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Spots and white light flares in an L dwarf

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Abstract. We present a summary of Kepler and supporting observations of a nearby L1 dwarf. We find periodic (8.9 hour) variations with an amplitude of 1.5%. The surface features have remained consistent for 15 months. Magnetic starspots are a plausible explanation, but a cloud-related feature is also possible. We also detect white light flares as powerful as the strongest solar flares, despite the low temperature of the photosphere.

Key words. Stars: atmospheres

1. Introduction

The Kepler Mission (Koch et al. 2010) photometrically monitored more than one hundred thousand main sequence stars in the optical for four years in order to detect planetary transits. Bandwidth limitations restricted the regular monitoring to a limited subset of pixels corresponding to desired targets. Unfortunately, at the time of mission launch, no ultracool L or T dwarfs were known in the field of view. In 2011, Gizis et al. (2011) discovered a nearby L1 dwarf, WISEP J190648.47+401106.8 (hereafter W1906+40). Although considerably fainter than the primary G dwarf targets, it is easily detected in the Full Frame Images. It was added to the target for Quarters 10-13 through Director's Discretionary Time (Program GO30101) and Quarters 14-17 through an Guest Observer proposal (Program GO40004). The resulting dataset comprises the longest and best sampled light curve for an early L dwarf. Here we present an overview of results on W1906+40. A full account and analysis is given in Gizis et al. (2013).

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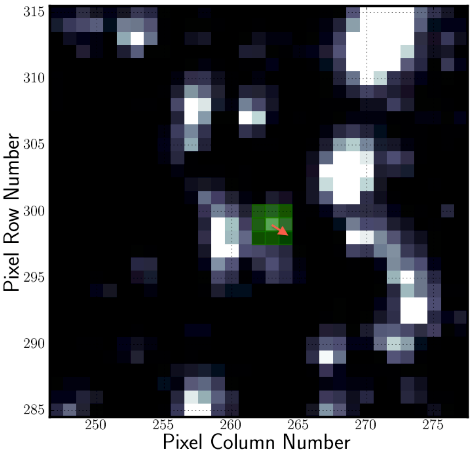

Fig. 1. Kepler image of W1906+40 from the Full Frame Images. Each pixel is four arcseconds on a side. The arrow marks the direction of motion.

W1906+40 is a ordinary L1 dwarf in both the optical and the near-infrared. There is no evidence of lithium absorption, and it is most likely a hydrogen-burning star. It does show evidence of magnetic activity in the form of radio emission and quiescent Hα emission (observed on five different nights with Gemini-North and MMT), which places it in the more active half of L1 dwarfs. Our preliminary trigonometric parallax places it at 16.4 parsecs. It is likely that W1906+40 is single, but there is not yet any high resolution imaging.

2. Photometric period and evidence of spots

The first five quarters (1.25 years) of data are shown in Figure 2. These "long cadence" observations consist of thirty minute exposures. The data are phased to a period of 0.37015 days, which we identify as the rotation period. This is consistent with our measurement of $v \sin i$. The most striking aspect of the plot is that, while some variations are apparent from quarter to quarter, the main variation of $\sim 1.5\%$ remains in phase for the entire period of observations. The uncertainty of each measurement is 0.5%. There is no evidence of aperiodic variations. This is quite different than cooler brown dwarfs, which do not remain in phase, and can change in a single rotation period (Radigan et al. 2012, also see the contribution by Burgasser in this volume). It is also in contrast to ground-based results for other early L dwarfs which suggest surface features evolve on the timescale of hours (Bailer-Jones & Mundt 2001) or are aperiodic (Gelino et al. 2002). To be sure, the W1906+40 periodic variations are too low amplitude to be detected in most ground-based studies of L dwarfs. One plausible explanation is that this is a long-lived magnetic starspot. As the Kepler photometry provides only a single filter, there are no constrains on the color or temperature of the surface feature. Indeed, it may even be brighter than the surrounding photosphere.

3. Evidence of flares

During Quarter 14, we also collected short-cadence data for W1906+40. This provides sampling every minute, but because there are fewer counts, the uncertainty per measurement is 2%. A number of white light flares are detected, with the rapid rise and slow decay typical of stellar flares. A few such candidate flares are also seen in the long cadence data for earlier quarters. Kepler is sensitive to flares because the broad filter allows the blue flare to dominate over the red photosphere (Figure 3). In some cases, the mission pipeline flags these sharp rises as possible cosmic ray strikes. However, we can confirm that these are genuine flares on W1906+40. On 29 July 2012, we were observing W1906+40 with the Gemini-North (Program GN-2012A-Q-37) GMOS spectrograph (Hook et al. 2004) when a series of flares occurred. A spectrum of the most powerful flare in its impulsive phase is shown in Figure 4. The time series is shown in Figure 5. A smaller flare preceded the main flare.

