The metallicity distribution in the Milky Way discs

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The radial metallicity gradient from Cepheids measurements

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Cepheids and gradients

- Classical Cepheids = pulsating variable stars in the thin disc

- Famous primary distance indicators (PL relations)
  ⇒ accurate distances
- Very luminous ⇒ probe both the inner and outer disc

- FGK supergiants
  - Absorption lines for numerous elements
  - Lines are well defined ⇒ reliable abundances

Outline

- Abundances
  - Are pulsations a problem ?
- Distances
  - Excellent, can still be improved
- Current results
- Needs and perspectives

Abundances

- FGK supergiants ⇒ abundances of numerous elements
  - Iron peak
  - Alpha elements
  - r,s process elements
  - CNO + Na abundances modified after the 1st dredge-up

⇒ Useful to study the chemical evolution of the thin disc

- Easy comparison with open clusters
- O lines challenging, no He lines ⇒ comparison with PNe & HII regions more difficult

Age

- Cepheids have ages from 20 to 300 Myr (Bono+2005)
  - Older than OB stars
  - Younger than Open Clusters, PNe

- How does the gradient evolve with time ? Flattening ? (Maciel+ 2006, 2010)

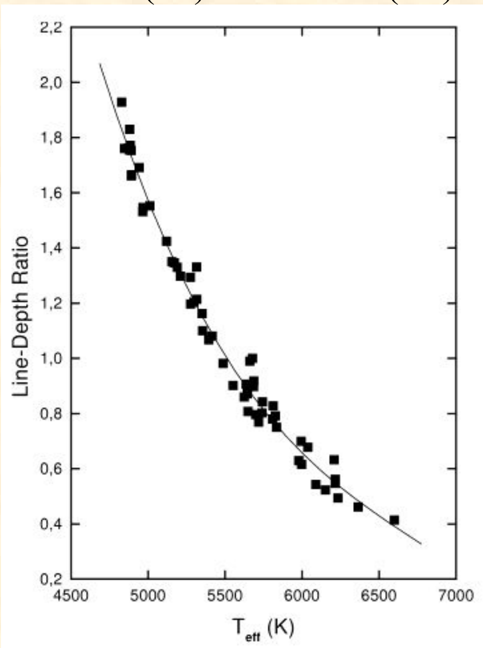
- Given this timescale (< 0.3 Gyr), what is the influence of radial migration on the Cepheids gradient ?

Abundances & Pulsations (1)

- No simultaneous photometry
  ⇒ atmospheric parameters derived from spectroscopy.
  (Teff: exc. eq; log g: ion. Eq; Vt: [Fe/H] indep EW)

- Line depth ratios (Kovtyukh+ 2000,2007)
  - Calibration relations for ratios of carefully selected lines
  - Excellent relative scale (~20K)
  - Good absolute scale (<150K)

6090.21 (VI) to 6091.92 (SiI)



Abundances & Pulsations (2)

