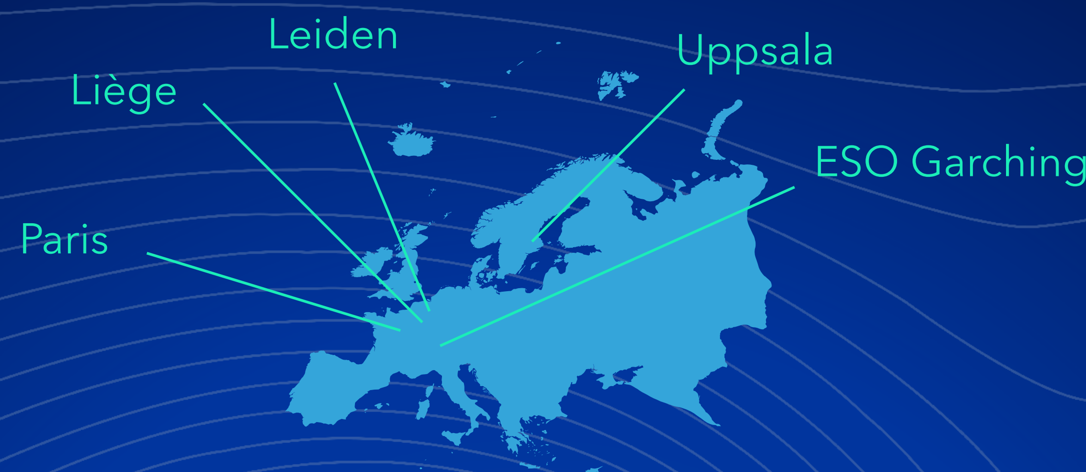
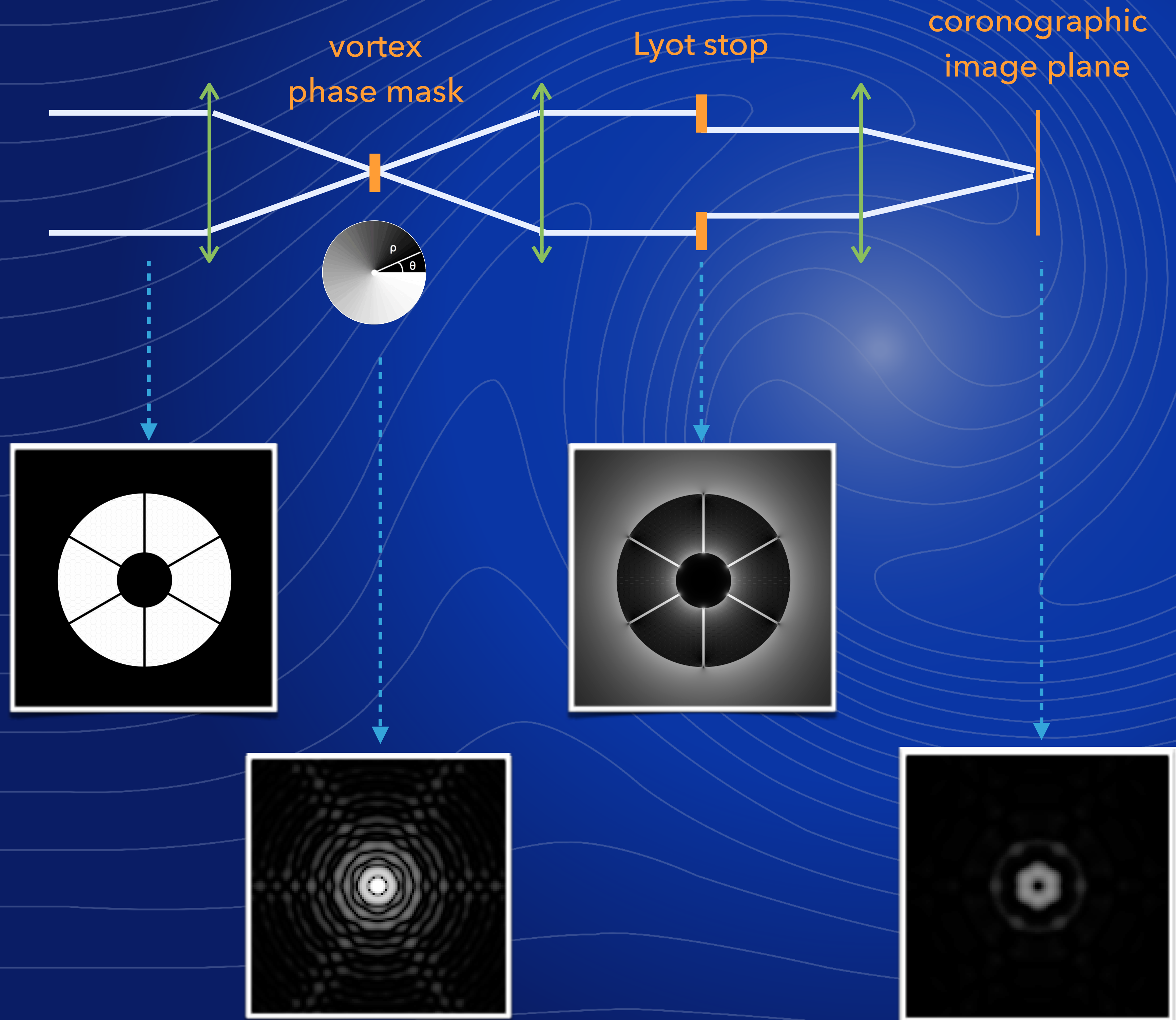


VORTEX

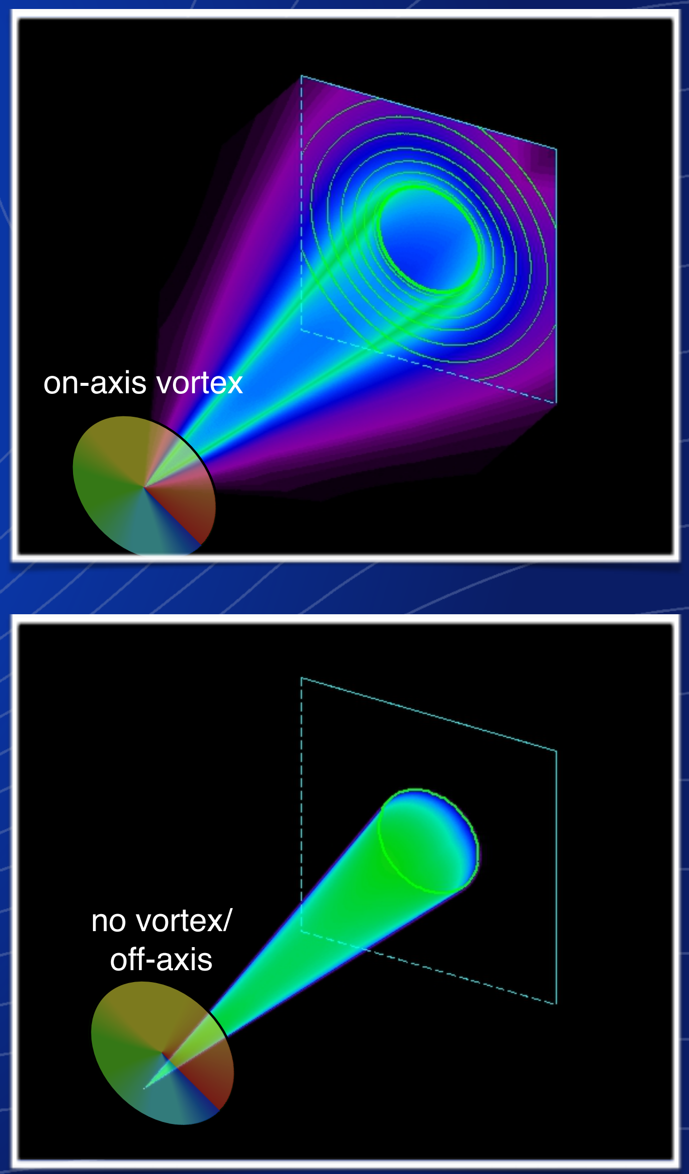
OLIVIER ABSIL

AROUND THE WORLD WITH THE INFRARED VORTEX CORONAGRAPH

THE VORTEX CORONAGRAPH IN A NUTSHELL

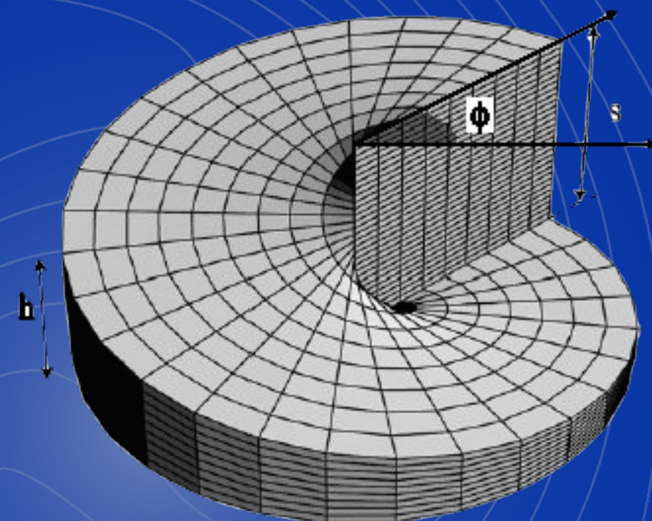


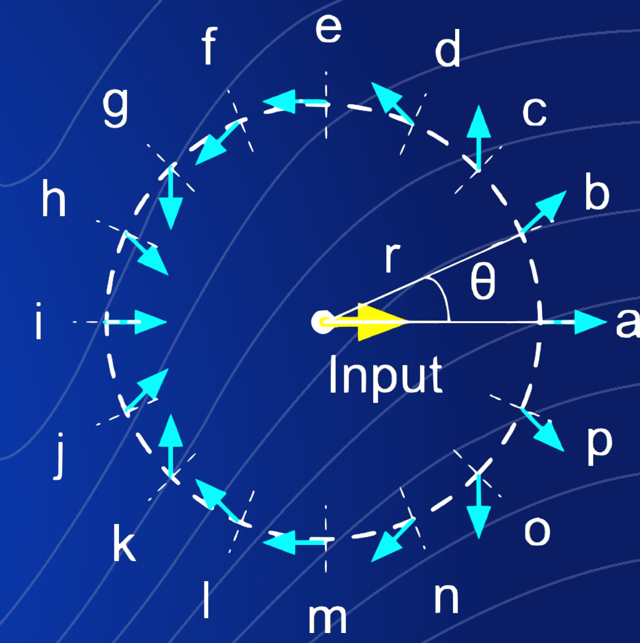
perfect on-axis cancellation for a circular aperture



IMPLEMENTATIONS OF THE VORTEX PHASE MASK

- scalar vortex
  - helical piece of glass
- vector vortex = spatially variant HWP
  - liquid crystal polymers
  - subwavelength gratings
  - photonic crystals



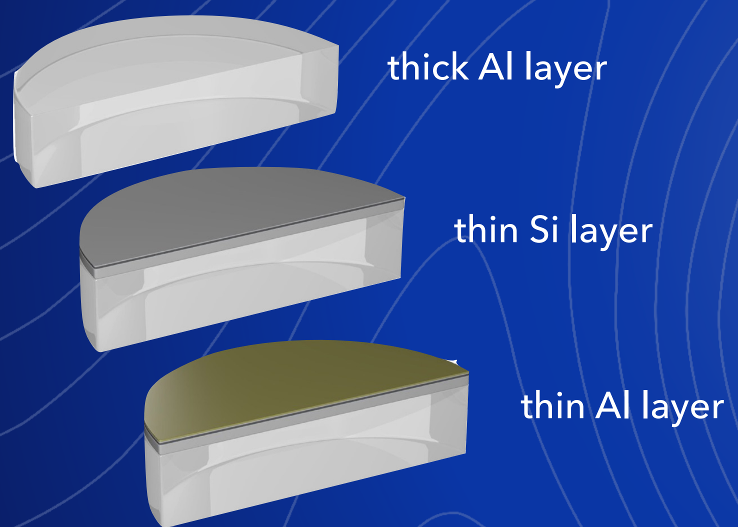


Annular Groove Phase Mask

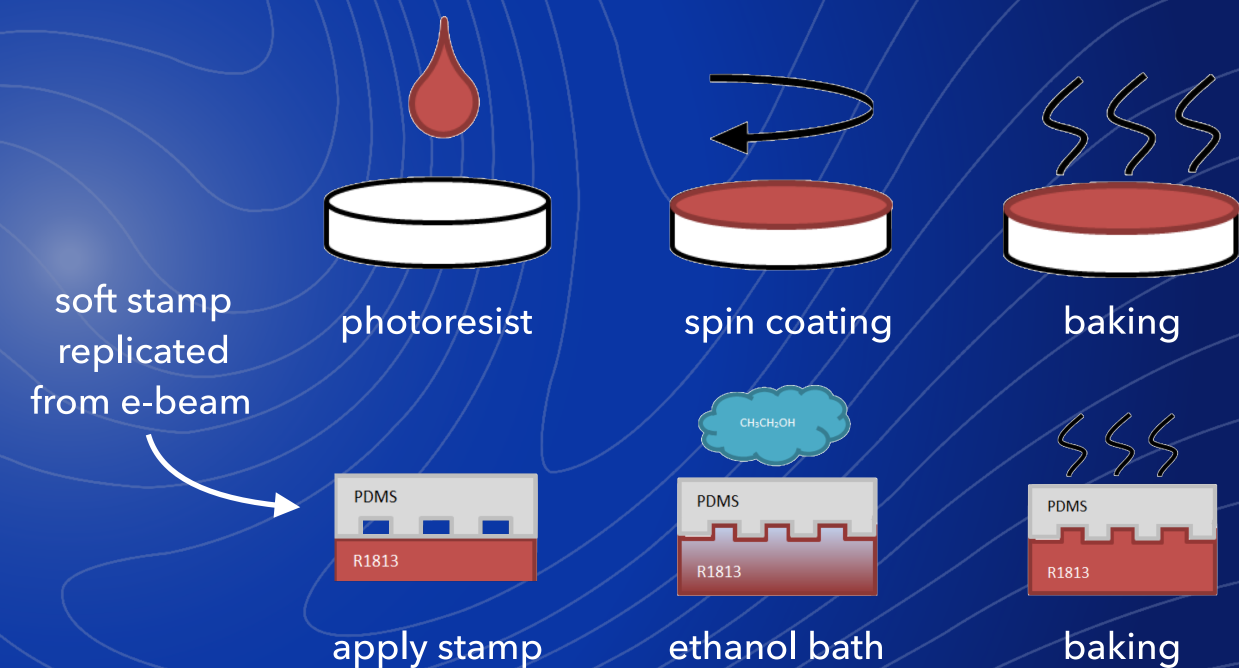
MANUFACTURING DIAMOND AGPM @ UPPSALA

Vargas Catalan et al. (2016)

