Thermal Emission From Active Lava Lakes: A Key To Understanding Io's Interior?

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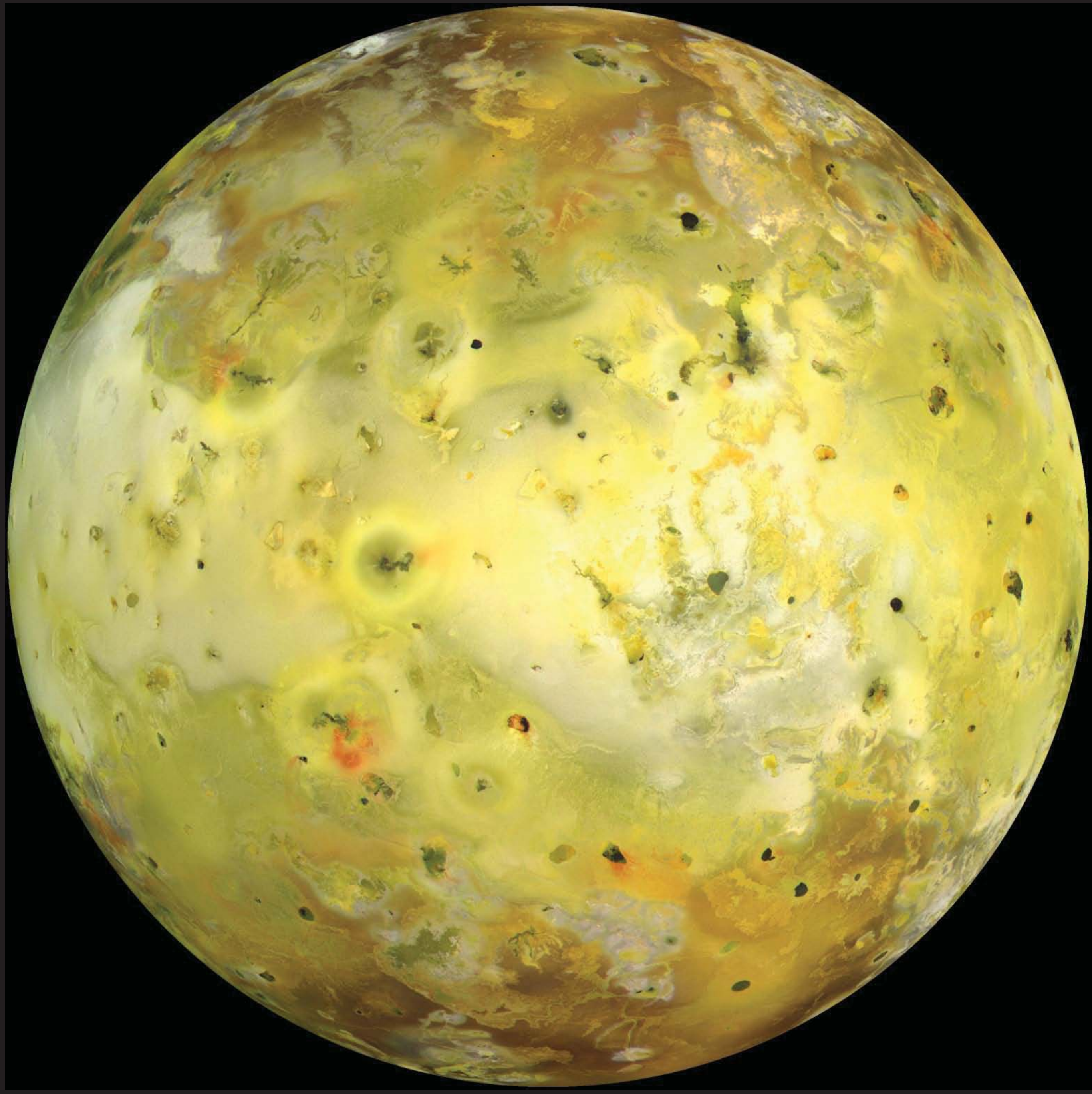
IAVCEI 2011 – Melbourne, Australia, July 2011



Why study Io's lava lakes?

1.1 Io is the only place in the Solar System (including Earth) where very large-scale silicate volcanic processes can be observed in action.

1.2 It is particularly important to derive eruption temperatures of Io's lavas because this applies strong constraints not only on composition but on the state of Io's mantle.

1.3 The mantle state, in turn, is a function of the degree of tidal heating caused by the evolving orbital resonance between Io, Europa and Ganymede.

1.4 Understanding the interior conditions of Io provides constraints on Europa's interior state and history. Io, as the most extreme example of tidal heating in the Solar System, is the best place to understand how this process works.

