

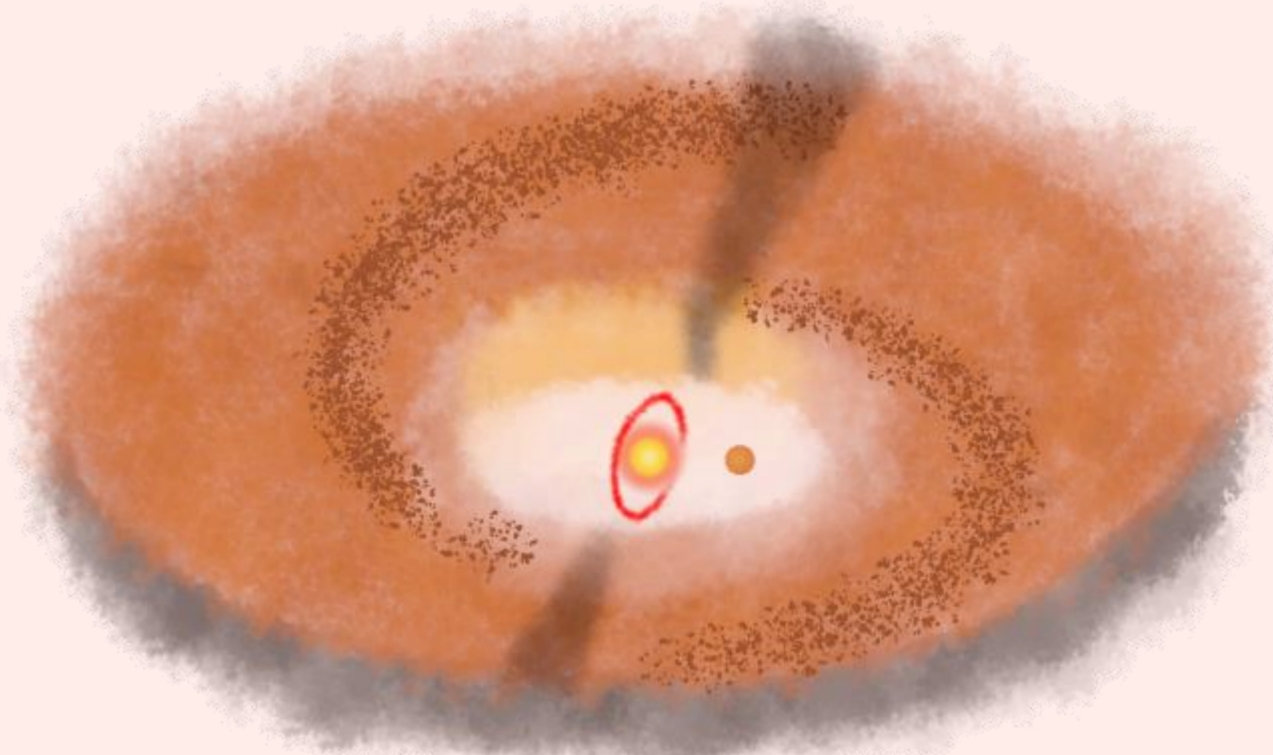
# Jointly Leveraging Angular Diversity and Reference Stars for Direct High-Contrast Imaging of Protoplanetary Systems

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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)



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

### Angular Differential Imaging (ADI)



→ **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...

$$\begin{aligned} \bar{S}_{n+1} &= \underset{\min=0}{\left[ H^q \left( \left[ \begin{array}{c} \text{Speckle} \\ Y_{sci} - R(\bar{d}_n) \end{array}, Y_{ref} \right] \right) \right]} \\ \bar{d}_{n+1} &= \underset{\min=0}{\left[ R^{-1} \left( Y_{sci} - \bar{S}_{n+1} \right) \right]} \end{aligned}$$

