Jointly Leveraging Angular Diversity and Reference Stars for Direct High-Contrast Imaging of Protoplanetary Systems

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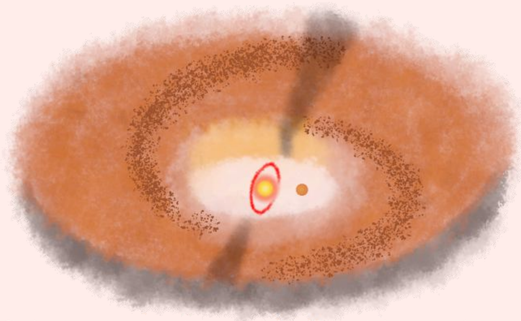
Context Direct Observation of Disk With High Contrast Imaging

Scientific Goal

Find link between the variety of structures observed in **protoplanetary disks** and their **protoplanets**.



Spirals, shadow lanes, misaligned inner disk

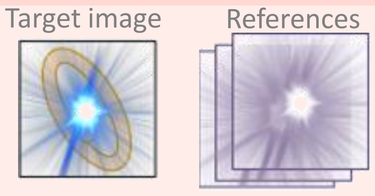
Example of planet-induced structures in disks (Benitsy 2023)

Engineering Task

Observing circumstellar signal with high contrast imaging is limited by **quasi-static speckles**, which generate patterns on the science images, as bright or even brighter than the signal of interest.

Reference Differential Imaging (RDI)

Target image References



→ RDI: Utilize a reference star as a model for subtraction from the dataset.

Angular Differential Imaging (ADI)

ADI sequence of the target

→ ADI: Let the field of view rotate with the earth motion during observation; the speckles remain quasi-static.

Our Contribution IPCA To Jointly Leverage ADI and RDI Strategies

Iterative Principal Component Analysis (IPCA), is an algorithm that iteratively re-estimates the speckles while removing the previous disk estimate. At each iteration, it enforces positivity of the signal.

The simultaneous use of RDI and ADI (ARDI) is expected to **mitigate limitation arising from each strategy**

One Step of the Iterative Process...

Concatenated

Speckle PCA ADI images Reference stars

$$\bar{S}_{n+1} = \lfloor H^{q}([\, Y_{sci} - R(\bar{d}_{n}) \,,\, Y_{ref} \,]) \rfloor_{\min = 0}$$

$$\bar{d}_{n+1} = \lfloor R^{-1}(Y_{sci} - \bar{S}_{n+1}) \rfloor_{\min = 0}$$

Disk

Mean derotated images

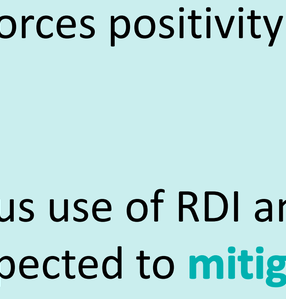
… Repeat Until Convergence

Application Analysis of the Structures of Protoplanetary Disks

The top images show protoplanet candidates previously reported in structured protoplanetary disks.

The bottom images are recent VLT/SPHERE Ks observations of the same disks processed with our method (details on the data in Ren et al. 2023a). A yellow circle indicate the positions of the candidates

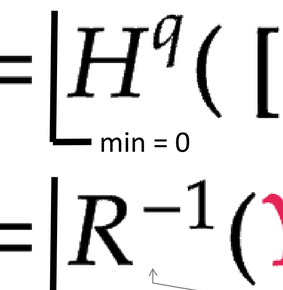
MWC 758



Reggiani et al., 2018

Two protoplanet candidates reported in Reggiani et al. (2018) and Wagner et al. (2019, 2023), respectively. Both candidates weren't confirmed by subsequent analyses. In our images, complex disk structures arise at the location of the candidate proposed by Reggiani et al. (2018).

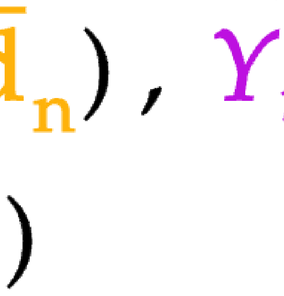
LKCa 15



Kraus et al., 2012

Protoplanet candidates reported by Kraus et al. (2012) and Sallum et al. (2015). Our new image does not reveal point sources, but instead shows a bright inner disk, consistent with interpretations from previous observations tracing filtered disk signals (Currie et al., 2019).

HD 100546



Quanz et al., 2013

A gas giant candidate at 52 au was seen in 2013 with VLT's NACO instrument (Quanz et al., 2013; Currie et al., 2014, 2015, 2017). Our images reveal an extended spiral-like structure at its location, indicating it might be a filtered disk signal.

← Full publication

IPCA on GitHub →