Publ. Astron. Obs. Belgrade No. 90 (2010), 105 - 112 *Invited Lecture*

LATEST RESULTS IN THE FIELD OF EXOPLANETS

E. ROVITHIS-LIVANIOU

Dept. of Astrophysics-Astronomy and Mechanics, Faculty of Physics,
Athens University, Zografos 157 84, Athens, Hellas
E–mail: elivan@phys.uoa.gr

Abstract. The latest findings in the field of exoplanets concerning observations, and theoretical developments are presented and discussed in this short review.

1. INTRODUCTION

After the first announcements about the possible existence of some planets orbiting the radio-pulsar PSR 1257+12, (Wolszczan and Frail 1992), and the (G2-3)-type star 51*Peg*, (Mayor and Queloz 1996), today and after systematic searches about **400** such planets have been reported. They are commonly named **extra solar** planets or **exoplanets**. The meaning of the first name is self-expanatory; while, the latter comes from the combination of the Greek word $'\epsilon\xi\omega$, (exo), which means **out**, and the word **planet**, to indicate that the planet is **out** of our **solar system**.

Most of the exoplanets discovered so far are giants with masses many times the mass of Jupiter. For this reason they are referred as Exo Giant Planets, or simply EGPs. Besides, as most of them were found to be very close to their parent-stars, they are usually called *hot Jupiters*. This does not mean that planets with smaller masses, or sizes, have not been discovered. On the contrary, exoplanets with masses like those of Saturn, Neptune or even a few times that of the Earth, (*super Earths*, as called the exoplanets with mass from $1.9M_{Earth}$ to $10M_{Earth}$), have been reported, too. For example *HD 83443b* has a mass similar to Saturn, *GJ 436b* has a mass like Neptune's, (Deming et al. 2007), and similar is *HAT-P-11b*, (Dittman et al. 2009); while, *GJ 1214b* is a *super Earth*, (Charbonneau et al. 2009).

On the other hand, stars hosting more than one exoplanets are known to exist, too. The first such star was υ *And*, some others are : *GJ 876*, (Rivera et al. 2005), *GJ 581*, (Udry et al. 2007) etc., with *55 Cnr* to have five exoplanets.

All these findings, are the result of a continuous and systematic search with very sensitive and acurate instruments. For example, Boss et al. (2009) built two specialized astrometric cameras to carry out their search for gas giant planets and brown dwarfs orbiting nearby low mass dwarf stars with the 2.5m du Pont telescope at Las Campanas Observatory in Chile.

Theoreticants, on the other hand, have tried to improve their models. As a result, hundreds are the papers published the last years concerning exoplanets.

In a previous paper hereafter referred as *Paper I*, a short review for exoplanets was presented, (Rovithis-Livaniou, 2008). In this *Paper I* the developed theories for exoplanets' formation and stability, together with some results concerning the HZ of their host stars, and the transits some of them in front of their parent stars were reported. Thus, in the present paper we shall be restricted and stress our attention mainly to some latest findings. Findings and results from both the theoretical and the observational point of view, starting from the later.

2. LATEST OBSERVATIONAL FINDINGS

The latest and very interesting observational findings about exoplanets concern mainly their **direct observation**; while others could be the results from transits, and the composition of the exoplanets' atmospheres.

2. 1. DIRECT OBSERVATIONS

Till recently all detections of exoplanets, including transits, were indirect; but, not any more. Because, since November the 13th, 2008, the first direct observations were reported. They concerned the stars *Fomalhaut*, (Kalas et al. 2008), and *HR 8799*, (Marois et al. 2008). To be more specific: Fomalhaut, *HD 216956*, is the brightest star, of m_V=1.16, in the Piscis Australis constellation, i.e. α *Psc Australis*. It is an A3V type star with $M = 2.06 M_{\odot}$, $T = 8540°K$, at a distance of $25ly$. Before the direct evidence and final confirmation, Kalas et al. (2005) had reported some indications for the possible existence of an exoplanet orbiting *Fomalhaut*.

On the other hand, *HR 8799* is a bright star, of **5.96** m and of A5V type. Its mass is $1.5 M_{\odot}$ and its distance $130ly$ from our Sun. Three exoplanets were found to rotate around *HR 8799*, (Marois et al. 2008). Besides, according to Fukagawa et al. (2009) there were indications about the presence of *HR 8799b* in their H-band images taken with Subaru in 2002, which they discovered re-analysing them.

