HI–5: A HIGH DYNAMIC RANGE THERMAL NEAR–INFRARED IMAGER FOR THE VLTI

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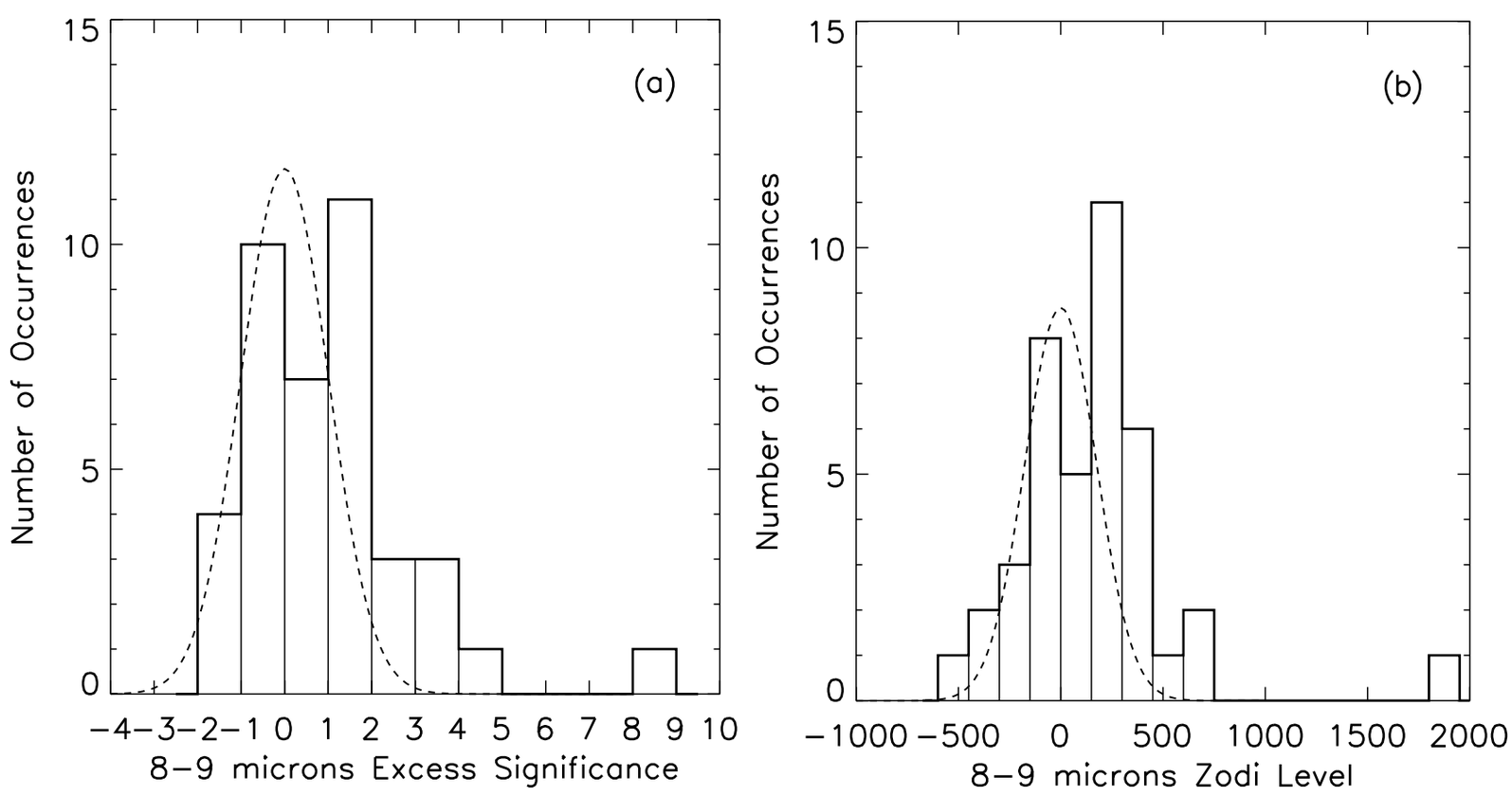
HISTORY OF HIGH CONTRAST STELLAR INTERFEROMETRY

- Three nulling experiments
  - Keck Interferometer Nuller (KIN)
  - Palomar Fiber Nuller (PFN)
  - Large Binocular Telescope Interferometer (LBTI)
- Two high-precision V^2 instruments
  - CHARA/FLUOR (& VLTI/VINCI)
  - VLTI/PIONIER (& IOTA/IONIC)
- Several closure-phase instruments
  - CHARA/MIRC
  - VLTI/PIONIER
  - Aperture masking experiments

NULLING AT KECK (KIN: 2008–2011)

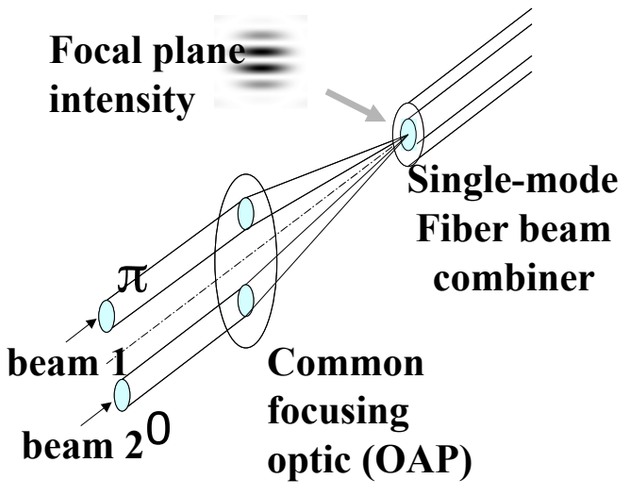
- N-band nulling with ~0.2% null accuracy
  - Mostly limited by background subtraction
- Survey of exozodiacal disks
  - 5/47 stars have mid-IR excess ~1%

