ISSI 1th Team Meeting supported also by Europlanet NA1/NA2 activity

During March 19. – 21. 2012 the first ISSI Team meeting on "Characterization of Stellar and Exoplanet Environments" was held at ISSI in Bern. The team meeting was also co-organized and supported by Europlanet NA1/NA2 activities because the meeting theme was closely linked to ground and space based observations.

The participants expertise of this meeting was related to observers, scientists who analyze and interpret data and theoreticians who develop complex numerical models so that the upper atmosphere structure, atmospheric species, exo-magnetospheric environments and their interaction with the host star's radiation and plasma, could be better understood.

The meeting was organized in a way that the participants briefed each one on the latest stage of the observations and advanced modeling techniques and discussions. Further, discussions related to near future HST UV observations of several hot gas giants were also carried out.

Below is a summary of the various talks and planned future activities of the team.

First day: 19. 03. 2012

1. Maurizio Falanga, ISSI: gave an introduction to the participants about ISSI and the activities related to the institute. This was informative because about 40 percent of the meeting participants visited for the first time the International Space Science Institute.

2. Fridlund, ESA: Give a short briefing on ESAs activities in the exoplanet field. Exoplanets, although they were defined as one of the most important scientific subject, not really a purely ESA-led exoplanet mission was so far selected and launched. PLATO is the latest studied M-class ESA-project but is so far also not selected as an M-size mission. The global financial crisis will also impact ESA and its future missions. Finally, Euclid the dark matter and energy mission was selected by the SPC instead of PLATO. Now PLATO goes into competition with the actual selected M-size missions such as a second exoplanet mission, EcHO. Recently the French space agency CNES went out from the PLATO project. Now other countries show an interest for taking over the former CNES part. During the meantime the EcHO mission is also well studied within ESA. EcHO would be Europe's exoplanet atmosphere characterization mission. At the present time, a problem may be related to the targets at least for small exoplanets. In the present absence of many small planetary targets, EcHO can for sure well characterize gas giants and hot Neptune's.

3. Bisikalo, INASAN/RAS: briefs the participants on the history and the latest stage of various UV-projects, and the Russian-led World Space Observatory-UV (WSO-UV). Heridage of WSO-UV. TAUVEX not clear but may be a future mission. WSO-UV should be launched during 2016 and operate about seven years. The funding from the Russian side for the space observatory is accepted. So lunch date is very optimistically that the launch date will be valid. The main cooperators are Russia, Spain and Germany. Several other countries contribute to the project. WSO-UV will for sure be a HST successor with better UV-observation capabilities. A 1.7 meter mirror telescope will be launched into a geosynchronous orbit with actual technology so that the data should be better than HST data. Due to the orbit, WSO-UV will avoid problems with the geochorona and produce high resolution spectra with very good resolution in the UV-relevant wavelengths.

Science with WSO-UV:
Core program (international core program involved by the scientists who developed the science tasks for WSO-UV);
Funding bodies program;
Open scientific international community.
Exoplanets are one of four main science cases, besides Galaxies, Milky Way in UV and outflows of bodies such as binary star interactions.

More informations on the WSO-UV mission can be found at: http://wso.inasan.ru/

4. Ribas, ICE/CSIC: Gave an update on ground-based exoplanet projects. From the present exoplanet surveys one can expect that planets are everywhere, for sure half of the stars may have planets. M-star surveys fits also in that suggestion. The chemical composition seems to be very different on these planets. At the present stage there are for sure natural and observational biases in the present data. HARPS north starts to operate in autumn 2012. Astrometry Gaia (2013) may also find smaller planets close to stars. For characterization the problem may be again the brightness of the host stars. The ground-based M-star planet search project CARMES was addressed, too.

   CARMENES: Is a project which searches Earth & super-Earth-type planets around M stars for follow up studies related to the detected planet's properties and potential habitability. The project operates in visible and near-IR. A survey of about 300 M stars will be carried out by the German/Spanish project at the 3.5 m Calar Alto telescope. Funding is there for a huge part. So far most exoplanet detection programs focused on the solar mass domain. With CARMENES this search will be expanded to the small star and low mass domain. Due to the cooler stellar environments planet orbiting within the host stars habitable zone can be discovered. CARMENES is a spectrograph build only for planet detection/characterization. The targets are focused on moderate to moderately active dwarf stars (M4V and M5V stars). Nearby objects within 13 pc, which can be observed by additional observations by other telescopes? How many planets could be around bright stars related to the projects? Ribas, Lovis et al. (in prep. 2012): How many bright transiting planets are out there? An article is under preparation. These targets around brighter stars can also be studied and characterized in the future with missions like EcHO.

