UKIRT/Michelle
Mid-IR esCHELLE

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United Kingdom Infrared Telescope (UKIRT)  
A most excellent site for IR and Michelle

- **UKIRT**: 40 years of operations
  - 3.8 meter telescope
  - Optimized for the infrared: 0.8 – 26 μm
  - 1 Wide-field camera
  - 4 imager/spectrometer cameras
    - Michelle for mid-IR

- **Location**: 13,800 feet (4200m)
  - **SEEING**:
    - Median = 0.43"
    - best quartile: <0.25"
    - Workable hours ~70%
  - **HIGH** and **DRY**

*Photo credits: Tom Kerr and http://www.ukirt.hawaii.edu/*
UKIRT
@Cassegrain

3.8m primary
f/36.4
2.8´ unvignetted FOV
Michelle: Mid-IR esCHELLE

8-26 µm imager & spectrograph
SBRC Si:As 320x240 pixels

- **Imaging**
  - 11 filters, broad and NB
  - 67.2" x 50.4" FOV
  - 0.21" per pixel
- **Imaging polarimetry**
- **Spectroscopy**
  - R=200 to 30,000
    - 91" long-slit
    - 0.38" per pixel
- **Spectro-polarimetry**

Figures from Glasse et al., 1997 SPIE 2871
Michelle on UKIRT & Gemini

*Expected 60-80x more sensitive on Gemini, actual ~2x*

<table>
<thead>
<tr>
<th></th>
<th>Michelle on UKIRT</th>
<th>Michelle on Gemini*</th>
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</thead>
<tbody>
<tr>
<td>Modes</td>
<td>Imaging, Spectroscopy, Polarimetry (both modes)</td>
<td></td>
</tr>
<tr>
<td>Wavelengths</td>
<td>8-13, 16-28 µm</td>
<td></td>
</tr>
<tr>
<td>Array type</td>
<td>SBRC Si:As</td>
<td></td>
</tr>
<tr>
<td>Array Size</td>
<td>320 x 240</td>
<td></td>
</tr>
<tr>
<td>Imaging FOV</td>
<td>67.2&quot; x 50.4&quot;</td>
<td>26&quot;</td>
</tr>
<tr>
<td>Imaging Plate Scale</td>
<td>0.21&quot;/pix</td>
<td>0.10&quot;/pix</td>
</tr>
<tr>
<td>Optical Throughput</td>
<td>57%</td>
<td>57%</td>
</tr>
<tr>
<td>Spectroscopy Resl’n</td>
<td>R=200 – 30,000</td>
<td></td>
</tr>
<tr>
<td>Slit width choices</td>
<td>1, 2, 3, 4, 8 pix</td>
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<tr>
<td>Slit length</td>
<td>91&quot;</td>
<td>46&quot;</td>
</tr>
<tr>
<td>Low-Res Plate Scale</td>
<td>0.38&quot;/pix</td>
<td>0.18&quot;/pix</td>
</tr>
<tr>
<td>Optical Throughput</td>
<td>30%</td>
<td>30%</td>
</tr>
</tbody>
</table>

Figures from Glasse et al., 1997 SPIE 2871
Why was Michelle built and what is its current status?

- **Why was it built?**
  - Built 1997, Royal Observatory Edinburgh for UKIRT & Gemini
  - There was no equivalent mid-IR instrument in the northern hemisphere at a suitable mid-IR site

- **Michelle at UKIRT and Gemini**
  - SPIE paper presented in 1997
  - Commissioned at UKIRT: Aug – Nov 2001
  - Shared Gemini/UKIRT 2001-March 2004
  - Just Gemini April 2004 – about 2011’ish
  - Just UKIRT ~2013 to UKIRT

- **Current status**
  - Functional
  - At UKIRT/Mauna Kea
  - Used in the past 5 years for NASA orbital debris observations, Lockheed, various astronomy programs through U Hawaii and U Arizona
What was Michelle's most spectacular science result?

- **Astronomers Spot Evidence for Colliding Planet Embryos in Famous Star Cluster** *P. Michoud, Wolpert, 2007*
  - Warm dust emissions betray catastrophic collisions in an evolving young planetary system around an adolescent-age solar type star.

- **Free floating Brown Dwarf discovery**
  - *Legget et al., 2000*

- **A Young Erupting Pre-main Sequence Star Takes a (Long) Nap**
  - Pre-main seq. 0.8M☉, 10^6 years
  - 37 years off, 1-2 years on
  - Si-dust evolution during outburst


Figures from: [https://www.gemini.edu/sciops/instruments/michelle/](https://www.gemini.edu/sciops/instruments/michelle/)
How Michelle special? What surprises did you encounter?

- **Special...One instrument, 3 modes**
  - Imaging
  - Spectroscopy
    - Also Echelle (!) - *special, part 1*
  - Polarimetry – *special, part 2*
    - Imaging polarimetry or spectro-polarimetry
  - Change modes instantly - *special part 3*

- **Special: Location, location, location**
  - Where seeing can be 0.18"
  - Can be as little as a few% humidity at 14,000’

- **Surprises**
  - How quickly commissioning went
    - Delivery Summer 2001, Aug
    - Science data by Nov 2001
  - How well it worked after taking a very long time to build

*Figures from: Glasse et al., 1997 SPIE 2871*
What noise, biases and problems do you suffer from most?

