LAMOST observations in the Kepler field

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Chinese group

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European group

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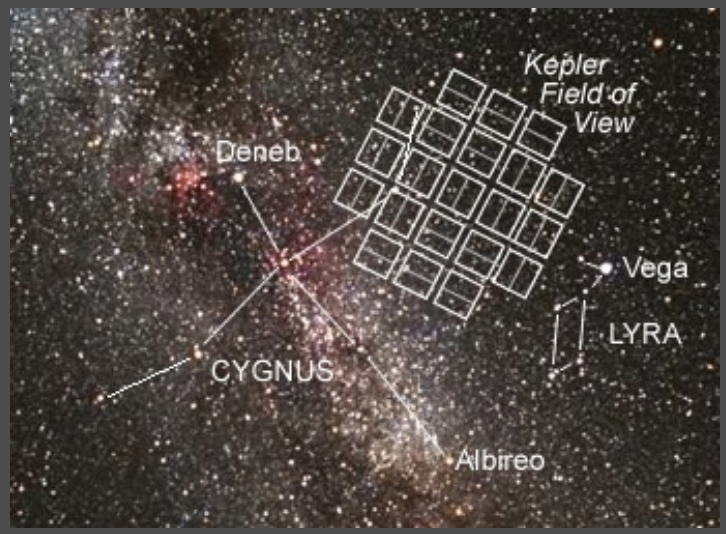
American group

Richard O. Gray (North Carolina), Chris J. Corbally (Arizona)

Introduction: NASA mission Kepler

- primary mirror: 1.2-m
- launch on 7 March 2009
  - Earth-trailing heliocentric orbit
  - lifetime ~3.8 years (failure on 14 May 2013)
- continuous monitoring of 1 star field in Cygnus-Lyra region
  - more than 100,000 stars
  - roll 90° about line-of-sight every 3 months
  - short (1 min.) or long (32 min.) cadence
  - broad band photometry with accuracy of few ppm



- main scientific goals
  - discover Earth-size planets (transit method)
  - characterizing planet-hosting stars by means of asteroseismic methods
  - opportinity for asteroseismic investigation of stars covering H-R diagram

Kepler Asteroseismic Science Consortium (KASC)

Introduction: asteroseismology

- *science in which stellar (aster) oscillations (seismo) are studied (logy) to gain information of stars*
  - *probe internal structure*
  - *derive stellar parameters with unprecedented precision (R, M, age,...)*
  - *direct tests to modeling of complex dynamical processes in stellar interiors (e.g. diffusion, convective overshoot)*
  - *improve understanding of stellar evolution*
- *ingredients*
  - *precise pulsation frequencies* ⇒ *provided by Kepler photometry*
  - *accurately identified modes*

    ⇒ *combine with ground-based follow-up (bright objects) observation of multiplets and/or frequency/period spacings*

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- ingredients
  - precise pulsation frequencies ⇒ provided by Kepler photometry
  - accurately identified modes
    ⇒ combine with ground-based follow-up (bright objects)
    observation of multiplets and/or frequency/period spacings
  - strong constraints on atmospheric parameters (to distinguish solutions)

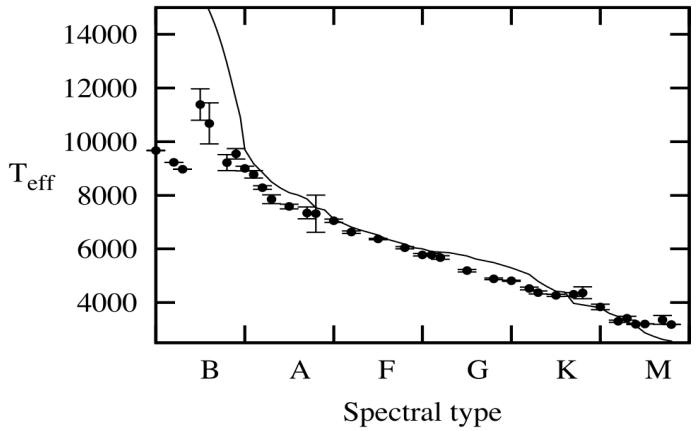


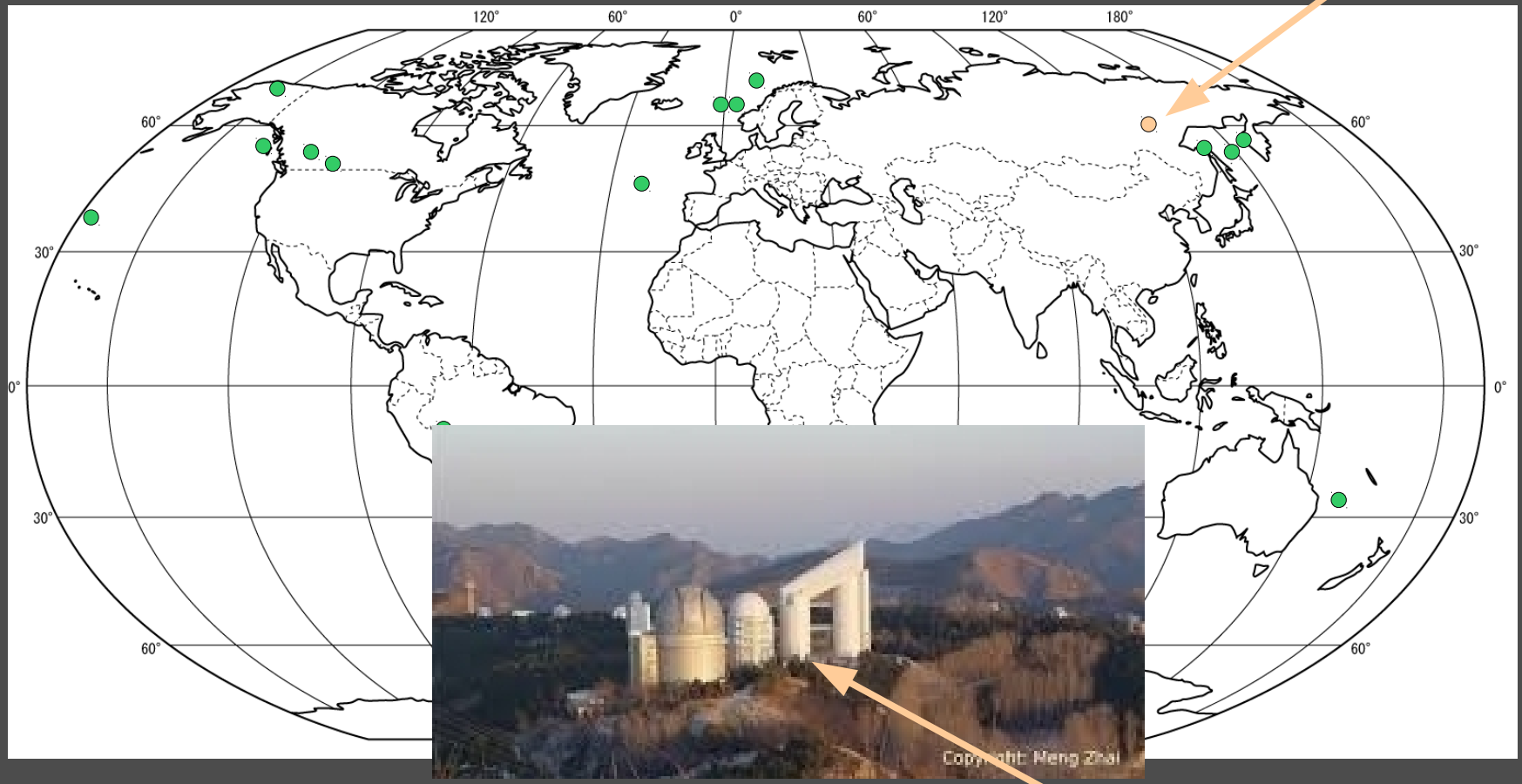
Figure 1. The effective temperatures from the KIC catalogue as a function of spectral type. The line is a recent effective temperature–spectral type calibration (Mamajek 2010).

Balona et al. (2011, MNRAS 413_2403)

LAMOST ⇒ Kepler Input Catalogue (KIC10) but not accurate enough!

Introduction: observatory

Xinglong observatory



4-m Guo Shou Jing Telescope

Large Sky Area Multi-Object Fiber Spectroscopic Telescope

low resolution (R=1,800)

LAMOST-Kepler project: goals

LAMOST observations of well selected fields

- *to cover whole Kepler field-of-view*
- *to characterize targets in homogeneous way*
  - T_{eff}, logg, *metallicity*
  - *spectral type*
  - *any peculiarities*
- *with low resolution spectroscopy*
  - *radial velocity* ⇒ *binaries, cluster membership*
  - *rotation velocity* ⇒ *restriction on* vsini
- *because it is the only instrument to observe thousands of targets efficiently*
  - *brightest targets (Kp ≤ 10.5): with 2-m class telescopes*
  - *LAMOST: focus on fainter targets*

LAMOST-Kepler project: proposal

selection of targets

- type of targets
  - ~250 standard targets (MK secondary standards)
  - ~7,000 KASC targets (KIC10; scientific interest for KASC)
  - ~150,000 planet targets (KIC10; scientific interest for planet search group)
  - ~1,000,000 extra targets (KIC10; no scientific interest)
  - field stars (USNO-B catalogue; no scientific interest)

  without parameters high to low T_{eff}
- brightness of targets
  - brightness intervals of maximum 5 magnitudes
  - bright targets ($9.0 < Kp < 14.0$)

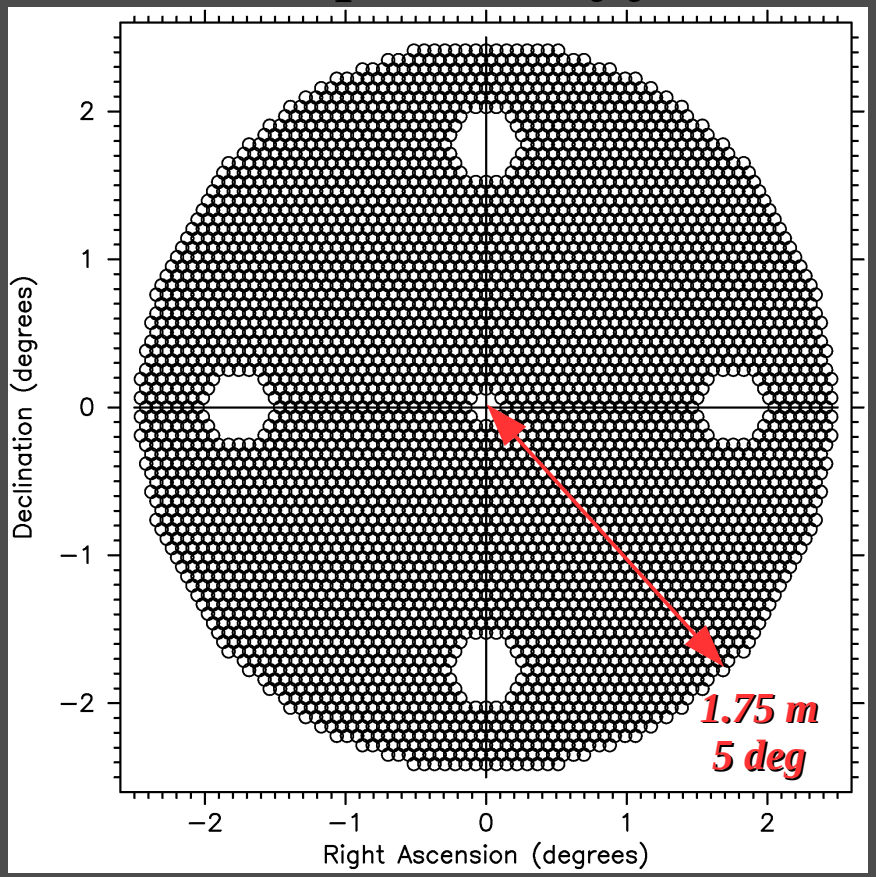
    from faint to bright (avoid saturation)
  - faint targets ($Kp > 14.0$)

