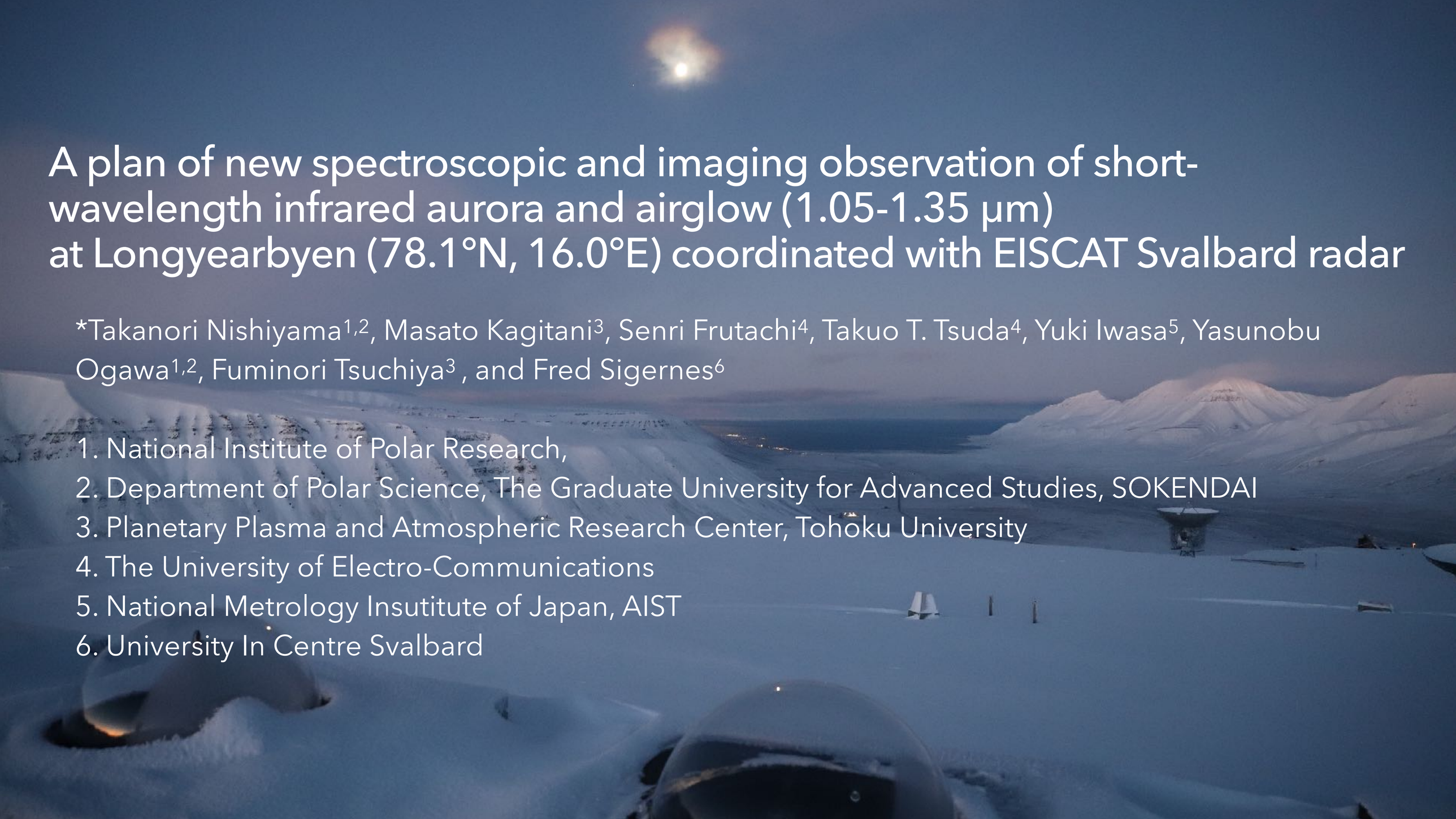

A plan of new spectroscopic and imaging observation of short-wavelength infrared aurora and airglow (1.05-1.35 μm) at Longyearbyen (78.1°N, 16.0°E) coordinated with EISCAT Svalbard radar

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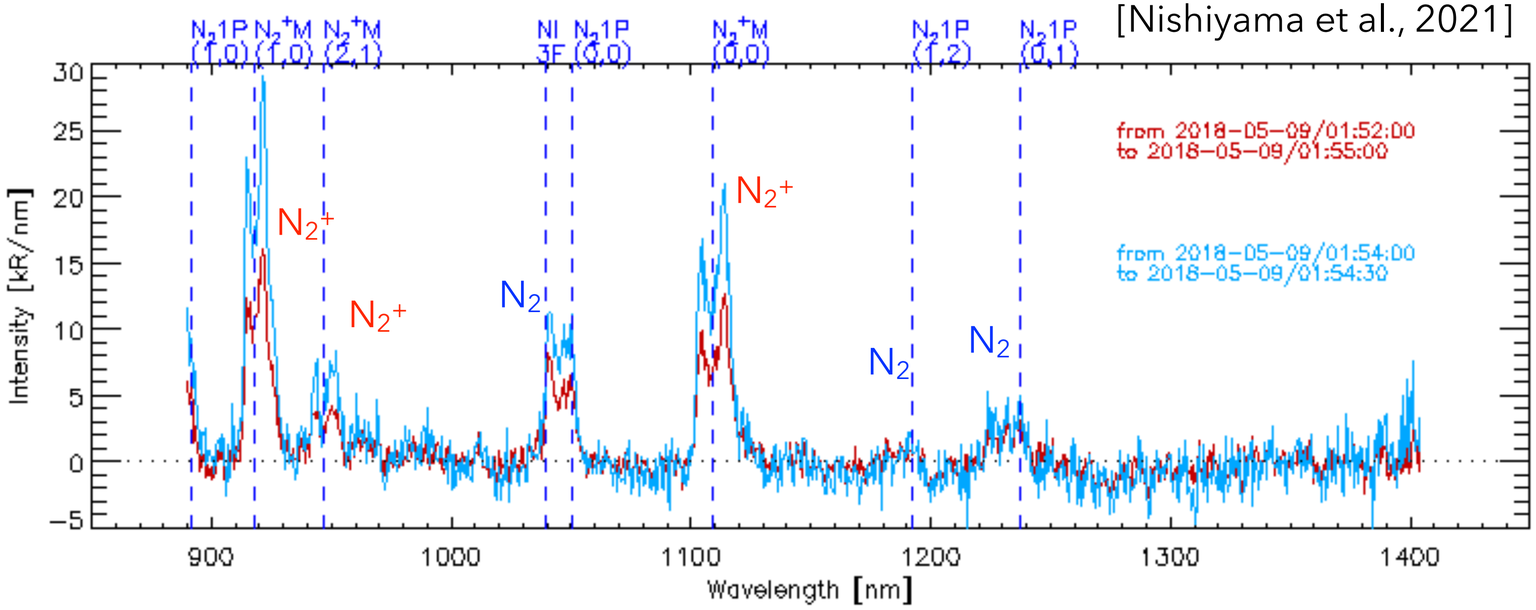
Introduction

SWIR aurora and airglow in 1.0-1.6 μm

- Spectroscopic surveys have been done from '70s to '80s.
  [e.g., Jones and Gattinger, 1976; Gattinger and Jones, 1981; Espy et al., 1987]
  - After the above studies, only a few further study was done so far.
  - Recently, spectroscopic observations for SWIR aurora using InGaAs FPA were reported [Nishiyama et al., 2021]

- OH airglow measurements in SWIR have been actively carried out over the last decade
  [e.g., Schmidt et al 2013; Pautet et al, 2014]

[Nishiyama et al., 2021]

