The Information Content of the Aurora

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Dimensions of Auroral Information

Magnetospheric Process

\( v(\text{space}, \text{wavelength}, \text{time}) \)

- \( \perp B \) - Horizontal Structuring
- \( \parallel B \) - Auroral Motions
- Altitude Emission Profile

Altitude: 15 km
Does a Meaningful Solution to \( d = Lv + n \) exist?

Overdetermined does not mean least squares solution exists! Must determine the rank of \( L \).

For linear discrete inverse problems, \( L \) should be diagnosed through a singular value decomposition.

\[
L = U[\text{diag}(s)]V^T \quad \quad L^{\text{inv}} = V[\text{diag}(1/s)]U^T
\]

(1)

U forms a basis for the range of \( L \). V forms basis for the null space \( \Leftarrow \) The rank is reflected in SVD’s.

Conundrum for Pixel-based Auroral Tomography

A well-conditioned pixel-based auroral tomography problem will have little useful solution resolution.

An auroral tomography problem with useful resolution will be ill-conditioned.
Parametric regularization.

Replace pixel basis with simpler 3 parameter model. Many simple non-linear parameterizations are possible, but a gaussian is a very good fit to modeled redline emission profiles.

\[ f(x, z) = V_0(x) \exp\left[-\left(\frac{z - Z_0(x)}{H_0(x)}\right)^2\right] \]

An attractive property.

\[ \lim_{H_0 \to 0} f(z) = V_0 \delta(z - Z_0) \]  

(Semeter & Mendillo, IEEE TGARS, 1996)

So it is possible to use this model for a thin layer inversion where we seek \( V_0(x) \) and \( Z_0(x) \).
Summary of COTIF Tomographic Results

COMPARISON OF RECONSTRUCTED VOLUME EMISSION RATE PROFILES

630.0nm SAR arc, 5 Mar 95 (Main Phase Storm, Dst=−86nT)

630nm diffuse aurora, 2 May 95, Kp=4

630nm diffuse aurora, 11 Apr 97, Kp=7

(Seomter et al, JGRA, 1999)
Does tomography make sense for active aurora?
The simple relationships predicted by kinetic theory do not hold in regions where $\phi_E(E)$ is non-Maxwellian, i.e.,

- When the aurora is very weak
- When the aurora is very energetic
- When the aurora is very turbulent
Simultaneous Spatial-Spectral-Temporal Analysis

Choose a set of discrete wavelengths that mimic the logarithmic energy spacing of particle detectors.
Figure 5: Simultaneous Allsky (6300) and SMI (λ's as labeled) measurements of a developing auroral arc on March 6, 2000.
Tomography is a valuable tool for studying stable features such as the diffuse aurora, but is not suitable for active auroral forms.

The physics of auroral formation will benefit from a consideration of detection problems associated with simultaneous 2-dimensional spectral imaging.

The general bias towards imaging bright aurora is physically unjustified.