Mennesson et al. 2014

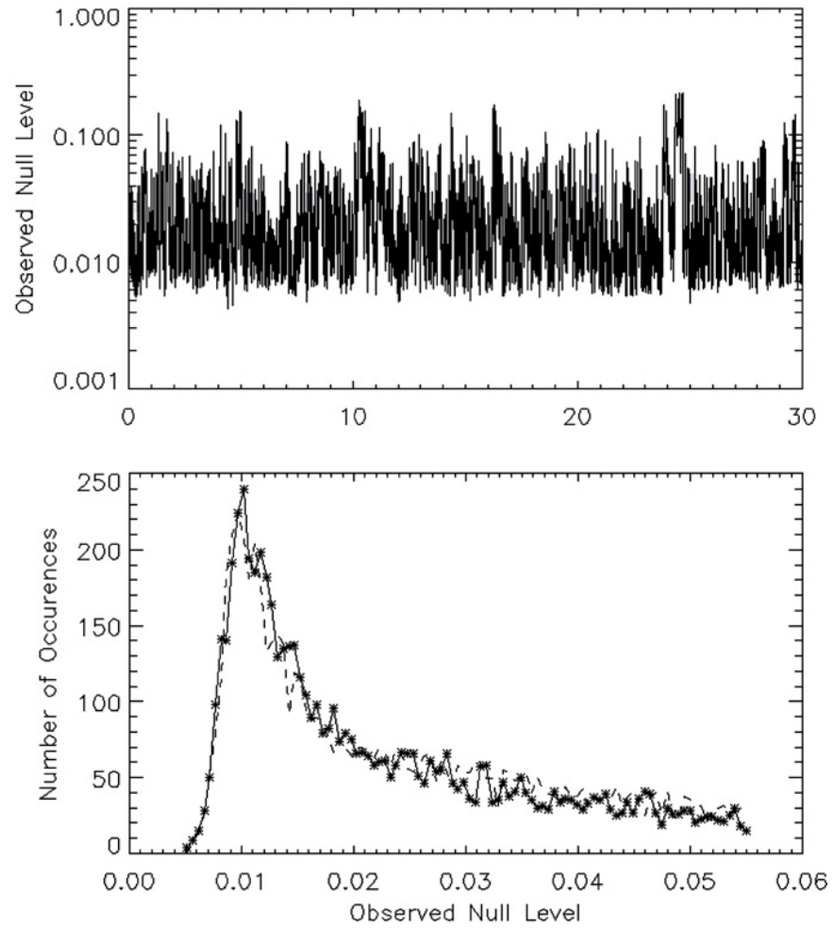


NULLING AT PALOMAR (PFN: 2008–2014)

- Two sub-pupils on Hale 200-inch telescope
  - In-fiber beam combination (nulling)
  - K-band instrument
- Development of a statistical "null self calibration" technique
  - Model the null fluctuations
  - Final accuracy ~0.01% after processing
- Used to constrain circumstellar emission around various targets



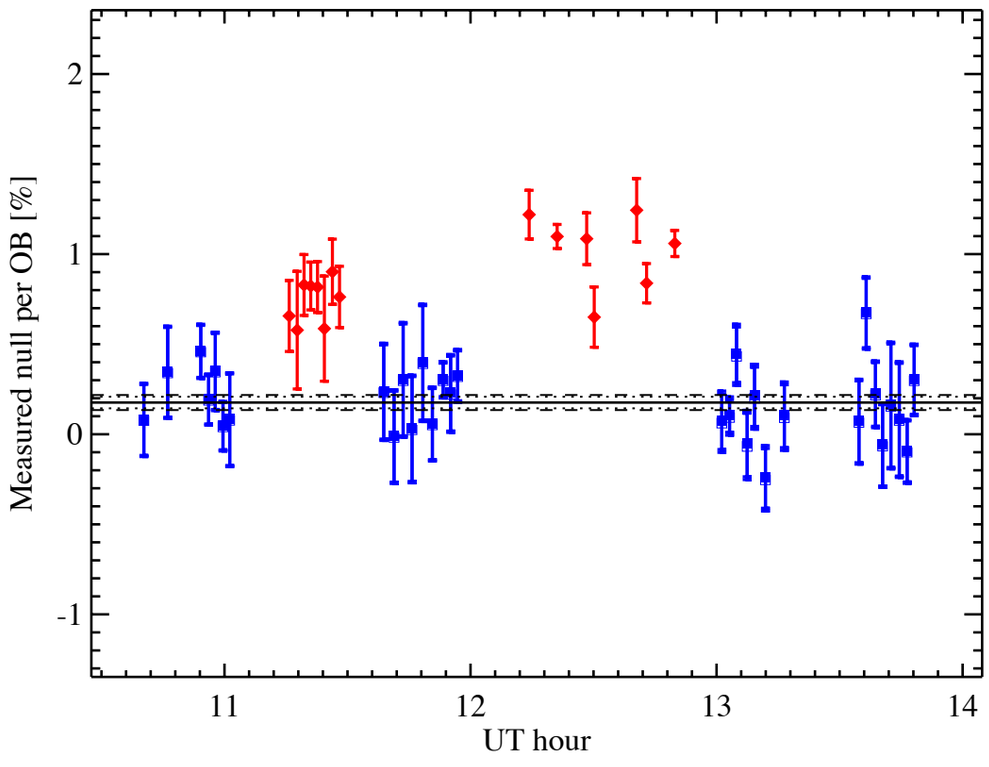
Hanot et al. 2011, Mennesson et al. 2011



