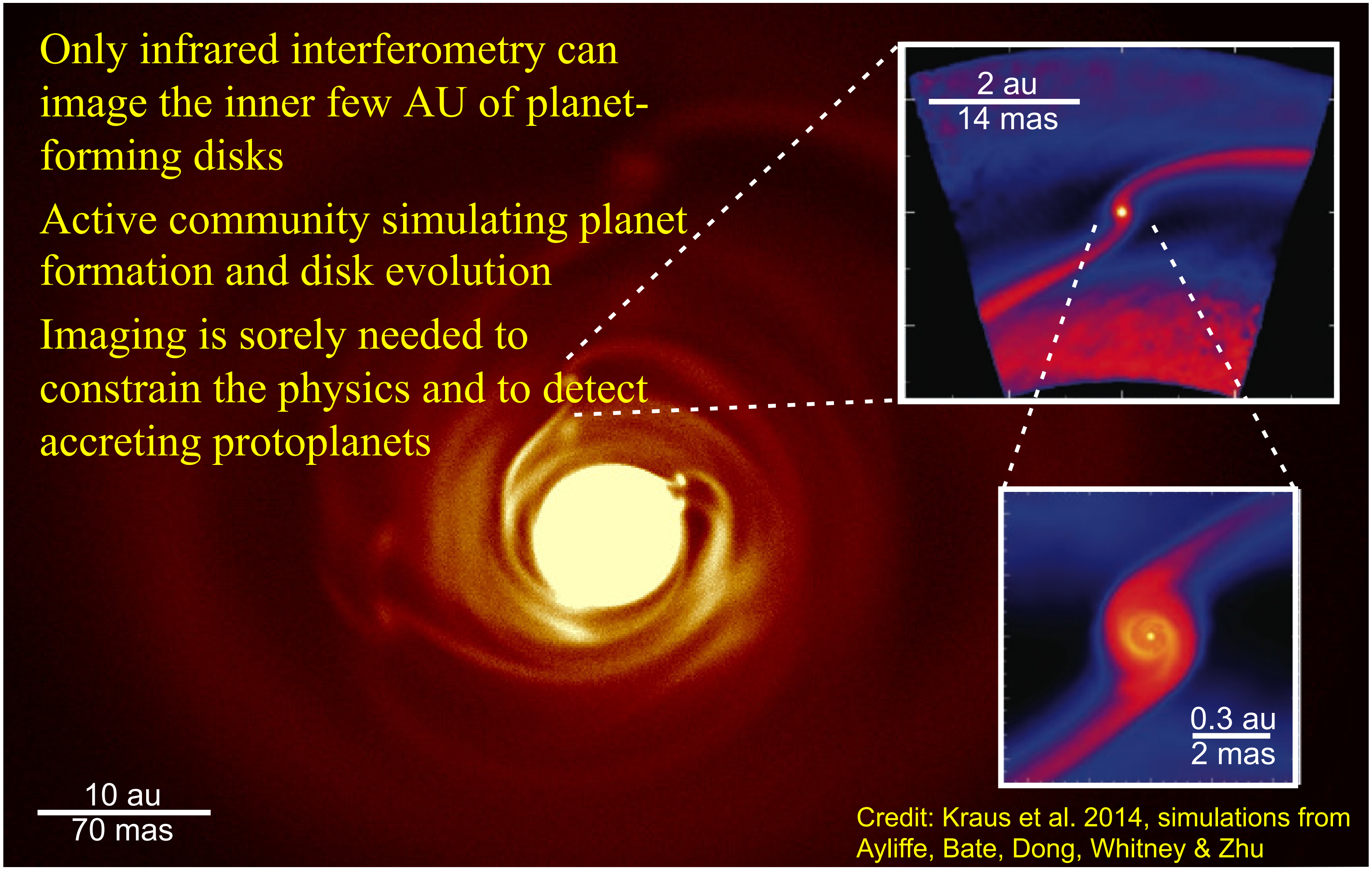
Plans for the new K-band combiner MYSTIC

John D. Monnier (U. Michigan)
Jean-Baptiste le Bouquin, Laurent Jocou (IPAG)
Rafael Millan-Gabet (IPAC)
Theo ten Brummelaar (CHARA)

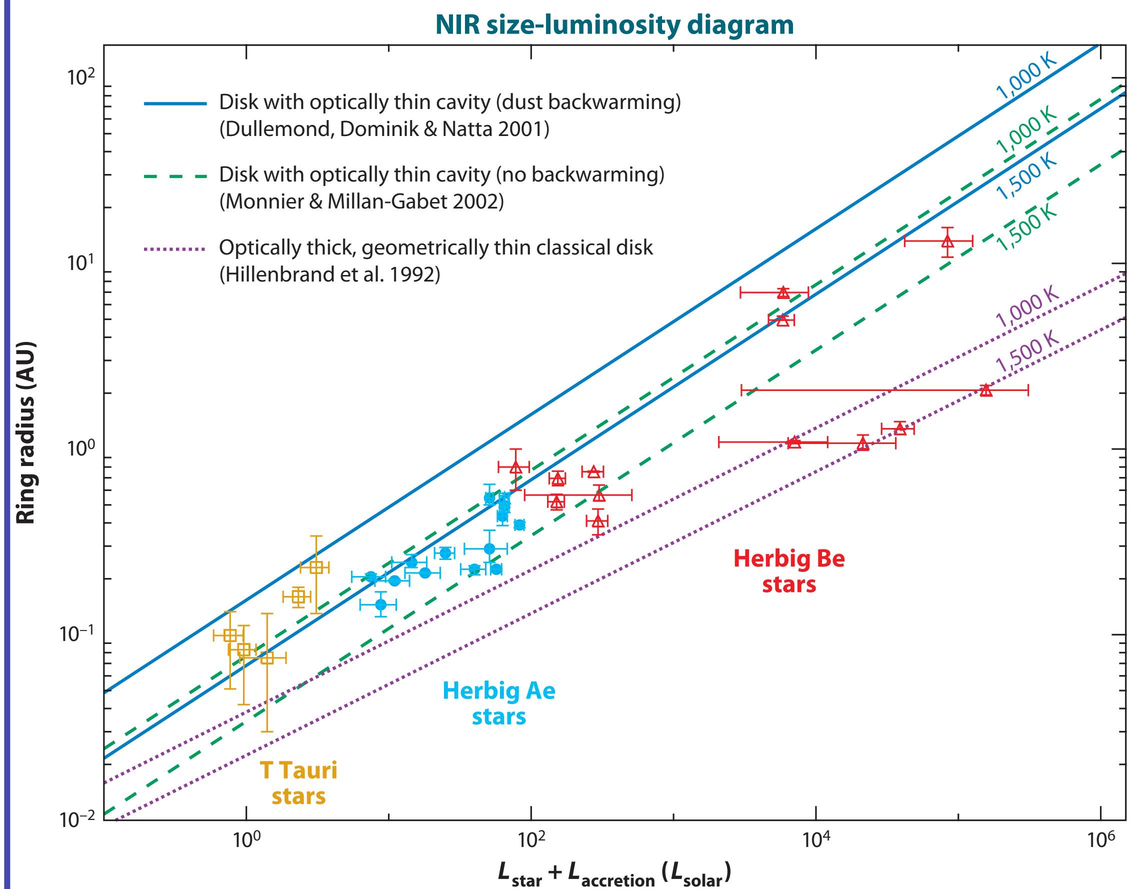
How do you planets form?

