# Stellar activity of young stars as key for understanding the diversity of exoplanets: The case of Upper Scorpius OB association

*Guenther, E.W., Greimel, R., Lammer, H., Leitzinger, M., Odert, P., Kislyakova, K.G.*

In our solar-system there are basically two species of planets: gas, or ice giants which have masses larger than 15 $M_{Earth}$ and densities between 0.7 to 1.6 g $cm^{-3}$, and rocky planets with densities between 3.7 to 5.5 g $cm^{-3}$, which have Earth mass or less. It was thus expected that extrasolar planets would have similar properties, but observations with the Kepler and CoRoT satellites have shown that extrasolar planets are much more diverse. This large diversity is particularly striking for low-mass planets, e.g. planets in the mass-range between 1 and 15 $M_{Earth}$. In this mass range, planets can have densities as low as 0.1 g $cm^{-3}$ (e.g. Kepler 51b, c, d), or higher than 10 g $cm^{-3}$ (e.g. Kepler-68c, Kepler-99b, Kepler-100b). What is most surprising is that planets of the same mass can have very different densities. The only reasonable explanation is that high-density planets are basically rocky, whereas the low-density ones must have a massive gaseous atmosphere that presumably consists of $H_2$ and He. This means the high-density planets either never had such an atmosphere, or lost when they were young. Low-density planets apparently formed with such an atmosphere but could never get rid of it (Erkaev et al. 2013, AsBio 13, 1011; Kislyakova et al. 2013, AsBio 13, 1030; Kislyakova et al. 2014, A&A 562, A116; Lammer et al. 2014, MNRAS 439, 3225). The processes how planets can lose such an atmosphere is of crucial importance for understanding the evolution of planets. **Understanding these processes is essential in order to assess which planets are potentially habitable and which are not.** It is now generally thought that stellar activity plays an essential role in the process of removing planetary atmospheres. A number of possible processes have already been identified, in which these primordial atmospheres are eroded by the XUV-radiation (X-ray + EUV) of the host star, by heating the atmospheres of the planets through flares, and coronal-mass ejections (CMEs). Studies of the Earth's atmosphere shows that the upper atmosphere is in fact significantly heated during flare events and by CMEs, leading to increased mass loss. However, these studies also show that an old, solar-like star is totally inadequate in order to remove a massive, primordial atmosphere (unless the planet has a very low mass, and is very close to the star). Thus, everything points into the direction that the primordial $H_2$/He atmospheres were removed at the early stages of the evolution of the star (Lammer et al., MNRAS 439, 3225). Even the Earth is believed to have had such a $H_2$/He atmosphere that was removed during the early stages of its evolution. To understand these processes, we have to study the XUV-radiation of stars during the formation period of terrestrial planets that is, during the first tens of Myrs. This is possible, because the XUV-radiation of low-mass stars is closely related to the photospheric activity, because the emission from the Chromosphere and Corona is ruled by the photospheric activity.

However, studies of the activity of young stars are usually difficult, because the level of stellar activity depends crucially on the age and the mass of the star, and photometric time-series of sufficient duration and precision are not available. At young ages, stars of the same age and mass can have quite different activity-levels, which means that statistically significant sample of stars has to be studied. The K2-observations of the upper Sco region thus are ideally suited for such a study: 1.). Kepler will obtain an uninterrupted time-series with the superb photometric accuracy of 400 ppm for a 12 mag star in 30 minutes. 2.) Stars in this region all have the same young age of 17 Myr (Pecaut et al. 2012, AJ 143, 72). 3.) The region is at a distance of only 160 pc. 4.) Stars in this region are typically 2-3 orders of magnitude brighter in X-rays than main sequence stars of the same spectral type. 5.) We have identified 7 G-stars, 15 K-stars, and 102 M-stars in this Kepler field (e.g. Preibisch, Guenther, Zinnecker 2001, AJ 121, 1040). This allows us to study a statistically significant sample of stars in each spectral type, and we have taken medium resolution spectra of all of them. Using the Kepler K2-data we will allow us to study the flare-activity, determine the spot-coverage and the rotation periods of the stars. These data will allow us to study the activity of these stars in far more detail than it was possible before. The quality of the K2-data will be comparable to the CoRoT-data, which we have already used to study flares and spots of young stars. For example, by measuring the frequency of flares, we will be able to find out if flares are relevant for the removal of the primordial $H_2$/He atmospheres. Given that CMEs are related to flares, we can also obtain a much better estimate of the effects of CMEs on the atmospheres of the planets. Combining the rotation periods, the spot coverage, and the X-ray brightness will allow us to obtain an estimate of the XUV-radiation, which in turn will allow us to find out how the XUV-radiation effects planetary atmospheres. **The proposed study will be the first comprehensive, and statistically significant study of the activity of a cluster of young, low-mass stars at an age when terrestrial planets are forming.**