Concatenated  
ADI images      Reference stars  
Disk  
Mean derotated images

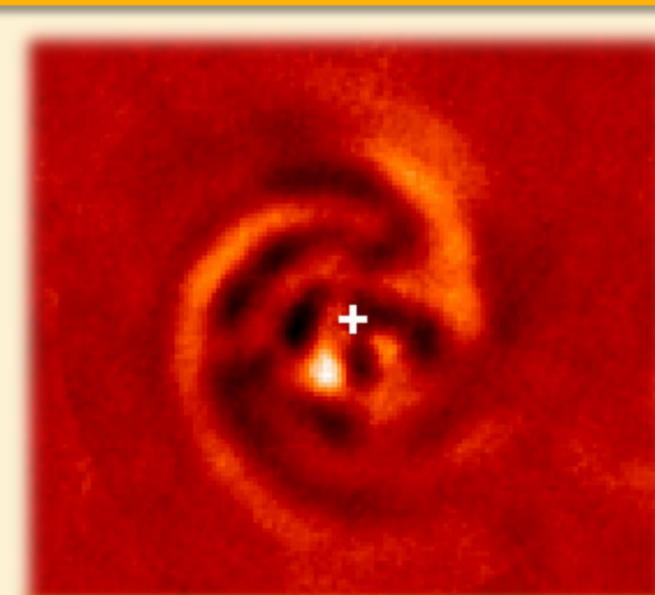
... Repeat Until Convergence

## Application Analysis of the Structures of Protoplanetary Disks

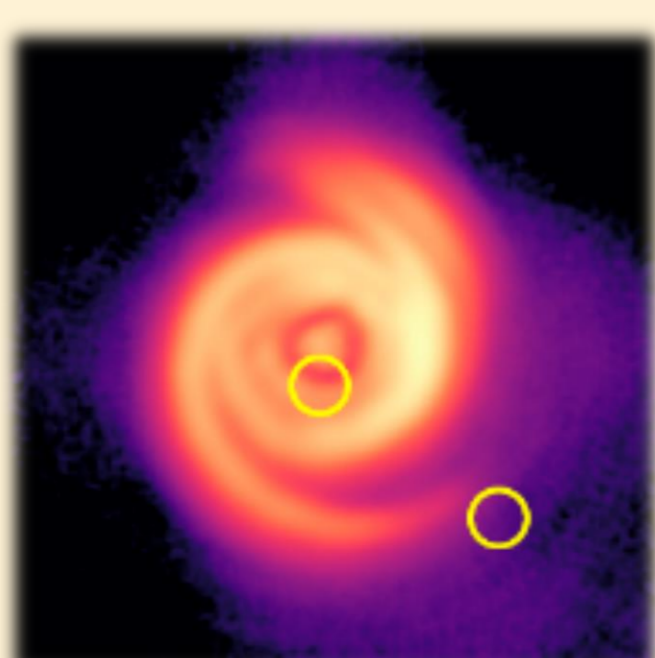
The **top images** show protoplanet candidates previously reported in structured protoplanetary disks.