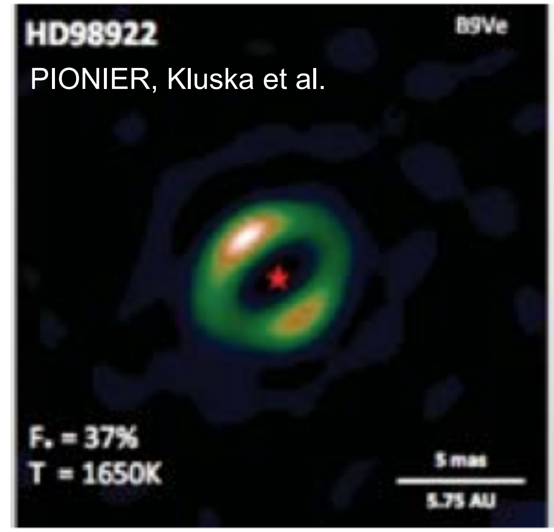
- Only infrared interferometry can image the inner few AU of planet-forming disks
- Active community simulating planet formation and disk evolution
- Imaging is sorely needed to constrain the physics and to detect accreting protoplanets

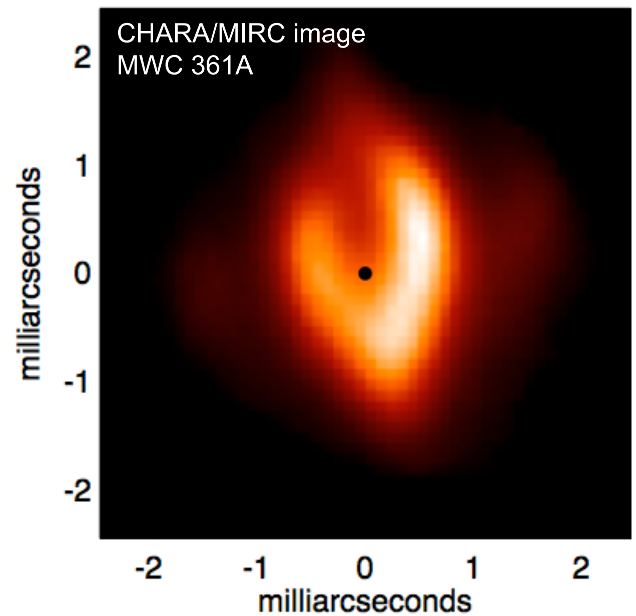


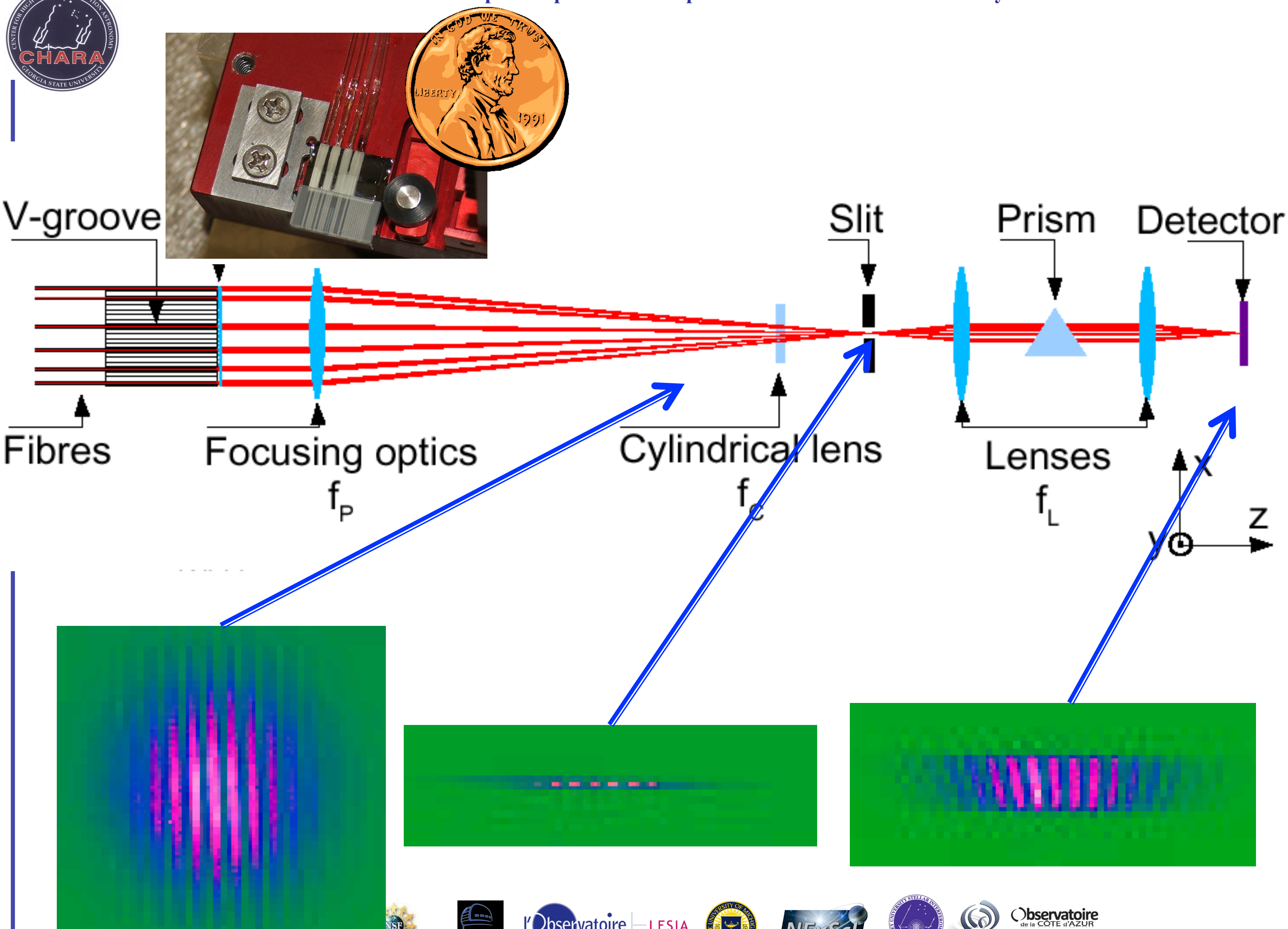
Credit: Kraus et al. 2014, simulations from Ayliffe, Bate, Dong, Whitney & Zhu

from Herbig sizes to images








V-groove
Slit
Prism
Detector
Fibres
Focusing optics
f_P
Cylindrical lens
f_C
Lenses
f_L
x
z
y