   After the mission and project overview, Ribas addressed issues related to the star-planet connection. First he briefed the team members from the Sun in Time project. The observational results showed the importance of the age of the host stars, because they are much more active in the younger age. A new article by Claire et al. (2012) which is in press in ApJ studies the UV fluxes in general over the solar history.

5. Güdel, IfA/Uni Vienna: his talk focused on the high energy part of the young Sun/stars. It was pointed out that so far nobody addresses higher energetic events then X-rays. Gamma Rays for instance. Decay in high energy radiation goes down slower in M-dwarfs. For M stars the X-ray decay is also slower. (Stauffer et al. 1994; Stern et al. 1995). The stellar activity is definitely connected with the spinning down of the rotation, except for some M dwarfs. A new study by Engle and Guinan (2012) applied the "Sun in Time" study to M dwarfs. The results indicate that the M star activity decay is probably less steeply compared to G stars. For the young Sun UV decays

from levels which are 10 to 30 times higher than at present. EUV from about 100 and X-rays from 1000 times. The coronae of young stars are hotter and the emissions are harder most likely due to stronger flaring. There are very energetic emissions beyond X-rays which go deep in the atmosphere.

The high energy particles (p+, e-, etc.) should have an effect on young planetary upper atmospheres – may modify the thermosphere temperature. Eike Günther showed CoRoT-data where they investigated about 100 flares.

6. Wood, Naval Obs.: briefed the participants on previous and actual efforts related to stellar wind observations with the HST in Lyman-alpha. An overview of various types of winds from other stars was given. For G-stars it's difficult to observe. Emissions in radio occur and X-rays will be produced due to the interaction with partially neutral ISM due to charge exchange with neutrals – from the astrosphere. A hydrogen wall (heated and compressed hydrogen, which is detectable in Lyman-alpha), builds up between the heliopause and the bow shock of the star's system. Interstellar deuterium absorbs at 1215.3 Å. As the result the blue side yields the astrosphere absorption in Lyman-alpha. From the absorption and the application of hydrodynamic models the mass loss of the observed stars can be obtained. There are model depended assumptions such as stellar wind velocity. In the very active – young star - regime not much data are available. The young stars xi-Boo A and xi-Boo B belongs to a binary system with a G star and a K star. Therefore, it is not well known from which star the wind is observed. Other stars with very young age are M dwarfs. The magnetic topology of young stars may be different and the mass loss and related plasma outflow may be affected. Mass loss from the young Sun (G-stars) was maybe up to 100 times higher about 4 Gyr ago. What happened before it's not well known and more observations are needed.

   Astrosphere observation proposal for HST/STIS could be discussed within the ISSI-team. It may support that a proposal may be accepted if a strong science case is defined by team members related to various disciplines.

   Redfield PI of one accepted proposal where also two stars will be observed where exoplanets are known – HD 9826, HD 192310.

   Possible HST-STIS proposal support from the members of this team:
   Wood figured out four new young solar like stars where astrospheres could be observed. This could be discussed further within team members.

7. Günther, Tautenburg Obs., discussed the observations related to WASP-33b which orbits close around a massive A5V star. At the present time it seems that there is a lack of planets orbiting around massive stars. It seems more massive stars have a lower number of planets. The planet was discovered by the Super WASP telescope. Ground-based telescopes may overlook a huge fraction of hot gas giants. The star is younger than 400 Myr this can be estimated because the star is on the ZAMS. The Rossiter-McLaughlin effect was used for the discovery of this planet around the rapidly rotating star. The planet around the A star orbits within 1.2 days or at an orbital location at 0.02 AU. The mass is < 2 $M_{\rm Jup}$ and about 1.5 $R_{\rm Jup}$. The rotation is retrograde. The planet's atmosphere is very hot and maybe detected in the IR? There was an observation with the TNG 3 meter telescope in La Palma, so far no detection

was made but could probably be done with a telescope which has a better signal-to-noise ratio.

Questions came up which can be discussed further in the future by team members if it would make sense to prepare an observational proposal with a telescope, which should have the resolution to detect some atmospheric traces?

