Metallicity gradients, 2D maps and chemical evolution

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with

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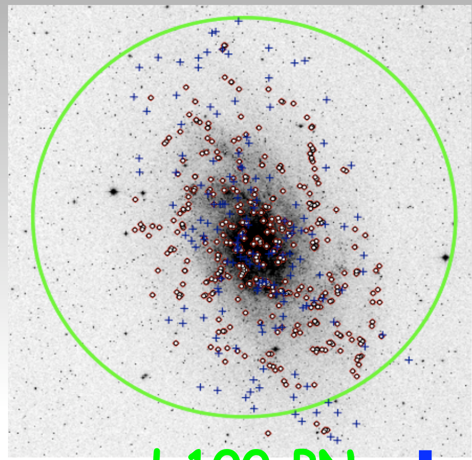
- **The metallicity distribution** (from spectroscopy)
- Why metallicity: chemical evolution, integrated star formation, nucleosynthesis processes
- The study of the metallicity in M33 from HII regions: a long history starting from the 70s (e.g. Smith 1975, Kwitter & Aller 1981, Vilchez et al. 1988) indicating a consistent O/H gradient of about -0.1 dex/kpc
- Recent results from individual object spectroscopy:
  - Infrared and optical spectroscopic observations of HII regions found a flatter radial metallicity distribution (e.g., Crockett et al. 2006, Magrini et al. 2007, Rosolowsky & Simon 2008, Rubin et al. 2008, Magrini et al. 2009 in prep)
  - Spectroscopy of Planetary Nebulae (Magrini, Stanghellini, Villaver 2009) found a similar gradient
  - Spectroscopy AB super-giant stars (e.g., Urbaneja et al. 2005, U et al. 2009) similar gradient, but different central metallicity

Outline:

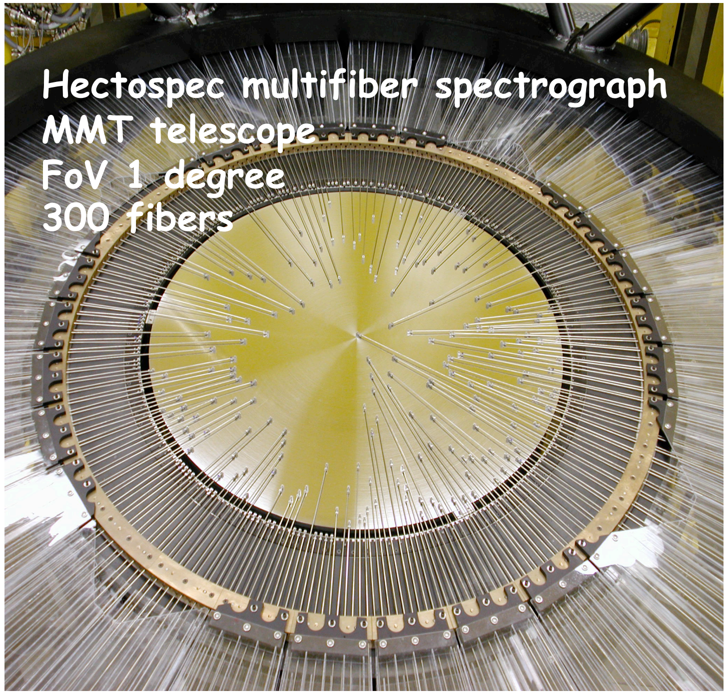
- What does the metallicity gradient (and its change with time) tell us about the formation and evolution of M33?
- **Method**
  - Observational constraints (HII regions and PNe)
  - Chemical evolution model

The observations

The idea: obtain at the same time (instrument, analysis technique, chemical element) the metallicity at two epochs



Observed 100 PNe ✚ and 50 HII regions ○

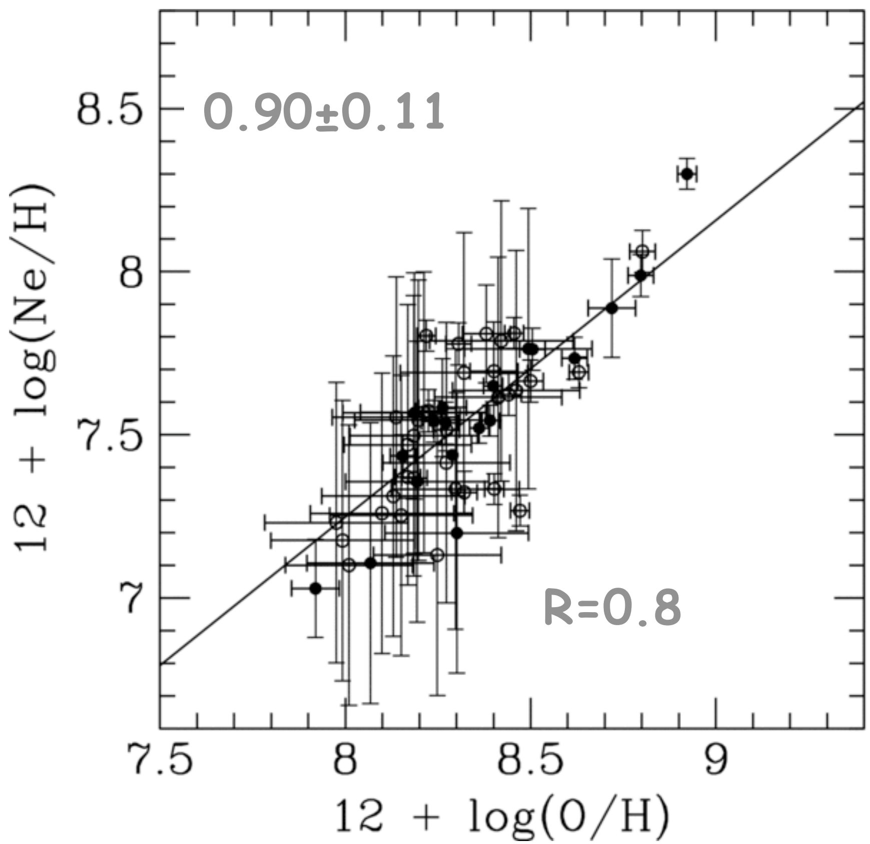


- Planetary nebulae:
  - LIMS progenitors

    1 M_{sun}<M<8 M_{sun} --> 0.3 Gyr < Age < 10 Gyr
  - do not modify (in most cases) the O, Ne, Ar, S abundances
- HII regions:
  - ionized by O-B stars
  - present-time ISM composition