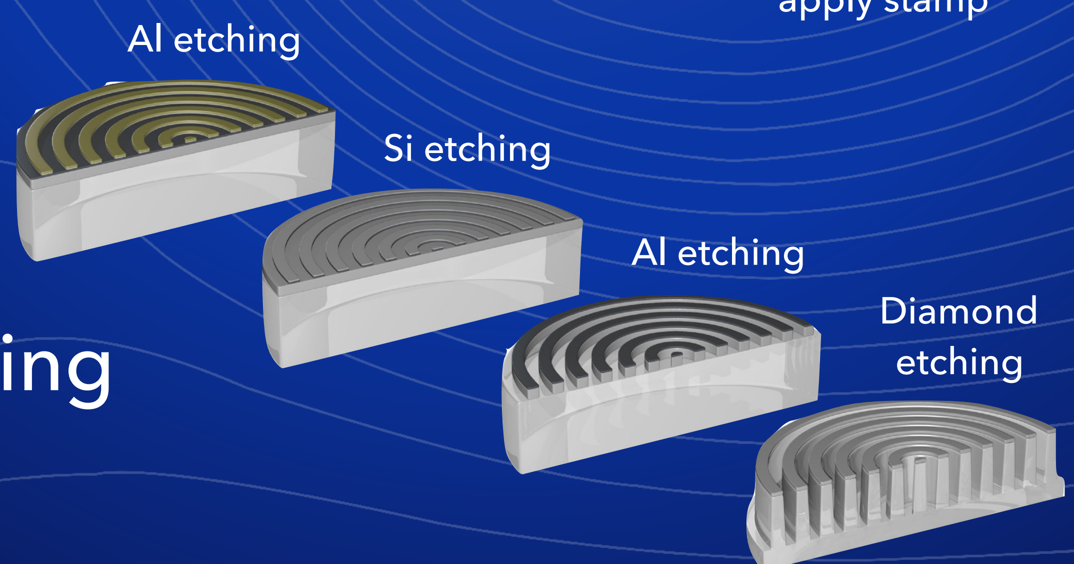
1. diamond coated with Al and Si layers (sputtering)

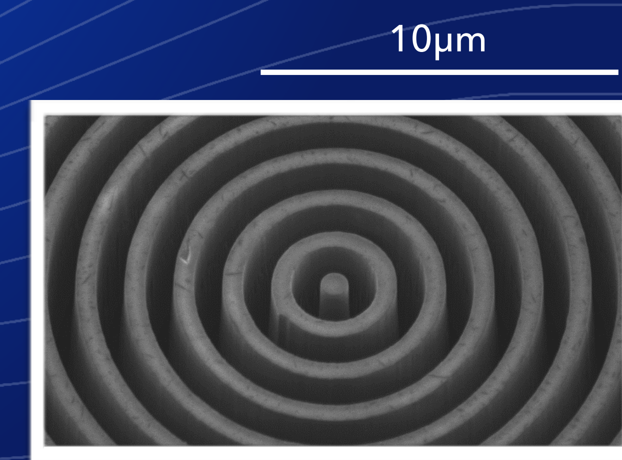


2. e-beam pattern transferred with solvent-assisted moulding



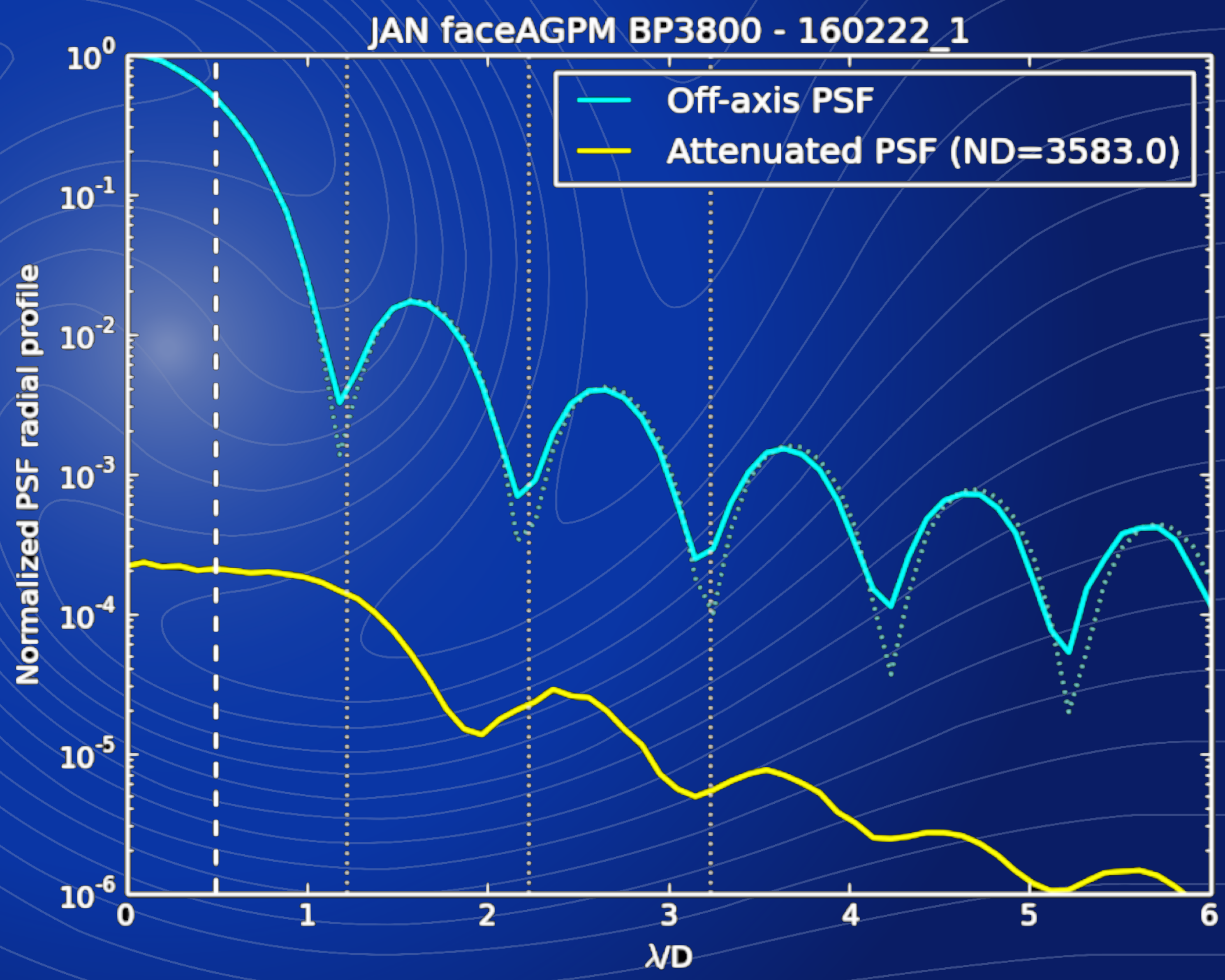
3. reactive ion etching





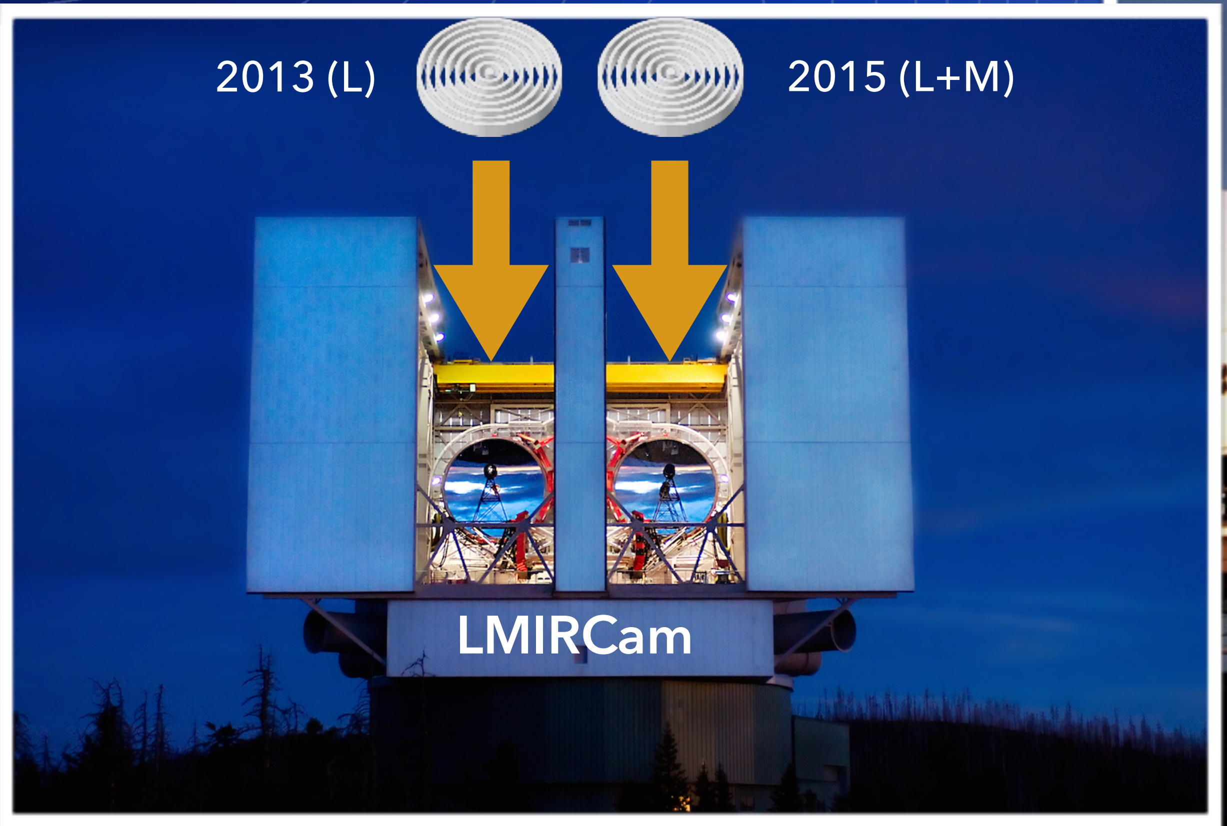
BEST PERFORMANCE IN THE LAB – 2018 UPDATE

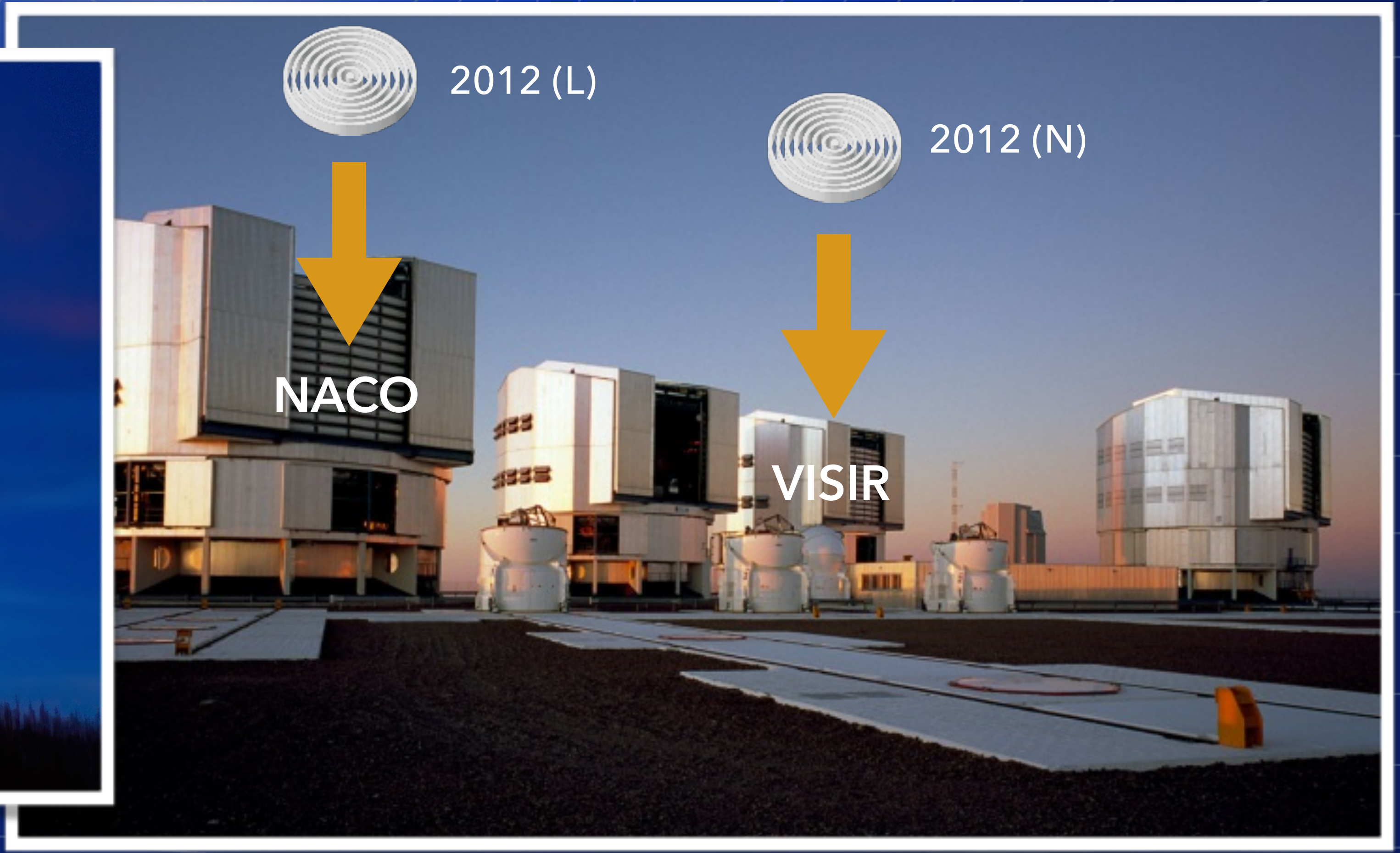
- dedicated test bench (VODCA) now available at ULiège
- 10+ science-grade L-band AGPMs etched & tested
- broadband rejection > 1000 : 1



