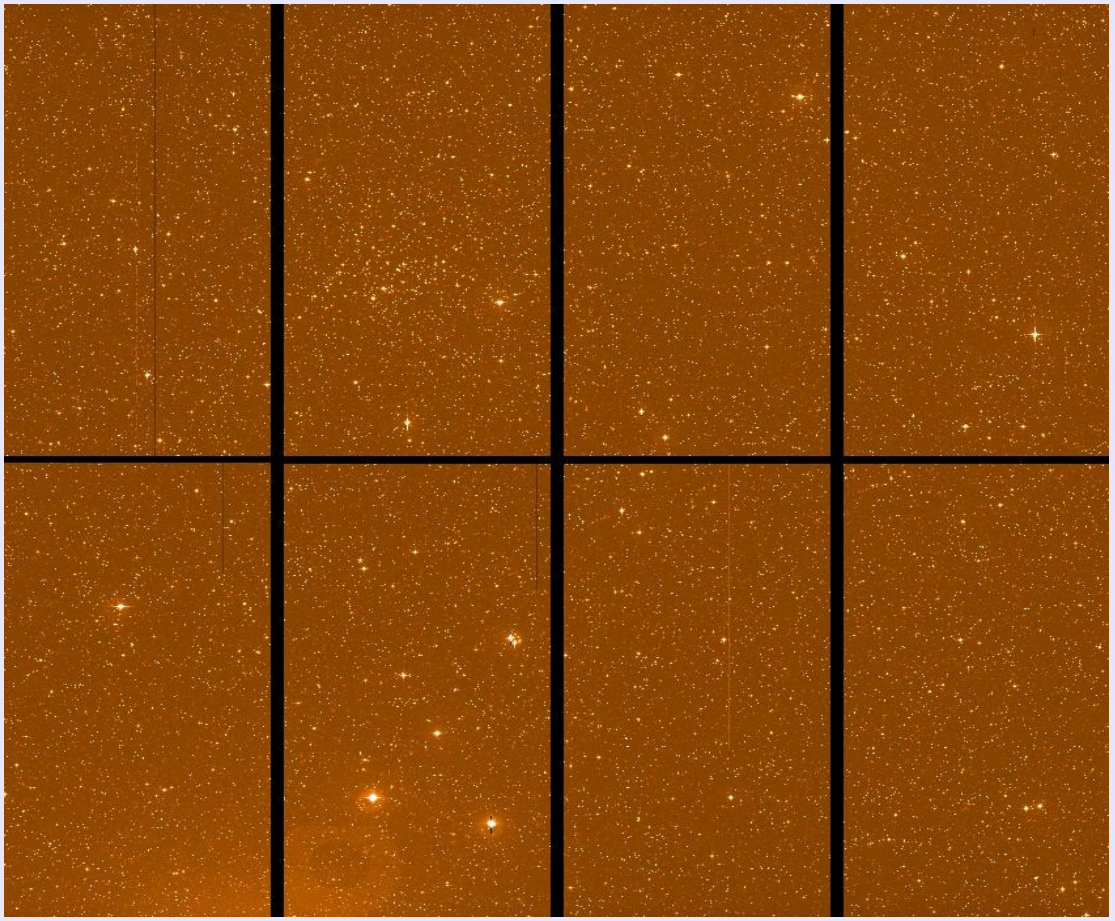
Follow-up analysis of a transiting planet candidate in the region of the old open cluster NGC 6253.



Marco Montalto, USM/MPE, 17/11/2009, RoPACS meeting at the IAC

Overview

The search for planets in open clusters;

NGC 6253: an old metal-rich open cluster inside the solar ring;

- -description of the transit search;
- -follow-up of the best planetary candidate;
- -discussion of planned observations;

VLT multi-epoch radial velocity survey toward NGC 6253;

Summary;

Why searching for planets in stellar clusters?

We want to answer some basic questions:

-Do planets form and survive in (massive) stellar clusters?

-Is planet frequency, and are planet properties similar in cluster environments and in the field?

Searching for planets in clusters surely offers a number of advantages (including the fact that stars have the same distance, age, abundance).