- No atmosphere models for pulsating stars

  Pulsation models (e.g. Fiorentino+ 2007) only have a simple atmosphere

⇒ Need to use classical (static) atmosphere models

- A few Cepheids belong to Open Clusters

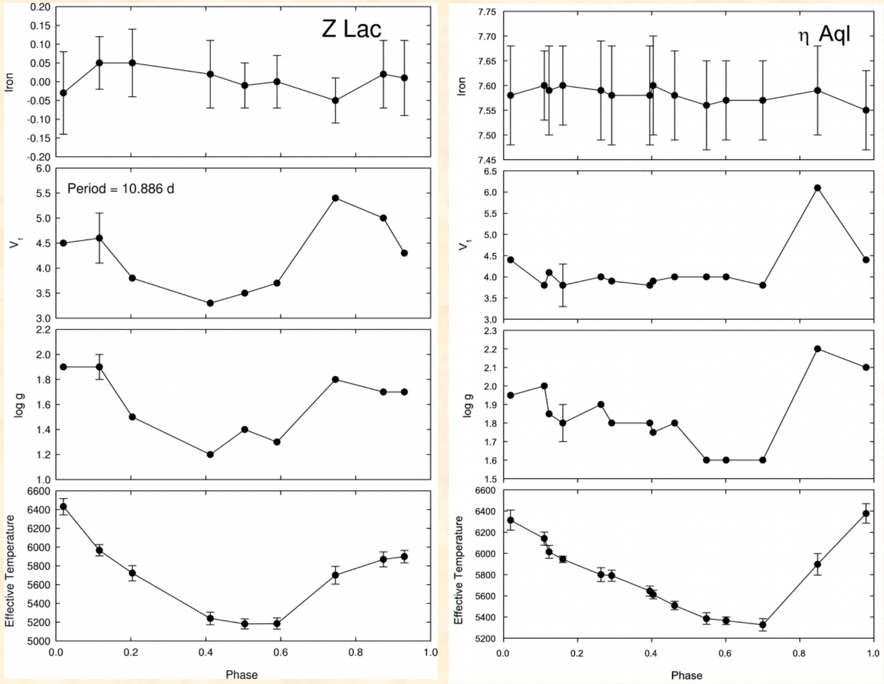
  Same abundances for Cepheids and dwarf stars in M25

  (Fry+ 1997)

Abundances & Pulsations (3)

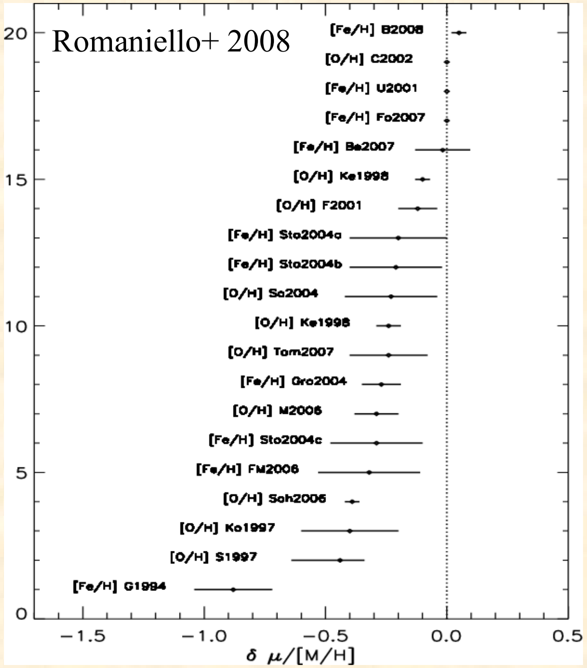
- No preferred epoch for observations along the period:
- Atm. param. vary but [Fe/H] very consistent

(Luck+2004, Kovtyukh+ 2005, Andrievsky+ 2005, Luck+ 2008)