INSTALLATION AND COMMISSIONING

- piggyback on existing coronagraphic IR cameras
- short commissioning runs (1-2 nights)



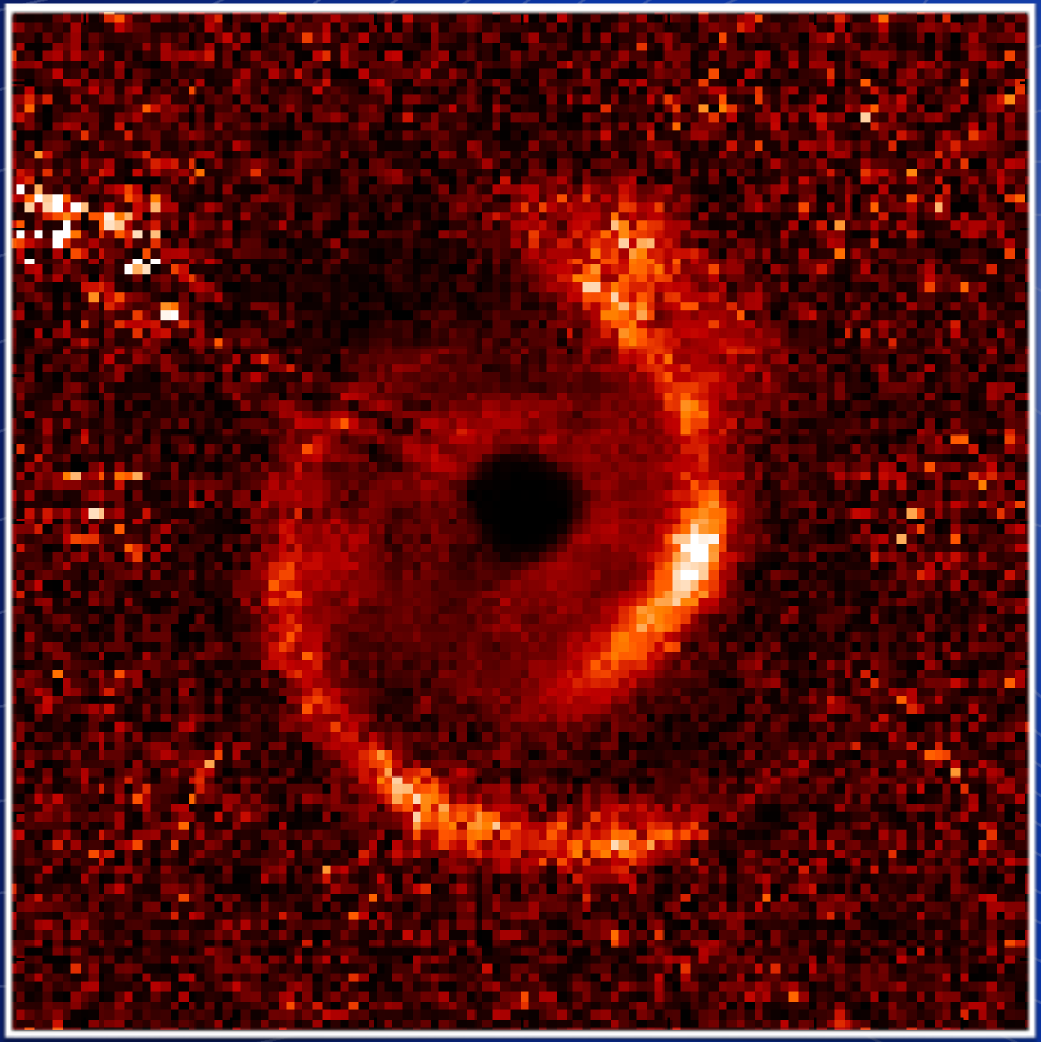


VORTEX

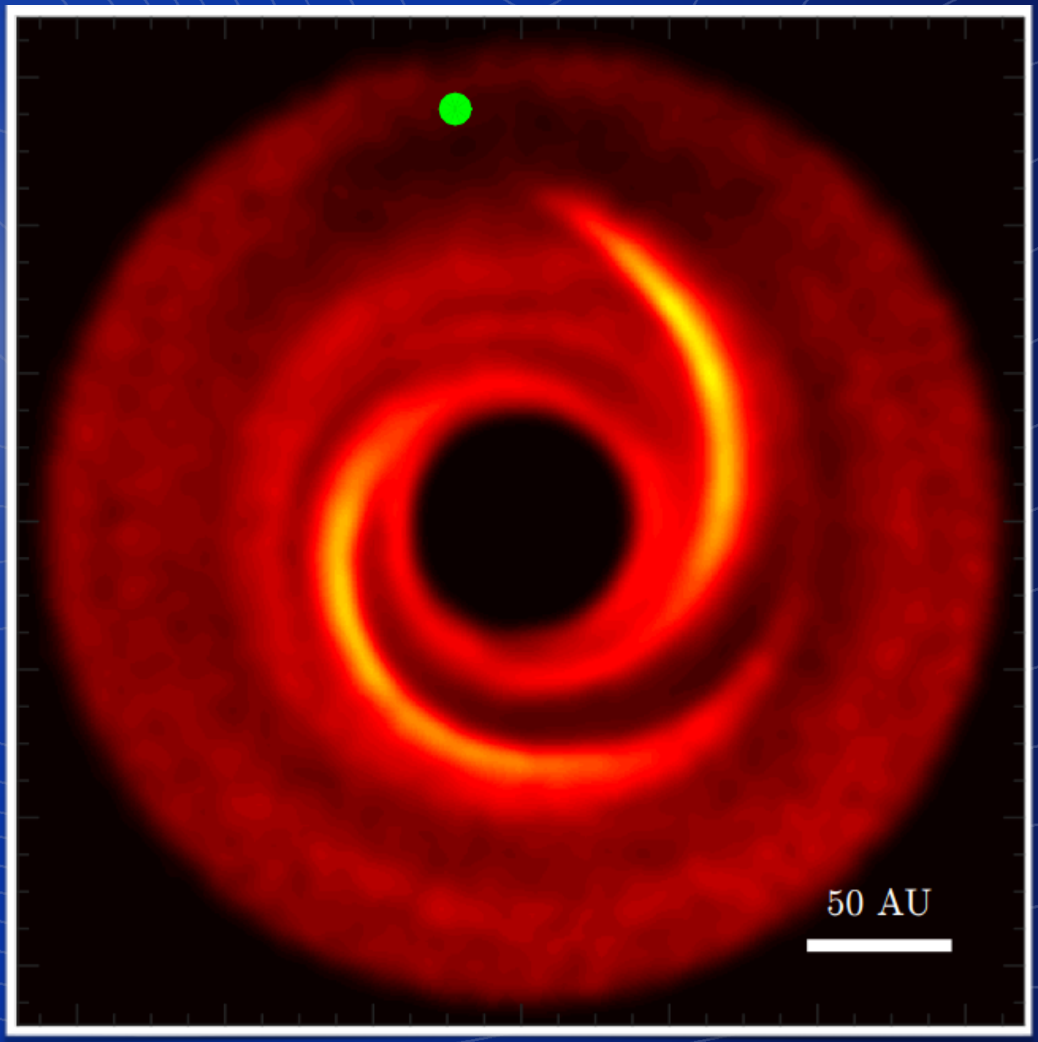
PERFORMANCE AND MAIN RESULTS SO FAR

NIRC2 & NACO TRANSITION DISK SURVEY

SPHERE/IRDIS Y band polarimetry (Benisty et al. 2015)

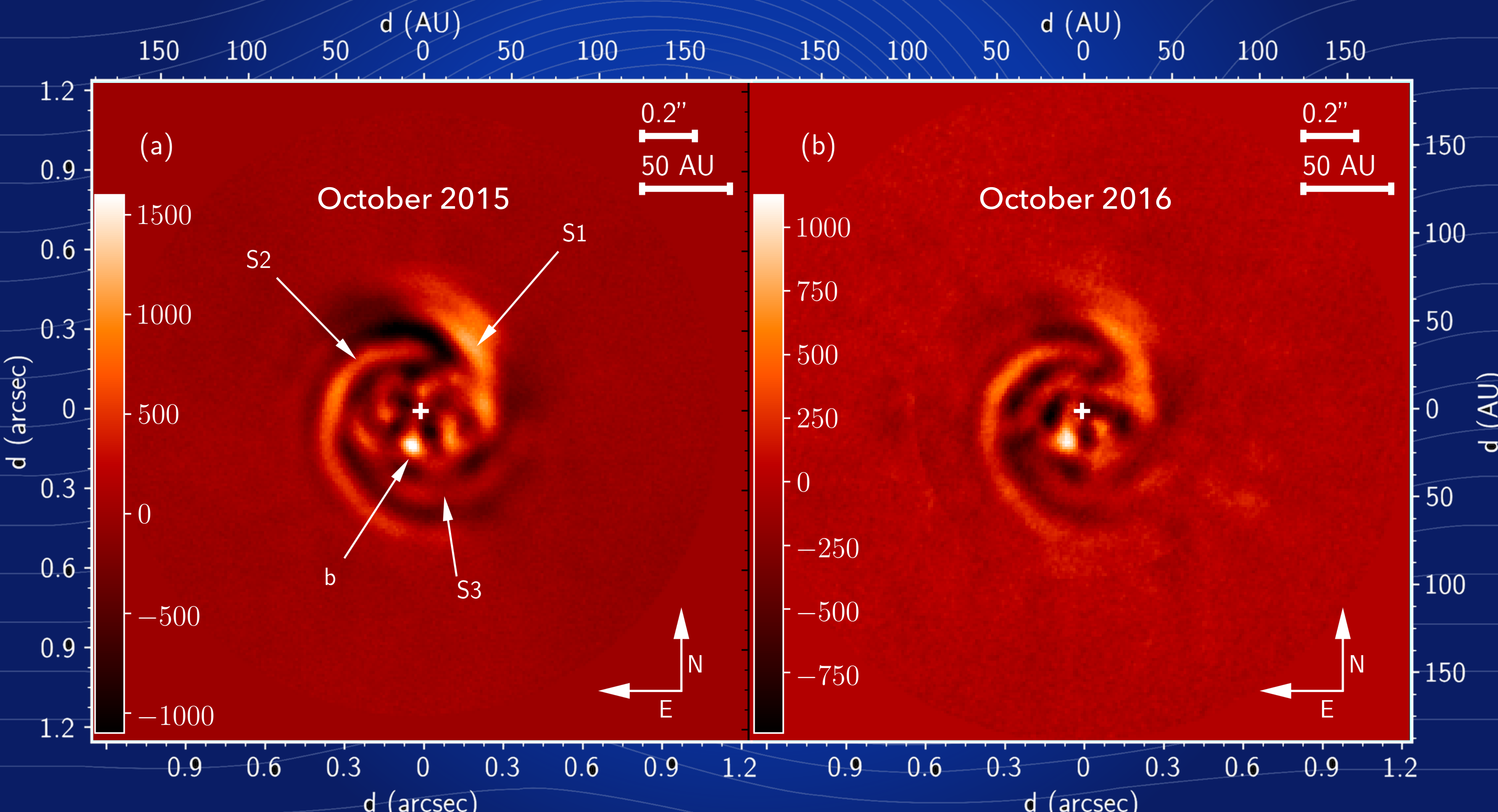


Protoplanet prediction (Dong et al. 2015)