The Big Question, post-*Galileo*

What is the dominant composition of Io's lavas?

Basaltic, or ultramafic?

Heating of Io and orbital evolution

1. Steady state (Yoder, 1979)

- Constant eccentricity
- ~Constant dissipation rate
- Orbital resonance is maintained
- All satellites slowly recede from Jupiter

2. Oscillatory solutions (e.g., Lainey et al., 2009)

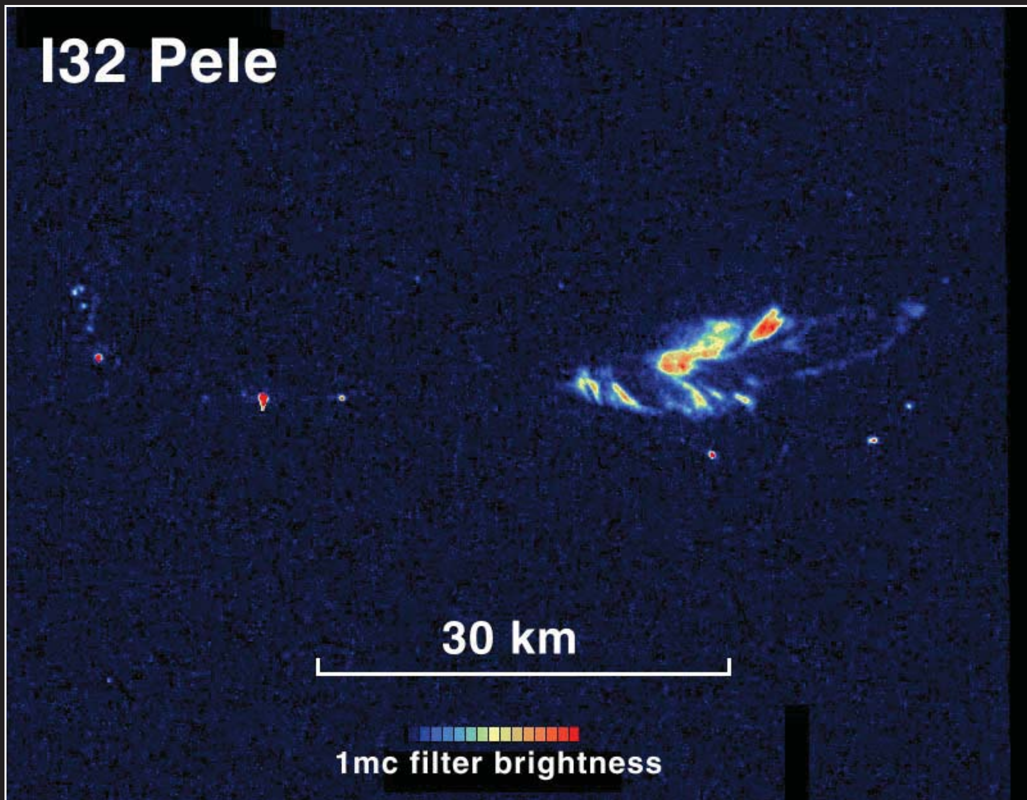
- Cold Io → elastic interior → increased eccentricity → increased tidal heating → Hot Io

- Hot Io → dissipative interior → decreased eccentricity → decreased tidal heating → Cold Io