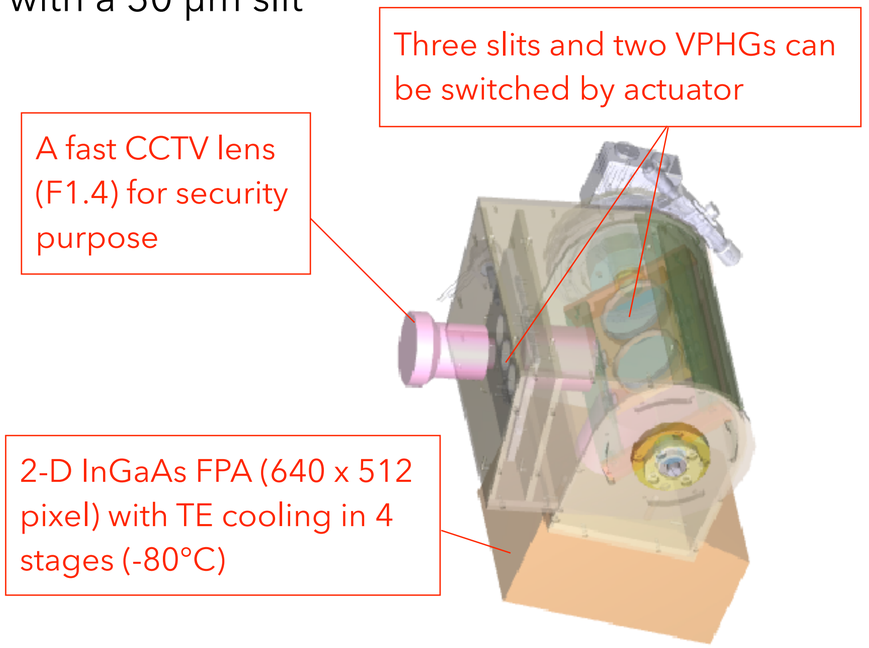


A photo of NIRAS

NIRAS-2

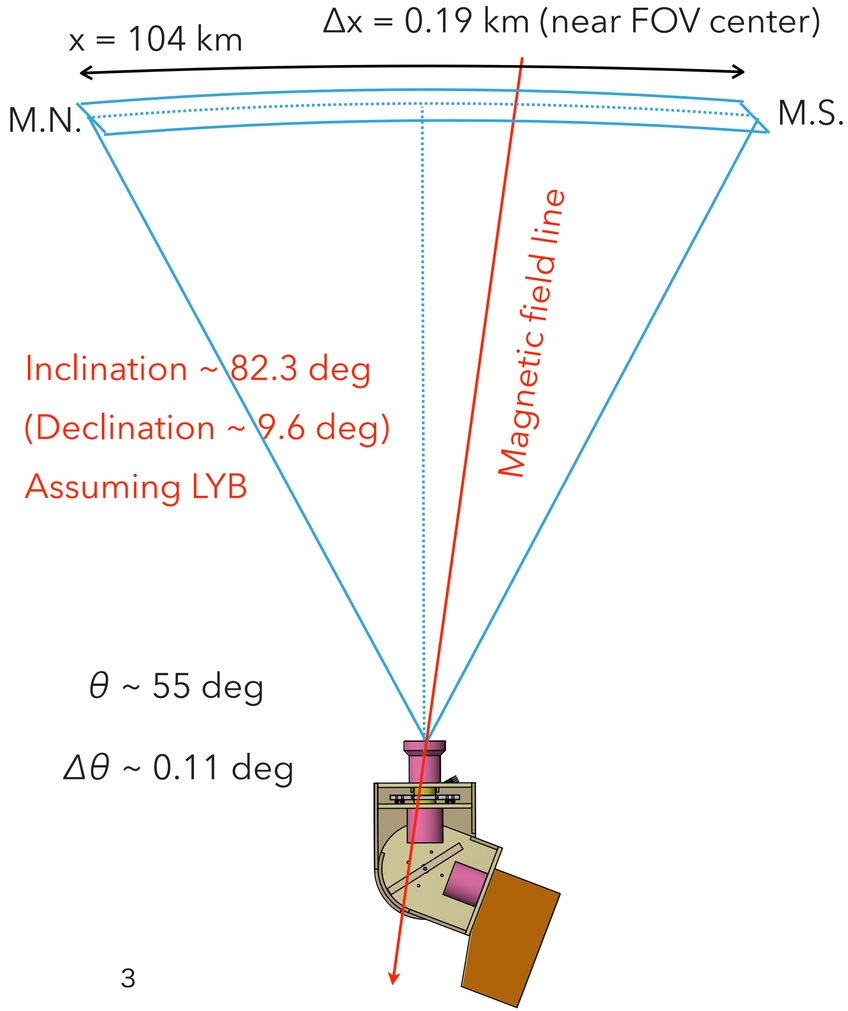
NIRAS-2 specifications

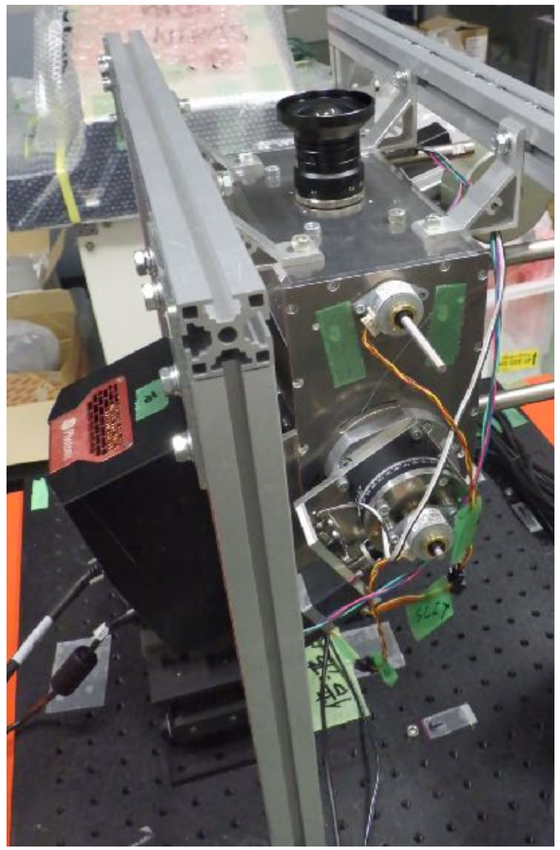
- **N**ear **I**nfra**R**ed **A**urora and airglow **S**pectrograph-2 (NIRAS-2)
  - a fast optical system (F1.4)
  - a wide FOV: ~ 55 deg with resolution of 0.11 deg
  - slits: 30, 60, and 90 μm (pinhole 15 μm)
  - two Volume Phase Holographic Gratings: 950 and 1500 lpmm
  - λ/Δλ: 2230 & 5070 (FWHM: 0.53 nm and 0.21 nm) with a 30 μm slit



Comparison between NIRAS and NIRAS-2 specifications

	Sensitivity peak	FWHM	slit/pixel size	*F*-number	FOV
NIRAS-2	1.1 μm	0.44 nm	60/15	1.4	1-D scan
NIRAS	1.5 μm	0.42 nm	100/25	4.1	Single point