goal: search for protoplanets at the origin of disk structures

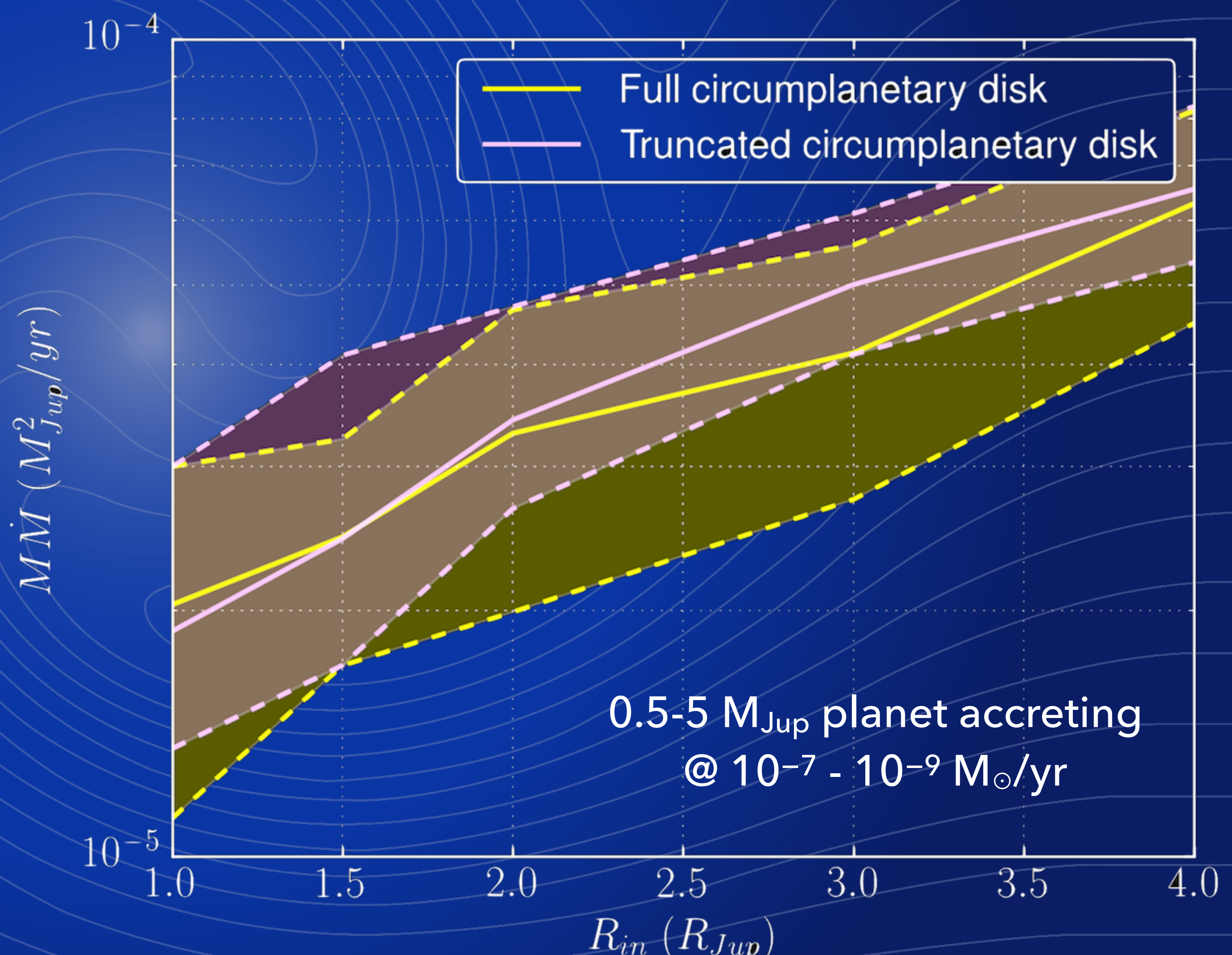
THE KECK/NIRC2 + VORTEX VIEW OF MWC758



Reggiani et al. 2018

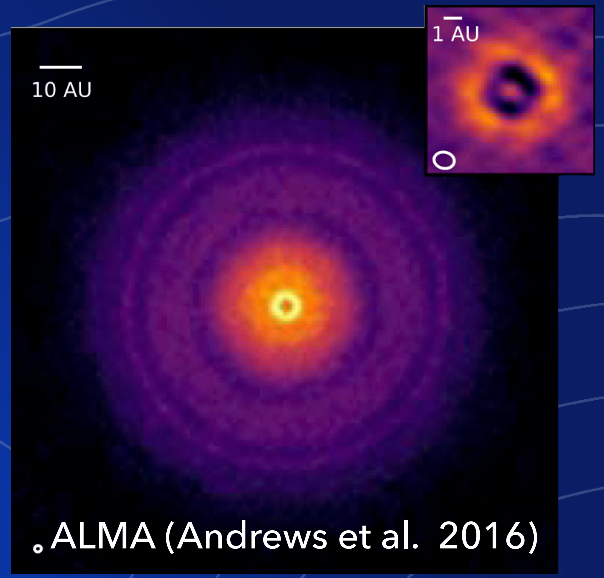
MWC758B: YET ANOTHER PROTOPLANET CANDIDATE?

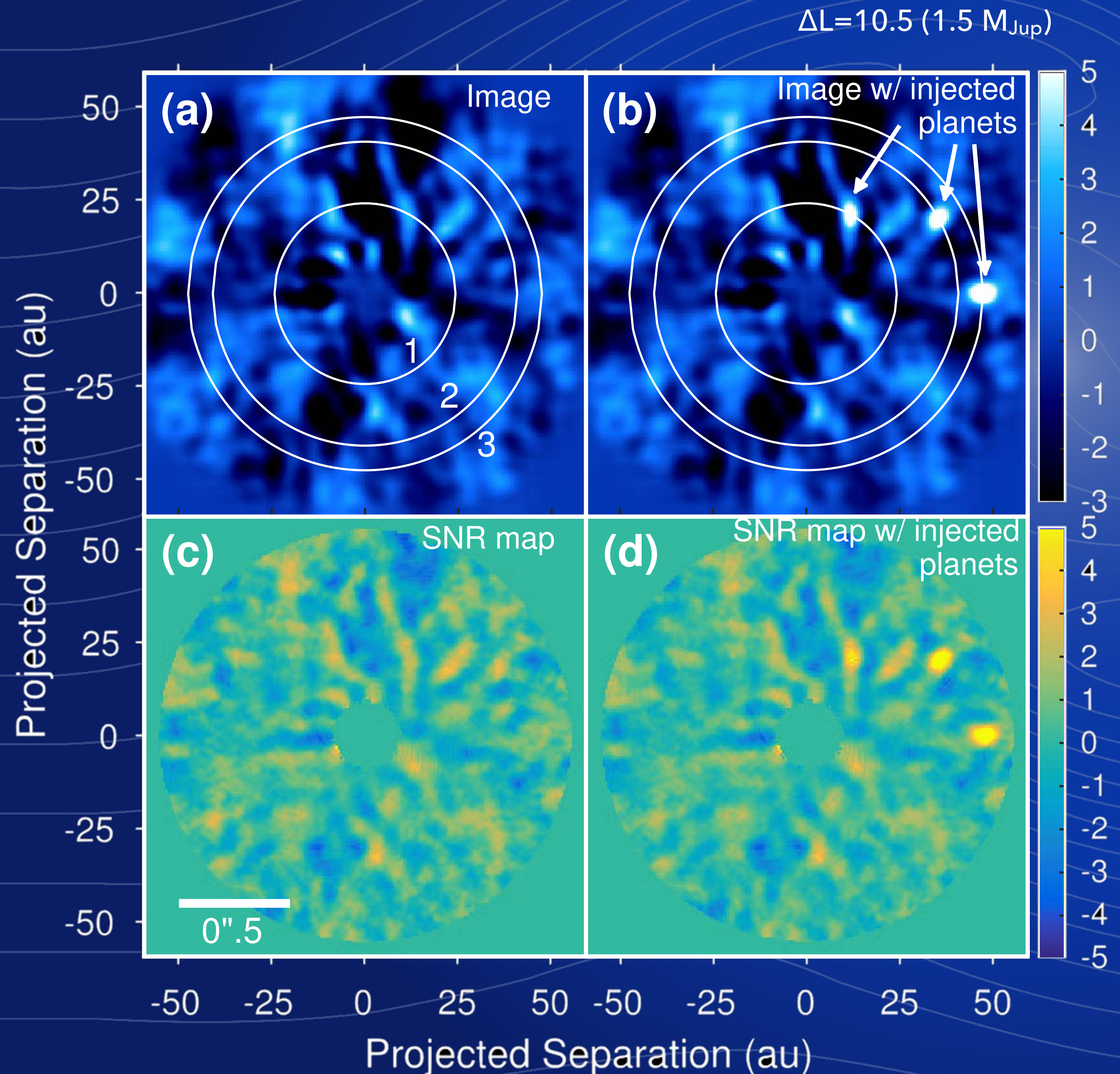
- 0.1'' separation (20 au), ΔL = 7
- movement consistant with Keplerian orbit
- if photospheric emission, would be ~50 M_{Jup}
  - not consistent with structure of inner disk
- accreting protoplanet or disk feature?