Distances : different methods

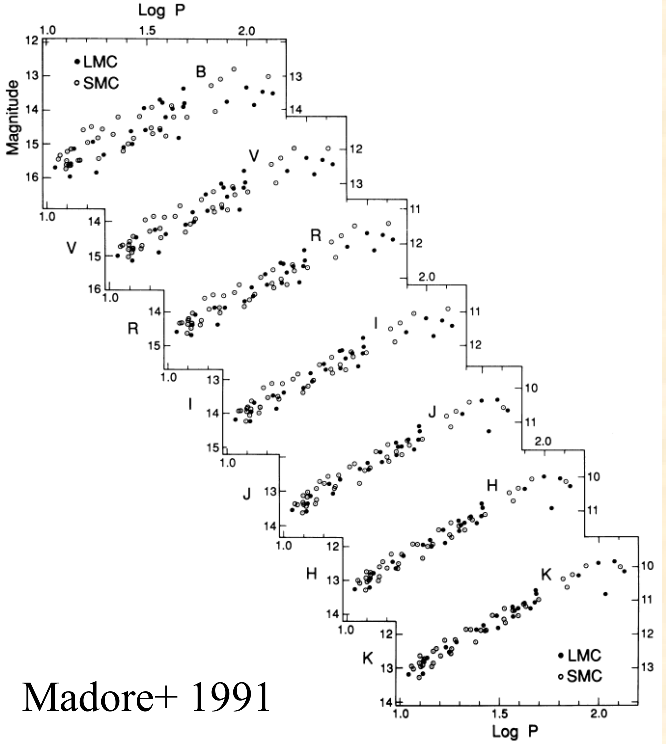
- Very accurate methods, but need numerous observations, apply only to stars close by… ⇒ not very suitable for gradients studies
  - Baade-Wesselink methods (integration of Vr + angular diameter variation from surface brightness relations, interferometry…) (Groenewegen+ 2008, Storm+ 2012)
  - HIPPARCOS, HST parallaxes (Benedict+ 2007, van Leeuwen+ 2007)



- « Historical » method: PL(V) relation
- BUT:
  - Intrinsic dispersion of the PL relation
  - Reddening is an issue
  - Metallicity effect on the PL relation

Distances: PL relations in the NIR

- PL relations in the NIR
  - Reduced intrinsic dispersion
  - Reduced reddening
  - Very weak (if any) metallicity dependence of PL relations in the NIR

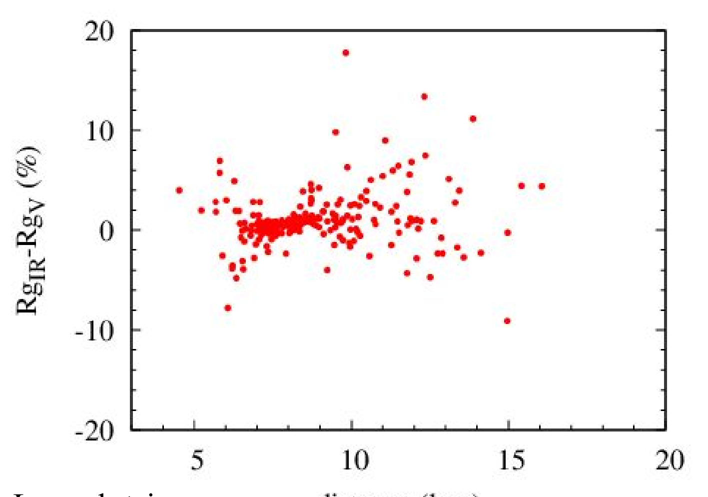


Madore+ 1991

- Used for gradients studies
  - Lemasle+ 2008, Pedicelli+ 2009
- Can still be improved

Distances: PW relations in the NIR

- Wesenheit index is a reddening free quantity by construction
- + dispersion reduced compared to corresponding PL relations
- Advantages studied from
  - Theory (Fiorentino+ 2007, Bono+ 2008)
  - Observations (Ngeow 2012, Inno+, in prep, Genovali+, in prep)



Lemasle+ in prep

Error of 5% at 10 kpc

→ 0.5 kpc error

Sampling

- ~650 MW classical Cepheids in the GCVS (Samus+ 2007-2012)
- 32 new classical Cepheids toward the bulge
  (OGLE III, Soszyński+ 2011)