8. Linsky, Univ. Colorado, discussed and presented new unpublished UV observations of exoplanet environments. He is involved in a large project related to observations of exoplanets with HST/COS, HST/STIS in Lyman-alpha and obscured EUV around G, K, and M stars. UV spectra of G0-G2 stars over ages (1340 – 1420 Å) were shown. Recent observation of the M star GJ 878 with HST/COS and STIS spectra at HZ (0.21 AU) compared to the quiet Sun at 1 AU were also presented. < 1500 Å are comparable to the Sun, longer wavelengths are weaker. Ad Leo and AU Mic were observed in Lyman-alpha by HST/STIS as shown in Wood et al. (2005). One has to reconstruct the line profile. A problem is ISM-Absorption and also the geo-corona. The geo-corona problem could be solved if WSO-UV is in orbit. Reconstructed Lyman-alpha profiles of GJ 876 were also shown; STIS observations and Lyman-alpha fluxes after the ISM absorption and geo-corona were corrected. Similar techniques were applied also to GJ832 and GJ667c. The star GJ 876 has four non-transiting exoplanets in orbits at 0.02, 0.12, 0.2, 0.33, AU. The Lyman-alpha observations were analyzed to the distance related to these planetary orbits. F(Lyman-alpha)=f(FUV), the fast rotating stars have much higher Lyman-alpha fluxes related to the age.

9. Fossati, Open Univ., presented and explained UV observations in various wavelength regions of WASP-12b. The ordinary visual lightcurve is not unusual but there is an early ingress in UV-B, etc. within 3σ. Possible explanations could be related to mass transfer or magnetic obstacle effects (e.g., magnetopause, bow shock, etc.). Methods or possibilities for early ingress observations such as hydrogen in the Balmer jump may be used for ground-based observations with photometry in different bands. Results of such an observation were shown. The light curve is symmetric and one can slightly see an early ingress by using this method.

   Several questions remained: Which kind of elements produces the absorption? Spectral points with a deviation of 5σ: Vanadium 2? The star has no emission in the MGII line. The age of the star is < 2.65 Gyr. The star rotates very slowly, not known if the planet rotates pro-grade or retro-grade. The planet's upper atmosphere should reach the Roche Lobe. MgII, FeI, FeII and MnII were detected.

   Similar ground-based observations and near future proposals for exoplanets WASP-18 & 19 + WASP-12 early ingress NUV and HST of WASP-18 & WASP-19 (early ingress + metals) were discussed after the presentation and during the meeting in general.

10. Jardine, Univ. St. Andrews, focused on the stellar magnetic structure of exoplanet host stars. Stellar magnetic fields are quite relevant for the interaction between stars and close-in planets. Solar wind models were shown for solar mass stars based on a previous article by the speaker. Magnetic fields of stars can be determined by the Zeeman effect, polarity, etc. Large scale fields can also be studied by these methods. AB Dor was mapped for a magnetic field between 1995 - 2004 (Donati et al. 1997; 1999; 2003). This is a very young solar-like star. The distribution of the flux is rather

different compared to the Sun. Stellar corona models were shown. By comparison between the masses of the stars one can see that low mass stars are fully convective. One finds a range of different magnetic field configurations which are related to the various stellar types. A full magnetic cycle was observed at Tau-Boo (who have a massive "hot Jupiter" orbiting). It is not clear how strong the exoplanet may have influenced the magnetic cycle of the exoplanet. Magnetic environments of planets will change if the rotation of the planet is not to tidally locked. The reason is due to the connection between the planetary magnetic field lines with the stellar ones. The planet will also influence and disturb the stellar magnetic field.

11. Bisikalo, INASAN/RAS, presented advanced theoretical MHD-models which were developed for binary stars and are now applied to star-exoplanet plasma interaction studies. The analogies between the modeling aspects of binaries with star-exoplanet analogies were discussed and shown. A very complex set of equations has to be solved numerically. INASAN has developed such a model which includes also the magnetic field of the host stars. The influence of strong stellar magnetic fields to the plasma flow regimes are shown and complex scenarios can be developed. The model was also applied to T-Tauri stars and discs. T-Tauri phases last about phase 10^6 to 10^7 years during the stars pre-main sequence lifetime. Bow shocks appear and the mass flows mainly form the lower mass object to the more massive body.

    Preliminary application to the exoplanet system HD209458 was shown. In the simulations where no planetary magnetic field was assumed an obstacle forms around 4 to 5 planetary radii with input parameters taken from the literature. UV observations can be used to fine tune the models and parameters, and finally could be used for validating numerical models.