MIRC

Weaknesses

- Four times extra background at synthetic aperture
- 20% extra at photometric channel
- Eight times extra background at spectrometer

MIRC Current limiting magnitudes

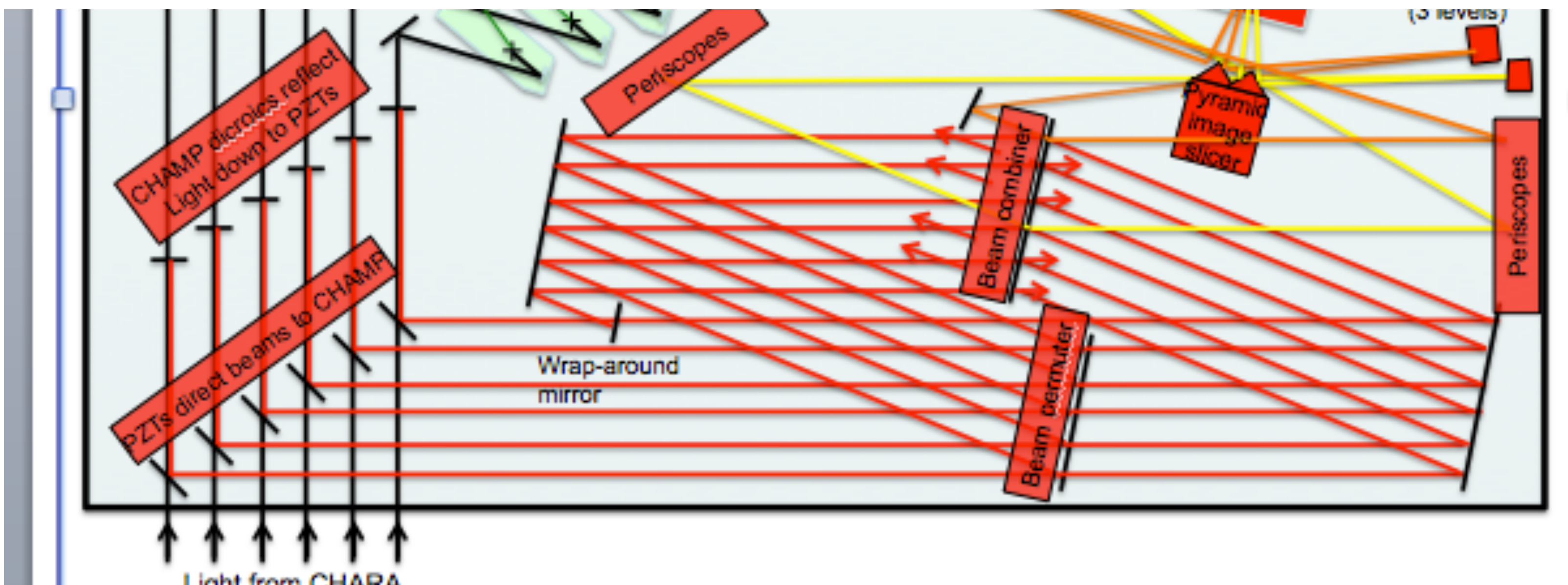
K~4.5 (compared to H~5.5)

no publications with K band

CHAMP

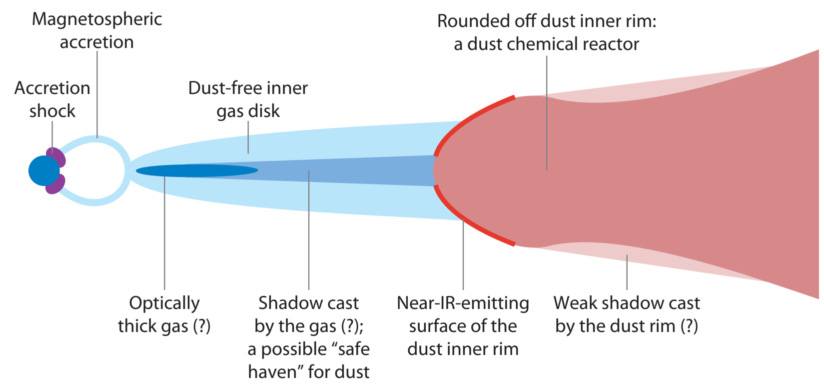
Weaknesses

- Two times extra background from first warm split
- Only 6 spanning baselines, no closure phases
- Limiting Mag K~6.5, but requires strong fringes

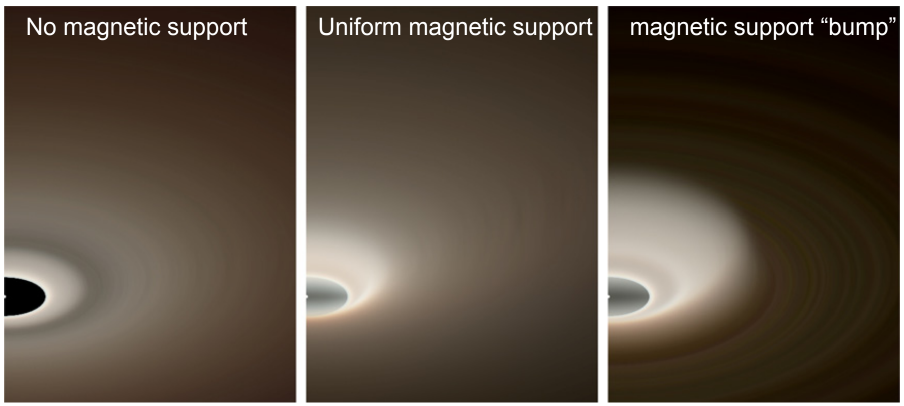


MYSTIC

- Michigan Young Star Imager at CHARA
  - Order of magnitude improvement in sensitivity with new camera
  - Focus on the 2-2.4 micron (K Band) where dust emission dominates over stellar light
    - Fully cryogenic combination w/ fiber optics
  - Image inner disks around "young Suns", the terrestrial planet forming region
- MYSTIC was funded this year by NSF, recruiting junior graduate student now



