ATISE Wind: Auroral Thermosphere Ionosphere Spectrometer Experiment - Wind measurement

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Abstract:

Solar activity poses a critical threat to terrestrial and orbiting infrastructure[1], yet a lack of high-resolution dynamic data in the upper atmosphere hinders accurate mitigation. To bridge this gap, the **ATISE Wind** project introduces a static interferometer designed to measure thermospheric and ionospheric winds with better temporal resolution than previous wind measurement instruments[2, 3].

Unlike traditional Fabry Perot devices constrained by mechanical optical path differences scanning (often exceeding one minute), the ATISE Wind instrument utilizes a **Fizeau-based architecture**. Eliminating moving parts enables direct interferogram measurements in just a **few seconds**[4, 5]. Successfully demonstrated during a 2026 ground-based campaign in Skibotn, the system proved its potential for near-future high efficiency even under nearly-low sky brightness conditions (≈ 15 kR). Exposure time down to 1s could be used to determine such wind speeds for the red (630 nm) and green lines (557 nm). Future developments will focus on real-time velocity retrieval to ensure robust monitoring of winds from both ground and space, as well as developing a design with the lowest possible sensitivity to environmental conditions.

KeyWords: ***Space Weather, Atmospheric Dynamics, Ionosphere & Thermosphere, Static Fizeau Interferometer, High Temporal Resolution***

A bit of theory:

Based on a Fizeau Interferometer (FI), ATISE Wind picture simulations are computed from the Hall[4, 6] model.

In Figure 1 (on the right), you can find a representation of an FI. We can obtain such a configuration with a Michelson Interferometer, but this one forces the reflective index to 0.5.

This paper describes the Intensity along an axis as a function of Fizeau's characteristics as follows:

$$I = A_0^2 T^2 \left| \sum_{p=1}^{\infty} R^{p+1} e^{i\delta_p} \right|^2$$

$$\text{with } \delta_p = \frac{1}{\lambda} f_p(t_p, \alpha, \theta)$$

(phase difference at the p-th bounce[1, 8])

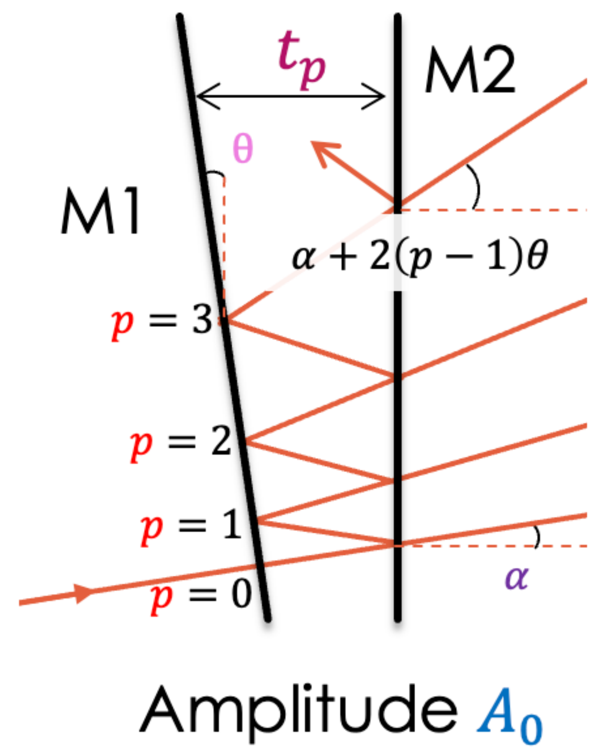

Figure 1. *Fizeau Interferometer representation. Composed of two plates M1 end M2, both having a specific (here the same) reflective index and slightly inclined. Thus, we obtain what we called an Air-Wedge configuration.*

Demonstrator development

A simulation tool based on the **T.A. Hall model** was developed to analyze the impact of design parameters. It generates realistic datasets by integrating several noise sources and optical artifacts.

