The HD 206893 planetary system seen with VLT/SPHERE

Upper limit on the dust albedo and constraints on additional companions

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ABSTRACT

Context. The detection and characterization of planets and debris disks is a very active field in current research. The F5V star HD 206893 hosts a ~25 MJup brown dwarf detected at ~10 au in VLT/SPHERE high-contrast images. This system is also known to host a debris disk, which is inferred from its high infrared excess. This disk was recently resolved in thermal submillimeter imaging with ALMA and extends from 30 to 180 au, with a ~27 au wide gap at ~74 au.

Aims. Our goal is to search for the scattered light emission of the disk using the largest amount of SPHERE imaging data available to date. We also want to bring tighter constraints on the presence of additional low-mass companions based on the available multi-epoch high-contrast imaging data.

Methods. We analyzed six epochs of SPHERE near-infrared data, processed with angular, polarimetric, and reference differential imaging, in order to detect the disk around HD 206893.

Results. We do not detect the debris disk. Based on recent constraints on the disk morphology from ALMA data, this non-detection is compatible with a maximum albedo of 0.55 in the H band and 0.96 in the K band. Furthermore, we do not detect additional low-mass companions in the system. A low-mass companion is expected from radial velocity and astrometric measurements between 1.4 and 2.6 au, and we estimate our probability of detection higher than 90% for brown dwarfs more massive than 55 MJup in this separation range. At 74 au, where a gap is detected in the disk in thermal imaging, this probability of detection corresponds to planets above 2.5 MJup.

Conclusions. The non-detection of the disk through the methods used in this study should not exclude an attempt with other techniques, such as advanced reference-star differential imaging using machine-learning-based libraries or star hopping. Furthermore, the future JWST instrument NIRCam might offer the possibility of detecting the disk in scattered light thanks to its increased sensitivity.

Key words. planet-disk interactions – instrumentation: high angular resolution – techniques: image processing – planetary systems

1. Introduction

Debris disks around stars have generally been detected by their excess emission at infrared wavelengths (Hughes et al. 2018). Resolving those debris disks in scattered light through high-contrast imaging is challenging because they are usually faint and close to their parent star. In addition, it is particularly difficult to disentangle this faint and extended signal from the bright starlight residuals for disks that show circular symmetry (e.g., seen pole-on or with a small inclination with respect to the line of sight). Nevertheless, since the first images in the 1990s, dozens of such disks have been resolved, both from space and from the ground (e.g., Esposito et al. 2020; Hughes et al. 2018; Schneider et al. 2016).

A circumstellar debris disk was inferred around HD 206893 through its large infrared excess ($L_{\text{dust}}/L_\star \approx 2.3 \times 10^{-4}$, Moór et al. 2006). It was characterized using its spectral energy distribution (SED) with the Infrared Spectrograph (IRS) and the Multiband Imaging Photometer for Spitzer (MIPS) on board the Spitzer Space Telescope (Chen et al. 2014) and marginally resolved by the Photodetector Array Camera and Spectrometer (PACS) on the Herschel Space Observatory (Milli et al. 2017). A tentative detection in scattered light using the VLT/Spectro-Polarimetric High-contrast Exoplanet REsearch instrument (SPHERE) was reported by Milli et al. (2017). HD 206893 is an F5V, 250$^{+500}_{-225}$ Myr old star (Delorme et al. 2017) located at 40.81 ± 0.11 pc (Gaia Collaboration 2018). It has an apparent V magnitude of 6.67 (Høg et al. 2000), a mass of 1.32 ± 0.02 MJup, and an effective temperature of 6500.0 ± 100 K (Delorme et al. 2017). Recently, Marino et al. (2020) and Nederlander et al. (2021) resolved the disk using ALMA data taken in band 7 at a wavelength of 0.8 mm and archival data from band 6 at a wavelength of 1.3 mm.