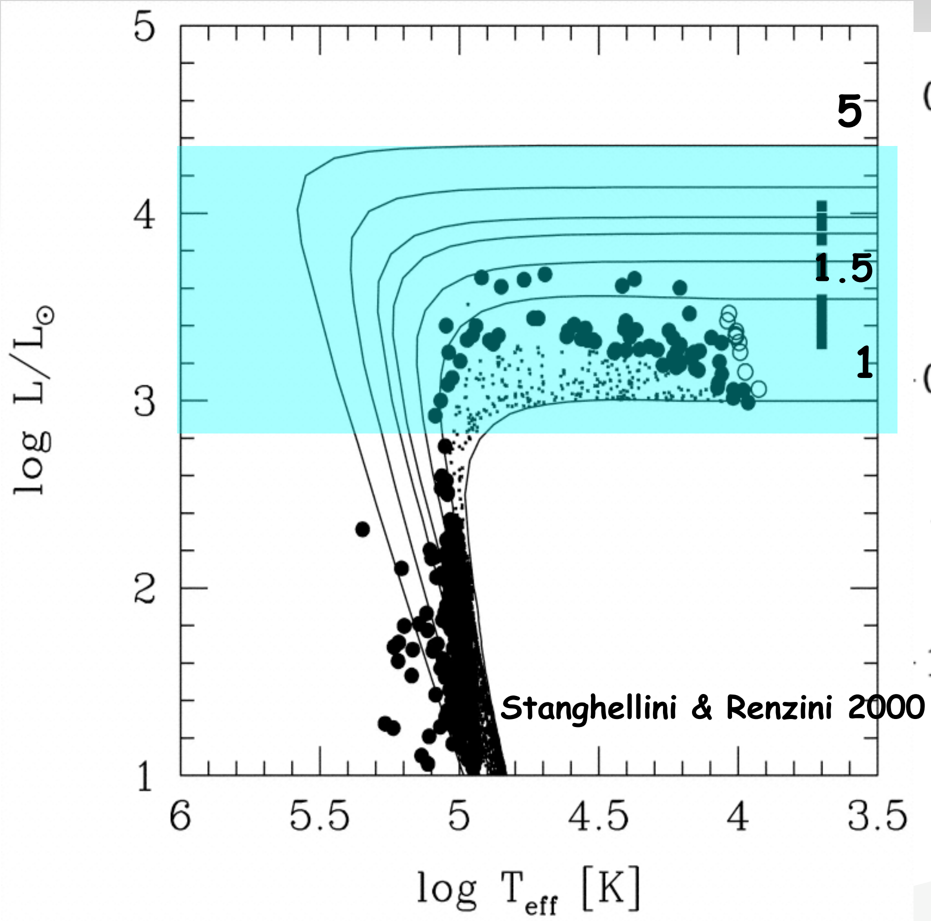
PNe: constraining the past ISM abundances

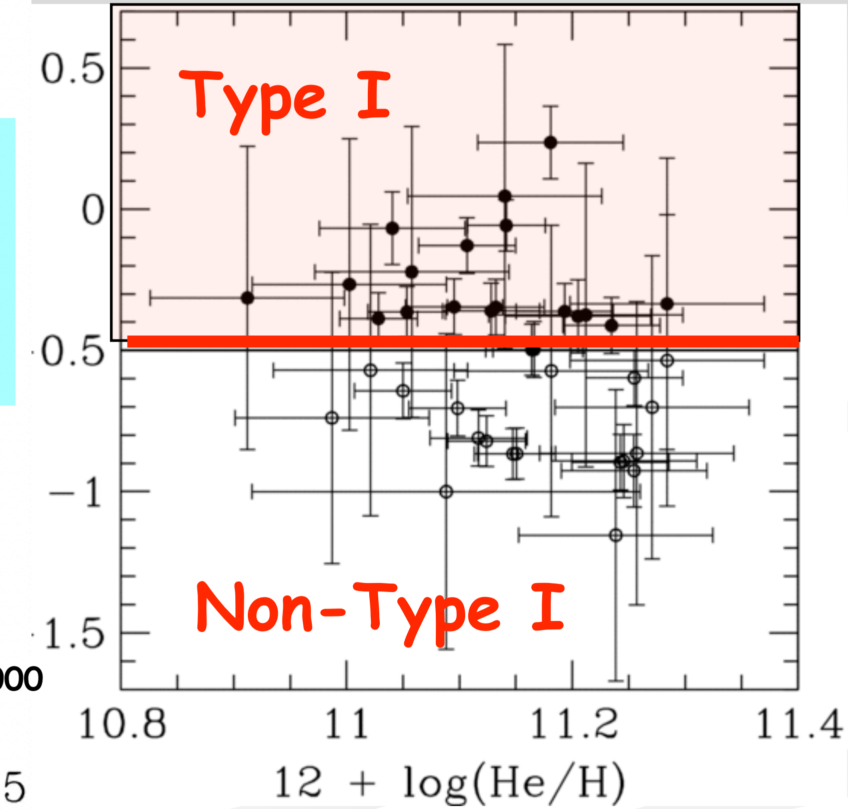
- Is oxygen a good tracer of the past metallicity? Is it really unchanged, nor produced neither destroyed?
- Ne is not modified by LIMS nucleosynthesis--> Ne/O constant means-->
- no important oxygen modification