2nd day: 20. 03. 2012

1. Müller-Wodarg, Imp. Col., discussed space weather effects on Solar System planets and what we can learn for exoplanets. Energy & angular momentum balance in the magnetosphere and atmosphere can be studied and the coupling between atmosphere dynamics, thermosphere and related response and escape which is related to atmosphere evolution. Auroral emissions in radio, IR, UV are observed in our own Solar System so one may study the same processes in a comparative way also from exoplanets. Brief reviews on aeronomy subjects for Solar System planets were presented. It was pointed out that early atmosphere modeling failed to predict the diurnal thermal structure on Venus (later observed by Pioneer Venus) due to a general inability of global models to account for small scale processes such as waves which profoundly affect dynamics, and thereby the thermal structure. Rotation in the case of Jupiter and also Saturn play a role too in the interaction process in relation with their magnetospheres. The atmosphere of Solar System gas giants is linked to the magnetosphere – angular momentum transfer. Joule heating and ion drag occurs. Similar processes should also occur in a probably different way on exosolar gas giants.

    The basic message in the presentation was that magnetosphere-ionosphere-thermosphere coupling had a profound influence on the upper atmospheres within and beyond our Solar System. This as incident plasma particle fluxes, atmospheric conductivity, magnetic field strength, degree of corotation and E-fields are all connected depending on the solar/stellar input in a very complex way.

A model frame work which tried to calculate the Saturn system was presented. The model couples thermosphere-ionosphere and suprathermal particles. Results of this advanced model in case of Saturn and its solar wind interaction were shown. The driver is related to the polar areas coupled to the thermosphere circulation. The model reproduces upper atmosphere temperatures of about 500 K near the polar areas, which agree with observations near the pole well. It was also shown that the exospheric temperature was controlled by key parameters such as electric field strengths and the particle energy flux and could thereby be used to constrain such magnetospheric parameters. Related to the location the exosphere temperature on Saturn varies between 700 K (auroral oval) to 420 K.

For exosolar gas giants the results indicate that one may also have different exosphere temperatures distributed over lat. and long. The exosphere temperature on Saturn related only to the solar EUV flux would be 200 K.

It was pointed out that for Saturn it is not easy to understand how the temperature can reach about 500 K at -30 to + 30 degree lat. Low lat. energy balance is not understood on gas giants in the Solar System and we should also keep this lesson when we extrapolate with global models to exoplanets. The question was raised whether we should really apply 3D models to exoplanets, given that they are depended on too many free parameters, or whether 1D models would be a better choice. However, it was pointed out that 3D models were still needed to properly simulate magnetosphere-ionosphere coupling, which is strongly controlled by dynamics. These can only be calculated with 3D models. However, one should point out that at orbital locations < 0.1 AU the stellar EUV radiation is very high and may take over the main contribution in the upper atmosphere heating.

Ben-Jaffel pointed out that a model by Sommeria et al., Icarus (1995) was proposed to explain the thermospheric heating of Jupiter. It was shown that the input energy in the auroral region has the right level and can be transported to heat up the thermosphere of Jupiter at the 1000K observed planetwide.

2. Chadney, Imp. Col., discussed giant planet hydrogen-type ionospheres under solar/stellar radiation fields. He studied also flaring on gas giants. It was pointed out that H_3^+ is quite a relevant IR-cooler! This molecular ion was observed in the hydrogen-dominated upper atmospheres of Solar System gas giants and can be very relevant for hydrogen-He atmospheres – as long as H_2 exists in molecular form. Besides EUV radiation, also electrons which participate in the upper atmosphere are quite relevant for thermospheric heating. A detailed explanation was given how the radiation fields penetrate into the upper atmospheres.

   Studies were also carried out on data available to the flaring M star AU Mic. Linsky pointed out that interstellar absorption should also be corrected. The ultimate goal is to understand the H_3^+ production and destruction and related photochemistry.

3. Ben-Jaffel, IAP, discussed the observations of hydrogen, oxygen and carbon around HD 209458b. First a brief overview of the system (star and planet) was given (e.g., Ballester and Ben-Jaffel, 2011; 2012). A brief summary of all UV observations was discussed. First Ben-Jaffel addressed also the early HST/STIS observations by Vidal-Madjar et al. (2003). The problem with the geocorona was pointed out as problems related to the statistical noise and stellar variation. In the high resolution analysis the

red part is probably more absorbed than the blue part. He pointed out that he finds not really an indication that a tail can be seen in the observations. In the low resolution analysis, Si III observations show a big difference between the data of Vidal-Madjar, Ben-Jaffel and Linsky. It was clearly shown that that a stellar variation observed at phases 25 makes uncertain the SiIII detection made by COS. Possible influences on the time variability of the star could play a role in this. Ben-Jaffel pointed out that energetic neutral atoms (ENAs), suprathermal atoms and thermal broadening could also solve the observations and maybe it's a mix of all three processes. One needs a higher resolution to separate the processes, or new observations of brighter stars with hot Jupiter's.