Furthermore, the star is known to host a low-mass companion (Milli et al. 2017). HD 206893 B, that is orbiting at a projected separation of ~10 au. Delorme et al. (2017) found a period of ~27 yr and a mass between 12 and 50 MJup, for an age in the range 50–700 Myr. As the age of the system is poorly known, the
The ALMA images reveal a 27\,au wide gap in the disk responsible for the proper motion anomaly that this system has. Between 1.4 and 2.6\,au and a mass of approximately 15\,MJup of the companion, HD 206893 C, with an orbital semimajor axis of 36.5 \pm 16\,au. By combining and analyzing data from six epochs obtained with SPHERE, the largest amount of data available to date, this study aims at complementing the information obtained by Milli et al. (2017). It intends to verify if the scattered light emission of the debris disk is detected through high-contrast imaging by ruling out some instrumental effects that could lead to a false detection, such as the low-wind effect (LWE; Milli et al. 2018) or the wind-driven halo (Cantalloube et al. 2018, 2020). Based on the results from Marino et al. (2020), we also discuss the surface brightness and dust albedo of the disk.

Grandjean et al. (2019) report variations in the radial velocity (RV) of the star, attributing these variations to an additional companion, HD 206893 C, with an orbital semimajor axis between 1.4 and 2.6\,au and a mass of approximately 15\,MJup. This is consistent with the subsequent results by Marino et al. (2020), who found that the inner companion could also be responsible for the proper motion anomaly that this system has. The ALMA images reveal a 27 \pm 5\,au wide gap in the disk at 74 \pm 3\,au, which would be compliant with yet another companion, a planet of 0.9^{+0.5}_{-0.3}\,MJup at a separation of \sim 1.81^\circ. Combining all but the polarimetric data, we estimate constraints on the presence of other companions in the system in addition to HD 206893 B.

The SPHERE observations and data we use are presented in Sect. 2. Section 3 presents the contrast results in order to determine if there is a signal consistent with the disk. In Sect. 4, we present a discussion on the albedo of the dust. In Sect. 5, we show the probability of planet detection around HD 206893 using this combined data set, and in Sect. 6 we conclude and summarize our results.

2. Observations
The six epochs were obtained with the SPHERE high-contrast instrument (Beuzit et al. 2019) between October 2015 and August 2018, using the InfraRed Dual-band Imager and Spectrograph (IRDIS; Doblen et al. 2008) in different modes: classical imaging (CI, also referred as broadband imaging), dual-band imaging (DBI; Vigan et al. 2010), and dual-beam polarimetric imaging (DPI; Langlois et al. 2014), as described in Table 1.

2.1. IRDIS broadband and dual-band imaging data
We used archival data obtained in DBI in the K1-K2 filter as part of the SpHere INfrared survey for Exoplanets (SHINE; Desidera et al., in prep.; Langlois et al., in prep.; Vigan et al. 2021). These data were presented in Delorme et al. (2017), for the September 15, 2016, observations, and in Grandjean et al. (2019), for the June 19, 2018, observations. We also used archival data obtained in the broadband K filter as part of the SPHERE High Angular Resolution Debris Disk Survey (SHARDDS; Wahhaj et al. 2016; Choquet et al. 2018). These data were presented in Milli et al. 2017, for the October 3, 2015, observations, and in Grandjean et al. 2019, for the July 13, 2017, observations. They were reduced using classical Angular Differential Imaging (cADI; Marois et al. 2006) and principal component analysis (PCA; Soummer et al. 2012) by the SPHERE Data Center, as described in Delorme et al. (2017), and using ANDROMEDA (Cantalloube et al. 2015).

2.2. IRDIS DPI data
The DPI observations are presented in van Holstein et al. (in prep.) and briefly described here. They were obtained in the K band on September 5 and 7, 2018, using the apodized Lyot coronagraph with a mask of 240 mas diameter (Carbillet et al. 2011; Guerri et al. 2011). They used the pupil-tracking mode to enable angular differential imaging (ADI; Marois et al. 2006) and to take advantage of the fact that in this mode the polarimetric efficiency is always high and the diffraction patterns of the secondary mirror support structure are suppressed (van Holstein et al. 2017). Using a detector integration time (DIT) of 32s, a total of 36 half-wave plate (HWP) cycles was obtained, resulting in a total on-source integration time of 77 min for the two epochs. The conditions were excellent, with an average atmospheric seeing and coherence time of approximately 0.6′′ and 12\,ms, respectively.