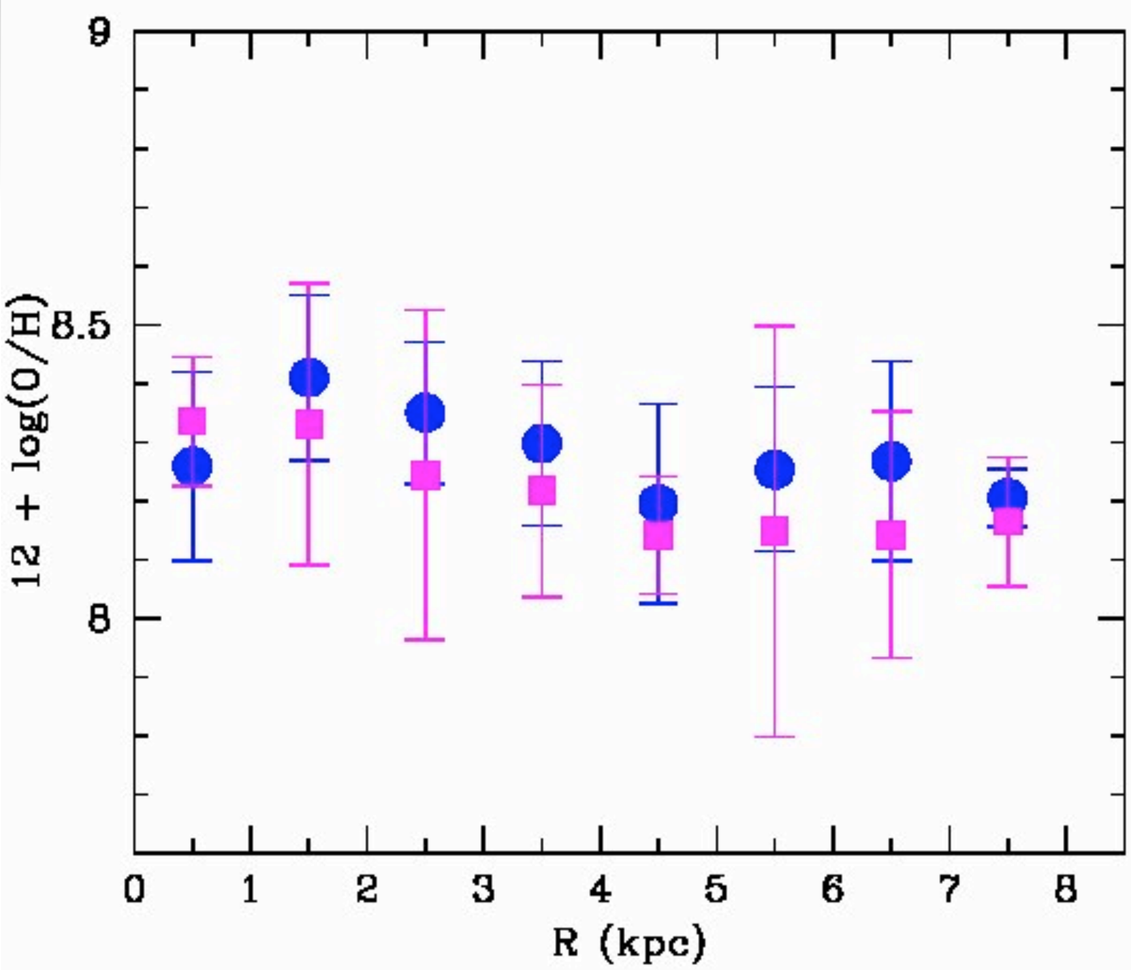
Magrini, Stanghellini, Villaver 2009

Dating the progenitors:





The metallicity gradient from HII regions and Planetary Nebulae



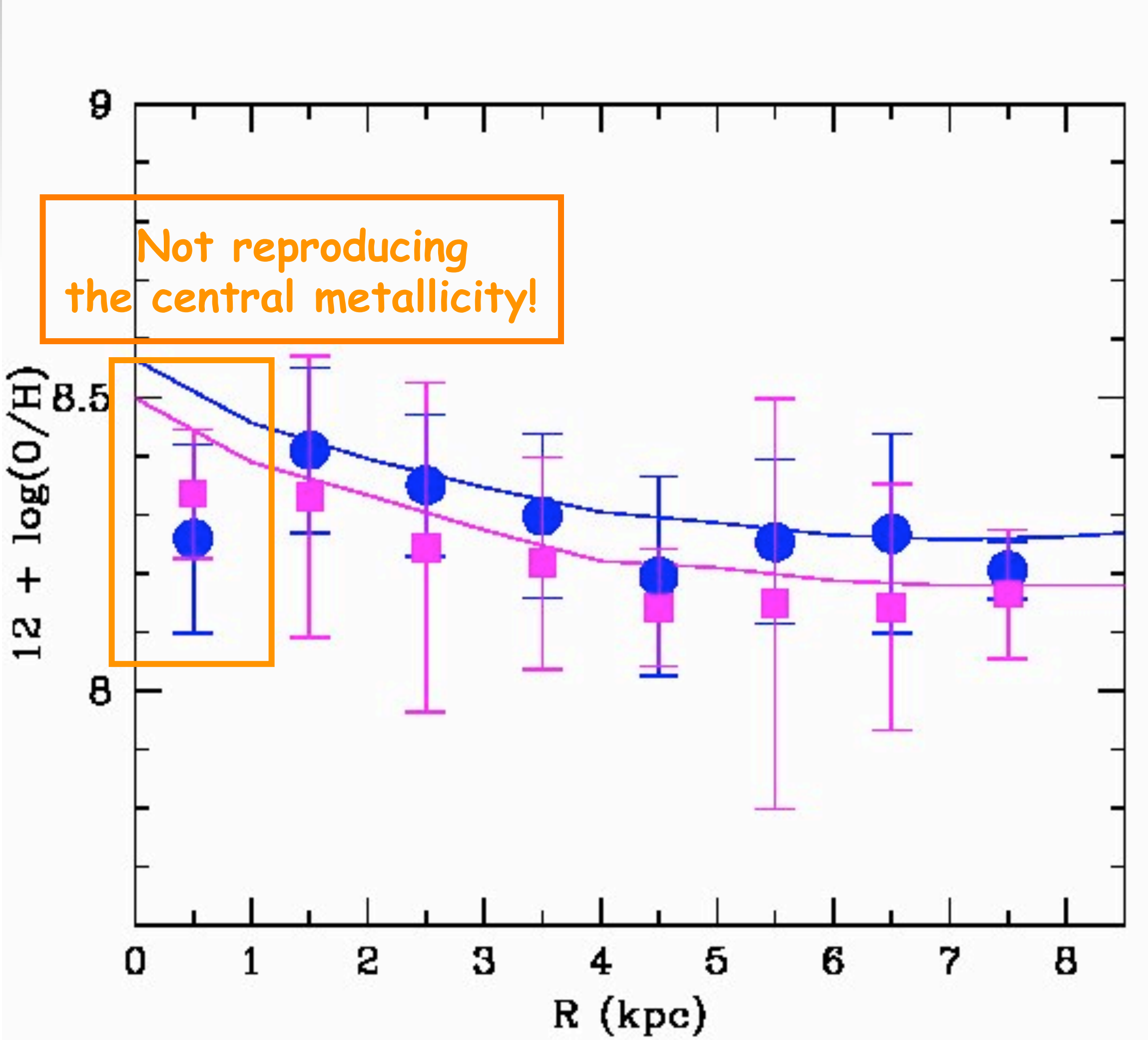
HIIr sample (96 objs):

