Metal-poor stars in the Galactic Halo

Elisabetta Caffau

In collaboration with:

Norbert Christlieb, Andreas Koch, Hans-Günter Ludwig, Luca Sbordone Landesstern-warte - Heidelberg

Piercarlo Bonifacio, Roger Cayrel, Patrick François, François Hammer, Monique Spite, François Spite GEPI - Observatoire de Paris

Lorenzo Monaco ESO - Santiago

Simone Zaggia INAF - Osservatorio Astronomico di Padova

Matthias Steffen Leibniz-Institut für Astrophysik Potsdam

Sergei Andrievsky Astronomical Observatory - Odessa

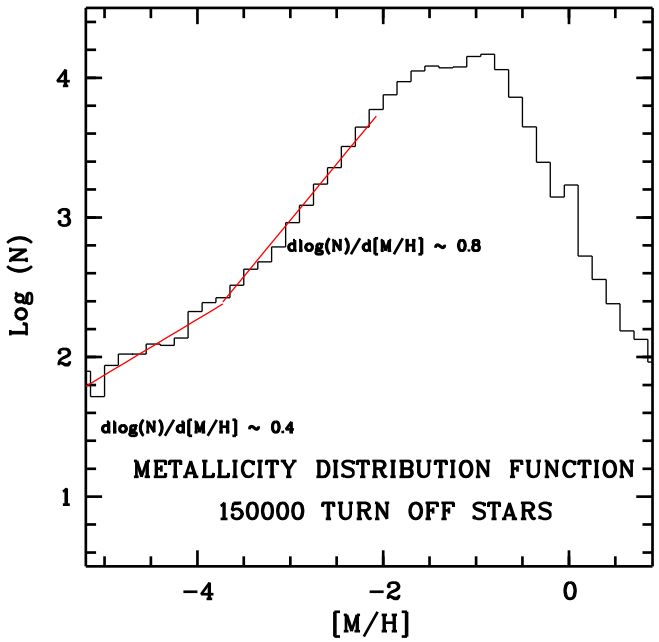
Vanessa Hill Université de Nice Sophia Antipolis, CNRS, Observatoire de la Côte d'Azur, Laboratoire Cassiopée

Paolo Molaro INAF - Osservatorio Astronomico di Trieste

Sofia Randich INAF - Osservatorio Astrofisico di Arcetri

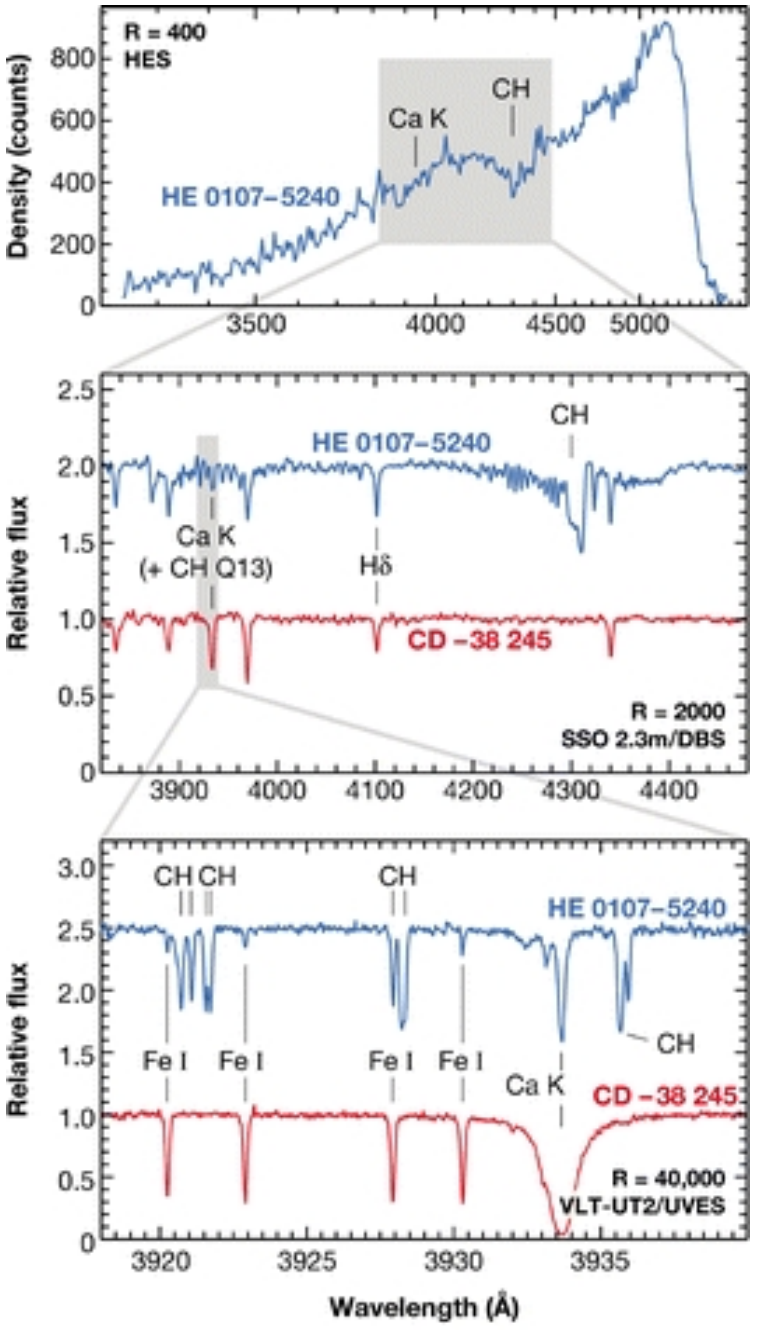
Metal-poor stars

Why metal-poor stars?



