Galileo-NIMS Observations of Io's surface

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Talk structure

1. **The Galileo Near Infrared Mapping Spectrometer**

2. **NIMS observations of Io: low resolution**

3. **NIMS observations of Io: high resolution**

4. **Surface Properties and Composition**
   - sulphur dioxide distribution
   - silicate volcanism
   - sulphur volcanism

5. **Thermal emission**
   - monitoring of volcanism
   - eruption evolution
   - eruption thermal signature

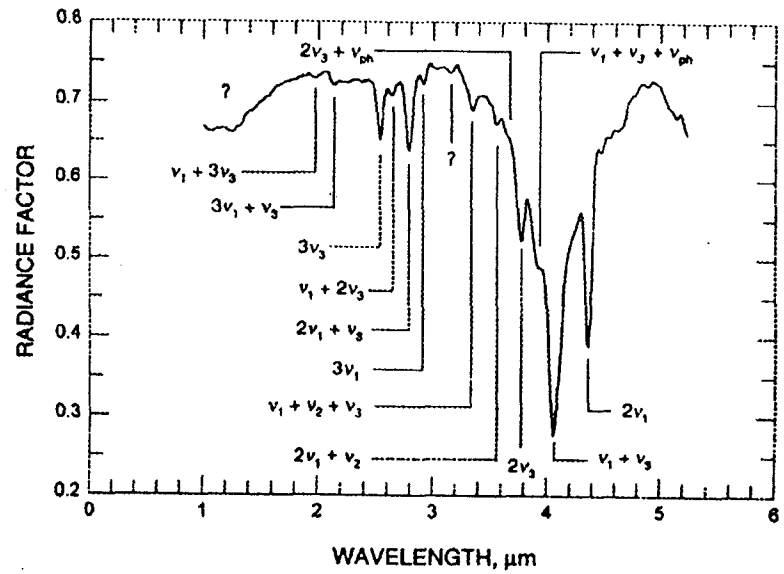
6. **Future observations**
7. **Summary**

A surface representation for Io : spectroscopic information

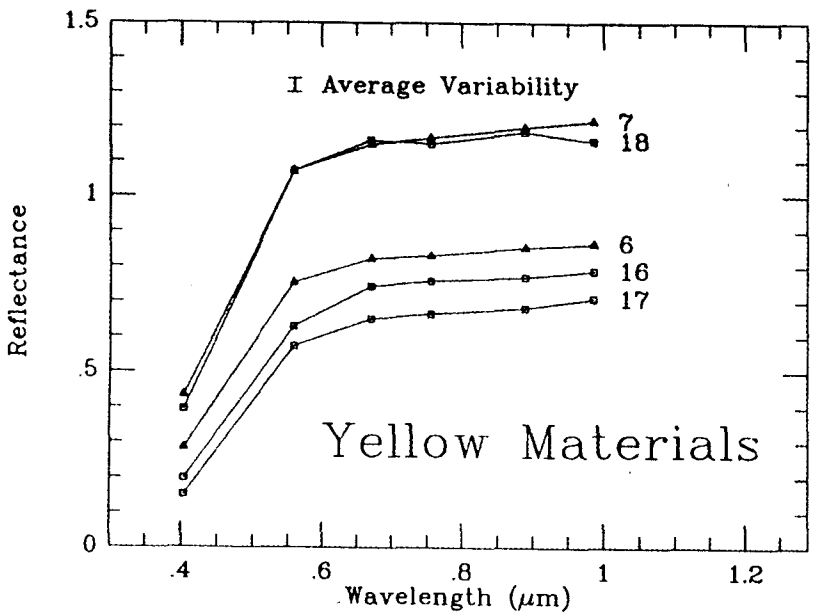
✓ **NIMS** : reflected contribution marked by numerous solid SO_2 bands

✦ other more modest signatures to be identified (ex: 1-1.4 μm)

Carlson et al. 1997



Geissler et al. 1999



✓ **SSI** : more than 70% of Io's surface blanketed by compounds like :

- Sulfur ($S_{8,4,3}$)
- Polysulfur oxides (S_2O,...)
- Sodium sulfides(Na_2S, ...)