2. 2. TRANSITS

The first measurements of light variations due to a transit of an exoplanet in front of the disk of its parent star was presented **10** years ago, (Charbonneau et al. 2000).

Although transiting systems present only a small fraction of the so far detected exoplanets, they are of great importance, because the knowledge from the binary star systems permits the determination of orbital inclination, which can not be find in other cases. For details see for example Giménez (2006ab). For this reason, some surveys like **TrES**, (Trans-Atlantic Exoplanet Survey), or **WASP**, *Wide Angle Search for Planets*, (Cameron et al. 2009), as well as the Missions **CoRoT** and **Kepler** are based on transits.

Most of the transits concern the first observed such exoplanet, i.e. *HD 209458b*, although many others have been reported lately. They are based on observations from space, and/or ground, as already mentioned. For example, results of the infrared ($8\mu m$) transit and secondary eclipse photometry of the hot Neptune-like exoplanet *GJ 436b* obtained by **Spinzer**, have been presented by Deming et al. (2007). From the big number of papers concerning many other transiting exoplanets we refer the **3** transits of the exoplanet *HD 189733b*, (Triaud et al. 2009), because this and *HD 209458b* have the best Spitzer and HST data available.

Eighteen exoplanets have been detected by **WASP** till now. From them, very interesting are the cases of: a) *WASP-8b* that was found to be denser than *Jupiter*; b) *WASP-12b*, which has the largest radius of any known transiting exoplanet, (Hebb et al. 2009); c) *WASP-14b* is the denser known exoplanet, (Joshi et al. 2009); d) *WASP-17b* that is the first exoplanet with retrograde orbit, (Anderson et al. 2009); e) *WASP-18b*, (*HD 10069b*, *HIP 7562b*), for its very low orbital period that is less than one day, (Hellier et al. 2009).

The first discovery made by **CoRoT** concerned a giant exoplanet transiting a G0V type star in the Monoceros constellation, (Barge et al. 2007). The exoplanet was named *CoRoT-exo-1b*, but now is simply called *CoRoT-1b*, and this holds now for all CoRoT detections. After this first announcement many others followed. For example, *CoRoT-2b* is a giant planet with $M = 3.5M_J$, orbiting a star similar to our Sun, at a distance of $800ly$. Similarly, *CoRoT-4b* is a gas-giant planet, orbiting a late F-type star with the longest period, $P = 9.20d$ of the known transiting exoplanets, (Moutou et al. 2008); while, *CoRoT-3b* was found to be a brown dwarf and not exoplanet, since its mass was estimated as high as $21.6M_J$. From the other exoplanets discovered so far by **CoRoT**, *CoRoT-7b* seems to have attracted the interest of many investigators. For instance, Léger et al. (2009) measured the radius of the exoplanet *CoRoT-7b*, using the 3-color **CoRoT** data and ground made observations based on the periodic dips in the light curves of its parent star. Furthermore, from other ground based observations made with the Euler Swiss telescope, and an intensive campaign made with HARPS at La Silla, its radial velocity signals yield to the presence of two *super Earths*, of $M_1 = 4.8 \pm 0.8M_{Earth}$ and $M_2 = 8.4 \pm 0.9M_{Earth}$, (Queloz et al. 2009).

2. 3. THE COMPOSITION OF THE EXOPLANETS' ATMOSPHERES

As was referred in *Paper I*, observations in the vicinity of the $Na - D$ doublet, have been interpreted as the first detection of sodium in the atmosphere of an EGP, (Charbonneau et al. 2002). Sudarsky et al. (2003), on the other hand, suggested some theoretical models for the composition of the exoplanets' atmospheres.

The first detected transiting exoplanet *HD 209458b* has been extentively observed and studied. The atmosphere of this exoplanet was expected to have high silicate and iron clouds with bases at $\sim (5 - 10)mbar$, as was referred in *Paper I*. From ground and space observations of *HD 209458*, details on the structure and composition of its atmosphere have been given, (e.g. Richardson et al. 2007, Knutson et al. 2008, Swain et al. 2009). The latter found that its atmosphere is dominated by features due to the presence of methane (CH_4), and water vapour (H_2O), with small contributions from carbon dioxide (CO_2).

