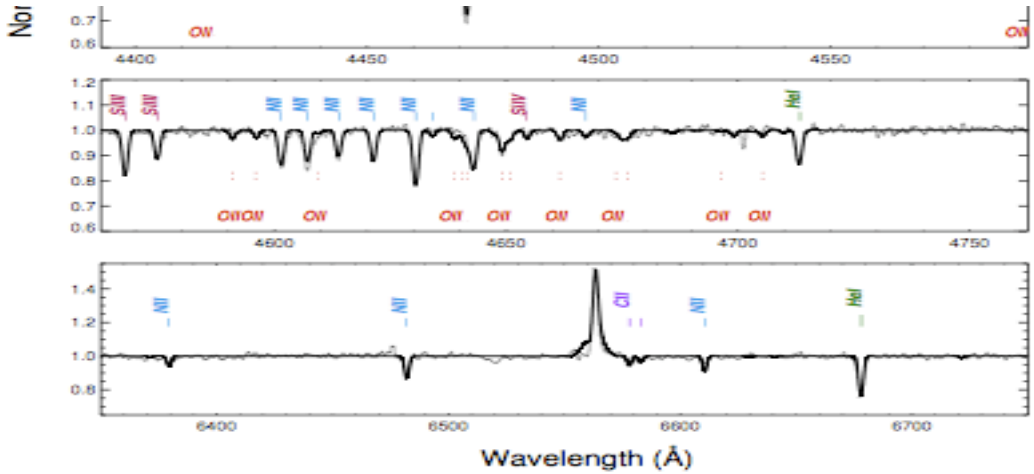

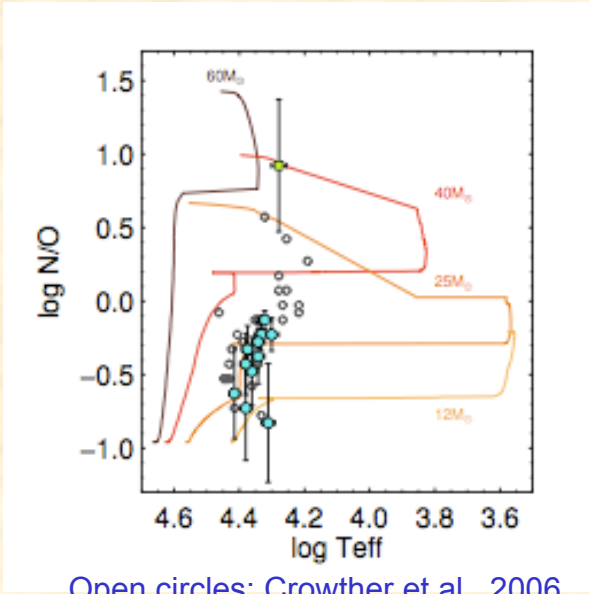

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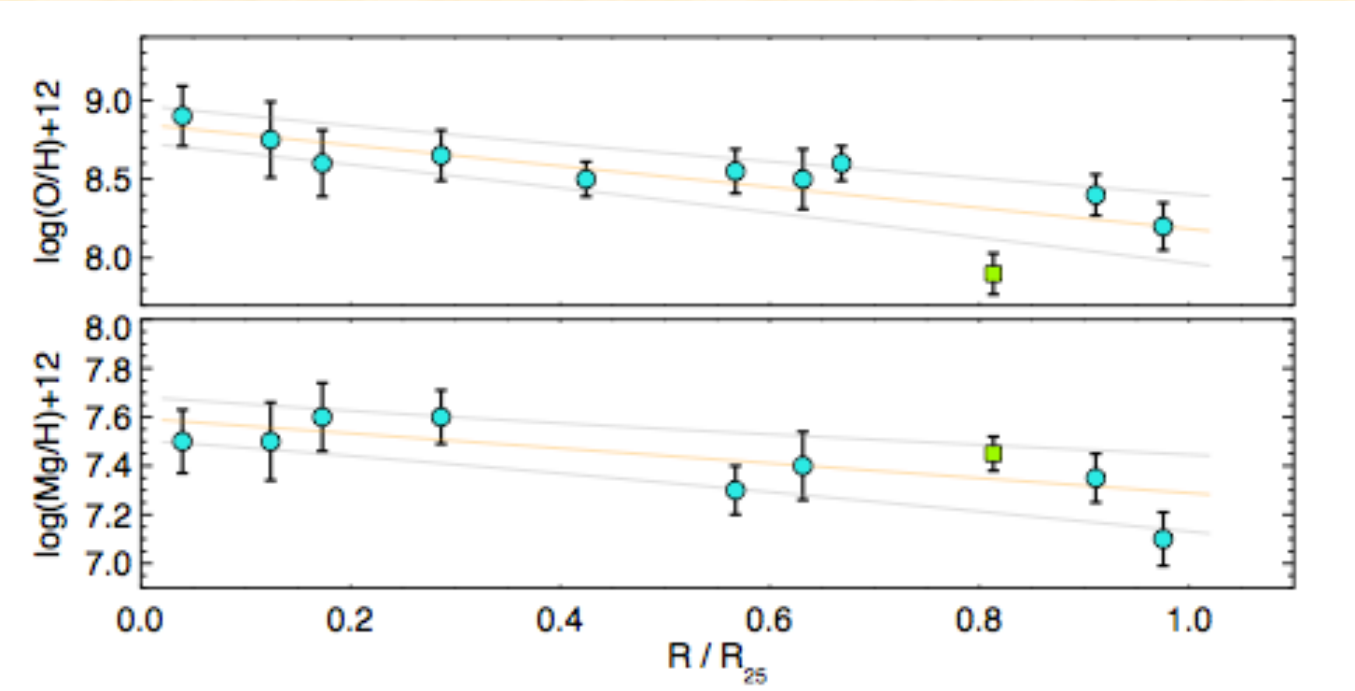
UIT005: a case of advanced stellar evolution in M33