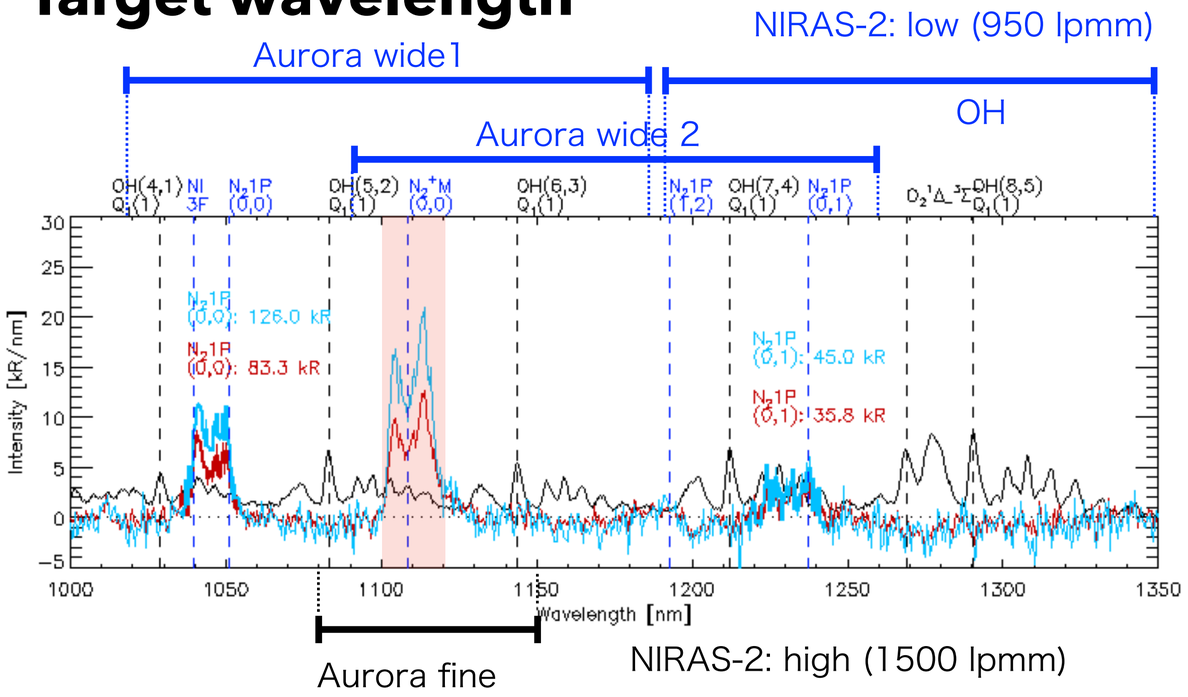




A photo of NIRAS-2

NIRAS-2

Target wavelength



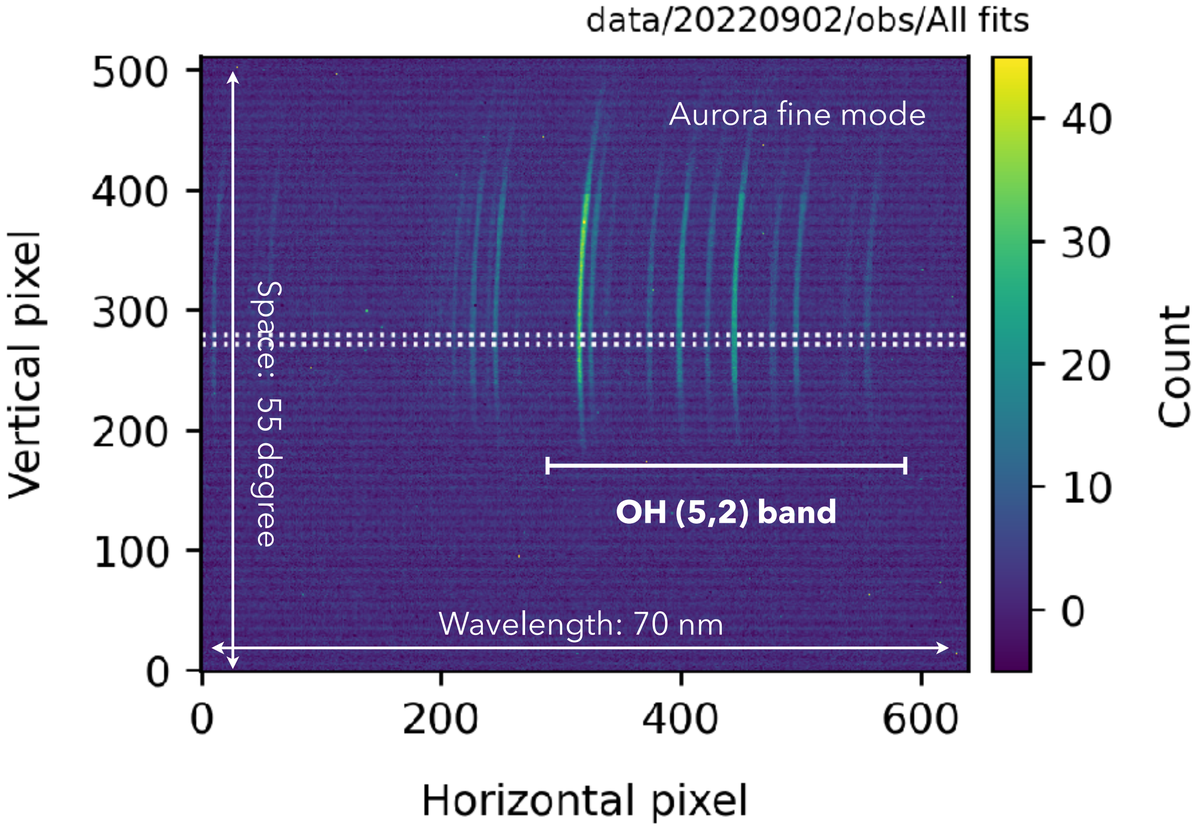


Fig. Aurora (red and light blue) and airglow (black) spectrum observed by NIRAS (previous model) with observation wavelength ranges of NIRAS-2

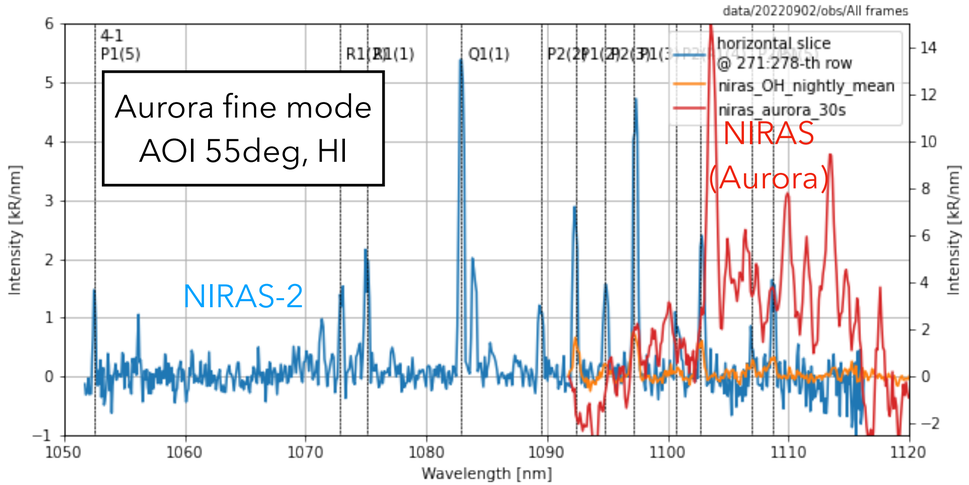
Table Planned observation modes of NIRAS-2

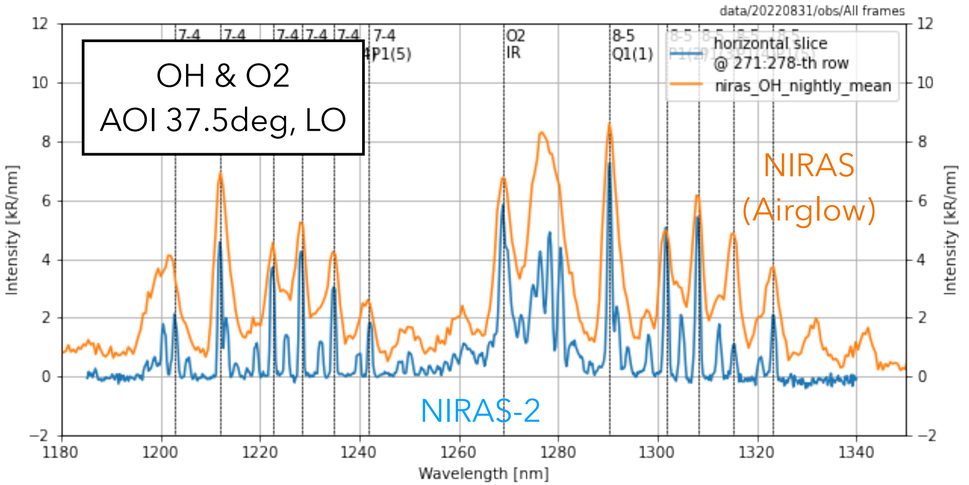
Mode	Grating	Center/Range	FWHM (30/60-μm slit)	Target
Aurora fine	Hi: 1500 lpmm	1105 nm/1070-1130 nm	0.21/0.44 nm	N_2^+ (0,0)
Aurora wide 1	Low: 950 lpmm	1090 nm/1020-1190 nm	0.53/1.1 nm	N_2 1P(0,0), N_2^+ (0,0)
Aurora wide 2	Low: 950 lpmm	1160 nm/1060-1230 nm	0.53/1.1 nm	N_2^+ (0,0), N_2 1P(0,1)
OH	Low: 950 lpmm	1255 nm/1175-1335 nm	0.53/1.1 nm	OH (7,4), (8,5)