Moreover, the first ground-based detection of sodium absorption in the transmission spectrum of an extrasolar planet concerned *HD 209458b*, (Redfield et al. 2007). And since this amount for *HD 189733b* was found to be about **3 times larger**, it may indicate that these two *hot Jupiters* possibly have significant different atmospheric properties.

Madhusudhan and Seager (2009), on the other hand, presented a new method of retrieving molecular abundances, and applied it to the exoplanets *HD 189733b* and *HD 209458b*, because they have the best Spitzer and HST data available. For the first they confirmed the presence of water vapour, carbon monoxide, methane and carbon dioxide. For the second, they reported detections of water vapour, carbon monoxide, methane and carbon dioxide on its dayside.

Furthermor, Mousis et al., (2009) found that the element abundances in the envelope of *HD 189733b* were $(1.2 - 2.4)$ times oversolar and proposed this discrepancy to be irradiation from its parent star.

On the other hand, Hartman et al. (2009) compared their observations of *HAT-P-12b* with theoretical models and found that this exoplanet is consistent with a $\sim$(1-4.5)Gyr middly irradiated H/He dominated planet.

Moreover, a secondary eclipse of the transiting exoplanet *HD 149026b* using the Spitzer Infrared Array Camera at **8** μm has been observed by Harrington et al. (2007). Their study derives a brightness temperature of $2.300{\pm}200°K$, which is well above the prediction of $1.741°K$ for even zero albedo. This exoplanet is known to be enriched in heavy elements, which may give rise to novel atmospheric properties needed further investigation.

3. THEORETICAL STUDIES

Many are the theoretical papers concerning exoplanets. In *Paper I*, we referred some of those dealing with formation, evolution, stability, and the presence of exoplanets in the HZ of their parent stars. As is known numerical simulations are used for exoplanets' formation and evolution, indepentently from which of the two main scenaria of formation is used. Planetary system formation with numerical simulations using an effective model of gravitational accretion was made for instance by Bogojević et al. (2006). Besides, very interesting are the cases of exoplanets in pulsars, and the scenaria concerning their formation. Similarly, the formation of habitable planets in binary systems that host *Jupiter*-like planets, as well as the effects of the binarity on the formation of *Earth*-like planets in the system's HZ, (Haghighipour et al. 2009).

Here we shall be restricted to some latest improvements related mainly with the expected future findings from space observations. Such is for instance Dupuy and Liu's (2009) study, who presented detail simulations of the Pan-STARS-1 (PS1) multi-epoch, multi-band 3π Survey. According to them, the 3π Survey will be most sensitive to deep eclipses, $(0.10m)$, caused by *Jupiters*-like exoplanets transiting M-type dwarf stars and eclipsing stellar/sub-stellar binaries. And assuming a short-period planet frequency of 0.5%, their simulations predict that about a dozen transiting *Jupiters* around low-mass stars, $(M_* < 0.3M_\odot)$, within $100pc$ are potentially detectable in the PS1 3π Survey, along with about **300** low-mass eclipsing binaries, (both component masses $< 0.5M_\odot$), including about **10** eclipsing field brown dwarfs.

Other simulations are referred to exoplanets evolutionary scenaria like those presented by Lyra et al. (2009a). More specifically: They performed global simulations of the dynamics of gas and solids with a large number of Lagragian particles. For 1 to $10cm$ radii, gravitational collapse occurs in the Lagragian points in less than 200 orbits. For $5cm$ particles a $2M_J$ planet is formed. A *Jupiter*-mass planet can induce the formation of other planetary embryos at the outer edge of its gas gap. Trojan *Earth*-mass planets are readily formed. Furthermore, Lyra et al. (2009b) performed 2D global simulations of the dynamics of gas and solids in a non-magnetized thin protoplanetary disk with the Pencil code, using multiple particle species of radius $1, 10, 30$ and 100 cm. Many other N-body numerical simulations have been carried out, too, as are for instance those by Rèche et al. (2008).

On the other hand, Miller-Ricci et al. (2009), examined how an observer could differentiate between hydrogen-rich and hydrogen-poor atmospheres by modelling *super-Earth's* emission and transmission spectra. And found that discrimination is possible by observing the transmission spectrum alone. Similarly, the possibilities of observing the reflecting light of a close by giant exoplanet in a bright star with BRITE have been summarized by Dvorak and Bazsó (2008).