- to determine the metal-weak tail of the Halo metallicity distribution function, below [M/H]=–3.5, where the low resolution is not sufficient
- to determine the relative abundance of the elements in the metal-poor stars, signature of the massive first stars
- to determine the trend of the lithium abundance in the matter at the beginning of the Galaxy
- to find the most metal-poor stars

- Stars of extremely low metallicity (EMP) are exceedingly rare
- To select them large amount of observations is needed
- Large databases available at low resolution
- Spectra of EMP stars show few lines and these are weak
- Follow-up at higher resolution is necessary



Beers, TC and Christlieb, N. 2005
Annu. Rev. Astron. Astrophys. 43: 531–80

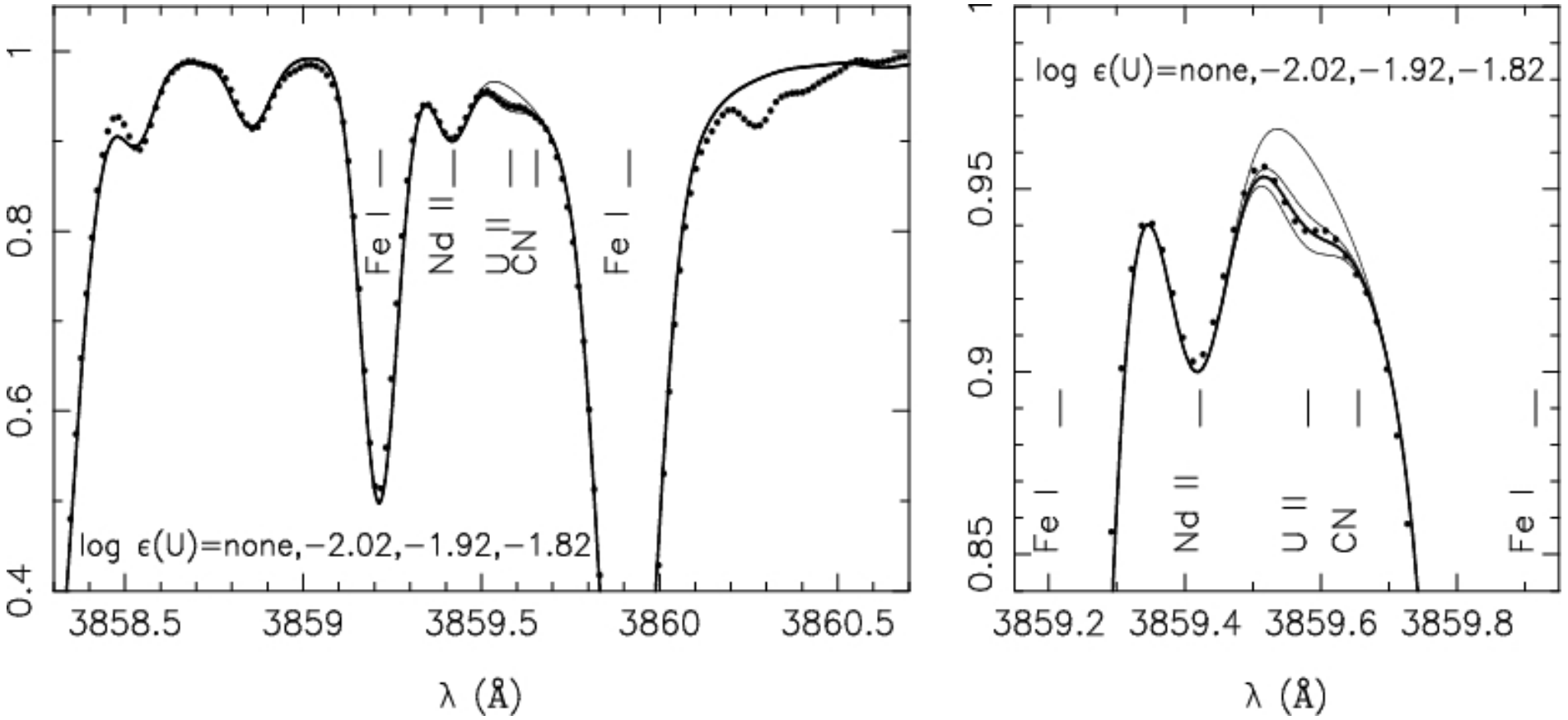
HR follow up Projects

- "First Stars" Project -- UVES on HK stars (Cayrel et al. 2004, Bonifacio et al. 2009)

- Keck:
  - "0Z project" -- HIRES (Cohen et al. 2004,2008)
  - ESI-HIRES Lai et al. (2007, 2008)
- HERES - for r-enhanced (Christlieb et al. 2004, Barklem et al. 2005)
- CASH - Hoberly-Eberly ...underway
- TOPOS follow-up (X-Shoter + UVES) of metal-weak tail of SDSS sample

First Stars, PI Roger Cayrel

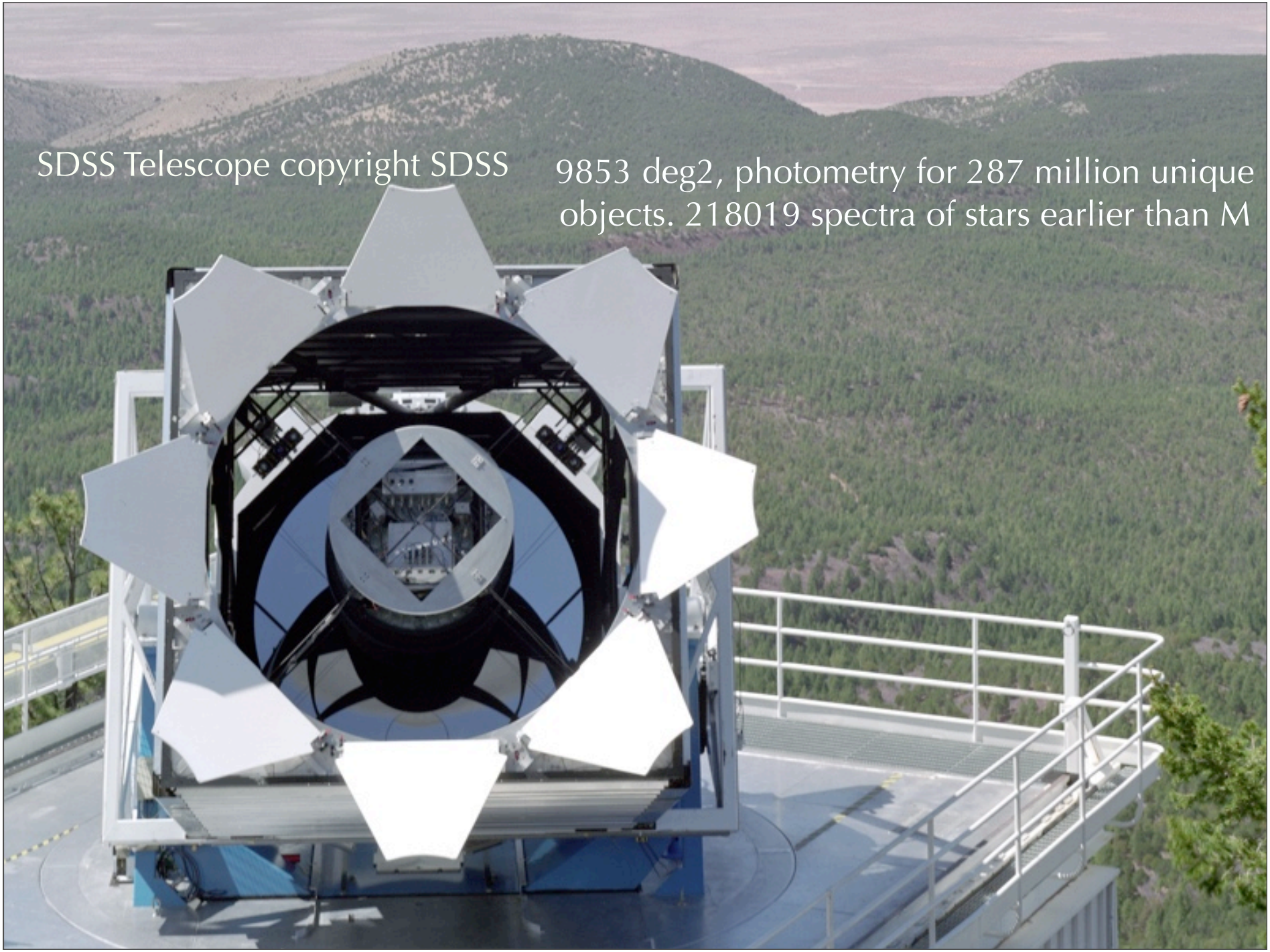
- 19 dwarf stars and 35 giant stars, in 15 refereed papers
- elements analysed: Li, C, N, O, Na, Mg, Al, Si, S, K, Ca, Sc, Ti, Cr, Mn, Fe, Co, Ni, Zn, Sr, Y, Zr, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Dy, Ho, Er, Tm, Yb, Th, U