and of course SO_2

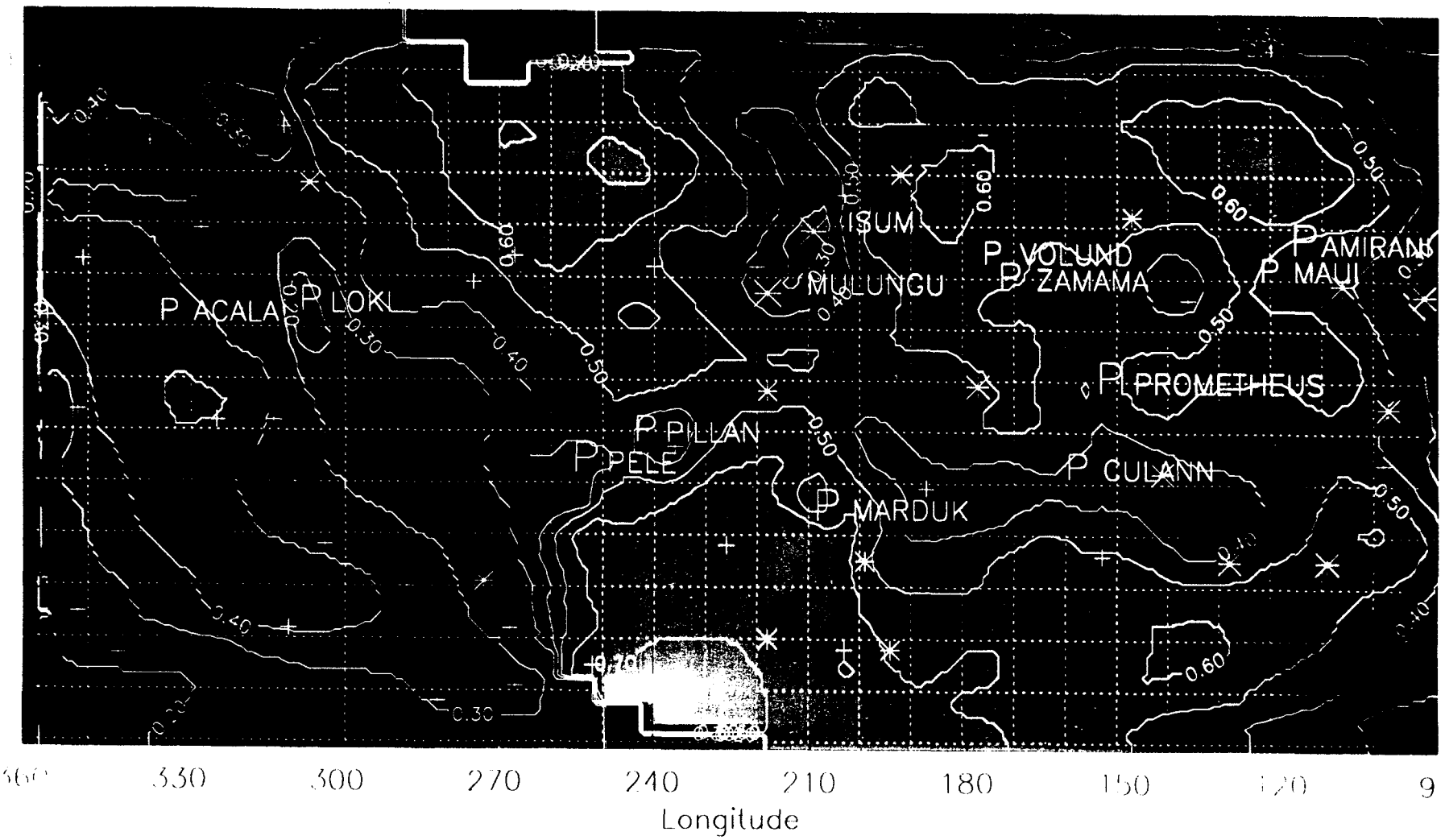
neutral and bright in the NIMS range

NIMS data and techniques used to map SO_2

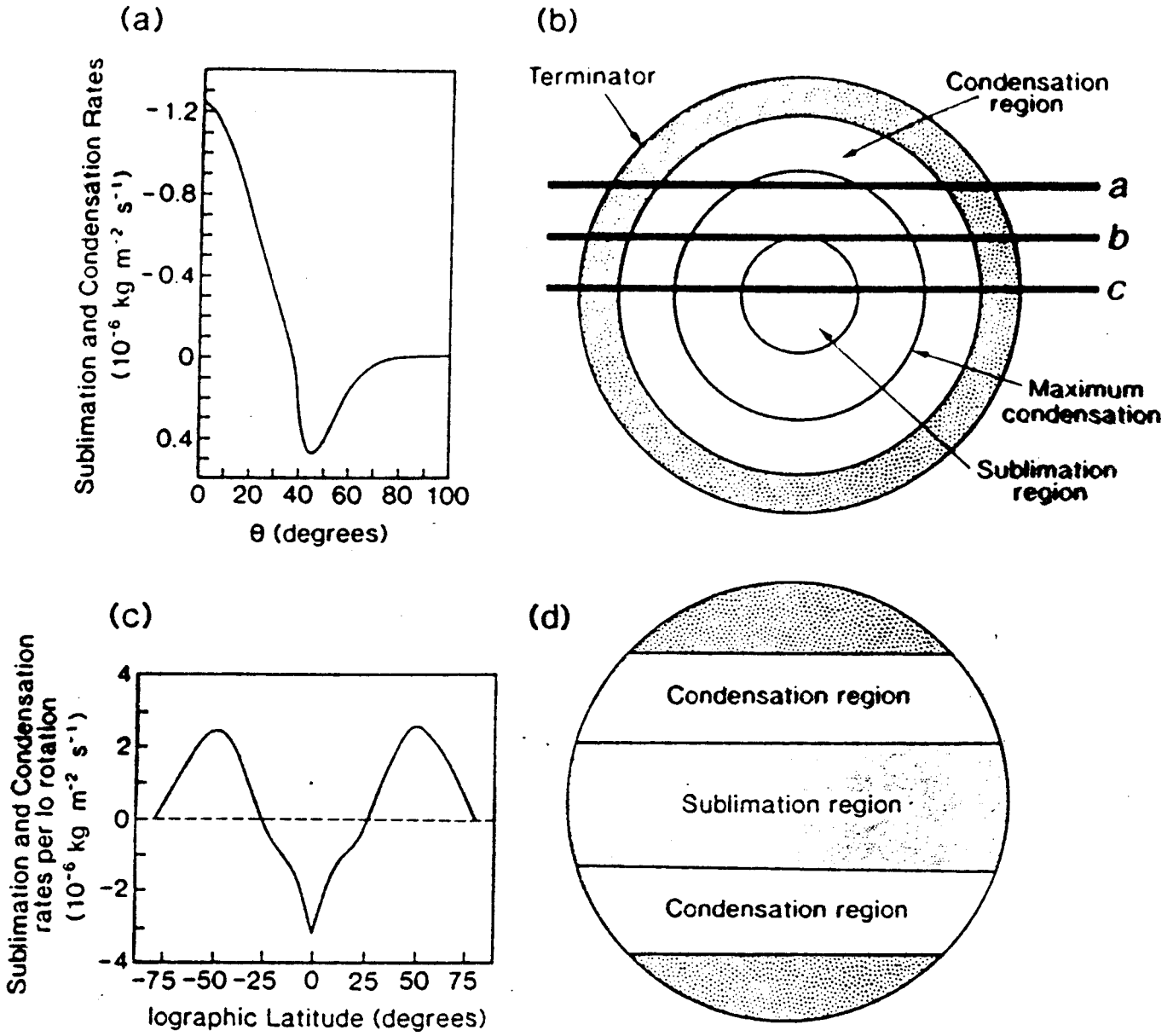
✓ 3 types of NIMS observations - 3 spatial scales:

- ✦ **Global** : 3/4 of Io's surface
  - series of images acquired from 06/96 to 05/98
  - spectral range: 0.7-5.23 µm
  - spectral resolution: 0.024 µm with 96, 216 or 408 wavelengths
  - Analysis ⇨ surface coverage and grain size of SO_2 frost
    - ➢ assumption: a geographical mixture of SO_2 and other sulfur compounds
    - ➢ method: modeling of the bands by a spectral bidirectional reflectance model
- ✦ **Regional** : Prometheus region I27 region01 (February 2000)
  - images I24region01 (October flyby) and I25region01 (November flyby)
  - reduced spectral sampling : 17 wavelengths between 1.0-5.2 µm
  - Analysis ⇨ surface coverage or abundance of SO_2 frost
    - ➢ assumption: geographical or intimate mixture of SO_2 and sulfur compounds
    - ➢ method: band ratio Reflect.(continuum) / Reflect.($\nu1+\nu3$ SO_2 strong band)
- ✦ **Local** : hot spot Culann - Tohil region
  - •

Distribution map of SO2



0.1 0.3 0.5 0.7 0.9



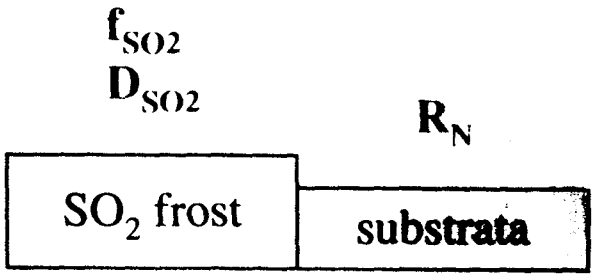
MORENO ET AL. 1991

Sulfur dioxide distribution

✓ **global scale** (~ 200 km/pixel) :