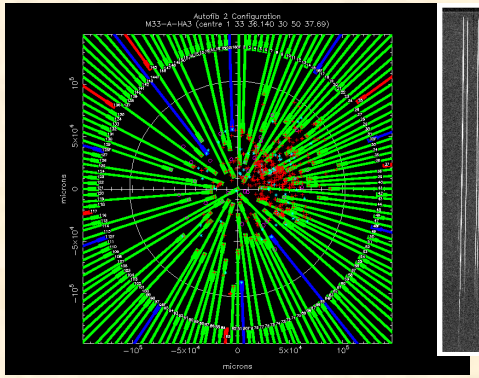
The peculiar status of UIT005 is clear from its position in the M33 radial O-abundance gradient

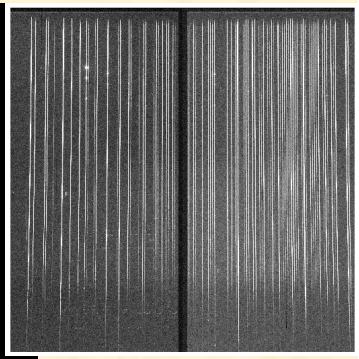


Observing massive stars in M33 with WHT

- Previous analyses of OBA supergiants in M33
  - Monteverde et al. (2000), WHT, 4 stars
  - Urbaneja et al. (2005), WHT+Keck, 11 stars, (7 new)
  - U et al. (2005), Keck, 22 stars (17 new)
  - Total of 28 objects
- We aim at increasing that number
  - For this project, we have used WYFOSS/AF2@WHT.
  - Large Multiplexing: > 100 stars in one single configuration (potentially!)
  - We aim at ~100 stars with V= 17-18 in two fiber configurations
    - Although WYFOSS can allocate > 100 fibers in one run, previous experiences indicate that 50 science objects/run is a realistic goal for M33 (limitation because of fiber collisions)
  - R~2000 → We need to reach SNR > 60 for abundance determinations
- This is a difficult attempt. We have several limitations:
  - Fiber losses (particularly in the blue)
  - Possible companions
  - Nebular contamination

Observing massive stars in M33 with WHT





- We have observed two configurations
  - 96 B-supergiants stars in 2 configurations (40 in a run in 2007; 56 in a run in 2010; other fibers were allocated to a simultaneous programme of LBV and LBV candidates monitoring)
- Stars with spectral types B0-B2.5 are excelent for O abundance determination:
  - strong OII lines without too much blends (Remember: our resolution is low!)
  - Weak dependence of the line EW on temperature for B0.5-B1.5
  - Our sample is restricted to stars of these types with good S/N (24 stars)
    - Typical errors: 10% in Teff, 0.2 in log g, 0.2 in log(O/H)
- Some skeletons (talks on Tuesday by Przybilla, Urbaneja, Nieva, Najarro, Simón-Díaz)
  - Atomic and atmosphere models
  - Crowding and multiplicity
  - Sample contamination by advanced evolutionary stages (UIT005 – like)

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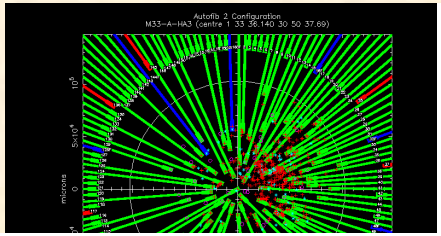