Hill et al. (2002)

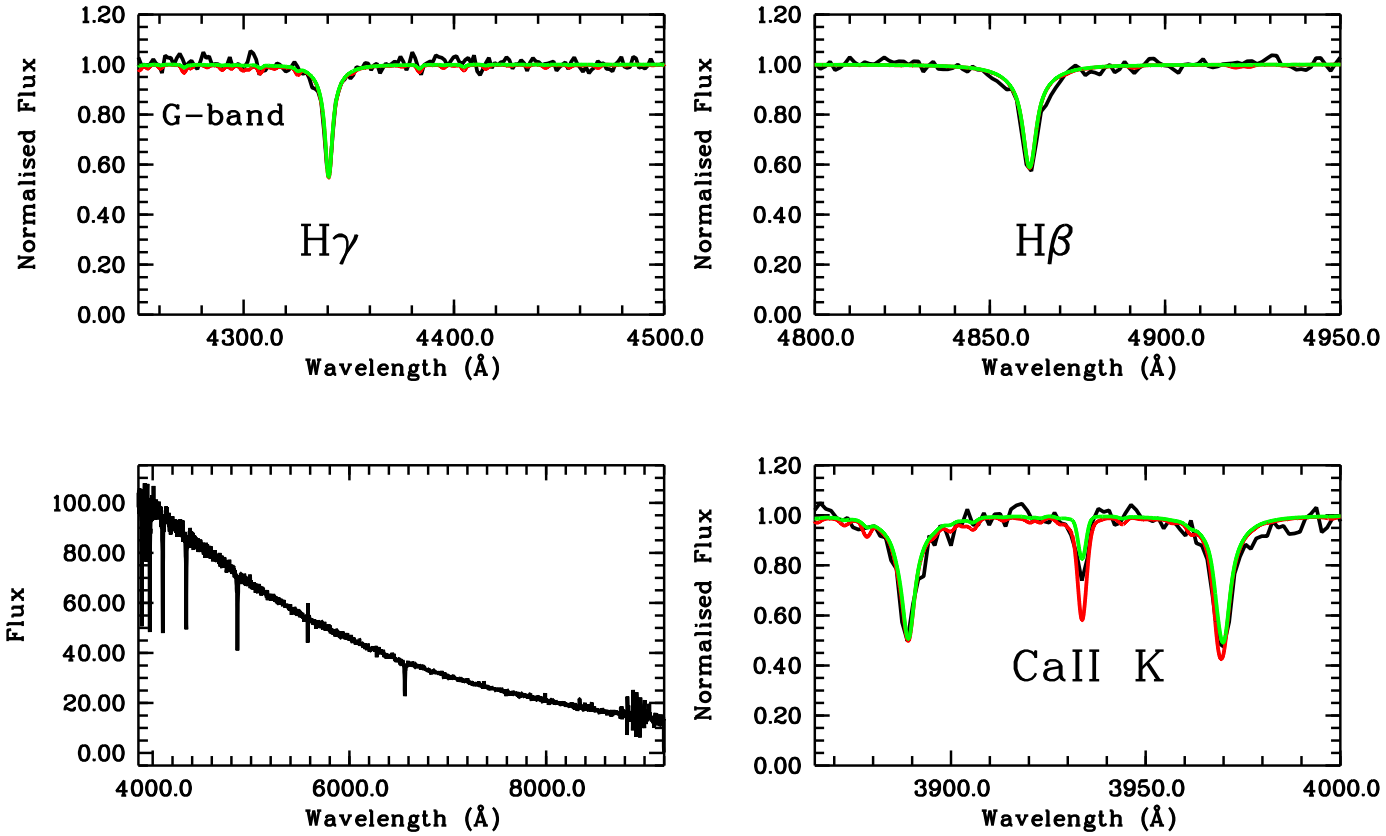
Most metal-poor stars

- GIANTS
  - CD -38 245 [Fe/H]=-4.2 "Bessel & Norris 1984"
  - BS 16467-062 [Fe/H]=-3.77
  - CS 22172-002 [Fe/H]=-3.86
  - CS 22885-096 [Fe/H]=-3.78
  - HE 1424-0241 [Fe/H]=-3.96 (peculiar)
- DWARFS
  - G 64-12 [Fe/H]=-3.50 Carney Peterson (1981)
  - CS 22876-32 [Fe/H]=-3.7 Molaro Castelli (1990)
- The record (but CEMP)
  - HE 0107-5240 [Fe/H]=-5.3 "Christlieb's star" (2001)
  - HE 1327-2326 [Fe/H)=-5.4 "Frebel's star" (2005)
  - HE 0557-4840 [Fe/H]=-4.8 "Norris's star" (2007)


