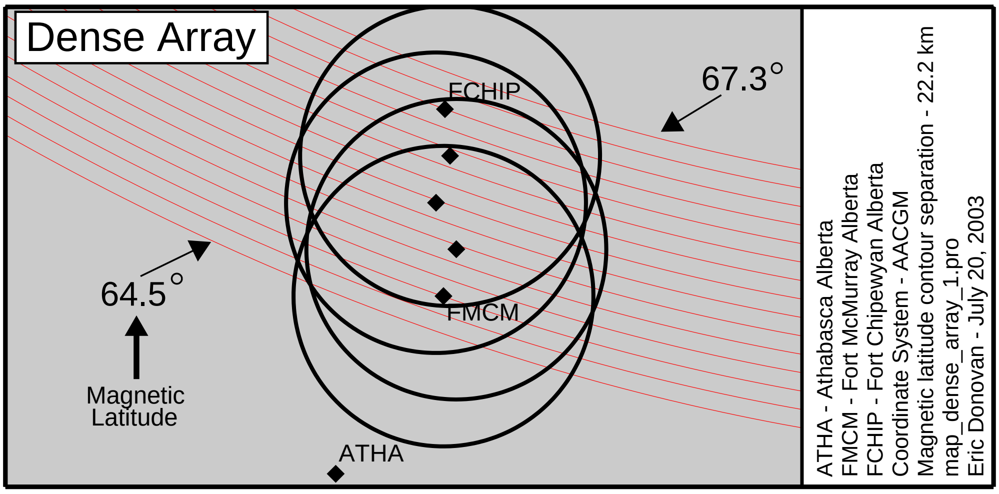
NORSTAR Fact Sheet - The Dense Array

The NORSTAR Dense Array will consist of three or four high resolution wide field of view (FOV) digital white-light imagers deployed in close proximity. These imagers will be deployed on a campaign basis (typically lasting weeks to months), operated by students, and will produce data that will be utilized in meeting the scientific objectives outlined below. The imagers will have higher spatial resolution than typical All-Sky Imagers. Multiple overlapping FOVs will create an extended latitude range over which spatial structures can be determined without the ambiguities that plague "off-zenith" auroral observations, and support reconstruction of the height profiles of auroral emissions through tomographic reconstruction. A possible deployment of the Dense Array is shown in the map below. Athabasca Alberta is located at 54.72° latitude and 246.72° longitude, about 1.5 hours drive north of Edmonton. Fort McMurray is located 4 hours drive further north. The highway stops at Fort McMurray, and our intention is to deploy the imagers at air polution monitoring stations that keep watch over the environmental impact of the Alberta Tarsands project.



Scientific Objectives

Gap in Auroral Arc Widths: Auroral arcs are aligned roughly along constants of geomagnetic latitude. The luminosity arises from electronic transitions in upper atmospheric atoms and molecules which have been collisionally excited by precipitating magnetospheric electrons. Arcs are a subset of what are called *discrete* aurora. Understanding the physics of auroral arc formation is a central goal in space physics research, and recognized as of significant importance by the larger plasma physics community. There are numerous models for the formation of auroral arcs (ie., *Lotko et al.* [1998], *Rankin et al.* [1999], *Knudsen et al.* [1996], *Atkinson* [1992], to name a few). The nature of the acceleration mechanism, and the reason for the characteristic spatial structuring of arcs are not presently understood. Auroral observational work seeks to provide measurements that constrain auroral arc theories [see *Borovsky*, 1993].

Over the last one hundred years, quantitative observations have provided a wealth of information about the phenomenology of auroral arcs (*Störmer* [1955], *Hallinan and Davis* [1970], *Reiff et al.* [1988], and *Trondsen and Cogger* [1998] are examples of ground-breaking observational auroral work). *Maggs and Davis* [1968] used a high resolution TV camera to carry out a survey of the widths of *fine-scale* auroral structures. Their distribution, shown in the left panel of the figure below, showed that structured auroras with widths on the order of 100 meters were common. Further, they found smaller scale features were more common than larger scale features, and that that trend held right down to the lower limit of their resolution, which was 70 m. On the other hand, surveys of *mesoscale* auroral arcs in All-Sky Imager (ASI) data have shown a distribution that peaks at widths on the order of 10 km, and falls off to essentially zero *below* about 3 km, and *above* about 40 km. The distribution of mesoscale arc widths obtained by *Knudsen at al.* [2001] is also shown in the left panel of the figure below.

The apparent *notch* in the width distribution at ∼1 km scales could mean that there is a physical mechanism suppressing ∼ 1 km scale auroral structures [see *Lessard and Knudsen*, 2001] or that arc processes operate at specific scale sizes [see *Knudsen*, 2001]. The fine-scale structure exists *within* mesoscale arcs, and so it is not necessary reasonable that the two distributions (ie., fine-scale and mesoscale) are parts of the same overall distribution [see *Borovsky*, 1995; *Trondsen and Cogger*, 1998]. The small FOVs of high resolution imagers and the limited resolution of ASIs precludes us forming a coherent picture comprised of both the small scale and mesoscale results. The results of a survey of ∼1km scale auroral features will be essential our ultimate understanding of the nature of auroral arcs. Exploring the full spectrum of auroral arc scale sizes, to firmly establish the existence (or lack thereof) of the aforementioned gap in auroral arc widths will be the primary scientific objective of the Dense Array.