Transit searches – open clusters

M37 - Hartman, J. D., Gaudi, B. S., Holman, M. J., et al. 2009, ApJ, 695, 336
NGC 188 - Mochejska, B. J., Stanek, K. Z., Sasselov, D. D., et al. 2008, AcA, 58, 263
NGC 7086 - Rosvick, Joanne M., Robb, Russell 2006, AJ, 132, 2309
NGC 1245 - Burke, C. J., Gaudi, B. S., DePoy, D. L., et al. 2006, AJ, 132, 210
NGC 2158 - Mochejska, B. J., Stanek, K. Z., Sasselov, D. D., et al. 2006, AJ, 131, 1090
NGC 6819 - Street, R. A., Horne, Keith, Lister, T. A. 2003, MNRAS, 340, 1287
NGC 6791 - Bruntt, H., Grundahl, F., Tingley, B., Frandsen, S., 2003, A&A, 410, 323
Mochejska, B. J., Stanek, K. Z., Sasselov, D. D., et al. 2005, AJ, 129, 2856
Montalto, M, Piotto, G., Desidera, S., et al. 2007, A&A, 2007, 470, 1137

Transit searches – globular clusters

47 Tucanae - Gilliland, Ronald L.; Brown, T. M.; Guhathakurta, P., et al 2000, ApJ, 545, 47
Weldrake, David T. F., Sackett, Penny D., Bridges, Terry J. et al. 2005, ApJ, 620, 1043
ω Centauri - Weldrake, David T. F., Sackett, Penny D., Bridges, Terry J., et al. 2008, ApJ, 674, 1117

Radial velocity surveys – open clusters

Giants stars

Hyades - Sato, Bun'ei, Izumiura, Hideyuki, Toyota, Eri, et al. 2007, ApJ, 661, 527 ----> **ε Tauri**
NGC 2423 - Lovis, C. & Mayor, M. 2007, A&A, 472, 657 ----> **NGC 2423 No3**
NGC 4349 - Lovis, C. & Mayor, M. 2007, A&A, 472, 657 ----> **NGC 4349 No127**

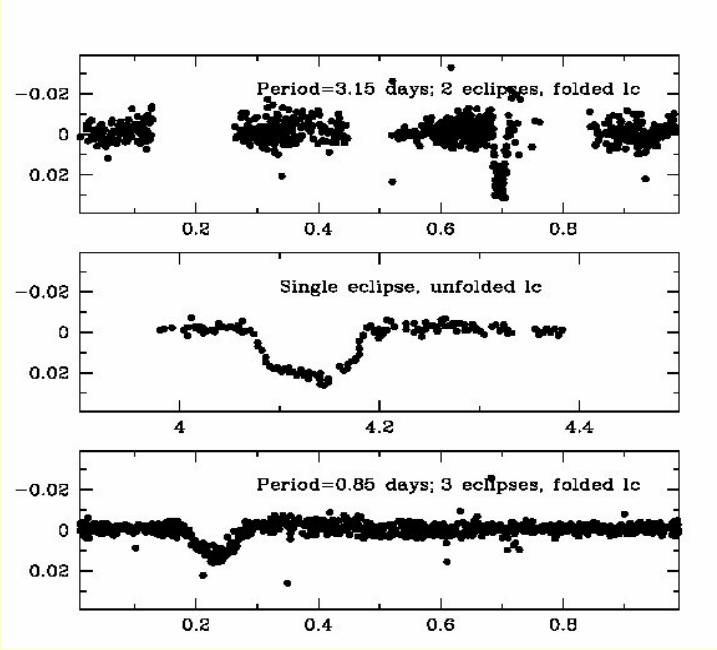
Main sequence stars

Hyades - Cochran, William D., Hatzes, Artie P., Paulson, Diane B. 2002, AJ, 124, 565

Transit search toward NGC 6253

NGC 6253 is an old (3.5 Gyr) and very metal-rich open cluster ([Fe/H]=+0.39 ± 0.08) located inward the solar ring at a galactocentric distance of 6 kpc.

In June 2004 we performed a 10 nights transit search toward NGC 6253 using the 2.2m telescope in La Silla. We measured 187963 stars in the region of the cluster, and 30000 stars had photometric precision <0.01 mag. We detected 3 potential planetary transit candidates:



V=18

V=15.26

V=17

Follow-up of the brightest planetary candidate (V=15.26)

Observations:

1) 1 HARPS spectrum in June 2006 (30 min. exp. time, tech. time);

2) VLT/UVES follow-up: 3 spectra in August 2008 (30 min exp. time);

3) April 2009 photometric and spectroscopic follow-up (MPE time):

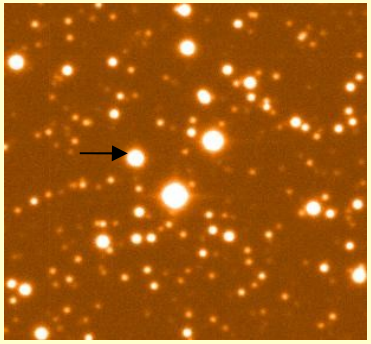
- 15 half nights at the 2.2m La Silla Telescope;
- 20 FEROS spectra obtained during the last 11 nights of observation (1 hour exposure time).

