Project Update:

**MYSTIC**
Michigan Young STellar Imager at CHARA

John D. Monnier, Jean-Baptiste le Bouquin, Narsi Anugu, Stefan Kraus, Jacob Ennis, Ben Setterholm, Cyprien Lanthermann, IPAG: Laurent Jocou
CHARA: Theo ten Brummelaar

* Funding thanks to National Science Foundation
Science Motivation

I. Imaging Inner disks of Young Stellar Objects

<table>
<thead>
<tr>
<th></th>
<th>MWC275 (Herbig Ae)</th>
<th>V1295 Aql (Herbig Be)</th>
<th>SU Aur (T Tauri)</th>
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</thead>
<tbody>
<tr>
<td>J/H/K uncorrelated</td>
<td>6.2 / 5.5 / 4.8</td>
<td>7.2 / 6.6 / 5.9</td>
<td>7.2 / 6.6 / 6.0</td>
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<tr>
<td>Visibility (V) on longest baseline</td>
<td>0.3? / 0.2 / 0.1</td>
<td>0.5? / 0.3 / 0.2</td>
<td>0.6? / 0.5? / 0.4</td>
</tr>
<tr>
<td>J/H/K correlated</td>
<td>7.5 / 7.2 / 7.3</td>
<td>8.0 / 7.9 / 7.6</td>
<td>7.8 / 7.3 / 7.0</td>
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II. Precision Closure Phases (exoplanets)

III. Polarization to detect scattered light

IV. Spectro-Interferometry (Br-gamma)

Integration with MIRCx for J+H+K simultaneous observing (+visible?)
Instrument Architecture

• 1.9-2.4 micron sensitivity
  • Assumes CHARA AO working before commissioning
• CRED-One camera + 200K cryogenic dewar
• 4 beam mode for high sensitivity
  • Using spare GRAVITY IO chip
  • No cross talk
• 6 beam mode for snapshot imaging
  • Using “classic” MIRC-style combiner
• Wollaston mode for polarization experiments
• Many options for grisms for spectroscopy
Team

• John Monnier (PI, UM)
• Jean-Baptiste le Bouquin (UM/IPAG)
• Narsi Anugu (Exeter)
• Stefan Kraus (Exeter)
• Ben Setterholm (UM graduate student)
• Jacob Ennis (UM undergraduate)
• Cyprien Lanthermann (IPAG grad student)
• IPAG: Laurent Joucou
• CHARA: Theo ten Brummelaar ++
Layout on “MIRC Table”
Warm optics (detail)

- New Polarization controller
  - Based on Lazareff et al. LiNbO3 plates
  - Tested for MIRCx already
Warm optics (detail)

- Fiber injection using OTS components
Single-mode IR Fibers

• Nufern PM1950
  • Low-OH silica fibers
    • 7%/m loss at 2.2μm, 15%/m at 2.37μm
  • Less expensive and robust than fluoride fibers
  • NA 0.20, compatible w/GRAVITY NA 0.19

• Fiber Feedthrough into Dewar
Cold optics Overview
Two cold combiners

- GRAVITY
  - 4 beams = 6 fringes
  - Each fringe has 4 outputs ABCD => 24 outputs
  - 180 μm separation
Two cold combiners

- MIRC-style

Custom-thinned Microlens array
Glued to vgroove
Two cold combiners

• MIRC-style
  • New approach to photometric channels
    • Reimage microlens array itself onto slit
Two cold combiners

- MIRC-style
- New pattern

Cross-talk resistant power spectra

Remove an inner fiber
For cross talk resistance!
Some Challenges*

- **Length-matching of fibers**
  - 2mm -> 5% visibility loss
  - Mitigation: use glass wedges in front to remove differential OPD

- **Cryogenic Mounting and IO/fiber interfaces**
  - Learning from GRAVITY and IPAG expertise

- **Mechanical Design of 200K Dewar**
  - We want 200K to be the cold plate temperature, not dewar price

- **Accumulation of Delays**
  - If we missing Summer 2019 commissioning window, then big problem.
Detector

• See other talks by Stefan and Cyprien on MIRCx results and camera performance analysis
Software

• Based on original MIRC realtime code modified for CRED-ONE

• Deployed first on MIRCx (working already)

• Re-writing all GUIs to be CHARA-compatible

• Unbelievable job by Narsi Anugu so far
## Timeline*

<table>
<thead>
<tr>
<th>Date</th>
<th>Milestone</th>
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<tbody>
<tr>
<td>2018 March</td>
<td>MYSTIC Design Review</td>
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<tr>
<td>2018 April</td>
<td>Prototype new photometric channels (for MIRCx)</td>
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<tr>
<td>2018 Aug</td>
<td>Final Design of 200K Dewar – place order</td>
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<tr>
<td>2018 Fall</td>
<td>Build “WARM” mystic in lab</td>
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<tr>
<td>2019 Jan</td>
<td>Receive dewar and move system inside</td>
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<tr>
<td>2019 Feb-Mar</td>
<td>Test system in Michigan</td>
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<tr>
<td>2019 May</td>
<td>On-sky commissioning at CHARA</td>
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<tr>
<td>2019 July</td>
<td>End of grant officially (JB goes back to France)</td>
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<tr>
<td>2020 July</td>
<td>All monies must be spent by then.</td>
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Backups
Spectrograph

• Geometrical Ray Trace
• Spot diagrams
Spectrograph

- Physical Propagation Calculation
  - Fiber -> detector
  - Check vignetting at awkwardly-placed cold stop
Project Status

Year 1: 2015 Aug-2016
- Funding starts (National Science Foundation)
- Narsi Anugu (Exeter) leads joint MIRCX software DAQ
- UM undergrads clone CHARA stepper motor control system
- CRED-ONE negotiations and contract

Year 2: 2016 Aug-2017 Jul
- Recruited graduate student Ben Setterholm
- Jacob Ennis leads design/build of polarization controllers
- Fiber testing and selection
- CRED-one acceptance testing
- MIRCx on-sky commissioning

Year 3: 2017 Aug-2018 Jul
- Jean-Baptiste le Bouquin starts at UM for 2-year work
- Finalize optical design work
- All new gtk guis
- MYSTIC project design review (this Wednesday)