NULLING AT THE LBTI (2013 – . . .)

- N-band nulling interferometer
  - Takes advantage of statistical NSC data reduction
  - Current null accuracy ~0.05%
  - Limited by background subtraction and PWV variations
- On-going survey of exozodiacal disks

Defrère et al. 2016

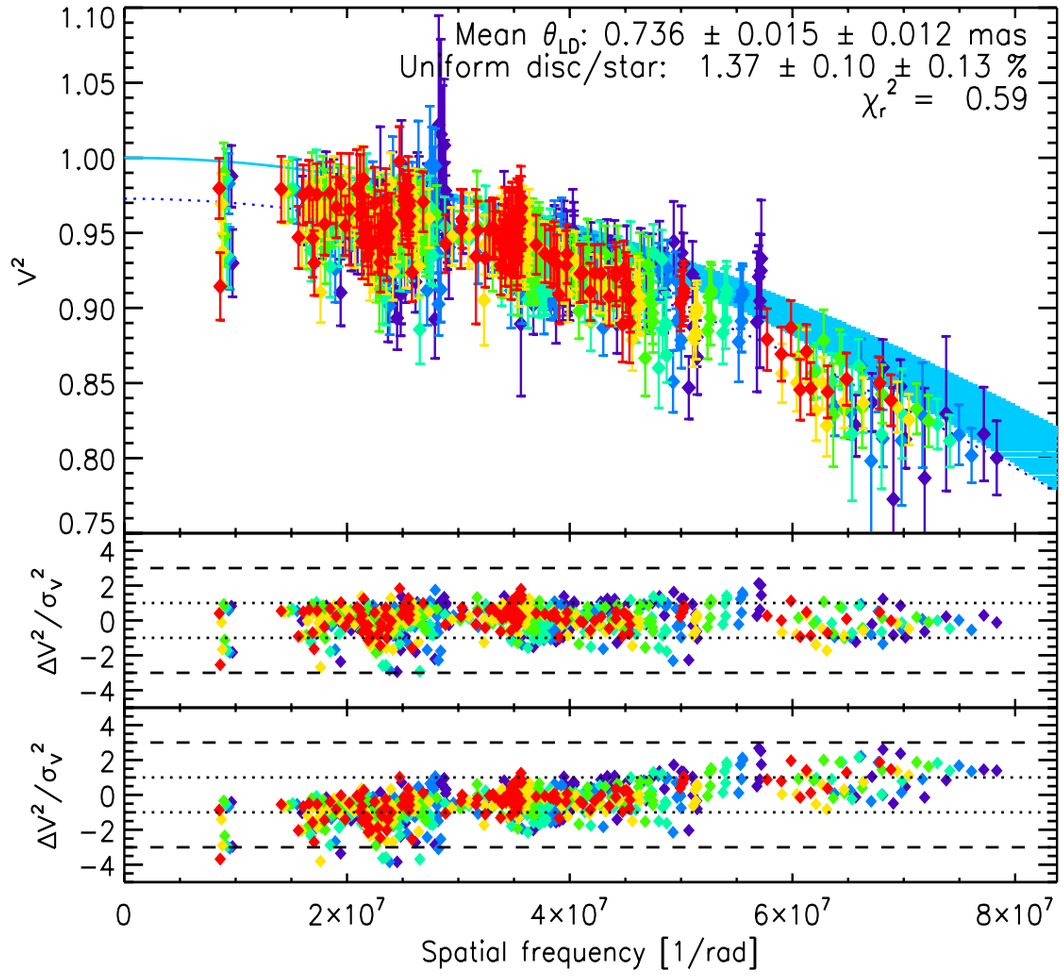


HIGH-PRECISION SQUARED VISIBILITIES

- FLUOR, VINCI, PIONIER, GRAVITY
  - Fibered / integrated optics beam combiners
  - Working at H/K bands
  - V^2 accuracy in the 0.5% - 1% range

- Used to search for faint circumstellar emission
  - Exozodiacal disk surveys
  - Envelopes around Cepheids