Regarding stability, Sandro et al. (2007) investigated the possible existence of terrestrial planets in systems with a giant exoplanet, and reported the development of a stability catalogue of the habitable zones of exoplanetary systems.

Laskar and Correia (2009), on the other hand, presented a global dynamical analysis of the extrasolar system, composed of 2 giant planets in a possible 3 : 1 mean motion resonance, around the star *HD 60532*. According to them, the best fit to the data corresponds to this resonant configuration, and the system is stable for at least **5** *Gyr*. Besides, stability is possible for a wide variety of orbital parameters around the best-fit solution and would also be if the inclination of the system orbital plane is as small as 15° with respect to the plane of the sky.

Moreover, the possible atmospheric mass loss from 57 known transiting exoplanets around F, G, K, and M-type stars over evolutionar timescales, (Lammer et al. 2009). They found that, under certain assumptions, at distances between $0.015 - 0.02$ A.U., *Jupiter*, and *sub-Jupiter* class exoplanets can loose several percent of their initial mass. And at orbital distances less than 0.015 A.U. low density gas giants orbiting solar-like stars may even evaporate to their core size.

4. DISCUSSION

Today, many and acurate ways are used to detect the presence of an exoplanet orbiting a star. Most of the known exoplanets have been discovered via RV measurements, while recently it was announced the first detection via astrometry, ((Pravdo and Shaklan 2009). On the other hand, after the detection of an exoplanet transiting its host star, RV observations are performed, too. This, except the two already referred cases of *HD 209458b* and *HD 189733b*, has been done for other exoplanets, too. As are for example *WASP-5b*, (Anderson et al. 2008), *WASP-18b*, (Southworth et al. 2009).

The exoplanets discovered so far exhibit a wide range of eccentricities. The distances from their host stars range from less than $0.1 A.U.$ to more than $5 A.U.$ and most of them are giants with masses many times the mass of *Jupiter*. As is known, there is an upper limit of about $(12-13)M_J$ between planets and brown dwarfs; but if an exoplanet has been discovered from radial velocity measurements, its mass is the **lowest** one. So, other observations are needed, too, to be sure if this is really a planet and not a sub-stellar companion. For instance, recently Bouchy et al. (2009), using the SOPHIE spectrograph installed on the OHP $1.93m$ telescope, reported the discovery of a sub-stellar component or a massive Jupiter orbiting the G5V star *HD 16760*. Because it was impossible to distinguish what really was the *object* hosted by this star. Similarly, some bodies detected to orbit other stars and originally considered to be exoplanets, it was later proven to be brown dwarfs from further investigations. This is for example the mentioned case of *CoRoT-3b*.

On the other hand, since M-type faint red stars are very numerous, (around 70% of all stars), they may host exoplanets similar to that detected via astrometry. Exoplanets that remain hidden and if detected they could be the most numerous class, (Pravdo and Shaklan 2009).

Observations have shown that multiple-planet systems with both giant Jupiter-like exoplanets, and with *super Earths* exist. This had been also shown theoretically, (e.g. Guedes et al. 2008 etc.).

On the other hand, stars hosting more than one exoplanets are known to exist, too. For example *GJ 876*, (Rivera et al. 2005), *GJ 581*, (Udry et al. 2007) etc. The first, *GJ 876*, is a M4 low mass (M=0.32 $M_{\odot}$) red dwarf at a distance less than **5** *pc* from the Sun, (Marcy et al. 1998). Its planetary system contains a $7.5 M_{Earth}$ *hot Earth* at $0.02 A.U.$ from its host star, as well as two giant planets with masses like that of *Jupiter* in 2:1 resonance, (Marcy et al. 1998, Rivera et al. 2005). And the existence of two such massive planets around *GJ 876* may indicate that its protoplanetary disk was particularly massive, (Lovis and Mayor 2007, Wyatt et al. 2007). The other, *GJ 581*, is a $10.55m$, M3V low mass (M=$0.31 M_{\odot}$) red dwarf at a distance of **6.3** *pc* from the Sun. The star belongs to the Libra constellation, and its planetary system was known till recently to consist of three *hot Earths/Neptunes*, (Bonfils et al. 2005, Udry et al. 2007). To these, a fourth planet has been added recently, (Mayor et al. 2009).