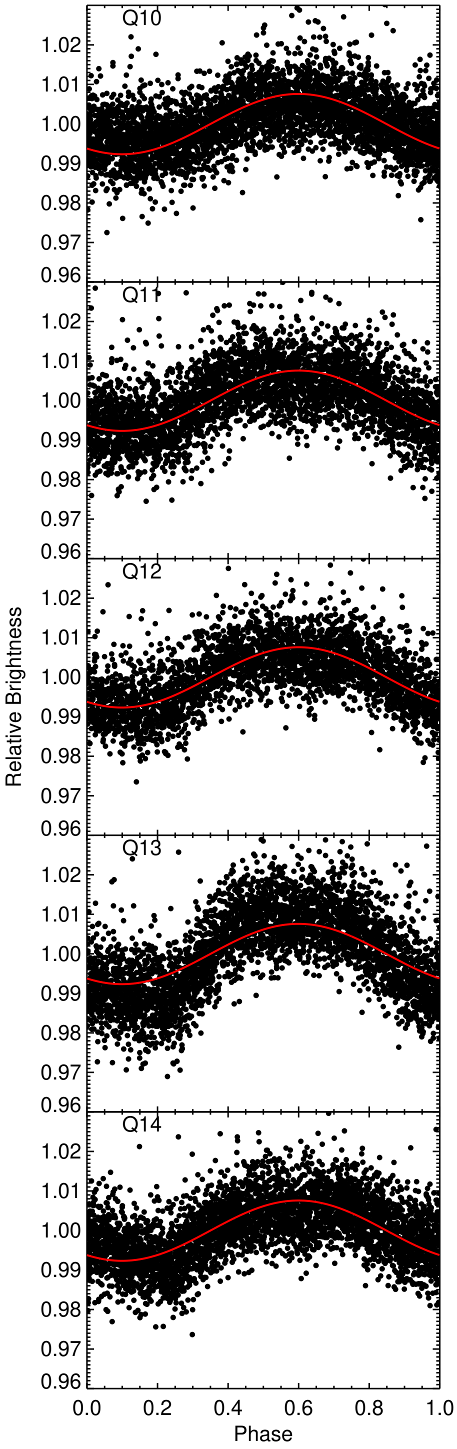

Fig. 2. Kepler photometry for five quarter years. The data is phased to an 8.9 hour period.

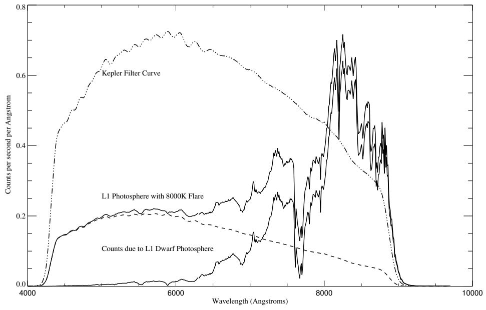

Fig. 3. Expected count rate for an L1 dwarf and a hypothetic 8000K blackbody flare that provides the same number of counts. The spectra are weighted by the Kepler filter response. Counts for the quiescent L dwarf photosphere are dominated by the red, but the wide filter is sensitive to flares.

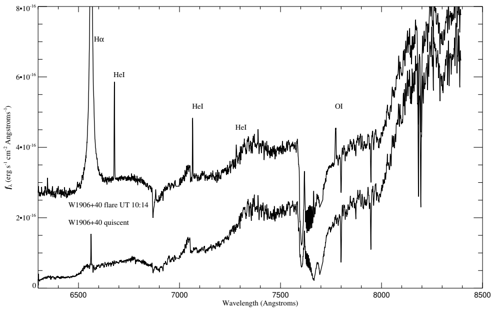

Fig. 4. Gemini-North GMOS spectra of W1906+40 in quiescence (below) and in flare. Note the broad Hα, atomic emission lines, and white light continuum during the flare.

The flare observations demonstrate that the flare is similar to those seen in hotter stars. The white light suggests that the photosphere is heated to $\sim$ 8000K, presumably by high energy particles accelerated after a magnetic reconnection event. A large volume of chromosphere is also heated, which cools more slowly than the photosphere.

4. Conclusions

Kepler monitoring of W1906+40 has revealed white light flares in an L dwarf for the first time. These flares are much less frequent than

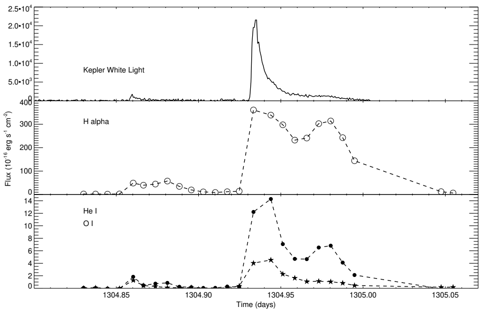

Fig. 5. Kepler photometry (top panel) and spectroscopic line strengths for the 29 July 2012 flares.

in M dwarfs with comparable rotation periods, but the frequency is comparable to the solar rate. There are also long-lived surface feature(s) which are likely due to magnetic starspot. The features seen in cooler brown dwarfs, associated with clouds, have much shorter lifetimes. The rotation period and $v \sin i$ are consistent with the expected radius.

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