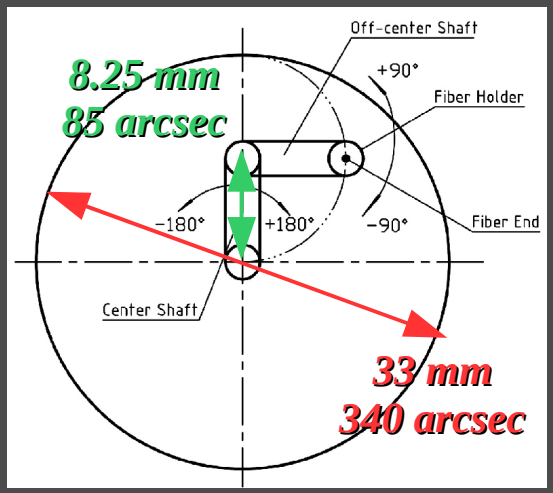
    from bright to faint (avoid too low flux)

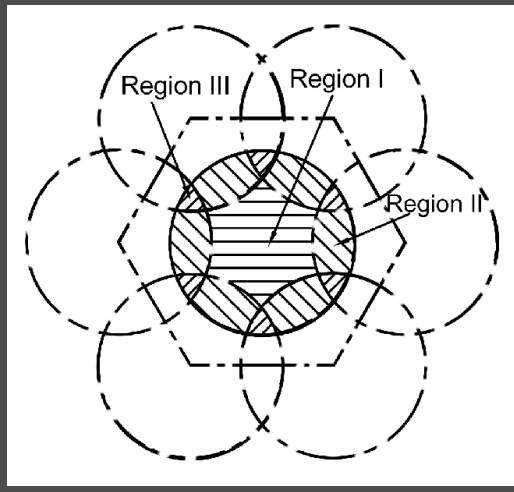
LAMOST-Kepler project: proposal

selection of fibers

- 16 spectrographs with 250 fibers each
- position of fibers





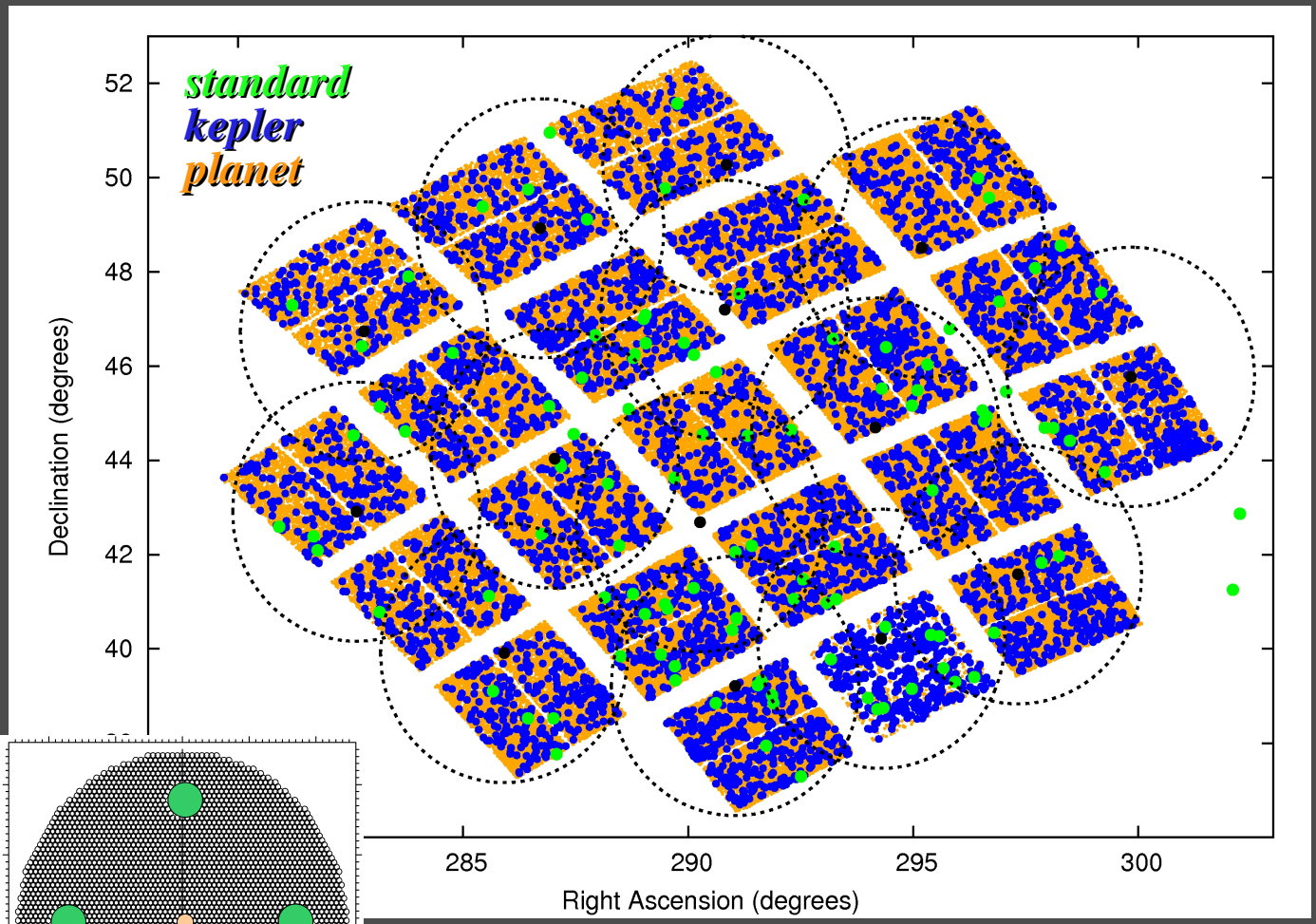


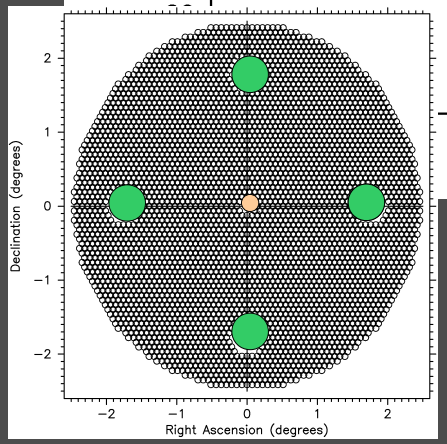
- free movement within region of ϕ340 arcsec
- overlapping regions
- code "Survey Strategy System"
  - allocation:
    - first region I
    - afterwards region II & III
  - min. 5 fibers standard stars
  - min. 20 fibers for object-free region

LAMOST-Kepler project: proposal

selection of fields

- 14 field needed to (almost) cover Kepler field-of-view
- optimize number of observable KASC targets
- requirements:
  - center hole star with V<8
  - off-center holes stars with V<17