4) June 2009 spectroscopic follow-up (MPE time), 2 FEROS spectra.

Follow-up of the brightest planetary candidate (V=15.26)

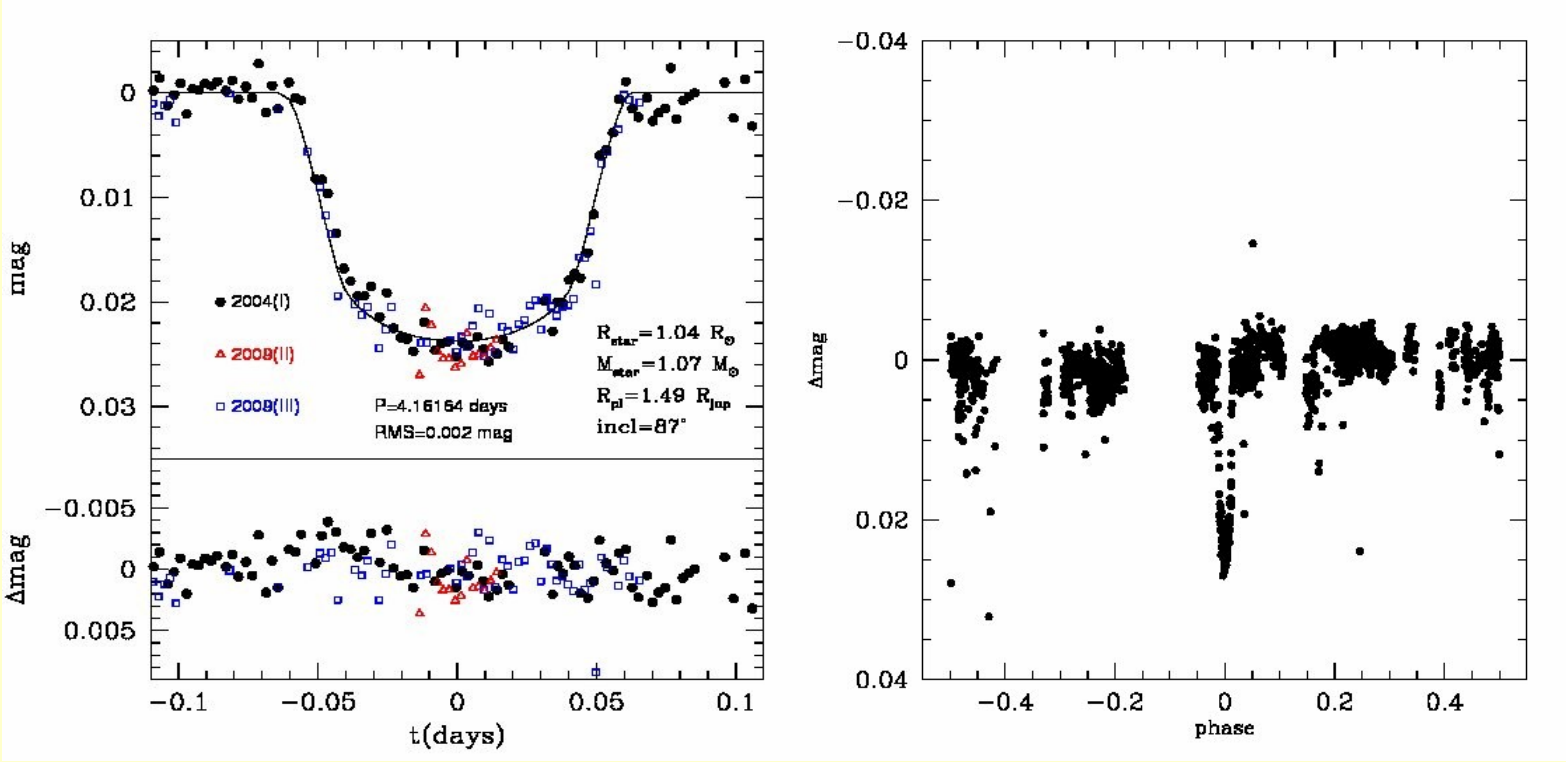
Photometry

2 new transits, a full transit and a partial transit.