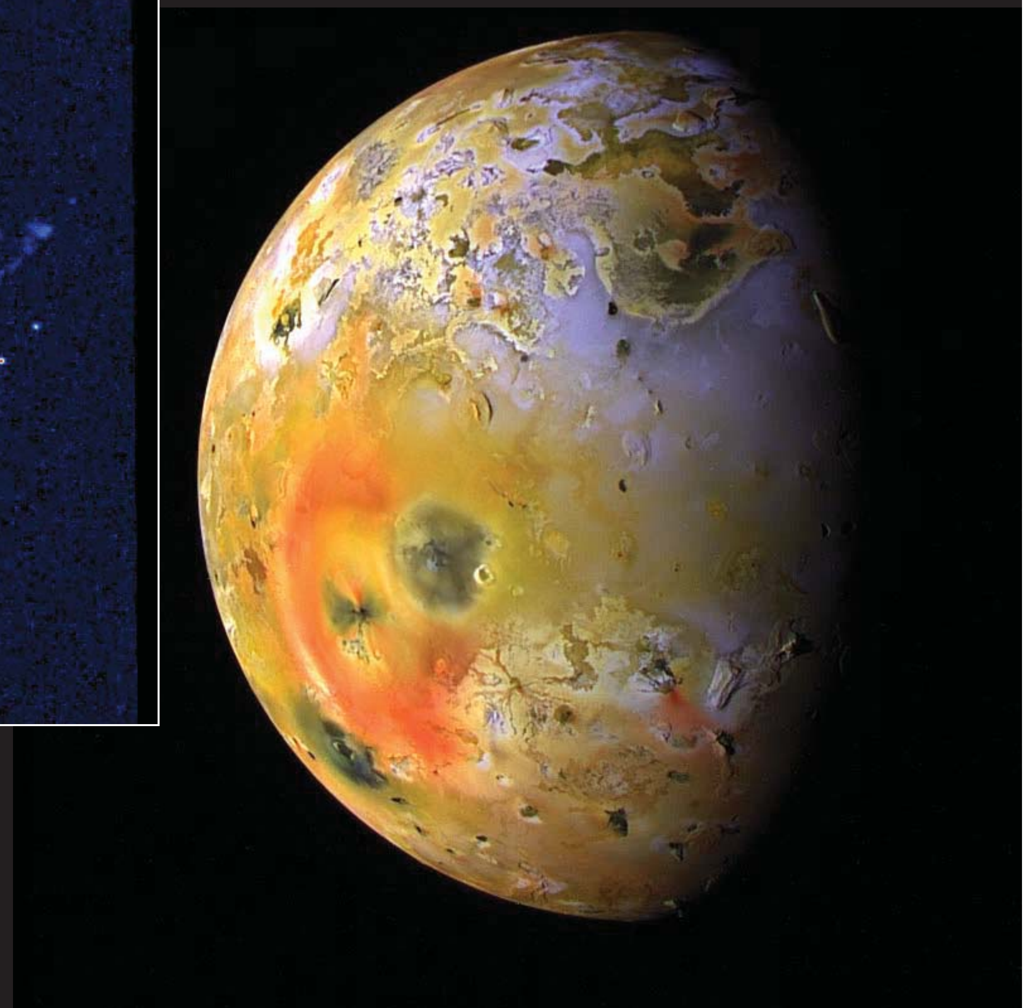
Oscillations produce varying tidal heating in Europa