Most of the so far discovered exoplanets are orbiting stars roughly similar to our Sun. This is natural, as the first systematic search were performed to such stars' types. Even so, systematic searches have been made to evolved giant and sub-giant stars, too. Because, some exoplanets were discovered to rotate around giants, and sub-giants by individual observations. Thus, as early as 1998, a systematic search for exoplanets around giants started, (Setiawan et al. 2003). They examined **83** giants with FEROS, and detected: Two giant exoplanets around *HD 47536*, one around *HD 11977*, and one around *HD 110014*. Another similar investigation concerned the examination of **300** giants of G and K spectral types, (Sato et al. 2005). Its result was the detection of exoplanets around the stars: *HD 104985*, ϵ *Tau*, *18 Del*, ξ *Aql*, *HD 81688*, *14 And*, *81 Cet*, as well as around the sub-giants *6 Lyn* and *HD 167042*. Furthermore, Döllinger et al. (2009) reported the detection of two exoplanets orbiting the giants *11 U Mi* and *HD 32518*. To be more specific: An exoplanet with 10.50 ± 2.47 M_J orbits the first, and an exoplanet with 3.04 ± 0.68 M_J orbits the latter star. This, was the result of RV measurements regarding **62** K giant stars, started on February 2004 and carried out with the $2m$ Alfred telescope of the Thüringer Landessternwarte (TLS). They tried to find the dependence of planet formation on the mass of the host star, too. Moreover, Han et al. (2009) selected **55** early K-type bright giants and observed their RV variations with BOES attached to the $1.8m$ telescope at BOAO. They already announced a first detection of an exoplanet orbiting the giant $\gamma 1$ *Leo*.

From many investigations regarding the metallicity of the stars hosting exoplanets, as was referred in *Paper I*, it was found that their metallicity is high. This has been confirmed by recent observational data, (Bakos et al. 2009). They found that the parent star of exoplanets *HAT-P-13b* and *HAT-P-13c* is rather metal rich with [Fe/H]$= 0.41 \pm 0.08$. Furthermore, according to Hebb et al. (2009) the star hosting the exoplanet *WASP-12b* has super-solar metallicity.

Recent observations of the SST have shown that stars of spectral class **O**, produce a photo-evaporation effect that inhibits planetary formation. On the other hand, the images of debris disks around some main sequence stars very often show asymmetric structures and clumps, which are commonly interpreted as particles trapped by an unseen exoplanet, (Mouillet el al. 1997). Many such debris disks have been examined, (e.g. Akeson et al. 2007, Roberge et al. 2008). Furthermore, after the discovery of the 3 massive exoplanets around *HR 8799* its debris disk was examine, (Su et al. 2009). Their results, among others, show high level of dynamical activity implied by the halo in the debris of *HR 8799*, (Su et al. 2009), which may provide some help in understanding the interaction of planets and planetary debris.

All these new detections, with their very interesting and impressive findings, have brought up again the old questions: *"Are we alone in the Universe?"*; *"Are there Earth-like exoplanets able to develope life?"*.

Although answers are not easy reseaches try. Try hopping to discover *hidden Earths*. Searches for "rocky" exoplanets, similar to our *Earth* have started, i.e. O'Toole et al. (2009). On the other hand, methane is very probably related to life signature, and it was detected in the atmosphere of the *HD 189733b*. Moreover, according to Vanish et al. (2008), THESIS is capable of identifying biogenic molecules in habitable-zone planets; while, from the theoretical point of view the stability of terrestrial exoplanets, and the formation of potentially habitable exoplanets in a binary-planetary system have been discussed, (Haghighipour et al. 2009).

Finally, I would like to remind that as early as the fifth century BC some Greek philosophers known as Atomists, not only believed that there are other words except our own, but they also proposed scenarios of how they had been constructed. Unfortunately, their views were overpassed and shadowed by those of another Greek philosopher, Aristotle, who believed that: *"There can not be more words than one"*.

Acknowledgments

Many thanks to the LOC organizers of the Meeting, as well as to UNESCO-BRESCE for its financial support. Besides, the Simbad Database, operated at CDS, Strasbourg, France, as well as http://exoplanet.eu/catalogue.php,
and http://www.jpl.nasa.gov/news, were used.