The second part of the presentation focused on numerical simulations of the solar wind with the local interstellar medium to show the strong distorsions in the heliosphere that result from an oblique ISM magnetic field. It was reported that those distorsions, as observed by Voyager 1 & 2 and IBEX, have been used to derive the ISM magnetic field of 2.4 microGauss (Strumik, Ben-Jaffel et al., ApJ, 2011). Linsky remarked that earlier studies reported an ISM strength of 4.8MG, a result that was probably based on a restricted set of observations. Also, it was an opportunity to show particles simulation of the stellar wind plasma interaction with a Jovian planet. The model produces naturally the current sheet after the gradual set-on of a planetary magnetic field – these are very time consuming simulations and include ions and electrons. IMF magnetic field effects are not considered now. They are planned to be included in the future. Such models developed for the study of Solar System planets can and will be applied in the future also to exoplanets.

4. Koskinen, LPL, discussed the Aeronomy of exosolar gas giants with a focus on HD 209458b. In his studies the atmosphere match exactly the 6.6 % line-integrated absorption as well as the absorption as a function of wavelength inside the line profile (see also: Koskinen et al. ApJ, 732, 116-128, 2010). The narrow wavelength limits in give about 8 %, which is consistent with 6.6 % across the whole line profile (there is no inconsistency between these values if you use the appropriate wavelength limits). By changing atmosphere parameters he can of course match also higher transits, but there are no reasons for doing it. Thus the model fits the observations and the detection of the heavy elements in the upper thermosphere is used to constrain the carbon and oxygen observations, by applying a photochemical model for the study of these elements in the lower atmosphere. Thermosphere models must include photochemistry of heavy species (ionization, recombination, charge exchange), but they do not necessarily need to include molecules (molecular ion chemistry of heavy elements is really complex). Then the H_3^+ IR-cooling is also considered as long as one has H_2 molecules in the thermosphere. The important point about H_2 dissociation by water chemistry is that it happens near 1 microbar instead of the much lower pressure of 1-10 nbar (Yelle 2004; Koskinen et al. 2007). This is the realization that originally allowed Koskinen to fit the H Lyman alpha data because with a higher dissociation pressure Ione get much more H at higher altitudes. Koskinen discussed his 1D hydrocode, where he also focused on the heating efficiency related to hydrogen-rich thermospheres. The pressure averaged temperature was not varied; it is calculated by the code and turned out to be between 6000 K and 8000 K (for heating efficiencies between 10 and 100 %). The H/H^+ transition occur in the model close to 3 $R_{\rm pl}$. transport of heavy species into the upper atmosphere is possible. The detection of oxygen indicates a minimum mass loss rate of about 6 times 10^9 g s^{-1}. This mass loss rate is required to drag O atoms up to the Roche lobe of HD 209458b. Comparison

with observations of HI, OI, CII 1334.5 A, CII 1335.7 A, SIII were also shown. These results are based on the assumption that the planet may possess a weak magnetic moment (e.g., Grießmeier et al. 2004). The extended ionosphere may screen radio emissions out if they are generated at low altitudes. A factor of 2 in EUV would not really affect the temperature profile much; it will be compensated by adiabatic and Lyman-alpha cooling.

A question on the origin of the observed heavy species was asked:
Regarding the possibility that the heavy species originated in the stellar wind, one can argue that if one believe the current thermosphere models for the structure of the upper atmosphere (i.e., temperature around 10,000 K, hydrodynamic escape etc.), then one almost have to believe that the heavy elements should be of atmospheric origin. Their presence is a natural consequence of the conditions most people now assume in the thermosphere of HD209458b. If, on the other hand, one postulates that the atoms are from the stellar wind there are some questions one needs to address.
These are: Is the density of heavy elements in the stellar wind sufficient?
What is the interaction of the stellar wind with the planetary atmosphere like and, if the density is sufficient, does this interaction create an obstacle that agrees with the observations?

The first question at least should be quite easy to check by using solar wind abundances as a guide.

5. Shematovich, INSAN/RAS, presented a study of suprathermal or hot hydrogen atom production and energy density functions and escape rates at HD 209458b. First the general production process and model results at Solar System planets like Mars, Earth, etc. were given. Photochemically produced atoms yield non-Maxwellian velocity distributions, which correspond on Mars to a main escape process of heavy atoms. There are photochemical and plasma sources for the production of suprathermal atoms. A brief introduction of hot atom kinetics was given. Elastic, inelastic and quenching collisions with the ambient atmosphere should be taken into account. In the case of Titan a hot particle population was also observed. Then Lyman-alpha observations on the aurora of Jupiter were discussed and the influences of the line profile of supra-thermal hydrogen atoms were shown.