J. Spencer, pers comm. 2009

Pele – a lava lake on Io



Galileo SSI observation (40 m/pixel) in 2001

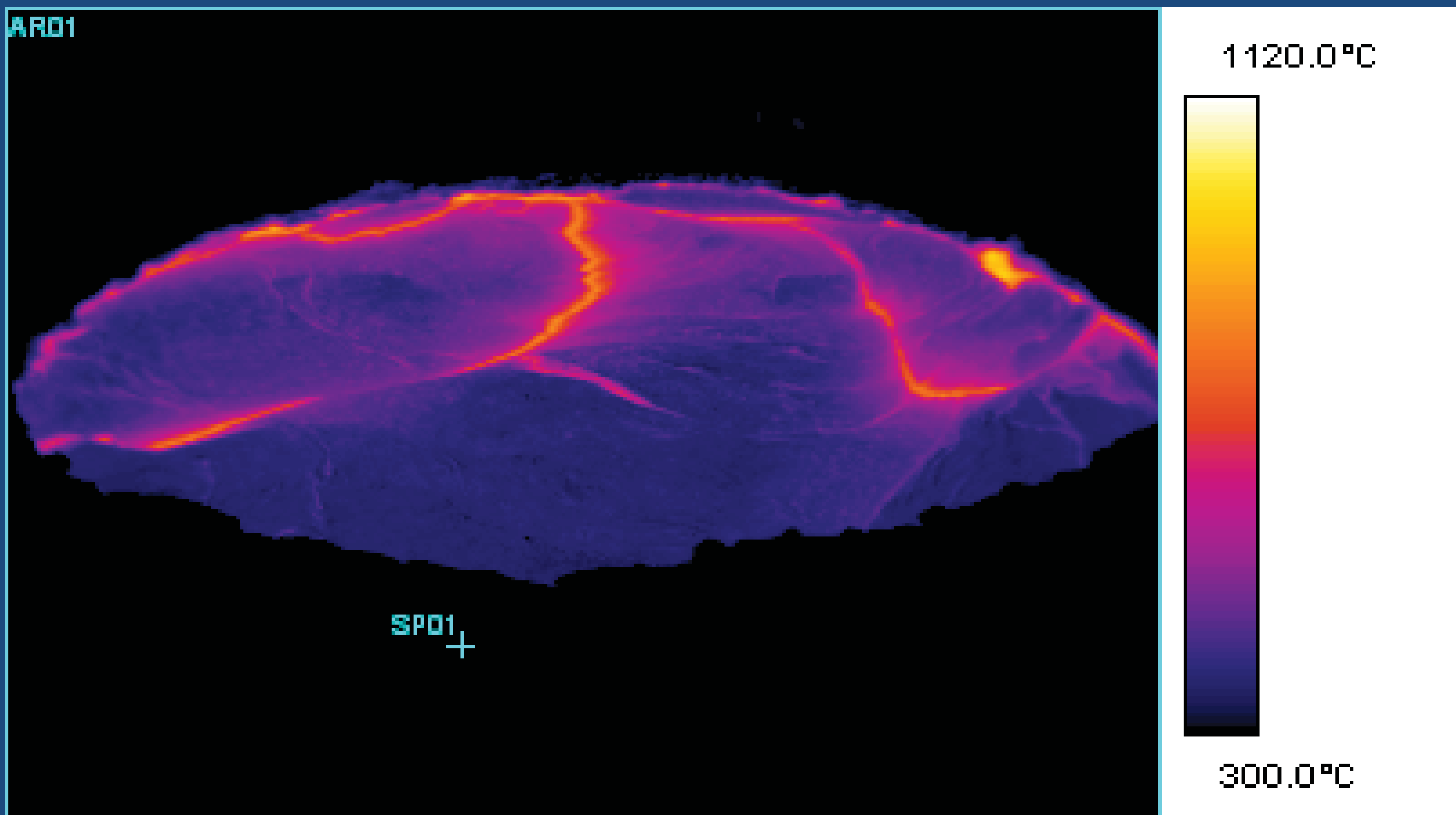


- Degassing disrupts the lake surface
- Escaping gas creates plume

Radebaugh *et al.*, 2004, *Icarus*.