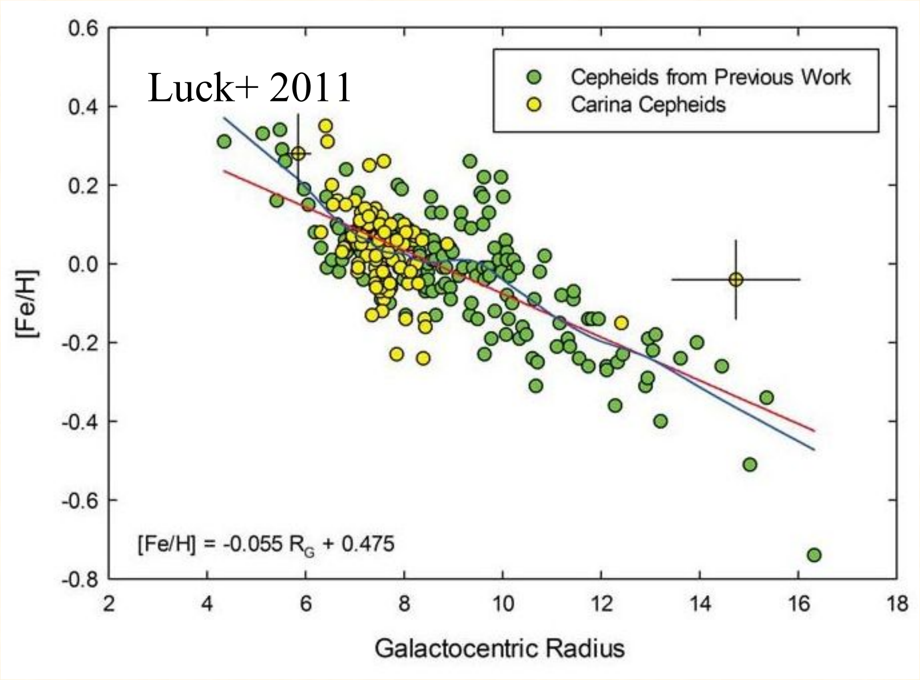
- Spatial repartition:
  - Solar neighbourhood OK,
  - inner and outer disk poorly sampled
  - Limited coverage in longitude

- To be compared to
  - LMC : 3361 (OGLE III, Soszyński+ 2008)
  - SMC : 4630 (OGLE III, Soszyński+ 2010)

The radial gradient (1)

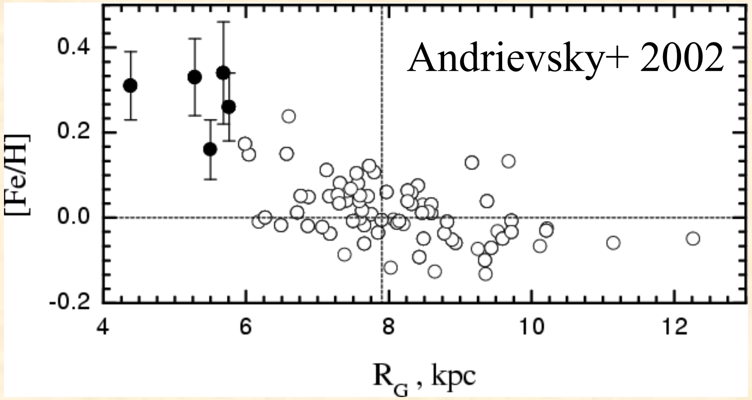
- Radial gradient of ~–0.06 dex/kpc

  Harris 1984, Andrievsky+ 2002, Luck+ 2006, Lemasle+ 2008, Pedicelli+ 2009, Luck+ 2011



The radial gradient (2)

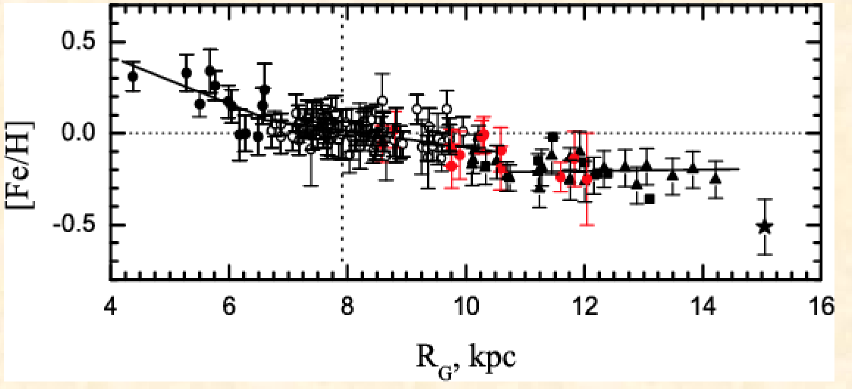
- Probably better described by 3 zones
  - Inner disc (< 6 kpc) : steep gradient of ~ -0.1 dex/kpc, poorly sampled (Andrievsky+ 2002, Pedicelli+ 2009)



