Jet observations and theories

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Transient Luminous Events are short-lasting electrical phenomena in the stratosphere and mesosphere related to lightning. The phenomena can be separated into glow-like phenomena as elves and halos; high-altitude initiated streamer discharges named sprites; and various sizes of upward streamer discharges originating inside thundercloud tops, collectively called jets. Additionally, secondary jet-like phenomena may occur during some sprites, known as trolls and palm trees. This topical talk will provide an overview of observations of the jet-like phenomena, their occurrence, their association with lightning and the thundercloud and will highlight models of their origins as well as their dynamics.

1. Jet types

After isolated eye-witness reports over almost a century, and possible recordings from space, jets have first been recorded and described in detail by Wescott et al. in 1996 [1]. The recording was made from two aircraft making it possible to see clearly the top of thunderstorm clouds without interfering dense air. The events were conically shaped blue emissions reaching altitudes of 30-40 kilometers and have been named "blue jets" by the authors. The luminosity decreases with height. A population of similar second jet-like phenomenon was named "blue starters", these reached distinctly lower altitudes of about 25 km [2].

Only in 2002, thirteen years after the discovery of sprites and numerous observation campaigns in the central United States, new jets were discovered in the Caribbean and the Chinese Sea which bridged the entire gap between the cloud and the ionosphere [3][4] at 80-90 km altitude. These "gigantic jets" or "giants" (GJ) often look like narrow shafts with visible tree-like branching at the altitudes where sprites normally appear (60-90 km). Some gigantic jets have a carrot-sprite-like upper body with the rounded patches at the top [4]. A unique characteristic of gigantic jets which accounts for much of its lifespan are the luminous beads slowly moving up between 40 and 65 km altitude. It gives the jet the appearance of a fountain and may last hundreds of milliseconds. The ISUAL satellite has been used to analyze optical emissions in detail (e.g. [5] and [6]), suggesting there may be hybrid forms and mechanisms of gigantic jets.

2. Occurrence

Compared to elves, halos and sprites, which may be observed tens to hundreds of times per year from a single location frequented by thunderstorms, jet phenomena have been reported very infrequently. There has been just one published study of blue jets since the publication of their discovery: [7]. Its rareness may be in part due to the fact that blue color is not perceptible over distances over some 150-200 km at ground level. Gigantic jets have been reported a couple of dozens of times by ground-based cameras since their discovery. From space, the ISUAL satellite had mapped about 60 of them by 2008 [8], mainly in the tropical regions where storm clouds tend to be very tall (17-20 km). However, shallow winter thunderstorms have been reported to produce gigantic jets as well (one positive polarity event discussed by [9] and three events on the forum of Japanese observers). The tropical airmass GJ events tended to occur during the growing stage of a storm [10][11].

3. Association with lightning

Unlike sprites and elves, jets are not directly associated with cloud-to-ground (CG) strokes but appear to evolve from lightning leaders inside the cloud, as proposed by [12]. [13] and [14] detected the negative leader of a gigantic jet and blue starter, respectively, with lightning mapping arrays. The two observational studies of blue jets [15] and [7] found blue jets to be triggered in storms with high flash rates shortly after the occurrence of bursts of -CG strokes. This behaviour has been reproduced by models [16]. Unlike blue jets, [5] did not find blue starters associated with CGs, rather with a strong intracloud flash activity around their emission time. Gigantic jets may prefer the lulls between CG flashes and do not necessarily occur during very high flash rates [10]. In fact, the winter GJ [9] was preceded by a half-hour long relative absence of CG lightning. The charge moment changes produced by

GJs vary between less than a few hundred [5][18] to more than 10,000 C·km [9][17].

4. Mechanisms and models

Krehbiel et al. [19] defined a framework based on the magnitudes of positive and negative thunderstorm charges and their effect on bidirectional leader growth. An imbalance is required to propagate a lightning leader through the minor charge region out of the cloud. The gigantic jet was suggested to initiate similarly to an intracloud flash, whereas the blue jet would be a discharge developing between a strong screening layer and the upper thunderstorm charge.
A discussion of models of jets will be included in the topical talk. The references below are not exhaustive.

5. References

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