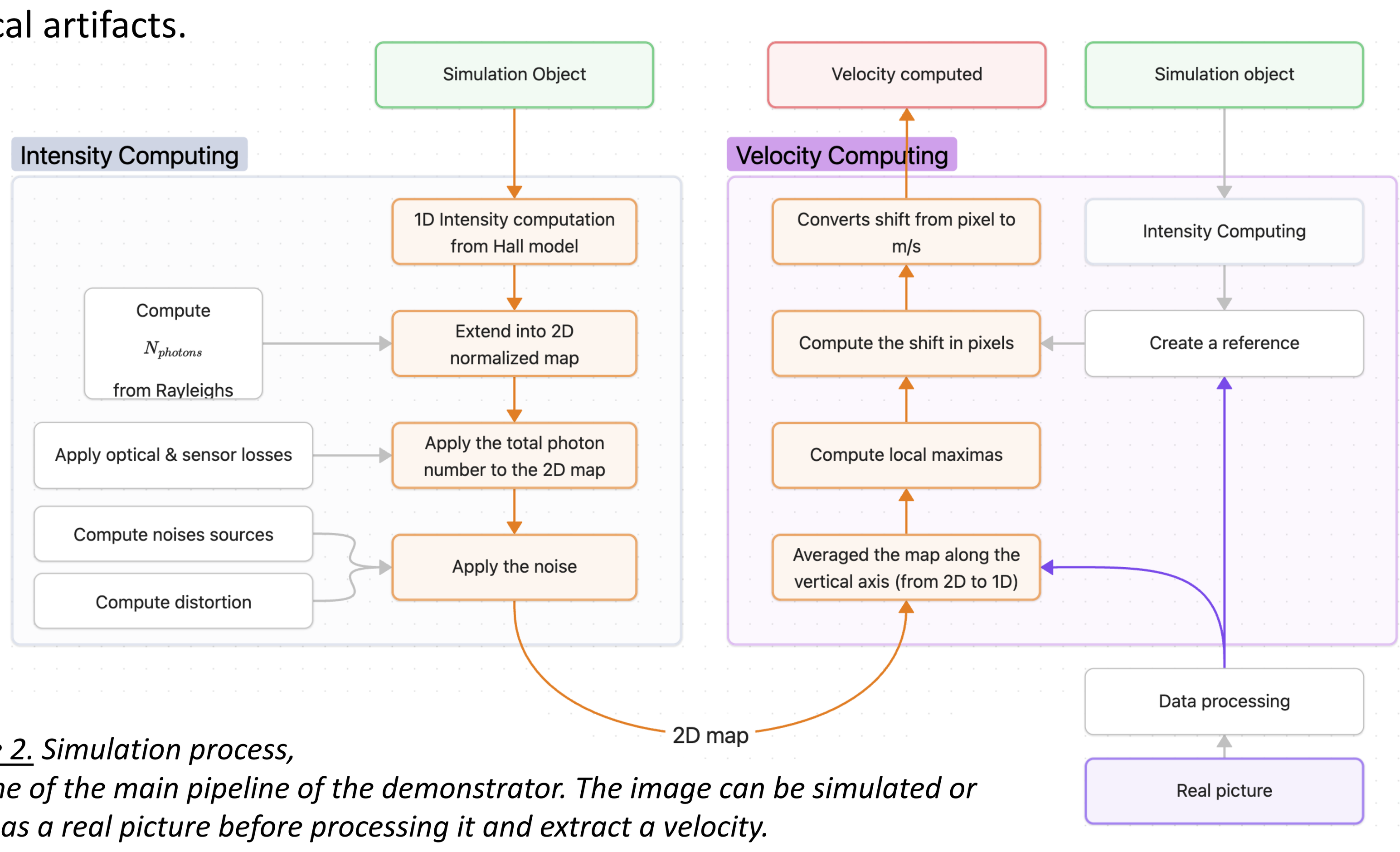

Figure 2. *Simulation process,*
Scheme of the main pipeline of the demonstrator. The image can be simulated or taken as a real picture before processing it and extract a velocity.

Realistic Noise Modeling:

- **Sensor Noise**: Read-out noise (Poisson law) and dark noise (manufacturer specs)[7].
- Physical Effects: Thermal Doppler broadening of target wavelengths.
- **Geometric and Optical issues**: Barrel and Pincushion distortions (fringes curving toward/away from center) in addition to vignetting [7].
- Obstructions: Simulated dust at 3 positions (projection lens, beamsplitter, collecting lens) with variable blurring in addition to radial blurring.