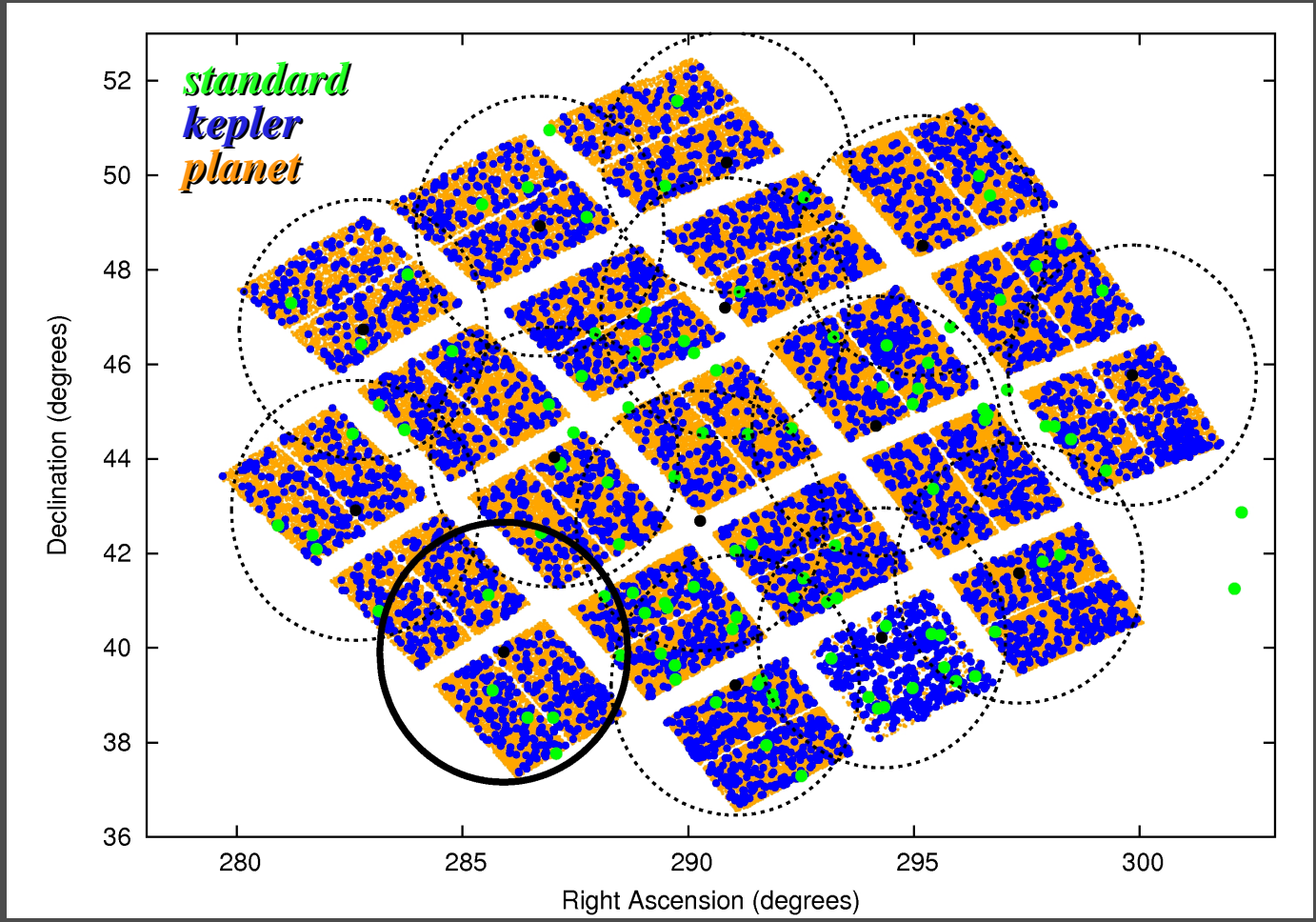




LAMOST-Kepler project: observations

2011

date	#	spectra
30/05/2011	2	1,107
08/06/2011	2	966

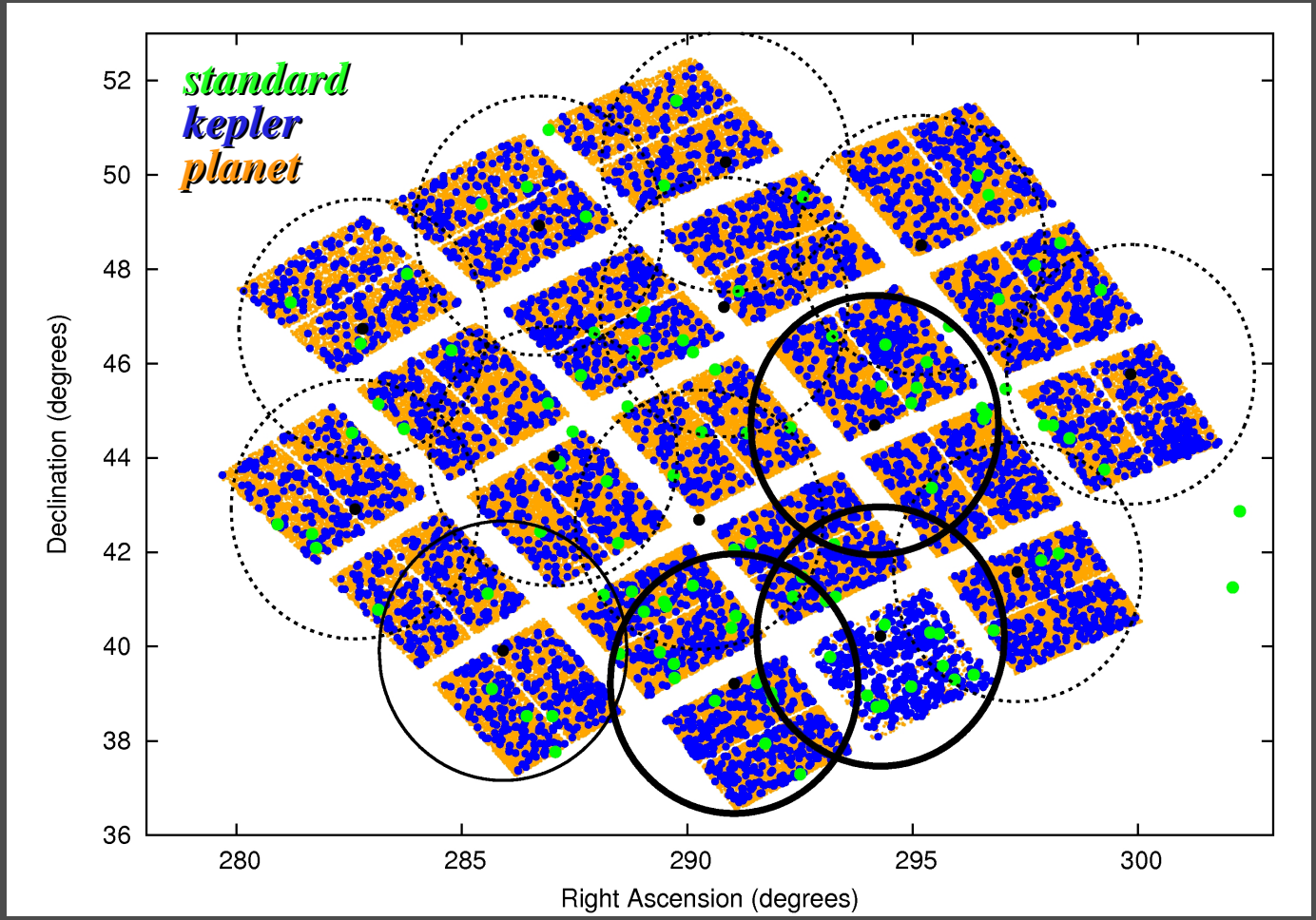


total	4	2,073

LAMOST-Kepler project: observations

2012

date	#	spectra
30/05/2011	2	1,107
08/06/2011	2	966
04/06/2012	1	1,737
15/06/2012	3	8,328
17/06/2012	3	10,526
total	13	22,664



LAMOST-Kepler project: observations

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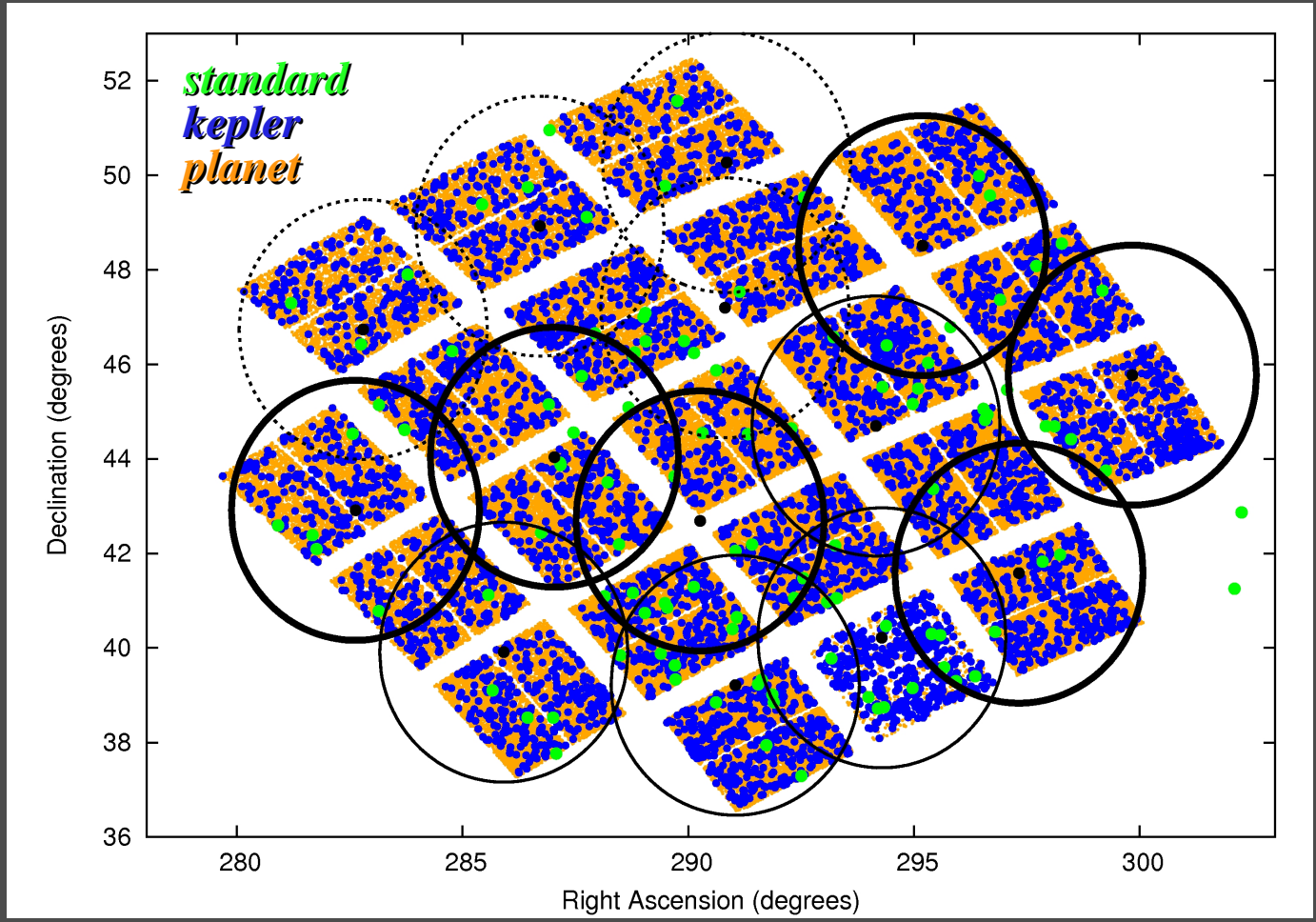
05/10/2013	2	8,000
22/05/2013	1	394
14/09/2013	1	3,250
19/05/2013	1	1,936
26/09/2013	1	3,750
02/10/2013	1	3,500
17/10/2013	1	3,250
25/09/2013	2	7,000
25/10/2013	1	3,500
04/10/2013	1	4,000
07/10/2013	1	3,500
total	24	64,744



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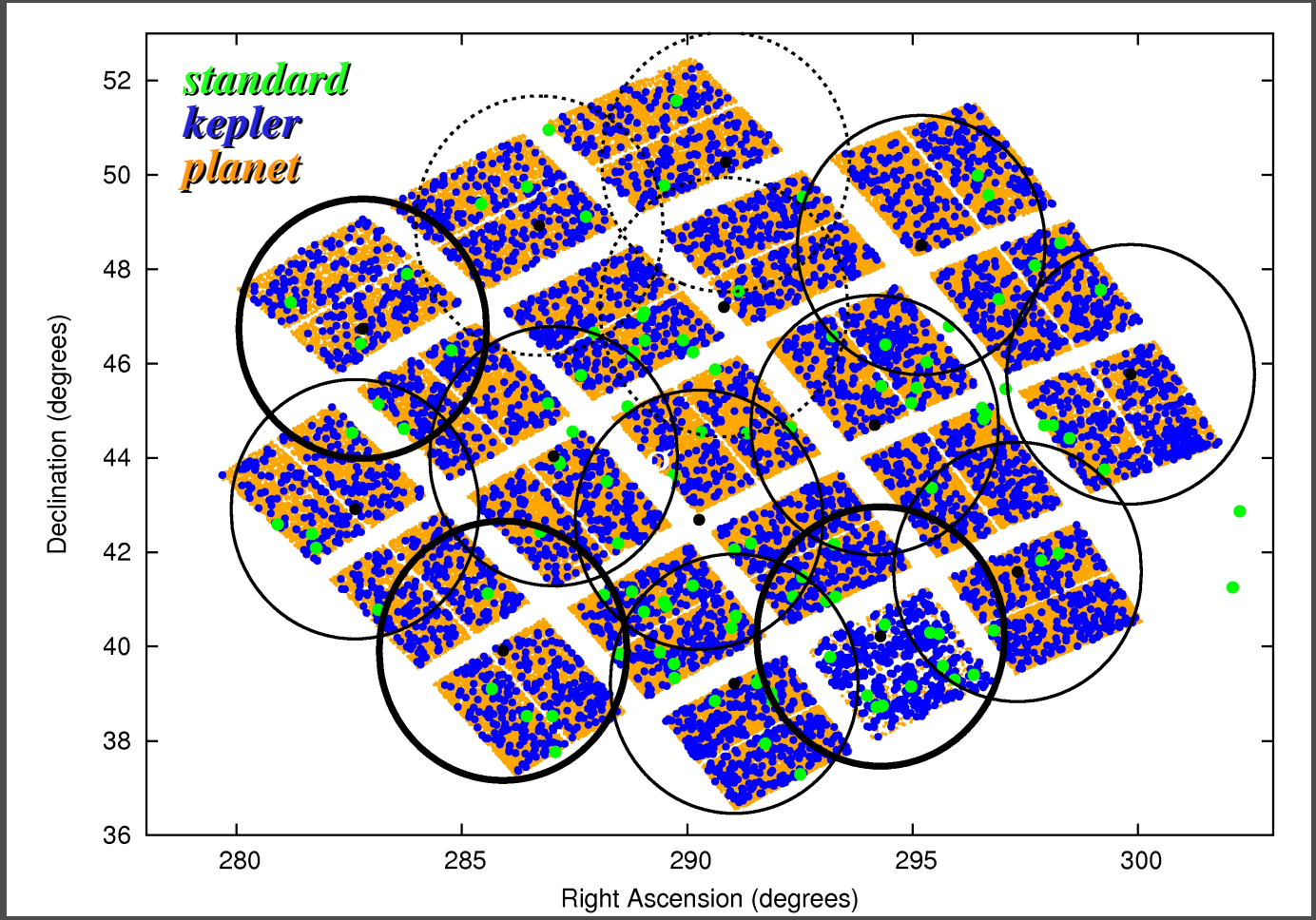