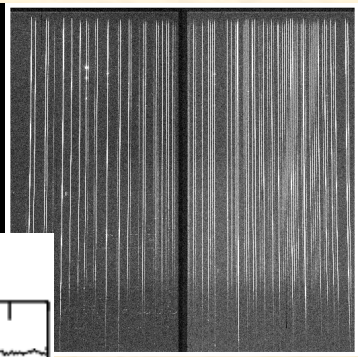

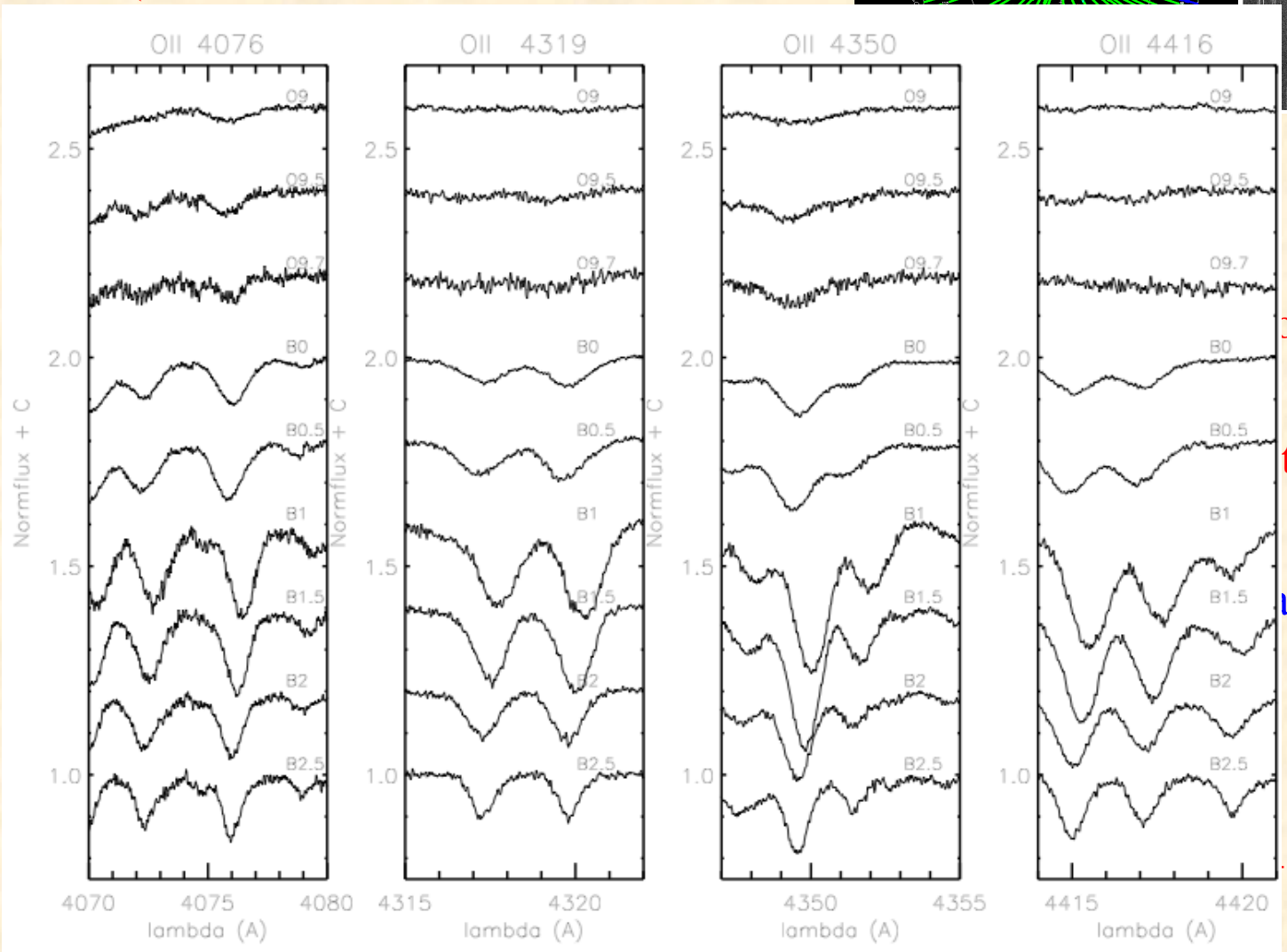

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like)

Analysis of M33 stars -- method

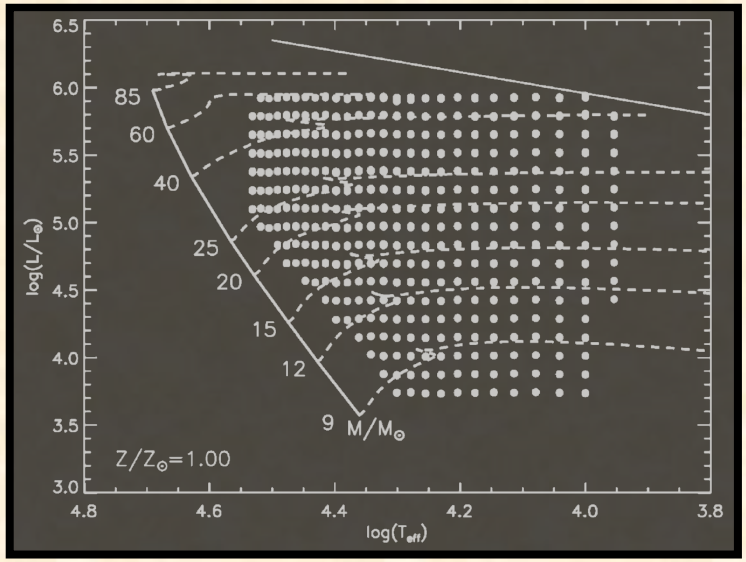
- Automatic method developed by N. Castro (2010, PhD, U. La Laguna), Castro et al. (2012, A&A, in press) (see also Urbaneja et al., 2005, ApJ 622, 862 and Lefever et al., 2007, A&A 463, 1093)

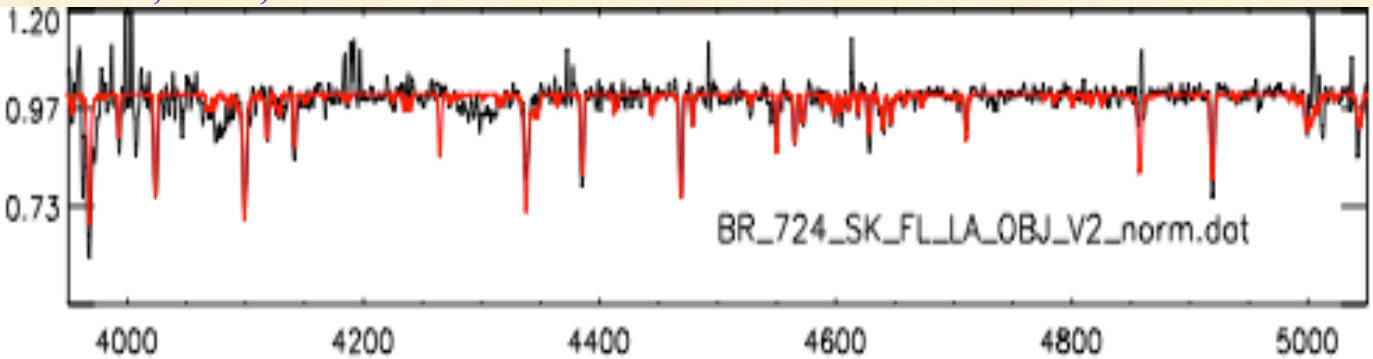
•χ^2-method was designed for comparison with a large model atmosphere grid

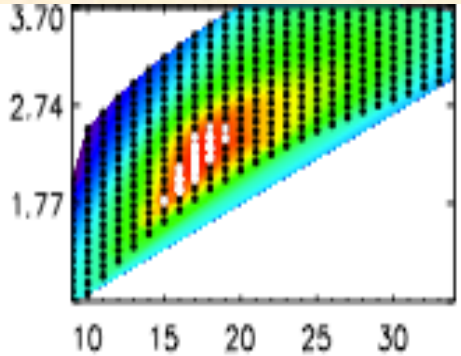
•The match was performed on the main optical H I and He I-II transitions plus the most relevant Si II-III-IV lines available in the observed spectra.