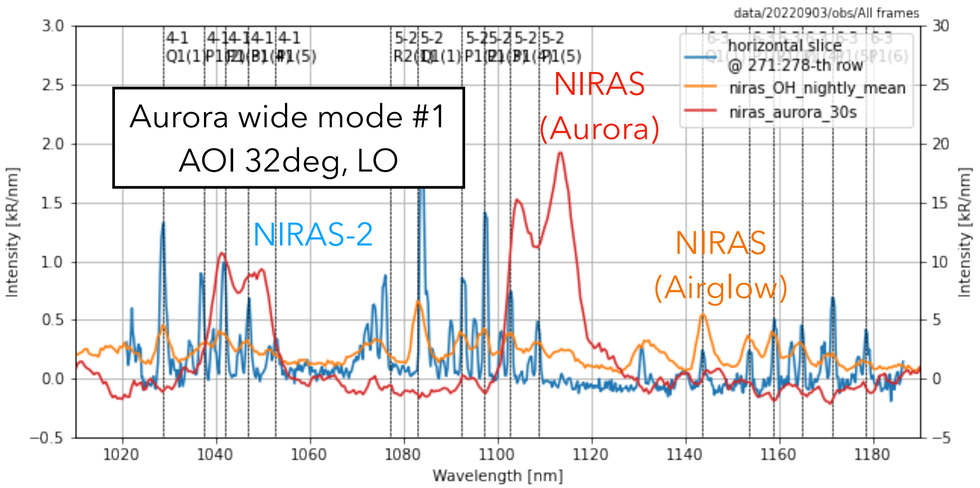
NIRAS-2

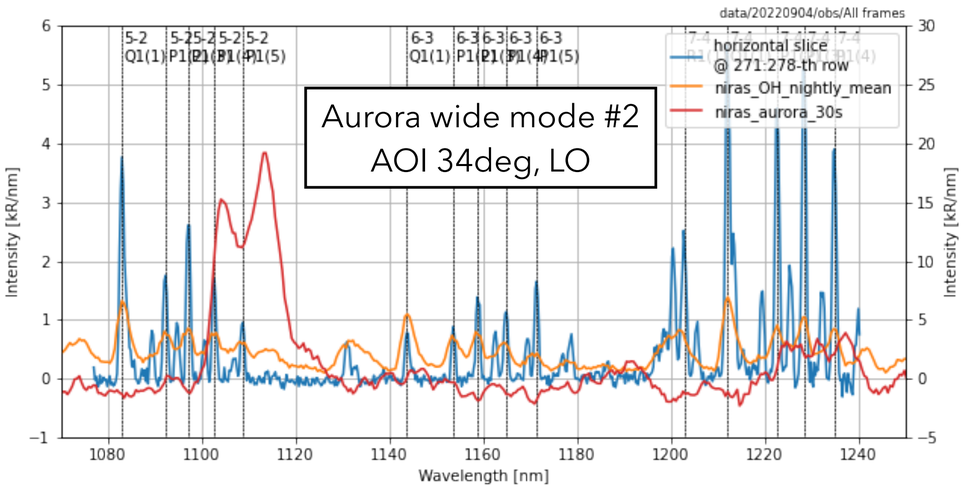
Examples of spectrum

- With the 60-μm slit
- 30-exposure time and 30-min integrations
- Sensitivity for each modes was calibrated (See Appendix), and therefore absolute intensity [R/nm] can be estimated







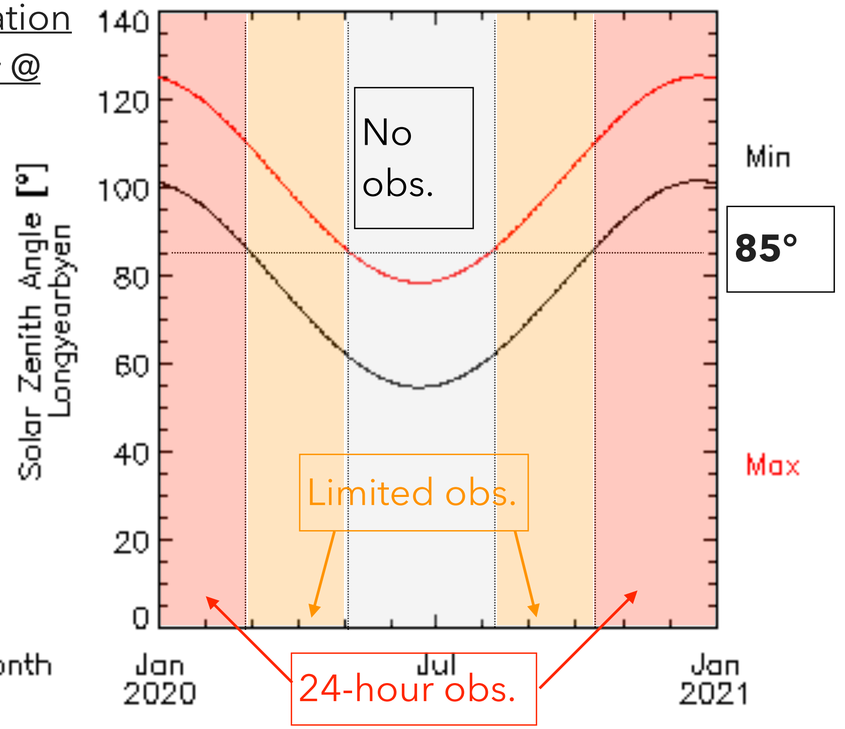


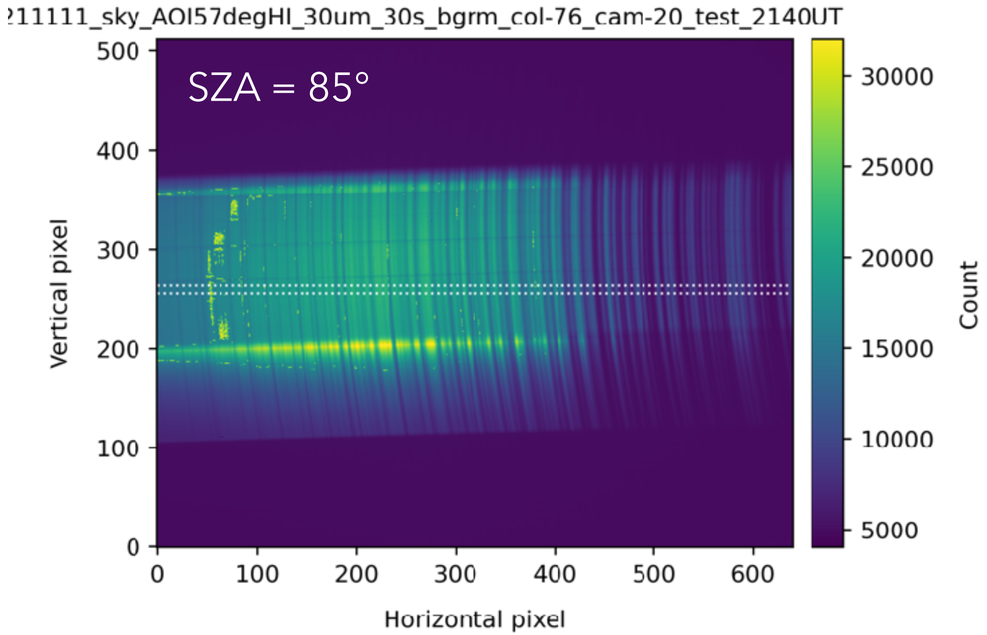
NIRAS-2

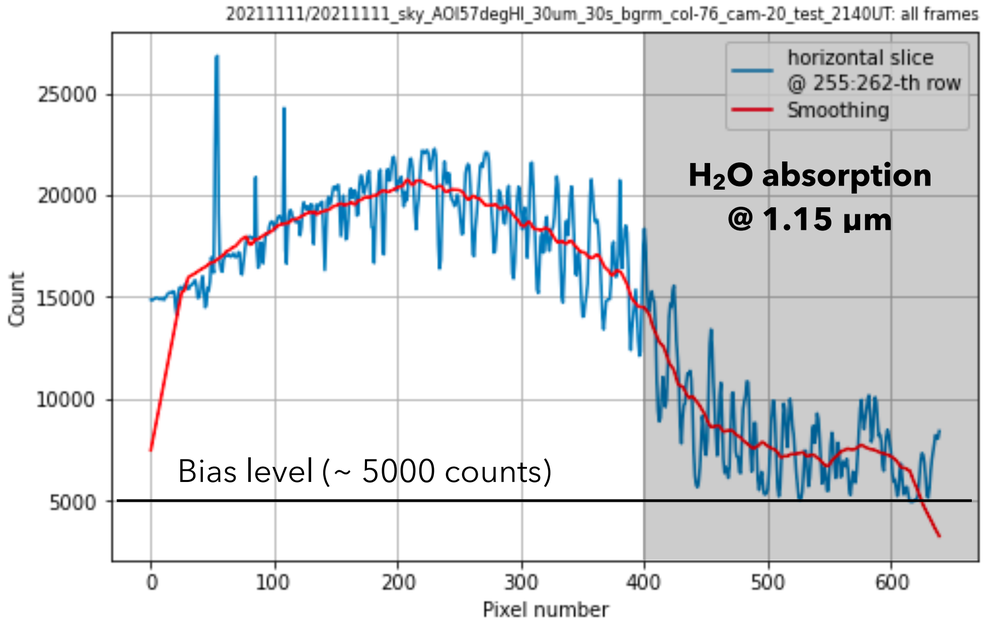
Test observation: sky background intensity

- SZA = 85° (0640 JST, Nov. 11, 2021)
  - 30-μm slit and 1500-lpmm grating
  - Peak count ~ 15000 (30-sec exposure), not saturated
    - Its shot noise ~ about 120 count
- Estimated peak count for N2+ (0,0) aurora ~ 300-500, S/N ~ 2-4
  - Strong aurora emission associated with shock aurora etc.,
  - but diffuse auroras are difficult to identify
- For example, 9-month operation @ LYB, including 24-hour obs. from Mid Oct. to end Feb is possible