- **Interference/noise from fans that cool the electronics**
  - Pick-up from the fans to cool the warm electronics generating noise on the arrays
  - Read noise was very high: Few hundred e-
  - Took a long time to isolate the fans, but eventually solved this

- **Temperature stability**
  - JT system (Joules-Thompson) needle valve used for cooling to 4k
  - Contaminants build up, freeze, blocks coolant
    - Blows out, reforms, T fluctuations inconsistent, not gradual
  - Warming the instrument to purge is required maintenance

- **Sacrificial window over main, thick hygroscopic window**
  - Degrades with time, replace regularly
  - But only 1 day to replace (vs. without thin sacrificial window)

*Figures from: Kerr 2004*
How do you calibrate Michelle?

- **Wavelength calibration**
  - Calibration at resolving powers 50-30,000
  - 4-inch diameter **integrating sphere** with 2 or more arc lamps
  - Arc lamps, integrating spheres for low-res spectroscopy
    - Higher order lines of **Xenon, krypon, argon** arc lamps
  - Echelle: Fabry-Perot etalon = grid of absorption features
    - 4mm thick germanium etalon (90% reflective)

- **Flat fielding**
  - Simple, **room-T low emissivity plate**
  - Fall-back: integrating sphere + flat plate with pinholes
    = point-sources

- **Sky Correction**
  - Flat field Black Body @ $T_{\text{effective}}$ (≈275K) of combined sky+Tel continuum emission

- **Telescope Simulator**
  - Uniform illumination of the focal plane just inside the cryostat window

- **Polarimetry**
  - Provide rotation of 2 half-wave plates
How do you calibrate Michelle?

- The calibration unit will comprise:
  - Static, 2.5 to 20μm (infragold coated), 4 inch diameter integrating sphere with two pencil-type arc lamps mounted in it.
  - An 'Offner relay' telescope simulator to reimage the exit pupil of the integrating sphere onto the telescope focal plane, with access to a focal plane where an ambient temperature pinhole target can be inserted.
  - Optics to relay light from the exit port of the integrating sphere onto the focal plane of the Offner relay.
    - Lens or mirror with a focal length of ~300mm, to match an f/4.3 beam from a 9mm diameter exit port in the integrating sphere onto the f/35 and 70mm diameter beam required by the Offner relay.
    - The exit port and Offner focal plane would be placed at the two foci of the relay lens/mirror.
How do you calibrate Michelle?

Engineering tests & checks

- **Mechanism and microswitch tests**
  - Array translation & rotation
    - Position of object on array
  - Image extractor repeatability
    - Position of object on array
  - Grating repeatability
    - \(~few\) pixel discrepancy expected
  - Slit repeatability
    - Slit position should repeat to \(<1\)pix
  - Internal focus

- **Array tests**
  - Bias/clock
  - Read-noise
    - \((\text{Bias}_1-\text{Bias}_2)/\sqrt{\text{noise}}\)
  - QE
    - 2 pixel slit throughput

Figures from: Glasse et al., 1997 SPIE 2871
What is the best performance that you ever achieved (in terms of the fundamental noise limit) and how did you achieve it?

- Isolating fans greatly improved performance
- Temperature stability matters
- **Best performance?**
  - When all the electronics, cryo-cooling are all behaving as expected
  - Unknown quantitative ‘best performance’
If you had a magic wand, what specific improvements would you make to Michelle/UKIRT?

- **Stabilize array temperature**
  - Replace JT-valve with something else
- **Cold finger contact**
  - Actual contact of the cold finger is often an issue
- **Cryogenics**
  - Something other than Liq He required
  - Array that can be run at warmer temps – easier to deal with
- **Array**
  - Replace array with higher QE
  - Less noise
  - Fewer cosmetic issues
- **Guide with near-IR option**

Figure from: https://www.gemini.edu/sciops/instruments/midir-resources/data-reduction/data-format-and-features#noise
What piece of advice would you give builders of thermal IR instruments for 30m class telescopes?

- **Chopping warnings**
  - ENSURE that if you must chop with a secondary that it communicates DIRECTLY with the instrument (*note: BIG issues with Gemini, not UKIRT*)
  - Better yet, get an array that doesn’t require chopping \(\rightarrow\) improve efficiency by at least 2x
    - Also, deeper wells, faster read-outs, better baffling in the instrument

- **Segmented mirrors**
  - Think long and hard about how emissivity is affected by gaps between segments

- **Minimize emissivity of the instrument/telescope**

- **Don’t limit yourself to just thermal IR**
  - Consider multi-spectral, expanding to Visible, near-IR reflected simultaneously

- **Think about how to be different from/complementary to JWST**
  - Design for better spatial resolution, larger FOV
  - JWST is now OLD technology – capitalize on NEW technology
References