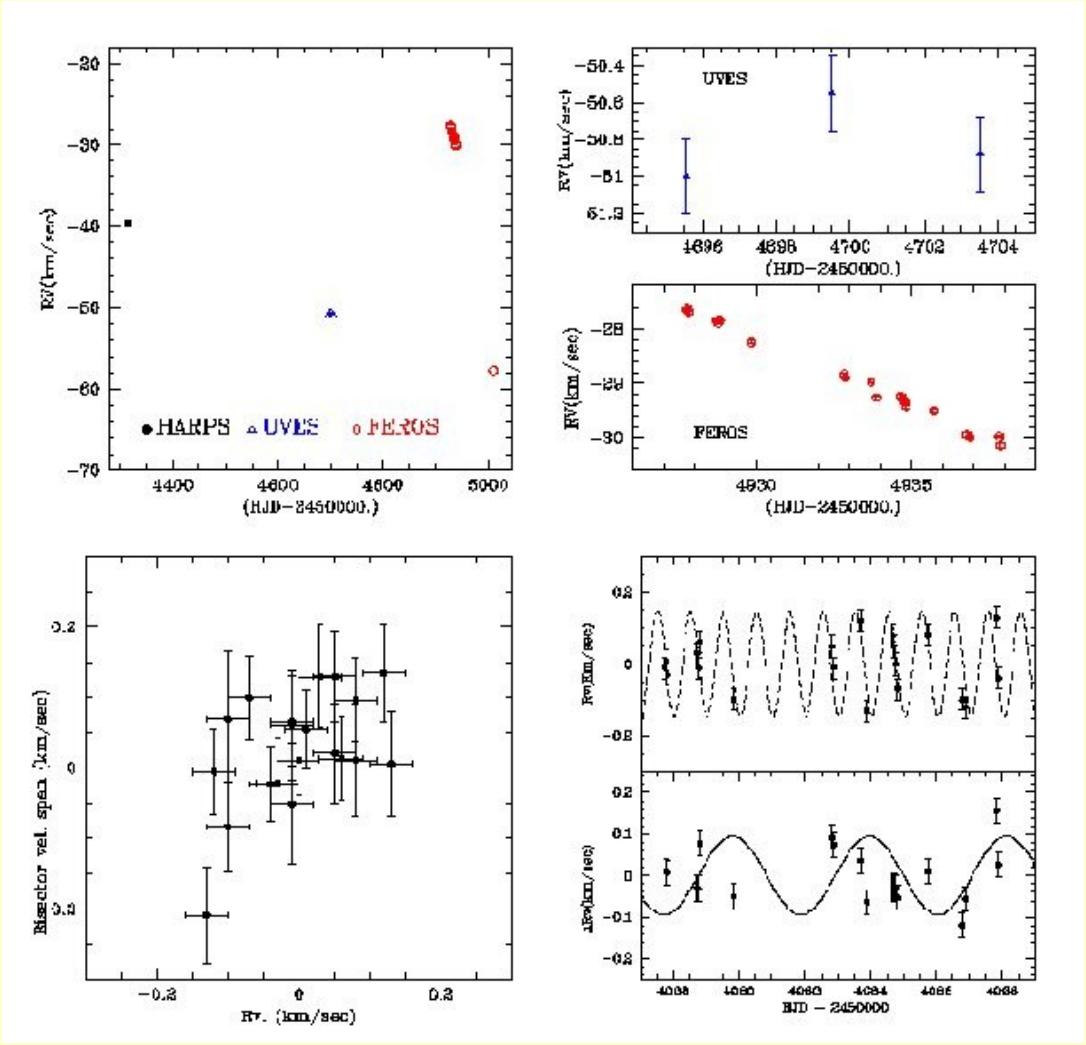


UVES spectroscopy

Teff= (5720 ± 50) K
lg(g) = (4.50 ± 0.20)
[Fe/H] = (+0.36 ± 0.02)