Daily SZA variation through a year @ Longyearbyen

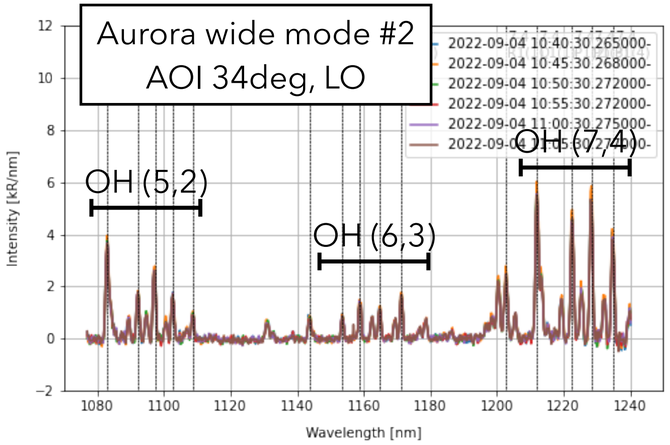


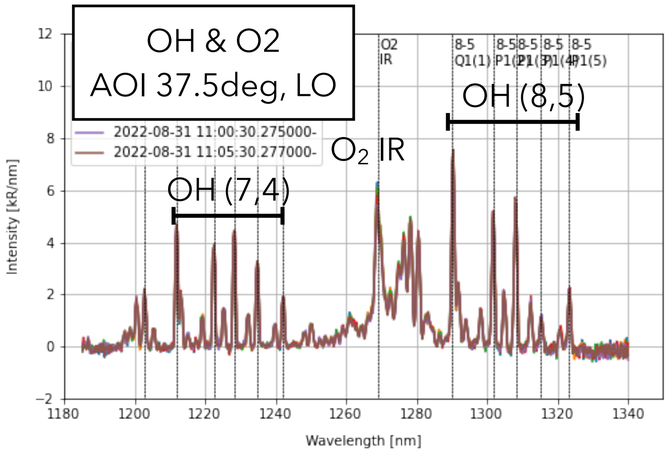


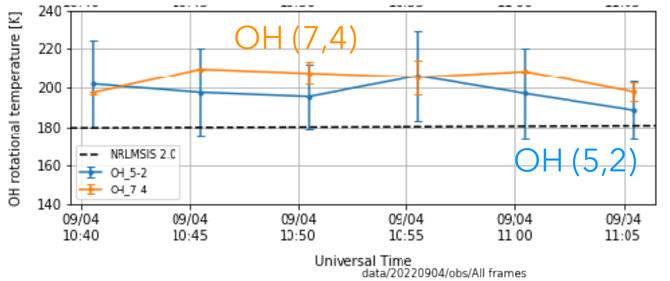


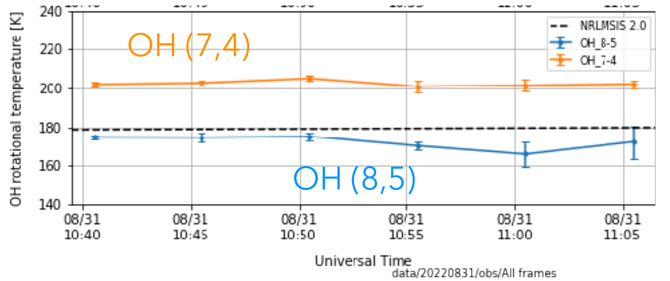
NIRAS-2

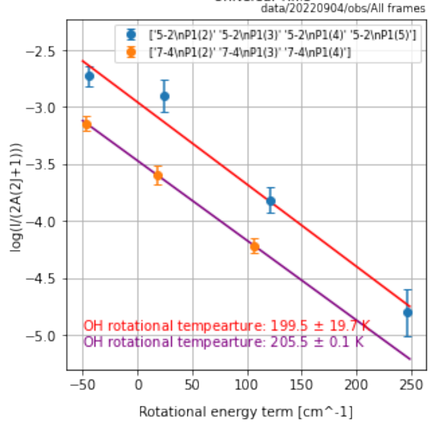
OH rotational temperature @ 1.2-1.3 μm, at NIPR