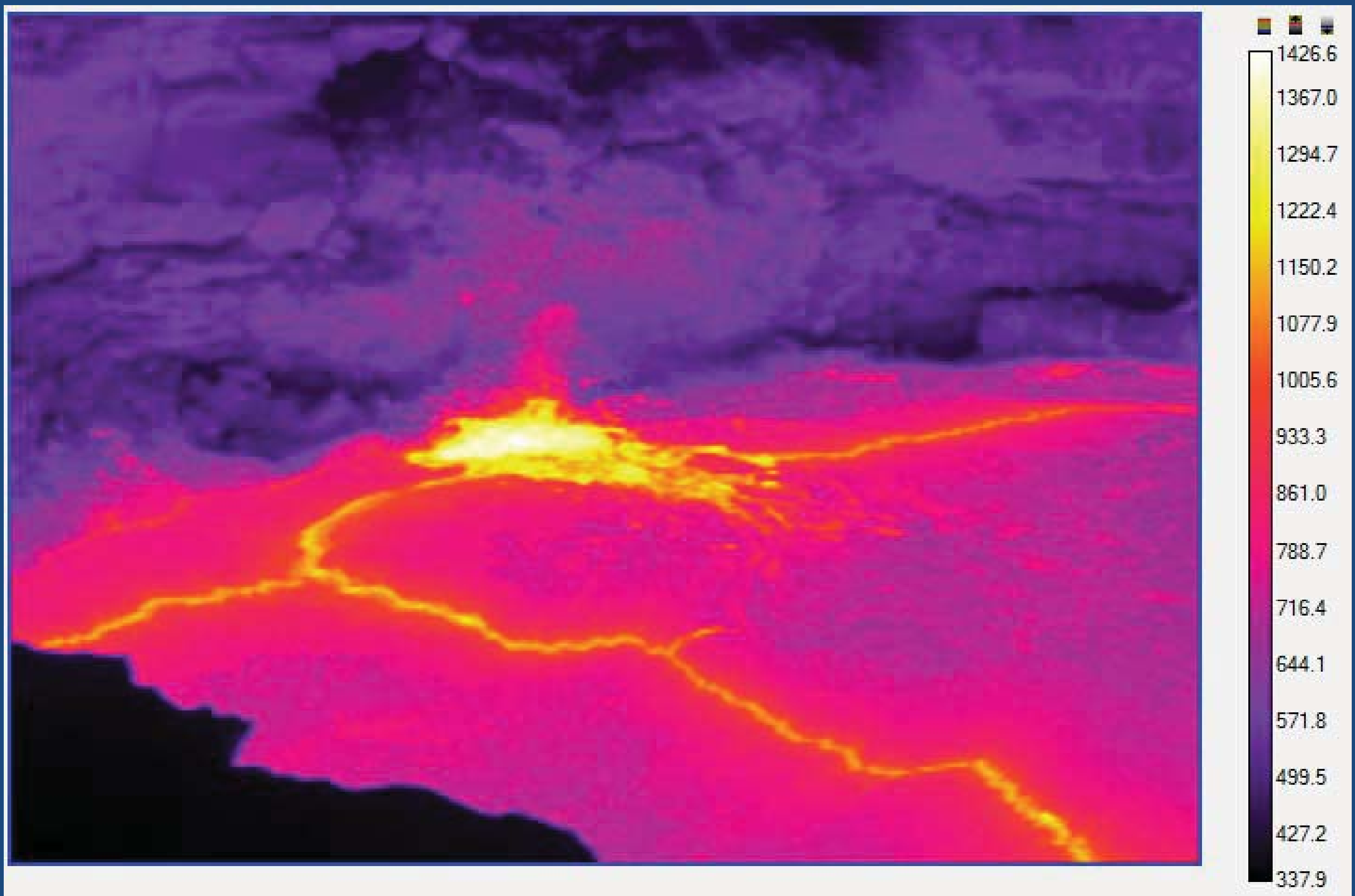
Erta'Ale – dynamic processes

FLIR data – P65

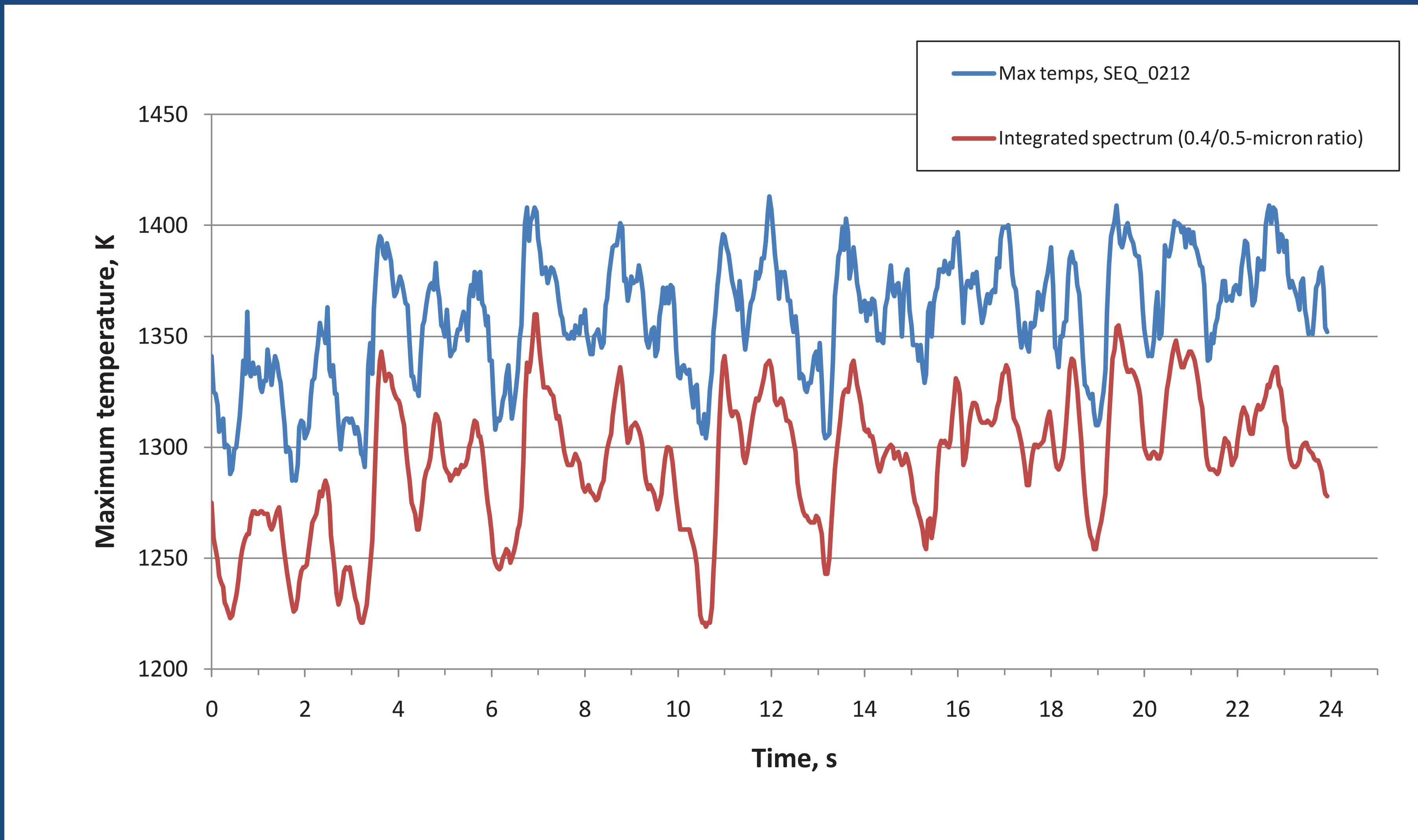


Lava fountains

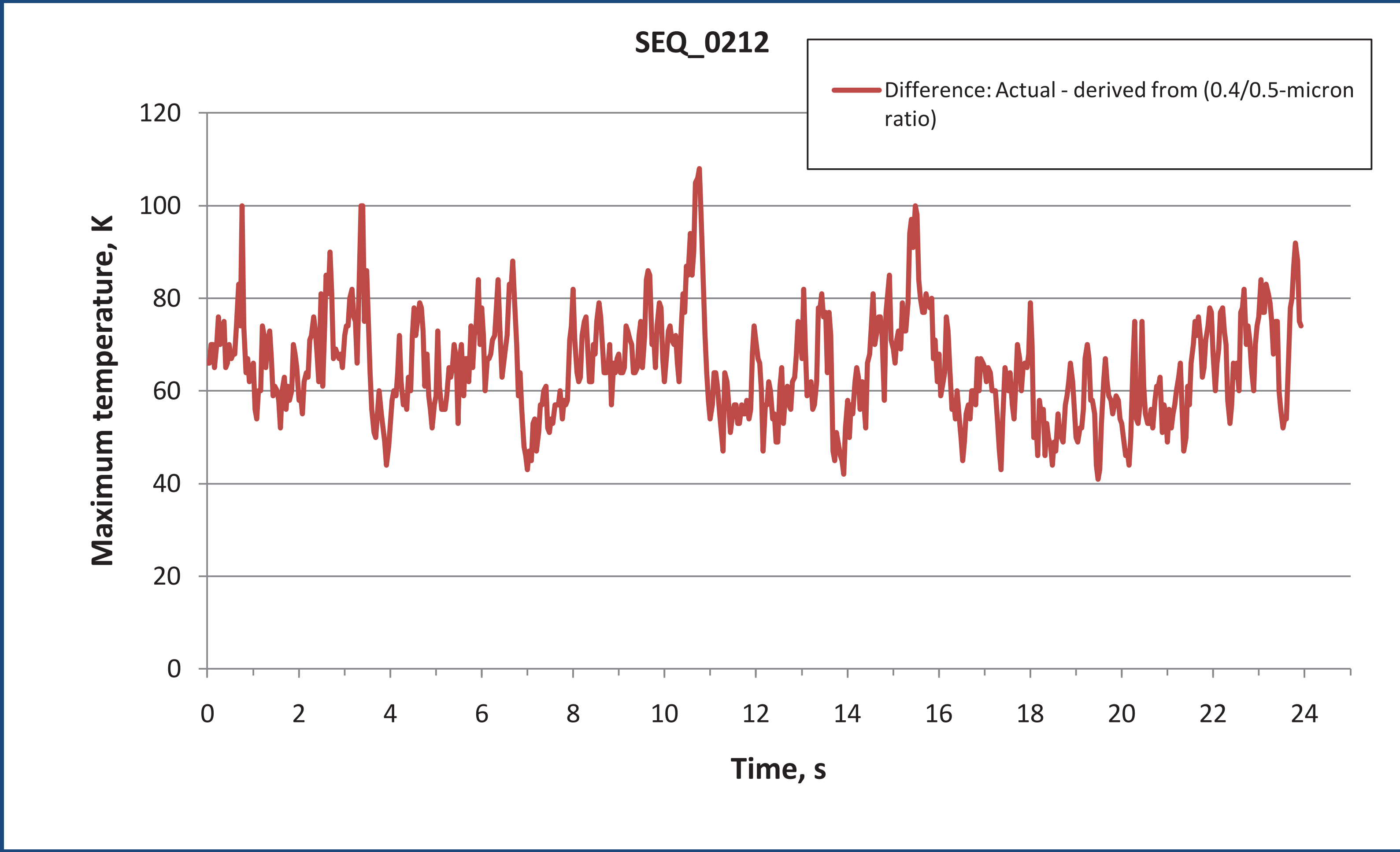
ThermaCAM P65



Measured and Derived Temperatures



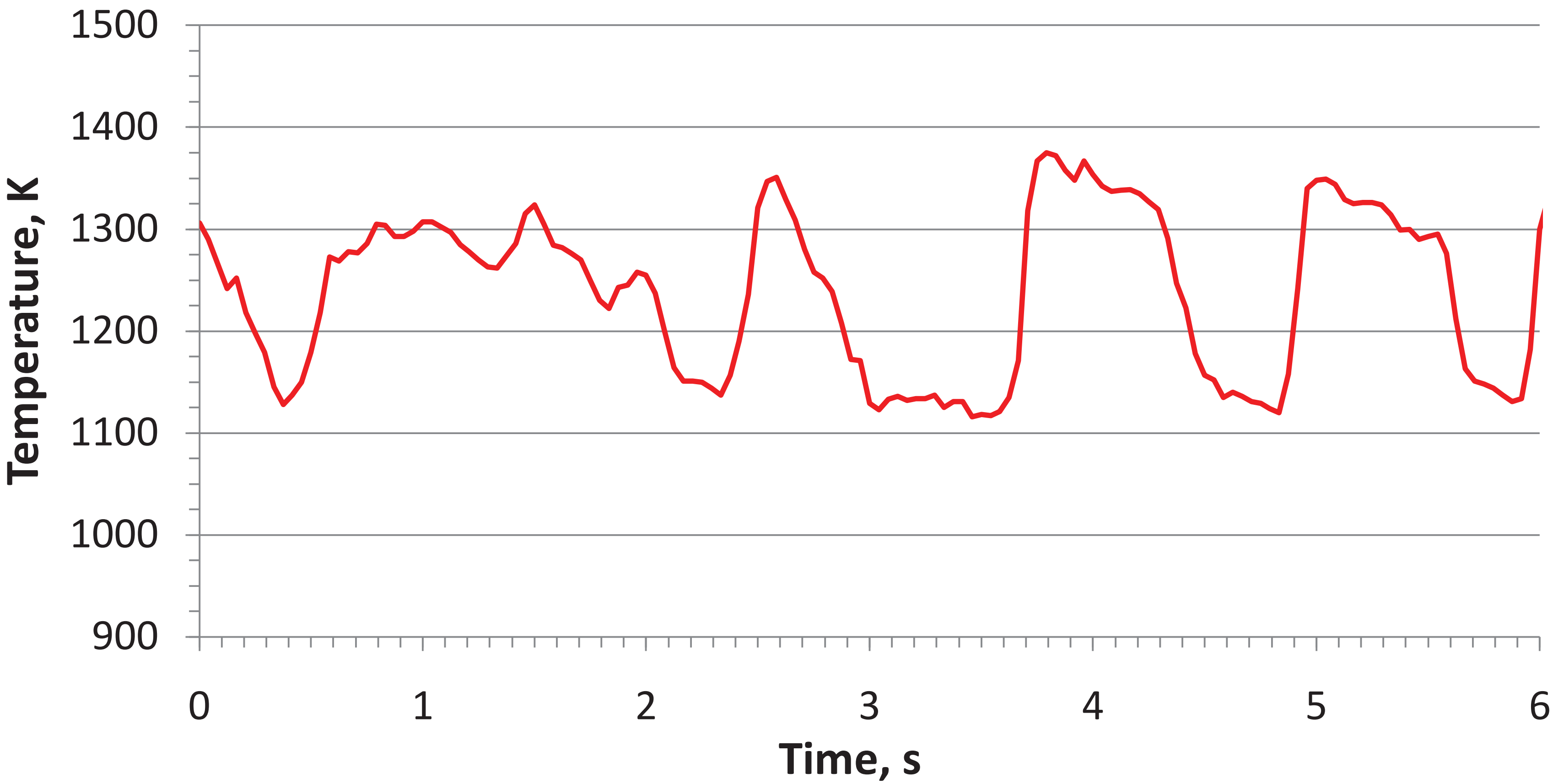
Temperature under-estimation



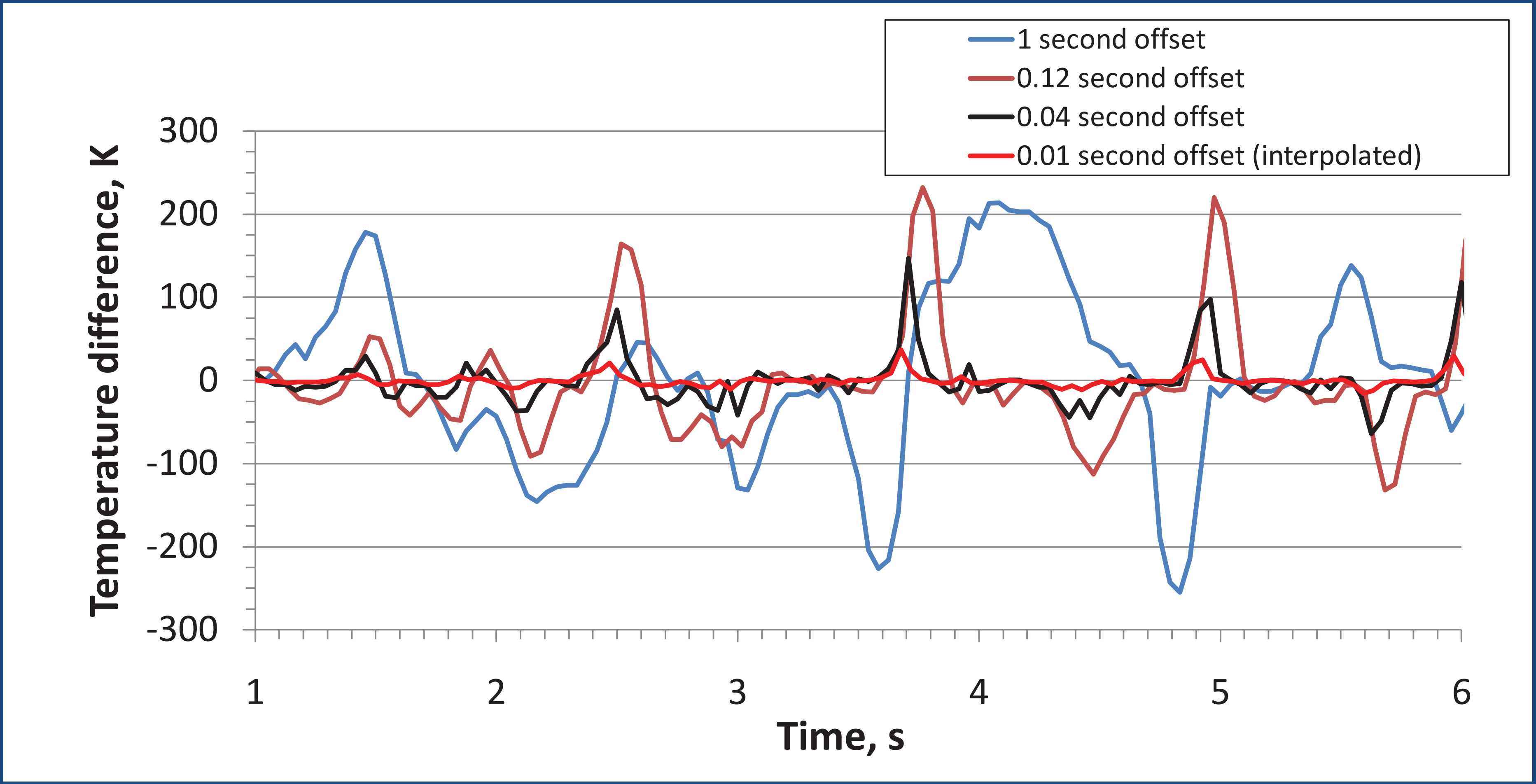
Summary of temperature derivations

2-colour underestimation of actual max. temperature			
	Integrated spectra, with T derived from 0.4/0.5-µm ratio	Maximum temperature from FLIR data	Difference (FLIR data – derived from ratio)