new observations in 2014

date	#
22/05/2014	2
29/05/2014	2
02/06/2014	1

LAMOST-Kepler project: observations

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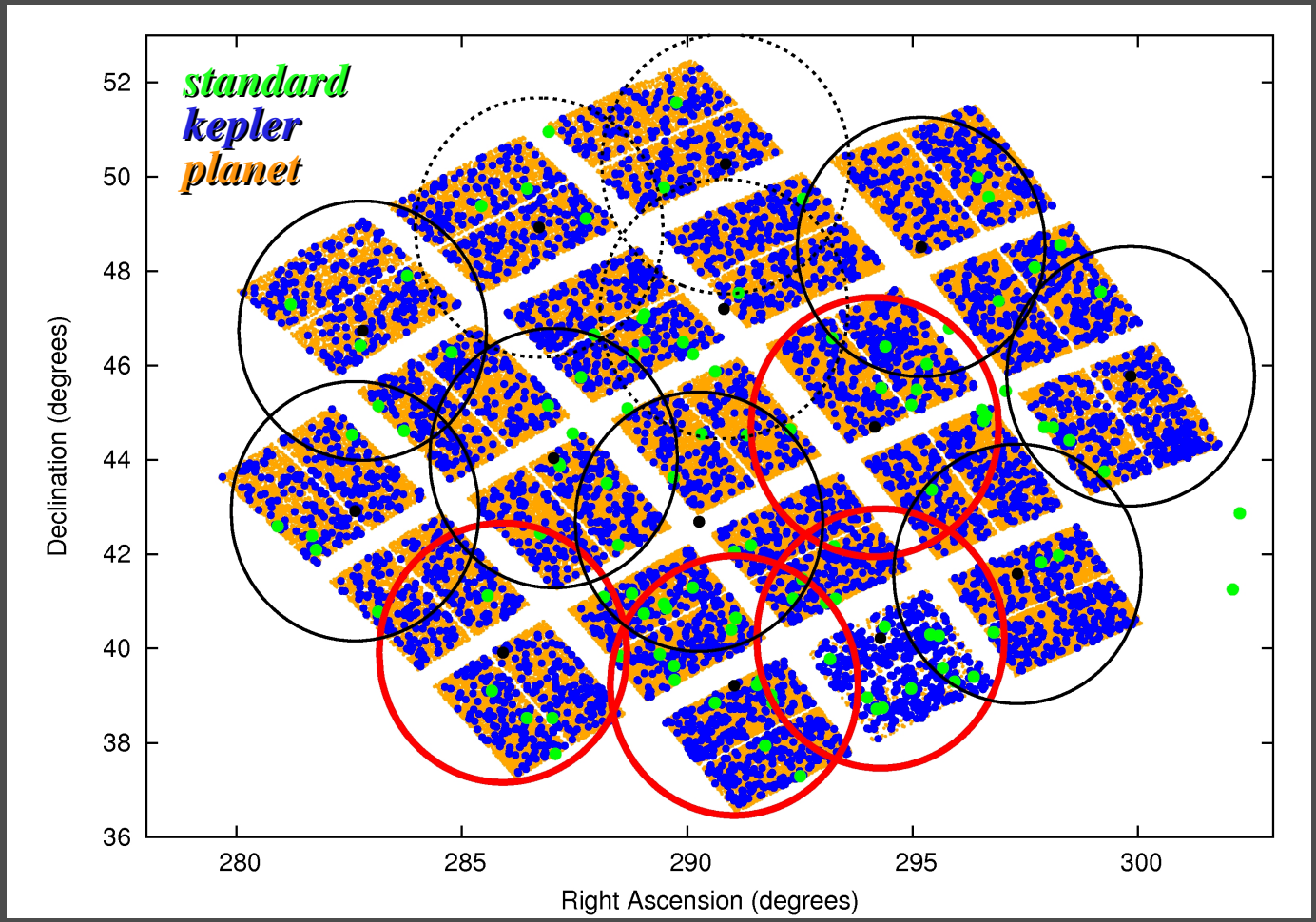
analysis of 2011 & 2012 observations

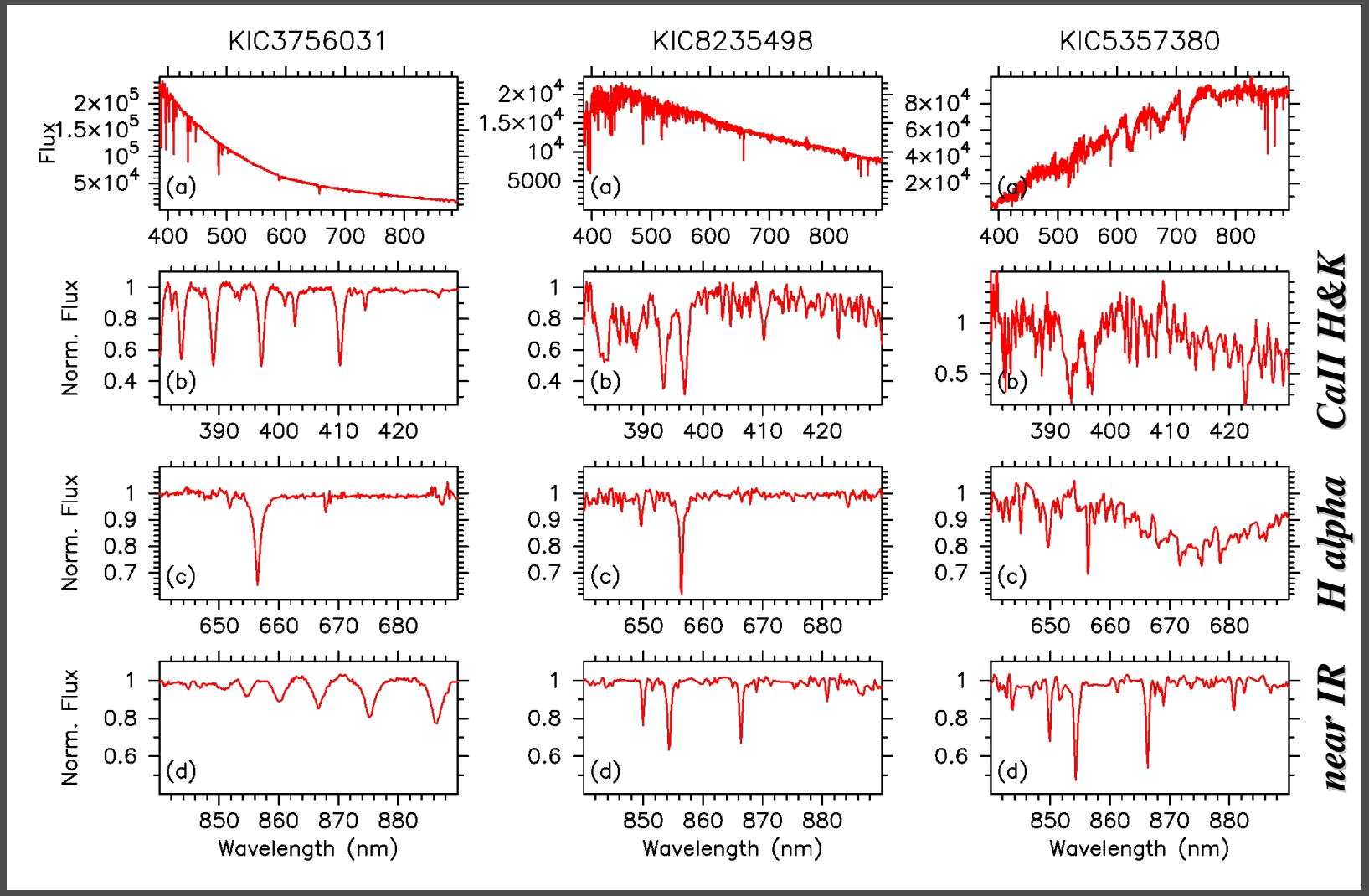


new observations in 2014

date	#
22/05/2014	2
29/05/2014	2
02/06/2014	1

LAMOST-Kepler project: observations

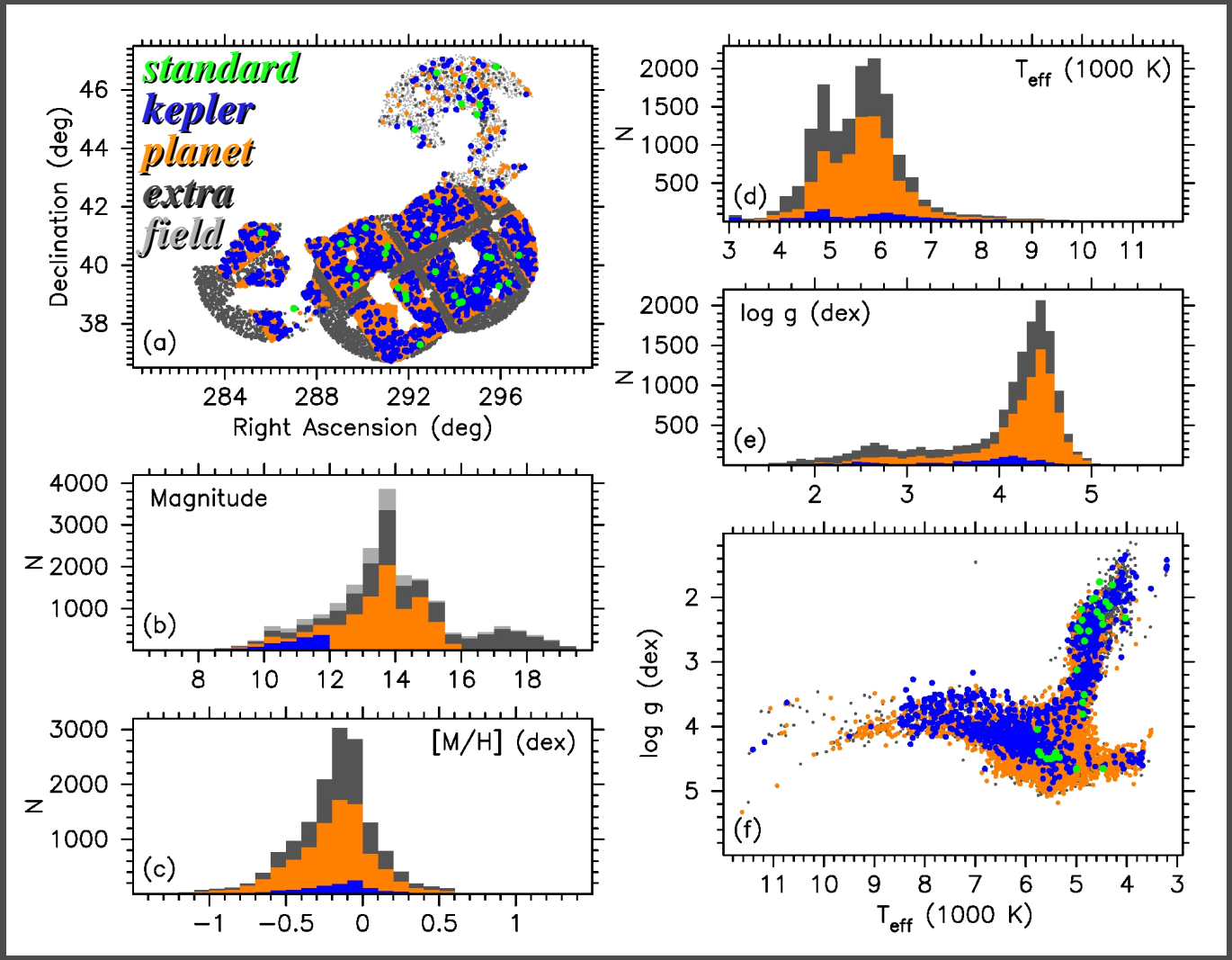
examples



B2.5V G0 M1III

LAMOST-Kepler project: observations

statistical overview



Results: Chinese team

(De Cat et al., in preparation)

