Lightning discharges in a Jovian atmosphere

A. Robledo-Martinez [(1)], L. A. Garcia-Villarreal, C. González-Armendáriz, J. M. Basurto

Departamento de Ciencias Básicas,Universidad Autónoma Metropolitana, Azcapotzalco, 02128 Mexico City, Mexico

[(1)] arm@azc.uam.mx

Since lightning in Jupiter's atmosphere was detected for the first time by a satellite in 1979 [1], numerous detections made afterward have produced a more detailed picture of the distribution and intensity of the strokes. Lightning was also detected by other probes such as Cassini [2], Galileo [3] and Juno [4]. Juno's team reported observations on shallow lightning flashes and identifies that out of six strokes, four of them were detected at altitudes corresponding to atmospheric pressures in the range 1.4-1.9 bar, which are within the scope of this work.

In the present work we set out to investigate some of the properties of lightning on a synthetic Jupiter atmosphere whose composition is: 90% hydrogen and 10% helium, both high-purity. For the experiments we used an encapsulated 300 kV Marx generator that has a rise-time of 0.7 μs and can deliver peak current of ~3 kA. A set of conical point-plane electrodes were set inside a large (6 m^3 capacity) vacuum chamber that contained the synthetic gas mix. The diagnostics used included: time-resolved spectroscopy, high-speed and conventional photography, as well as electric field and pulse current sensors.

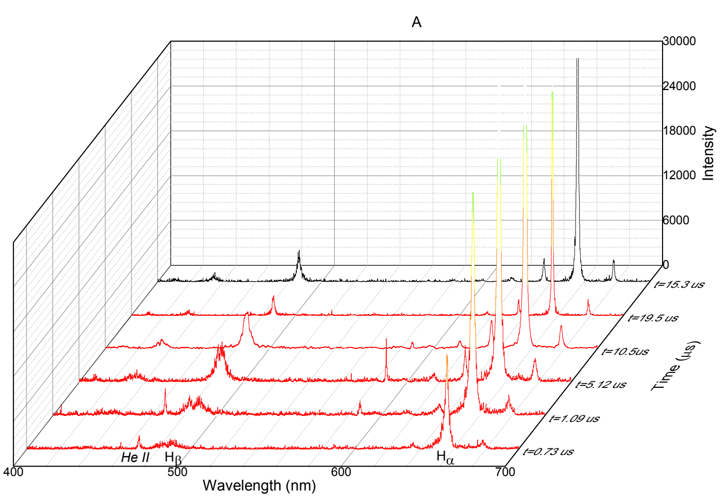

Fig. 1.Time resolved spectra. Pressure: 0.5 atmospheres. Peak current: 3.1 kA. Gap: 11.5 cm.

Figure 1 shows spectra of the discharge recorded with time resolution within the time interval 0.7-15 μs using an acquisition time that was roughly 10% of the delay time. The graphs shows that the spectrum has very little continuum, even at short times (t<1 μs) whereas this type of arc has strong continuum in other atmospheres. Similar experiments made in air showed strong continuum for delays up to 2 μs [5]. The H_α, H_β and the H_γ lines of the Balmer series are clearly visible in the spectra.

Figure 1 shows that most of the radiation emitted is contained in the H_α line. At short times (t<5 μs) the singly-ionized He II (468.5 nm) line is clearly visible but it disappears at later times.

The electronic excitation temperature was calculated using the line-to-continuum ratio method [6]. The H_β line was employed to obtain the temperatures shown in Fig. 2. The figure shows that the temperatures decrease sharply in the first 8 μs for the Jovian atmosphere. For the sake of comparison, this graph includes the results obtained in a discharge performed in an air atmosphere under identical circumstances [5].

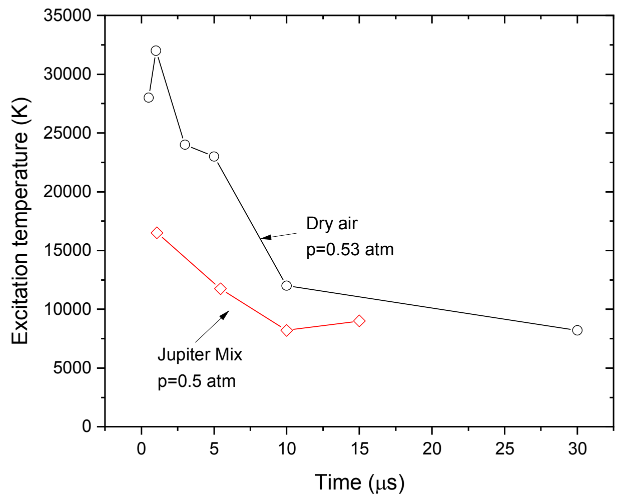

Fig. 2. Electronic excitation temperature. Comparison of the results obtained in the present work with discharges in dry air (see Ref. 5).

The experiments performed show that lightning in a jovian atmosphere emits surprisingly less continuum radiation than a similar discharge in atmospheric air. The fact that the He II line is clearly visible at short times is a clear indication that the plasma is quite hot initially and cools down at later times. This inkling is confirmed by the results of Fig. 2 that show that the temperature decreases rapidly from 17,000 K to 7,000 K in less than 8 μs. This figure also shows that an arc discharge performed under the same conditions in air (same gap separation, same peak current) results in electronic temperatures twice as large as those of the Jovian atmosphere.

[1] A. F. Cook II, T. C. Duxbury and G. E. Hunt, *Nature* **280** (1979) 794.

[2] D. A. Gurnett *et al.*, *Science* **253** (1991) 1522-1525.

[3] B. Little *et al.*, *Icarus* **142** (1999) 306.323.

[4] H. N. Becker *et al.*, Nature 584 (2020) 55-58.

[5] A. Robledo-Martinez, H. Sobral and A. Ruiz-Meza, *J. Phys. D: Appl. Phys.*, **41** (2008) 175207.

[6] H. R. Griem, *Principles of Plasma Spectroscopy*, Cambridge University Press, Cambridge, UK, 1997.