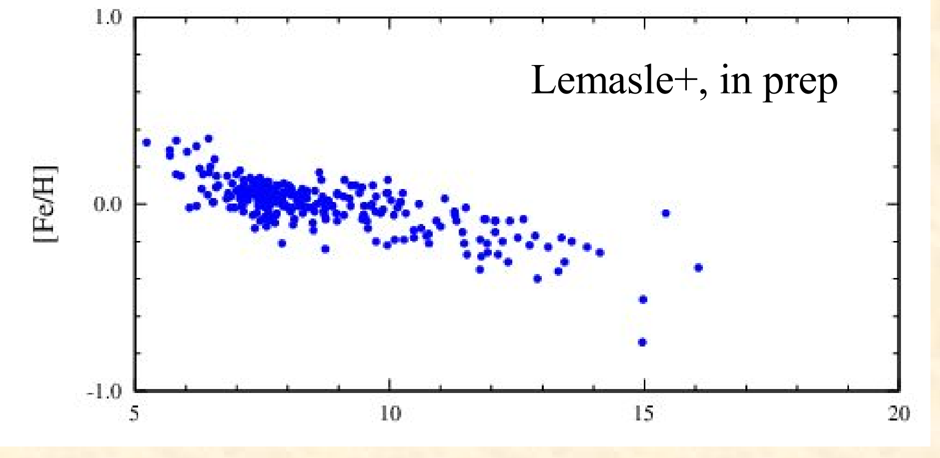
  - Central region (6-10kpc) : mild gradient of ~ -0.03 dex/kpc
  - Outer disc (> 10 kpc), poorly sampled

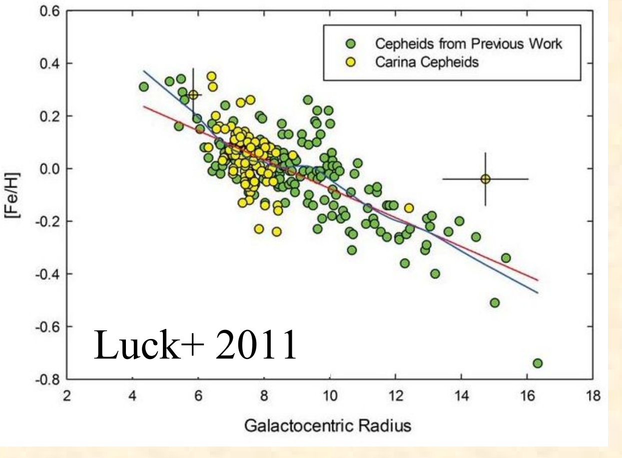
The radial gradient (3)

- Increased dispersion ?
- Metallicity step at 10 kpc ?
  ring-shaped gap in the density of
  at the corotation radius (Lépine+



- Flattening ?