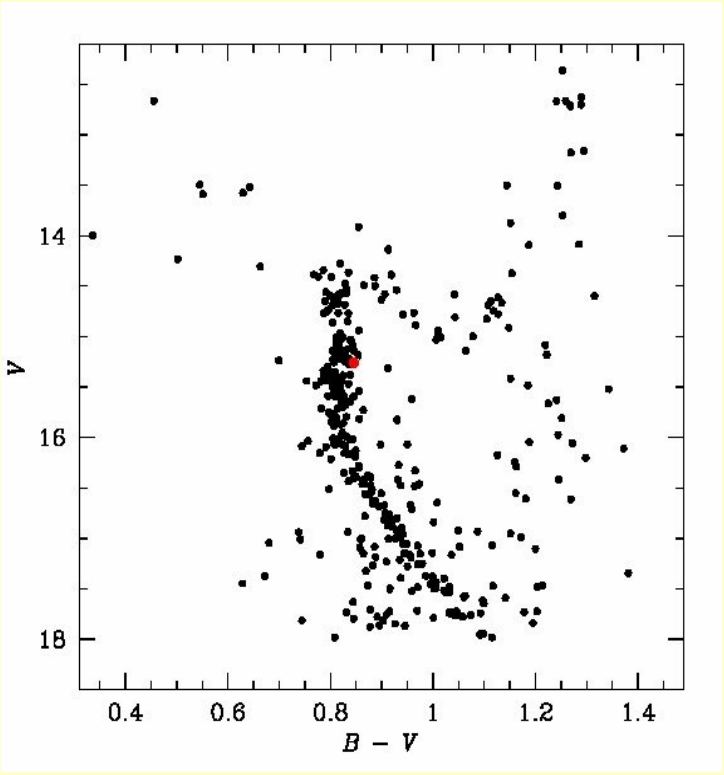


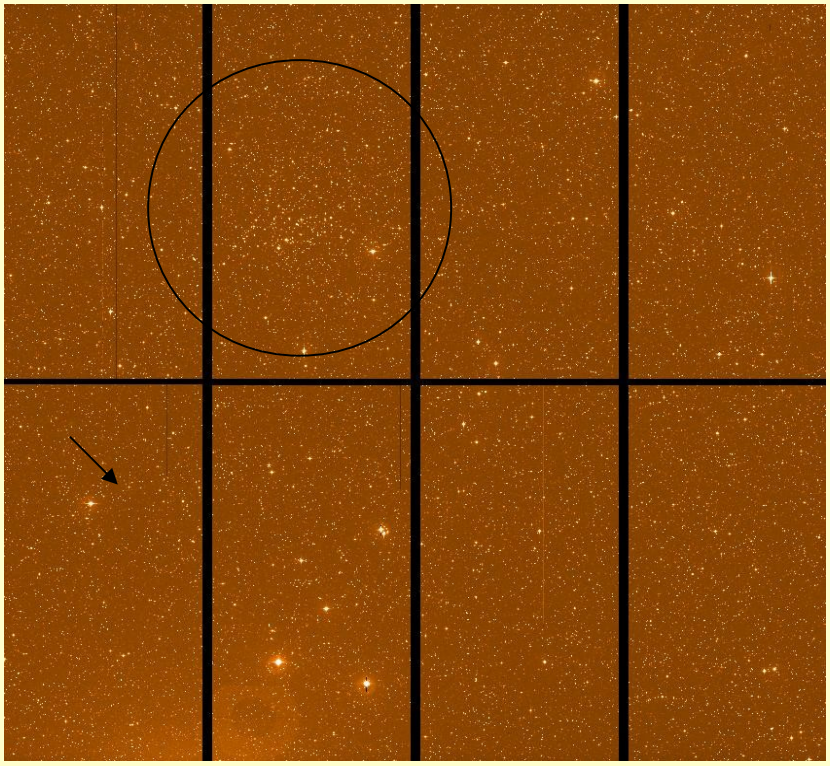
Spectroscopic measurements:



The host is a single lined spectroscopic binary (period 100-400 days), but we have a transiting object with a period of ~4 days...

Cluster's membership:





The star is very metal rich and its metallicity ([Fe/H] = +0.36 ± 0.02) agrees with that one of the cluster ([Fe/H] = +0.39 ± 0.08, Sestito et al. A&A, 465, 185).

Its displaced position with respect to the cluster's center may be explained by dynamical evolution (→ orbital motion calculation, accurate abundance analysis).

Interpretations of the observations:

1)- Transiting planetary companion orbiting around the primary star of a spectroscopic binary system (S-type orbit);

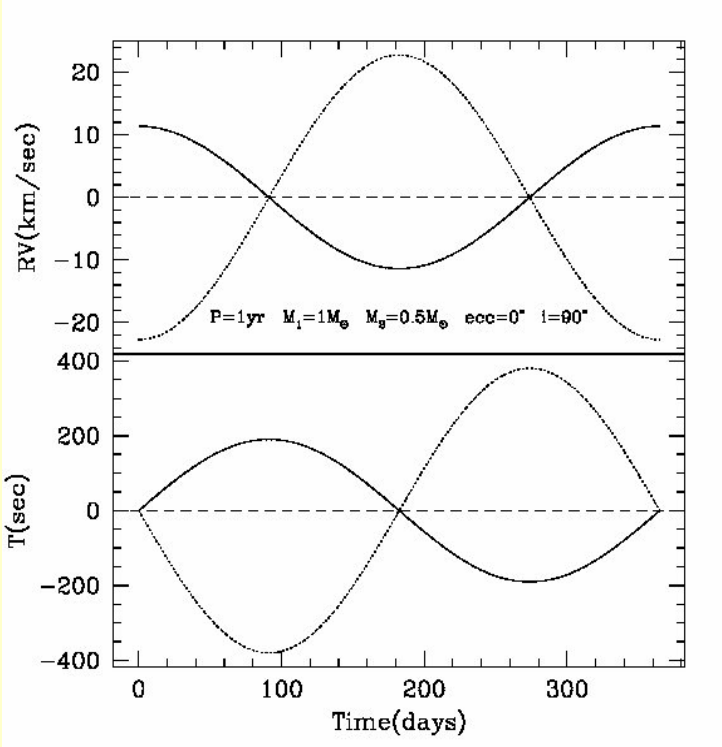
2)- Hierarchical triple system, with the object orbiting around the secondary component of the spectroscopic binary;