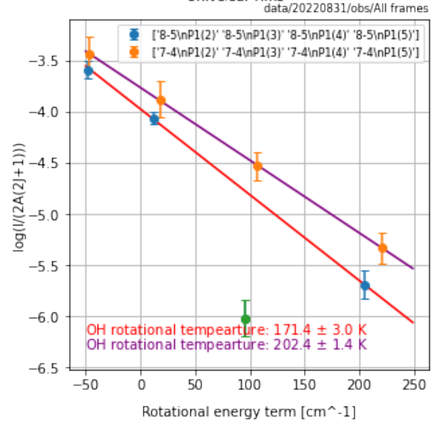








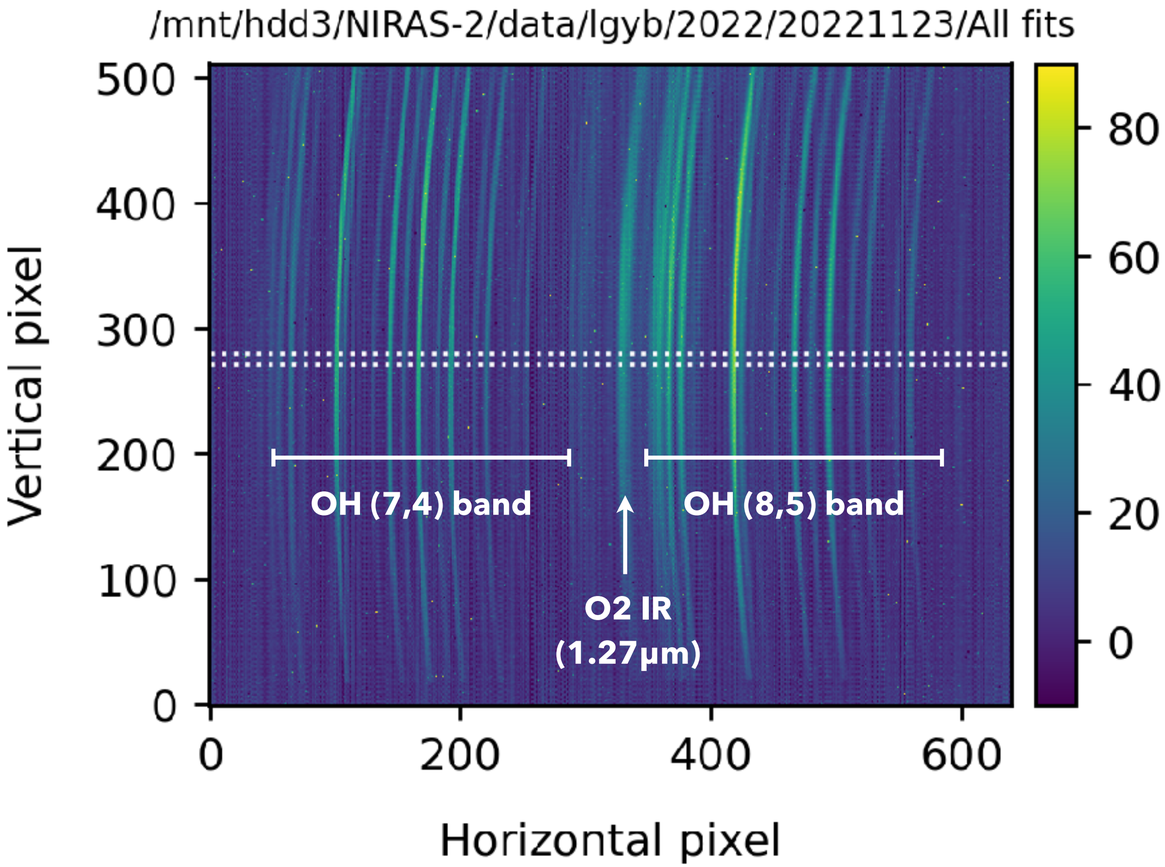


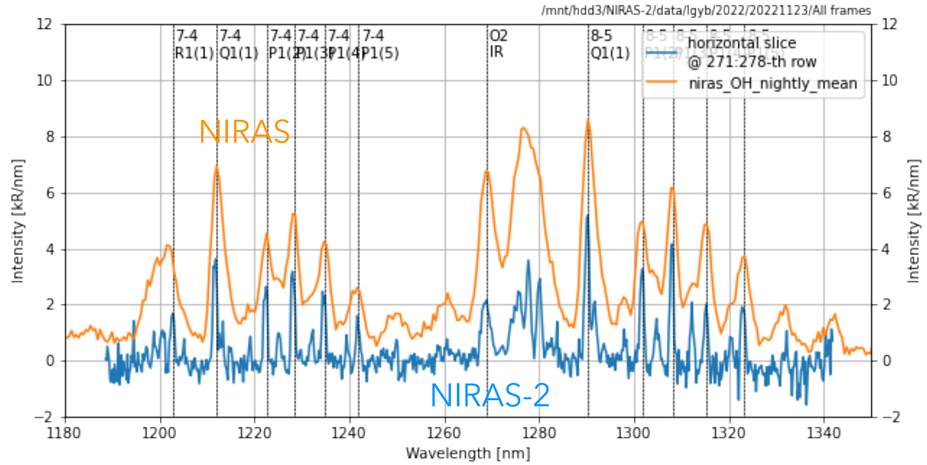


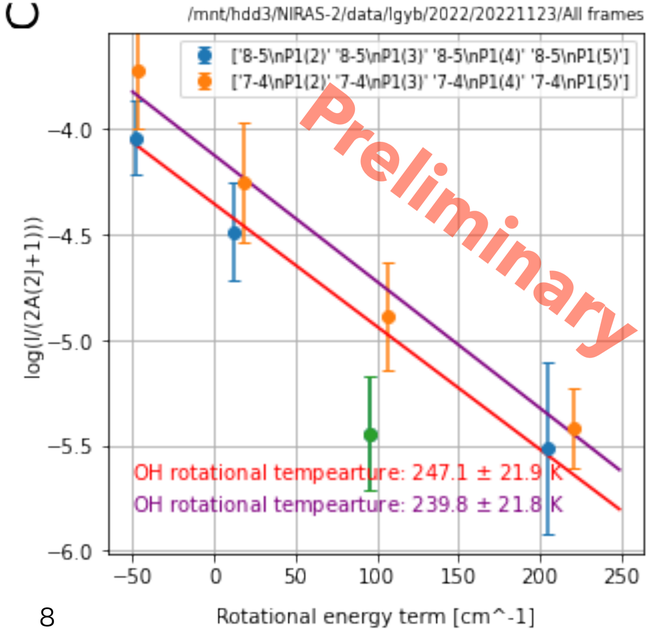
- OH (7,4) and (8,5) band is relatively strong emission band
  - Better S/N is expected
  - NIRAS-2 is optimized at not 1.2-1.3 μm but 1.1 μm
- Estimated temperature by OH (8.5) band seems to be lower than that of other bands and MSISE 2.0
- Errors of estimated temperature are significantly improved compared to those by OH (5,2) at 1.1 μm
  - With 60-μm slit and 5-min integration, errors are less than 3 K
- Collaborative study with Ebert-Fastie spectrometer at KHO/UNIS (e.g., Sigernes et al., 2003)
- NIRAS observation suggested that OH airglow might be less affected by aurora contaminations around 1.3 μm.

NIRAS-2

OH rotational temperature @ 1.2-1.3 μm, at KHO (2022.11.23)







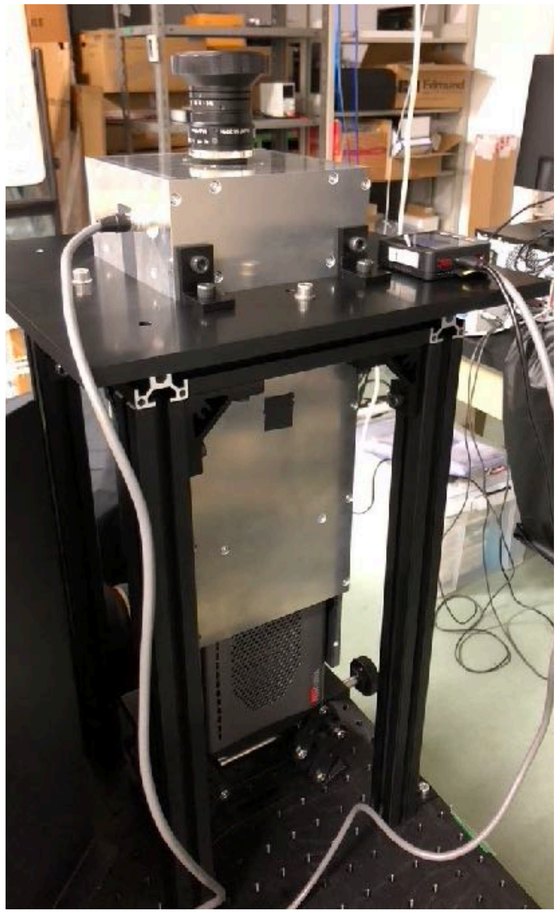
Averaged 21 hours, but S/N is not so good.
We are still waiting for good weather!

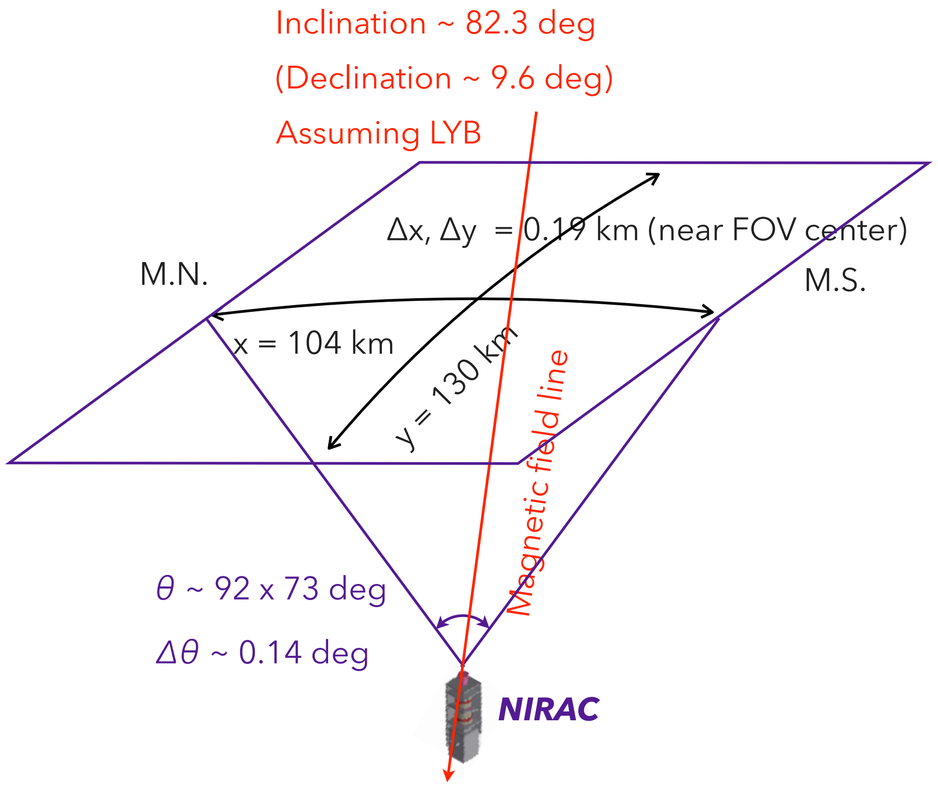
Even with large error bars, rotational temperatures by OH (7,4) and OH (8,5) bands are comparable, which suggests less effect of water vapor absorption.