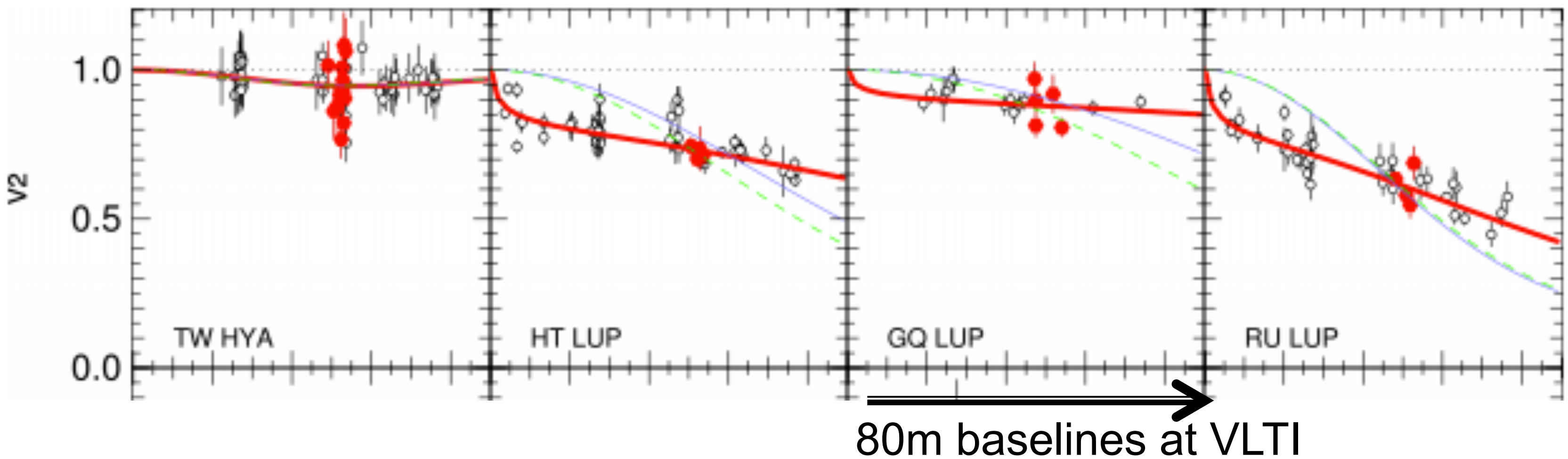
Synthetic images (log scale) of inner AU of "young Sun"



T Tauris disks

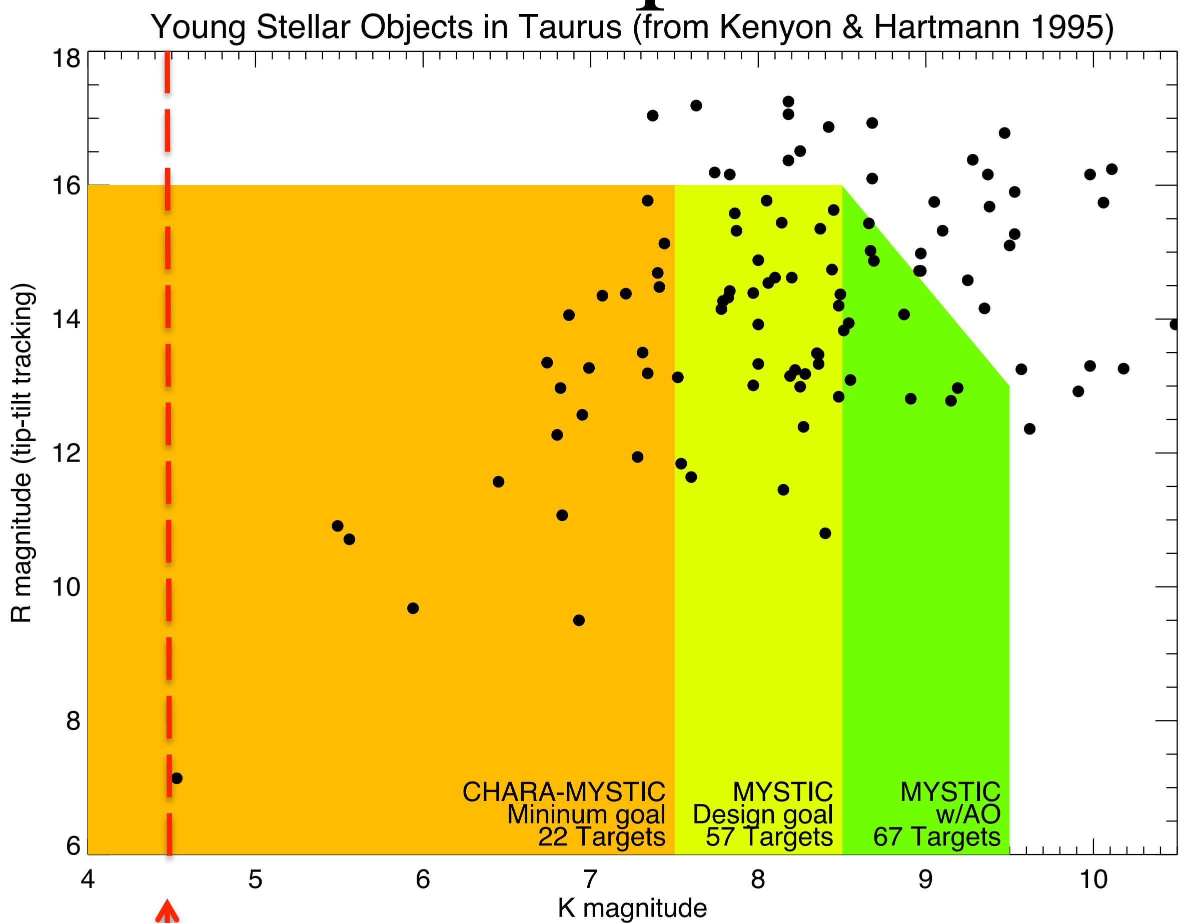
- TTS disks are 3-10x smaller than Herbig disks

Anthonioz et al. 2015



- TTS disks are 10-100x fainter!

MYSTIC will open TTS to imaging



Current MIRC sensitivity limit!