SDSS Telescope copyright SDSS
9853 deg2, photometry for 287 million unique objects. 218019 spectra of stars earlier than M

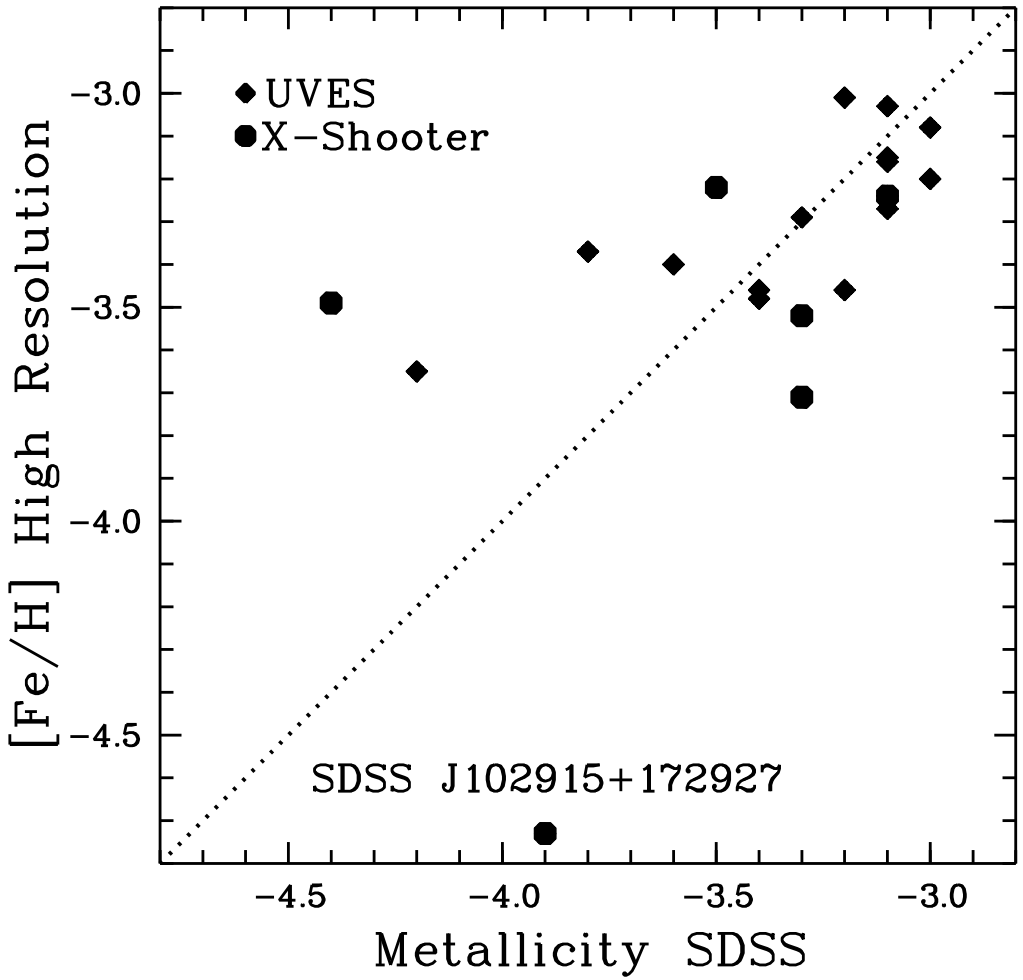
Selection

- Limited information derived from R=2 000 resolution spectra + photometry
- Many such spectra available from several surveys, essential for searching for rare objects
- Extremely metal-poor stars can be extracted from low resolution surveys
  - **150 000 SDSS spectra** (potentially TO stars) analysed automatically
  - final selection by visual inspection