   Then a hot atom model was applied to HD 208458b. It is pointed out that the transition regions of H_2 to H and the H/H^+ upper atmosphere are very relevant in the production rates of suprathermal hydrogen atoms. The model scheme related to suprathermal hydrogen atoms within the upper atmosphere of the exoplanet was explained. The production of hot atoms for the models of Yelle (2004) and Grazia-Munoz (2007) were produced. The energy density functions of the suprathermal hydrogen atoms were calculated and presented. The loss rate of these atoms is about about 6 times 10^9 g s^{-1}. The velocity of these atoms is about 30 to 45 km/s. Such a loss rate is about one order of magnitude lower compared to the thermal escape rate of the bulk gas.

   But suprathermal hydrogen atoms will also show up in the observed absorption at the Lyman-alpha spectra. In reality line broadening, suprathermal atoms and also ENAs will act on these planets and influence the observations and data interpretations. The efficiency of these processes will be different on different planets and are related to the efficiency of the stellar EUV radiation and plasma conditions, as well as the magnetic properties of each particular planet.

6. Holmström, IRF Kiruna, briefed the participants on the observations and production of ENAs around various Solar System planets and due to the extreme conditions such as extended upper atmospheres, related exospheres and stellar wind properties ENAs should also be produced around exoplanets and especially close-in hot gas giants. ENAs are produced via charge exchange and lower energetic ones also by atmospheric sputtering. If the ion flux interacts with the neutral atoms from a planetary corona or exosphere, ENAs will be generated via charge exchange and the newborn atom will carry the information of the plasma flow (velocity, direction, etc.). ENA production around magnetized, non-magnetized and airless bodies such as the Moon was also discussed. On Earth we observed ENAs which are produced by ions accelerated within the ring current of the magnetosphere. Due to many observations of ENAs around Venus, Mars and Earth a lot of information regarding ENA production and related phenomena are well known and understood.

   For hot Jupiter's which have extended magnetospheres one may also expect high energetic ENAs such as at Earth.

   Ben-Jaffel and Koskinen asked why the Ben-Jaffel (2008) Lyman-alpha absorption (8.5 - 9 %) was not applied so far in ENA-modeling efforts. Holmström pointed out that the ENA-code was updated during the past months and various sensitivity studies related to the shape of planetary obstacles (i.e., magnetopauses, etc.) were carried out. The Ben-Jaffel (2007; 2008) Lyman-alpha spectra will be implemented in the code during the next weeks. The upgraded code which is used for the study of ENAs around exoplanets includes now also natural broadening.

   Vidotto, Univ. St. Andrews, discussed the UV observations of WASP-12b and the asymmetric ingress in connection with stellar wind interaction and the estimation of the planet's possible magnetic properties. It was found that there could be a bow-shock produced due to the planet's velocity within the plasma flow. B-field estimates: 24 G maximum field strength; P_B: 8E^{-3}dyn cm^{-2}. A simple Monte Carlo model, which included various obstacle geometries in the transit simulations, was presented, including a best fit. More exoplanets which may be possible to observe similar as WASP-12b were identified. Magnetosphere size estimates of exoplanets in Vidotto et al. (2011a). Discussions after the talk resulted in:

   - A further study on WASP-12b could probably result in an interesting short article related to stellar wind and magnetosphere colleagues.
   - There are several targets which could be observed probably in a similar as WASP-12b – observation plans see also talk by Fossati will be carried out.

7. Alexeev, Moscow State Univ., talked about magnetosphere studies and observations in the Solar System and how one may extrapolate the knowledge to close-in hot Jupiter's. First all values and configurations of planetary magnetospheres were compared. Magnetosphere timescales were compared. Two main current systems which are used in a so-called paraboloid model of the Moscow-group were explained. These current systems are magnetopause currents near the magnetopause stand-off distance and tail currents. Spacecraft measurements such as from Cassini, Galileo, and Ulysses at Jupiter were also presented. Spacecraft data and observations were used to validate the paraboloid model.

The signatures of the Galilean moons related to HST observations at Jupiter's cusp region were also discussed. The auroral oval of Jupiter could be determined by these moon related observations. An analogy between Jupiter and its satellites and the stars and hot Jupiters was pointed out.

The plasma disk properties and disk formation related to magnetospheres of gas giants were discussed. Close to the planet the plasma corotates with the planet. When the plasma reaches the outer areas, due to the fast rotation of the planet the plasma does not co-rotate anymore with the planet and a magnetodisk is generated by current systems. On Jupiter the current systems generate a magnetic field, which is of the same strength as the dynamo field. Such induced magnetic fields should also play a role on hot Jupiters and may modify the dipole field of the planet.