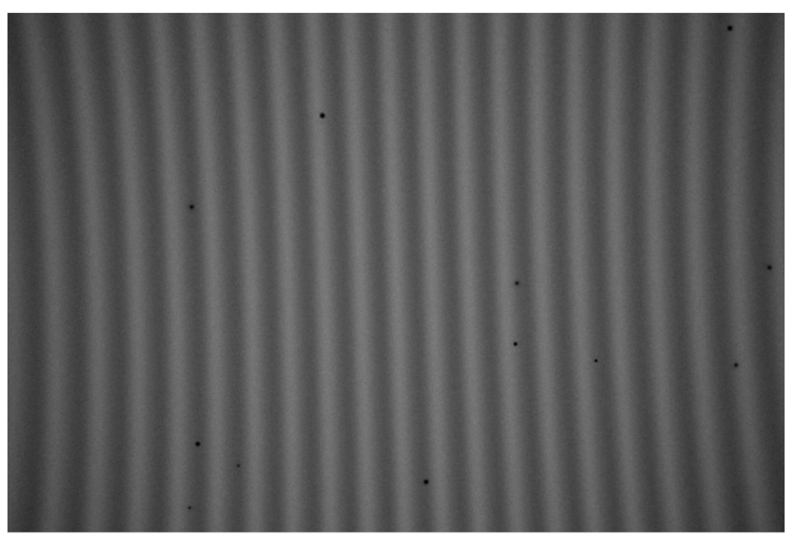

Figure 3. *Simulation result, finding parameters of the system. Simulated by taking into account several sources of noise. The parameters of the optical system are:*
R = 0.5, θ = 2.576e-04 rad, FOV = 0.5 deg, t = 1 µm, G = 1.
We can compare this simulation to the figure obtained during the Skibotn campaign, shown in fig 6.

ATISE Wind setup

Based on a Fizeau interferometer using auroras as an **extended source**[8], this experimental setup aims to change the function of the pre-existing ATISE[9] lens (addossed to a fizeau interferometer) not as a spectrometer anymore, but as an **interfero-velocimeter.**

A narrow-band filter selects the target wavelength before a projection lens (optically conjugated to the Fizeau median plane) images the interference fringes.

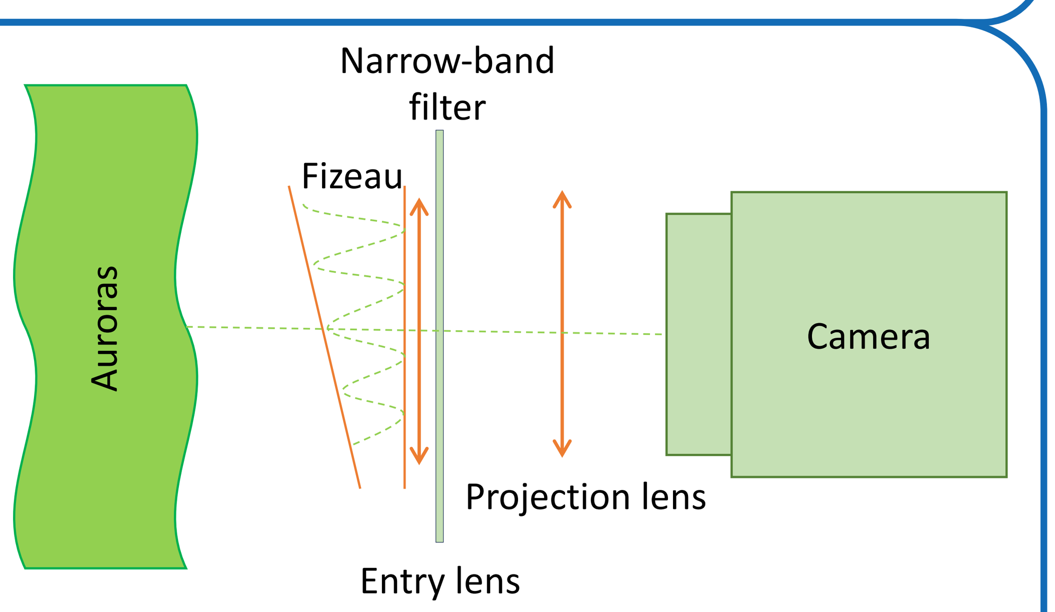

Figure 4. *ATISE Wind: Final Flight Configuration*
Compact Fizeau Interferometer (FI) optimized for space. A primary collecting lens maximizes light throughput, followed by a narrow-band filter. A final projection lens images the interference fringes directly onto the sensor for real-time interferogram processing.

Ground-Based Validation

(Skibotn – feb 2026)

The instrument concept obtained a **first validation** during the Winter 2026 campaign at Skibotn Observatory, Norway, in a Michelson Interferometer (MI) configuration.

