Origins: From the Protosun to the First Steps of Life
Proceedings IAU Symposium No. 345, 2018
B. G. Elmegreen, L. Viktor Tóth & M. Güdel, eds.

doi:10.1017/S1743921318008359

An Unbiased SPHERE-IFS Survey of Nearby Herbig Ae/Be Stars: Are All Group I Disks Transitional?

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Abstract. Using a novel method for speckle noise suppression from SPHERE-IFS data, we performed a systematic survey for disks in 22 Herbig Ae/Be stars, spatially resolving five disks and detecting seven new companion candidates. The fraction of sources with spatially resolved disks is systematically higher in the Meeus *et al.* (2001) group I sources, showing that disks are indeed more easily seen in scattered light in this sub-class of Herbig stars, consistent with the interpretation of group I sources having large gaps in their disks.

Keywords. Techniques: high angular resolution, protoplanetary disks, stars: pre-main-sequence

1. Introduction

One of the main goals of current planet-formation studies is to find planets still embedded in a proto-planetary disk, in order to catch the planet formation process as it happens (e.g. Testi *et al.* 2014). These young planets are expected to imprint signatures of their formation, such as cavities, gaps or asymmetries, which can be observable in the scattered light.

Maaskant *et al.* (2013) have suggested that the large near-infrared excesses observed in the Spectral Energy Distributions (SEDs) of Meeus *et al.* (2001) group I Herbig Ae/Be stars can be explained by inferring the presence of a large gap in their disk. In contrast to this, the disks surrounding Meeus *et al.* (2001) group II sources, which exhibit a more continuous SED, would not have such large gaps according to this hypothesis.

A strong prediction of this scenario is that the outer edge of the dust gap should be visible in scattered light for the group I sources, but not for the group IIs. We here analyze coronagraphic near-infrared (0.95–1.65 μm) Integral Field Spectrograph (IFS) data for an unbiased sample of 22 Herbig stars obtained with SPHERE, the extreme adaptive optics system at the VLT (Beuzit *et al.* 2008), in order to test this prediction.

2. A novel method for speckle noise suppression in IFS data

We have obtained SPHERE coronagraphic near-infrared integral-field spectrograph (IFS) data for 22 nearby Herbig Ae/Be stars. One of the main issues in detecting faint disks next to bright stars in adaptive optics images is residual speckle noise due to static wavefront aberrations within the adaptive optics system. Traditional methods to correct

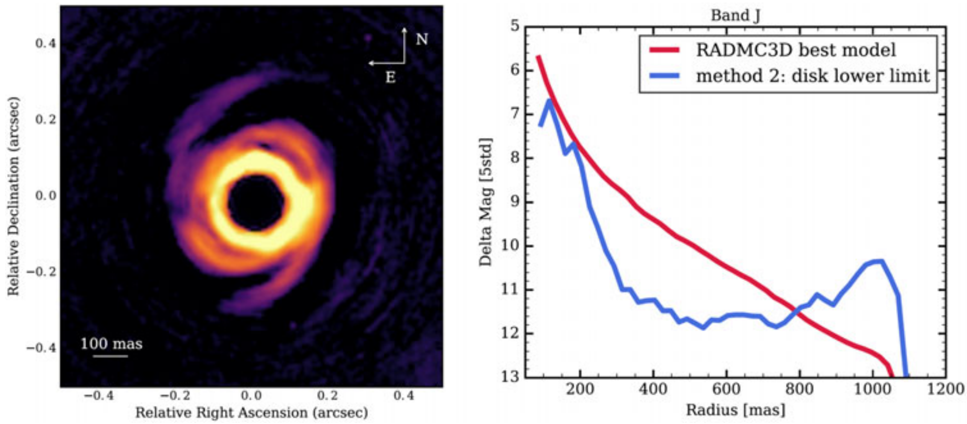

Figure 1. Speckle-corrected SPHERE-IFS image of HD 100453 in the J-band (left) and J-band contrast curve compared to a RADMC3D model for HD 100453 (right). The central dark spot in the image is due to the obscuration of the central star by the coronagraph.

for speckle noise, such as angular differential imaging (ADI), filter out radially symmetric extended structures, such as disks.

Therefore we employ a novel method for correcting for speckle noise in our IFS data, based on the following ingredients: (1) the position of a speckle is moving in a known way with wavelength, (2) the position of a real source or a disk component is stable at different wavelengths, and (3) as speckles are caused by uncorrected light from the central star, the spectral slope of speckle noise is known. Using the above ingredients, a map of speckle noise can be created for each of the 39 wavelengths, and subtracted from the data to create a corrected image in which the signal of the circumstellar disk is revealed (Fig. 1).

3. Conclusions

Using the method outline above, we have detected five spatially extended disks, and seven new companion candidates within our sample of 22 Herbig stars. The fraction of sources with detected disks in 0.6 ± 0.3 in the group I sources and 0.1 ± 0.1 in the Group II sample, showing that disks are indeed more easily spatially resolved in scattered light in Meeus *et al.* Group I sources, as predicted by the Maaskant *et al.* scenario. We will further test the models of Maaskant *et al.* (2013) using RADMC3D (Dullemond 2012) to perform a more quantitative test between the observed and predicted surface brightness of the disk in the Y, J, and H-bands as a function of radius (Fig. 1). In addition, we are currently performing follow-up observations on the detected companion candidates to confirm that they are physically connected to the Herbig star.

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