8. Khodachenko, IWF/ÖAW, continued to explain an application of the parabolic model to hot Jupiters and points out that similar processes may induce a disk on these bodies too. Comparative issues between Jupiter and close-in gas giants were discussed, issues such as nonthermal ion mass loss which is related to magnetospheres, discussions on tidal locking and weak magnetic fields of close-in exoplanets were also addressed. One would expect that close-in hot Jupiter's would experience strong mass loss if they are not protected by magnetic obstacles. This assumption depends on the dipole generation + current induced magnetic fields such as magnetodisks, etc.

   In case of Jupiter a sling-type formation process, which is related to fast rotation of the Solar System gas giant is one formation process, while in the case of hot Jupiters, ions which are embedded in the hydrodynamic expanding and outward flowing planetary gas can also produce a current induced magnetodisk, which contributes to the magnetosphere configuration and modifies it. Beyond the Alfvénic radius the plasma flows outside.

   The results of a recent study which was published by Khodachenko et al. (2012) in ApJ showed that a magnetodisk may increase the magnetic field strength of related to a dynamo of about 40 to 60 % and may depend on an individual planet, rotation, ion outflow, EUV, orbital distance, etc. The process may be important for hot gas giants and protects them additionally against nonthermal ion erosion of CMEs at that close orbital distances.

3th day: 21. 03. 2012

1. Grießmeier, CNRS, Orleans, discussed the magneto-dynamo hypothesis that slow rotating planets may have reduced magnetic moments. First the importance of the magnetospheres for gas and terrestrial planets were discussed. The processes related to the dynamo generation within the cores were discussed. There exists no equation of state (EST) for super-Earths. Most scientists expect that super-Earths may have a problem to generate a strong dynamo because due to problems related to the formation of an inner solid core – too hot in the interior (Venus-like). Plate tectonics are relevant for the temperature regulation. Zuluaga et al. (2012) estimated the magnetic fields of exoplanets. For all studies one needs to understand the interior structure of the planet. The latest results indicate that super-Earths and slow rotating planets may not generate or have problems to keep up strong dynamos for long time. These suggestions are currently supported by most studies, although the models including their results cannot be trusted for 100 %, only trends can be derived.

Indications from plasma remote sensing around exoplanets (ENAs, radio, ionized particle escape from hot Mercury-type planets, etc.) are important for models of planetary interiors too, because a magnetosphere evidence could constrain the interior models or enhance the information's related to magnetic dynamo generation.

2. Reiners, Univ. Göttingen, discussed convection-based magnetic field theories from stars to brown dwarfs to gas giants. In this hypothesis the rotation of the planet does not have really a strong effect in the dynamo field strength. It was shown form stellar observations that there is a connection between the Rosby number and time (age). Detailed observation-based indications and theories were discussed how the magnetic fields, energies etc. decreased with age of stellar/dwarf star magnetic field (flux density). Reiners (2012) [Living Rev. Solar Phys. 9, 1]. In the non-saturated regime, the rotation determines the magnetic flux and as a result the magnetic field. In the young age, rotation does not influence the dynamo really. The convecting energy flux is very important in the dynamo generation. If this hypothesis is a real scenario then young planets should have stronger magnetic dynamos.

1. Belenkya, Moscow State Univ., talked on the possible forms of disturbances arising in the magnetic plasma flow due to the different obstacles – planets or their moons. The magnetized plasma flow around these obstacles forms the bow shock in front of the magnetosphere, or, the so-called Alfvén wings for the super-Alfvenic, or sub-Alfvenic regime, respectively.. The various plasma properties and related Mach numbers (e.g., Alfvén Mach numbers, sonic and magnetosonic Mach numbers) were shown for various cases of bodies in the Solar System. The difference in formation of Alfven wings in the magnetospheres of Jupiter for the magnetized (Ganimed) and unmagnetized moons (Io, Europa, Callisto) in the subsonic and sub-Alfvénic flow of the Jovian plasma was discussed. In spite of Ganymede has the strong own magnetic field, it builds up a so called Alfvén wing type magnetopause and no bow shock. Is there a connection to exoplanets? Analytical solutions and MHD model simulation results were shown. The analogy between Ganymede and Jupiter could be drawn for certain close-in exoplanets.
After the detailed explanation and review of Solar System obstacles and their formation processes the analogies to exoplanets and the stellar wind plasma interaction was addressed. In the case of hot Jupiters they may be in a sub-Alfvénic regime. Ip et al. (2004) considered the electrodynamical interaction of close-in exoplanets with their host stars in the sub-Alfvénic regime. Several scenarios related to orbital distances and stellar wind plasma properties were discussed. Finally, WASP-12b which was discussed during the days before was again addressed related to the bow shock or obstacle question. It was concluded that in the case of this planet, which moves relatively fast within the stellar plasma flow, one cannot exclude at present that a bow shock may also develop.