3)- Background eclipsing binary blended with a foreground spectroscopic binary.

Bisector analysis and multi-color photometry...

$$RV(f) = \frac{n\,a\,m_2\,sin(i)}{\sqrt{(1-e^2)}\,(m_1+m_2)}\,[cos(\omega+f)+e\,cos(\omega)]$$

$$\tau(f) = \frac{a\,(1-e^2)\,m_2\,sin(i)}{c\,(m_1+m_2)}\,\frac{sin(\omega+f)}{1+e\,cos(f)}$$



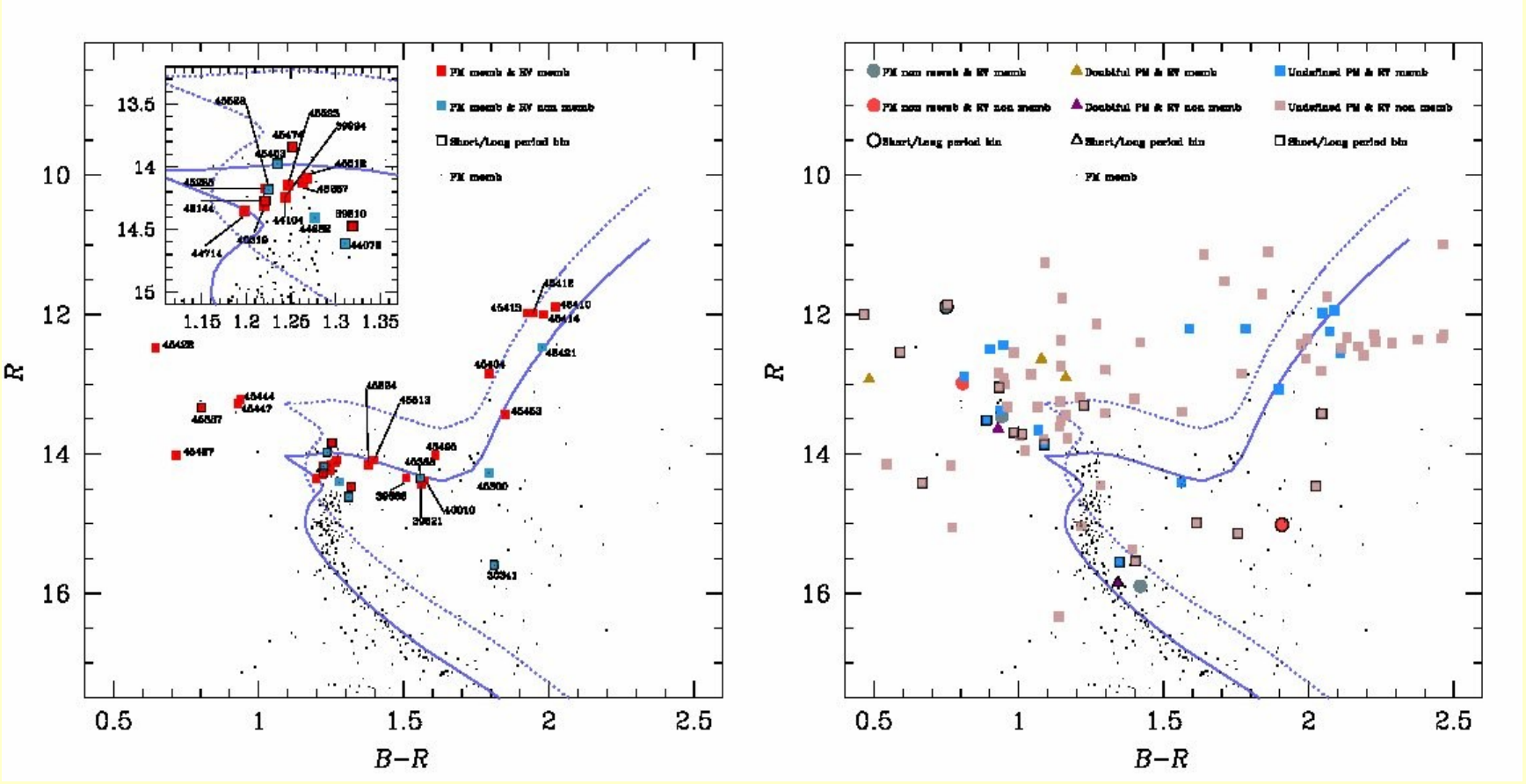
Two types of observations:

-Radial velocities of the host star;

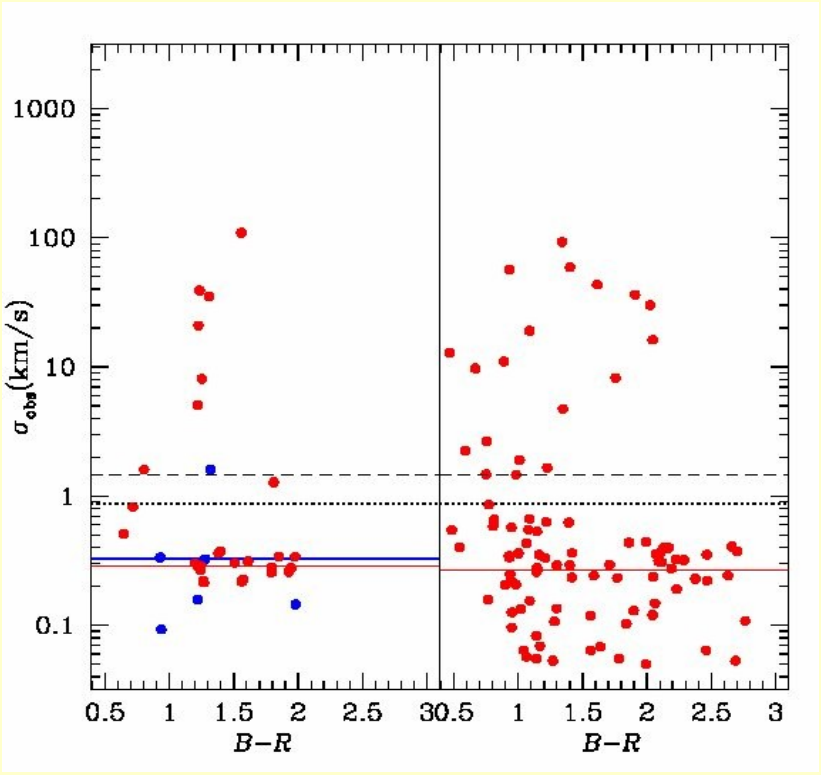
-Transit timing;

Looking at the radial velocity curve and at the transit timing curve it is possible to distinguish between different scenarious.

VLT multi-epoch radial velocity survey toward NGC 6253



3 epochs separated by 4 days in August 2008 (FLAMES/UVES/GIRAFFE).
137 stars analyzed (105 stars with 3 epochs, 32 stars with 6 epochs).
35 cluster's members studied.