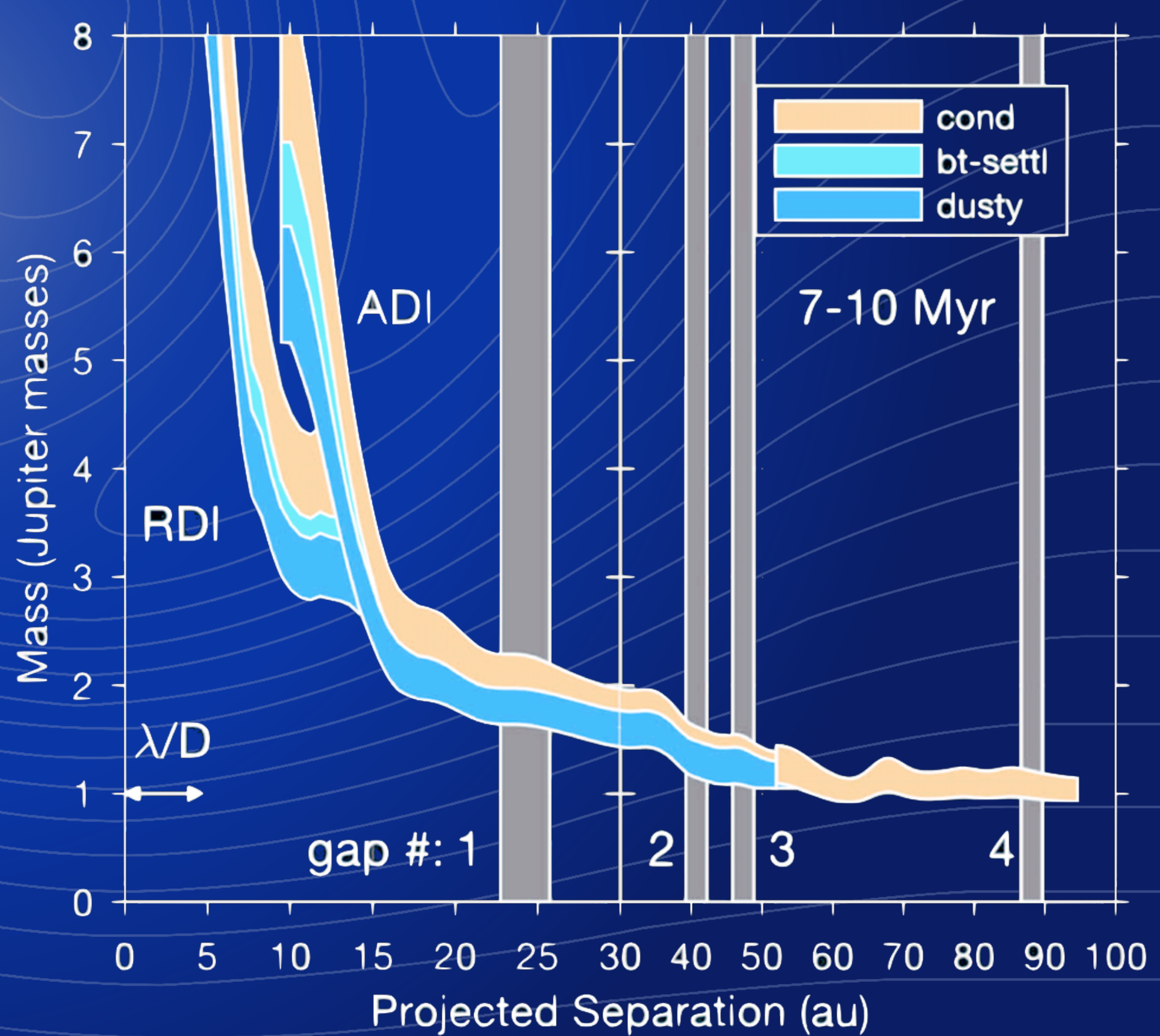


Reggiani et al. 2018

KECK CORONAGRAPHIC DEEP FIELD: TW HYA



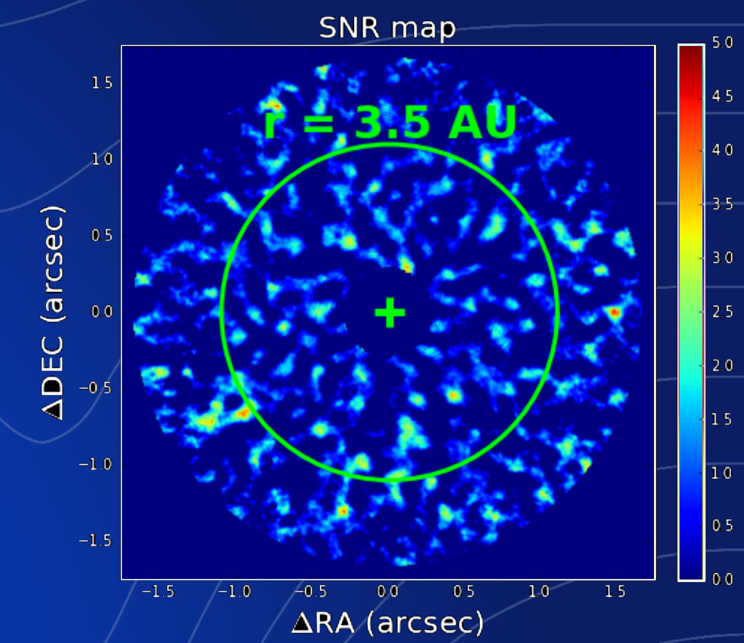


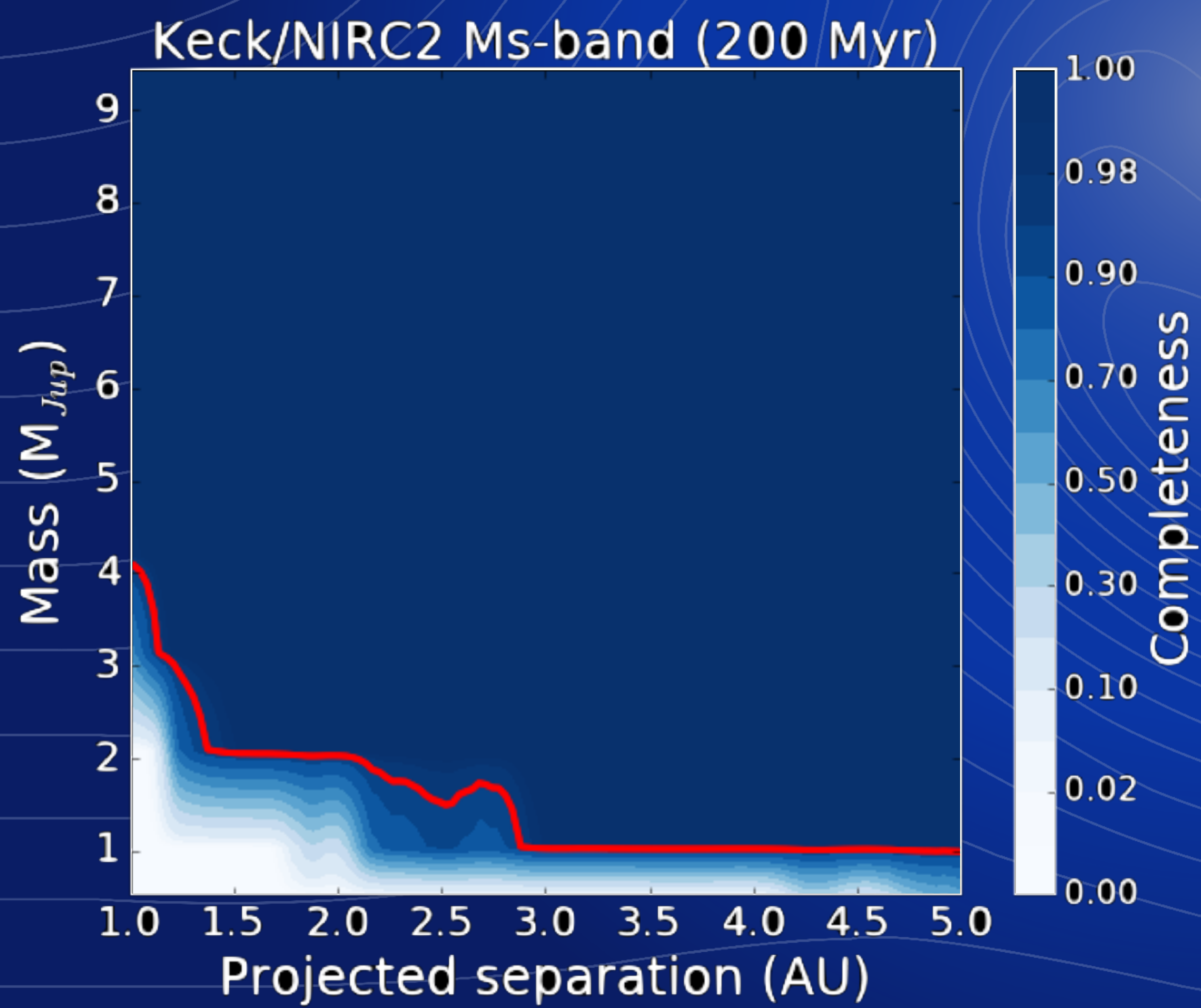


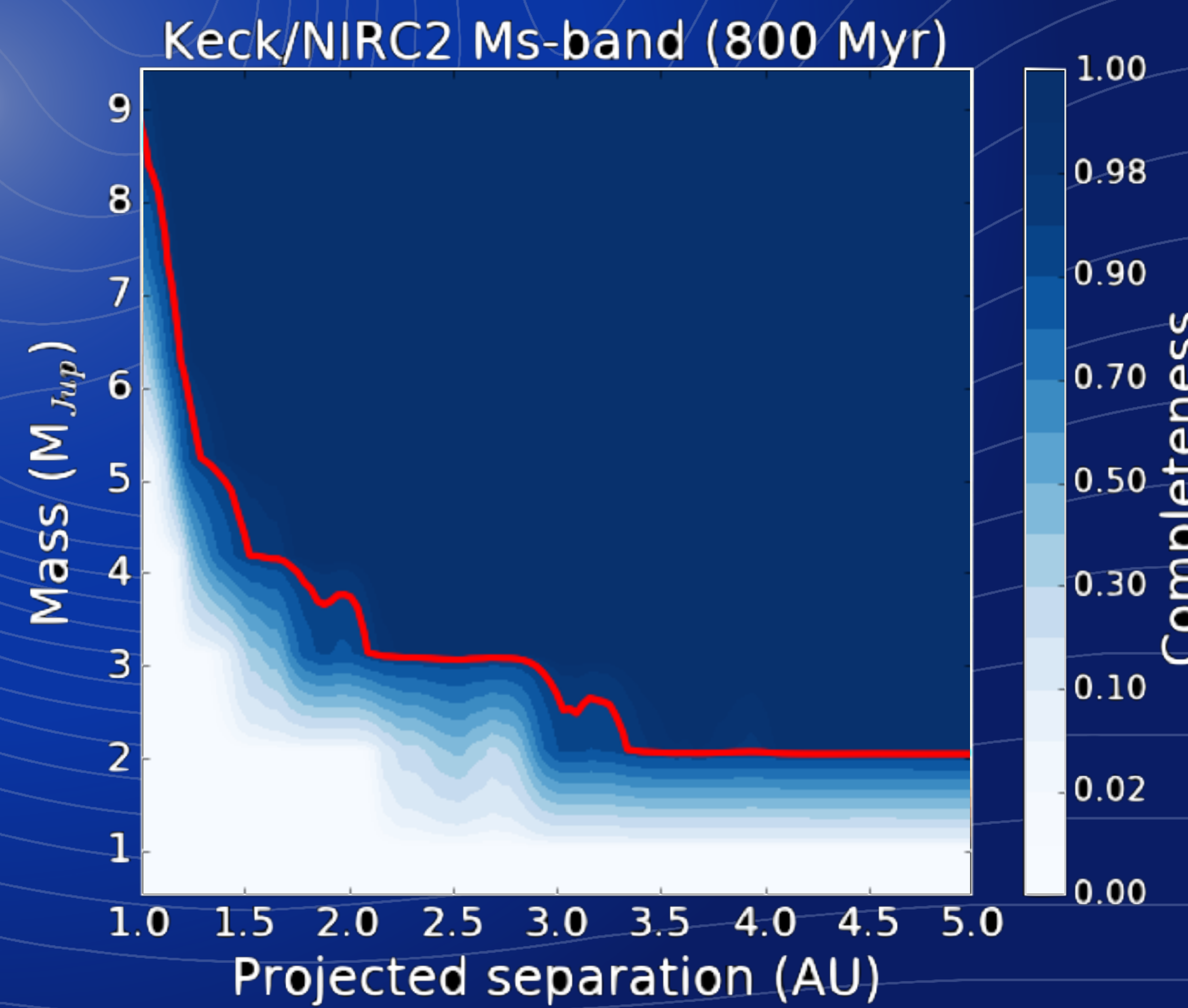
Ruane et al. 2017

KECK CORONAGRAPHIC DEEP FIELD: EPS ERI

- deepest detection limits around an adolescent Sun-like star





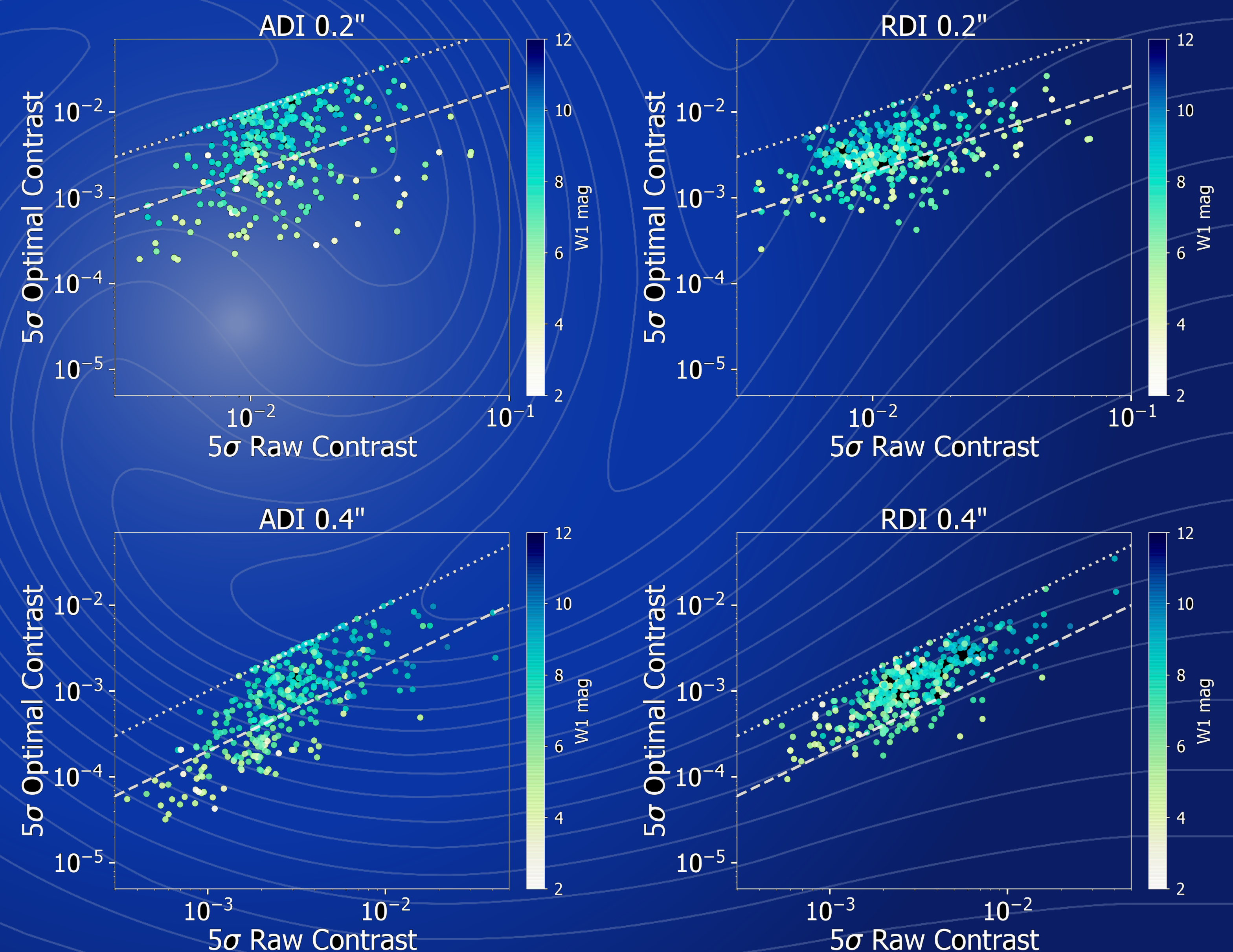


Mawet et al. (subm)

ON SKY PERFORMANCE: THREE YEARS OF VORTEX @ NIRC2

- 359 vortex observations in 2016-2017, using QACITS focal-plane pointing control
- automatic pipeline provides raw and post-processed contrast curves for ADI and RDI

gain in contrast from post-processing

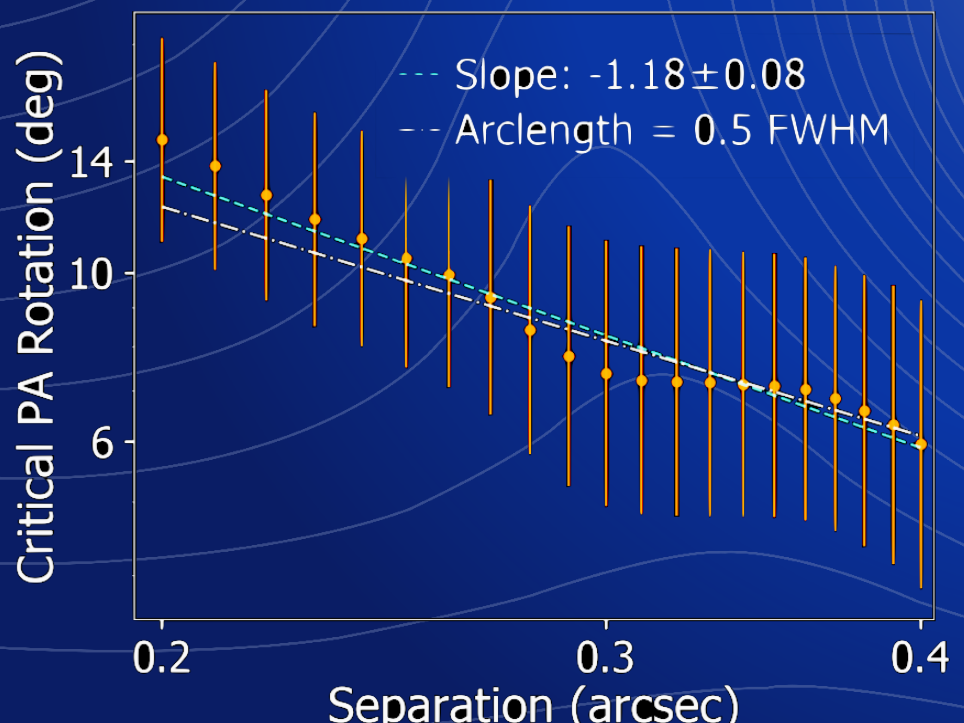


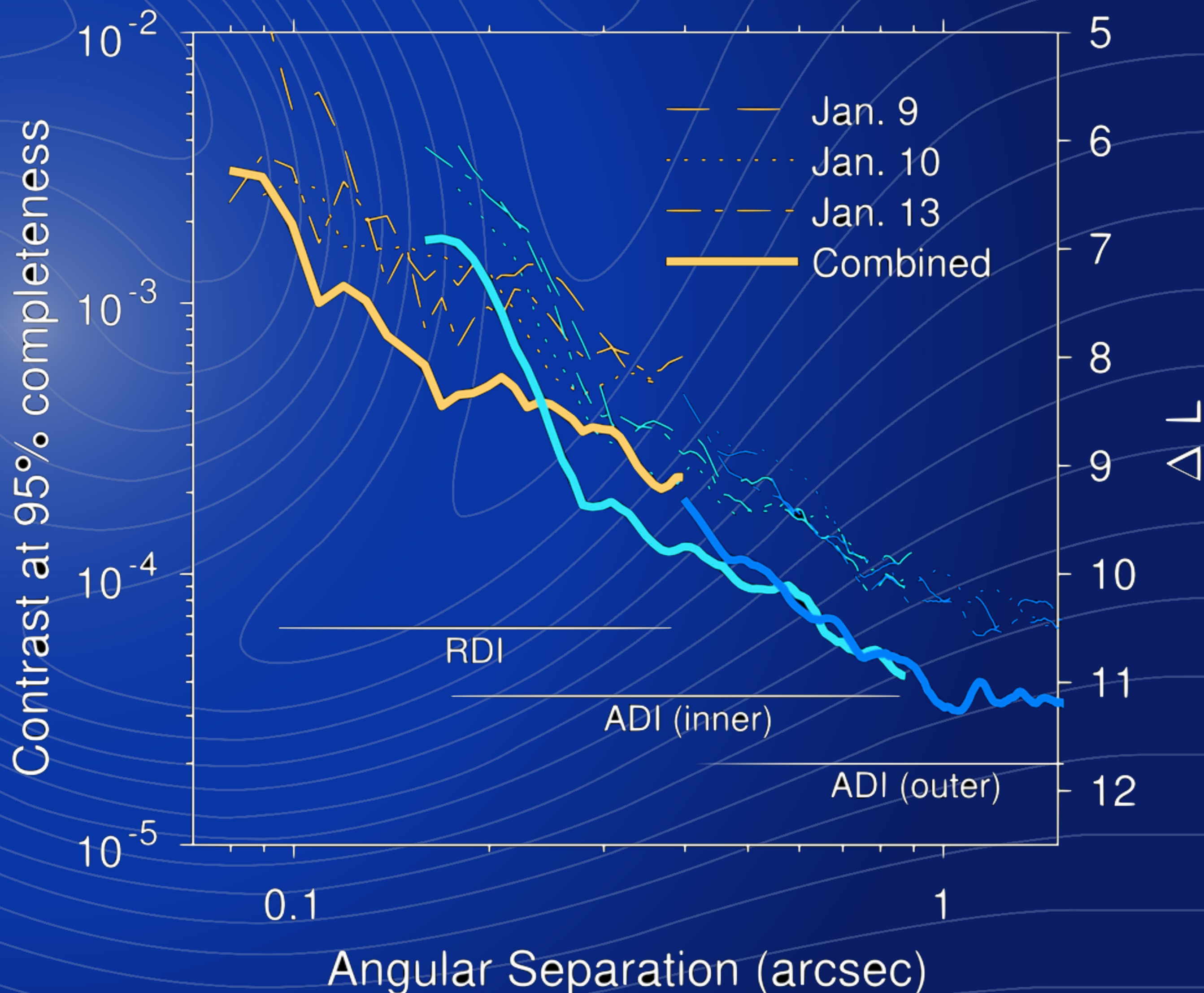
Xuan et al. (subm)