Observed spectrum and over-imposed synthetic spectra [Fe/H]=-3.0 and [Fe/H]=-4.0

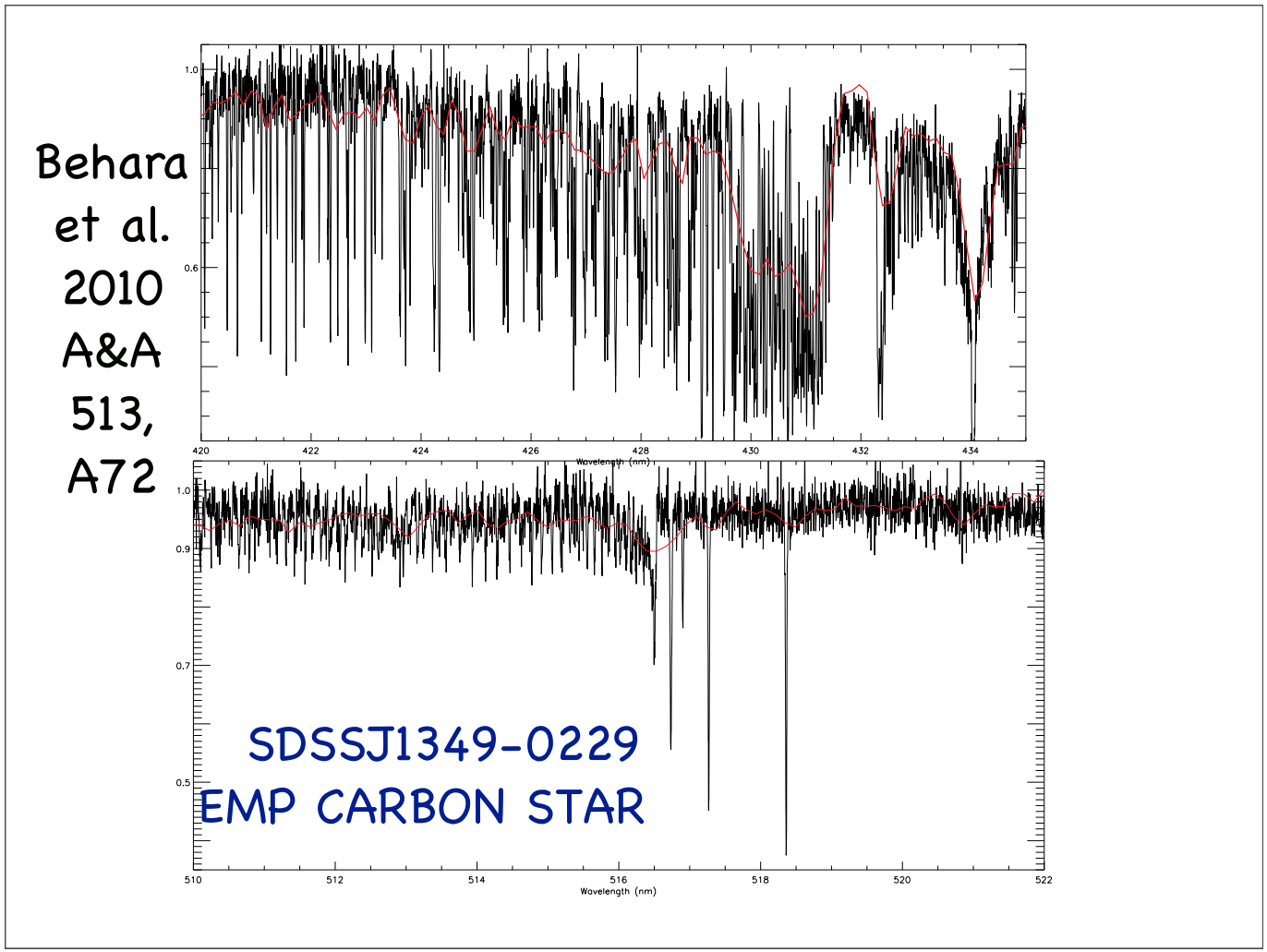
High resolution follow-up



Caffau et al. (2011) A&A 534,4

- SDSS spectra are inadequate for chemical analysis of extremely metal-poor stars
- necessary follow-up at higher resolution for the most promising candidates
  - UVES
  - X-Shooter

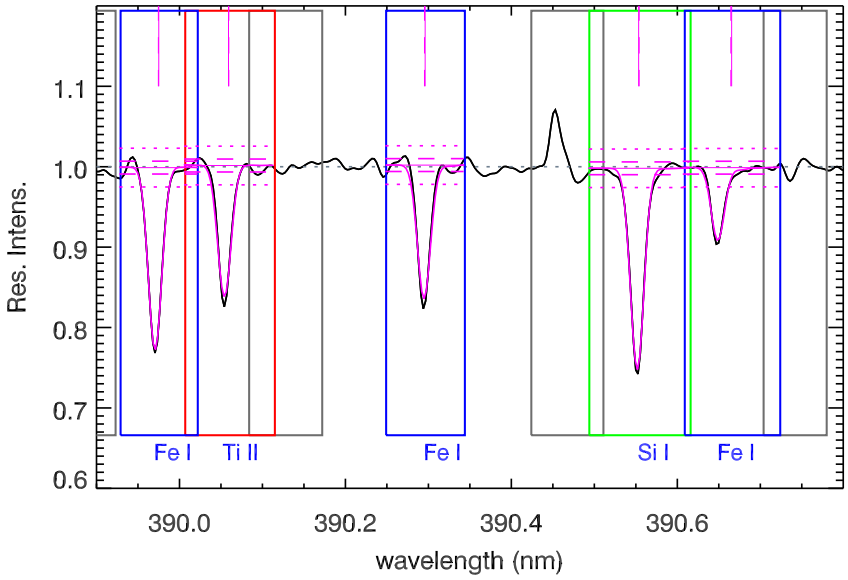
Carbon enhanced extremely metal-poor star selected from SDSS and observed with UVES at VLT

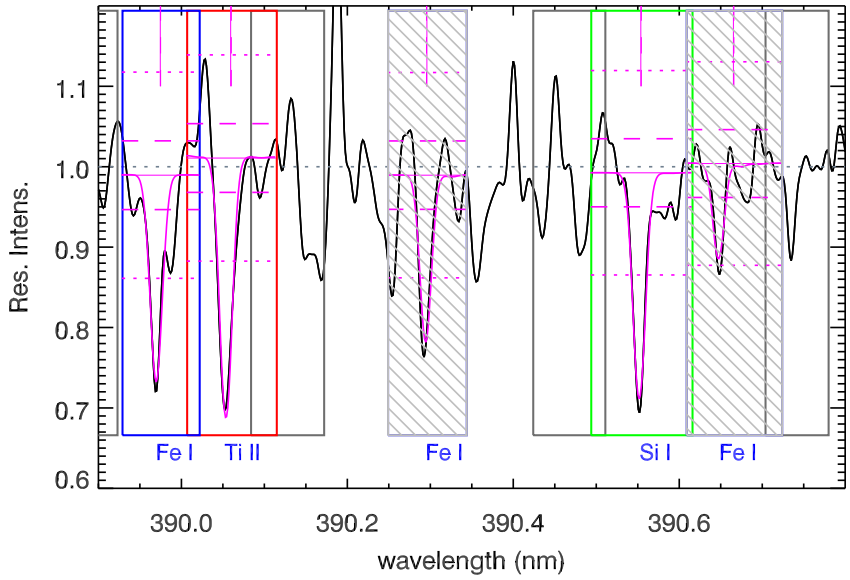


- large radial-velocity variation ($\approx 30 \mathrm{km\,s^{-1}}$) indicating it is a member of a binary system
- strong C enhancement
- from three abundance indicators (CH, C2, CI) not consistent results, either in 1D or in 3D analysis