Maximum (K)	1360	1413	**108**
Minimum (K)	1219	1285	**41**
Average (K)	1292	1357	**65**
Stand. dev. (K)	31	28	**11**

One pixel: Temperature difference with different time offsets



One pixel: Temperature difference with different time offsets



Minimising time delay

Optimisation of observation time				
Offset, s	1	0.12	0.04	0.01
Average difference, K	74.0	41.0	16.4	4.1
Standard deviation, K	62.4	44.4	20.0	5.0
Median, K	53	26	10	2.5
Max. diff., K	255	232	179	45

Conclusions

1. Erta'Ale volcano is probably the best terrestrial analogue for activity at Pele (Io).

2. To extract useful temperature estimates from remote-sensing data requires:

(a) High spatial resolution data to isolate lava fountains from lava flows – this is only possible with close fly-bys;

(b) Rapid acquisition of multi-colour data;

(c) Recognition of the style of volcanic activity taking place;

(d) An appropriate model of the eruption process and cooling mechanisms.

Conclusions

3 Future missions to Io must incorporate such instrument capabilities, as has been done with the proposed Discovery-class *Io Volcano Observer*

Work in progress…

Further work is necessary to constrain the effects on temperature derivation of

- noise
- filter response
- radiation

Acknowledgements

This work was carried out at the Jet Propulsion Laboratory-California Institute of Technology, under contract to NASA.

AGD gratefully acknowledge the support of the NASA Planetary Geology and Geophysics Program and thanks the BBC for logistical support for the 2009 Erta'Ale field campaign.