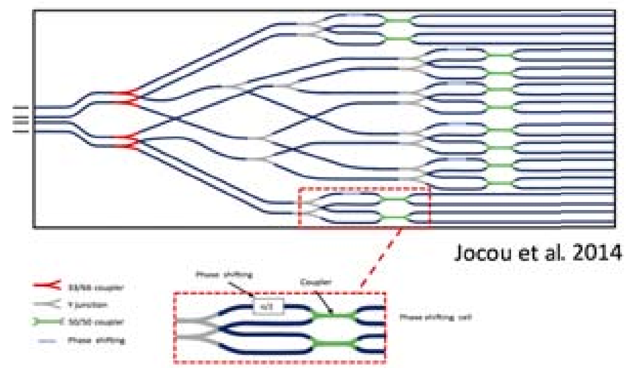
MYSTIC Architectures
a) 3x GRAVITY

- Grenoble has a number of spare GRAVITY integrated optics chips
- Combine three 4-beam combiners to allow all 15 beam combinations

+ Advantages: pair-wise system has no cross-talk; IO chips exist!

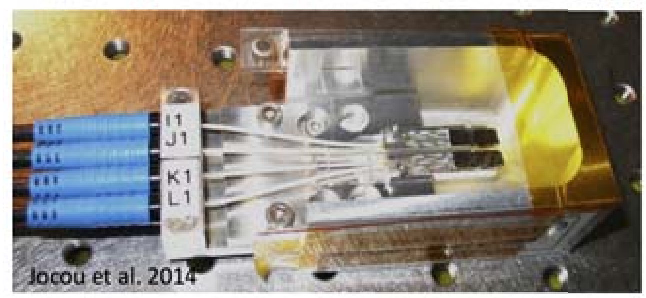
- Serious practical risks due to fiber splitting and packaging in dewar

Schematic of GRAVITY beam combiner



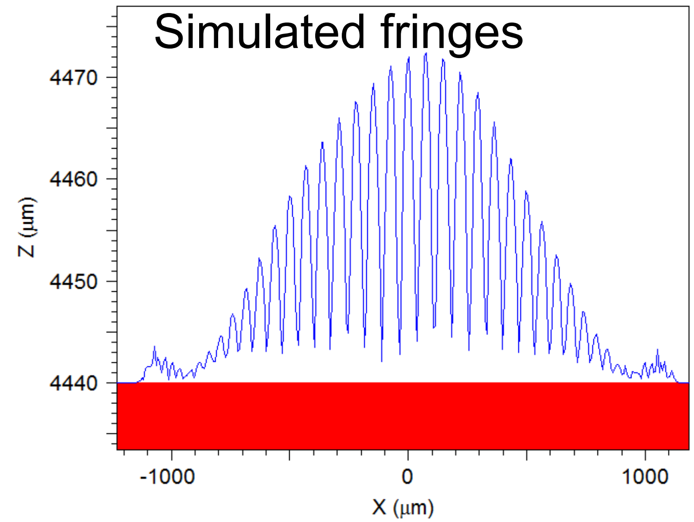
Picture of GRAVITY IO chip

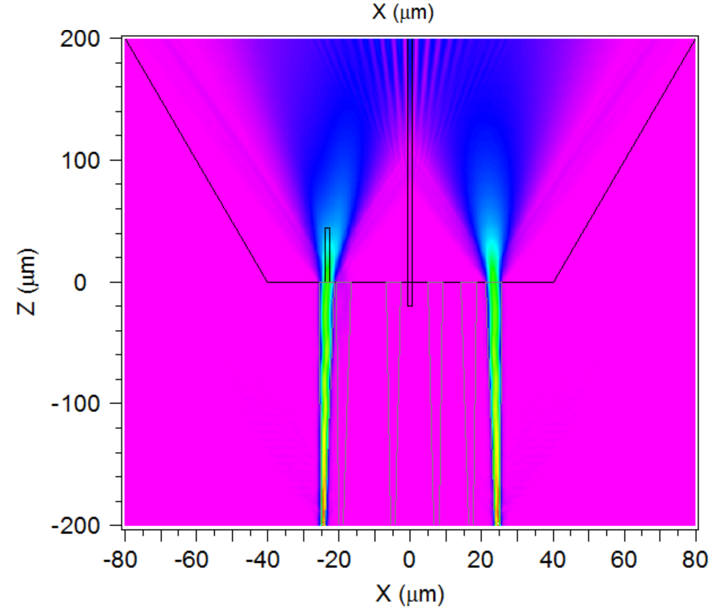
Fiber-to-GRAVITY interface made at IPAG



MYSTIC Architectures
b) New Integrated Optics

- Silica-based technologies difficult, lossy at these wavelengths and fairly expensive development
- New Chalcogenide effort at ANU (Madden, Goldsmith, Ireland) promises very high throughput and inexpensive development
  - MIRC-style
  - Pair-wise possible too
- Risks: immature tech, coupling challenges with this high index material