NiPR

NIRAC: a New SWIR imager

Near InfraRed Aurora Camera: NIRAC





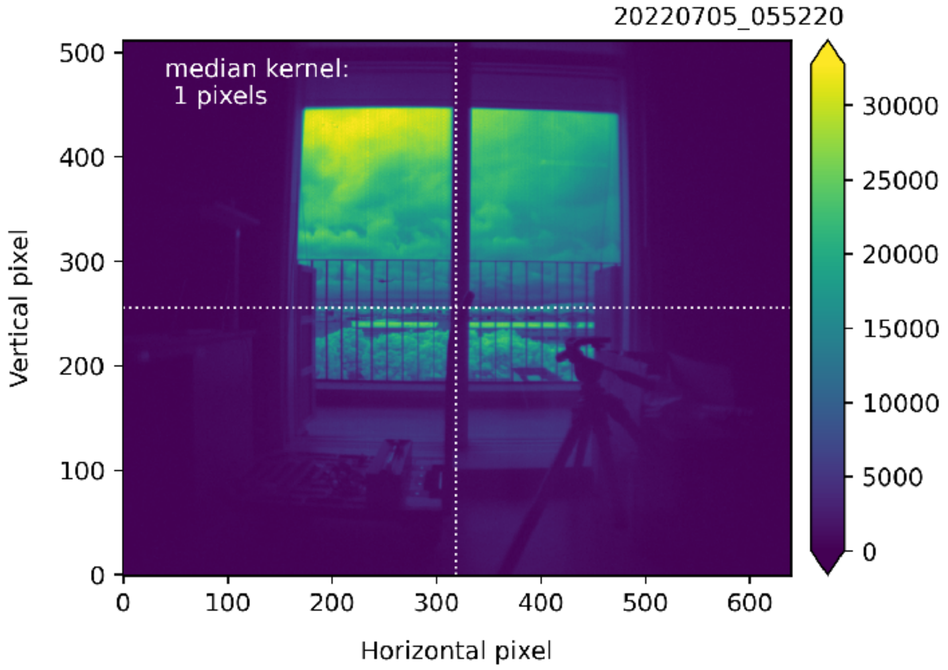
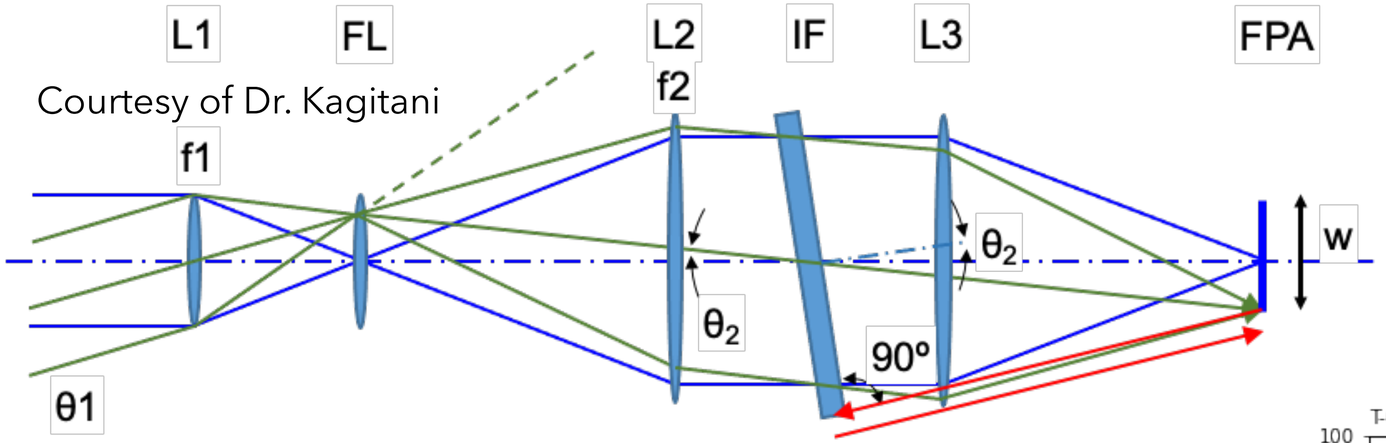


Fig. Photos of NIRAS-2 and NIRAC, a schematic illustration of their field-of-views (fov)

NiPR

NIRAC: a New SWIR imager

Optical design



L1: First imaging lens, fl=f1 f 8mm
FL: field lens
L2: collimator lens, fl=f2 f 100mm
IF: interference filter The detail as shown below
L3: Second imaging lens, fl=f3 f 100mm
FPA: focal plane array, w=diagonal length 640 x 512 pixels

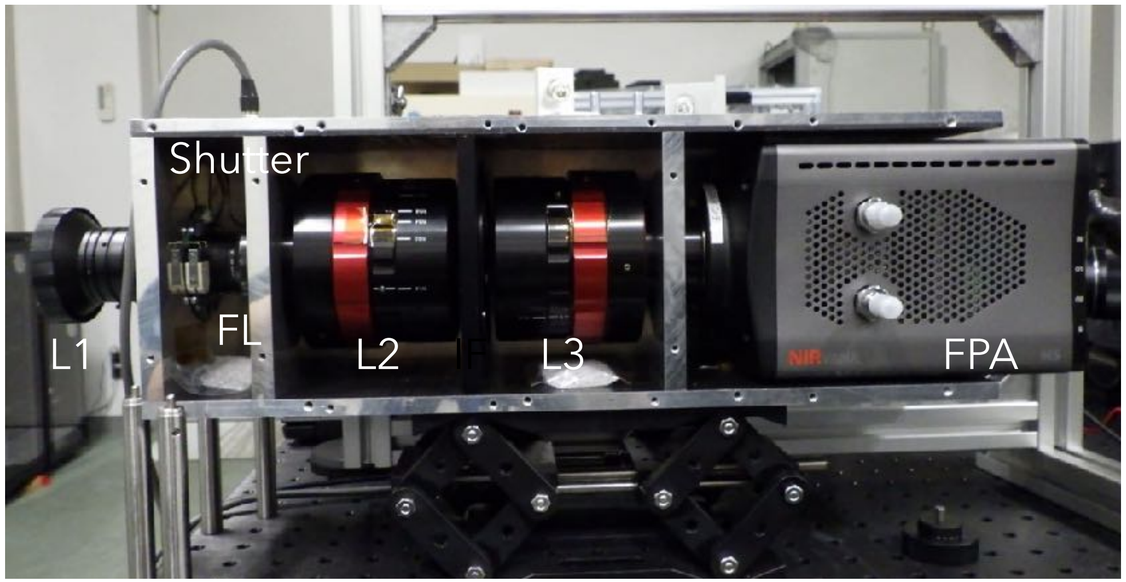


Fig. (Top) A schematic illustration of NIRAC optical system design (Bottom) A photo of the assembled optics