1. Magrini at al. 2007 (including all previous works, like Vilchez et al. 1988, Kwitter & Aller 1981, etc.)
2. Rosolowsky & Simon 2008
3. This work

PN sample (72 objs):

1. MSV09
   non-Type I PNe

Which scenario is consistent with an almost flat gradient and its slow evolution?



Results:

1. Evolution in the average metallicity at each radius (0.1-0.15 dex)
2. Evolution in the slope:

-0.020 ± 0.008 dex kpc^{-1} HIIr

-0.028 ± 0.006 dex kpc^{-1} PNe

BEST MODEL:
Slow accretion (constant infall of primordial gas) and SF driven by a Schmidt law

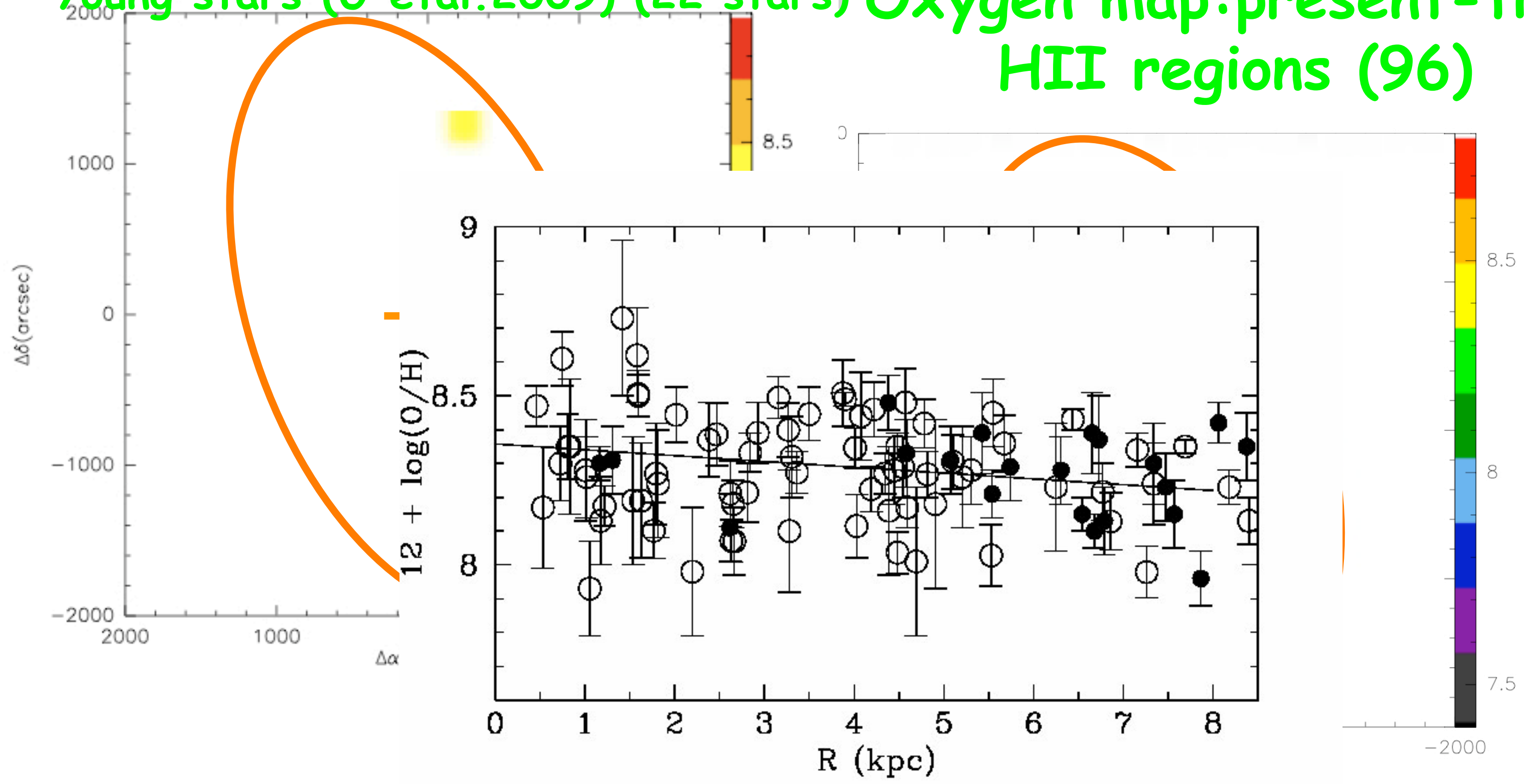
$$\Sigma_{SFR} = A\Sigma_{molgas}^{1.2}.$$

2-d metallicity distribution:

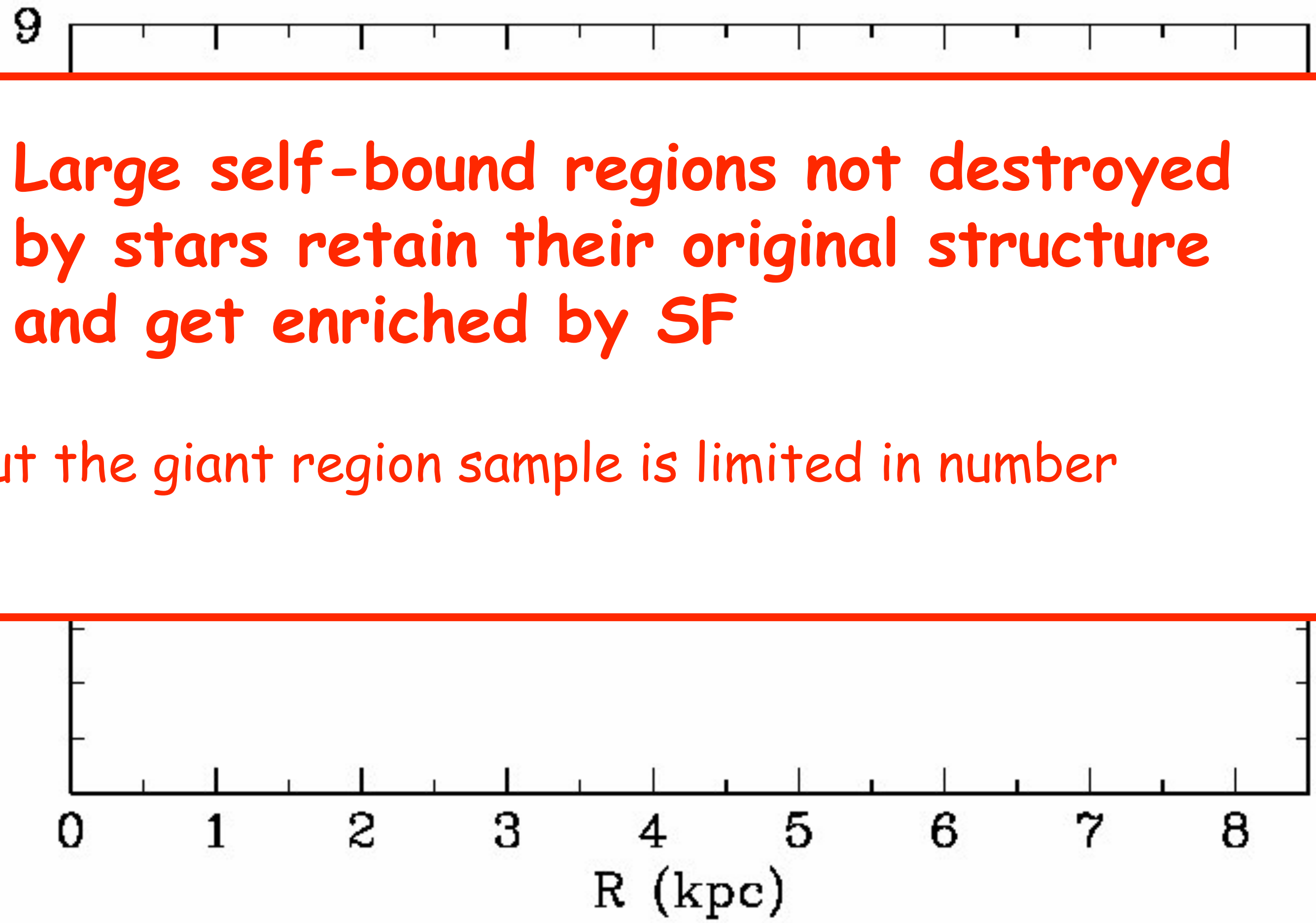
Binned map

Young stars (U etal.2009) (22 stars)

Oxygen map:present-time HII regions (96)



Population-dependent HIIr metallicity gradient



- **Large self-bound regions not destroyed by stars retain their original structure and get enriched by SF**

…but the giant region sample is limited in number

Summary and conclusions

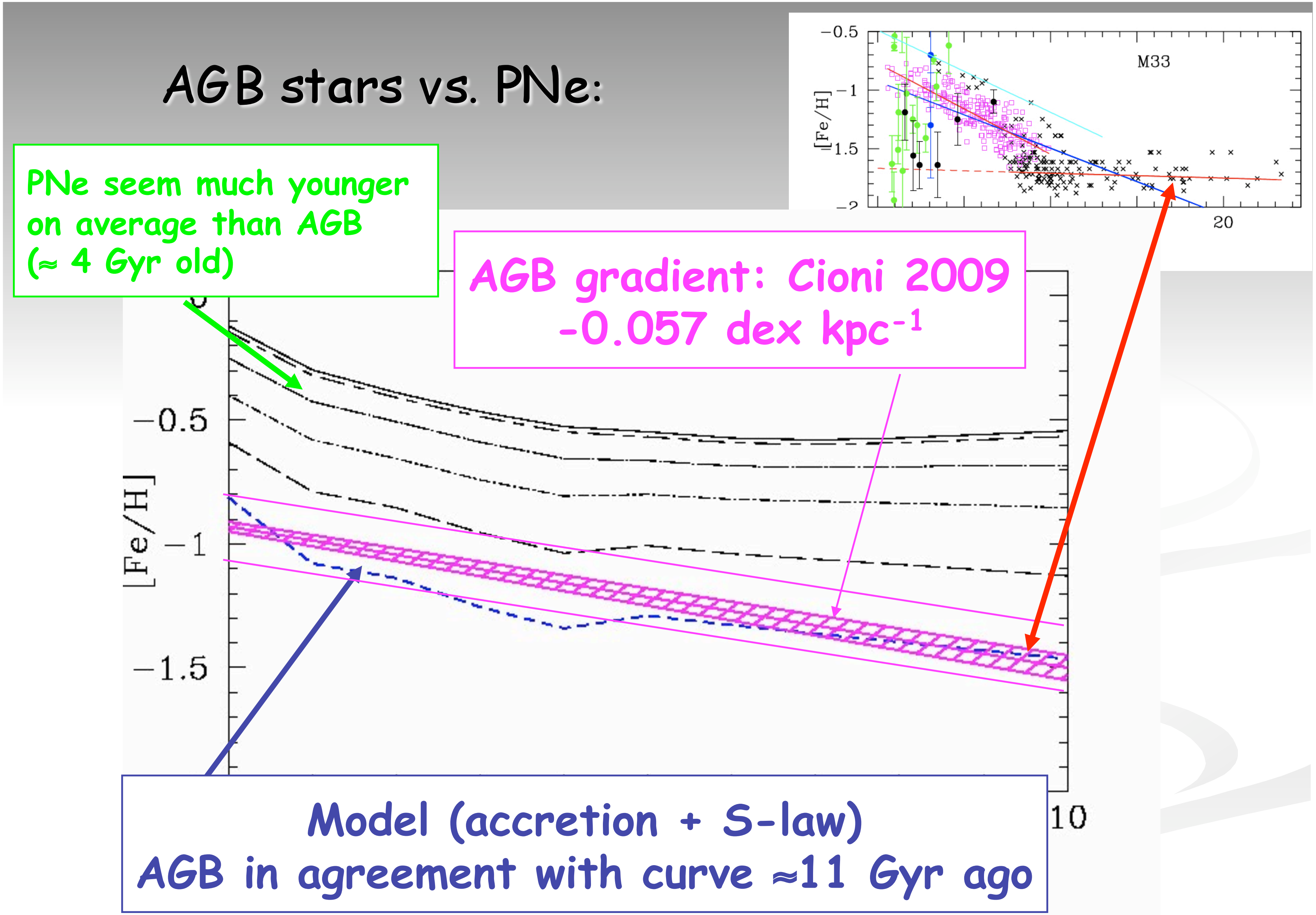
- New MMT observations of a large sample of PNe and HII regions, together with literature data, confirmed:
  - the evolution of the average metallicity (0.1 dex in ≈4 Gyr)
  - the slight flattening with time of the gradient of M33