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

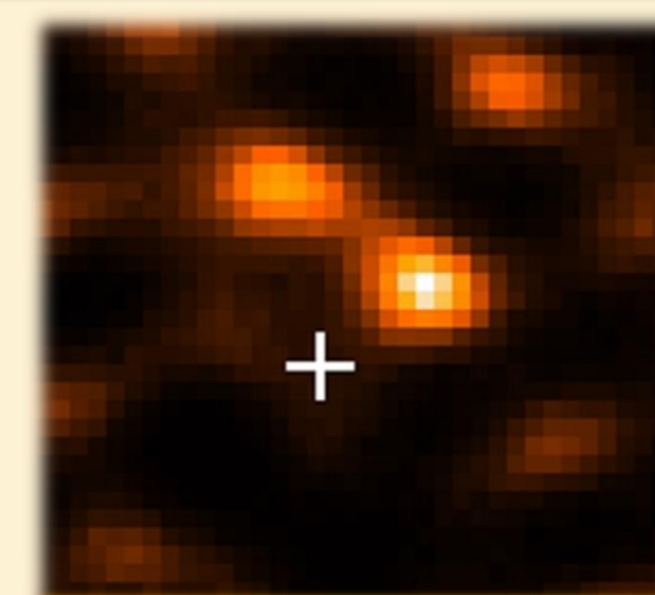


Reggiani et al., 2018

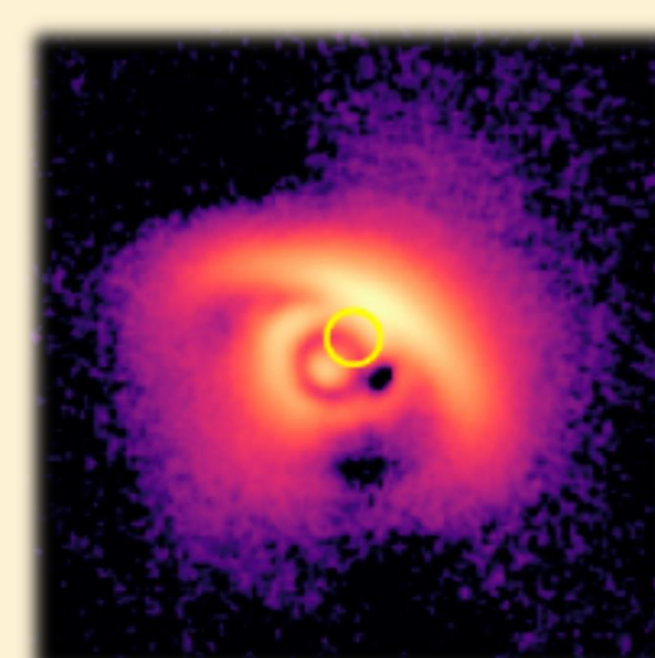


Two protoplanet candidates reported in Reggiani et al. (2018) and Wagner et al. (2019, 2023), respectively. Both candidates weren't confirmed by subsequent analyses. In our images, complex disk structures arise at the location of the candidate proposed by Reggiani et al. (2018).

### LKCa 15

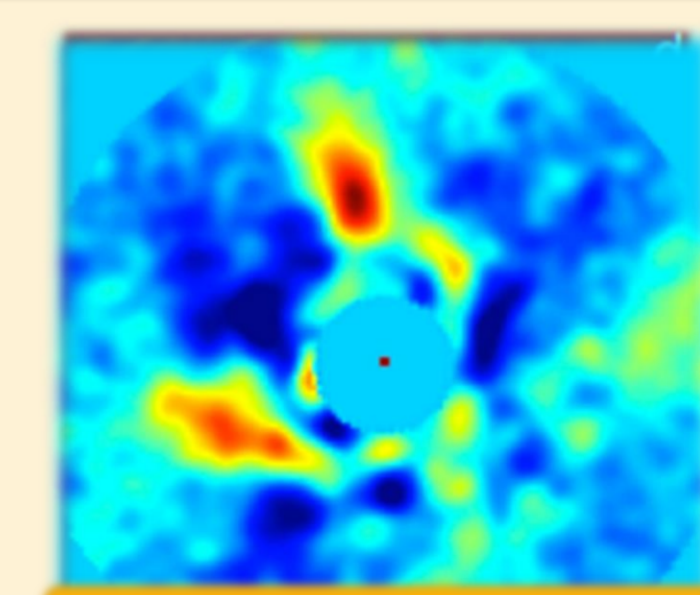


Kraus et al., 2012

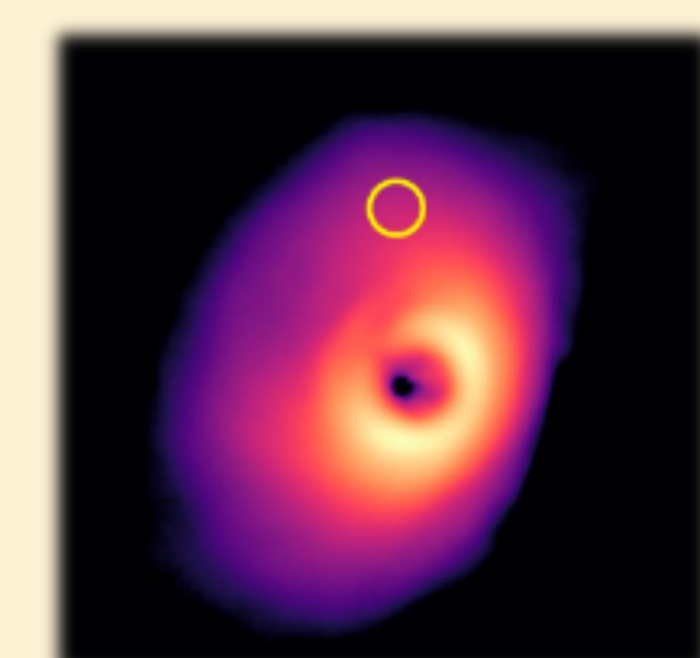


Protoplanet candidates reported by Kraus et al. (2012) and Sallum et al. (2015). Our new image does not reveal point sources, but instead shows a bright inner disk, consistent with interpretations from previous observations tracing filtered disk signals (Currie et al., 2019).

### 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 →