✦ Assumption : linear spectral model

- pure, optically thick SO_2 (variable grain size)
- spectrally neutral unit

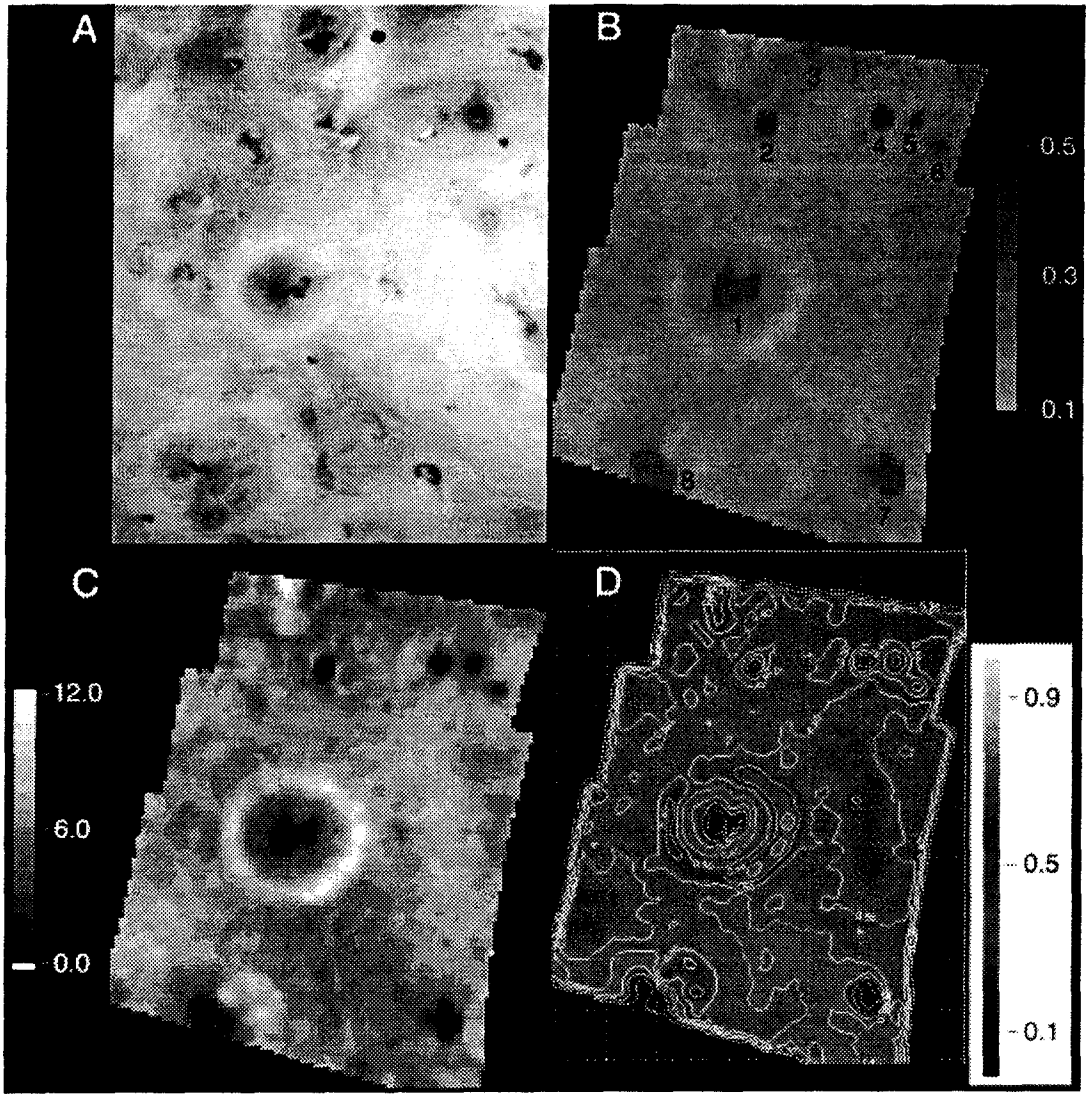


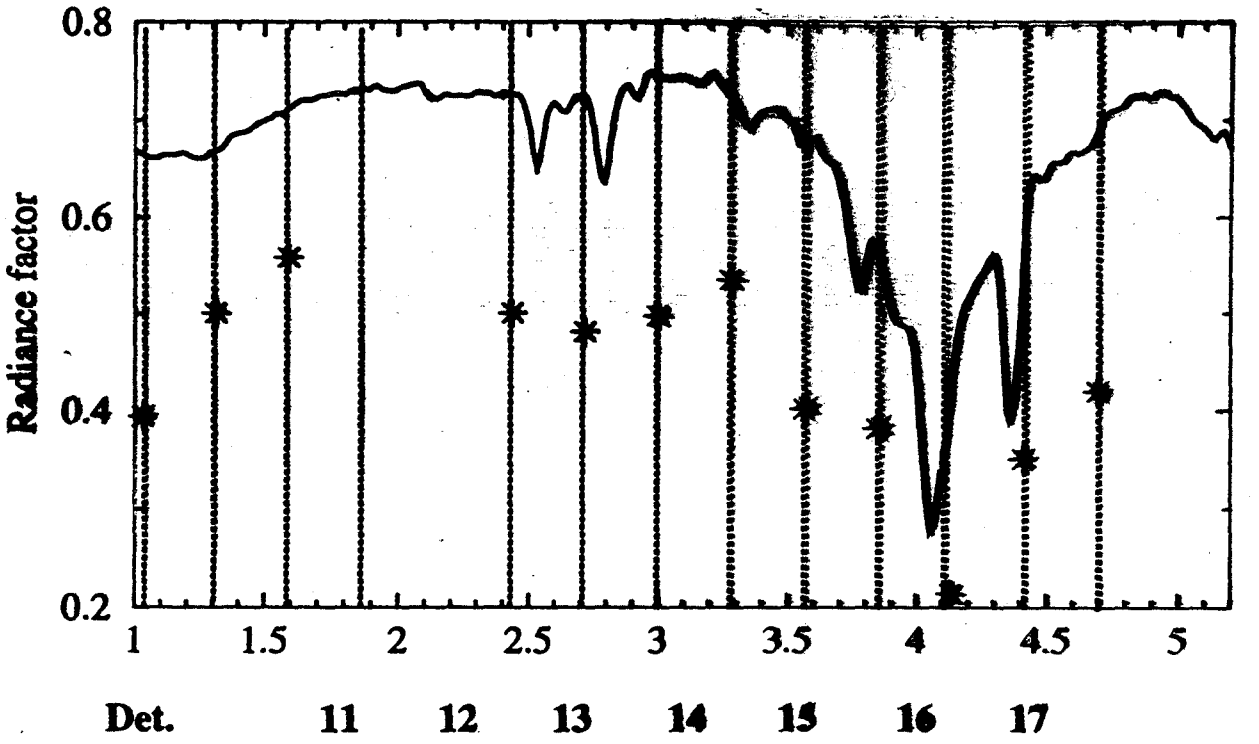
global obs. G2-E16

✦ **Results : global mosaic mapping frost aeral abundance**

- SO_2 everywhere at the surface
- several SO_2 rich large areas centered at medium latitudes
- longitudinal correlation with plumes

⇒ plumes : sources of SO_2 gas


A
B
0.5
0.3
0.1
C
12.0
6.0
0.0
D
0.9
0.5
0.1


0.8
0.6
0.4
0.2
Radiance factor
1
1.5
2
2.5
3
3.5
4
4.5
5
Det.
11
12
13
14
15
16
17

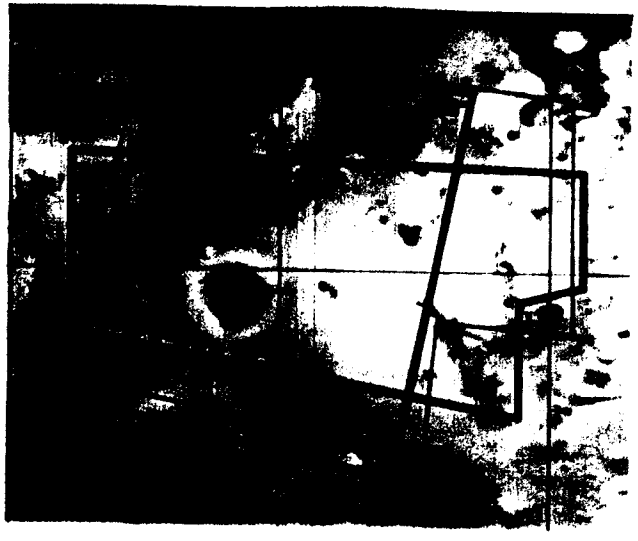
✓ Global scale

					Image I.D.
350	200	232	124	210	Spatial resol.(km/pixel)
42°	31°	51°	34°	27°	Phase angle

✓ Local scale

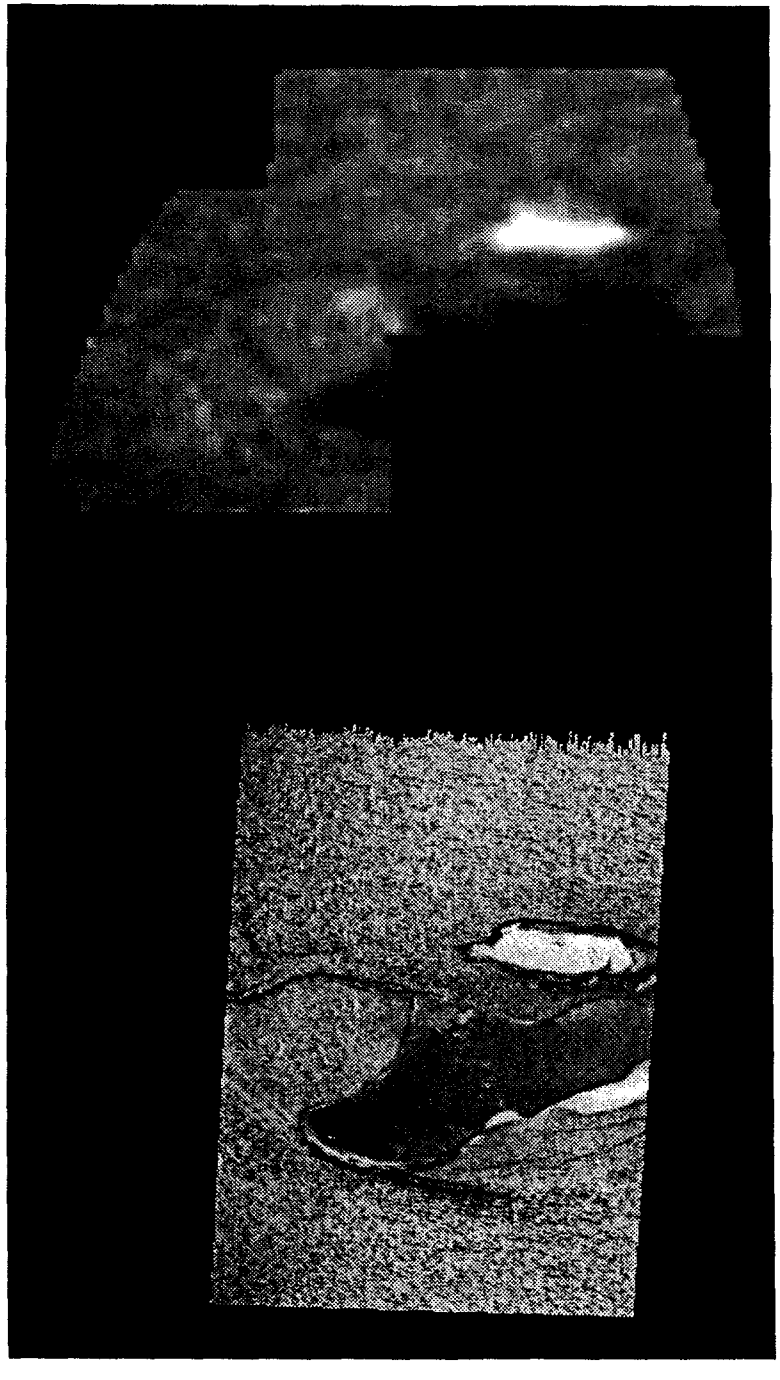
Image I.D.	resol. km/pixel
I25culann01	11
I24Tohil01	5
⋮	