We reduced these data with IRDIS Data reduction for Accurate Polarietry\(^1\) (IRDAP; van Holstein et al. 2020, 2017), a highly automated pipeline that reduces IRDIS polarimetric data using polarimetric differential imaging (PDI). After conventional preprocessing steps, IRDAP computes Stokes Q and U images using the double difference method. It then corrects the images for instrumental polarization and crosstalk using an experimentally validated Mueller matrix model and computes the final Q and U images. Finally, IRDAP calculates the Q_0 and U_0 images following the definitions presented in de Boer et al. (2020).

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\(^1\) https://irdap.readthedocs.io/
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Fig. 1. PCA-reduced images showing the detection of HD 206893 B (white arrow). North is up, and east is to the left. The intensity scale is adapted for each epoch according to the intensity peak of the companion.

Table 2. Relative astrometry of HD 206893 B.

<table>
<thead>
<tr>
<th>MJD</th>
<th>Night</th>
<th>Separation (mas)</th>
<th>PA (°)</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>57 299.2</td>
<td>2015-10-03</td>
<td>270.4 ± 2.6</td>
<td>70.0 ± 0.6</td>
<td>(a)</td>
</tr>
<tr>
<td>57 647.1</td>
<td>2016-09-15</td>
<td>265.0 ± 2.0</td>
<td>62.3 ± 0.2</td>
<td>(b)</td>
</tr>
<tr>
<td>57 948.4</td>
<td>2017-07-13</td>
<td>260.3 ± 2.0</td>
<td>54.0 ± 0.4</td>
<td>(c)</td>
</tr>
<tr>
<td>58 289.4</td>
<td>2018-06-19</td>
<td>250.2 ± 3.3</td>
<td>45.5 ± 0.02</td>
<td>(c)</td>
</tr>
<tr>
<td>58 367.2</td>
<td>2018-09-05</td>
<td>248.6 ± 4.9</td>
<td>41.8 ± 0.1</td>
<td>(d)</td>
</tr>
<tr>
<td>58 369.2</td>
<td>2018-09-07</td>
<td>252.2 ± 3.7</td>
<td>42.5 ± 0.1</td>
<td>(d)</td>
</tr>
</tbody>
</table>

References. (a)Milli et al. (2017), (b)Delorme et al. (2017), (c)Grandjean et al. (2019), (d)This work.

2.3. Astrometry of HD 206893 B

HD 206893 B is clearly detected in all images. Thanks to the sensitivity of SPHERE, it could be monitored from angular separations of 270 mas down to 248 mas during this period. Figure 1 shows images of the companion on the various dates, employing a PCA reduction to remove the starlight. Table 2 provides its relative position in relation to the star, which includes two new astrometric points with respect to Grandjean et al. (2019), obtained using the polarimetric data set reduced in ADI with the ANDROMEDA algorithm (Cantalloube et al. 2015). As these two new points were taken shortly after the previous ones, they do not contribute significantly to further constraining HD 206893 B’s orbital parameters (see Figs. B.1 and B.2).

3. Searching for the disk in SPHERE data

3.1. Excluding instrumental effects

Milli et al. (2017) reported a very faint and extended emission along the position angle 60° (east of north) in the data taken on October 3, 2015. However, after visually inspecting the data, we noticed the presence of a mild LWE. This effect is described in Sauvage et al. (2016) and Milli et al. (2018), and it generally degrades the resolution and the accuracy of the target centering behind the coronagraph. In our data set, what we see is a second order effect, making the spider diffraction pattern visible intermittently during the observing sequence (for an illustration of this effect, see Fig. 4 of Milli et al. 2018). Even though this was very tenuous, it did affect a significant percentage of the data. To avoid possible false detections, we discarded all the images from all epochs where the LWE was present. This resulted in 24.5% of the data from the first epoch, in 2015, and 14.4% of the 2017 data being excluded from the analysis.