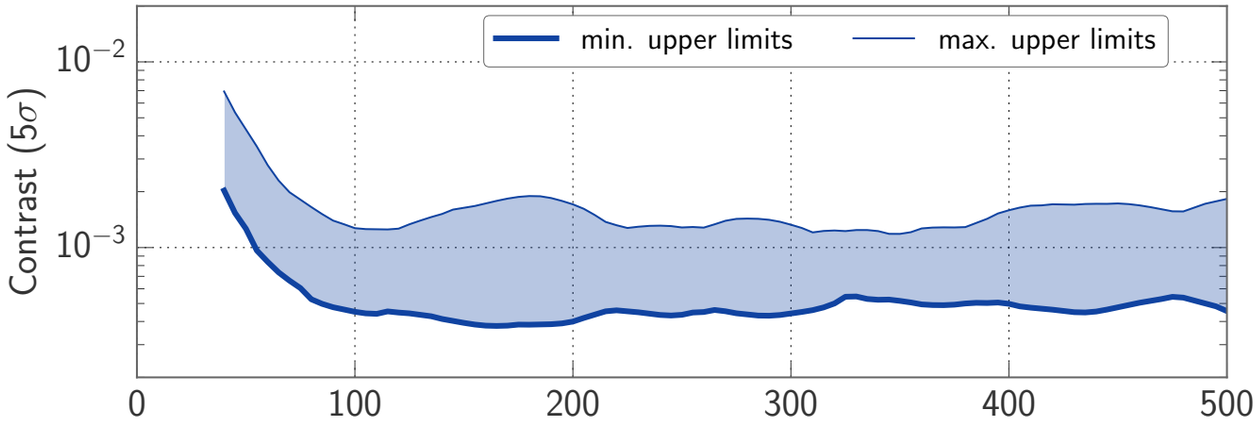
Defrère et al. 2012



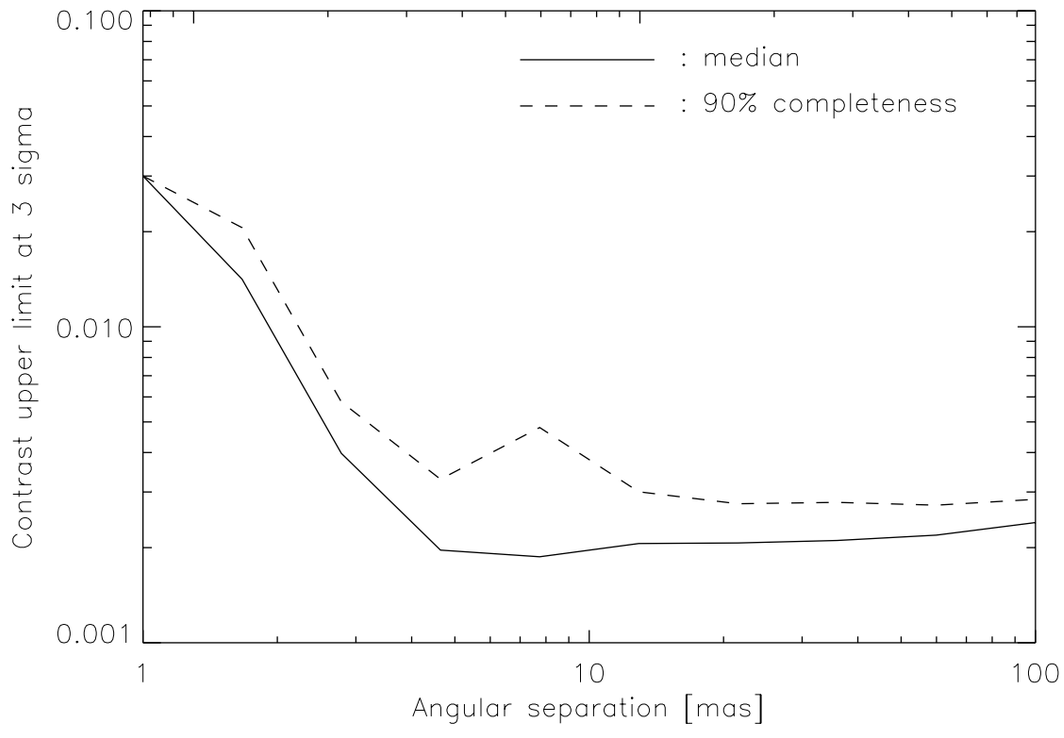
HIGH-PRECISION CLOSURE PHASES

- MIRC, PIONIER
  - Typical accuracy of 1 deg on individual data points
  - Dynamic range down to ~0.1% when accumulating data
- Aperture masking
  - Many CP measured at once
  - Typical dynamic range of 0.1%

Gauchet et al. 2016 (Fomalhaut @ NACO)



