Photometric Array Imaging of Elves

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A multi-anode photometric array imaging device called PIPER has been developed at Stanford University for the purpose of measuring low-light optical ionospheric and atmospheric phenomena. Capable of high temporal resolution and high optical sensitivity, PIPER is especially suited for imaging elves, and PIPER observation rates of elves have been much higher than originally anticipated. We present PIPER photometric imaging data for observed elves, conducting statistical analyses to determine the correlation of elve properties with several factors: sprite-association, lightning flash strenth and polarity, storm size, *etc.* Other properties such as elve brightness and lateral size are also discussed.

1 Extended Summary

A new multi-anode photometric array imaging device called PIPER (Photometric Imaging of Precipitation of Electron Radiation) has been developed at Stanford University for the purpose of measuring low-light optical ionospheric and atmospheric phenomena. The instrument has been deployed at various locations around the world (including Colorado, Alaska, Virginia, France, and Australia) and has been used in precipitation, auroral, and transient luminous event studies.

The PIPER instrument contains four multi-anode photomultiplier tubes arranged in pairs: each pair operates behind a different set of optical interference filters to offer multi-spectral measurements of the same field of view. Each multi-anode photometer pair consists of 16 linearly arranged anodes, each with a detector size of 0.8 mm x 16 mm, yielding the capability for crude spatial resolution in addition to the very high optical sensitivity and temporal resolution typical of photometers. In each photometer pair, one photometer is oriented vertically to achieve vertical spatial resolution while the other photometer is oriented horizontally to achieve horizontal spatial resolution. Interpreted together, the high-speed (25,000 measurements per second per anode) structural evolution of the the field of view at very low light levels can be inferred. This capability is especially suited for imaging elves, and PIPER observation rates of elves have been much higher than originally anticipated. These observations suggest that elve generation rates may be higher than originally anticipated and that elves may actually play a large role in ionospheric modification.

We present PIPER photometric imaging data for elves observed in Yucca Ridge Colorado, and over Europe. The aim of the study is to conduct statistical analyses on a large number of recorded elves to determine the correlation of elve properties with factors such as storm size, sprite-association, the polarity of causative cloud-to-ground lightning flashes, peak causative lightning current, *etc.* Other properties such as elve brightness and lateral size and their variabilities are also discussed.