The Thermal Infrared Investigation on Cassini:
A Challenge for Laboratory Studies

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5 May 2010
CIRS Development Team at Goddard in 1996
Location of CIRS on Cassini
## Instrument Description

<table>
<thead>
<tr>
<th>Parameter</th>
<th>FAR-IR</th>
<th>MID-IR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telescope Diameter (cm)</td>
<td>50.8</td>
<td></td>
</tr>
<tr>
<td>Interferometers</td>
<td>FAR-IR</td>
<td>MID-IR</td>
</tr>
<tr>
<td>Type:</td>
<td>Polarizing</td>
<td>Michelson</td>
</tr>
<tr>
<td>Spectral range (cm(^{-1}))</td>
<td>10 - 650</td>
<td>600 - 1450</td>
</tr>
<tr>
<td>Spectral range (microns)</td>
<td>15.4 - 1000</td>
<td>6.9 - 16.6</td>
</tr>
<tr>
<td>Spectral resolution (cm(^{-1}))</td>
<td>0.5 to 20</td>
<td>0.5 to 20</td>
</tr>
<tr>
<td>Integration time (sec)</td>
<td>2 to 50</td>
<td>2 to 50</td>
</tr>
<tr>
<td>FOCAL PLANES:</td>
<td>FP1</td>
<td>FP3</td>
</tr>
<tr>
<td>Spectral range (cm(^{-1}))</td>
<td>10 - 650</td>
<td>600 - 1125</td>
</tr>
<tr>
<td>Detectors</td>
<td>Thermopile</td>
<td>PC HgCdTe</td>
</tr>
<tr>
<td>Pixels</td>
<td>2</td>
<td>1 x 10</td>
</tr>
<tr>
<td>Pixel FOV (mrad)</td>
<td>3.9</td>
<td>0.273</td>
</tr>
<tr>
<td>Peak D*(cm hz(^{1/2}) W(^{-1}))</td>
<td>4 x 10(^8)</td>
<td>2 x 10(^{10})</td>
</tr>
<tr>
<td>Data Telemetry Rate (kbs)</td>
<td>2, 4</td>
<td></td>
</tr>
<tr>
<td>Instrument Temperature (K)</td>
<td>170</td>
<td></td>
</tr>
<tr>
<td>Focal Planes 3 &amp; 4 Temperature (K)</td>
<td>75 - 90</td>
<td></td>
</tr>
</tbody>
</table>

5 May 2010
CIRS on RSP

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CIRS Ready for Thermal-Vacuum Testing
CIRS' Backside

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CIRS
Mechanical Layout

GSFC
CIRS

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CIRS FOV's Projected on Titan's Limb
Voyager IRIS

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Laboratory spectroscopy and Voyager IRIS

HC$_3$N

C$_2$N$_2$

C$_4$N$_2$

C$_4$H$_2$
Composite Brightness Temperature of Titan
Titan FP1 Large Average

Titan FP1 90S-90N -2500 to 300 km 30341 spectra

CH₄
C₃H₂
C₂N₂
C₂H₆
C₃H₄
H₂
HC₃N
C₂HD
H₂
CO₂

radiances

wavenumbers

0.0E+00
0.5E-08
1.0E-07
1.5E-07
2.0E-07

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Titan 60-90N latitude 50-150 tangent height 1006 spectra
Titan FP4 Large Average

Titan FP4 disk+limb 60-90N 19769 spectra

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Titan’s Atmospheric Haze

North polar haze cap

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CIRS FP1 spectrum at 0.5 cm\(^{-1}\) resolution

Titan 0.5 cm\(^{-1}\) 60-90N 289 spectra Disk+Off-Limb

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Solid Propionitrile as a candidate for 200 cm\(^{-1}\) feature

Laboratory
Crystalline CH\(_3\)CH\(_2\)CN
Khanna, Icarus 177, 116 (2005)

Titan
CIRS

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Amine torsional group frequency as a candidate for 225 cm\(^{-1}\) emission feature

Craven, Appl. Spect. 26, 449 (1972)

5 May 2010
Do group frequencies on heavy molecules contribute to the infrared spectrum?

"Discovery of Heavy Negative Ions in Titan's Ionosphere"
From Cassini CAPS; Coates et al., GRL 34, L22103 (2007)
Identifications of condensed species in Titan from laboratory studies

Khanna et al. 1987
Samuelson et al. 1997

DelloRusso & Khanna 1996
Khanna 2005

solid $\text{C}_4\text{N}_2$

solid $\text{HC}_3\text{N}$

HC$_3$N gas

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Carbon isotope enrichment on Titan varies among molecular species.

- Ethane is the main product of the destruction of methane.
- Ethane is ~10% depleted in $^{13}$C compared to methane.
- Ethane's $\delta^{13}$C ~ 0 is close to telluric and Solar System values.

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Is the $^{12}\text{C}/^{13}\text{C}$ enrichment in ethane caused by the kinetic isotope effect?

Assume steady-state

$\frac{^{12}\text{C}}{^{13}\text{C}}_{\text{reservoir/methane}} \approx \text{KIE} \cdot \frac{^{12}\text{C}}{^{13}\text{C}}_{\text{atmosphere/methane}} \approx \frac{^{12}\text{C}}{^{13}\text{C}}_{\text{atmosphere/ethane}}$

- Ethane is formed from methyl ($\text{CH}_3$), which comes from methane dissociation.

- At 200-300 km methyl is formed through $\text{CCH} + \text{CH}_4 = \text{C}_2\text{H}_2 + \text{CH}_3$.

- The kinetic isotope effect (KIE) might generate the observed $^{12}\text{C}$ enrichment in ethane over methane.

- The near-zero $^{13}\text{C}$-enrichment in ethane implies a primordial origin for the methane reservoir.

- The KIE in $\text{CCH} + \text{CH}_4 = \text{C}_2\text{H}_2 + \text{CH}_3$ has not been measured in the lab.

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Isotopic species: identification of $^{13}$C-diacetylene in Titan from laboratory measurements

Laboratory spectra of $^{13}$CCCCH and $^{13}$CCH Titan from CIRS observations

Modeling Titan’s spectrum requires improved molecular parameters.

Missing $\text{C}_3\text{H}_6$ hot band in earlier model later fit with improved linelist from laboratory spectroscopy.

Need for improved molecular parameters from laboratory measurements

1460 cm\(^{-1}\) region. Model residual compared with C\(_3\)H\(_8\) lab spectrum.

Pseudo linelist used for C\(_2\)H\(_6\) \(v_7\).

920 cm\(^{-1}\) region. Model residual compared with C\(_3\)H\(_8\) lab spectrum.

Low temperature spectra needed.


5 May 2010
Ethane $v_4$ Torsional Band at 288 cm$^{-1}$ in Titan

Moazzen-Ahmadi et al. 1988, JCP, 88, 563.