ON SKY PERFORMANCE: ADI VS RDI

- RDI better at small separations
- critical separation depends on amount of field rotation

Ruane et al. 2017



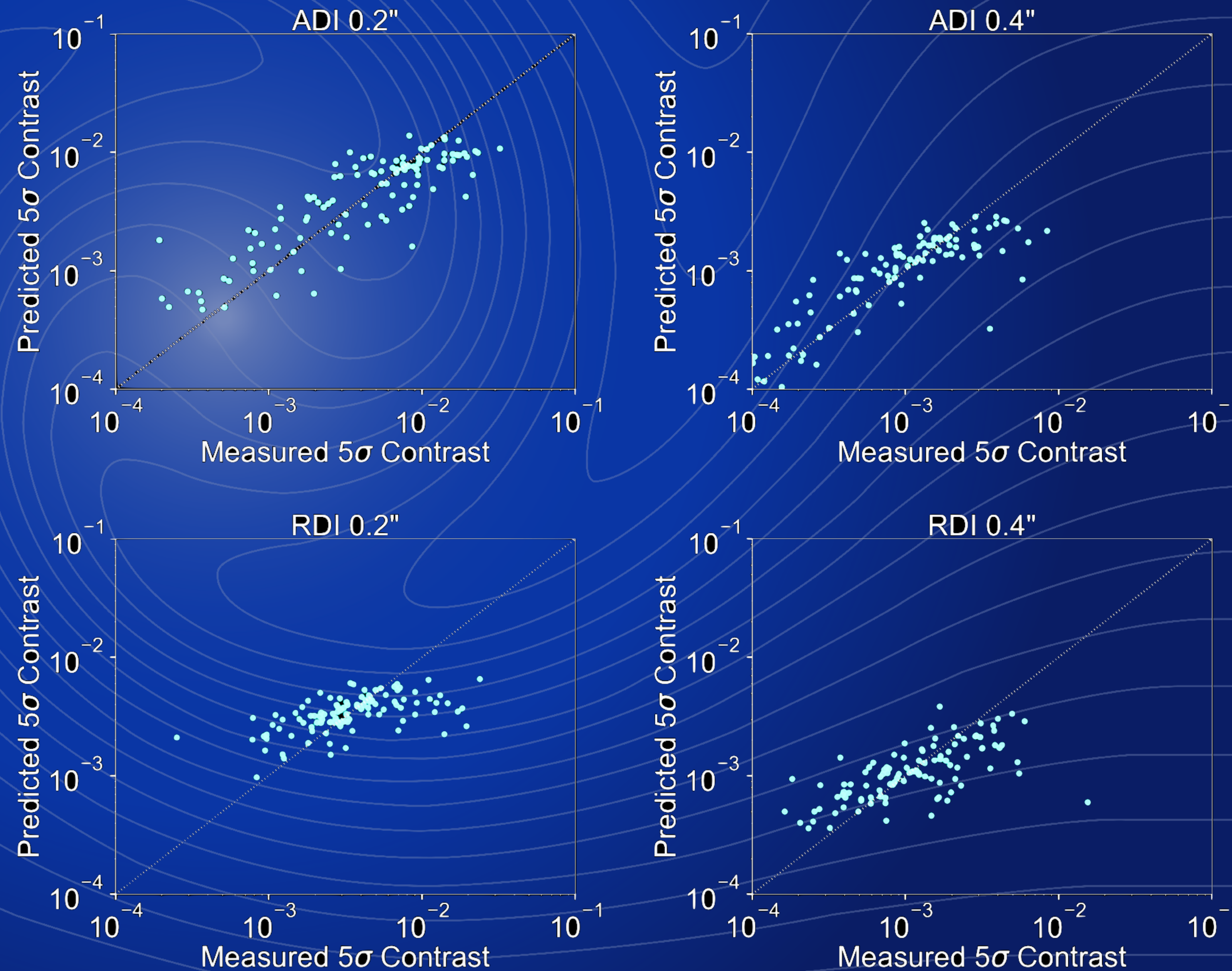


Xuan et al. (subm)

CONTRAST PREDICTIONS BASED ON RANDOM FORESTS

- random forests used to identify main explanatory variables and make predictions
- ADI performance mostly explained by (i) field rotation, (ii) integration time, (iii) magnitude
- for RDI performance, FWHM of PSF becomes as important

predicted vs measured contrast



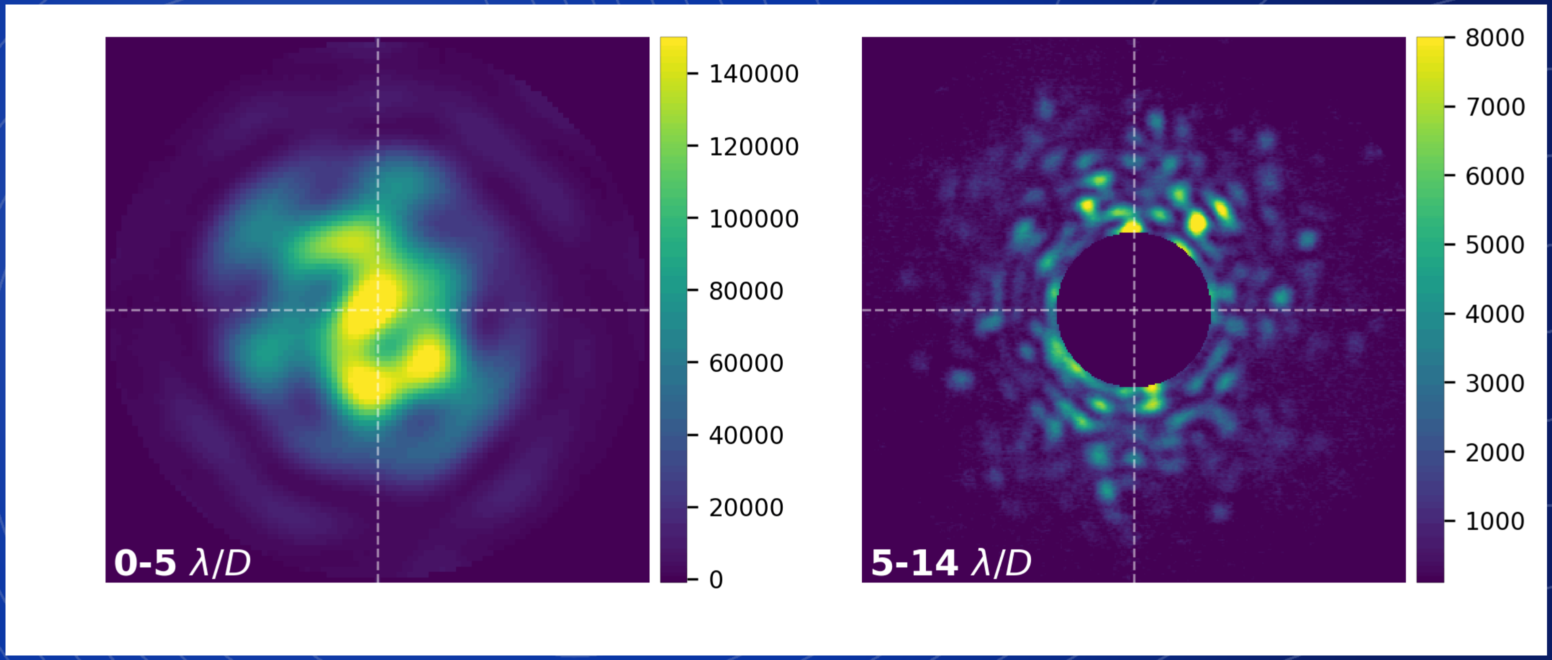
RMSE ~ 0.3 dex

Xuan et al. (subm)

HOW TO BETTER EXPLOIT THE DATA?

- interesting science at 1-3 λ/D
  - strongly affected by residual speckles
  - non-Gaussian noise –> more false positives
  - hard to validate candidates

NIRC2+vortex image sequence

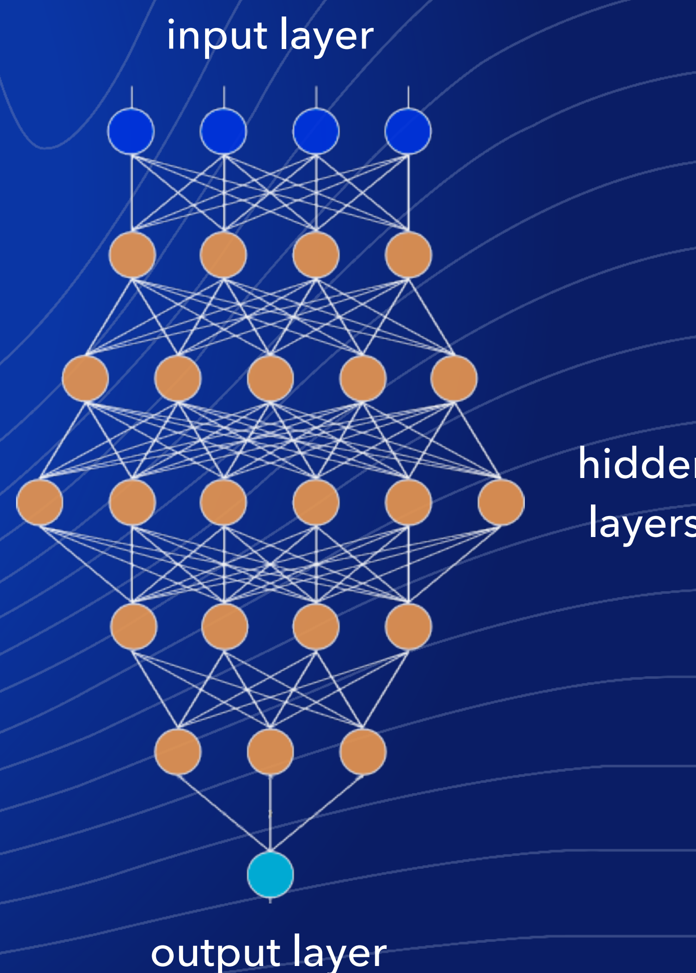


- ADI-based techniques produce SNR, but do not inform on nature of the source
- machine learning can help

SUPERVISED LEARNING

- goal: learn function f mapping input samples $\mathcal{X}$ to labels $\mathcal{Y}$ given a labeled dataset $(x_i, y_i)_{i=1,\ldots,n}$:

$$\min_{f \in \mathcal{F}} \frac{1}{n} \sum_{i=1}^{n} \mathcal{L}(y_i, f(x_i)) + \lambda \Omega(f)$$