Needs and perspectives

- Need of new targets from photometric surveys
  - VVV public survey (Vista Variables in the Via Lactea)
  - GAIA (6000 expected Cepheids, Eyer+2000)
- Need of spectra from 4-8m telescopes
  - R=20000, exp. time ~1h
  - MOS : only if borrowing 1-4 fibres to large surveys (GES, WEAVE, 4MOST)
- NIR spectra (CRIRES) for other quadrants ?
  - Comparison with other tracers easier
  - Very few Fe II lines, no LDR…
  - Unlikely to get obs. time on a 8m single fibre spectrograph

The Wesenheit index

Madore 1982

II. THE WESENHEIT FUNCTION

a) General Remarks

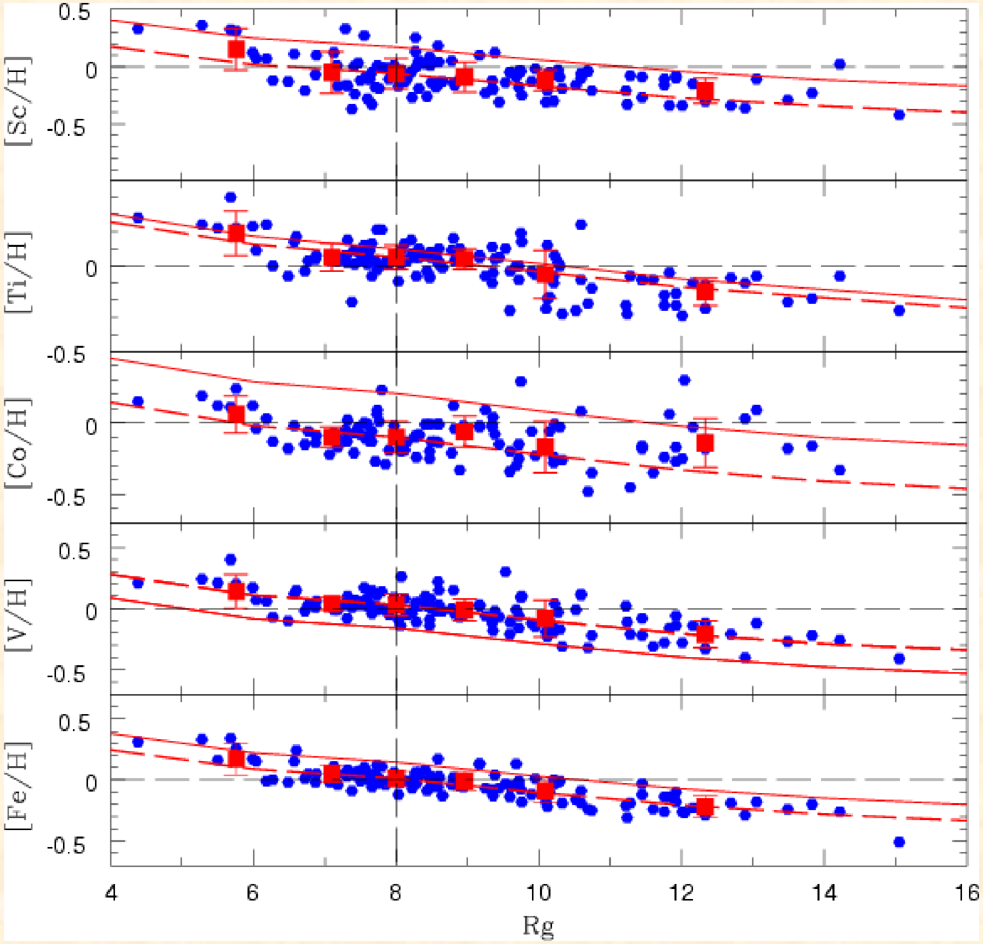
Only one linearly independent combination of V and $(B-V)$ can be made that is itself independent of reddening. This is W, the Wesenheit function. If R is the ratio of total-to-selective absorption, then

$$W = V - R(B-V)$$
$$= V_0 + A_v - R(B-V)_0 - RE(B-V)$$
$$= V_0 - R(B-V)_0. \quad (1)$$

This quantity W is formed from V and $(B-V)$ as observed, and it is numerically equal to the *intrinsic values* of those two magnitudes and colors so combined. W is reddening-free.

The radial gradient : models

Cescutti+ 2007



A metallicity island ?