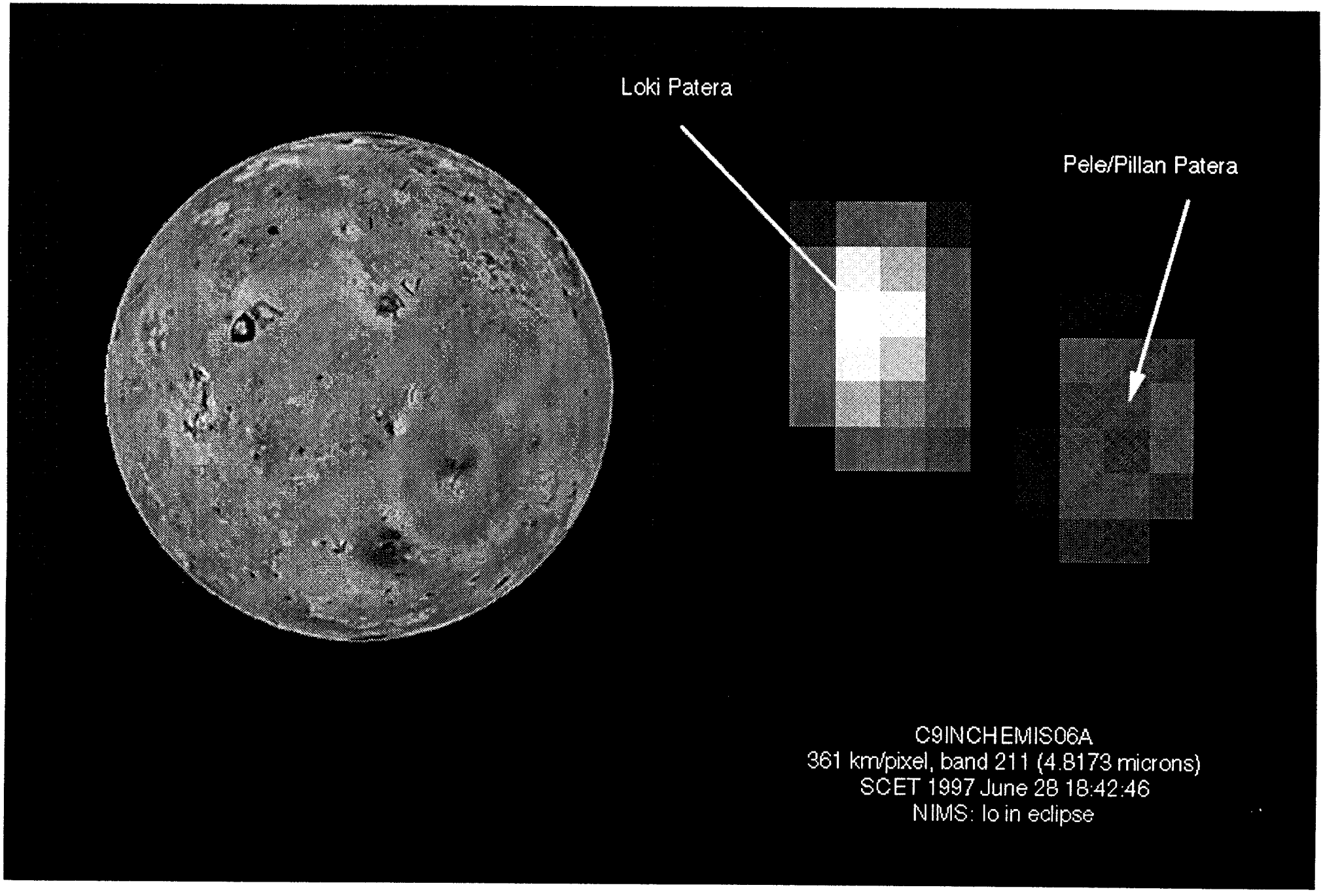
SSI mosaics
After Geissler et al. 99

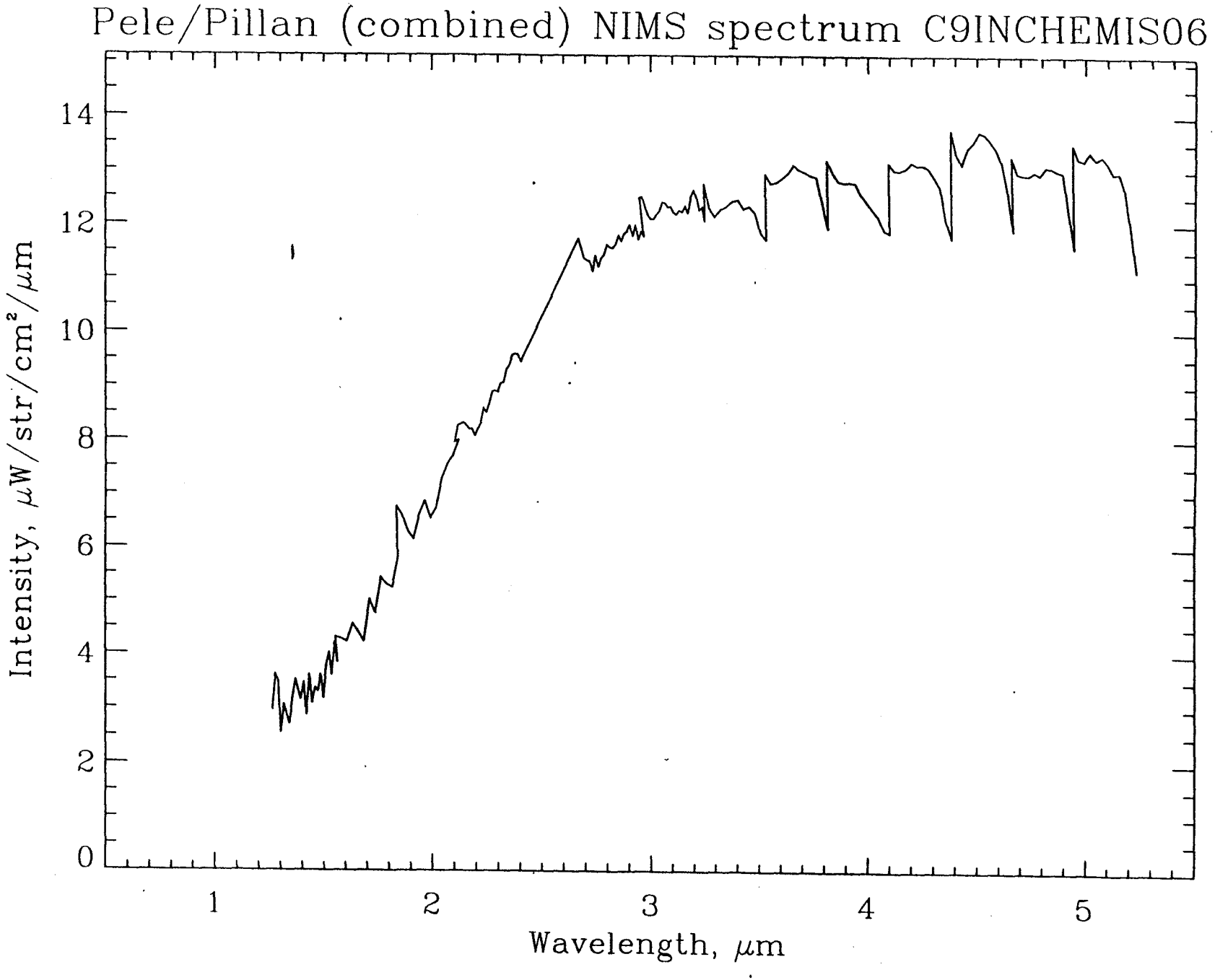


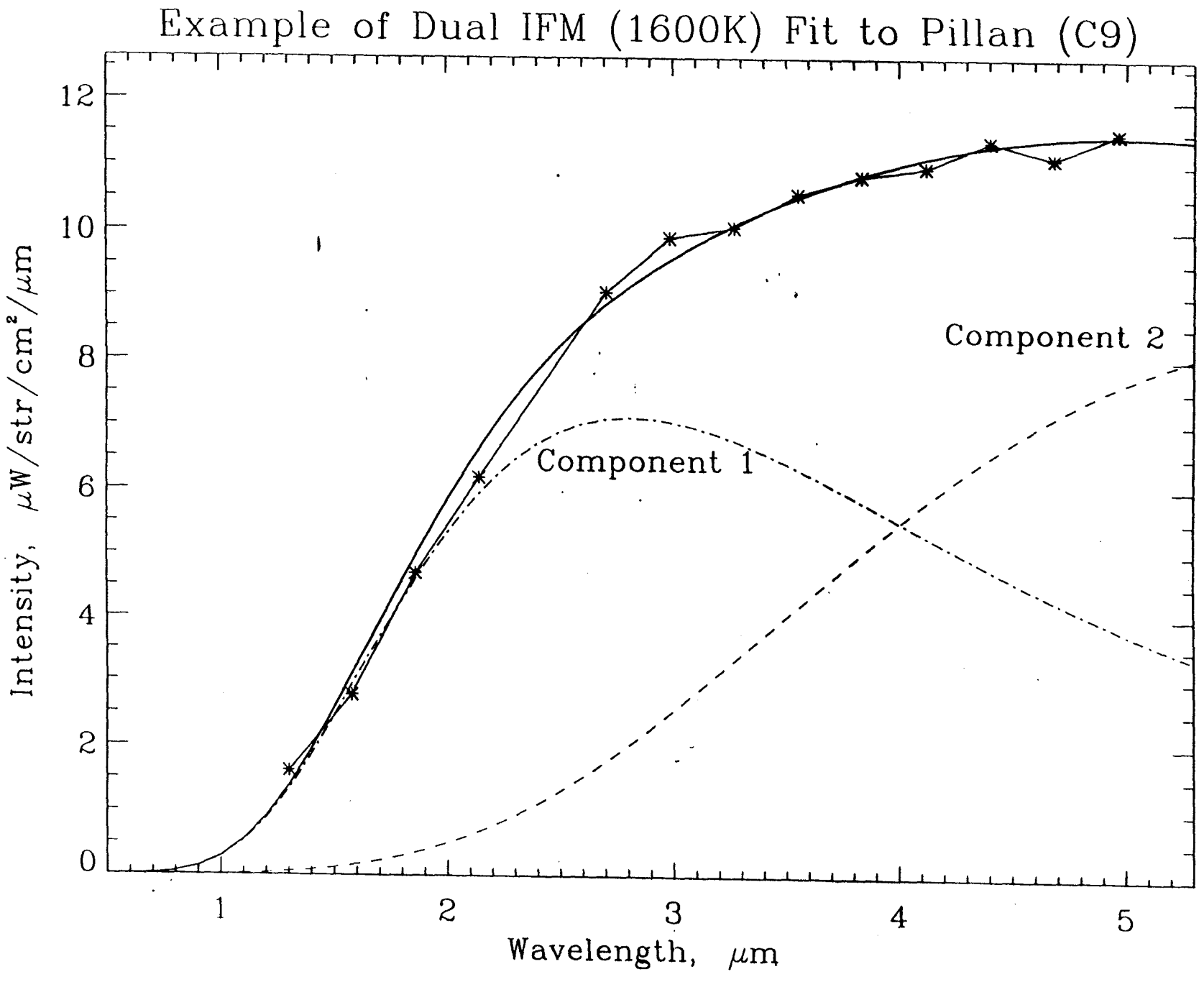
✓ Regional scale

Image I.D.	resol. km/pixel
I24region01	26
I25region01	18
I27region01	24




Loki Patera
Pele/Pillan Patera
C9INCHEMIS06A
361 km/pixel, band 211 (4.8173 microns)
SCET 1997 June 28 18:42:46
NIMS: Io in eclipse