References

Akeson, R. L., Rice, W. K. M., Boden, A. F. et al.: 2007, *Astrophys. J.*, **670**, 1240.
Anderson, D. R., Gillon, M., Hellier, C. et al.: 2008, *Mon. Not. RAS*, **387**, 4.
Anderson, D. R., Gillon, M., Hellier, C. et al.: 2009, arXiv0908.1553.
Bakos, G. A., Howard, A. W., Noyes, R. W. et al.: 2009, *Astrophys. J.*, **707**, 446.
Barge, P., Baglin, A., Auvergue, M. et al.: 2008, *Astron. Astrophys.*, **482**, 17.
Bogojević, A., Balaz, A. Belić, A.: 2006, *Publ. Astron. Obs. Belgrade*, **80**, 149.
Boss, A. P., Weinberger, A. J., Anglada-Escudé, G. et al.: 2009, *Publ. Astron. Soc. Pacific*, **121**, 1218.
Bouchy, F., Hebrard, G., Udry, S. et al.: 2009, *Astron. Astrophys.*, **505**, 853.
Cameron, A. C., Pollacco, D., Hellier, C. et al.: 2009, *IAUS*, **253**, 29.
Charbonneau, D., Betra, Z. K., Irwin, J. et al.: 2009, *Nature*, **462**, 891.
Charbonneau, D., Brown, T. M., Latham, D. W., Mayor, M.: 2000, *Astrophys. J.*, **529**, L45.
Charbonneau, D., Brown, T. M., Noyes, R. W. et al.: 2002, *Astrophys. J.*, **568**, 377.
Deming, D., A'Hearn, M. F., Charbonneau, D. et al.: 2007, *DPS*, **39**, 2202.
Dittmann, J. A., Close, L. M., Green, E. et al.: 2009, *Astrophys. J.*, **699**, 48.
Döllinger, M. P., Hatzes, A. P., Pasquini, L. et al.: 2009, *Astron. Astrophys.*, **505**, 1311.
Dupuy, T. J. and Liu, M. C.: 2009, *Astrophys. J.*, **704**, 1519.