3.2. Searching for dust emission

The data from all epochs were reduced using cADI with a pixel binning of two. The binning allowed us to increase the sensitivity, and cADI preserves more flux from an extended signal than other reduction techniques such as PCA (Milli et al. 2012). We then computed contrast curves associated with each data set. At this stage we did not correct the contrast curves by the throughput of the algorithm.
Assuming the disk position angle of $61°$ and the inclination of $40°$ suggested by Marino et al. (2020), we tried to separate the region of interest by defining a conical mask oriented along the disk position angle and with an opening angle of $68°$. This should allow the putative disk to be included in the masked area. Separately, we applied the same mask perpendicularly to the disk, isolating an area where one would expect mostly noise (see Fig. A.1).

For each of the mask’s orientations, we then computed the azimuthal RMS profile as a function of the separation from the star. When we compared the obtained results, we expected to find greater values in the first case, indicating the presence of a disk.

In Fig. A.2 we provide the azimuthal RMS curves along the two mask orientations for each data set, consisting of the pixel-to-pixel variation along the radial profile from 0 to 6′′. We do not find a significant difference between the results, with the mask positioned along the region of interest showing no signal that is clearly above the noise found in the perpendicular case. We thus conclude that the disk is not detected in scattered light in our SPHERE data sets.

Considering we have different observation periods with different setups (Table 1), we wanted to calculate which data offer the best contrast. For this, we reduced all the data using the same cADI reduction technique. The data obtained in polarimetry have a better sensitivity within one arcsecond than all the other epochs, as shown in Fig. 2.

We then compared two different reduction techniques for the same polarimetric data: PDI, explained in Sect. 2, versus a cADI, where all channels are simply co-added to use the sky-rotation for speckle subtraction. We found the image reduced in ADI to be more sensitive than in PDI beyond 1.3′′, as shown in Fig. 3. An important caveat here is that the noise profile in ADI is not corrected for the self-subtraction inherent to ADI (Milli et al. 2012). A throughput of ~40% was measured with the cADI algorithm at a separation of 3′′ by injecting and retrieving a synthetic disk. We found the image reduced in ADI to be more sensitive than in PDI beyond 1.3′′, as shown in Fig. 3. An important caveat here is that the noise profile in ADI is not corrected for the self-subtraction inherent to ADI (Milli et al. 2012).

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Given this image library, we were able to build a reference cube with this matrix. As a result, we obtained 775 coronographic images of the 24 stars most correlated with those of HD 206893, without including the object of study in the result, to then subtract the halo of the star without generating a self-subtraction as it occurs in cADI. In addition to the above, a synthetic disk was injected into the BB_H 2017 data set, with a maximum surface brightness of 96.0 mJy arcsec$^{-2}$. This disk can be detected with an ADI reduction (Fig. 4), but it is not detected in reference differential imaging (RDI), hence, RDI is not sensitive enough for such an extended disk. This conclusion is similar to that obtained for point sources by Xuan et al. (2018), who found that ADI processing is more sensitive than RDI processing beyond 0.25 arcseconds.

4. Constraints on the dust albedo

As our study could not confirm the scattered light emission of the disk reported by Milli et al. (2017), we calculated an upper limit on the single-scattering albedo $\omega$ using Eq. (2) of Marshall et al. (2018). It assumes a dust absorption opacity...
constant at optical-to-near-infrared wavelengths and that the scattering is isotropic:

$$\omega = \left( \frac{f \times F}{2\pi \cdot \phi \cdot d\phi \cdot S \cdot \cos(i)} + 1 \right)^{-1},$$

where $S$ is the surface brightness of the disk in $\mu$Jy arcsec$^{-2}$, $F$ is the total star flux in $\mu$Jy, $\phi$ is the separation of the scatterers, $d\phi$ is the disk width in arcseconds, $i$ is the inclination, and $f$ is the fractional luminosity.