•Those models with a χ^2 lower than certain threshold, defined by the spectra quality, were selected to obtain the stellar parameters: Teff, log g, He/H, ξ, Z, wind strength, β (wind velocity law)

•O abundances are determined using a finer grid of models centered in the determined parameters and selecting by eye the best fit using (mainly) OII 4076, 4319, 4350, 4416

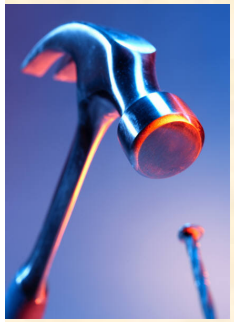




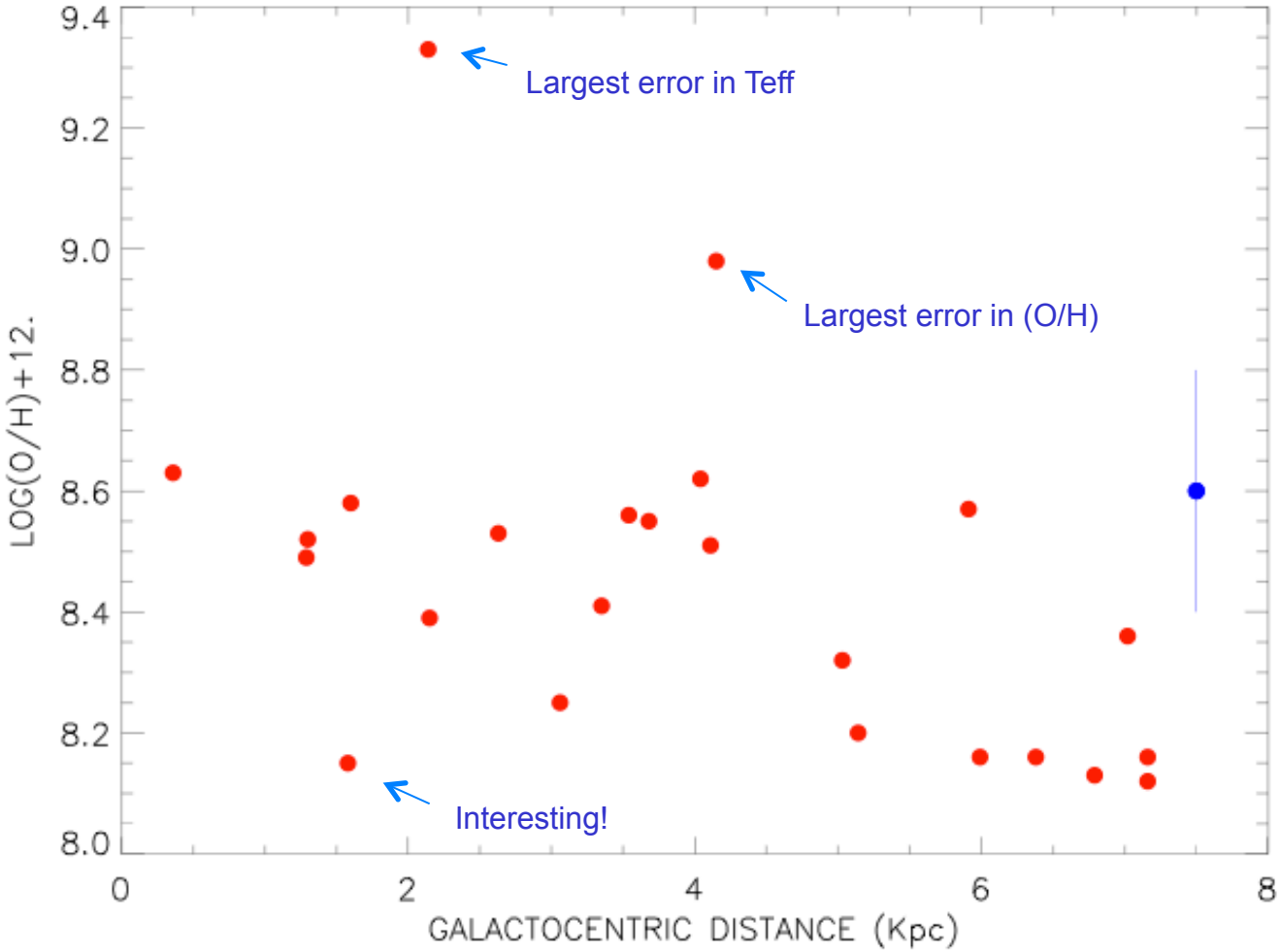


Analysis of M33 stars -- results

$$\log(O/H)+12 = 8.64 \pm 0.06 - 0.06 \pm 0.02\ R$$