Pele/Pillan (combined) NIMS spectrum C9INCHEMIS06
Intensity, μW/str/cm²/μm
0
2
4
6
8
10
12
14
1
2
3
4
5
Wavelength, μm


Example of Dual IFM (1600K) Fit to Pillan (C9)
Intensity, μW/str/cm²/μm
Wavelength, μm
Component 1
Component 2
0
2
4
6
8
10
12
1
2
3
4
5

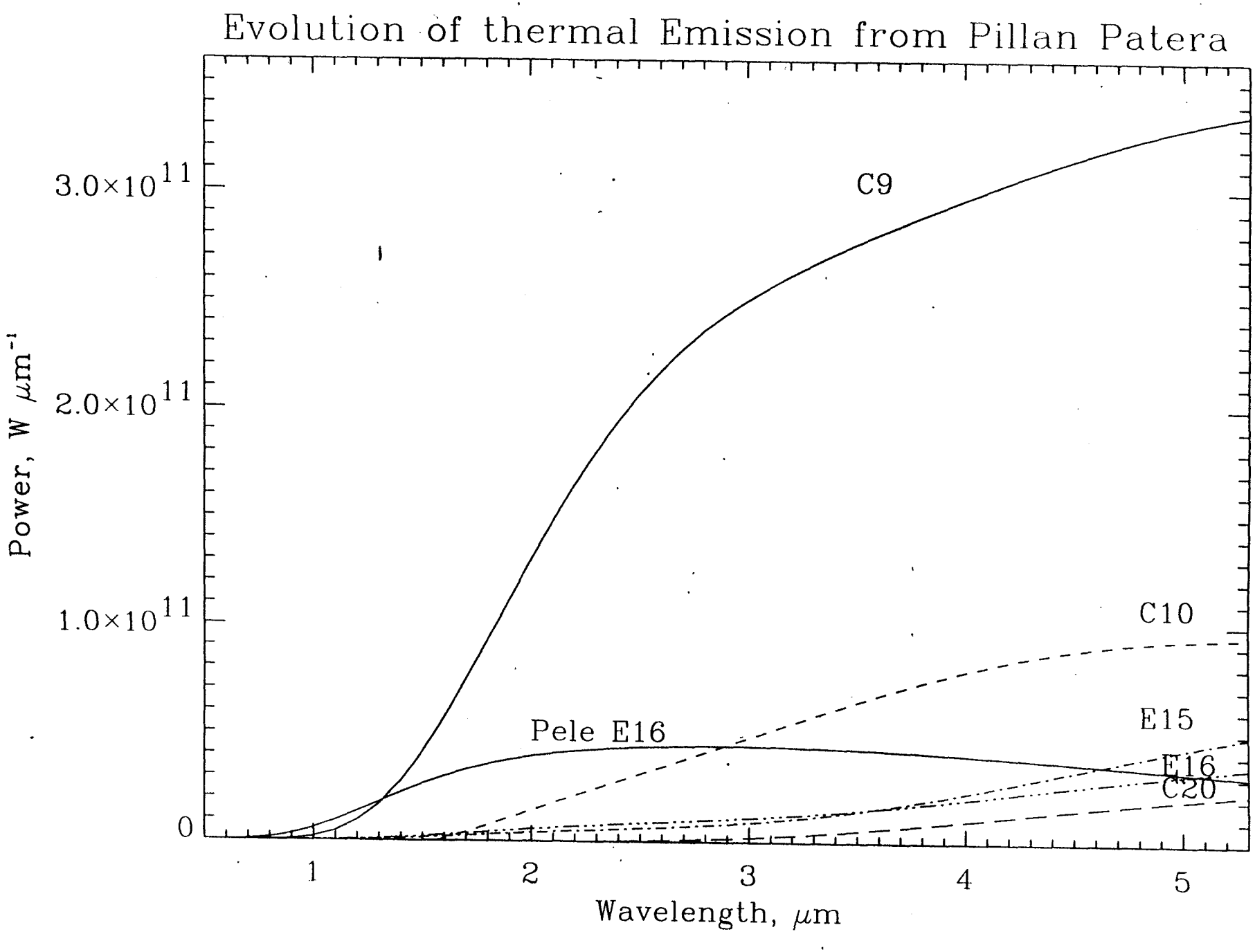
Two-temperature fits to Pele and Pillan Patera data: Orbits C9, E15, E16: Pele is constant, while the Pillan Patera eruption dies down.

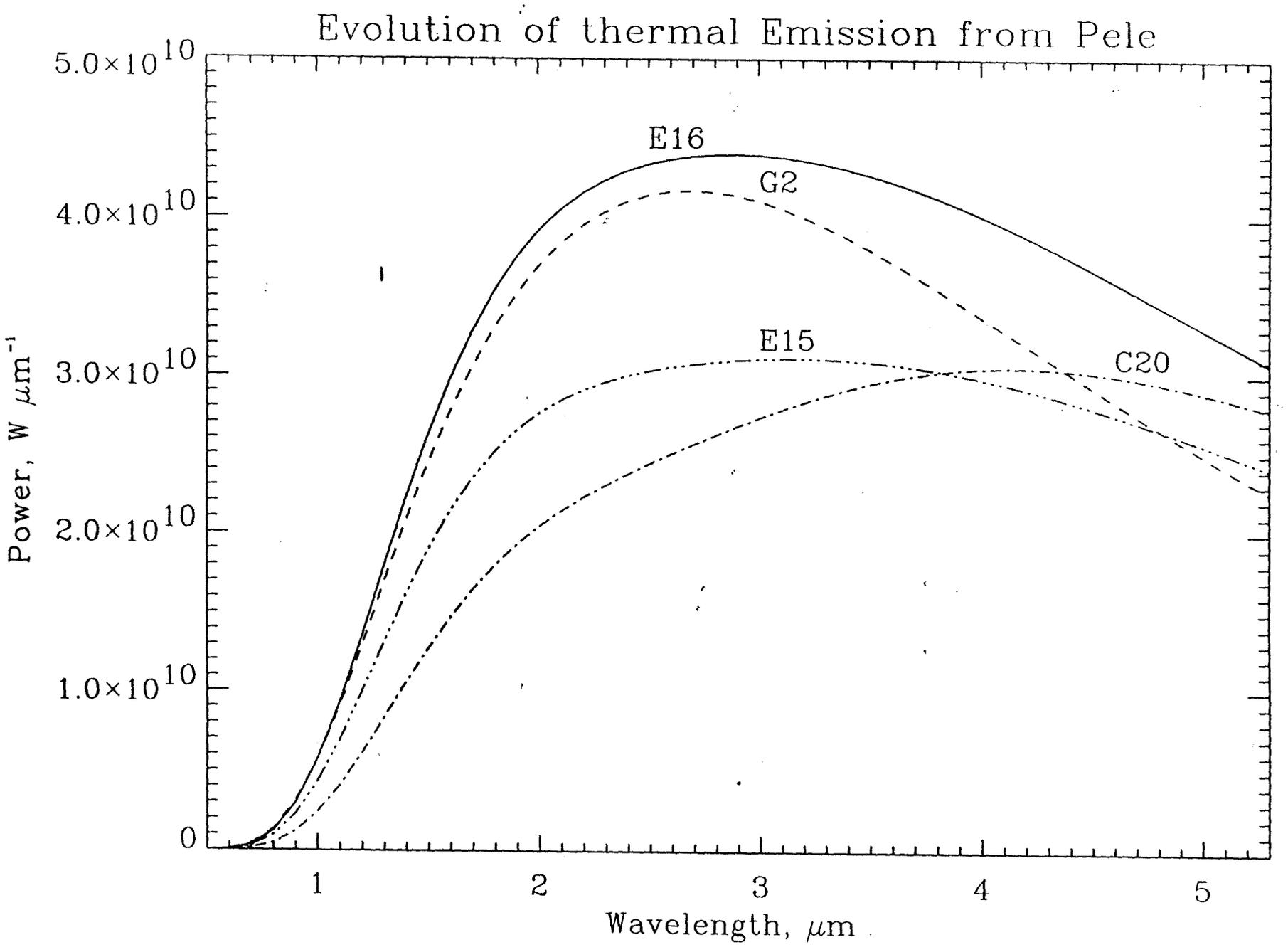
Pele	Component 1		Component 2		SSI synthesised clr/1mic ratio
	Temperature, K	Area, km^2	Temperature, K	Area, km^2	
C9*	1353 ± 46	0.63 ± 0.11	649 ± 16	15.9 ± 1.7	12.9 ± 2.0
E15	1369 ± 141	0.42 ± 0.27	625 ± 43	15.4 ± 3.6	13.2 ± 3.1
E16	1353 ± 46	0.63 ± 0.11	649 ± 16	15.9 ± 1.7	12.9 ± 2.0