The minimum albedo enabling the detection of the disk was calculated through an iterative process in which a synthetic disk was created, as shown in Fig. 4. This disk was injected into the corresponding data sets of different epochs at 1.6 and 2.2 microns, respectively, assuming the disk morphology presented by Marino et al. (2020), with the exception of the gap at 74 au: a position angle of 61°, an inclination of 40°, and an extension from 30 to 180 au.

The disk is no longer detectable when the surface brightness is below the values shown in Table 3 in the $H$ and $K$ bands for HD 206893.

### Table 3. Upper limits (UL) on the surface brightness and albedo in the $H$ and $K$ bands for HD 206893.

<table>
<thead>
<tr>
<th>Night</th>
<th>Filter</th>
<th>Surface brightness UL ($\mu$Jy arcsec$^{-2}$)</th>
<th>Albedo UL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016-09-15</td>
<td>K1-K2</td>
<td>1.80</td>
<td>0.96</td>
</tr>
<tr>
<td>2017-07-13</td>
<td>BB_H</td>
<td>0.096</td>
<td>0.55</td>
</tr>
</tbody>
</table>

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Table 4. Boundaries for the orbital parameters generated by MESS2.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Min</th>
<th>Max</th>
<th>Number of steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semimajor axis (au)</td>
<td>1</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Mass ($M_{\text{Jup}}$)</td>
<td>0.1</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Eccentricity</td>
<td>0</td>
<td>0.6</td>
<td>–</td>
</tr>
<tr>
<td>Inclination (deg)</td>
<td>25</td>
<td>40</td>
<td>–</td>
</tr>
</tbody>
</table>

**Fig. 5.** Probability map of detecting a companion around HD 206893 as a function of its mass and semimajor axis, assuming an age of 200 Myr. The position of the RV candidate proposed by Grandjean et al. (2019) is indicated in red. The position of the putative companion proposed by Marino et al. (2020) is indicated in green.

Increasing distance from the star. The detection probability is 90% for masses of 2.5 $M_{\text{Jup}}$ at 74 au and masses above 55 $M_{\text{Jup}}$ between 1.4 and 2.6 au.

As estimated by Marino et al. (2020), the disk extends from 30 to 180 au, with a maximum brightness at 120 au, surface density peak at 114$^{+5}_{-2}$ au, and a 27 ± 5 au wide gap at 74 ± 3 au, which could be caused by a planet of 0.9$^{+0.8}_{-0.5}$ $M_{\text{Jup}}$. The probability of detecting the putative planet is below 10% according to our model. We thus conclude that we do not have the sensitivity with the present data to detect a sub-Jovian planet, such as the Marino et al. (2020) presumed companion.

Despite SPHERE’s limitation, JWST should be able to detect a sub-Jovian planet with its expected high sensitivity at thermal IR. To quantify this, we simulated a 1 h integration with the JWST Mid-Infrared Instrument (MIRI) 15 µm coronagraphy mode using PANCAKE² (Van Gorkom et al. 2016; Schneider et al. 2016; Perrin et al. 2018; Girard et al. 2018; Carter et al. 2020), which is based on the official JWST ETC Pandedia (Pontoppidan et al. 2016). We then extracted a contrast curve from this simulated observation, which we then used to produce a planet mass versus semimajor axis detectability map, as shown in Fig. 6. This map was produced as follows. Each planet mass was translated to a magnitude contrast using Bern EXoplanet models (BEX; Linder et al. 2019), the latest models for 0.02–2 $M_{\text{Jup}}$ planets formed through core accretion, and assuming an age of 200 Myr. Then, at each point in this map, we produced an ensemble of random points with different separations along the orbit of the planet. We assumed a circular orbit that is inclined in line with the debris disk and determined the likelihood of it leading to a 5σ detection. Then, the probability in this detectability map is the likelihood of a planet of that mass and semimajor axis reaching a >5σ detection. We note that we do not expect these planets to have eccentricities greater than ≥0.1 based on the already observed levels of axisymmetry in this disk.