UVES sample

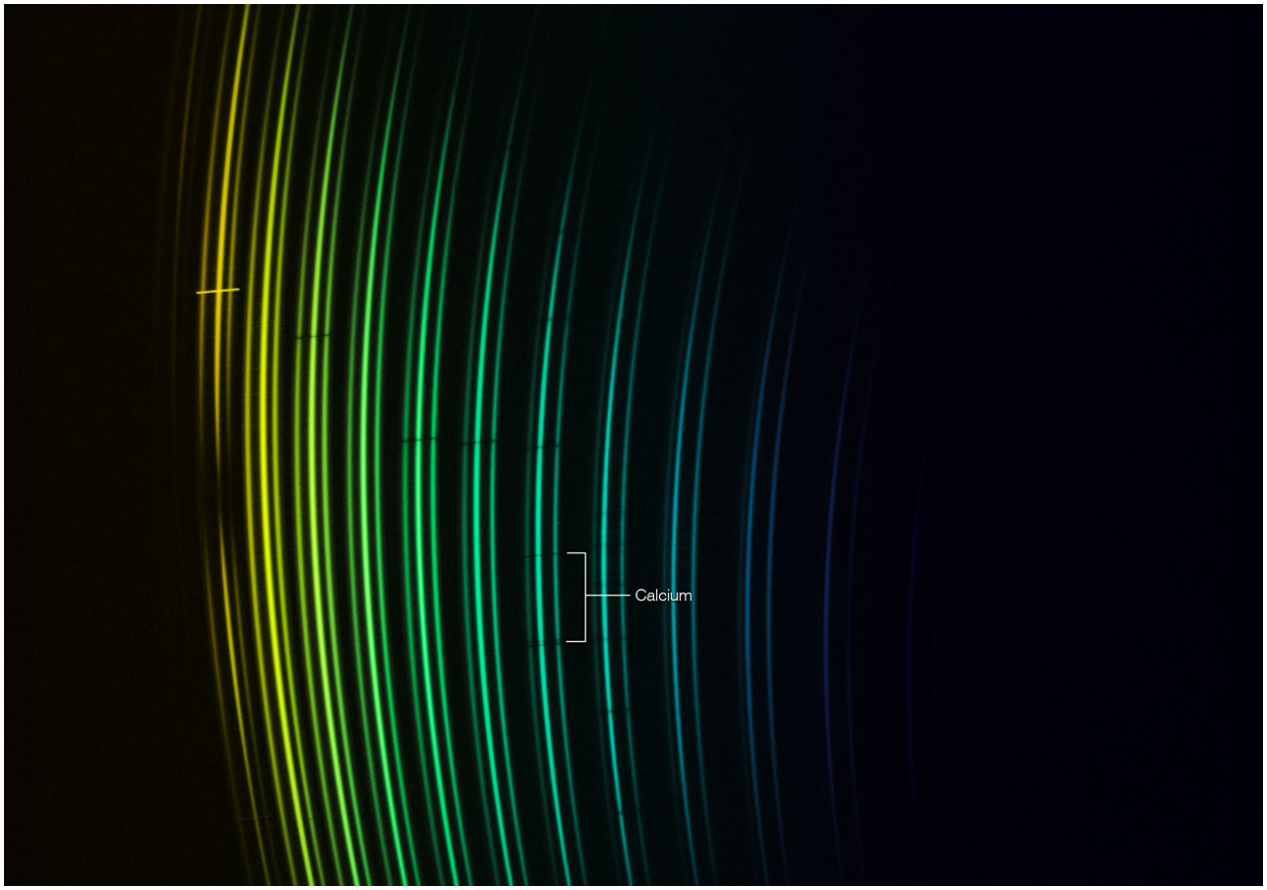
A sample of 15 stars analysed with automatic code MyGIsFOS
Bonifacio et al. A&A (2012)





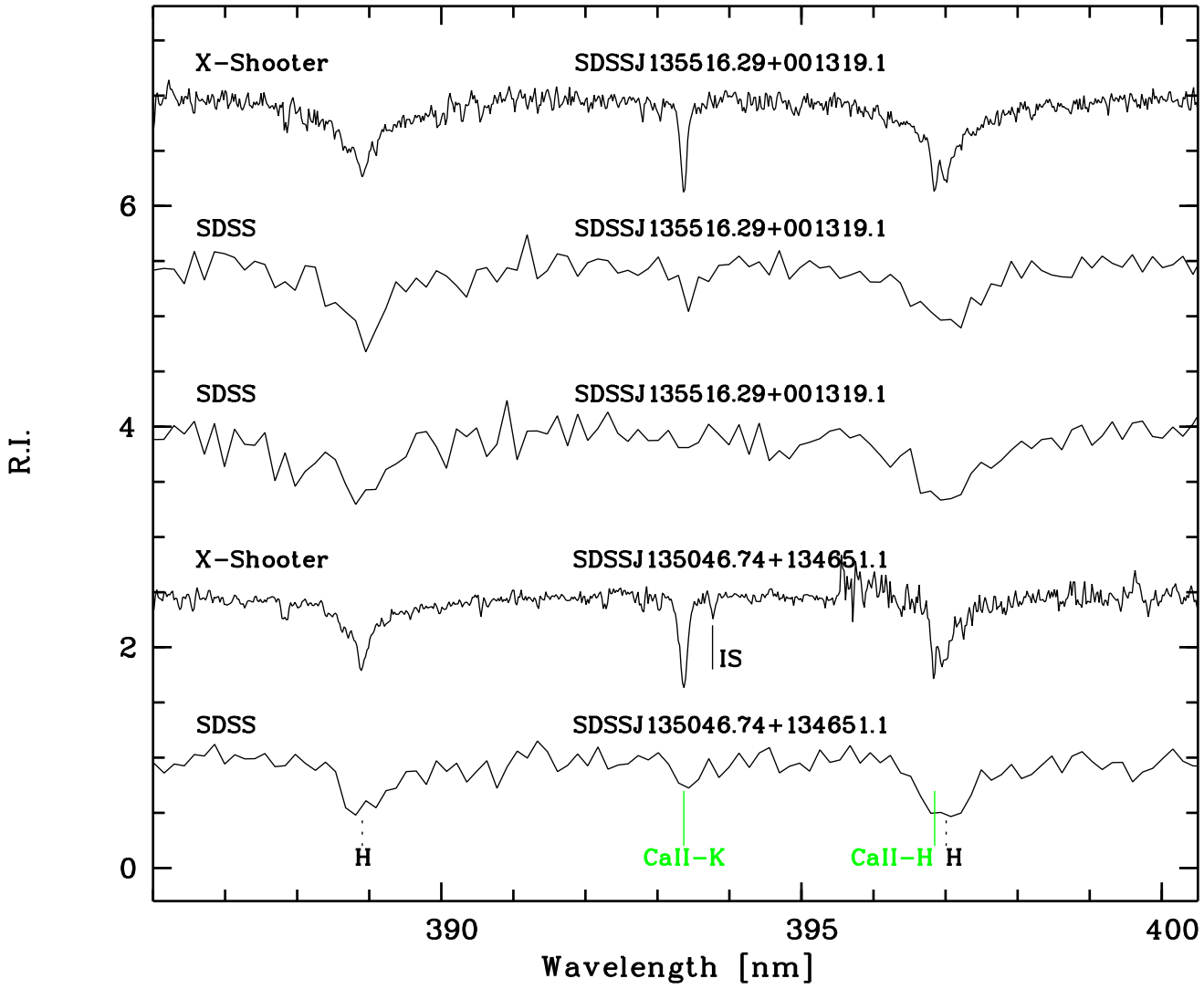
X-Shooter

We had the opportunity to observe a sample of stars during the French-Italian GTO of X-Shooter, the single target spectrograph for the Cassegrain focus of UT2 (Kueyen) of the VLT-ESO.



