Using Adaptive Optics to Study Volcanism on Io

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Introduction to Io

* Galilean moon of Jupiter
* Synchronous rotation with Jupiter
* Most volcanically active body in Solar System
* Tidal interactions with Jupiter and Europa ⇒ Heat Source

Mass = \(8.93 \times 10^{22}\) kg
Diameter = 3700 km

= 1 arcsecond ("")
Io in Infrared

- In JHK ⇒ surface features mainly seen (reflecting Sunlight)
- In LM ⇒ thermal output from eruptions
- Brightness of hot spots in multiple bands ⇒ T and SA of active regions.
May 27, 28, 29, 30 2004 ⇒ high resolution images of Io using Keck AO

NIRC-2 ⇒ Near Infrared Camera

Wavelength Range ⇒ 0.9 – 5.3 microns

NEW volcano detected on 5/28 and 5/30!

Hot spots detected in L and M bands; if visible in H and K ⇒ high temp/young eruption
Anti-Jovian hemisphere
Numerous hot spots can be seen
As the two curves converge ⇒ Higher contrast
*Jupiter-facing hemisphere
*Period of revolution = period of rotation = ~46 h
*Hot spot “A” seen for the first time ever
   ⇒ Extremely bright!
Faint hot spots in L and M bands, NOT in K band
Data taken in K band to see if any high temp. components
Hot spot “A” can be seen in H band
High temp (T>1400K) $\Rightarrow$ young eruption, extremely bright
Analysis of Data

• Identification of hot spot positions:
  a) Ephemeris ⇒ mean time, size, SEP Lat./Long., NP angle
  b) Cylindrical Equidistant Projection
     ⇒ coordinates of the active centers

• Extraction of Intensities:
  a) Aperture photometry
  b) Correction of the flux by PSF profile
# Hot Spot Data

<table>
<thead>
<tr>
<th>Label</th>
<th>Date of Obs.</th>
<th>Coordinates</th>
<th>Intensity In L (GW/sr/µm)</th>
<th>Intensity In M (GW/sr/µm)</th>
<th>Candidate¹</th>
<th>Best T (K)</th>
<th>Surface Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>May 27</td>
<td>83.9W,2.3N</td>
<td>4.5±0.7</td>
<td>7.0±2.2</td>
<td>Hi’iaka</td>
<td>440</td>
<td>157 ±13</td>
</tr>
<tr>
<td>E</td>
<td>May 27</td>
<td>95.4W,16.0N</td>
<td>2.0±0.9</td>
<td>4.4±0.9</td>
<td>Gish Bar</td>
<td>395</td>
<td>204 ±13</td>
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<td>F</td>
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<td>118.5W,22.3N</td>
<td>2.0±0.9</td>
<td>4.4±0.9</td>
<td>Amirani</td>
<td>635</td>
<td>20 ±3</td>
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<td>G</td>
<td>May 27</td>
<td>132.3W,33.8S</td>
<td>1.7±0.2</td>
<td>2.9±0.5</td>
<td>Malik</td>
<td>565</td>
<td>10 ±1</td>
</tr>
<tr>
<td>H</td>
<td>May 27</td>
<td>144.3W,17.4S</td>
<td>3.3±1.1</td>
<td>3.7±0.2</td>
<td>Tupan</td>
<td>850</td>
<td>2</td>
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<tr>
<td>I</td>
<td>May 27</td>
<td>158.0W,0.6S</td>
<td>5.5±0.8</td>
<td>9.7±2.2</td>
<td>Prometheus</td>
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<td>25 ±5</td>
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<td>A</td>
<td>May 28</td>
<td>6.3W,17.5S</td>
<td>166 ±6</td>
<td>152±38</td>
<td>Unnamed</td>
<td>&gt;735</td>
<td>188 ±3</td>
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<td>9.5±2.0</td>
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<td>16300±50</td>
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<td>311.6W,14.0N</td>
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<td>95±9</td>
<td>Loki</td>
<td>350</td>
<td>11600±400</td>
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<tr>
<td>R</td>
<td>May 28</td>
<td>344.3W,51.7S</td>
<td>26±2</td>
<td>61±3</td>
<td>Creidne</td>
<td>375</td>
<td>4400 ±100</td>
</tr>
</tbody>
</table>

¹ Candidates from Lopes et al., 2004
## Hot Spot Data (cont.)

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<tr>
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<th>Candidate</th>
<th>Best T (K)</th>
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</thead>
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<tr>
<td>J</td>
<td>May 29</td>
<td>166.0W,17.1S</td>
<td>5 ± 1</td>
<td>5.4±2.2</td>
<td>3.8±0.8</td>
<td>Culann</td>
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<tr>
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<td>3.9±2.2</td>
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<td>4.3±0.6</td>
<td>7.4±1.9</td>
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<td>161±5</td>
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<td>660 ± 100</td>
<td>18±5</td>
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<td>435</td>
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<tr>
<td>C</td>
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<td>620 ± 70</td>
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<td>R</td>
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<td>344.3W,51.7S</td>
<td>4400 ± 100</td>
<td>12.8±1.5</td>
<td>33±6</td>
<td>Creidne</td>
<td>375</td>
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<td>S</td>
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<td>4.4±1.4</td>
<td>10±3</td>
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</tbody>
</table>

**18 hot spots observed in total**
Hot Spot “A”
Detected May 28 & May 30, 2004
5.4 W, 17.4S
Brightness in Lp: 166 +/- 6 GW/sr/micron & 148 +/- 5 GW/sr/micron
Brightness in Ms: 152 +/- 38 GW/sr/micron & 161 +/- 5 GW/sr/micron
Brightness in Kc: 7.4 +/- 0.2 GW/sr/micron
Brightness in H: 3.4 +/- 0.3 GW/sr/micron

**Hot spot A is extremely energetic!

Rate of aerial coverage = 6497 m²/s
Total area = 3368 km²
Age of surface = 144 hours ~ 6 days
T = 1475 to 405K
Total Output:
= 9.3 x 10¹² W
= 10% Io total thermal output
>Tvashtar 2001

Basaltic Lava Cooling Flow

Courtesy of Ashley Davies, JPL, 2004
Conclusion

• Importance of adaptive optics for studying volcanism on Io
• Intensity of hot spot yields surface area and temperature, ⇒ portion (%) of active volcanism on the surface
• Hot spot “A” is a young, hot, fire-fountaining eruption

What’s Next?

• Identify active centers by comparison with Galileo images
• Improve sharpness of images by process of deconvolution
Acknowledgements

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References

• de Pater, I., et al. 2003. Keck AO Observations of Io In and Out of Eclipse. ICARUS.