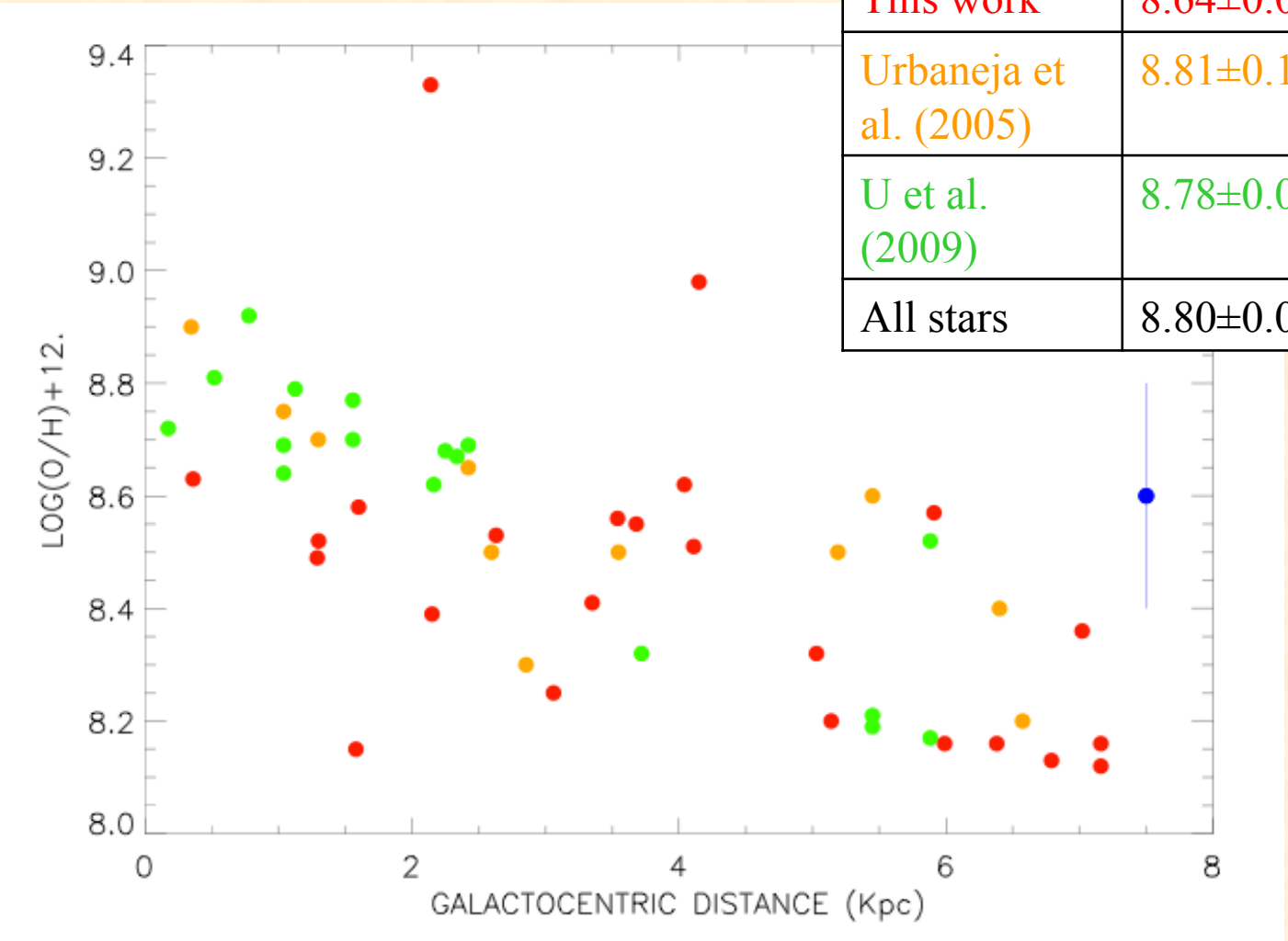


work in progress…



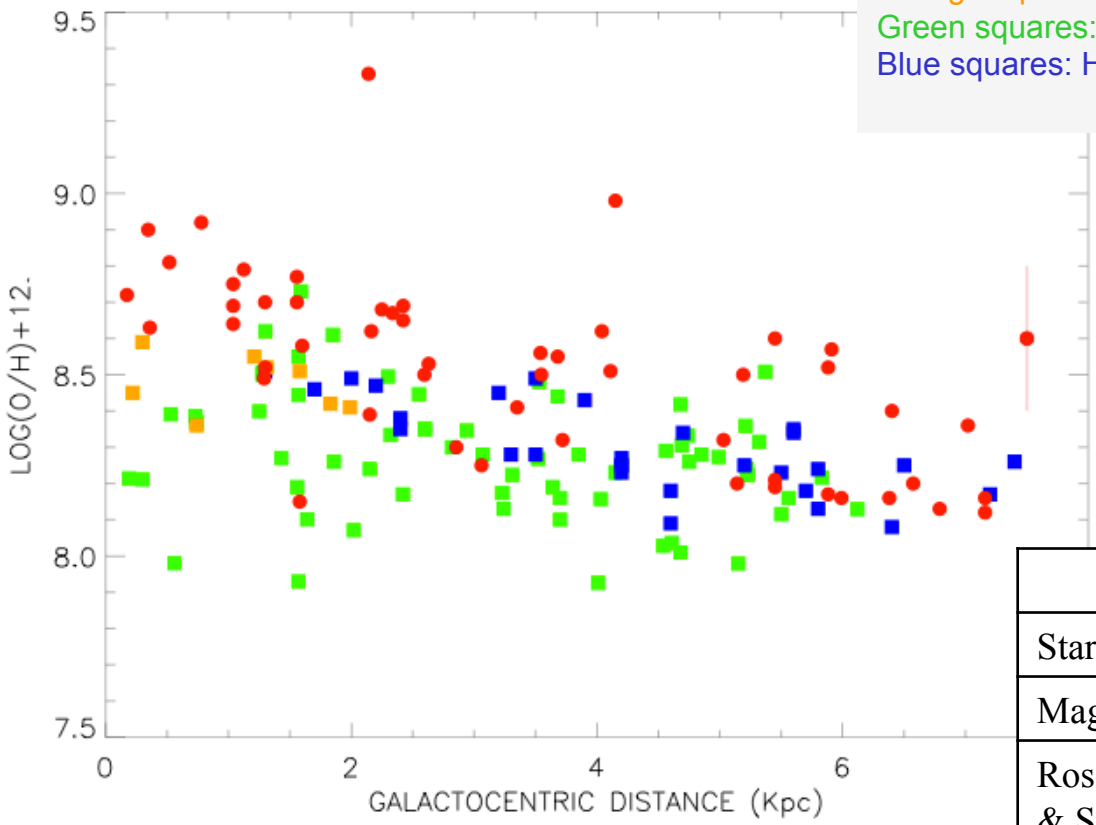
Analysis of M33 stars -- results

	Central O ab.	grad (dex kpc^{-1})
This work	8.64±0.06	-0.06±0.02
Urbaneja et al. (2005)	8.81±0.11	-0.08±0.01
U et al. (2009)	8.78±0.04	-0.07±0.01
All stars	8.80±0.03	−0.09±0.01



Analysis of M33 stars -- results

Red circles: Stars, this work + Urbaneja et al., 2005 + U et al. 2009
Orange squares: HII regions, Bresolin, 2011
Green squares: HII regions, Rosolowsky & Simon, 2008
Blue squares: HII regions, Magrini et al., 2007