3. Lammer, IWF/ÖAW, pointed out that the observational methods and studies which were discussed during the meeting will also be important for the future characterization of smaller exoplanets within the Earth- and super-Earth-mass domain. He presented recent and ongoing studies (Lammer et al. 2012; Orig. Life Evol. Bio. 41:503–522; DOI 10.1007/s11084-012-9264-7), related to the origin of hydrogen-rich nebular-based protoatmospheres around terrestrial planets. Besides nebular-based hydrogen envelopes it was shown that dense steam (H_2O) atmospheres, with surface pressures from ~100 to 10^4 bars, equivalent to an amount of hydrogen contained in

~0.4–40 Earth oceans, can be produced during the magma ocean solidification process. If the atmospheric escape processes or giant impacts cannot remove these initial hydrogen and water inventories, a terrestrial planet will accumulate a dense abiotic oxygen-rich atmosphere, or otherwise it will become a sub-Uranus type body, even within the habitable zone of its host star. On the other hand, if a terrestrial planet's atmosphere evolved during the high EUV phase of its young host star to a nitrogen-rich, Earth-like atmosphere too early, then all of its nitrogen inventory might have been lost. This indicates that the nitrogen-inventory of the Earth might have been protected from escape by a higher amount of IR-cooling CO_2 in the thermosphere, or by a dense hydrogen or oxygen envelope.

If the initially outgassed water inventory of an early Earth were much larger than ~500 bar, and the Moon-forming impact did not remove a part of it, the Earth might have accumulated an abiotic oxygen-rich atmosphere or evolved to a "water world" with no continents and an H_2O and CO_2 atmosphere surrounded by an atomic hydrogen envelope. If the Earth originated dryer, the young Sun might have been active enough to remove the less dense initial atmosphere and the planet might have ended up with a present-day Venus or Mars-like CO_2 atmosphere.

Hence it follows that the Earth-like planets within HZs of less active F-stars might have a greater problem to lose their protoatmospheres, while the planets orbiting more active, lower mass stars (K- and M-type) might have lost their atmospheres more easily during their lifetimes. More massive "super-Earths" which outgassed, most likely very dense steam and CO_2-rich atmospheres, may also be good candidates for accumulating during their life-times abiotic oxygen-rich upper atmospheres.

Comment from Koskinen on the dissociation of hydrogen:

The dissociation mechanisms of the basic molecules (H_2, water, etc.) are now quite well understood. Therefore it should not be too difficult to check how high the solar flux has to be at Earth distance to dissociate the basic molecules in the thermosphere or below. If one takes 100 times the present solar EUV flux, for instance, that corresponds to moving the Earth to 0.1 AU. Then one is inside the H_2 dissociation limit. At 25 time present Sun one is at 0.2 AU and outside my H_2 dissociation limit (at this point one could expect mass loss rates in the Jeans or diffusion limited regime that are typically much lower than blow off. Of course these may be rough estimates, one have to be careful because the modeled results were obtained for gas giants.

All participants agreed that one would need more exoplanet transits around bright (nearby) host stars. Bright stars are important for any follow up observation technique which allows a good characterization of atmospheric species and/or plasma properties around exoplanets.

Individual articles were discussed also and some may come out (e.g. WASP-12b, hot atoms on HD 209458b and ENA modeling by using the reanalyzed Lyman-alpha absorption spectra by Ben-Jaffel (2007; 2008)).

The next activity is related to observations. Luca Fossati will prepare a summary on the planned future HST UV observations to find early ingresses on observation candidates. This will be distributed to all team members and a smaller observational/proposal type meeting could be arranged via Europlanet NA1/NA2 activities before the next ISSI Team meeting.

Because H. Lammer was conducted some time ago by Springer, who showed an interest for a book related to "Observations and Characterizations of Stellar and Exoplanet Environments" all participants also agreed with the idea to prepare a book with various chapters for Springer. The book will be edited by H. Lammer & M. L. Khodachenko.

A possible outline for the planned book was prepared during the meeting.

All agreed also that a special ISSI Team Web-site should be prepared with a short description of the teams research topic, publications, meeting updates, etc. and a restricted location where the presentations of the meetings and internal information's will be posted.