Figure 6 shows that the putative planet at the gap (orange error bar) would be easily detected with a 1 h integration. The red and green regions are excluded by the SPHERE observations presented here and by ALMA observations that imaged the disk, respectively. The white region represents planet masses and semimajor axes that would be detected by JWST observations. This demonstrates the discovery potential of JWST, which will allow these types of putative planets to be confirmed or ruled out. Moreover, such observations could also reveal the presence of a planet sculpting the disk’s inner edge near 30 au, with a mass between 0.2 and 5 $M_{\text{Jup}}$, which could have been missed by our SPHERE observations.

Finally, as the Grandjean et al. (2019) RV companion is angularly very close to the star (typically less than 70 mas), we see from Fig. 5 that a detection in direct imaging with SPHERE is not possible. Nevertheless, Gaia will allow its characterization.

6. Concluding remarks and perspectives

We analyzed six SPHERE data sets of HD 206893 obtained between 2015 and 2018. HD 206893 B is detected in all six data sets, from a separation of 267 mas in 2015–50 mas in 2018. These values comply with what was reported by Grandjean et al. (2019). In addition, we obtained two new astrometric data sets, from a separation of 267 mas in 2015–50 mas in 2018. HD 206893 B is detected in all six SPHERE observations. Finally, as the Grandjean et al. (2019) RV companion is angularly very close to the star (typically less than 70 mas), we see from Fig. 5 that a detection in direct imaging with SPHERE is not possible. Nevertheless, Gaia will allow its characterization.

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2 https://github.com/spacetelescope/pandeia-coronagraphy

Reducing all of our data with the cADI technique has shown that the polarimetry data have the best sensitivity within one
arcsecond. Given the throughput of ~40% at 3′′ obtained by injecting and retrieving a synthetic disk in the data, we estimate that our ADI reduction has a greater sensitivity than PDI for this particular disk. Even though we excluded data that could lead to false detections and applied different techniques to increase the sensitivity, we do not detect the scattered light of the debris disk in the present data set.

From the surface brightness upper limits that we derived assuming the morphology presented by Marino et al. (2020), we can conclude that the single-scattering albedo of the disk is <0.55 in the H band and <0.96 in the K band. Based on these upper limits, we can rule out a disk composition of pure water ice if the dust is dominated by particles smaller than a few tens of microns, but stronger constraints on the size or composition cannot be made.

Despite these results, the possibility of successfully resolving the debris disk using another technique should not be excluded. One possible approach is to use RSDI, either from a machine-learning-based library, currently under study by C. Romero et al. (in prep.), or a second star close to the target during the same observation night (hopping). Moreover, assuming the single-scattering albedo at 2 µm to be larger than 0.5, the future JWST instrument NIRCam might offer the possibility of detecting the disk in scattered light thanks to its increased sensitivity.

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References

Van Gorkom, K., Pueyo, L., Lajoie, C.-P., & JWST Coronagraphs Working Group. 2016, AAS Meeting Abstracts, 228, 317.03
Appendix A: Masking the disk

Fig. A.1. Reduced images (top row), mask created to segment the area of interest where the disk would be (middle row), and its perpendicular to make the comparison between them (bottom row).

Fig. A.2. Radial curves of the noise in the corresponding area of interest (solid blue line) versus the same profile but at 90° where no signal is expected (solid orange line).
Appendix B: Orbital constraints

Fig. B.1. Possible orbits for HD 206893 B (left) using the same methodology as Marino et al. (2020) and adding the astrometric points from the polarimetric data. The data points are shown in orange, and the respective separations and parallactic angles are shown on the right.

Fig. B.2. Posterior distribution of the semimajor axis, eccentricity, inclination, argument of pericenter, and longitude of ascending node. The vertical dashed lines represent the 16th, 50th, and 84th percentiles, and the contours the 68, 95, and 99.7% confidence regions. This plot was generated following the same procedure used by Marino et al. (2020).