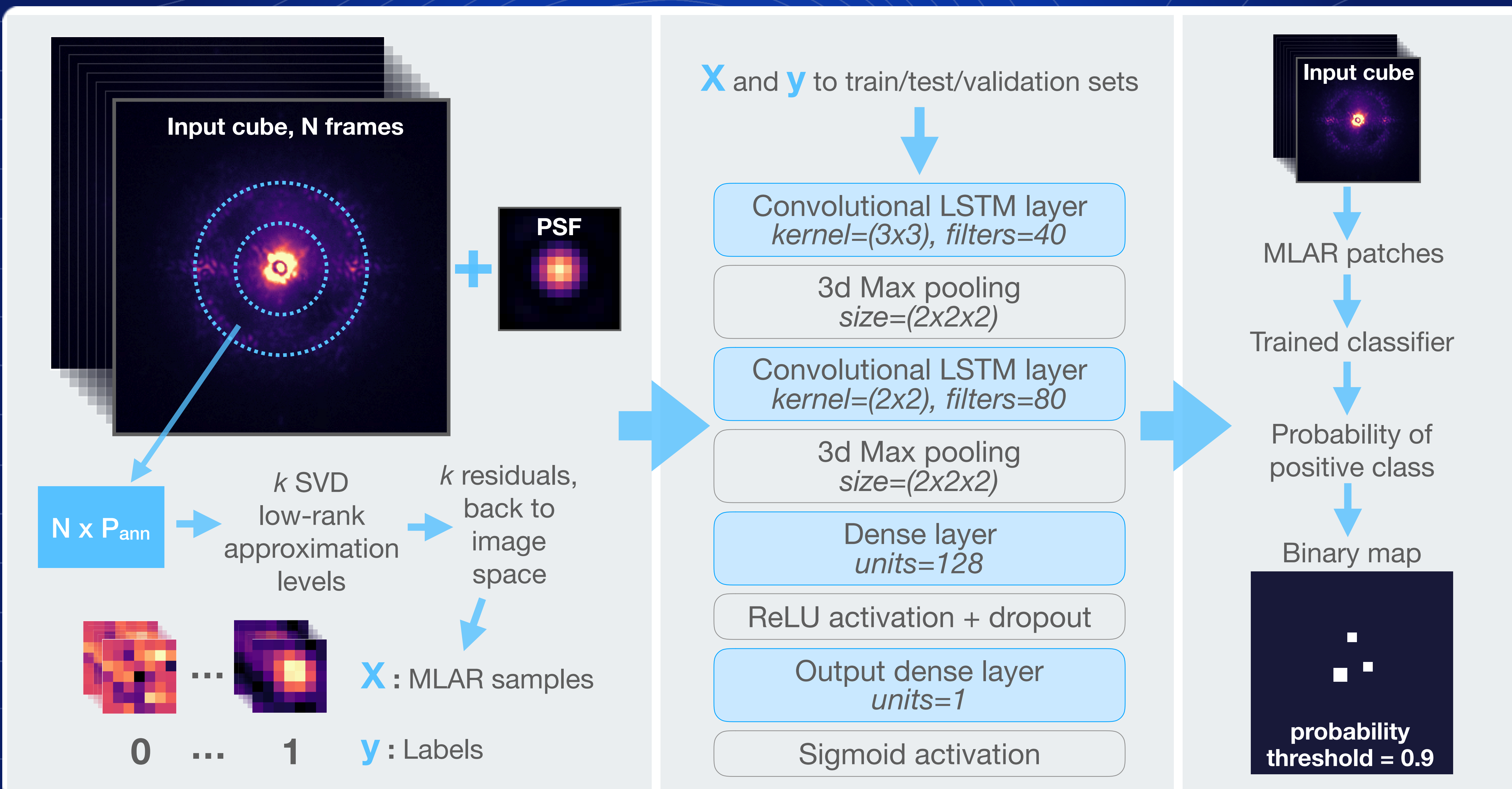


- mapping function f based on (deep) neural network
  - layers of neurons whose parameters can be tuned to approximate a complex function
  - DNN can be trained with labeled datasets
- problem: need labels & large training sample!

SUPERVISED DETECTION OF EXOPLANETS

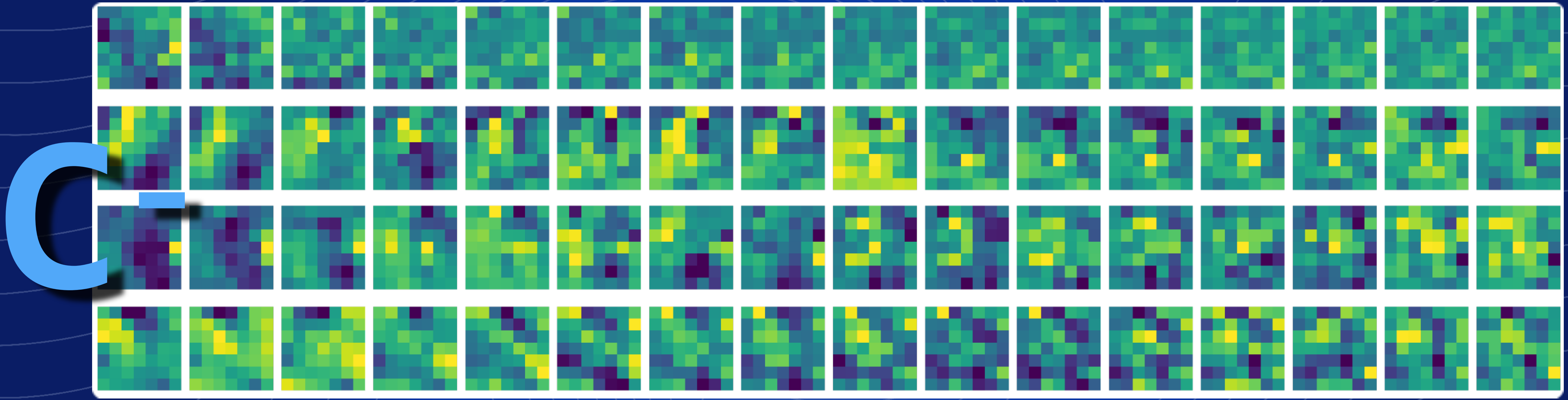
Gomez Gonzalez et al. 2018

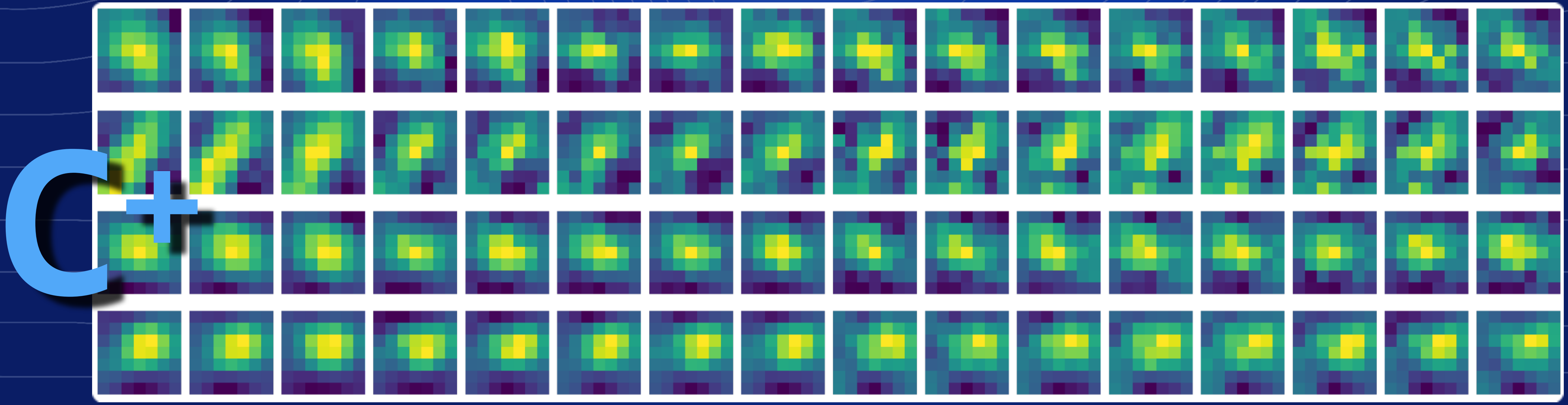
1. generation of labeled data
2. training the DNN
3. prediction



LABELED DATASET

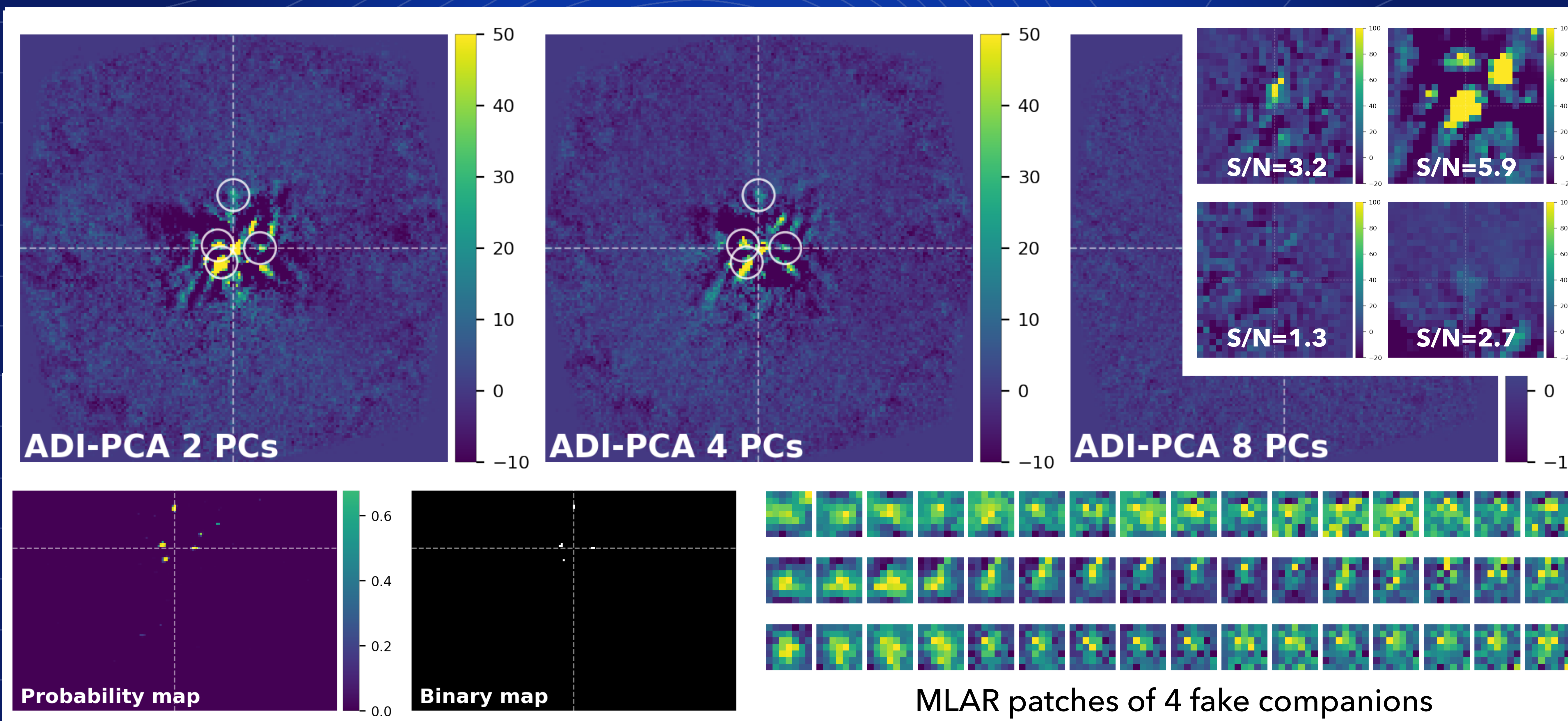
Labels: $y \in \{c^{-}, c^{+}\}$





TEST WITH INJECTED COMPANIONS (SPHERE/IRDIS DATA)

4 fake companions injected in data set … can you spot them?

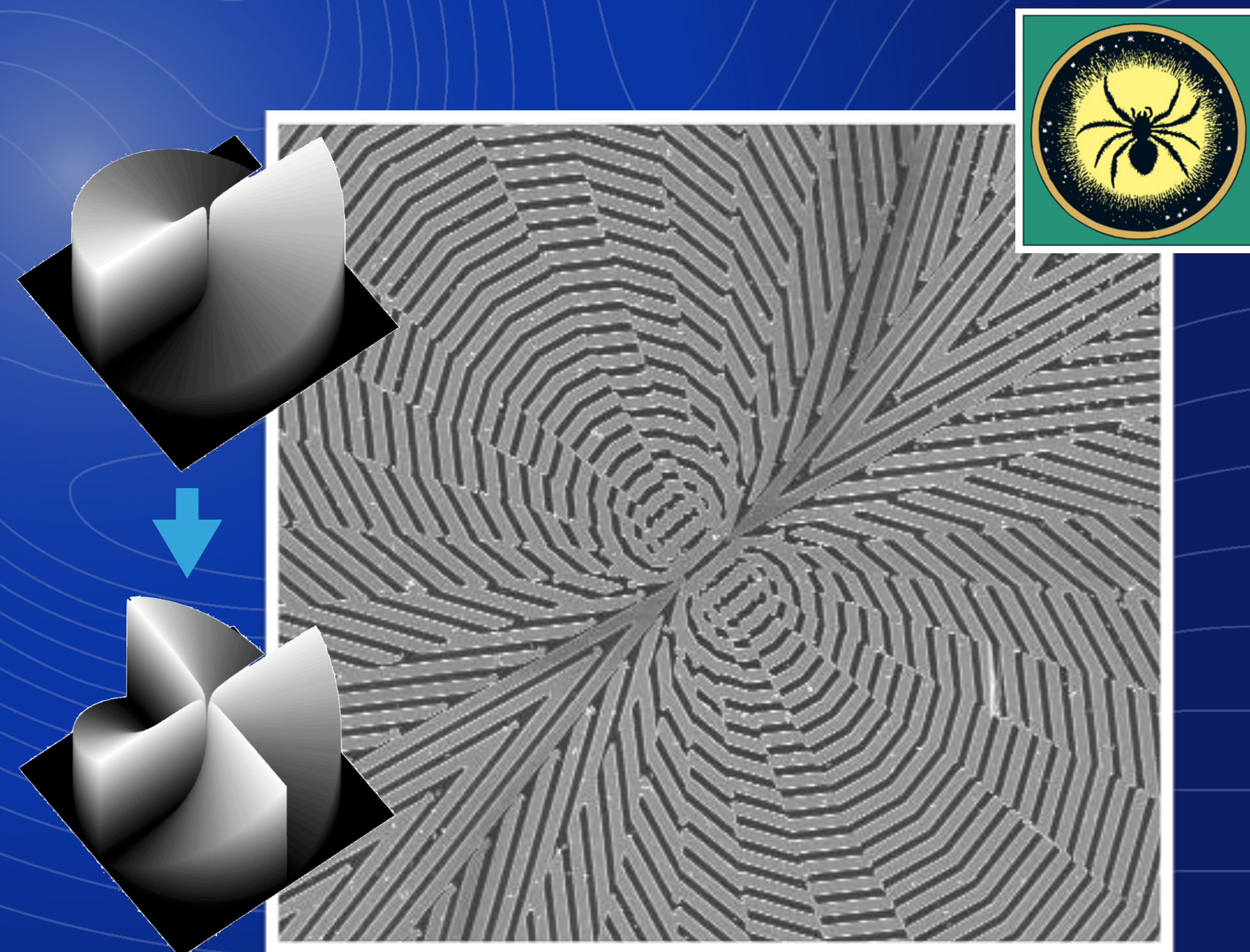


VORTEX

NEW RESEARCH PATHS AND FUTURE PROJECTS

EXTENDING THE AGPM CONCEPT

- AGPM first developed for thermal infrared (L, M, N bands)
  - excellent performance on ~30% bandwidth
- shorter wavelengths
  - science-grand K-band AGPM now available
  - H-band AGPM development started
- higher topological charges
  - less sensitive to tip-tilt, at the expense of larger IWA