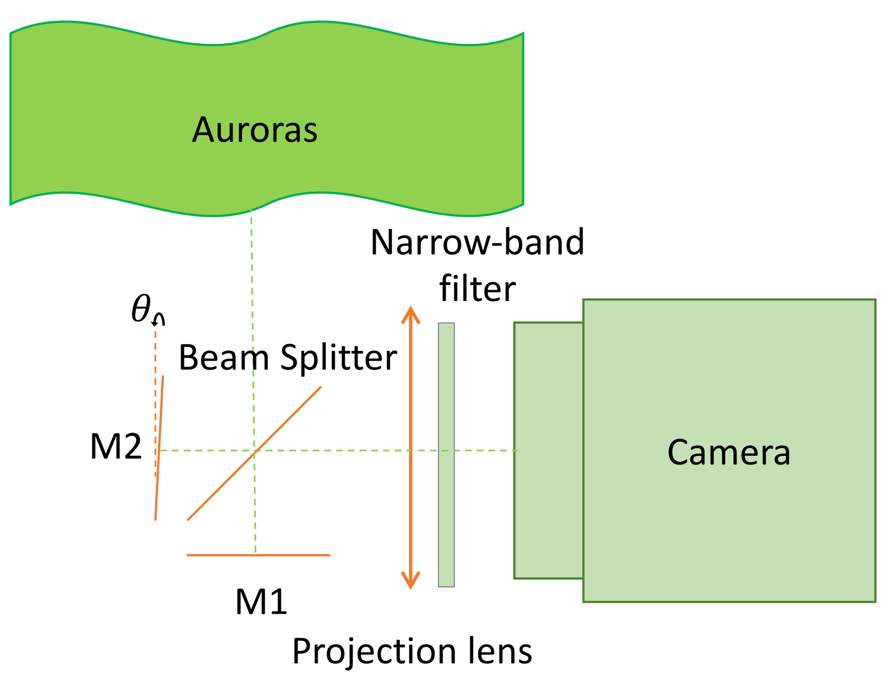

Figure 5. *ATISE Wind: Current Experimental Setup*
Michelson Interferometer (MI) configuration acting as an air-wedge (θ ≈ 10⁻⁴rad). The beam splitter divides incident light toward two mirrors, and a projection lens conjugates the fringe pattern onto the camera sensor. A narrow-band filter ensures precise selection of the targeted emission line.

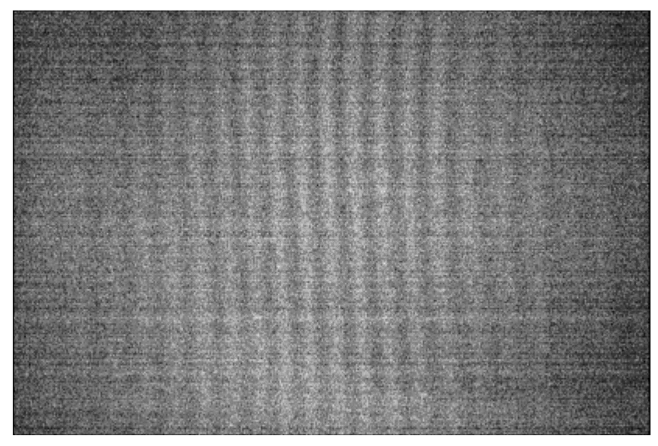

Figure 6. *First light aurora fringes*
Raw interferogram captured at Skibotn Observatory (Norway) with a 1s exposure time.

Results:

- Concept Proven: Successful observation of interference fringes under real-sky conditions.
- Temporal Advantage: Exposure times of 1-5s (auroral) vs. several minutes for conventional scanners.
- Current Work: Signal processing to extract Doppler velocity from background noise.
- Mechano-thermical sensitivity ?

Conclusion

The ATISE-Wind project successfully **demonstrates** the viability of a static Fizeau-based architecture for high-cadence thermospheric wind measurements. By eliminating mechanical scanning, this **compact design** achieves a temporal resolution of approximately 1s, a significant improvement over traditional Fabry-Perot interferometers.
The 2026 ground-based campaign at Skibotn Observatory provided **critical validation**, proving the instrument's sensitivity to auroral emissions under real-sky conditions[8]. These results pave the way for the integration of the final flight-ready optical chain into a space-borne configuration. Future developments will focus on **refining real-time** Doppler velocity retrieval algorithms to provide robust, **continuous monitoring** of ionospheric dynamics[2, 5, 10, 11] and improve our understanding of the upper atmosphere's response to **solar activity**.

Key Points:

Platform:	12U CubeSat-ready architecture.
Target Lines:	Red (630 nm) and Green (557.7 nm) O emissions.
Winds Altitude:	≈ 110 km & ≈ 220 km.
Targeted Precision:	Better than 5 m/s (1 m/s per pixel).
Temporal Resolution:	1s exposure (vs. minutes for scanning devices).
FOV:	< 1° x 1° for localized thermospheric mapping.
Reliability:	Fully static optical chain with no moving parts.

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