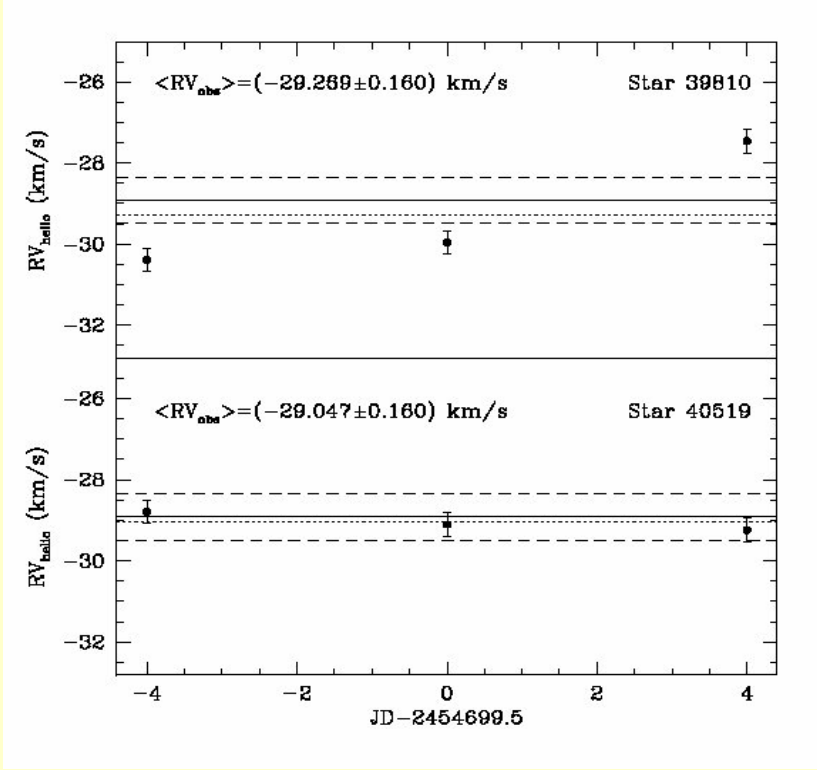


The median RV precision is 290 m/s

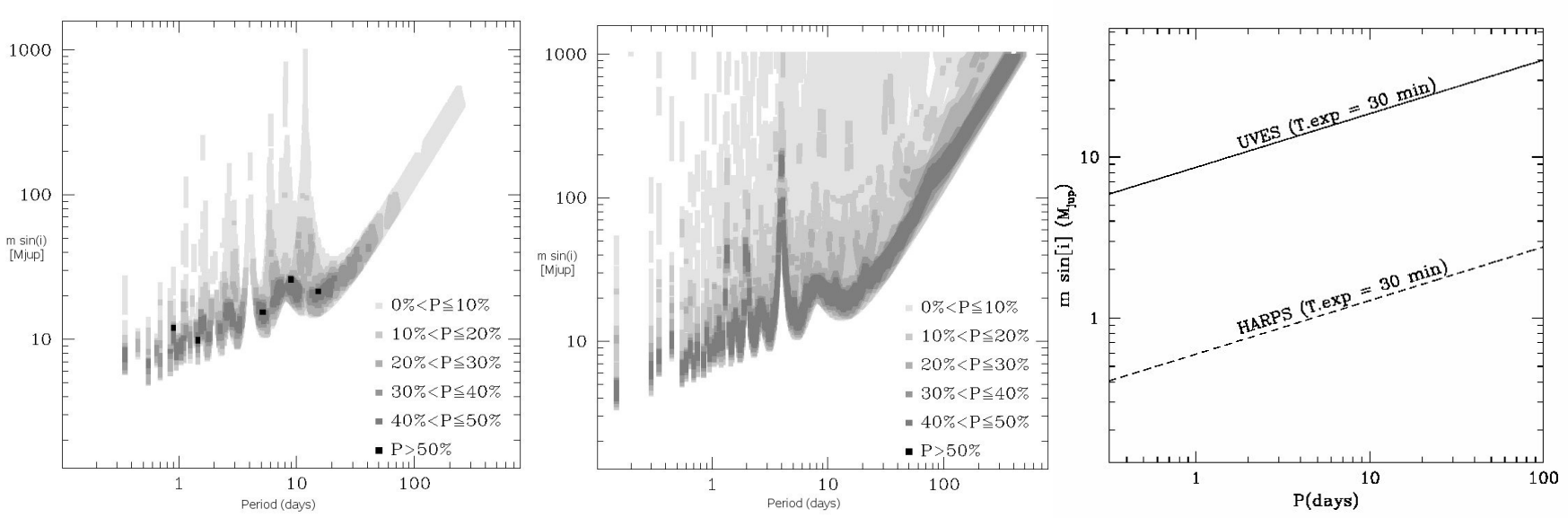
Candidate substellar companions of clusters stars should have:

1)-Mean radial velocities consistent with the cluster's recession velocity;

2)-RV variations within the range of substellar companions;



Simulations



Radial velocity searches of planetary and sub-stellar companions around old open clusters turn-off stars are possible providing:

1)- Accurate pre-selection of target stars (proper motions, color magnitude diagram, radial velocities) ;
2)-Multi-object spectroscopy (few epochs) permits to isolate candidate sub-stellar objects and RV "constant" stars at the precision of UVES/GIRAFFE;
3)-The best targets can be followed-up with HARPS with the same strategy (few epochs - few days); 40 stars in NGC 6253 (20 m/s per measurement) → 60h → 1.4 planets.

Complementary to transit searches.

Summary

-We have a transiting planetary candidate in a single lined close spectroscopic binary system (RV follow-up, transit timing analysis);

-Cluster's membership is dubious, though the object could have been a member of NGC 6253, then migrated in the field;

-Radial velocity searches of sub-stellar and planetary companions around turn-off stars of old open clusters appears feasible with present day instrumentation.