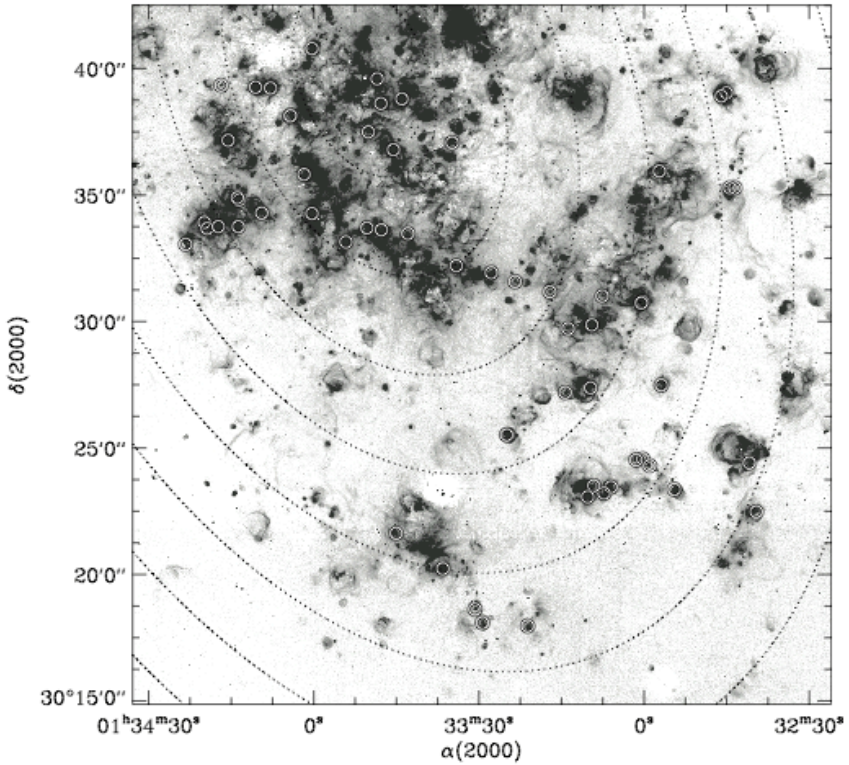


	Central Ab.	grad (dex kpc^{-1})
Stars	8.80±0.03	− 0.09±0.01
Magrini et al.	(8.54±0.03)*	− 0.054±0.011
Rosolowsky & Simon	8.36±0.04	− 0.027±0.012

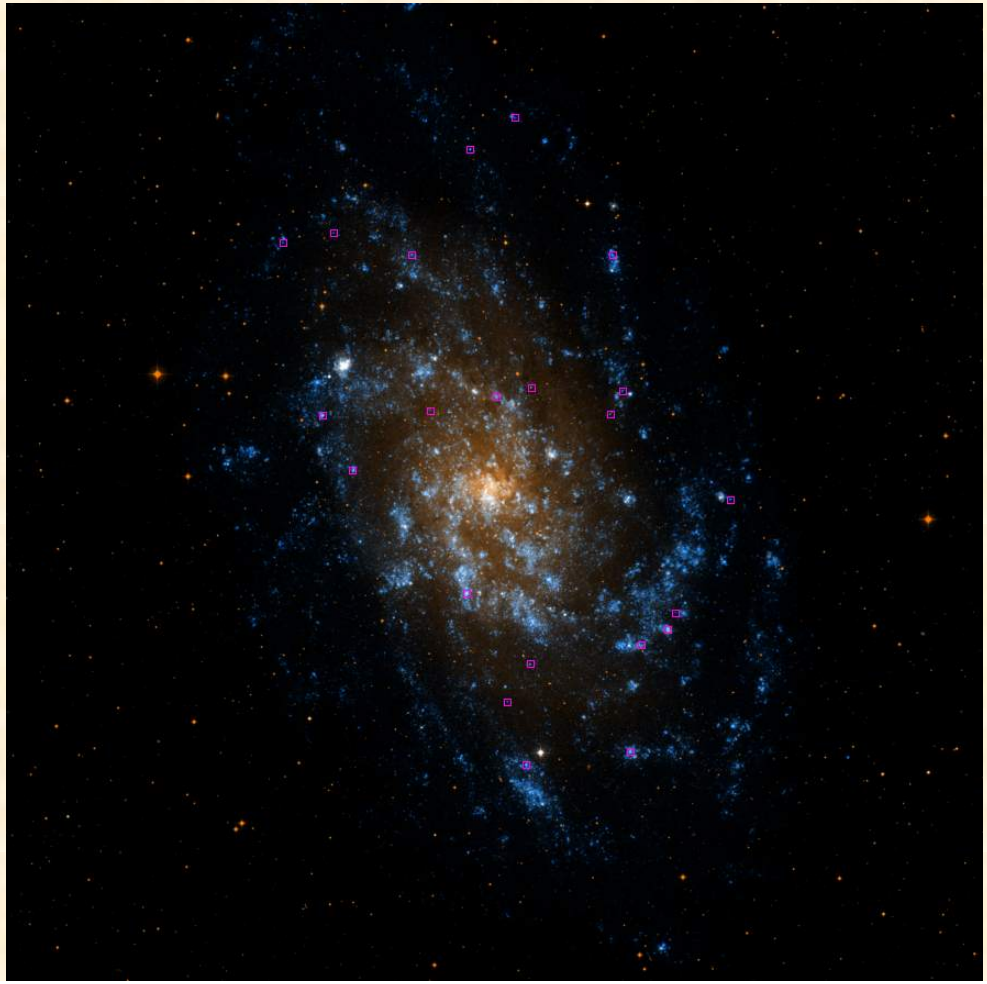
- Stars give a consistent result
- HII regions from Magrini et al.(2007) and Bresolin (2011) give results consistent with stars in the outer regions and with the lowest stellar values closer to the center
- Rosolowsky & Simon (2008) results are also in the lower band, and present a large scatter at any r → real?

Analysis of M33 stars – North-South variations

Rosolowsky & Simon, 2008



$(8.41 \pm 0.07) - (0.039 \pm 0.021)\ R_{kpc}$. We note that all of our targets are located in southwest half of the galaxy (see Fig. 2), and therefore that the other half of the galaxy could conceivably have a different gradient, but we regard this possibility as unlikely. Finally, we have correlated our derived metallicities and