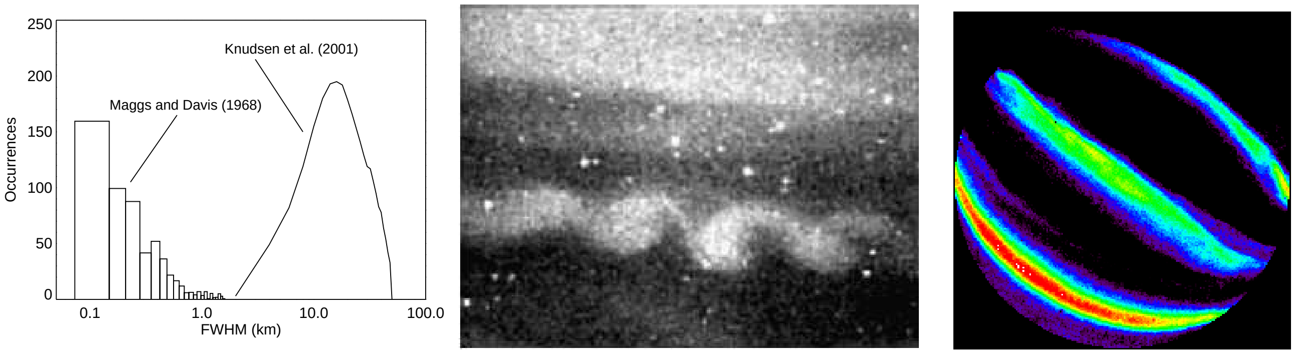


Figure: Left) Distribution of auroral arc widths from a high resolution TV camera [*Maggs and Davis*, 1968], and the CANOPUS Gillam ASI [*Knudsen et al.,* 2001]. **Center)** Image of fine-scale structure obtained with the PAI. Grey scale indicates brightness. FOV is roughly 7X5 km, presuming 105 km altitude emissions. The structure in the top half of the image is the edge of a mesoscale arc. The vortices are <1km in diameter, and the width if the structure joining the two vortices in the middle is <100m. White dots are stars. **Right)** CANOPUS Gillam ASI of mesoscale auroral arcs. Arcs are aligned roughly along constants of geomagnetic latitude, and are on the order of 15 kilometers wide. The field of view of the imager, presuming 110 km altitude emissions, is ∼500 km across. The image was obtained through a 557.7 Å filter (∼20 Å bandpass), and the colours indicate brightness of the atomic Oxygen ^{1}D-^{1}S transition.

Reconstructing the Height Profile of Auroral Emissions: Knowledge of the time-evolving two-dimensional distribution (ie., looked at as a projection onto a surface at the base of the ionosphere) communicates invaluable information about auroral mechanisms and magnetospheric dynamics. The multiple overlapping FOVs of the Dense array will provide access to the height profile of auroral emissions via tomographic reconstruction [eg., *Frey et al.*, 1996; *Gustavsson*, 1998]. The height profile, in conjunction with electron transport codes, will in turn provide information about the energy distribution of the precipitating electrons. This will be of significant importance, for example, in studies of substorm onset, where knowledge of the time evolution of precipitating particle energy will be used to clarify the nature of the onset mechanism. This capability will complement the network of NORSTAR/CANOPUS riometers.

Ancillary Objectives

Maintaining Technical Expertise in Canada: There is an ongoing program of international magnetospheric satellite missions (ie., Magnetospheric Multiscale). Mission plans call for the utilization of wide arrays of ground-based instruments to provide complimentary observations. At present, worldwide, there are at least twenty-five ASIs in operation. The usefulness of these instruments will continue. With improving technology, there is every reason to believe that there will be a healthy market for these imagers for at least the next decade. Until this year, the primary supplier of these imagers was R. Eather (KEO Consultants). Dr. Eather is refocussing his activities on the production of IMAX films, and will be closing Keo Consultants in the near future. T. Trondsen's expertise in ground-based auroral imagery is world renowned. Our goal is to develop the capacity to build CCD-based ground-based auroral imagers in house at the U of C. In doing so, we will protect our ability to deploy state-of-the-art auroral imagers. Further, there is the very real possibility of a *high-tech spin off company* which would produce imagers.

Training of Highly Qualified Personnel: Our objective is to have the Dense Array deployed and operated by students at the MSc and PhD level. These students will also be involved in the construction of these (and similar) imagers, and obviously in the subsequent scientific analysis of the data. Students involved in this aspect of the NORSTAR program will gain expertise in CCD technology, low light level imaging, image processing, tomography, and plasma and auroral physics.

References

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