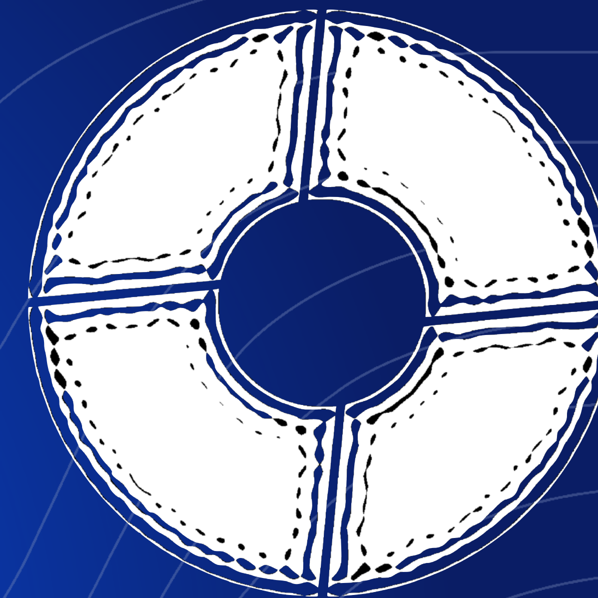
charge-4 vortex, work in progress

NEAR – NEW EARTH IN THE ALPHA CENTAURI REGION

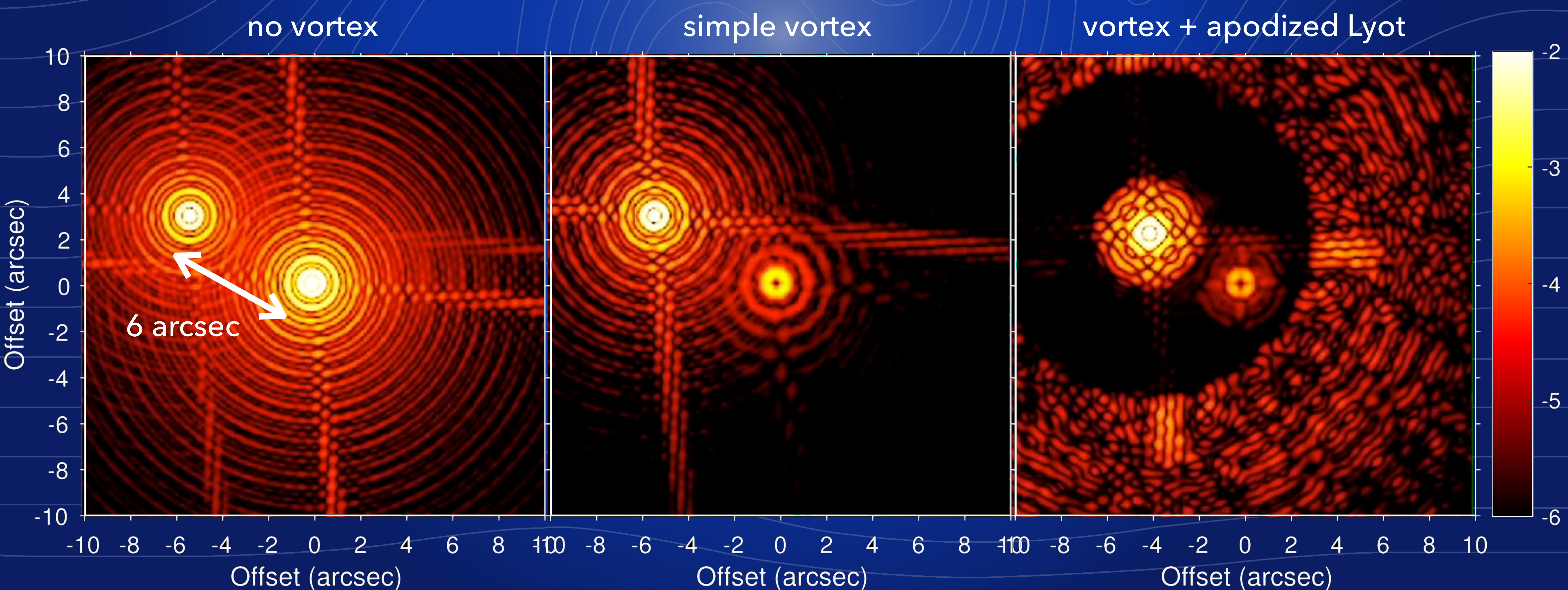
10702-12 KÄUFL
(Sunday talk)

- ESO project funded by Breakthrough Initiatives
  - what? search for rocky planets around α Cen A&B
  - how? refurbish VISIR and put it behind UT4+AOF
  - when? 100h observing campaign in mid-2019
- vortex team contribution
  - provide optimized AGPM for 10-12.5µm filter
  - design optimized Lyot stop
  - develop closed-loop focal-plane pointing control (QACITS)

NOTIONAL IMAGES OF ALPHA CENTAURI SYSTEM



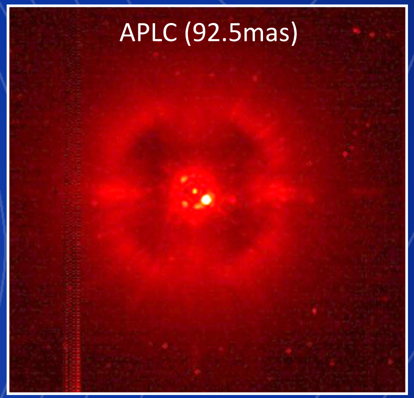
- habitable zone at 0.8″ - 1.1″ (A) or 0.5″ - 0.65″ (B)
- contrast ~10^{-6} for 2 $R_{\oplus}$ planet
- apodized Lyot stop to carve dark hole around secondary

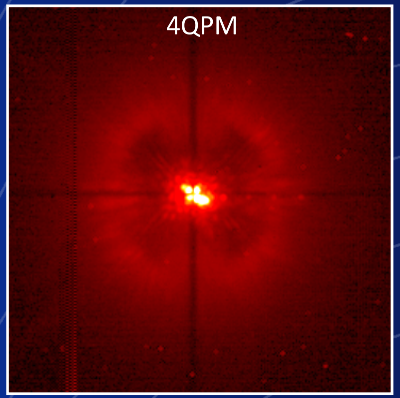


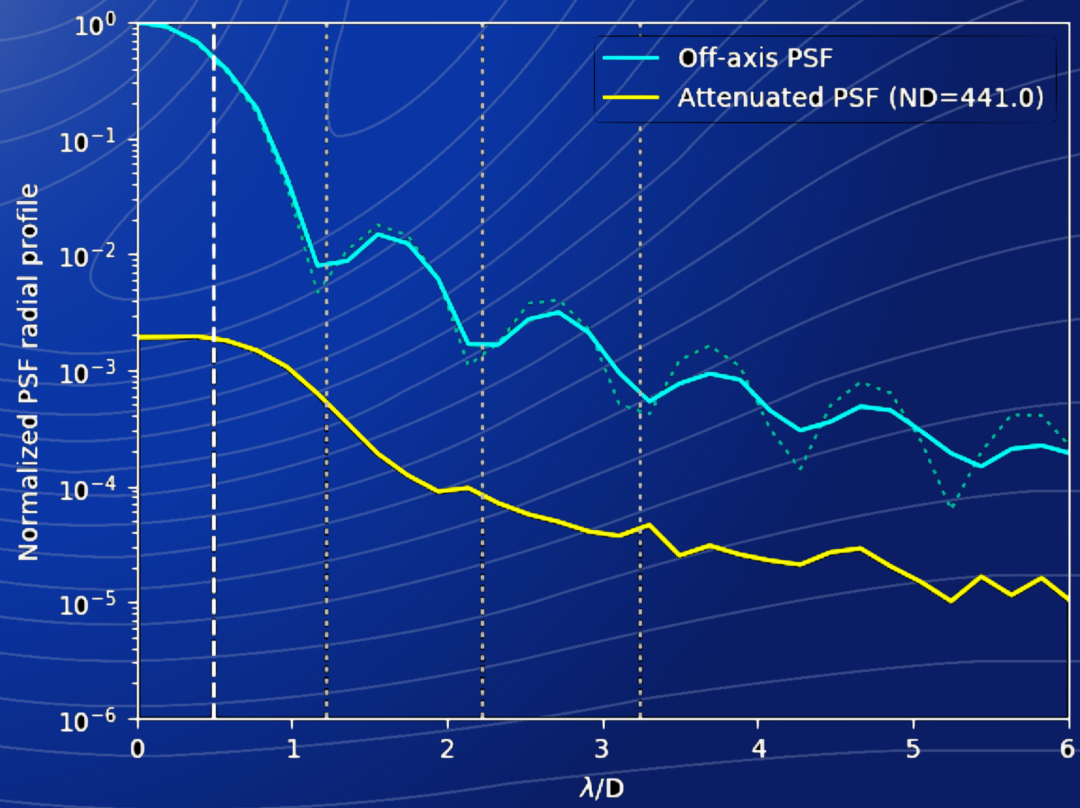
A VORTEX UPGRADE FOR SPHERE?

10702-145 HUBY (Monday poster)

- goal: open the 1-3 λ/D parameter space
  - increase number of detections
  - access a few RV planets
- need to identify main limitations to 4QPM performance
  - component degradation?
  - effect of dead actuators?
  - low-order WF aberrations?
- K-band AGPM ready to go!







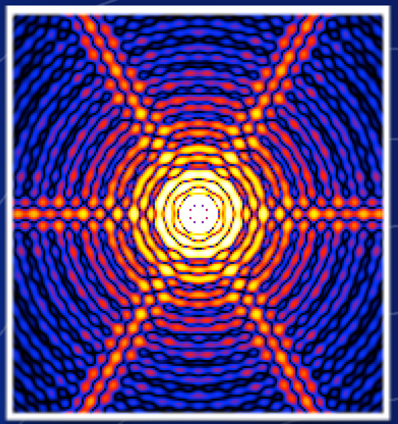
NEXT STEPS: VLT/ERIS AND ELT/METIS

10702-151 KENWORTHY
(Monday poster)

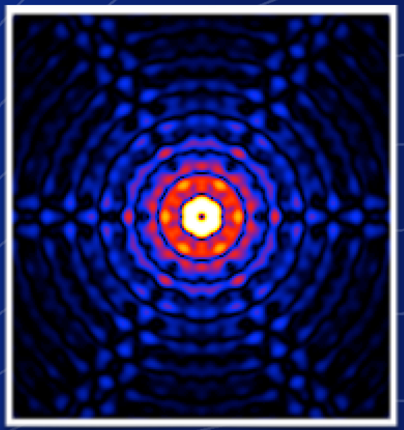
10702-369 KENWORTHY
(Thursday poster)

- ERIS: L & M band AGPMs
  - ✳ standard vortex coronagraph with simple Lyot stop
- METIS: L, M & N band AGPMs
  - ✳ ring-apodized vortex coronagraph: cancels diffraction from huge central obstruction

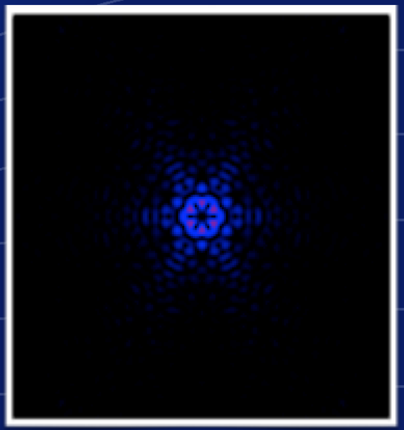
ELT



ELT+VC

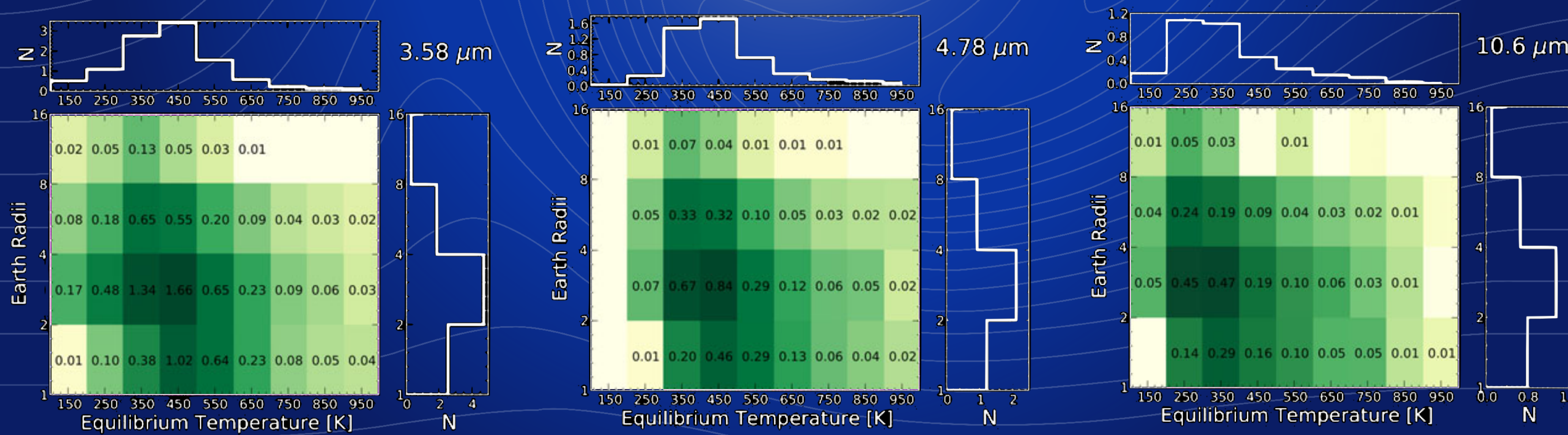


ELT+RAVC



METIS SCIENCE HIGHLIGHTS

- direct imaging of several RV planets
- potential to detect temperate rocky planets
- exoplanet characterization with high-res LM-band IFS



Quanz et al. (2015)

AROUND THE WORLD WITH

VORTEX

keep light spinning!