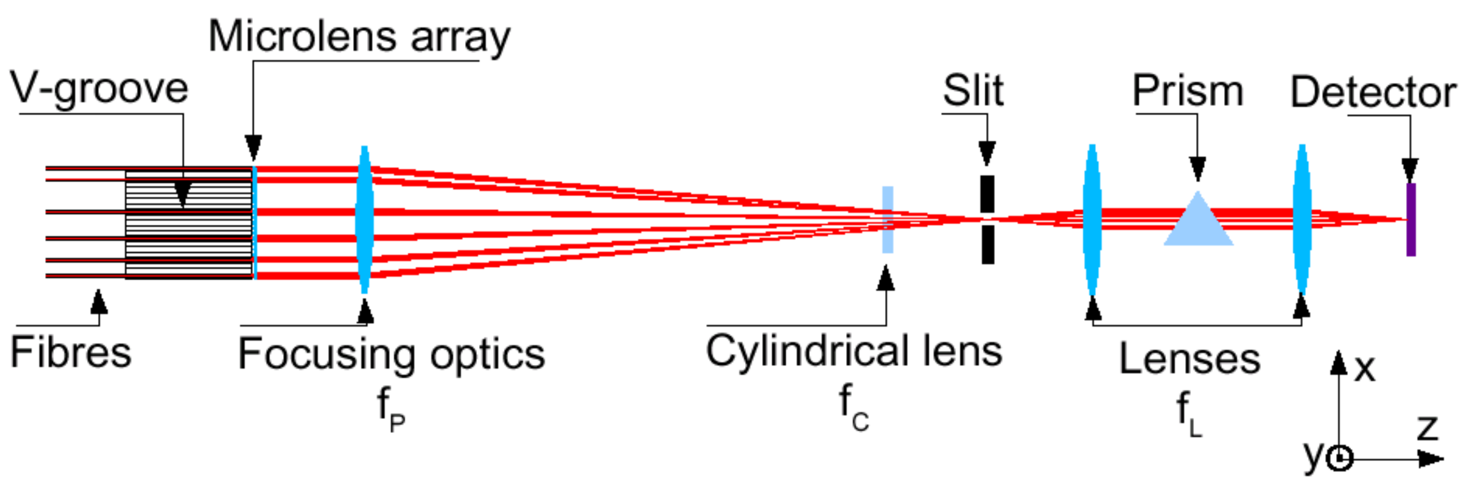


MYSTIC Architectures c) cryogenic MIRC

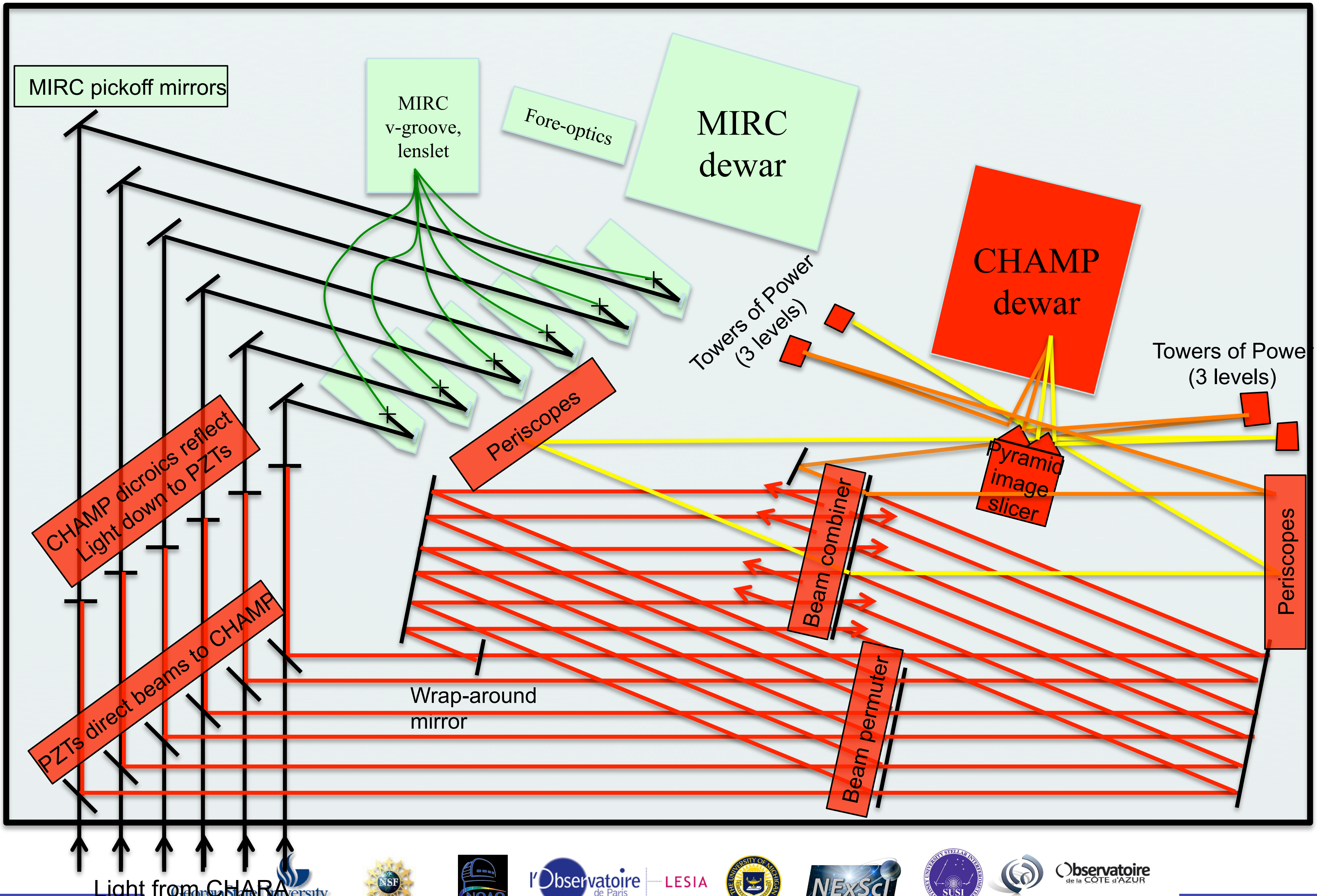
- MIRC is already a miniaturized image plane combiner
  - MIRC
- Components are simple to acquire

\- Risks: lots of small pieces, inelegant photometric channel, dealing with alignment *in vacuo*