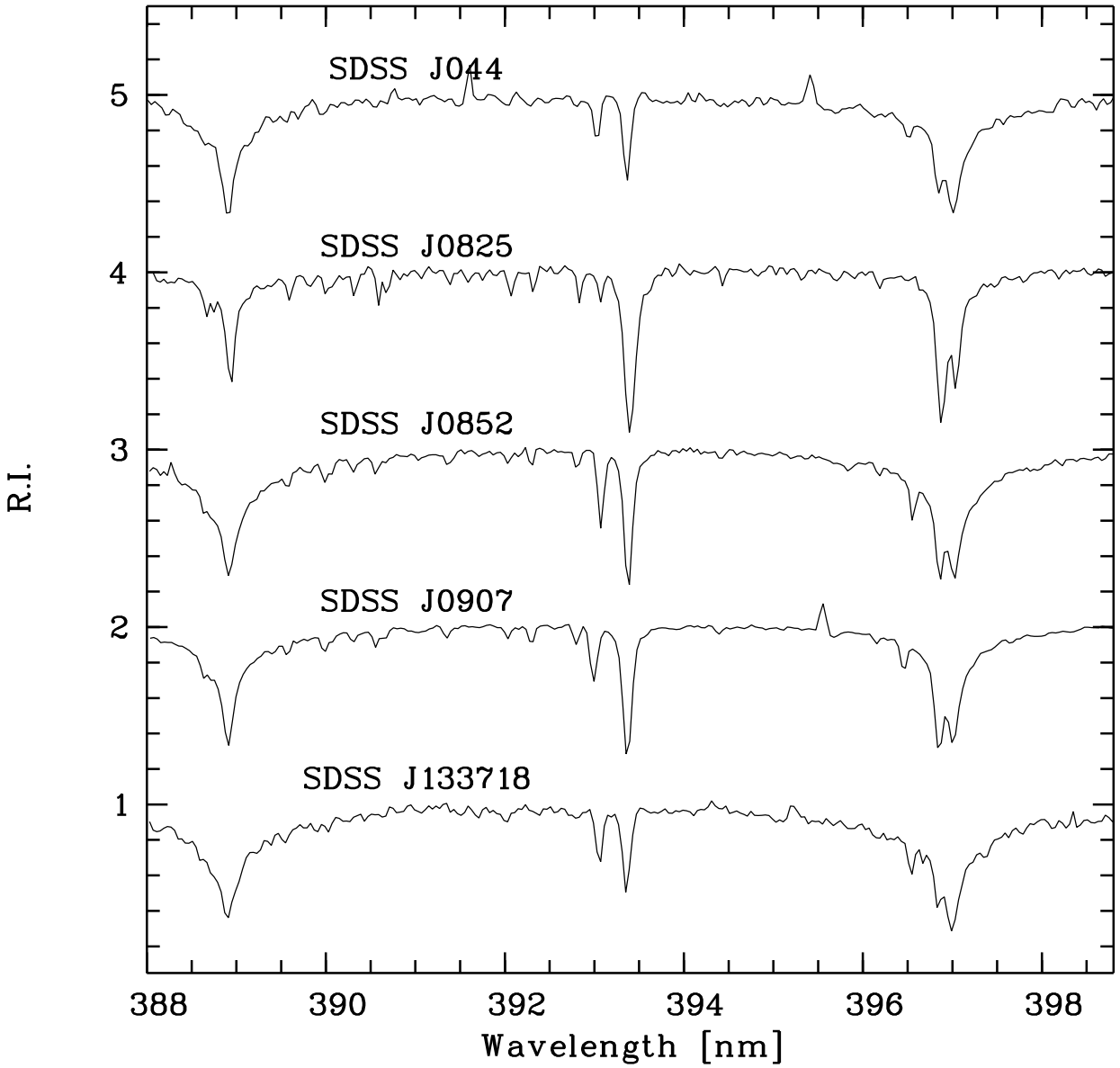
The distribution of the light coming from star SDSSJ́102915+172927 after it has been split up by X-Shooter. The spectrum of the star appears to be triple at each wavelengths as it was split up using an integral field unit (IFU) to collect as much light as possible.

Metal-poor star selected from SDSS and observed during the GTO of X-Shooter at VLT - June 2010



- SDSS J135516
  - g = 18.97
  - distance 9.1 Kpc
- SDSS J135046
  - g = 18.29
  - distance 3.9 Kpc

Metal-poor star selected from SDSS and observed during the GTO of X-Shooter at VLT - February 2011



$[Fe/H] = -3.71 \pm 0.27$

$[Fe/H] = -3.22 \pm 0.24$

$[Fe/H] = -3.24 \pm 0.24$

$[Fe/H] = -3.52 \pm 0.14$

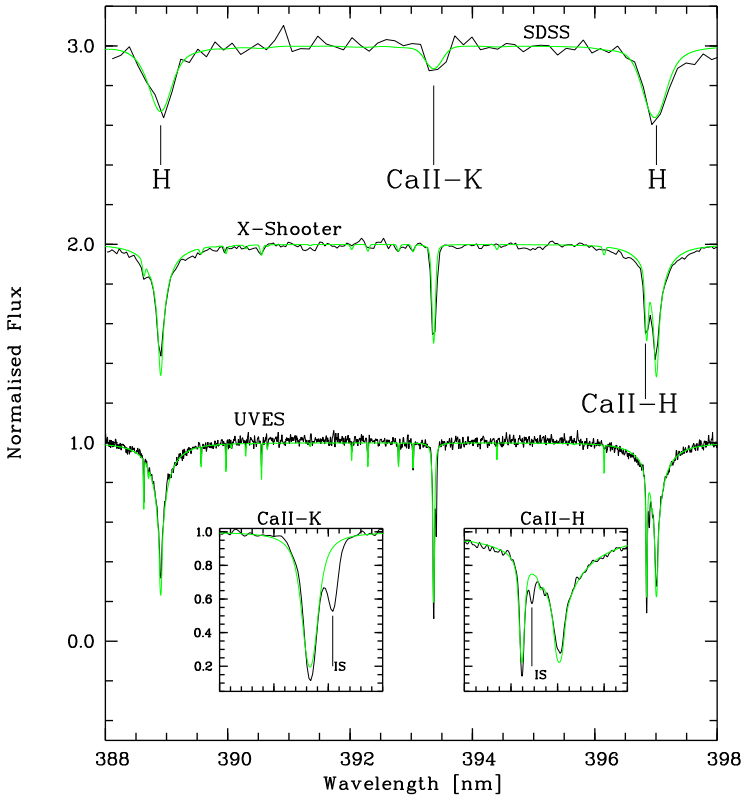
$[Fe/H] = -3.49 \pm 0.32$

Caffau et al. 2011 A&A

A primordial star in the hart of the Lion

E. Caffau, P. Bonifacio, P. François, L. Sbordone, L. Monaco, M. Spite, F. Spite, H.-G. Ludwig, R. Cayrel, S. Zaggia, F. Hammer, S. Randich, P. Molaro, V. Hill