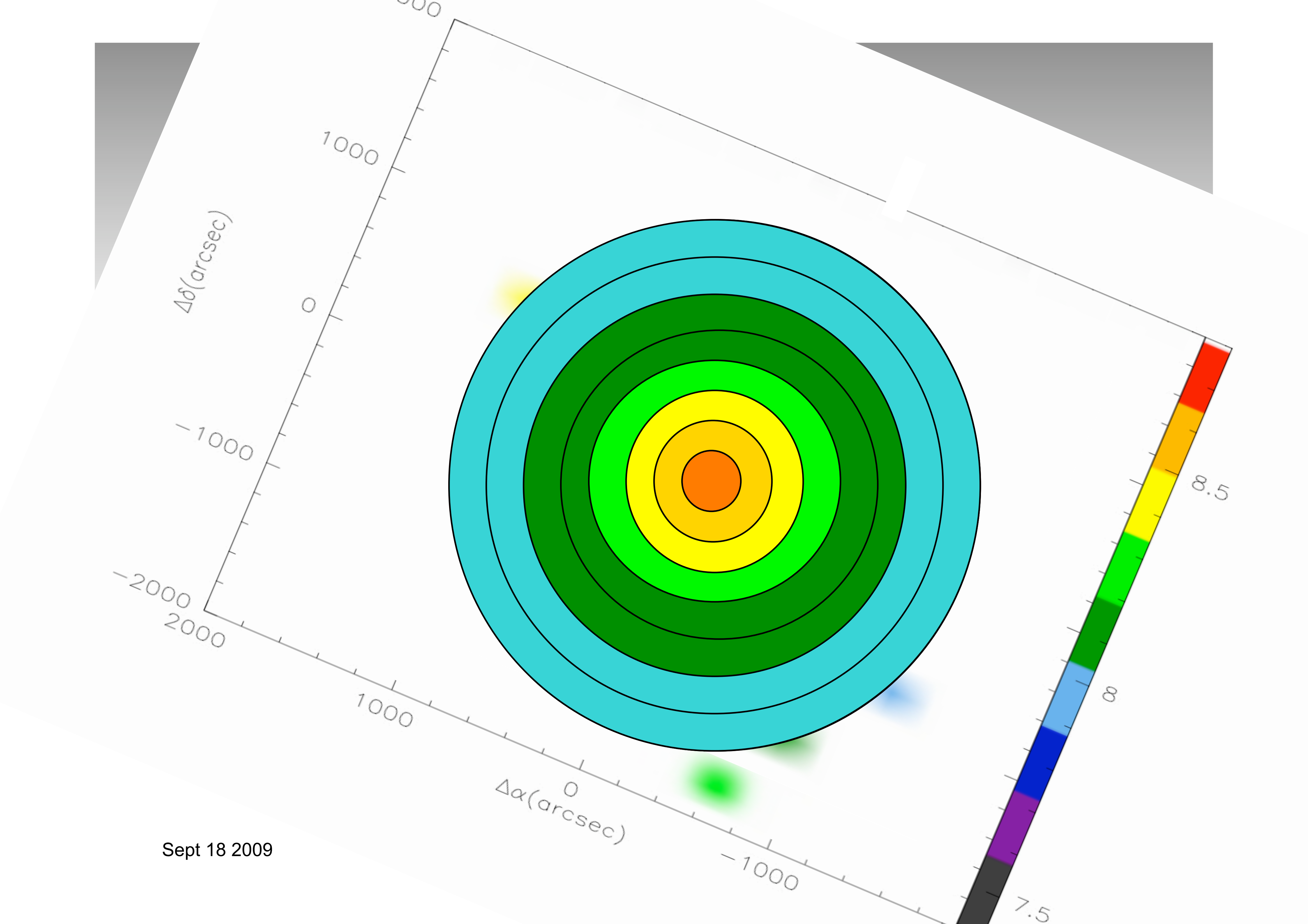
- A scenario where the infall rate is constant with time and the SF is driven by a Schmidt law can explain this behaviour

Open questions

- Which is the origin of the off-centre in the metallicity distribution?
- Giant vs.'normal' HII regions: is their metallicity gradient really different?
- AGB stars vs. PNe: why their gradient is so different? Fe/H vs O/H or/and different age of the progenitors?