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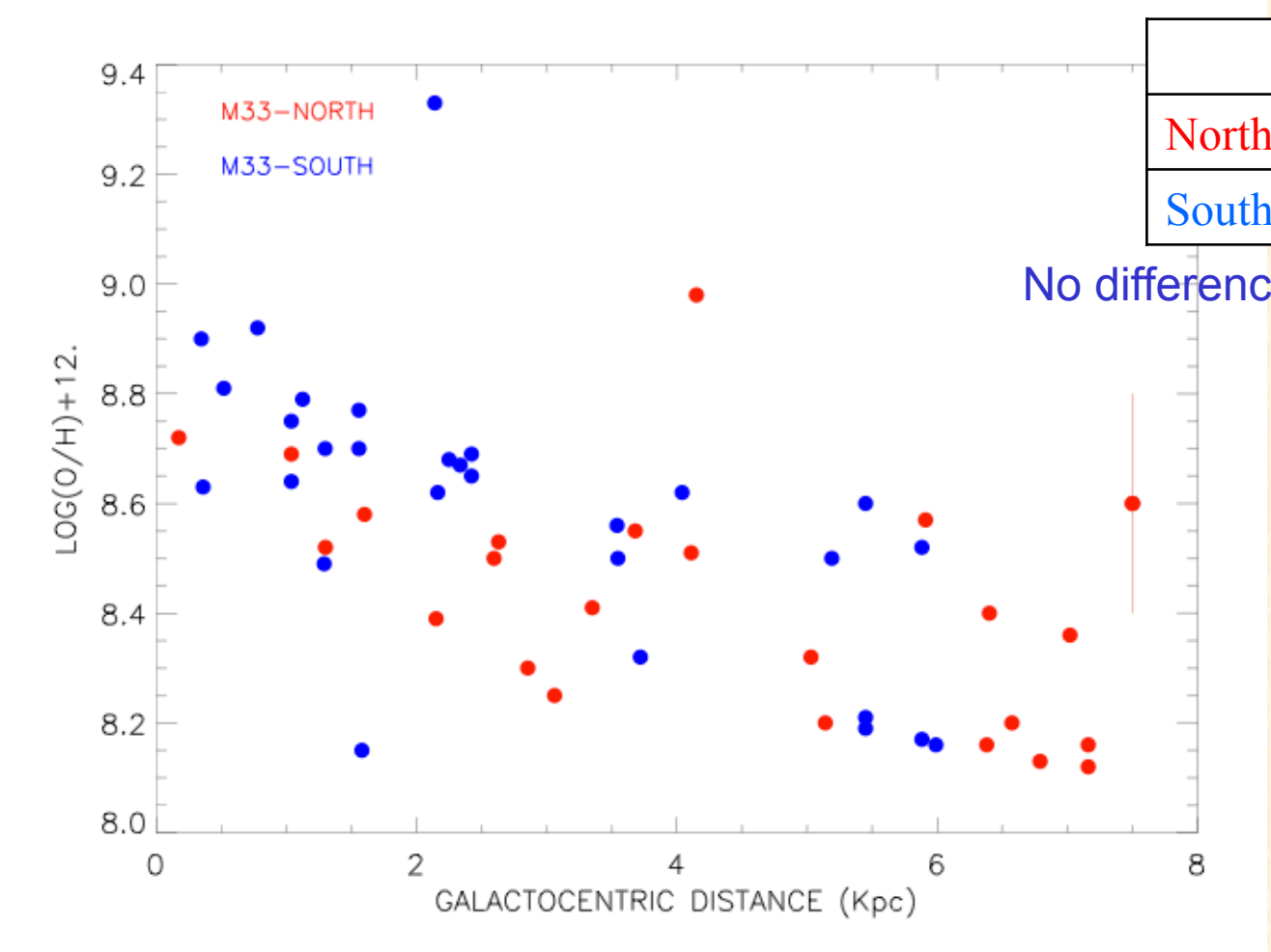
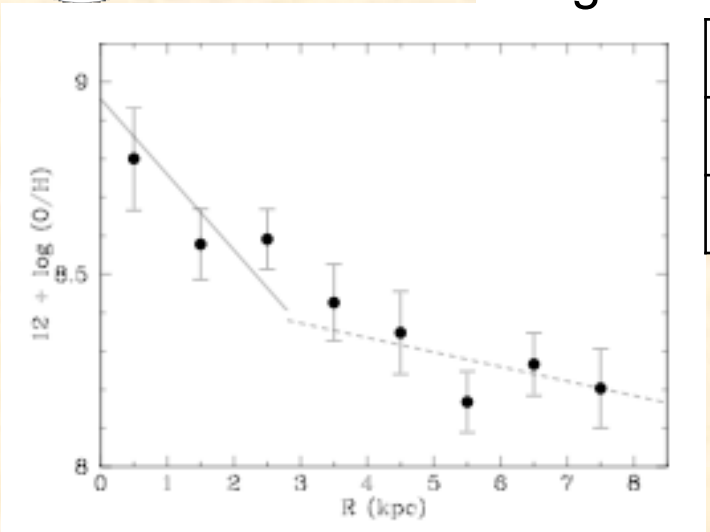


	grad (dex kpc^{-1})
North	-0.07±0.01
South	-0.10±0.02

No difference in the gradient slope

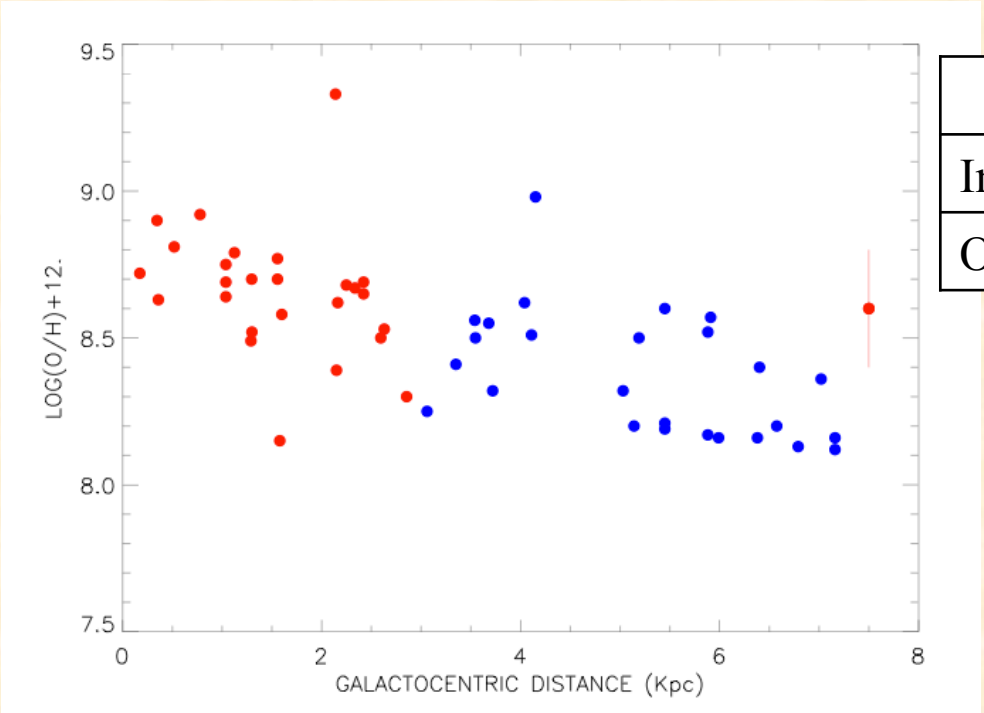
Analysis of M33 stars – 2-zone gradient?