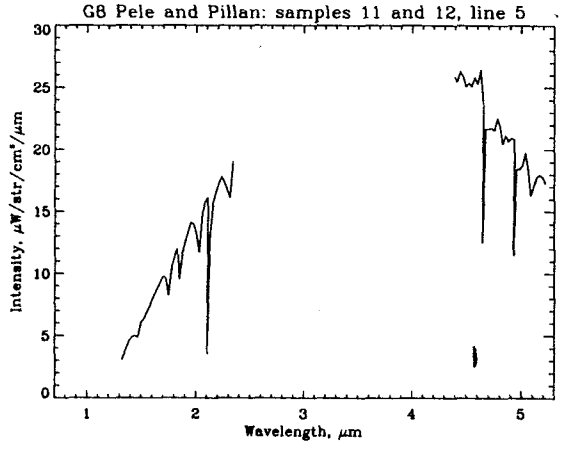
* As Pele is so constant, the E16 data were used to separate the fluxes from Pele and Pillan Patera in the C9 data, having corrected for emission angle.

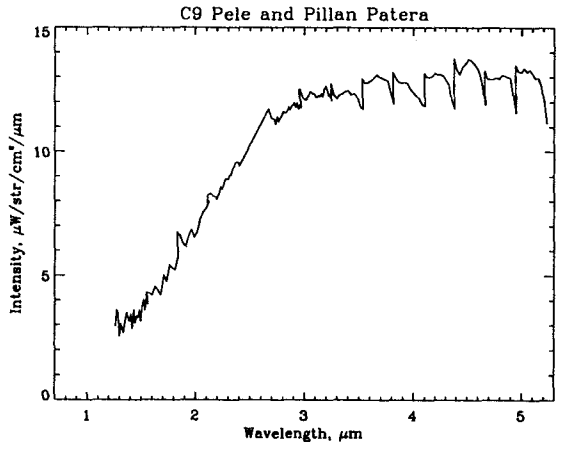
Pillan Patera	Component 1		Component 2		SSI synthesised clr/1mic ratio
	Temperature, K	Area, km^2	Temperature, K	Area, km^2	
C9#	924 ± 13	26.6 ± 3.1	406 ± 49	1814 ± 1392	5.23
E15	1004 ± 153	0.44 ± 0.41	378 ± 16	684 ± 212	6.31
E16	986 ± 65	0.71 ± 0.33	392 ± 13	350 ± 105	6.00

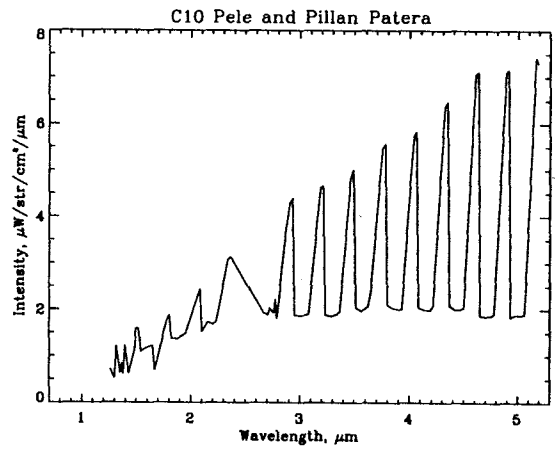
\# C9 Pillan Patera data derived from subtracting E16 Pele flux from combined C9 Pele and Pillan Patera data, having corrected for emission angle.

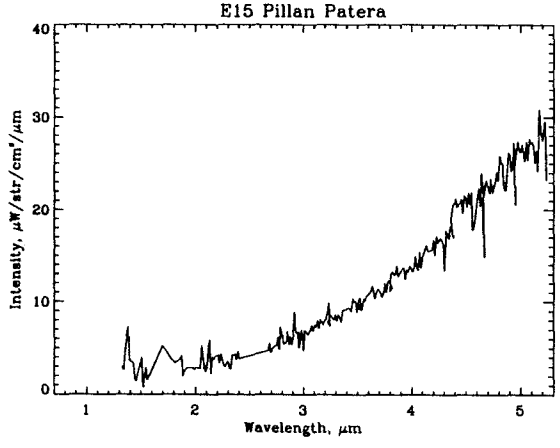

Evolution of thermal Emission from Pillan Patera
3.0×10^11
2.0×10^11
1.0×10^11
0
Power, W μm^-1
C9
C10
E15
Pele E16
E16
C20
1
2
3
4
5
Wavelength, μm

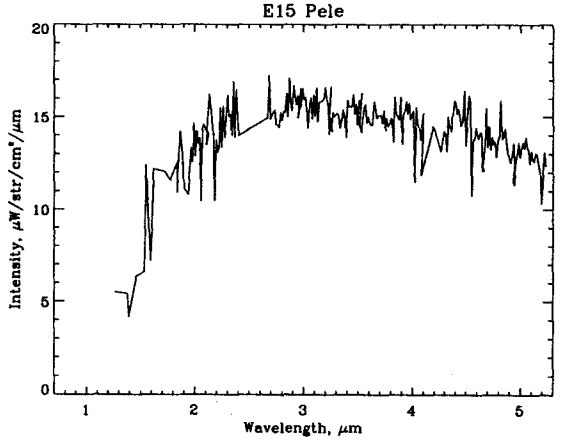

Evolution of thermal Emission from Pele
5.0×10^10
4.0×10^10
3.0×10^10
2.0×10^10
1.0×10^10
0
Power, W μm^-1
E16
G2
E15
C20
1
2
3
4
5
Wavelength, μm

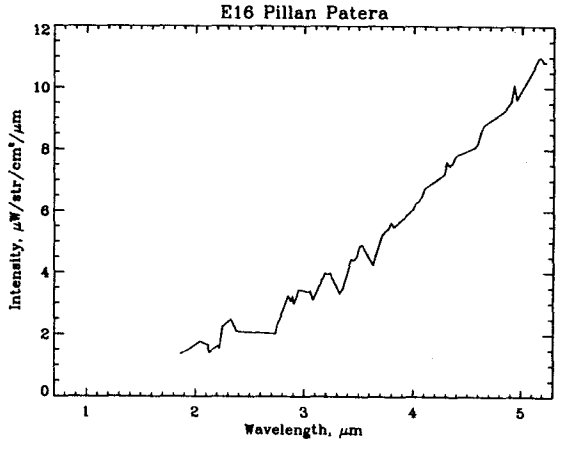

G8 Pele and Pillan: samples 11 and 12, line 5
Intensity, μW/str/cm²/μm
Wavelength, μm