AGB stars vs. PNe:





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The metallicity evolution:

radial distribution

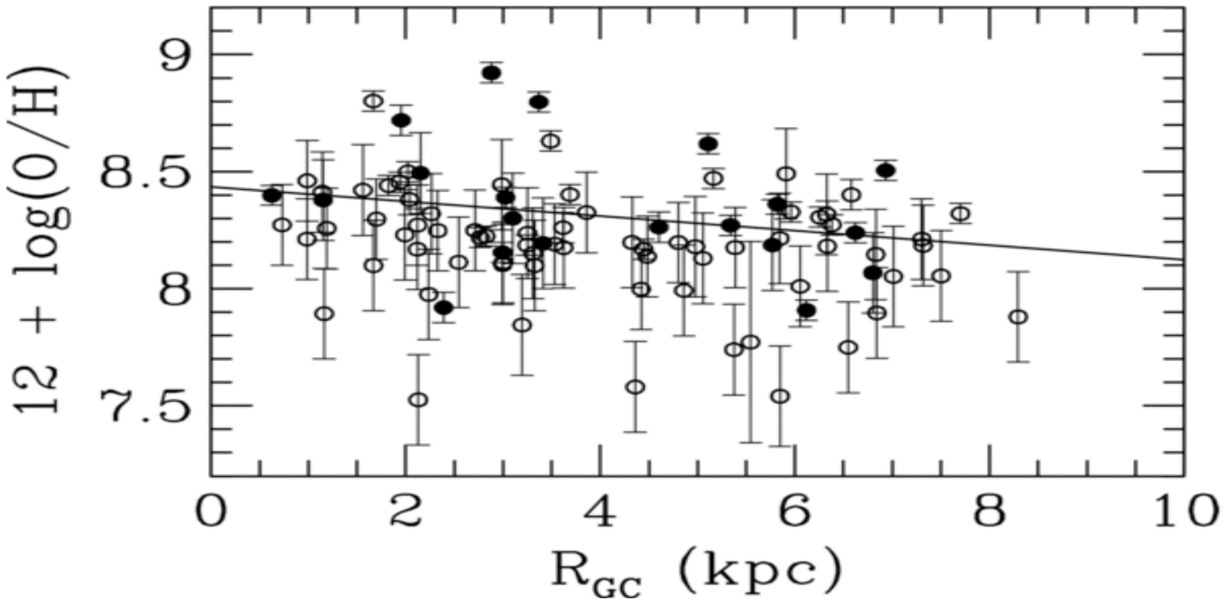
HIIr sample (96 objs):

1. Magrini at al. 2007 (including all previous works, like Vilchez et al. 1988, Kwitter & Aller 1981, etc.)
2. Rosolowsky & Simon 2008
3. This work

PN sample (91 objs):