Magrini et al. (2007)



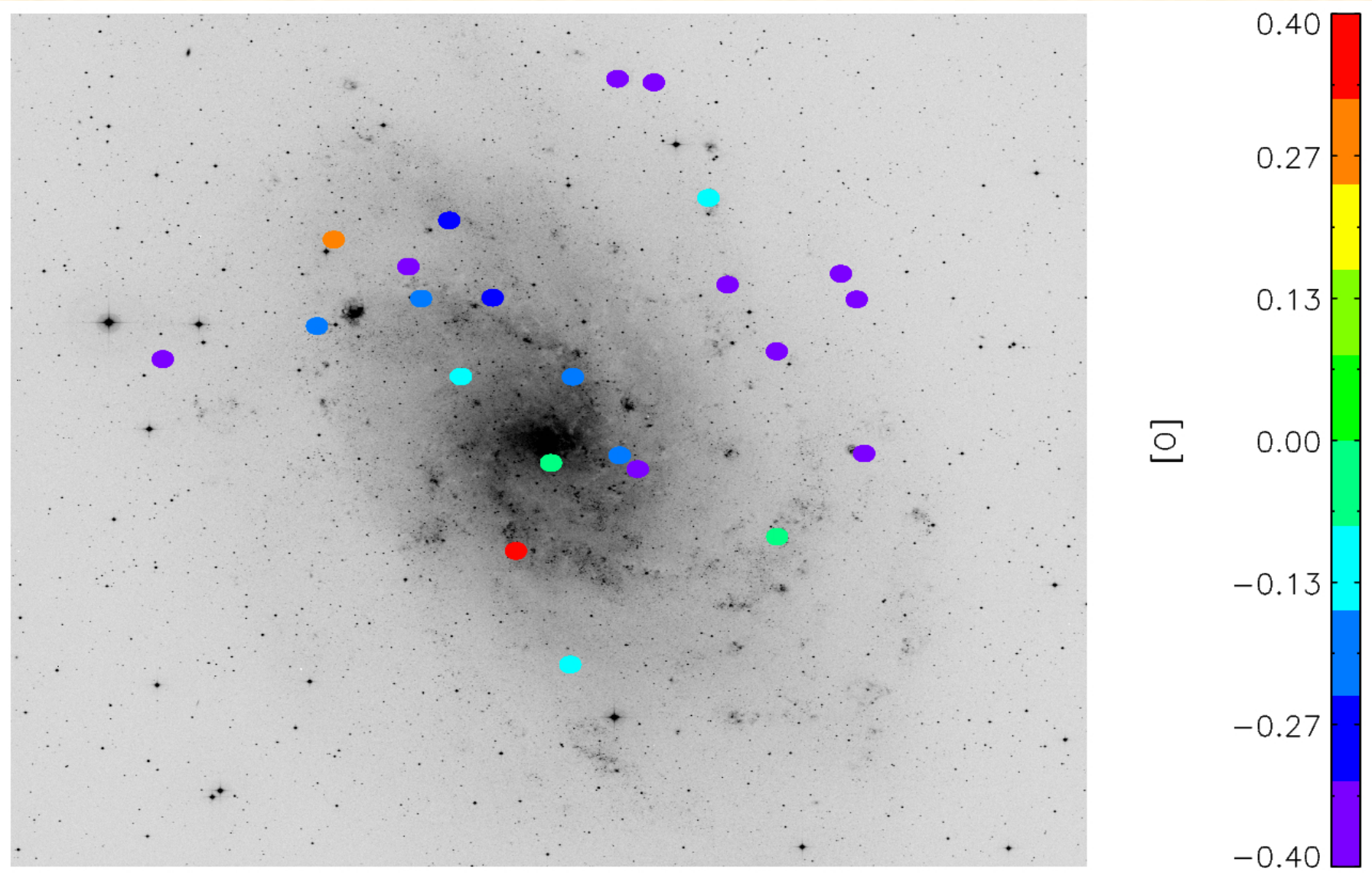
	grad (dex kpc^{-1})
Inner (R < 3 kpc)	− 0.19±0.08
Outer (R > 3 kpc)	− 0.038±0.015

We see no change in the gradient slope

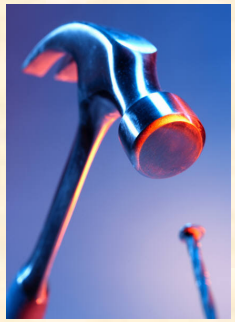


	grad (dex kpc^{-1})
Inner (R < 3 kpc)	− 0.08±0.03
Outer (R > 3 kpc)	− 0.09±0.02

Analysis of M33 stars – other variations?



Conclusions



- This is work in progress

Wait, man!!!

(Urbaneja, 2012; Discussion I)

But... some facts…

- Analysis of extragalactic (massive) stars can be very rewarding
  - For stellar atmopshere and evolutionary models
  - For galactic structure and evolution
- Massive stars analyses give consistent results
  - Note that all authors have the same skeletons!
- Massive stars give a slightly higher gradient than the HII regions from Magrini, 2007
- We do not
  - find North-South gradient variations
  - find inner-outer regions gradient variations
  - confirm the large scatter found by Rosolowsky & Simon at a given r
- We think it is worth to continue the analysis following the spiral arms