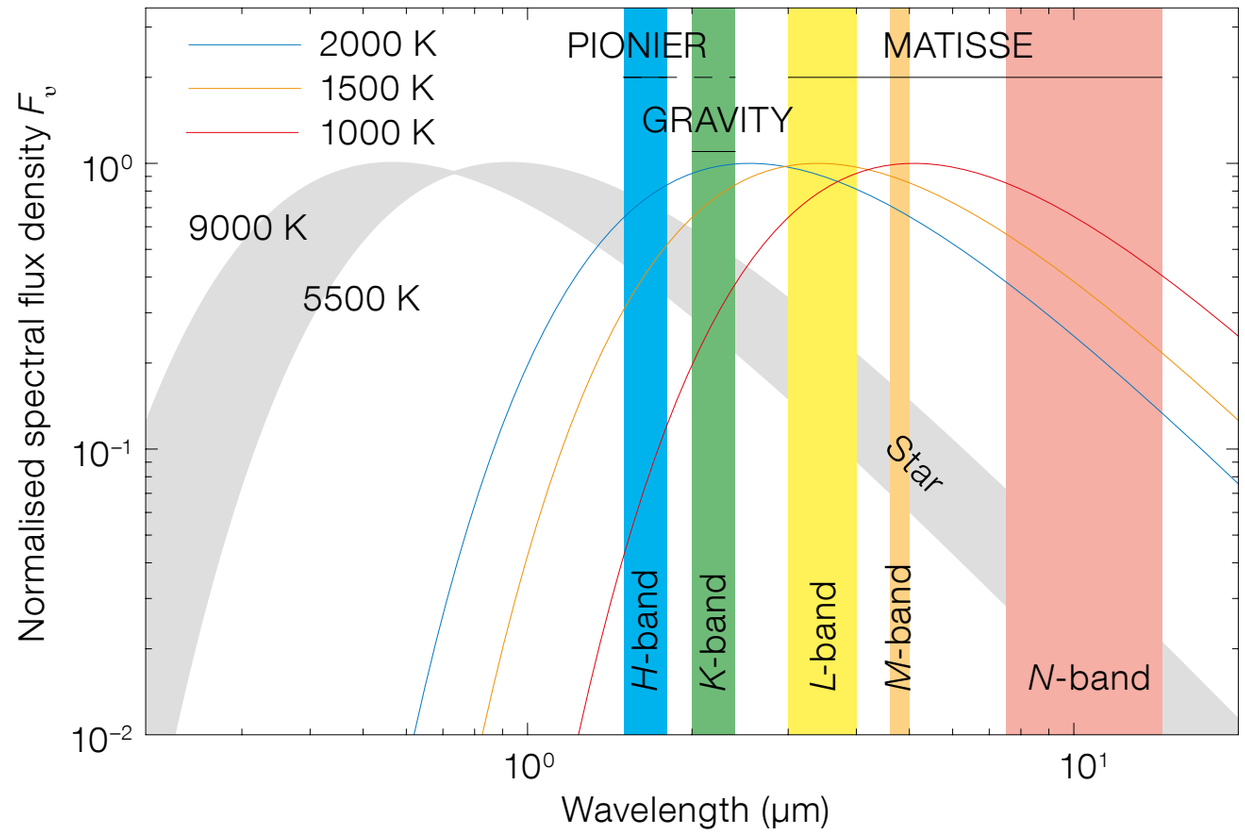
Absil et al. 2011 (Fomalhaut @ PIONIER)