1. MSV09
   - ● Type I PNe (younger)
   - ○ non Type I PNe

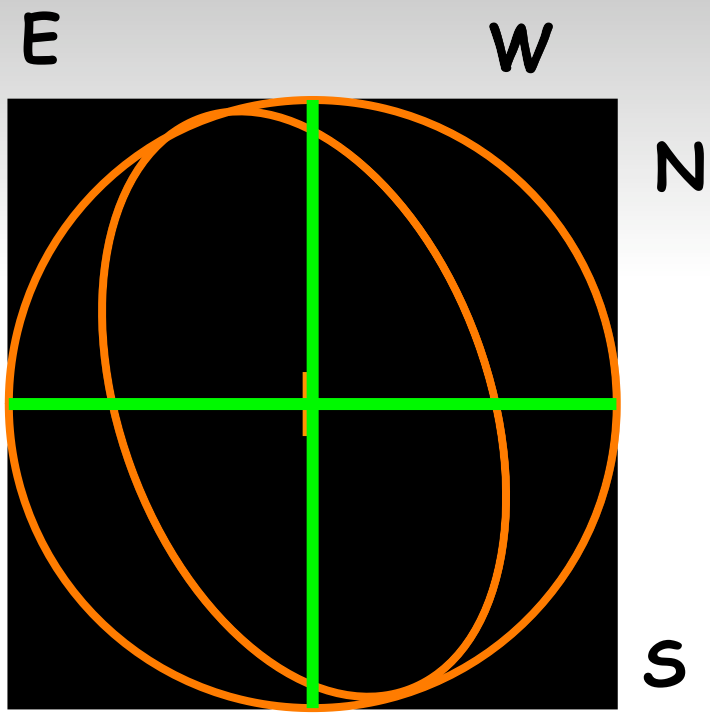
HII regions vs PNe

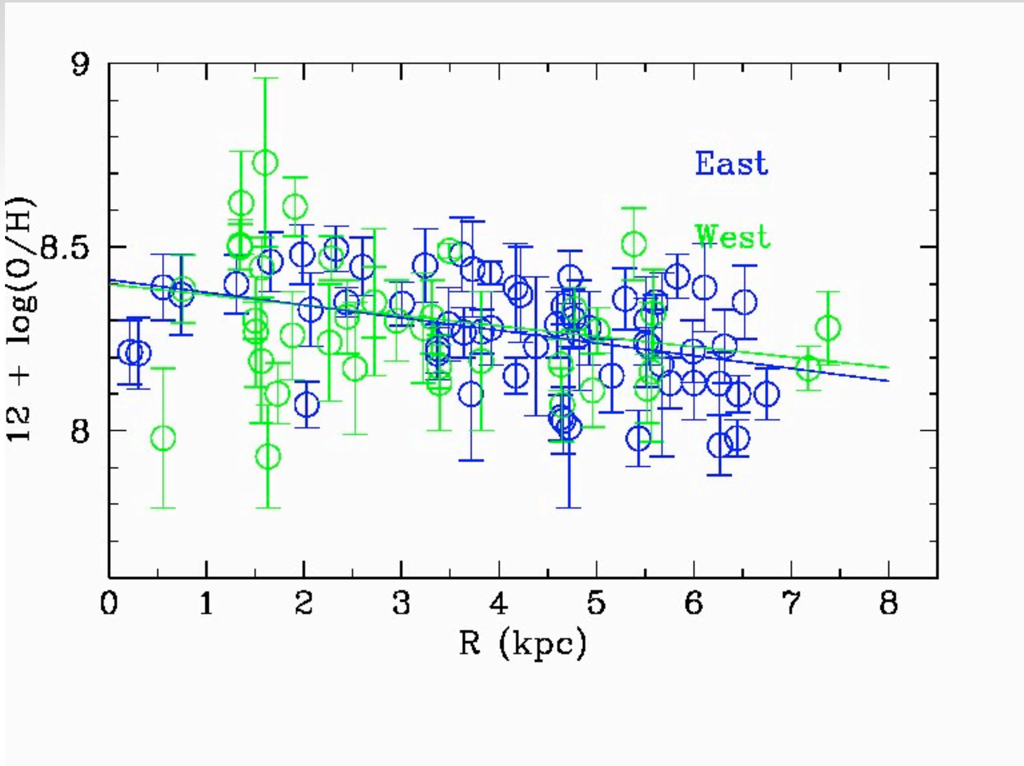


No changes in the O/H gradient

From MSV09, Magrini et al. 2007, Rosolowsky & Simon 2008

2-d metallicity distribution

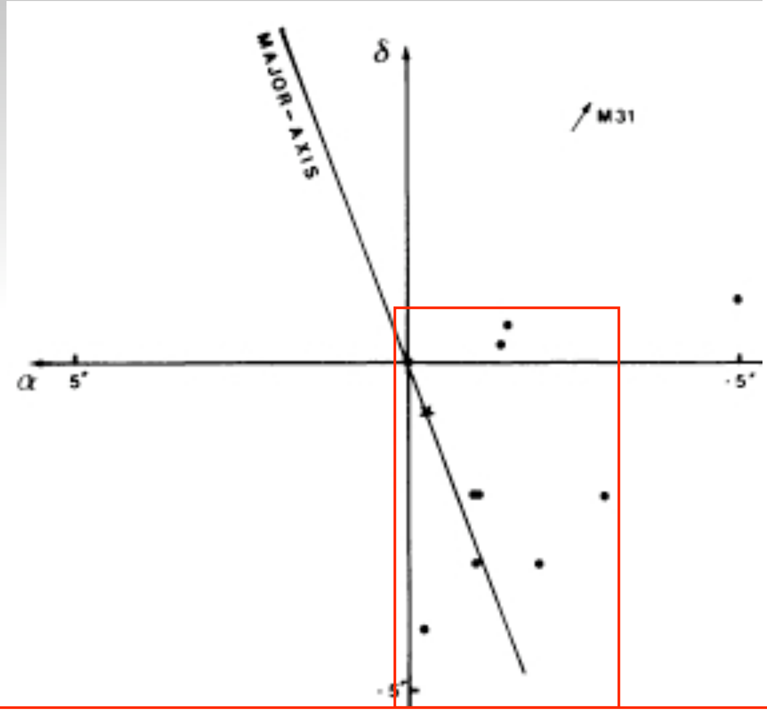


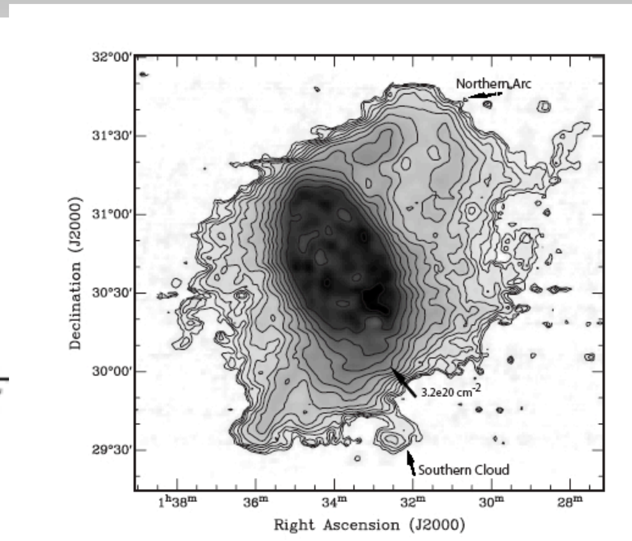


The location of the metallicity peak does not affect the symmetry North-South and East-West of the gradient

2-d metallicity distribution

Optical continuum
High luminosity stars
Integrated neutral hydrogen
H II regions
H II regions
Integrated neutral hydrogen
H II regions
H II regions

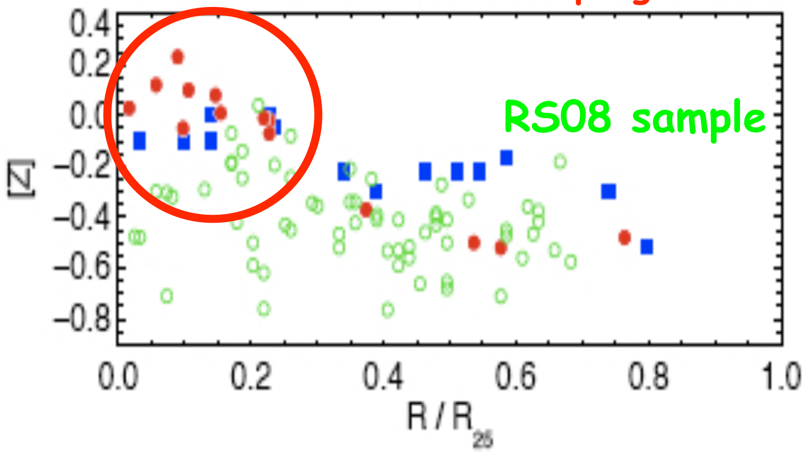


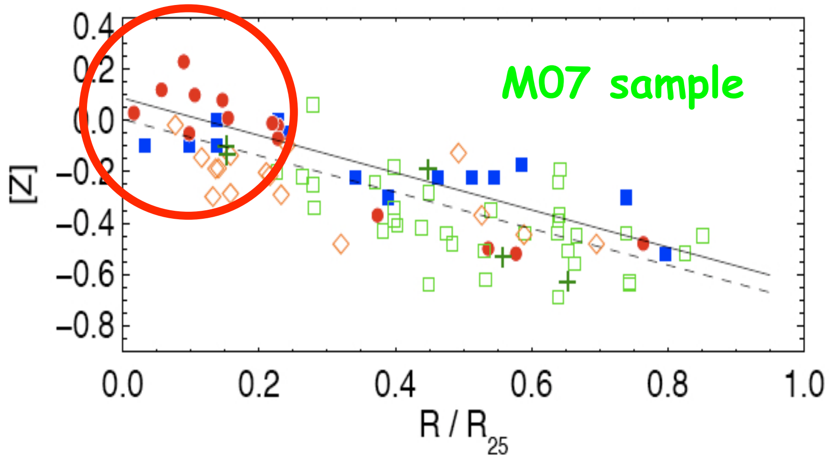


The absence of a dominant gravitational source in the center and the interaction with M31 are possible reasons for the off-centered metallicity

J. Colin and E. Athanassoula

A & B supergiants in M33 (U et al. 2009)





A & B supergiants in NGC300 (Bresolin et al. 2009)