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Warm dust in systems with transiting planets

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Abstract

Debris disks are known to exist around many planet-host stars, but no debris dust has been discovered so far in systems with planets detected by the transit method. We have found six systems, each with one transiting "hot Jupiter", that possess significant excess emission in the mid-infrared. These are CoRoT-14, XO-5, HAT-P-5, TrES-2, CoRoT-10, and CoRoT-8. Modeling suggests that the observed excesses stem from dust rings with radii between about 0.1 AU and 25 AU and dust masses in the range from about $\sim 10^{-7}$ to $\sim 10^{-3}$ Earth masses. In some systems dust may be produced by collisional cascade in asteroid belt analogs, while in some others a transient nature of dust appears more likely. The presence of debris dust may put important constraints onto scenarios of formation and migration of hot Jupiters.

1. Introduction

Many debris disks have been found in systems with known radial velocity (RV) planets [1, 7, 2], and a few systems with debris disks and directly imaged planetary candidates are known [3, 5, 4]. However, debris dust has not been found yet in systems with planets detected by transits.

In this paper, we search for debris dust in systems with transiting planets, using publicly available catalogs of transiting planets and several infrared (IR) surveys. Our motivation is to extend the list of known “full” planetary systems that harbor both planets and asteroid or Kuiper belt analogs. Furthermore, it is the transit technique that allows determination of many planetary parameters, such as masses, radii and densities, and is able to provide insights into properties of planetary atmospheres and interiors. Therefore, systems with transiting planets are of special interest.

2. Search for dust

A list of currently known systems with transiting planets was taken from `exoplanets.org` [8] on May 11, 2011. This list was compared with the Wide-Field Infrared Survey Explorer (WISE) Preliminary Source Catalog, which we accessed through IRSA, the NASA/IPAC Infrared Science Archive at `http://irsa.ipac.caltech.edu`. We found that, of 93 systems with transiting planets listed in `exoplanets.org`, 54 have been observed with WISE. Four systems (XO-5, HAT-P-5, TrES-2, and CoRoT-8) have a significant 22 µm excess. The first three of them also show a 12 µm excess at a more than 2σ level, albeit a small one. Finally, there are two systems, CoRoT-14 and CoRoT-10, where a large 12 µm but not a 22 µm excess is present.

3. Parameters and origin of dust

The six stars listed above are in the spectral type range between F9 V and K1 V, 230–1300 pc away, with V-magnitudes from 11.4^m to 16.0^m. Each has only one known transiting planet with an inferred semimajor axis between $0.03...0.11$ AU and a mass between 0.2 and 7.6 Jupiter masses. For these stars, we have collected optical and near-IR photometry from several catalogues and found a best-fit photospheric model by a minimum χ^2 fitting of the stellar photospheric fluxes by NextGen models, only to 2MASS and WISE points at wavelengths between 1 µm and 5 µm where no excess emission is expected (Fig. 1).

The excesses at 12 µm and/or 22 µm were fitted with a modified blackbody (BB) emission model (Fig. 1). This modeling suggests that the observed excesses stem from dust with a mass of $\sim 10^{-7}$ to $\sim 10^{-3}$ Earth masses and a fractional luminosity in the range from 3×10^{-4} to 7×10^{-3}. The estimated radii of the dust rings vary strongly from one system to another. The system with a 22 µm excess only (CoRoT-8) shows a belt with a radius of ~ 25 AU. The rings of stars with excesses both at 12 µm and 22 µm (XO-5,

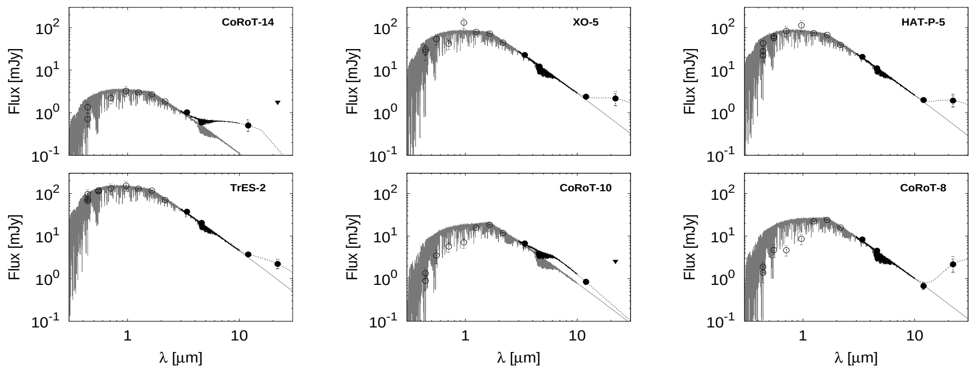

Figure 1: SEDs of six selected stars. Gray solid line: predicted photosphere. Open circles: visual and near-IR photometry data, filled circles: WISE data, bottom-up triangles: WISE upper limits. A low position of data points in the visual with respect to the predicted photosphere, seen for the most distant CoRoT stars, is due to interstellar extinction. Black dashed line: modified BB model.

HAT-P-5, TrES-2) are comparable in size with the asteroid belt. Finally, the belts in systems with a 12 µm excess only (CoRoT-14 and CoRoT-10) have radii of a fraction of an AU. In the case of CoRoT-10, the belt probably lies just outside the zone where it would be disrupted by the planet ($a_{pl} = 0.105$ AU, $e_{pl} = 0.53$).

4. Conclusions and Discussion

In this paper, we have found six systems with both transiting planets and debris disks. Each of the systems hosts one known close-in planet and a dust belt outside its orbit. Systems with excesses at 12 µm but not at 22 µm are very compact and so may only harbor additional planets outside the belts. In other systems, more planets could orbit both inside and outside the belts. Additional planets, if close enough to the star, could be revealed by in-depth RV analyses, transits, or transit time variations of already known planets.

The origin of the observed dust and its production mechanisms are unclear. The systems with 12 and 22 µm (or only 22 µm) excesses may be massive "asteroid belts", replenishing dust by a steady-state collisional cascade. However, in two systems with 12 µm-only excesses (CoRoT-14 and CoRoT-10), amounts of dust are too large for a steady-state collisional evolution of a population of asteroids with moderate eccentricities. One faces a similar difficulty in explaining other systems with hot excesses that have been known before, such as HD 69830 [6].

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