\+ *We can build it now*



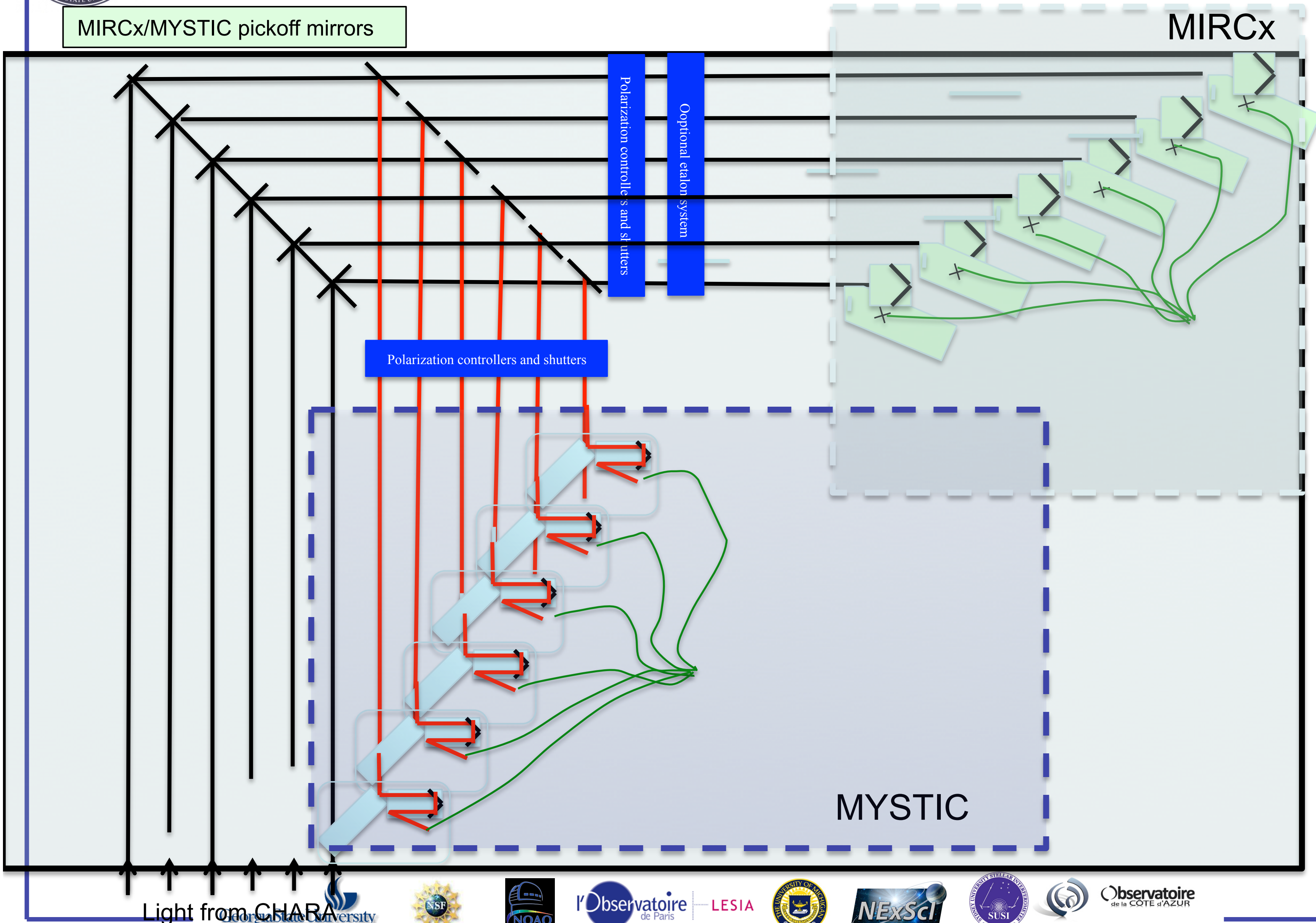
Beam Layout: Today



Goals of new beam layout

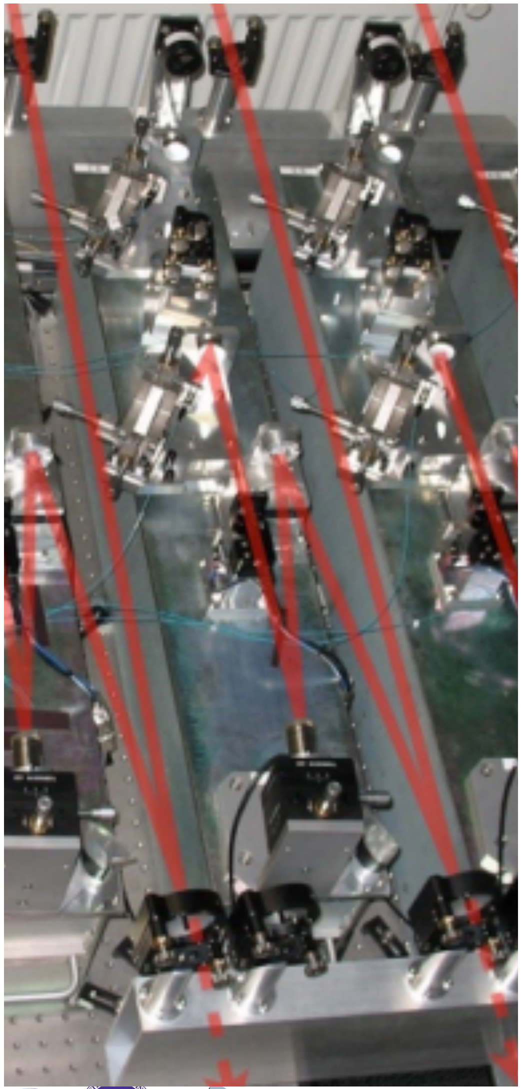
- Quick to switch in MIRCx/MYSTIC
- "Clean" OPD control for each beam for easy fine tuning with other CHARA instruments
- Need more room for:
  - new polarization controllers
  - shutters
  - wavelength-calibration étalon
  - Polarization calibration tools, e.g., half-wave plates

Beam Layout: Proposed



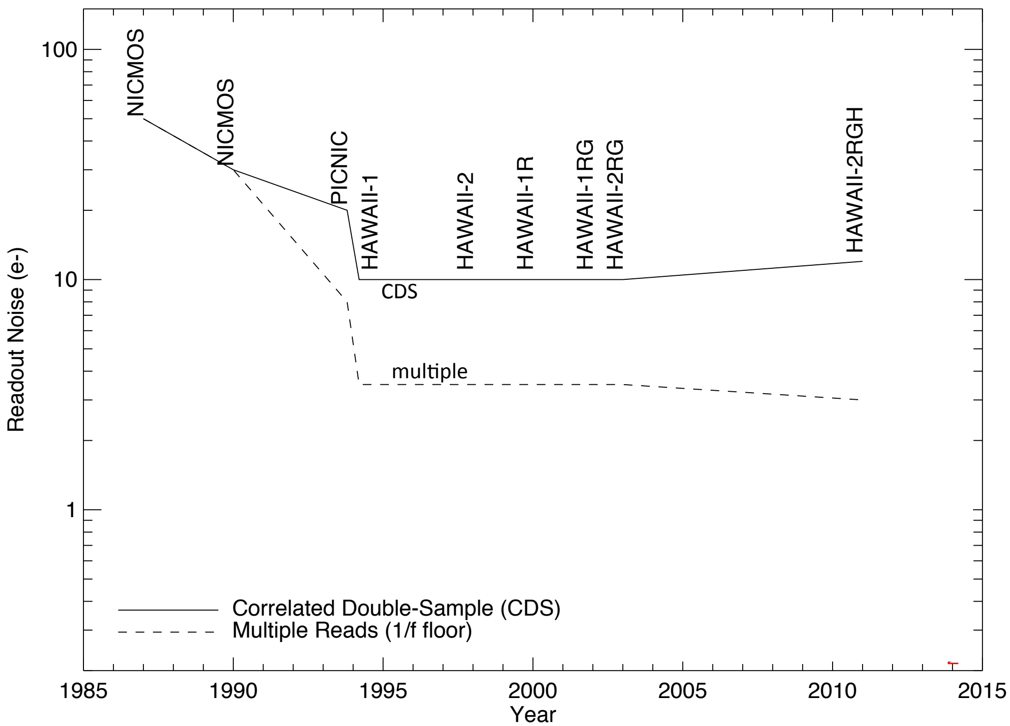
Other trades being investigated

- Choice of fibers
  - Single-mode, Polarization-maintaining fiber
  - Avoid Fluoride based on GRAVITY experience
  - Plan to characterize NUFERN fibers this spring w/ Grenoble partners
- Lithium-Niobate plates for dynamic polarization control
  - PIONIER legacy
  - Also add Wollaston mode to MIRCx + MYSTIC