method

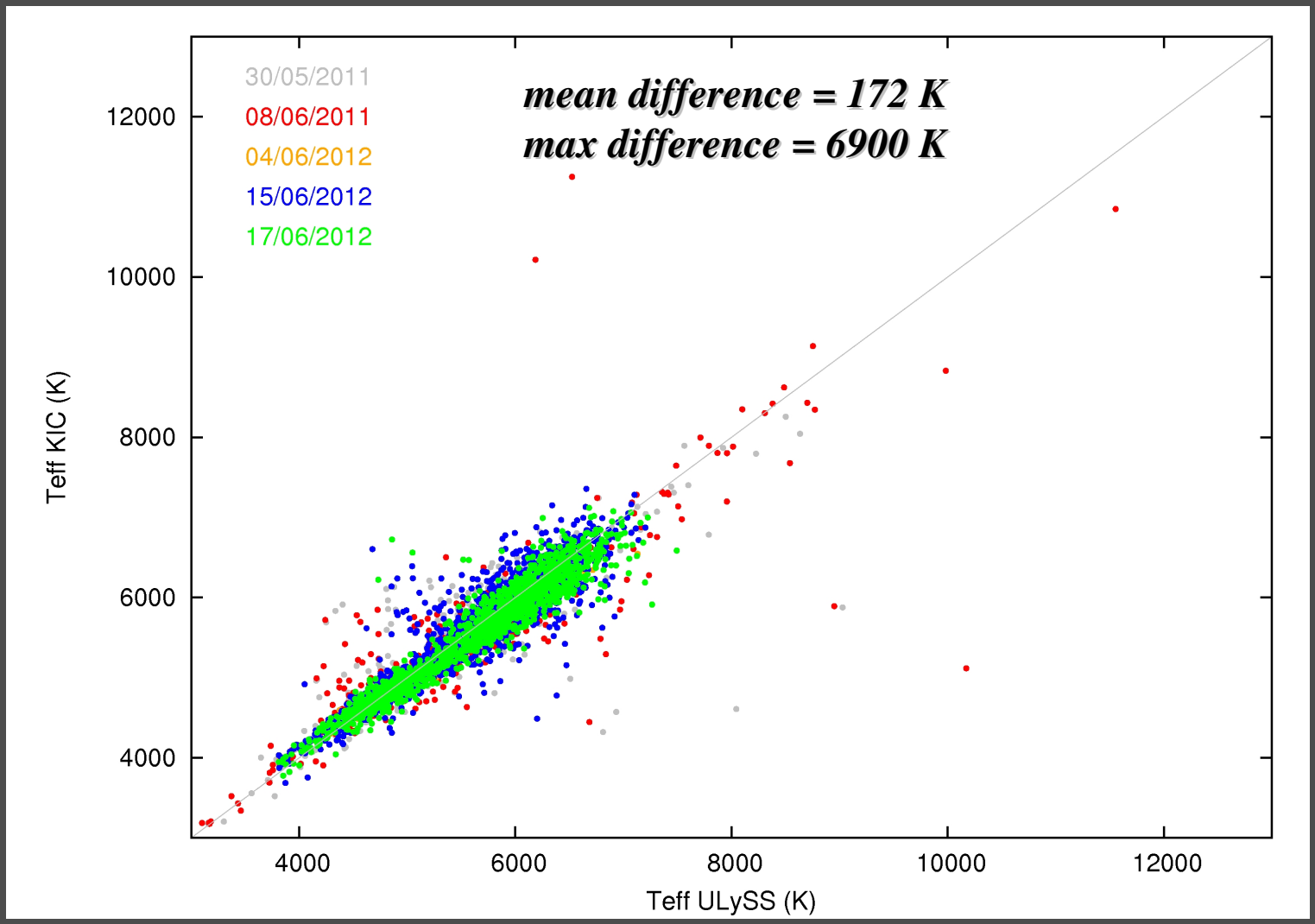
- code **ULySS** (University of Lyon Spectroscopic analysis Software)
  (Kovela et al., 2009, A&A 501, 1279)
  - χ^2 minimisation: fit of parametric model to observed spectrum
    - linear combination of non-linear components → grid of theoretical models
    - convolved with a line-of-sight velocity distribution
    - multiplied by a polynomial function → absorps effects of imprecise fluxes and of Galactic extinction
  - in pixel space
  - adapted for LAMOST observations (R~1800)
    - T_{eff}
    - logg
    - [Fe/H]

    } can be compared with KIC10 parameters (based on Sloan photometry)
    - v_{rad}

Results: Chinese team

(De Cat et al., in preparation)

comparison with KIC10 values



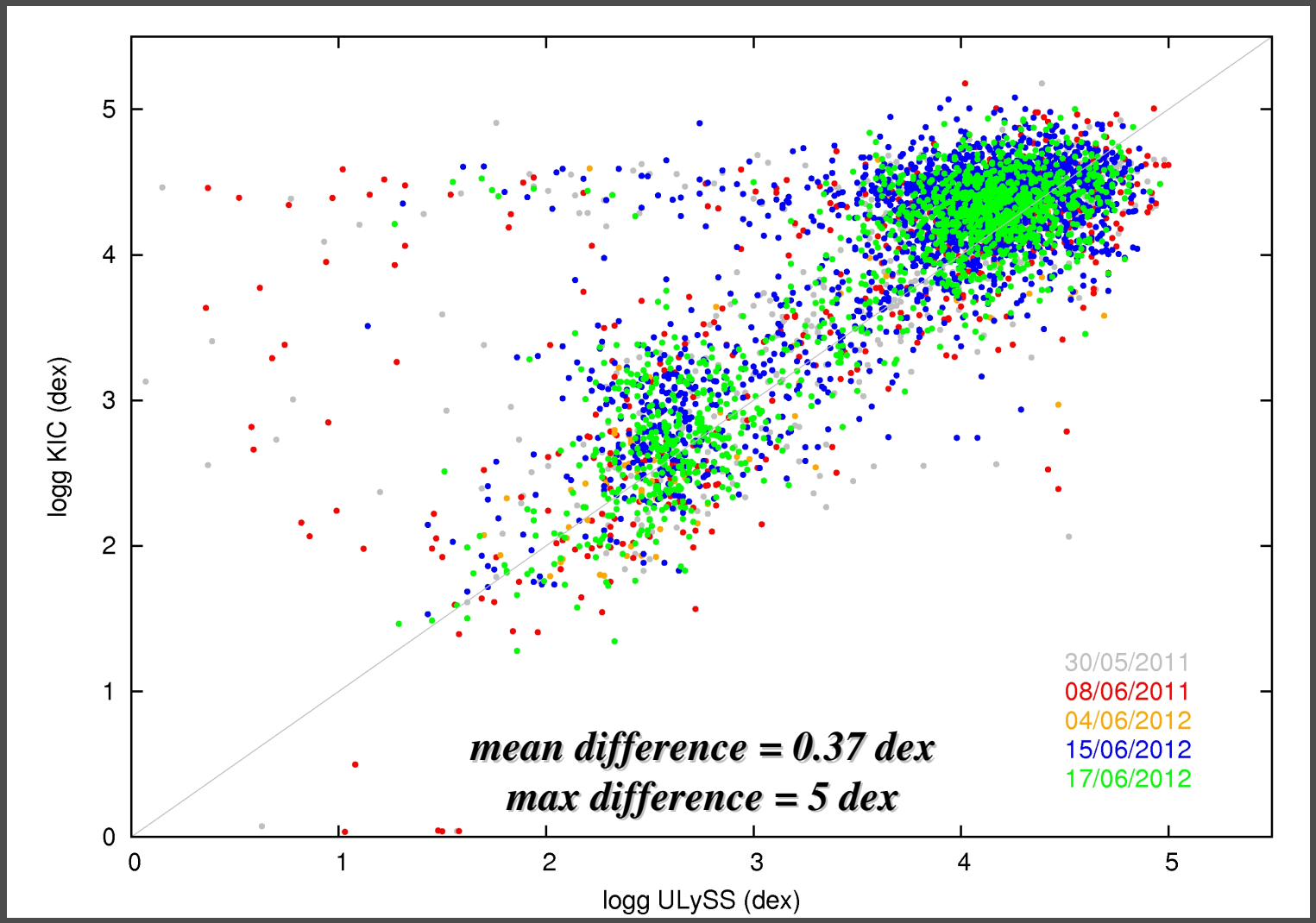
effective temperature T_{eff}

Results: Chinese team

(De Cat et al., in preparation)

comparison with KIC10 values

effective temperature T_{eff}
surface gravity logg

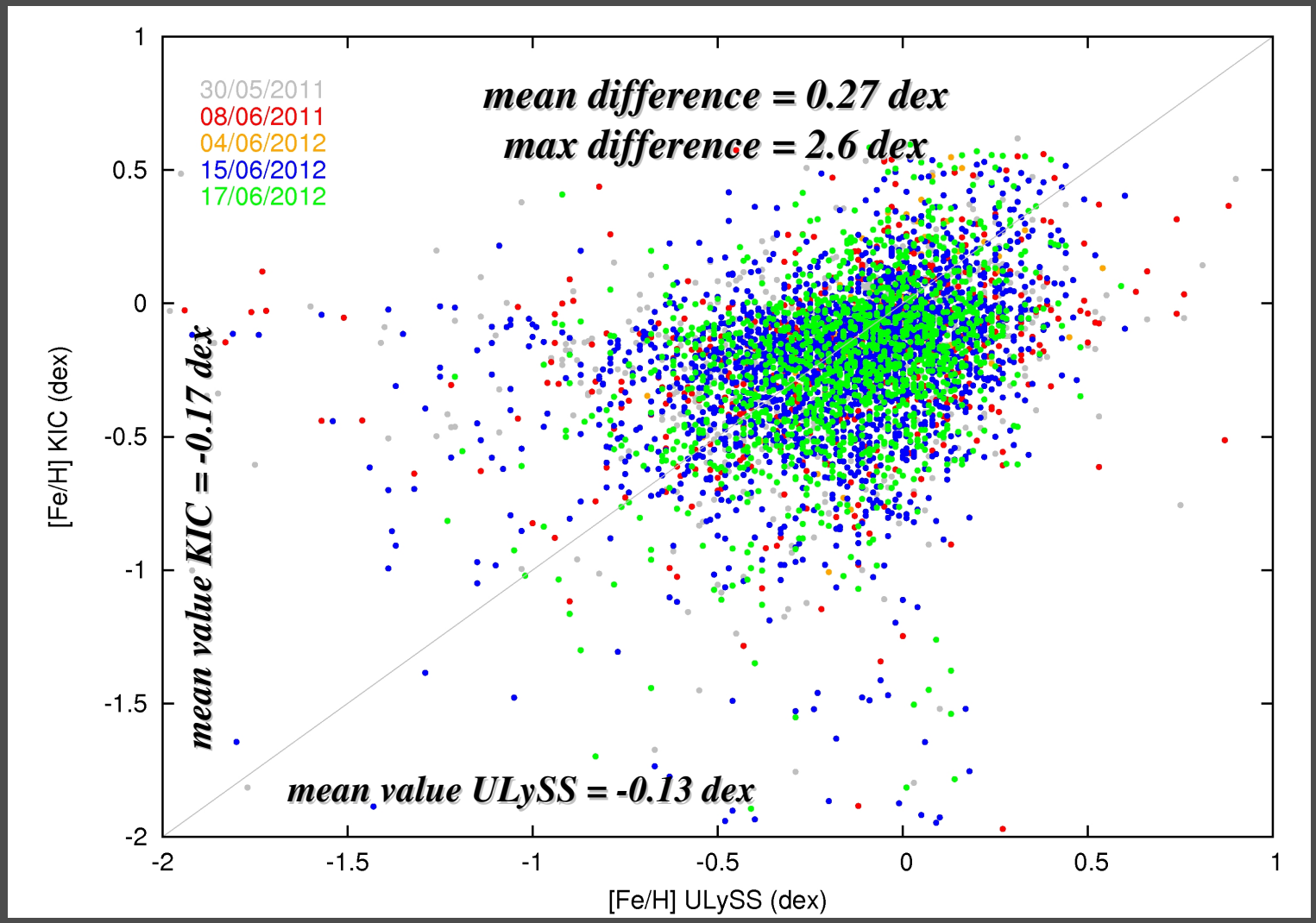


Results: Chinese team

(De Cat et al., in preparation)

comparison with KIC10 values

effective temperature T_{eff}
surface gravity logg
metallicity [Fe/H]

