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High-speed imaging of explosive eruptions: applications and perspectives

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Explosive eruptions, being by definition highly dynamic over short time scales, necessarily call for observational systems capable of relatively high sampling rates. “Traditional” tools, like as seismic and acoustic networks, have recently been joined by Doppler radar and electric sensors. Recent developments in high-speed camera systems now allow direct visual information of eruptions to be obtained with a spatial and temporal resolution suitable for the analysis of several key eruption processes. Here we summarize the methods employed to gather and process high-speed videos of explosive eruptions, and provide an overview of the several applications of these new type of data in understanding different aspects of explosive volcanism.

Our most recent set up for high-speed imaging of explosive eruptions (FAMoUS – FAst, MUltiparametric Set-up,) includes: 1) a monochrome high speed camera, capable of 500 frames per second (fps) at high-definition (1280x1024 pixel) resolution and up to 200000 fps at reduced resolution; 2) a thermal camera capable of 50-200 fps at 480-120x640 pixel resolution; and 3) two acoustic to infrasonic sensors. All instruments are time-synchronized via a data logging system, a hand- or software-operated trigger, and via GPS, allowing signals from other instruments or networks to be directly recorded by the same logging unit or to be readily synchronized for comparison. FAMoUS weights less than 20 kg, easily fits into four, hand-luggage-sized backpacks, and can be deployed in less than 20’ (and removed in less than 2’, if needed).

So far, explosive eruptions have been recorded in high-speed at several active volcanoes, including Fuego and Santiaguito (Guatemala), Stromboli (Italy), Yasur (Vanuatu), and Eyjafiallajokull (Iceland). Image processing and analysis from these eruptions helped illuminate several eruptive processes, including:

1) Pyroclasts ejection. High-speed videos reveal multiple, discrete ejection pulses within a single Strombolian explosion, with ejection velocities twice as high as previously recorded. Video-derived information on ejection velocity and ejecta mass can be combined with analytical and experimental models to constrain the physical parameters of the gas driving individual pulses.

2) Jet development. The ejection trajectory of pyroclasts can also be used to outline the spatial and temporal development of the eruptive jet and the dynamics of gas-pyroclast coupling within the jet, while high-speed thermal images add information on the temperature evolution in the jet itself as a function of the pyroclast size and content.

2) Pyroclasts settling. High-speed videos can be used to investigate the aerodynamic settling behavior of pyroclasts from bomb to ash in size and including ash aggregates, providing key parameters such as drag coefficient as a function of Re, and particle density.

3) The generation and propagation of acoustic and shock waves. Phase condensation in volcanic and atmospheric aerosol is triggered by the transit of pressure waves and can be recorded in high-speed videos, allowing the speed and wavelength of the waves to be measured and compared with the corresponding infrasonic signals and theoretical predictions.