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SEARCH FOR DEBRIS DISKS BY AKARI AND IRSF

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ABSTRACT

Debris disks are important observational clues to understanding on-going planetary system formation. They are usually identified by significant mid-infrared excess on top of the photospheric emission of a central star on the basis of prediction from *J*-, *H*-, and *Ks*-band fluxes and the stellar model spectra. For bright stars, 2MASS near-infrared fluxes suffer large uncertainties due to the near-infrared camera saturation. Therefore we have performed follow-up observations with the IRSF 1.4 m near-infrared telescope located in South Africa to obtain accurate *J*-, *H*-, and *Ks*-band fluxes of the central stars. Among 754 main-sequence stars which are detected in the AKARI 18 μm band, we have performed photometry for 325 stars with IRSF. As a result, we have successfully improved the flux accuracy of the central stars from 9.2 % to 0.5 % on average. Using this dataset, we have detected 18 μm excess emission from 57 stars in our samples with a 3σ level. We find that some of them have high ratios of the excess to the photospheric emission even around very old stars, which cannot be explained by the current planet-formation theories.

Key words: infrared: stars; circumstellar matter; planetary systems: formation

1. INTRODUCTION

Debris disks are dust disks around main-sequence stars with ages of 10^7–10^9 years. According to the previous works, about 10–30 % of main-sequence stars possess debris disks (e.g. Chen et al., 2005; Bryden et al., 2009; Fujiwara et al., 2013). The dust in these disks should be supplied by planetesimal collisions because the dust of proto-planetary system origins has been dissipated at their evolutionary stages. Therefore debris disks are important observational clues to understanding on-going planetary system formation. We search for debris disks to reveal the planetary system formation process.

2. OBSERVATION AND DATA ANALYSIS

In this work, debris disks are identified by mid-infrared excess on top of the photospheric emission of main-sequence stars. We prepare samples, estimate their photospheric emission, and judge whether or not there is mid-infrared excess.

2.1. Sample

We prepare 1735 main-sequence candidates which are selected from the Tycho-2 spectral catalogue (Wright et al., 2003) or Hertzsprung-Russel diagram based on the Hipparcos catalogue (Perryman et al., 1997). We investigate their AKARI 18 μm fluxes in the AKARI mid-infrared point source catalogue. Then we remove

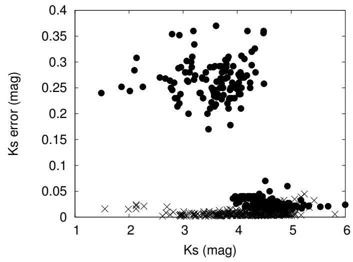

Figure 1. *Ks*-band photometric error versus magnitude for our samples. Circles and crosses indicate the 2MASS photometric data and IRSF photometric data, respectively.

double stars, stars in a cluster, and suspected YSOs or AGBs out of them based on the SIMBAD classification. Finally, we obtain 754 main-sequence samples with the 18 μm measurement.

2.2. Follow-up observations

In order to estimate photospheric emission accurately, we have performed follow-up near-infrared observations of bright samples using the IRSF telescope, because the 2MASS near-infrared photometry suffers large uncertainties due to the saturation. The IRSF telescope is located in South Africa and managed by Nagoya University. The observations are performed in August 2011, February 2012 and June 2013. We have observed 325 objects and improved their flux accuracies from 9.2 % to 0.5 % in the *Ks*-band (Figure 1).

2.3. Detection of debris disks

We estimate the 18 μm flux of the central stars on the basis of prediction from their *B*-, *V*-, *J*-, *H*-, and *Ks*-band fluxes with Kurucz model spectra. For *J*-, *H*-, and *Ks*-band fluxes, the 2MASS data are used for 429 objects (sample A) while the IRSF data are applied to the other 325 objects (sample B). Then we judge the excess emission at 18 μm as

$$\frac{F_{\rm disk}}{F_*} = \frac{F_{{\rm obs},18\mu{\rm m}} - F_{*,18\mu{\rm m}}}{F_{*,18\mu{\rm m}}} > 3\sigma, \qquad (1)$$

where $F_{{\rm obs},18\mu{\rm m}}$ is the observed flux, $F_{*,18\mu{\rm m}}$ is the predicted flux of photosphere, and σ is the flux errors of our samples which is estimated by the Gaussian fitting to the distribution of $F_{\rm disk}/F_*$.

3. RESULTS

As a result, we have identified 57 debris disk candidates out of 754 main-sequence star samples. Figure 2 shows SEDs of two examples from our debris disk candidates. HD 65372 and HD 99022 are newly confirmed as debris

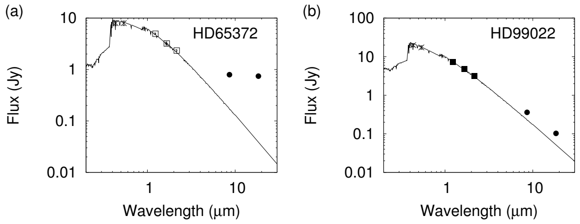

Figure 2. SEDs of two examples from our debris disk candidates. The crosses, open squares, filled squares, and filled circles indicate photometry with Hipparcos, 2MASS, IRSF, and AKARI, respectively. The curves indicate the spectra of the photosphere predicted by the Kurucz model.

Table 1
The number of debris disk candidates.

Sample	Debris disks / Total	σ
Sample A	34 / 429	0.18
Sample B	23 / 325	0.13
Total	57 / 754	

disks, although they have been reported as mid-infrared excess candidates (McDonald et al., 2012). Table 1 summarizes the number of sample stars, the number of debris disks, and σ for samples A and B. For sample B, by using IRSF photometry instead of 2MASS photometry, σ is improved from 0.20 to 0.13 and the detection rate of debris disks is improved.

4. DISCUSSION

We discuss the evolution of debris disks using our samples. The evolution of debris disks can be explained as $F_{\rm disk}/F_* = t_0/t$ based on the conventional collisional cascade model (e.g. Wyatt et al., 2007; Kobayashi & Tanaka, 2010), where $F_{\rm disk}$, F_*, t, and t_0 indicate the flux of a disk, the flux of a central star, the stellar age, and the mass depletion time due to collisional cascade, respectively. Figure 3 shows the ratio of the excess to the photospheric emission as a function of the stellar age for F- and G-type stars. Some of our debris disk candidates show too high excess ratios to be explained by the model. Thus these objects require other scenarios like a giant impact, comet activities, or resonance traps.

5. SUMMARY

Debris disks are dust disks around main-sequence stars. They are believed to be observational clues to understanding on-going planetary system formation. Using AKARI, IRSF and 2MASS photometry, we have found 57 debris disk candidates with 18 μm excess emission on top of the photospheric emission. Some of them show

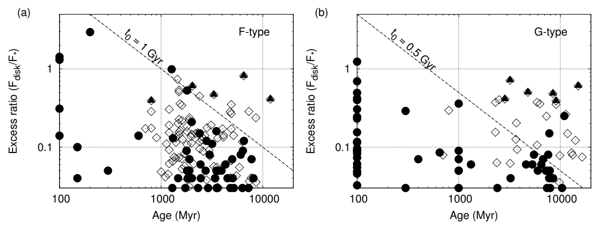

Figure 3. Excess ratio versus stellar age for (a) F-type and (b) G-type stars. Filled circles, filled triangles, and open diamonds indicate samples from previous works, our debris disk candidates, and all our samples, respectively. Dashed line indicates the evolutionary track predicted by the collisional cascade model.

high excess ratios for their ages, which cannot be explained by the standard model. Our result requires scenarios other than the collisional cascade.

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