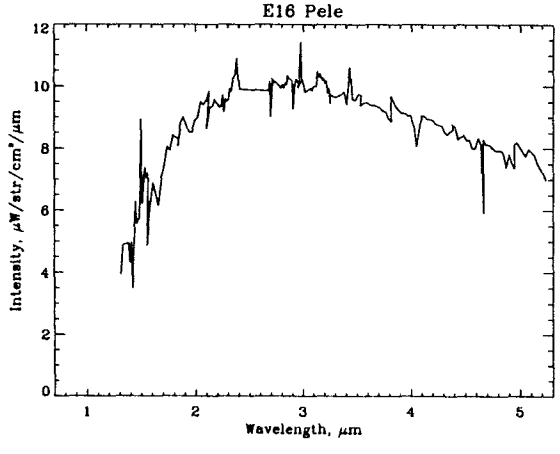

C9 Pele and Pillan Patera
Intensity, μW/str/cm²/μm
Wavelength, μm

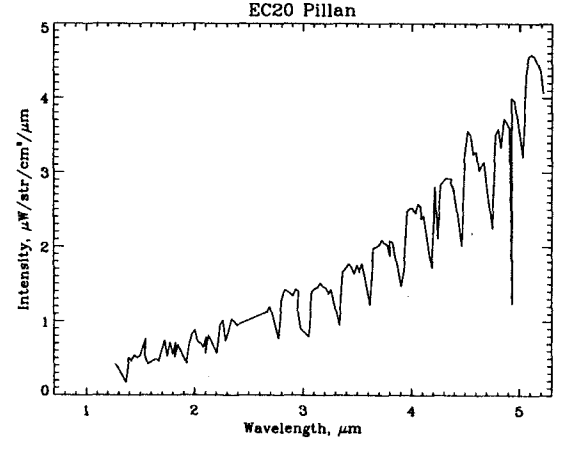

C10 Pele and Pillan Patera
Intensity, μW/str/cm²/μm
Wavelength, μm

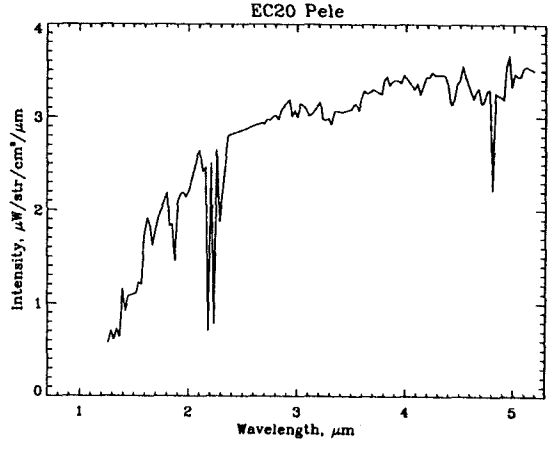

E15 Pillan Patera
Intensity, μW/str/cm²/μm
Wavelength, μm

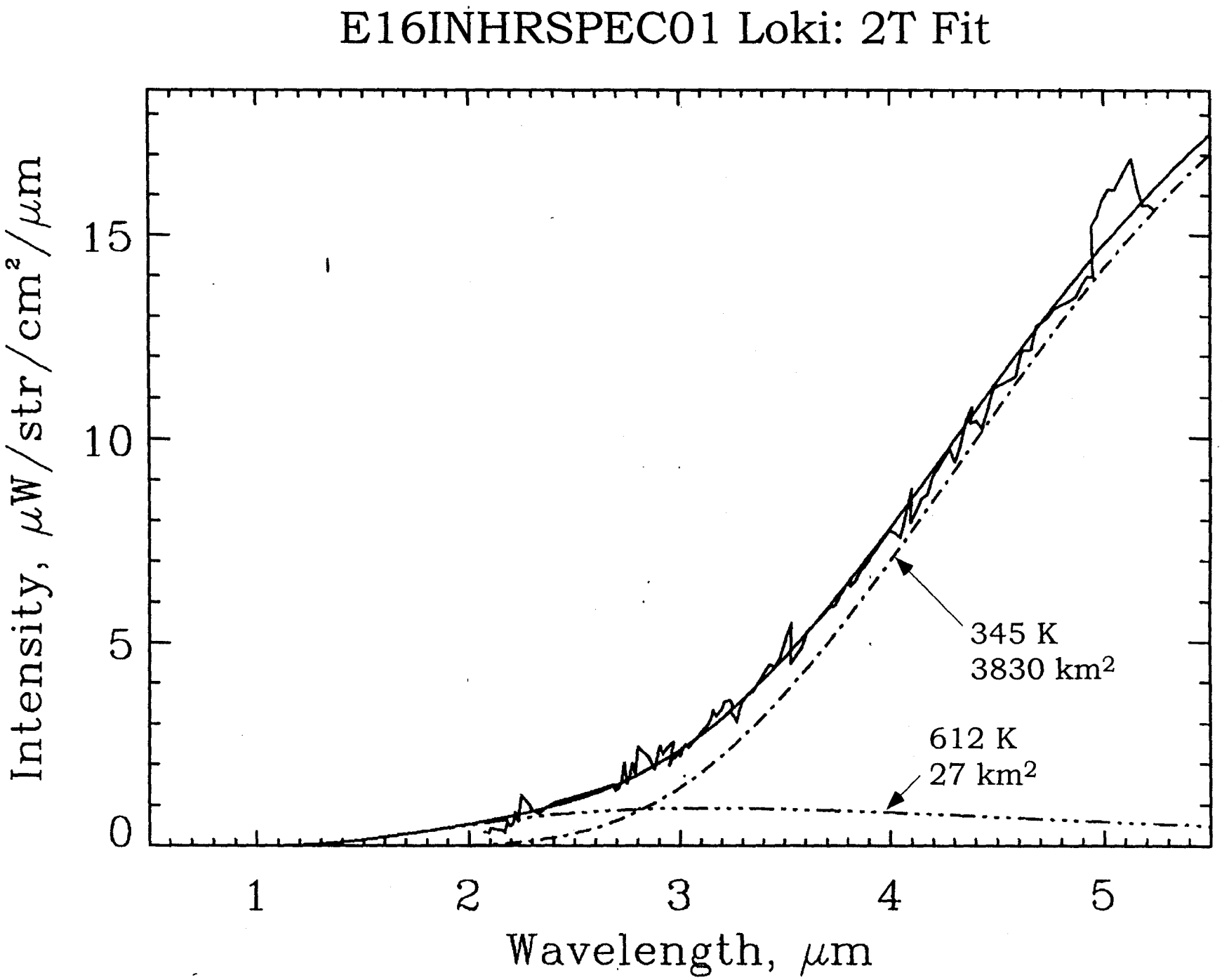

E15 Pele
Intensity, μW/str/cm²/μm
Wavelength, μm


E16 Pillan Patera
Intensity, μW/str/cm²/μm
Wavelength, μm

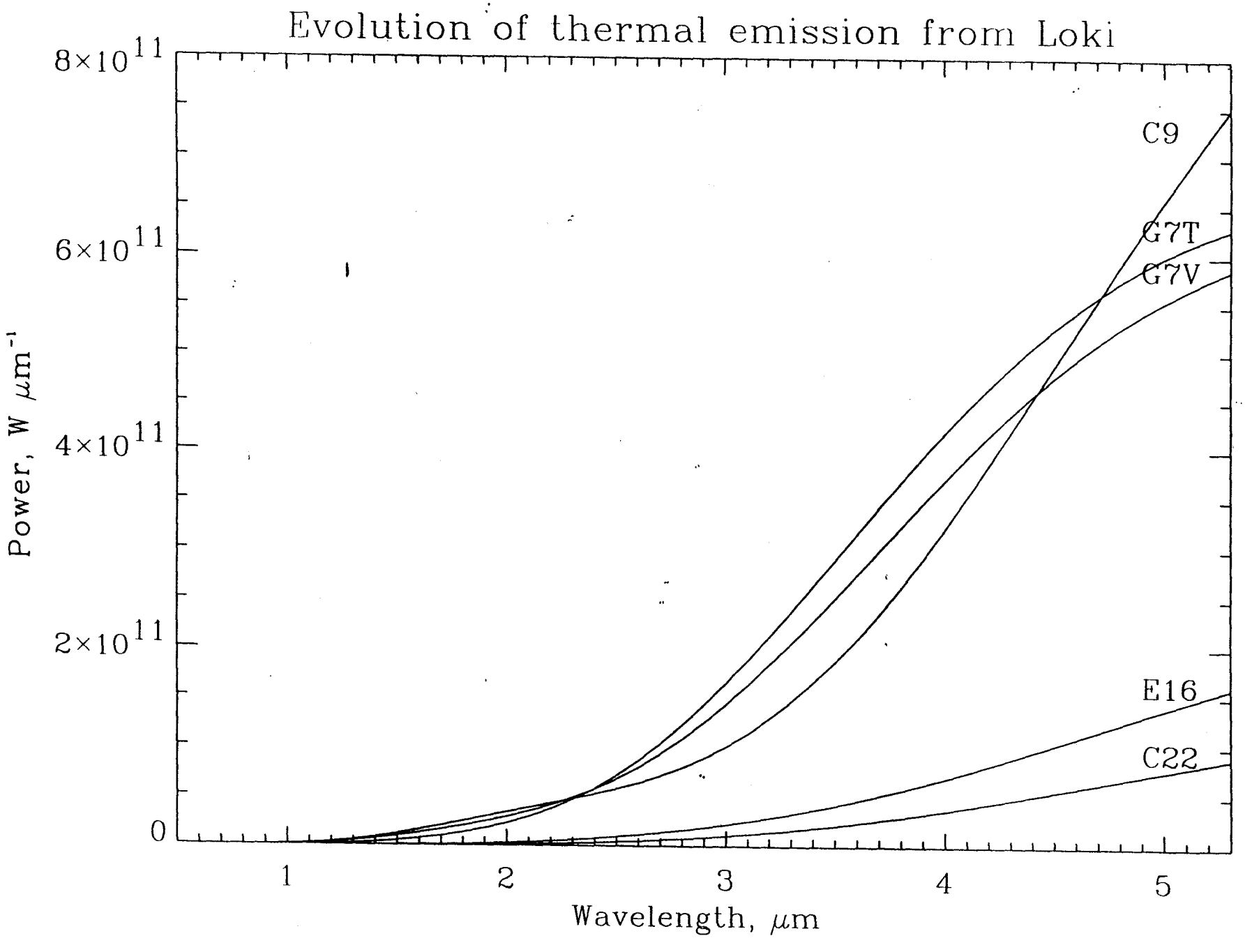

E16 Pele
Intensity, μW/str/cm²/μm
Wavelength, μm


EC20 Pillan
Intensity, μW/str/cm²/μm
Wavelength, μm


EC20 Pele
Intensity, μW/str/cm²/μm
Wavelength, μm


E16INHRSPEC01 Loki: 2T Fit
Intensity, μW/str/cm²/μm
0
5
10
15
1
2
3
4
5
Wavelength, μm
345 K
3830 km²
612 K
27 km²

Loki: Comparison of two-temperature fits and 3.5 micron brightness							
Observation	Date and Time	Range, 000 km	Temp 1 K	Area 1 km^2	Temp 2 K	Area 2 km^2	3.5 micron brightness GW/str/mic
G7INVOLCAN05	04APR97 01:07 Z	556	990	3	460	2320	80
G7INTHRMAL06	05APR97 05:10 Z	1,391	877	5	476	2030	91
C9INCHEMIS06	28JUN97 18:42 Z	1,449	962	5	373	11700	60
16INHRSPEC01	20JUL98 06:08 Z	704	612	27	345	3830	13
22INHRSPEC01	12AUG99 04:43 Z	787	576	21	339	2420	7