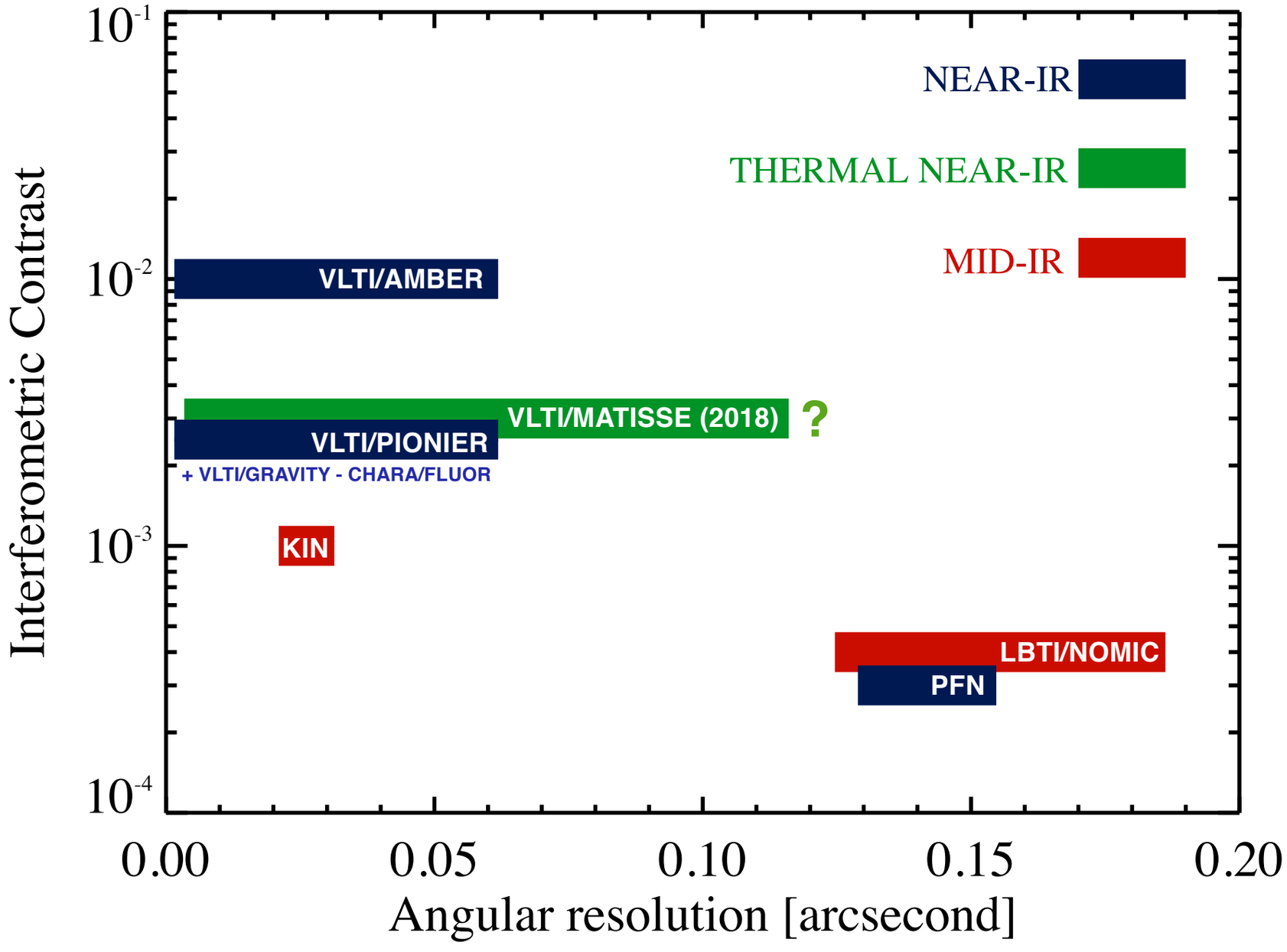
THE NEAR-IR / MID-IR GAP

- Dynamic range of a few 10^{-4} now at H/K and N bands
- Thermal near-infrared (3 - 5 μm) not addressed
  - Onset of thermal emission
  - Sweet spot for imaging young planetary systems
  - Many molecular species
  - Less thermal background wrt KIN and LBTI —> potential for higher accuracy