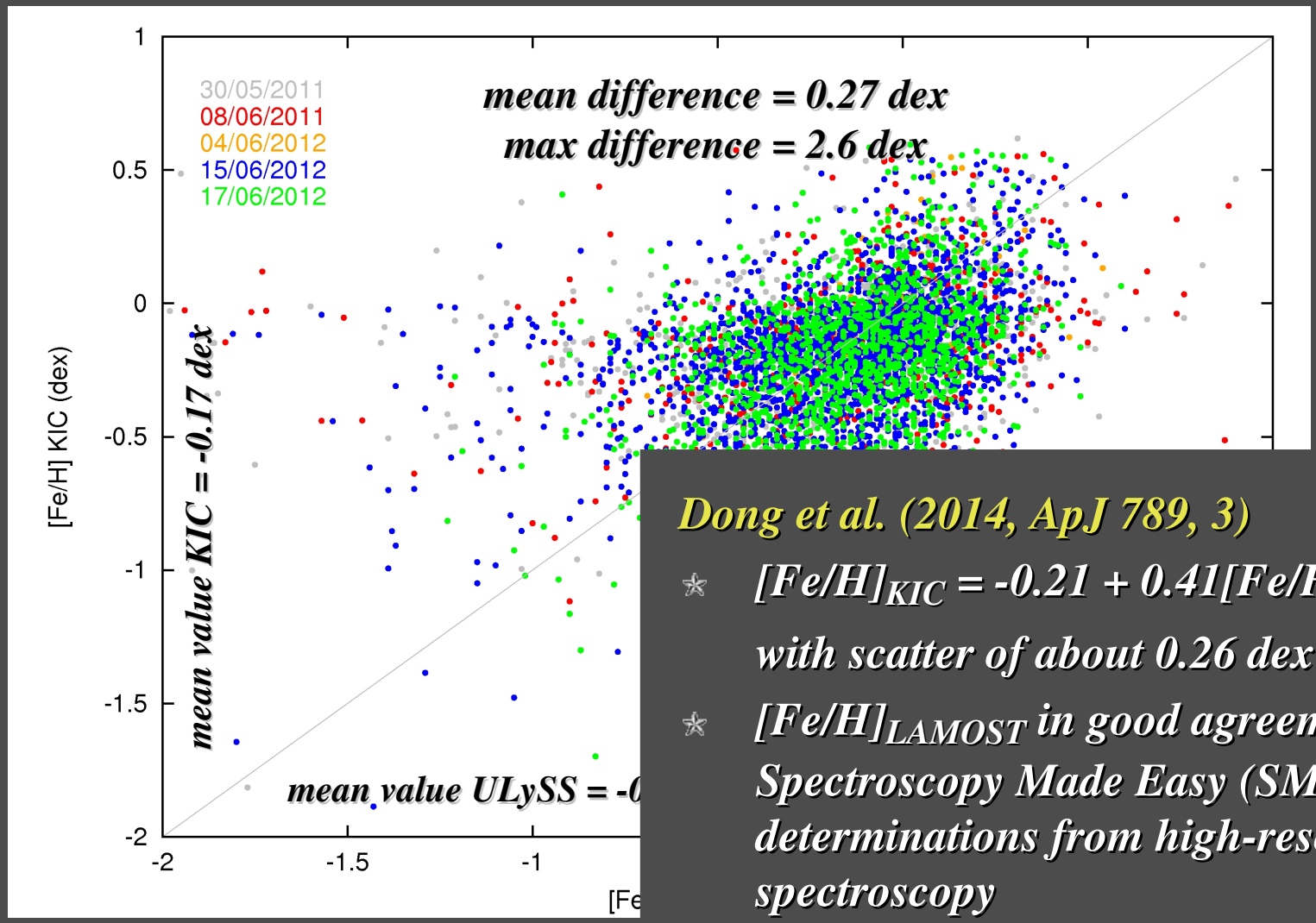


Results: Chinese team

(De Cat et al., in preparation)

comparison *with KIC10 values*

effective temperature T_{eff}
surface gravity **logg**
metallicity [Fe/H]



Dong et al. (2014, ApJ 789, 3)

- $[Fe/H]_{KIC} = -0.21 + 0.41[Fe/H]_{LAMOST}$ *with scatter of about 0.26 dex*
- $[Fe/H]_{LAMOST}$ *in good agreement with Spectroscopy Made Easy (SME) determinations from high-resolution spectroscopy*

Results: European team

(Frasca et al., in preparation)

method

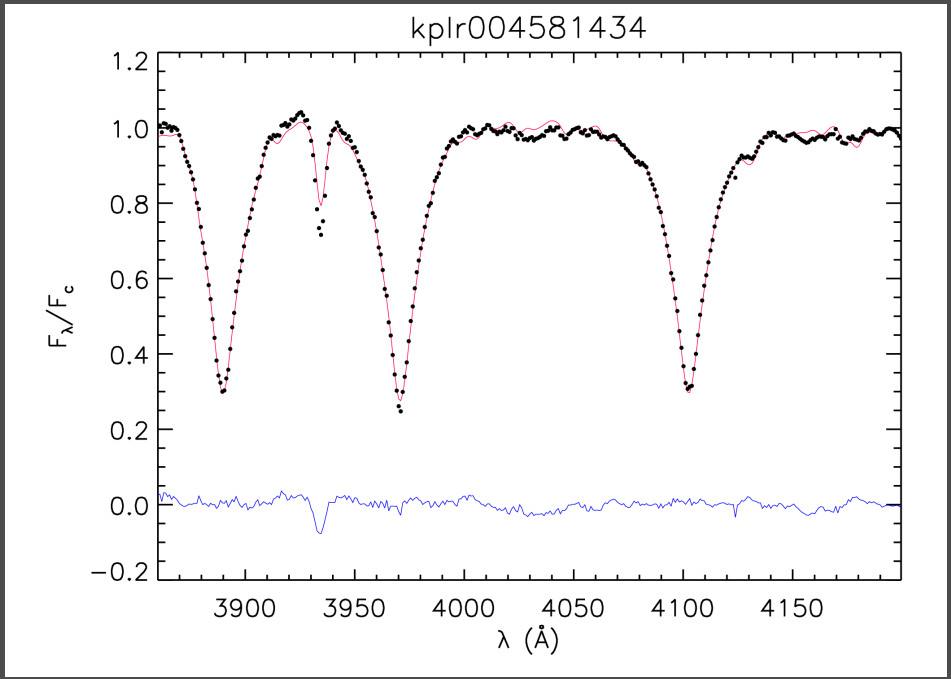
- code **ROTFIT** *(e.g. Frasca et al., 2010, A&A 518, 48)*
  adapted to LAMOST spectra
  - semi-automatic normalisation with IRAF
  - librabry of 1150 stars with known stellar parameters (T_{eff}, logg, [Fe/H]) from Indo-U.S. Library of Coude Feed Stellar Spectra *(Valdes et al. 2004)*
  - degrading to match low-resolution LAMOST spectra
  - comparison for slices of the spectra
  - stellar parameters derived as weighted mean of parameters from best 10 templates for each slice

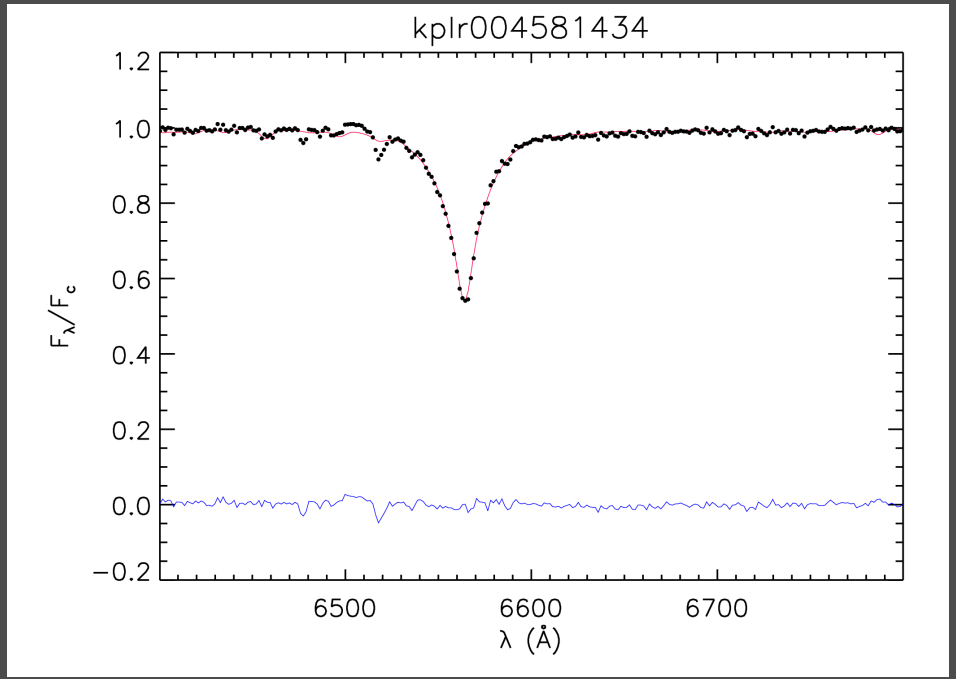
Results: European team

(Frasca et al., in preparation)

examples

target	SpT	Teff	logg	[Fe/H]
☆ KIC4881434	A1V	9305(90)	3.81(12)	-0.25(14)





Results: European team

(Frasca et al., in preparation)

examples

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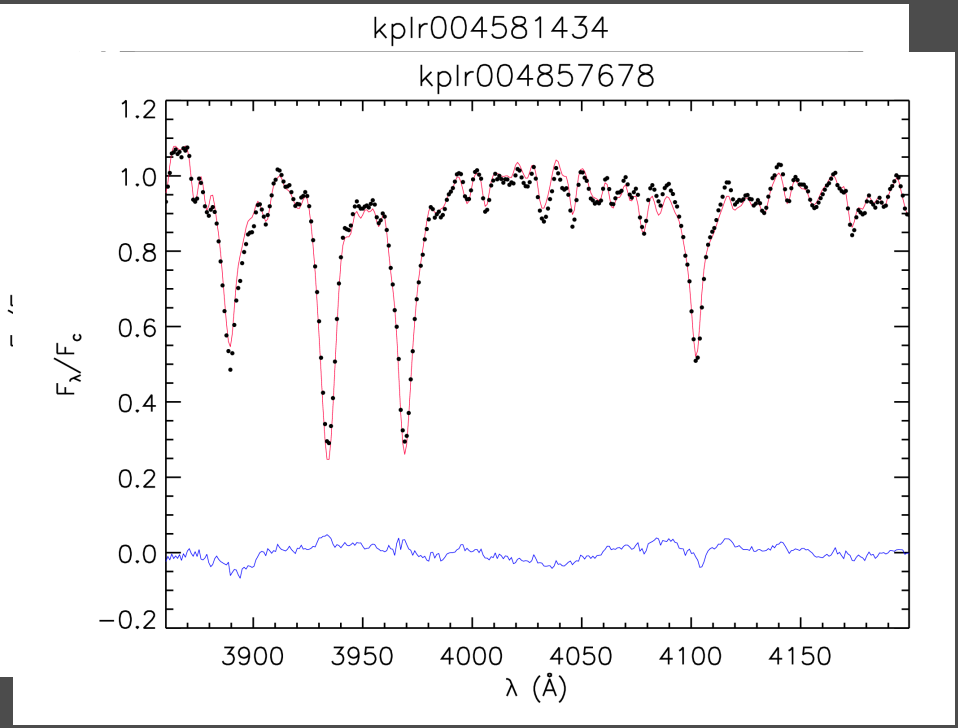
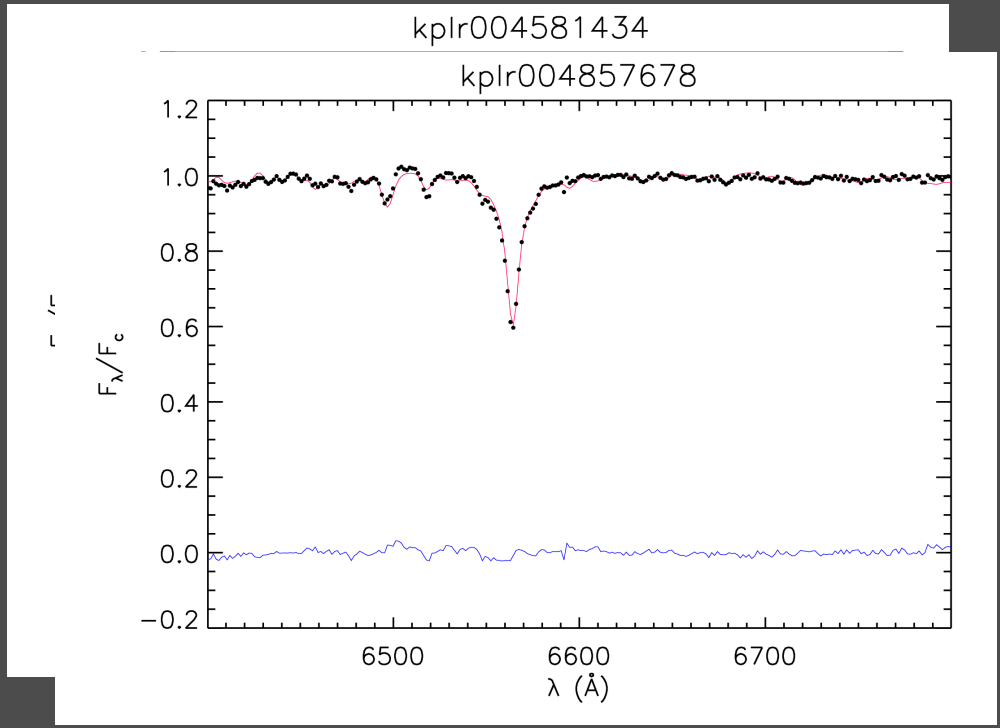
☆ KIC4881434	A1V	9305(90)	3.81(12)	-0.25(14)
☆ KIC4857678	F3V	6465(80)	4.13(11)	-0.24(13)





