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SILICATES VERSUS SULPHUR - SEARCHING FOR CLUES ABOUT IONIAN VULCANISM WITH CANARICAM

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Vulcanism was first detected on Io in 1978 by Voyager 1. Since then it has been recognised that Io is the most volcanically active body in the Solar System. Although the initial volcanic activity observed was in the form of SO_2 geysers and sulphur lakes, the Galileo mission has detected temperatures as high as 1800K on the surface, far in excess of the temperatures that can be explained by sulphur-driven activity. Galileo observations suggest that silicate vulcanism is the principal driver of activity, even though the temperatures measured are even in excess of those measured in terrestrial silicate vulcanism, but the relationship between silicate and sulphur-driven activity is not well understood. We propose a project to monitor low-temperature vulcanism on Io systematically, using CanariCam on the GTC. This project will allow a better understanding of the mechanisms of sulphur-driven vulcanism, and the relative importance of silicate and sulphur-driven activity.

Ionian Vulcanism

In 1978 IR observations showed unsual variations on its brightness. At the beginning of 1979, Pearl predicted possible vulcanism on Io due to a melting by tidal dissipation where Jupiter and Europa play the most important roles. In March 1979, Voyager 1 discovered the first evidence of vulcanism. Voyager 2 confirmed the discovery and showed the high level of activity of Io on short time scales.

Tidal dissipation on Io generates 40 times the energy of its terrestrial equivalent. The volcanic activity generates the characteristic umbrella shaped plumes observed, typical of SiO_2 geysers. The plumes produced have this shape due to the low ionian gravity (1/6 terrestrial) and the quasi-unexistent atmosphere.

Superficial Morphology

Io's surface is formed by 3 different morphological structures: plains, mountains and volcanoes with colours from white through yellow to red and black. Those colours make one think of a sulphur vulcanism, as elemental sulphur changes its colour as it is heated. The volcanoes and hot spots are similar to the terrestrial equivalents. They reach temperatures from 350K to 1000K and 1800K in some cases. Taking into account that the boiling point of elemental sulphur is 450K in the ionian atmosphere, it suggests that it is impossible that elemental sulphur is the driver. It is possible that some of the lower temperatures also come from silicate cooling processes.

Spectrum

In spite of the evidence of silicate vulcanism from the temperatures measured, Io's spectrum is dominated by sulphur compounds, with no evidence of silicates. Its spectrum is the result of the combination of several contributions, where the hot spots dominate between 5 and 10μm.

Starbursts

Starbursts are the most dramatic volcanic events which have ever been seen on Io, with very high temperatures and fluxes and short life times. These events usually at least duplicate the characteristic total flux of Io at 5μm. The number of observed events of this kind is small. On 2001, Marchis detected the most energetic eruption on Io near to the volcano Surt using adaptative optics tecniques.

Why is the study of Io interesting?

- Only on Io and Venus is it possible to see large scale geological phenomena.
- We can learn about tidal heating, large scale volcanic processes and basic planetary physics.
- Io can teach us something about the historical volcanic activity on Mars and our Moon.
- T>1700K allows us to study processes which only occurred on the Earth the distant past.

There are many questions about Io that have not yet been answered. For instance, nobody knows how to explain the existence of ionian vulcanism without

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tectonic plates. Nor the effects of a quasi-unexistent atmosphere and low gravity. Futhermore, the heat which is generated may be impossible to explain using only tidal dissipation, so it may have an additional, unknown heating component. And, of course, the magmatic composition and the relationship between SO_2, S and Si vulcanism are the most important unknowns.

Exploring Io on the future

Space probes: there are no active or planned proyects for space missions to study Io at present. Several projects were presented between 1996 and 1999, but none was accepted due to technical problems. **Space telescopes:** it would be of great interest to observe Io with SIRTF in the Mid-IR, but ecliptic objects are very difficult to study with SIRTF because their short visibility and focal plane movements restrictions. So ground-based observations will be the only ones available at least for the next 15 years.

Adventajes of using GTC+CCam

• A large number (22) of broad and narrow-band filters covering a range in wavelength from 2.2 - 25μm. These include broad-band L' and M as well as the silicate filters in the N window.

• High sensitivity - 1s/1s $\sim$12mJy in broad band N, which scales to >>40mJy in a 15% filter.

• High spatial resolution - the diffraction-limited image quality of CanariCam corresponds to 50 elements of resolution on the surface of Io, equivalent to 500km on the surface of the satellite.

• Good temporal resolution - in the case of observing a sudden increase in flux from an eruption we can obtain resolutions of a second or less.

• The ability to change to spectroscopic mode with almost no loss of time - individual caldera can be observed in the low or high-resolution mode to study the silicate and sulphur emission.

• A reliable system of calibration - we will have the advantage of the best mid-IR calibration available in the world. This will allow a high data quality.

• Queue observing mode and time pressure - with relatively low time pressure on the GTC in its initial operation we can consider ambitious monitoring programmes that will not be possible when the suite of available instruments is increased. The Queue Observing mode will allow short observations to be taken on a regular basis.

Observational Proyect

• CanariCam has 8 filters of interest, which cover the range from 3.8 to 12.5μm - the 6 silicate filters of 10-15% bandpass and the broad band L' and M filters below the 10μm window. These filters are sensitive to a wide range of temperature from the hottest silicate eruptions through to low-temperature SO_2 geysers. By careful selection of the filter set and excellent flux calibration we can fit the black body curve with precision and measure the temperature and energy budget for individual caldera.

• We propose to use 6 filters that cover the full wavelength range. For a mean flux of 1Jy - typical of eruptions on Io - we estimate that we can obtain s/n >> 50 in 50 seconds per filter. This is the minimum s/n that we require. There is no point in taking longer exposures to obtain s/n > 100 as it is not possible to calibrate in the mid-IR to 1%.

• We estimate that, with dead time and calibration, we will need 600s of telescope time per night to observe Io in 6 bands. Observations should be taken every 2 nights during the observing season for Jupiter. This is equivalent to a requirement for just 20 hours of observing time per year over the 2-3 years that we anticipate the project lasting.

It will be the first systematic monitoring Programme of low-temperature Ionian vulcanism and will provide a unique insight into the different volcanic processes on this satellite.

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