Ertel et al. 2015

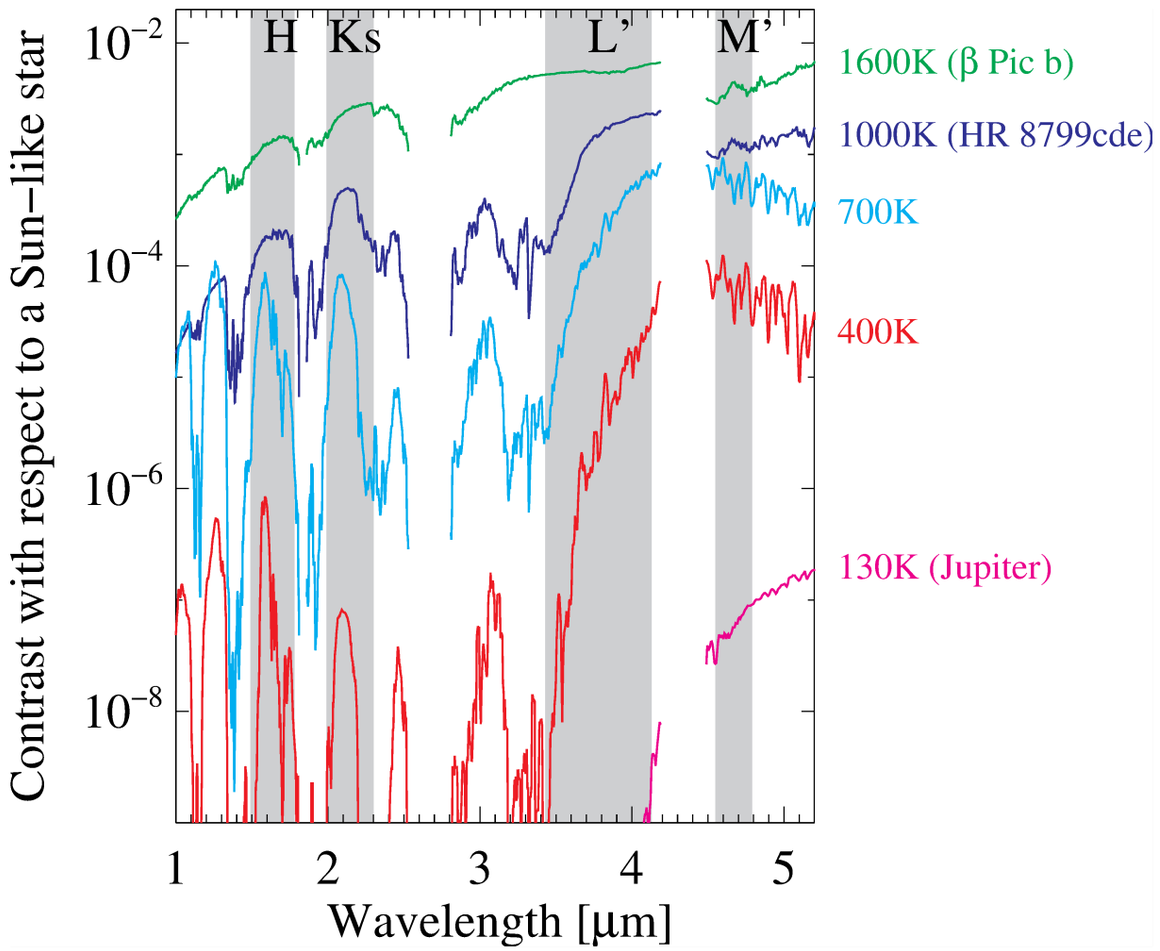


THE HIGH CONTRAST STELLAR INTERFEROMETRY LANDSCAPE



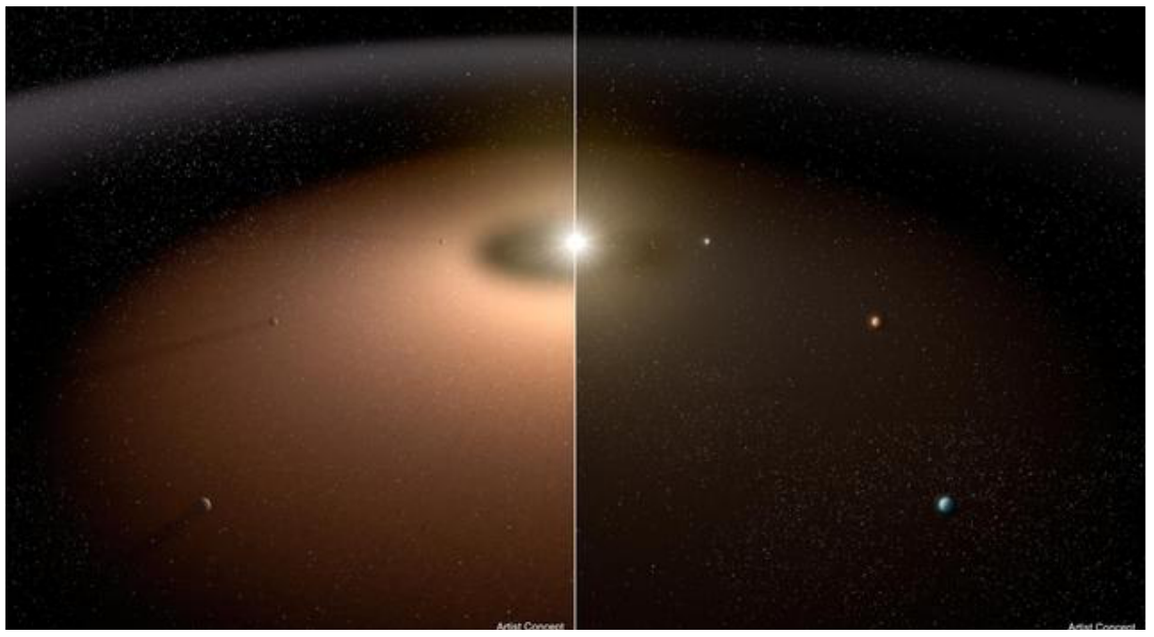
SCIENCE CASES (1/3): EXOPLANETS

- L-band = sweet spot for direct exoplanet imaging
  - Favorable star/planet contrast
  - Access to planet radius and temperature
  - Molecular bands / non-equilibrium chemistry
- 10 mag contrast enough for dedicated (sub)AU-scale survey in moving groups



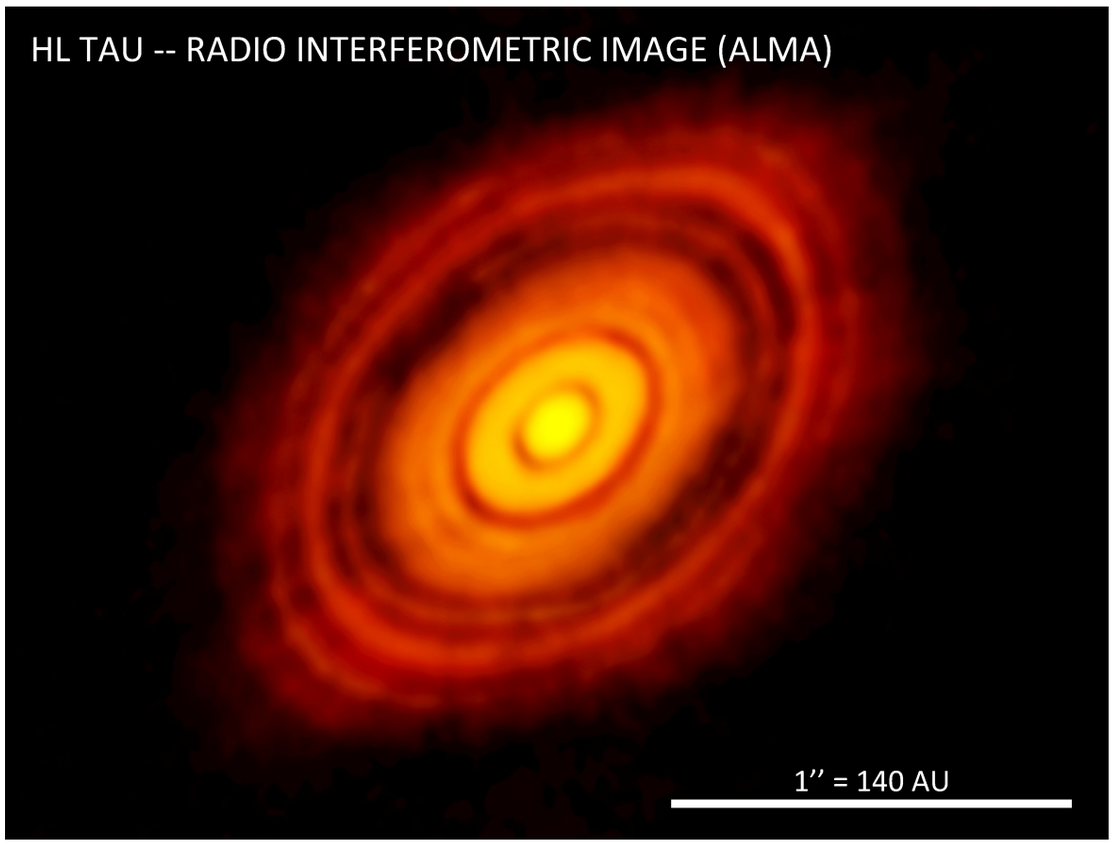
SCIENCE CASES (2/3): FAINT CIRCUMSTELLAR DISKS