Results: European team

(Frasca et al., in preparation)

examples

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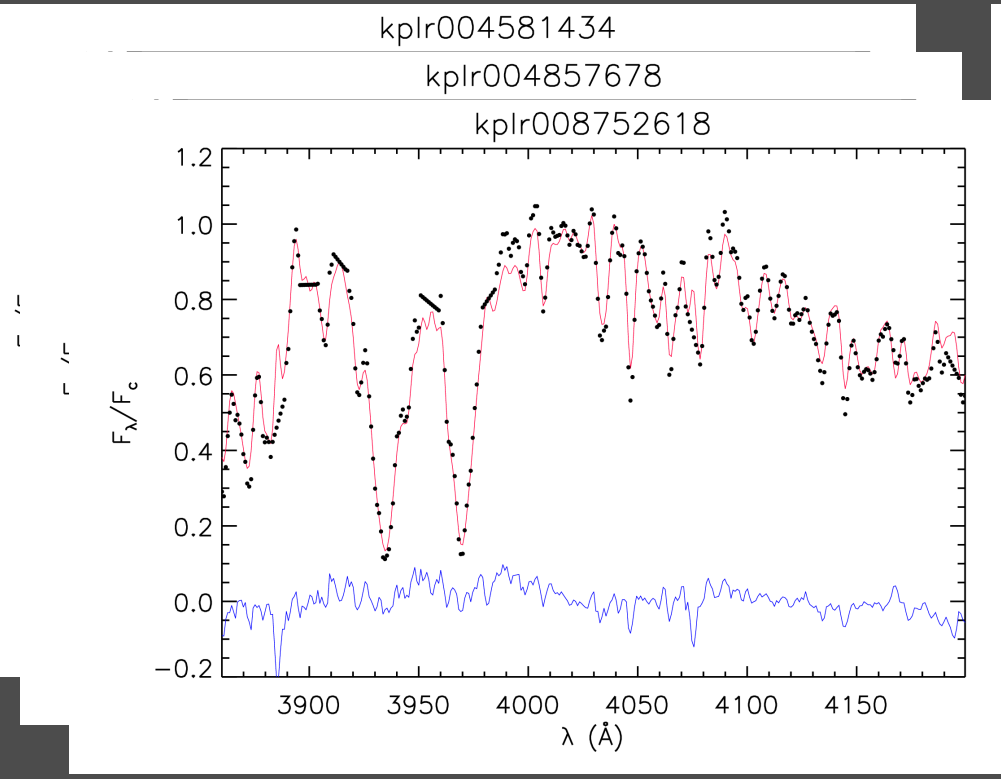
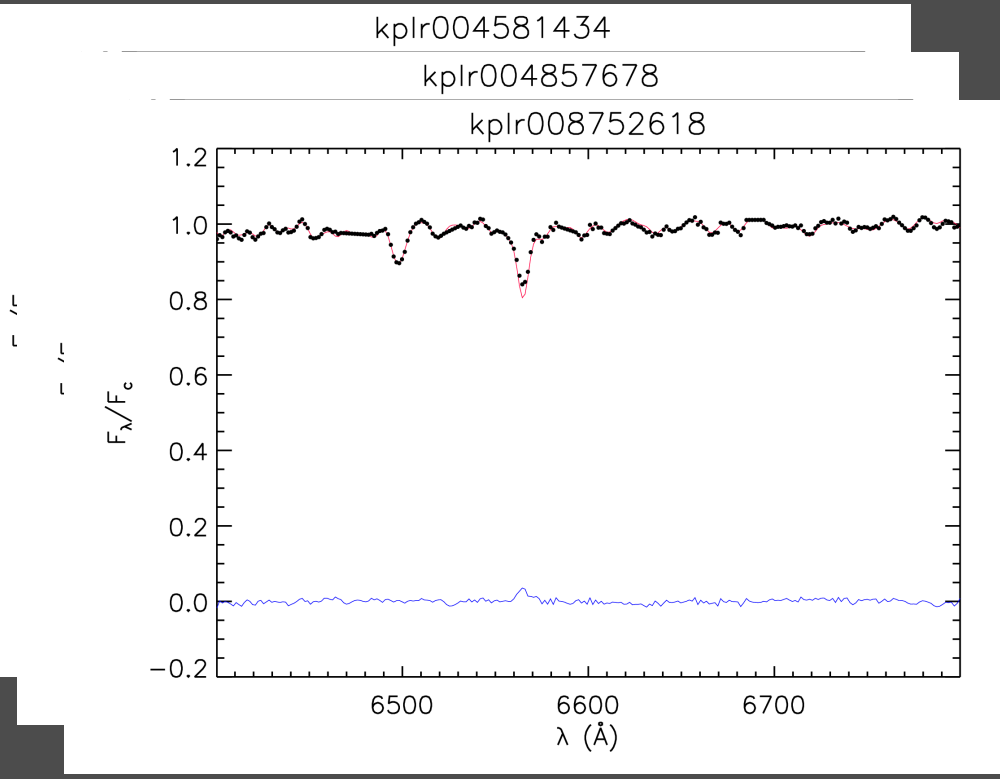
KIC4881434	A1V	9305(90)	3.81(12)	-0.25(14)
KIC4857678	F3V	6465(80)	4.13(11)	-0.24(13)
KIC8752618	G8II	4730(100)	2.60(17)	-0.01(12)



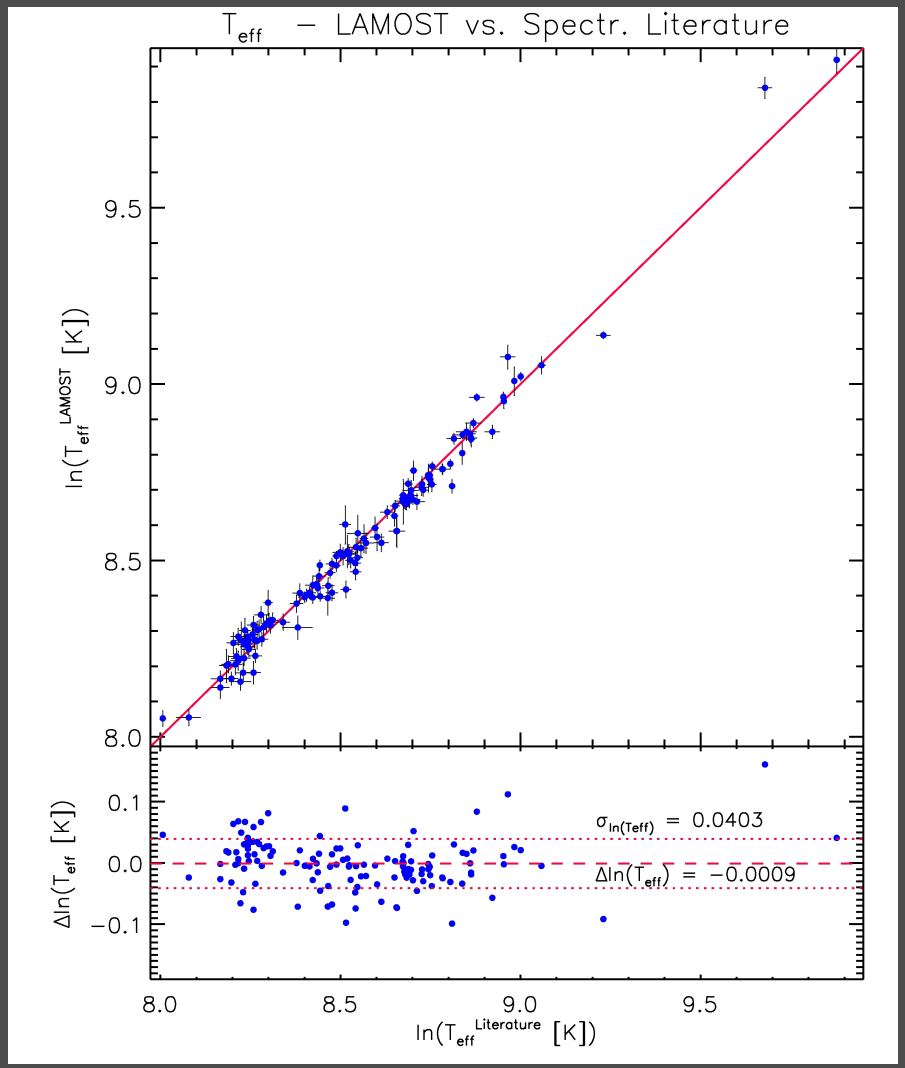


Results: European team

(Frasca et al., in preparation)

validation *by comparison with values derived from high resolution spectroscopy*

effective temperature T_{eff}

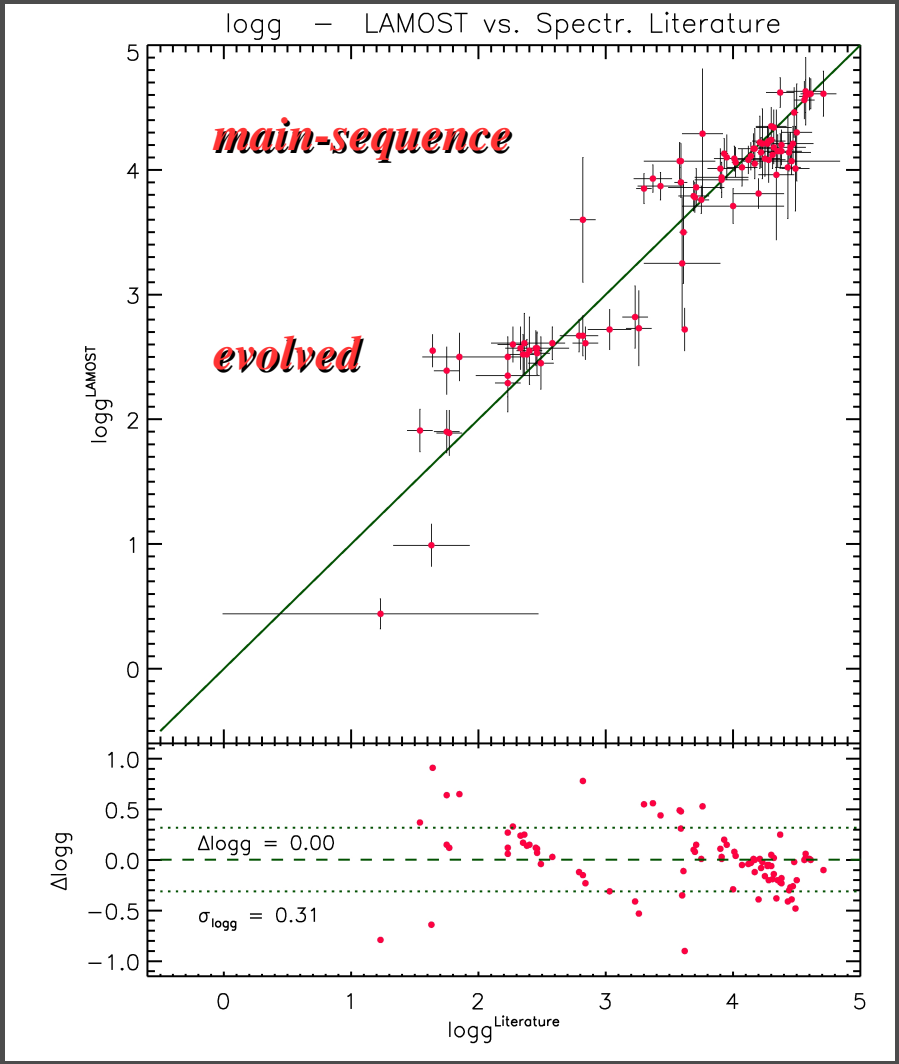


Results: European team

(Frasca et al., in preparation)