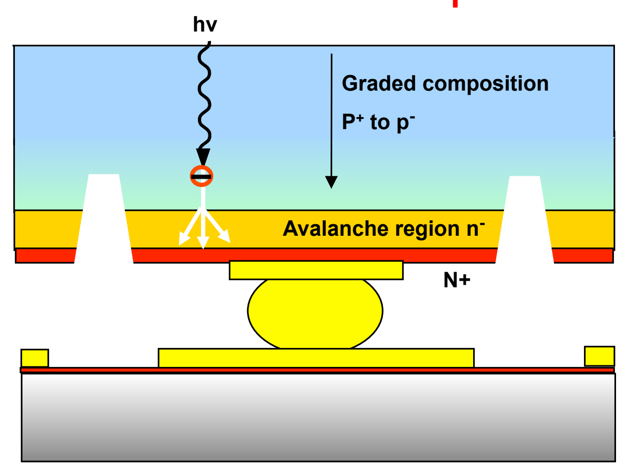


Breakthrough in near-IR Avalanche Photodiode Arrays

Historical progress in reducing readnoise



An APD in each pixel!

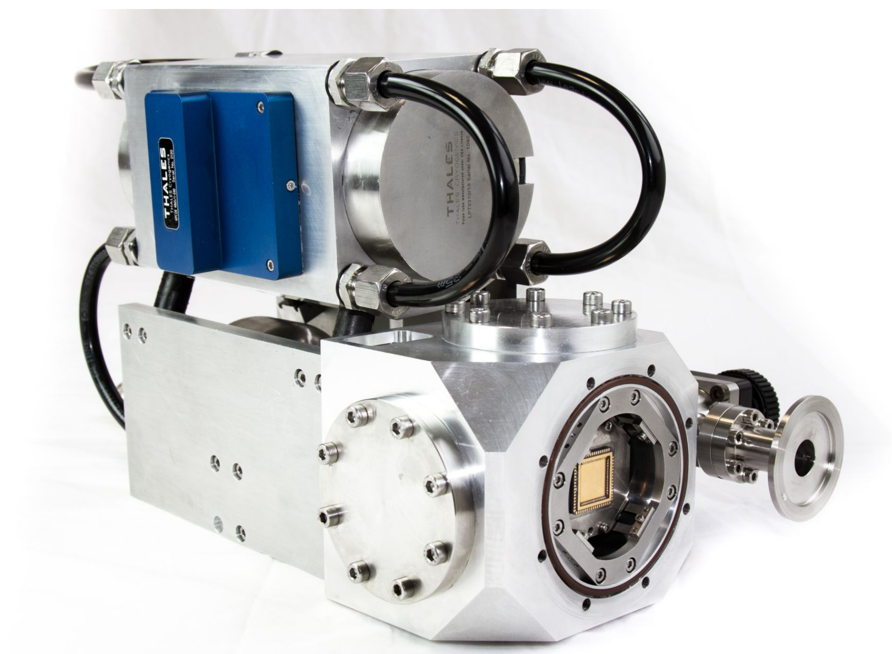


Schematic from Baker et al. (2012)

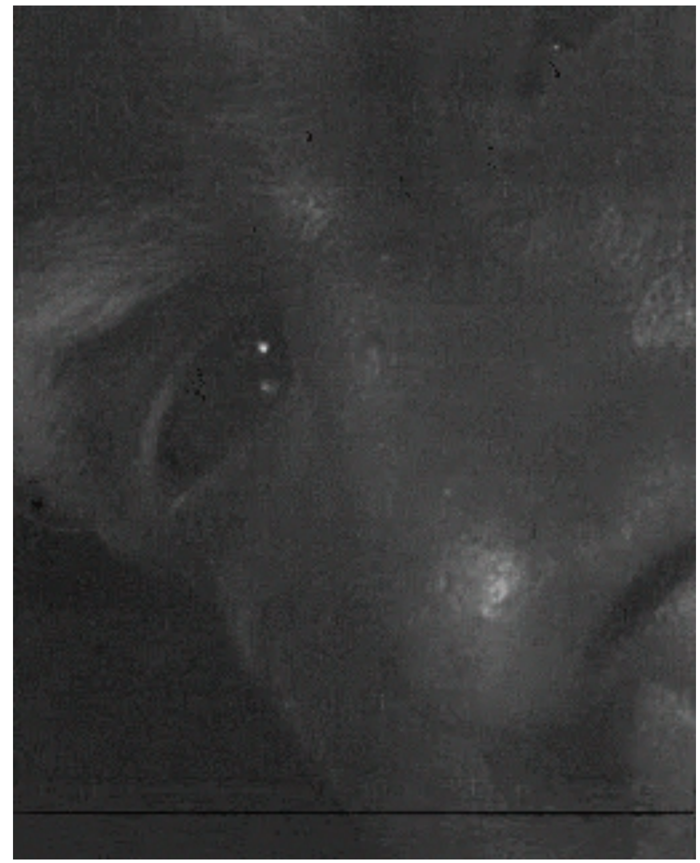
First Light: C-RED

Best near-IR camera in the world
Based on SELEX SAPHIRA chip

- 80% QE
- <1 e- read noise



2400 frames/second. ~1 e- read noise



Partners

- Michigan
  - PI Monnier + new grad student
  - Design, construction, integration at UM before shipping to Mt. Wilson
  - Welcome postdoc participation via fellowship applications, e.g., Sagan, Hubble, Marie Curie, McLaughlin (UM), Michigan Society of Fellows
- Grenoble
  - Jean-Baptiste le Bouquin, will spend 2 years at UM
  - Laurent Jocou, expert from GRAVITY, consultant
  - Cryogenic tech;, e.g., fiber feedthroughs, mounting
  - Fiber equalization and ruggedization
- Caltech/IPAC
  - Rafael Millan-Gabet, commissioning and consulting
- CHARA
  - Theo ten Brummelaar, software and CHARA integration
- Also .. Exeter
  - Close connection with MIRCx team: Stefan Kraus & Narsi Anugu

CHARA 2020

<u>"Building out" the infrared infrastructure of CHARA</u>

(funding in hand!)

MIRCx + MYSTIC

- Built on best available eAPD array detectors
- Optimized for CHARA AO
- Full J,H,K simultaneous observing
- All telescopes available for flexible baseline bootstrapping across wavelength bands
- Possible new polarization and high spectral resolution modes
- Reduced operations burden: no more LN2 fills!
- 6-beam group delay tracker for FRIENDS