Dvorak, R. and Bazsó, Á.: 2008, *CoAst.*, **152**, 166.
Fukagawa, M., Itoh, Y., Tamura, M., Oasa, Y. et al.: 2009, *Astrophys. J.*, **696**, L1-L5.
Giménez, À.: 2006a, *Astron. Astrophys.*, **450**, 350.
Giménez, À.: 2006b, *Astrophys. Space Sci.*, **304**, 19.
Guedes, J. M., Rivera, E. J., Davis, E. et al.: 2008, *Astrophys. J.*, **679**, 1582.
Haghighipour, N., Dvorak, R., Pilat-Lohinger, E.: 2009, arXiv0911.081.
Han, I., Lee, B. C., Kim, K. M. et al.: 2009, arXiv0911.0968.
Harrington, J., Luszcz, S., Seager, S. et al.: 2007, *DPS*, **39**, 2904.
Harrington, J., Luszcz, S., Seager, S. et al.: 2007, *Nature*, **447**, 691.
Hartman, J. D., Bakos, G.Á., Torres, G.: 2009, *Astroph. J.*, **706**, 785.
Hebb, L. Collier-Cameron, A., Loeillet, B. et al.: 2009, *Astroph. J.*, **693**, 1920.
Hellier, C., Anderson, D. R., Cameron, A. C. et al.: 2009, *Nature*, **460**, 1098.
Joshi, Y. C., Pollacco, D., Cameron, A. C. et al.: 2009, *Mon. Not. RAS*, **392**, 1532.
Kalas, P., Graham, J., Chiang, E., Fitzgerald, M. et al.: 2008, *Science*, **322**, 1345.
Kalas, P., Graham, J., Clampin, M.: 2005, *Nature*, **405**, 1067.
Knutson, H. A., Charbonneau, D., Allen, L. E. et al.: 2008, *Astrophys. J.*, **673**, 526.
Lammer, H., Odert, P., Leitzinger, M.: 2009, *Astron. Astrophys.*, **506**, 399.
Laskar, J. and Correia, A. C. M.: 2009, *Astron. Astrophys.*, **496**, L5-L8.
Léger, A., Rouan, D., Schneider, J. et al.: 2009, *Astron. Astrophys.*, **506**, 2009.
Lovis, C. and Mayor, M.: 2007, *Astron. Astrophys.*, **472**, 657.
Lyra, W., Johansen, A., Klahr, H. and Piskunov, N.: 2009a, *Astron. Astrophys.*, **493**, 1125.
Lyra, W., Johansen, A., Zsom, A. et al.: 2009b, *Astron. Astrophys.*, **497**, 869.
Madhusudhan, N. and Seager, S.: 2009, *Astrophys. J.*, **707**, 24.
Marcy, G. W. and Butler, R. P.: 1998, *Annual Reviews Astron. & Astrophys.*, **36**, 57.
Marois, C., MacIntosh, B., Barman, T., Zuckerman, B. et al.: 2008, *Science*, **322**, 1348.
Mayor, M., Bonfils, X., Forveille, T. et al.: 2009, *Astron. Astrophys.*, **507**, 487.
Miller-Ricci, E., Seager, S., Sasselov, D.: 2009, *Astrophys. J.*, **690**, 1056.
Mouillet, D., Larwood, J. D., Papaloizou, J. C. B. et al.: 1997, *Mon. Not. RAS*, **292**, 896.
Mousis, O., Lunine, J. I., Tinetti, G. et al.: 2009, *Astron. Astrophys.*, **507**, 1671.
Moutou, C., Bruntt, H., Guillot, T. et al.: 2008, *Astron. Astrophys.*, **488**, 47.
O'Toole, S., Tinney, C. G., Butler, R. P. et al.: 2009, *Astrophys. J.*, **697**, 1263.
Pravdo, S. H. and Shaklan, S. B.: 2009, *Astrophys. J.*, **700**, 623.
Queloz, D., Bouchy, F., Moutou, C. et al.: 2009, *Astron. Astrophys.*, **506**, 303.
Rauer, H., Queloz, D., Csizmadia, Sz. et al.: 2009, *Astron. Astrophys.*, **506**, 281.
Rèche, R., Beust, H., Augereau, J-C, Absil, O.: 2008, *Astron. Astrophys.*, **480**, 551.
Redfield, S., Endi, M., Cochran, W. D., Koesterke, L.: 2008, *Astrophys. J.*, **673**, 87.
Richardson, L. J. R., Deming, D., Horning, K. et al.: 2007, *Nature*, **445**, 892.
Rivera, E. J. et al.: 2005, *Astrophys. J.*, **634**, 625.
Roberge, A. and Weinberger, A. J.: 2008, *Astrophys. J.*, **676**, 509.
Rovithis-Livaniou, H.: 2008, *Amer. Inst. Phys.*, Exploring the Solar System and the Universe, Eds. V. Mioc, C. Dumitrache and N.A. Popescu, **1034**, 358.
Sandro, Zs., Suli, A., Erdi, B. et al.: 2007, *Mon. Not. RAS*, **375**, 1495.
Sato, B., Kambe, E., Takeda, Y. et al.: 2005, *Publ. Astron. Soc. Japan*, **57**, 97.
Setiawan, J., Pasquini, L., da Silva, L. et al.: 2003, *Astron. Astrophys.*, **397**, 1151.
Southworth, J., Hinse, T. C., Dominik, M. et al.: 2009, *Astrophys. J.*, **697**, 1263.
Su, K. Y. L., Rieke, G. H., Stapelfeldt, K. R. et al.: 2009, *Astrophys. J.*, **705**, 314.
Sudarsky, D., Burrows, A. and Hubeny, I.: 2003, *Astrophys. J.*, **588**, 1121.
Swain, M. R., Tinetti, G., Vasisht, G. et al.: 2009, *Astrophys. J.*, **704**, 1616.
Triaud, A. H. M. J., Queloz, D., Bouchy, F. et al.: 2009, *Astron. Astrophys.*, **506**, 377.
Udry, S. et al.: 2007, *Astron. Astrophys.*, **469**, L43.
Vanish, G., Swain, M. R., Akeson, R. L. et al.: 2008, *SPIE*, **7010**, 112.
Wolszczan, A. and Frail, D. A.: 1992, *Nature*, **355**, 145.
Wyatt, M. C., Clarke, C. J., Greaves, J. S.: 2007, *Mon. Not. RAS*, 380, 1737.