Nature 2011, 477, 67



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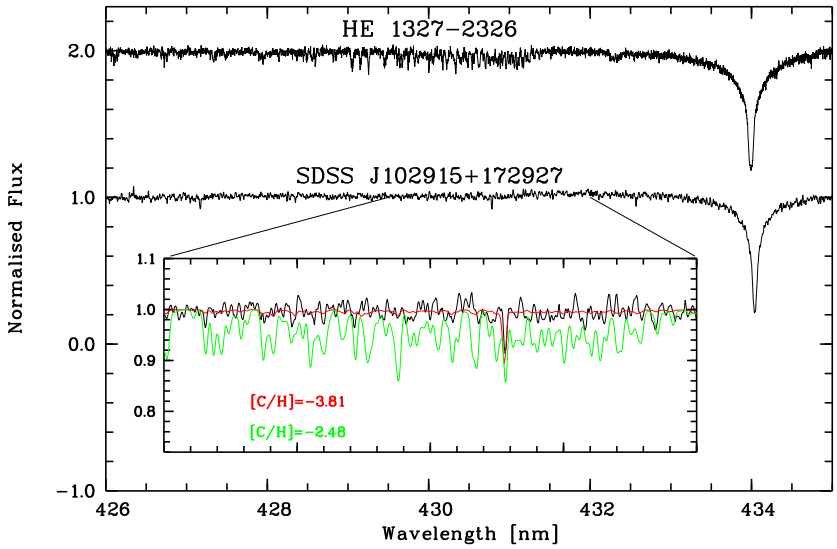
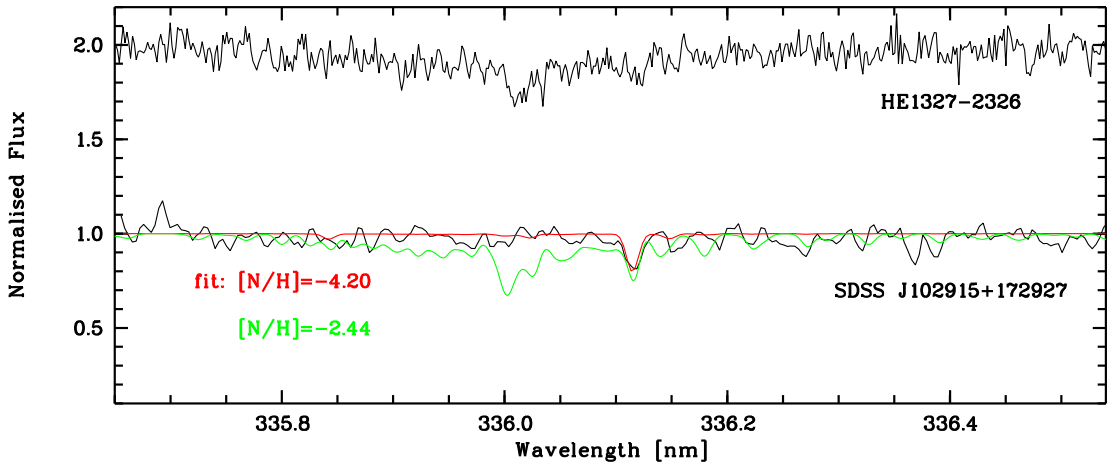
TIME

Tuesday, Sep. 06, 2011

Cosmic Anomaly: The Star That Shouldn't Exist

By Michael D. Lemonick





Why the Leo-star was unexpected

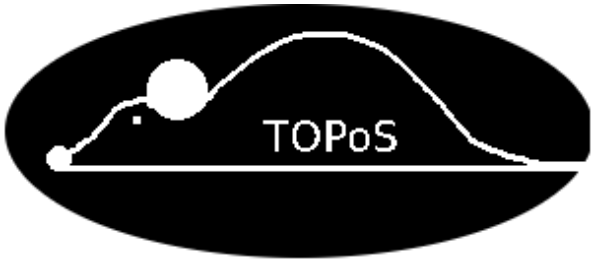
- according to some theories, stars cannot form from the primitive interstellar medium until it has been enriched above a critical value of Z (Bromm & Loeb 2003, Schneider et al. 2003)

- formation of solar or sub-solar mass stars requires some minimal metallicity
  - this results supported
    - by absence of observed UMP stars
    - the three most Fe-poor object known are all strongly C-N-O enhanced

- other theory based on other cooling methods
  - Schneider et al. 2011:
    - conditions which do not rely on carbon and oxygen line-cooling
    - presence of dust key driver for the formation of low-mass stars

Turn Off Primordial Stars

PI Elisabetta Caffau



- Observations:
  - 150 h @ VLT
  - four semesters, starting from 89
  - 120 h X-Shooter
  - 30 h UVES
- Targets:
  - 80-100 stats with X-Shooter
  - the most interesting stars (≈ 5) with UVES
- Scientific goals:
  - to determine the metal-weak tail of the Halo metallicity distribution function, below [M/H]=–3.5, where the low resolution SDSS spectra are inadequate;
  - to determine the relative abundance of the elements in EMP-UMP stars, signature of the massive first stars;
  - to determine the trend of the lithium abundance in the matter at the beginning of the Galaxy;
  - to improve understanding in star formation from primordial gas.

4MOST (PI Roelof de Jong)

- Phase A study of high-multiplex, wide-field fibre-fed spectrograph for VISTA-ESO
  - field-of-view of $6\ \mathrm{degree}^2$
  - two simultaneous modes of operation, low (>5000) and high (20000) resolution
  - > 1500 low resolution fibers (goal 3000)
  - $\approx$ 10% fibers on high resolution
- Scientific goal:
  - complement and complete informations (radial velocities and abundances) form Gaia on the Milky Way
  - characterise the metallicity distribution function at [M/H]≤ -2.5 by increasing the statistic by a factor 10