- Exozodiacal disks
  - Thermal near-IR = missing link in current exozodiacal disk models (interactions between hot dust and asteroid belts)
  - Measuring the faint end of the exozodi luminosity function (complementary with LBTI in northern hemisphere)
- Other circumstellar disks
  - Cepheids, AGBs, etc



SCIENCE CASES (3/3): PLANET FORMATION

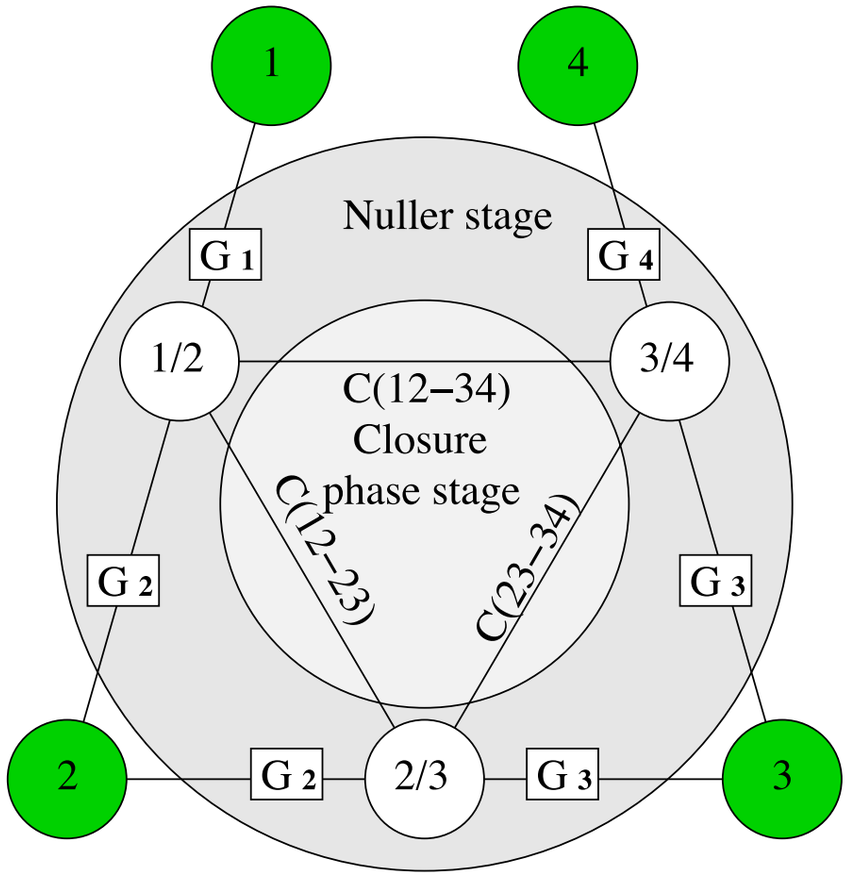
- Imaging young stars in nearby star forming regions
  - Search for young, forming planets (e.g., explore the cavities of transitions disks)
  - Similar angular resolution as E-ELT in near-IR and ALMA in sub-mm
  - Need good imaging capabilities in addition to high contrast
  - Prepare for PFI science



INSTRUMENT CONCEPT: "HI-5"

- L- and M-band beam combiner
  - At least four beams
  - Single-mode fibers and/or integrated optics
- A few possible architectures
  - PIONIER-like 4T-ABCD combiner
  - Multi-telescope nulling interferometer
  - Combination of nulling + close phases
- Spectroscopic capabilities

Lacour et al. 2014



A POSSIBLE PATHWAY TOWARD HI-5

- Build upon an existing infrastructure
  - Upgrade of PIONIER or MATISSE vs new instrument?
  - Take advantage of GRAVITY fringe tracking
- 1st step
  - Scanned or ABCD beam combiner à la PIONIER
  - Dynamic range $\sim 10^{-3}$
- 2nd step
  - Add high contrast (nulling?) capabilities + custom data processing
  - Dynamic range $\sim 10^{-4}$
- Long-term perspective
  - Add high-resolution spectroscopy based on astrophotonics?
  - Upgrade from 4 to 6 telescopes?

THE HI-5 CONCEPT STUDY (2017-2020)

- Refine the science cases
- Explore the GRAVITY / MATISSE dynamic range
- Test & compare available technologies
  - Lithium niobate vs fluoride vs chalcogenide beam combiners
  - In-lab study of intensity balance, chromaticity, polarization, etc
- Explore impact of data processing
  - Statistical NSC method has potential to significantly relax constraints on beam combination & fringe tracking
  - Develop framework for multi-telescope NSC method + lab tests
- Identify implementation pathway

THE HI-5 CONCEPT STUDY

- OPTICON funding for 3-yr study
- Coordination: D. Defrère @ ULiège
  - Main partners: Cologne, Paris, Grenoble (+Arizona, Sydney, etc)
  - Contributions welcome!
- Deliverable
  - Report including performance analysis and implementation plan
- Timeline
  - Kick-off / brainstorming meeting in Fall 2017 (to be announced)
  - Study phase: 2018-2019
  - Final report: early 2020