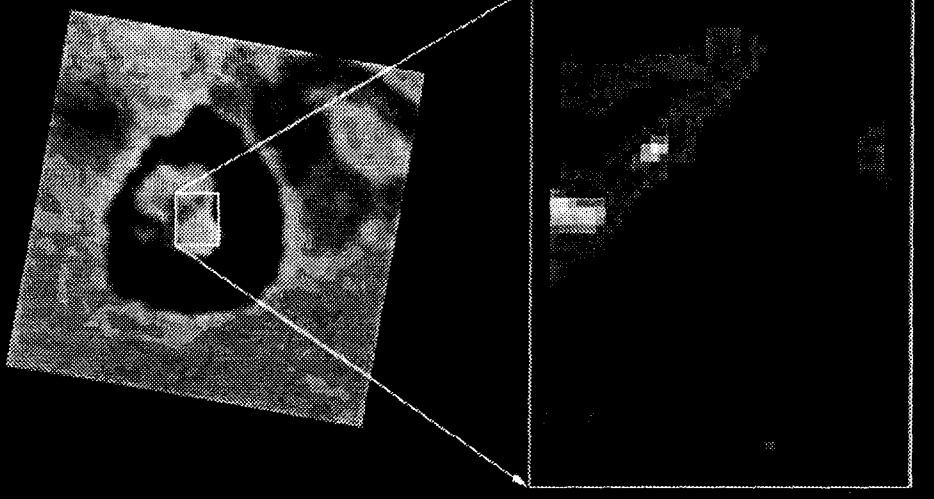

Evolution of thermal emission from Loki
8×10^11
6×10^11
4×10^11
2×10^11
0
Power, W μm^-1
1
2
3
4
5
Wavelength, μm
C9
G7T
G7V
E16
C22

Summary 1

Thermal output from 2T fits			
Loki	Component 1, W	Component 2, W	Total, W
G7INVOLCAN05	1.63 e+11	5.89 e+12	6.05 e+12
G7INTHRMAL06	1.68 e+11	5.91 e+12	6.08 e+12
C9INCHEMIS06	2.43 e+11	5.91 e+13	1.31 e+13
16INHRSPEC01	2.15 e+11	3.08 e+12	3.29 e+12
22INHRSPEC01	1.31 e+11	1.81 e+12	1.94 e+12

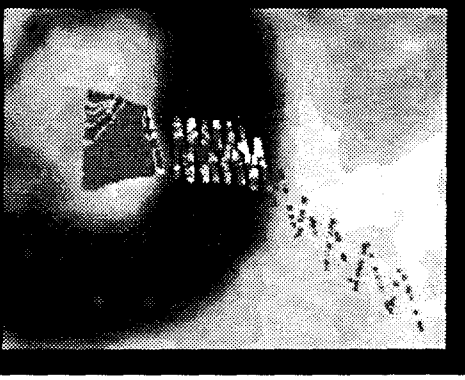
Pillan Patera	Component 1, W	Component 2, W	Total, W
C9	1.10 e+12	2.80 e+12	3.90 e+12
C10	E16 Pele subtracted from Pele-Pillan spectra		8.24 e+11
E15	2.54 e+10	7.92 e+11	8.17 e+11
E16	3.80 e+10	4.69 e+11	5.07 e+11
C20	1.68 e+10	3.32 e+11	3.49 e+11

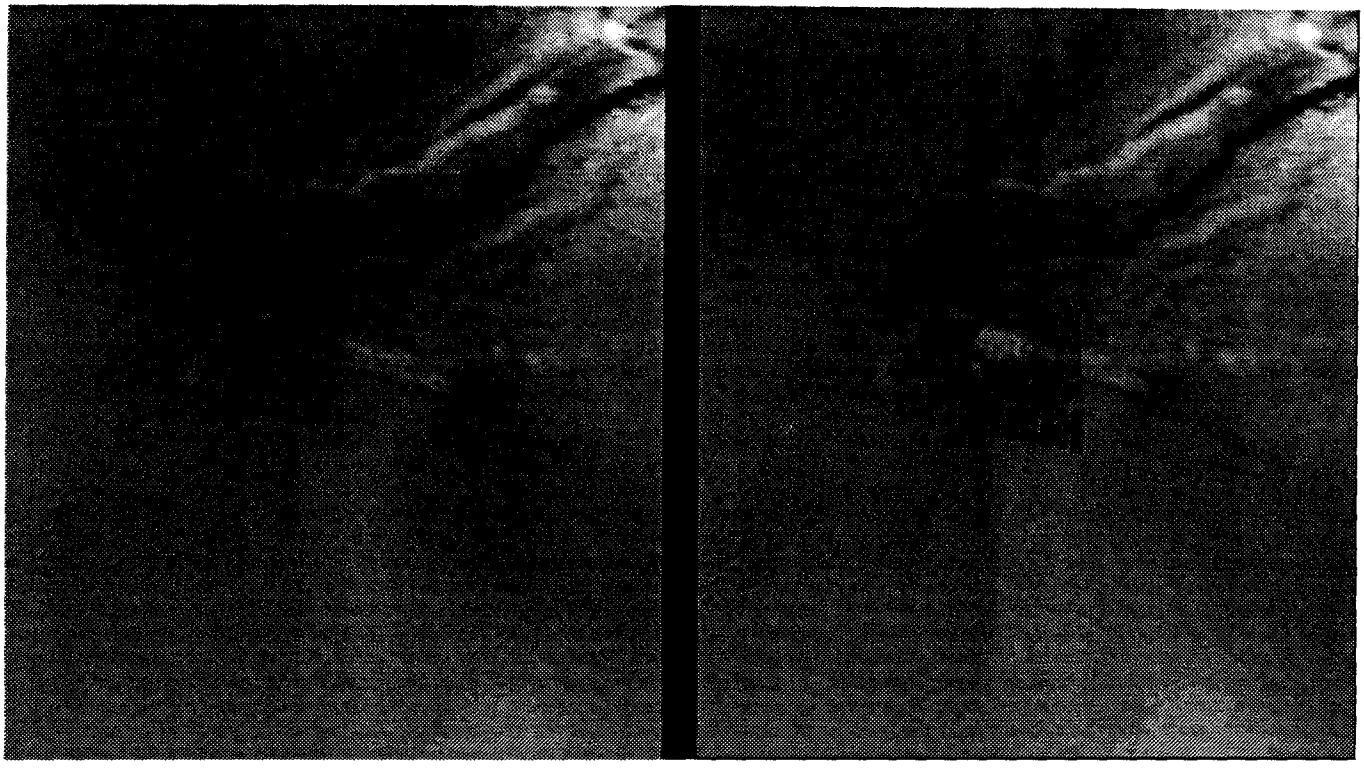
Pele	Component 1, W	Component 2, W	Total, W
G2	9.85 e+10	1.16 e+11	2.14 e+11
E15	8.37 e+10	1.33 e+11	2.17 e+11
E16	1.20 e+11	1.60 e+11	2.80 e+11
C20	6.62 e+10	1.72 e+11	2.38 e+11



Loki Patera
SSI context image

24INLOKIRA01
11 October 1999 UT 04:20
4.7 microns 1.3-2.1 km/pixel





Summary 2

Three Volcanoes: Three Styles of Eruption

Pele's relatively constant thermal emission, and shape of the emission curve, is consistent with that from an overturning lava lake: SSI has imaged what appears to be the margin of the lake, and I27 data may reveal the active portion of Pele.

Pillan Patera was a large, dynamic eruption that covered a large area in a short time. The cooling trend, followed from orbit to orbit by NIMS, is consistent with the cooling of a large flow field, revealed in subsequent SSI images. The magma eruption temperature is close to 1900 K, suggesting a komatiitie-style composition, and the rapid speed of emplacement and rate of cooling is indicative of relatively thin, low viscosity, lavas, possibly turbulently emplaced.

Loki is the most active volcano on Io: eruptions periodically re-surface the floor of the large caldera. The thermal signature from Loki, as seen by NIMS, is indicative of spreading, cooling flows, but as yet the excess thermal emission at short wavelengths, seen at Pillan during a smaller eruption has not been observed at Loki by NIMS.

SUMMARY:

THERMAL EMISSION FROM VOLCANIC CENTERS:

- Io has myriads of small and/or faint volcanoes that could not be detected from global observations
- Maps of local distribution of temperatures in volcanic centers show complex structures with multiple centers or breakouts
- High temperatures at Pele and Tvashtar consistent with basaltic lavas, but may also be consistent with ultramafic volcanism
- Temperature distribution at Loki consistent with large expanses of cooling lava flows on surface of caldera or with cooling surface of a lava lake
- Temperature distribution at Prometheus consistent with lava flowing through tubes with skylights or breakouts, and with plume erupting from near distal margins
- Significant changes in activity seen to occur in timescales of 1-3 months

SURFACE COMPOUNDS:

- Local distribution of SO_2 not well correlated with surface colors (except for anti-correlation with dark warm areas)
- High concentration of SO_2 observed inside small caldera near Chaac
- Local distribution of the yet-unidentified 1-micron band shows an anti-correlation with low-albedo and green deposits