validation *by comparison with values derived from high resolution spectroscopy*

- *effective temperature* T_{eff}
- *surface gravity* **logg**

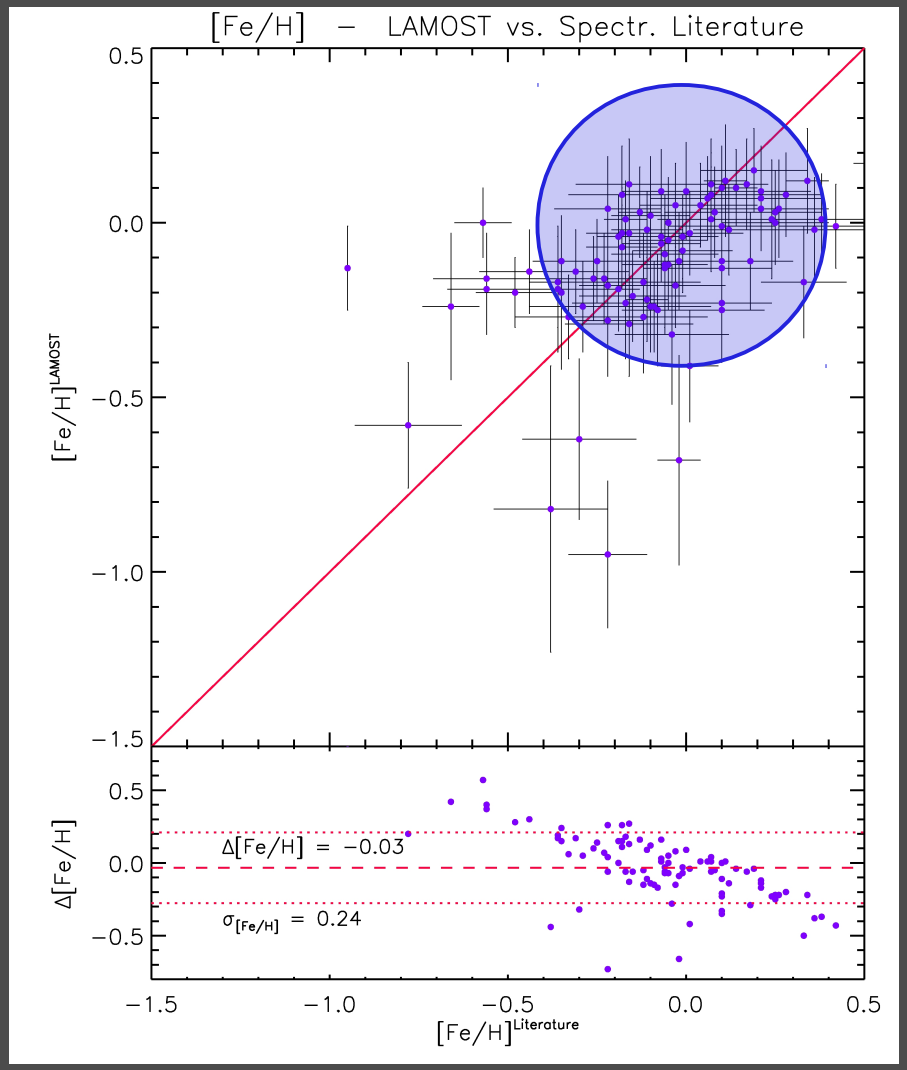


Results: European team

(Frasca et al., in preparation)

validation *by comparison with values derived from high resolution spectroscopy*

- *effective temperature T_{eff}*
- *surface gravity* **logg**
- *metallicity [Fe/H]*

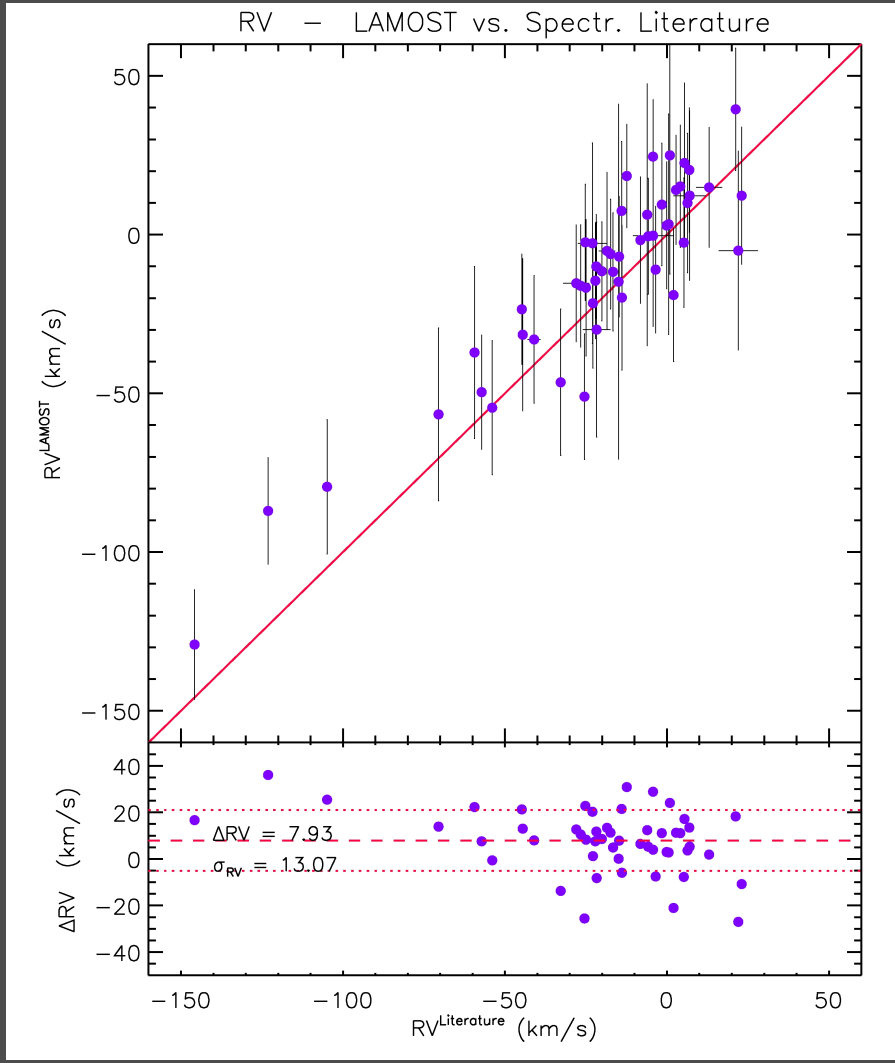


Results: European team

(Frasca et al., in preparation)

validation *by comparison with values derived from high resolution spectroscopy*

- *effective temperature T_{eff}*
- *surface gravity* log*g*
- *metallicity [Fe/H]*
- *radial velocity v_{rad}*



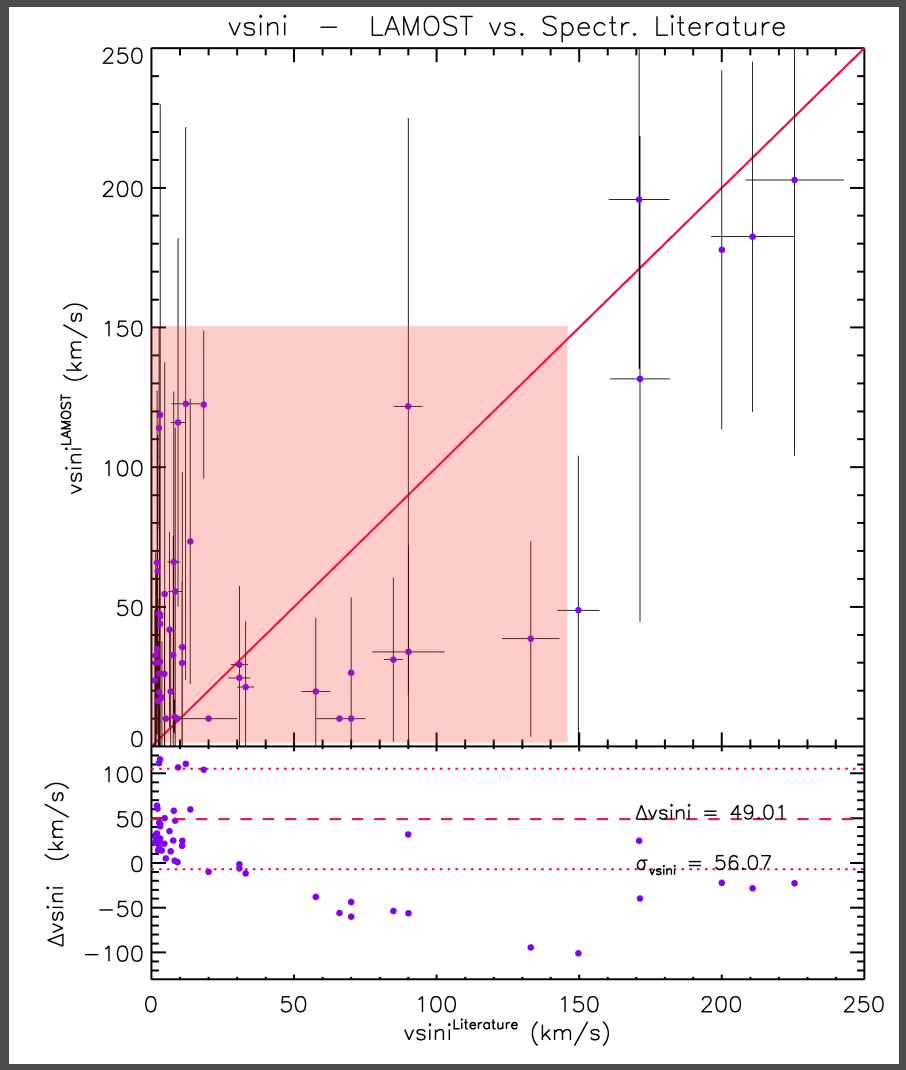
- *by correlation between the target spectrum and best template from list of 20 spectra with different spectral type from the Indo US library (giving highest cross correlation peak)*

Results: European team

(Frasca et al., in preparation)

validation *by comparison with values derived from high resolution spectroscopy*

- *effective temperature T_{eff}*
- *surface gravity* **log**g
- *metallicity [Fe/H]*
- *radial velocity v_{rad}*
- *projected rotational velocity* **v**sini



- *alignment of reference spectra with v_{rad}*
- *broadening by convolution with rotational profile of increasing vsini (in steps of 5 km/s) until minimum in χ^2*

Results: American team

(Gray & Corbally, in preparation)

method

- code **MKCLASS** *(Gray & Corbally, 2014, ApJ 147, 80)*
  - automatic classification on MK Spectral Classification system
    - in a way similar to humans by direct comparison with MK classification standards
    - several peculiarities can be detected
    - temperature: precision of 0.6 spectral subclass (e.g. B2 → B3)
    - luminosity: precision of ½ luminosity class (e.g. IV → V)
  - library of spectral standards
    - step 1: automatic classifier with available library after degrading to resolution of LAMOST spectra (observations Dark Sky Observatory to fill holes)
    - step 2: construction of spectral library from LAMOST spectra themselves (observation of LAMOST stars + precise spectral types for secondary standards)
    - step 3: automatic classifier with LAMOST spectral library (accurate spectral types + detection of peculiarities)

problem with negative fluxes

Conclusions

With this presentation we have shown that...

- *the LAMOST-Kepler project*
  - *is an ambitious observational project*
  - *can provide accurate stellar parameters derived from low resolution spectra*
    - *in an efficient way (4000 fibers)*
    - *for faint(er) objects than most ground-based facilities (4-m telescope)*
  - *is not finished yet:*
    - *not all requested field are observed (should be done in 2014)*
    - *not all observed LAMOST spectra are analysed (we have to work)*

LAMOST spectra available upon request:
Peter.DeCat@oma.be

LAMOST-Kepler workshop

Beijing – August 18-22, 2014

http://202.112.85.102/meeting/kepler_lamost2014/

- 40 € — 1 day excursion to Xinglong observatory (visit LAMOST facility)
- 200 € — 4 days of science with goals:
  - presentation of LAMOST facility and the opportunities it opens for the international scientific society
  - highlight usefulness for large observational surveys
  - present results obtained for the targets observed by the satellite mission Kepler and other stars
  - create/strengthen international collaborations with LAMOST community

Registration still possible