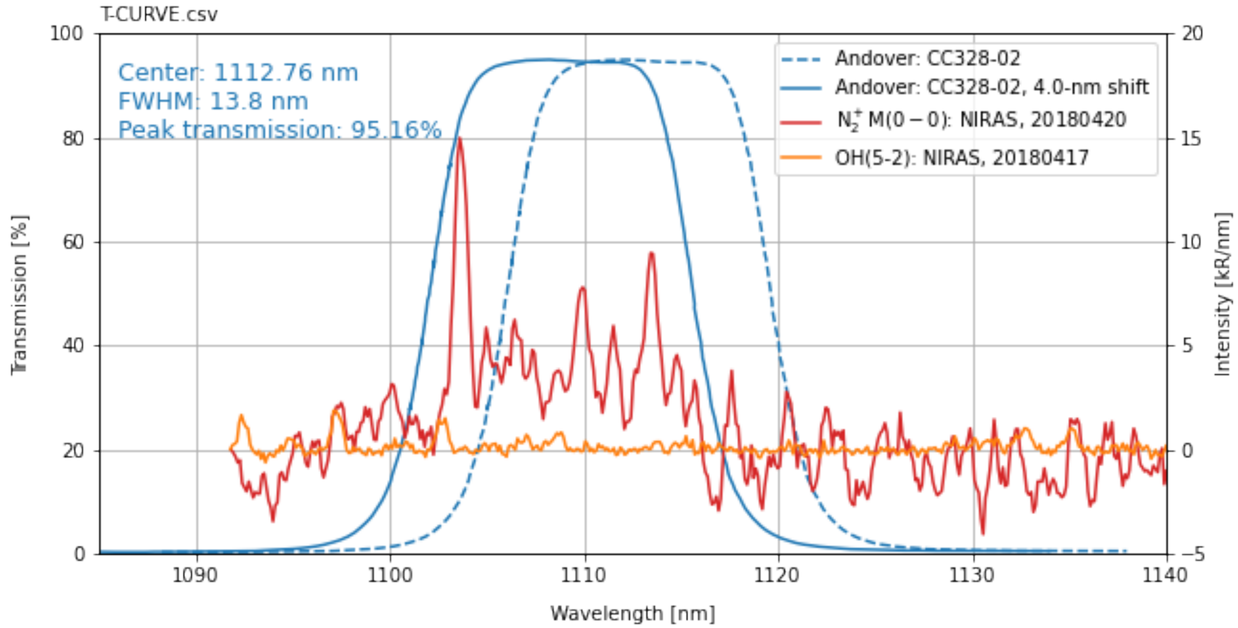


Fig. Transmittance of the filter, aurora (red) and airglow (orange) spectrum

NiPR

NIRAC: a New SWIR imager

Aurora and airglow images at KHO

Each frame: about 30-sec exposure

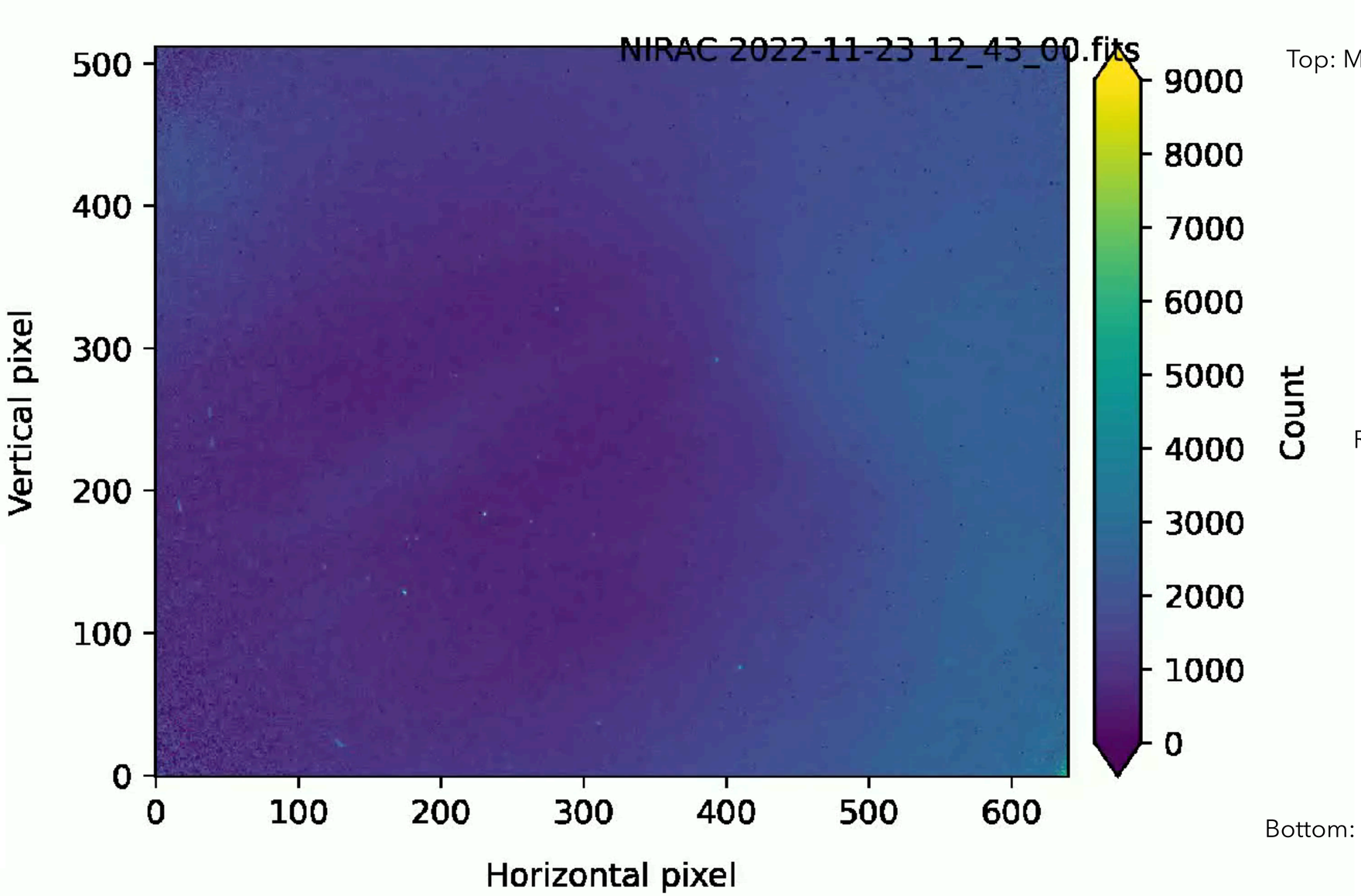
Top: Magnetic north

Left: Magnetic east

Right: Magnetic west

Bottom: Magnetic south

Download the movie

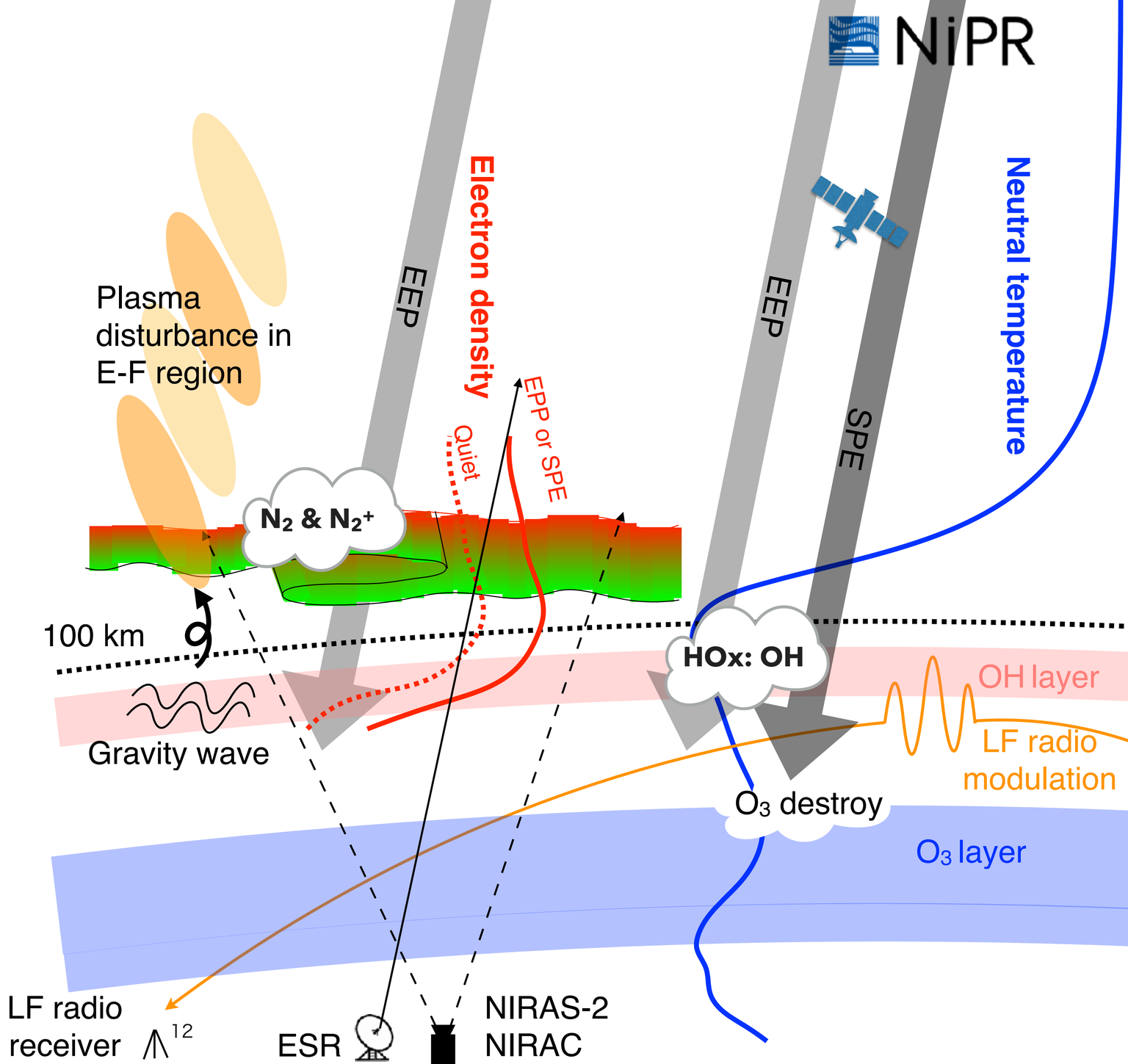


Future plan

Scope of observations in 2022

- Collaborative Instruments
  - EISCAT Svalbard Radar (meridional scan)
    - Electron density, ion temperature, electric field, and energy flux of precipitating particles
  - VLF/LF radio receiver
    - D-region ionization due to EPP

- Scientific targets
  - Dayside aurora characteristics
  - Monitoring mesopause temperature
    - Various wave activity and coupling E-F region
    - Compared to PMSE (and PMWE…?)
  - EPP effects on OH and temperature
  - N_2^+ resonant scattering and O_2 dayglow in twilight



NiPR

Conclusion

Key points and Future works

- The 2-D imaging spectrograph for SWIR aurora measurements has been developed.
  - with a fast optical system (F1.4) and a wide FOV ~ 55° (resolution: 0.11°)
  - Selectable three slits (30, 60 and 90 μm) and two VPGHs (950 and 1500 lpmm)
  - Target emissions:
    - Aurora: N_2^+ M (0,0) @ 1.10 μm, N_2 1P (0,0) @ 1.05 μm, N_2 1P (0,0) @ 1.05 μm, and N_2 1P (0,1) @ 1.24 μm
    - Airglow: OH (5,2), (6,3), (7,4), (8,5) band @ 1.08 - 1.33 μm, O_2 IR band @ 1.27 μm
  - N_2^+ M (0,0) aurora can be measured with time resolution shorter than 30 seconds.
    - At SZA of 85°, S/N ~ 2-4 for strong aurora activities
  - With OH (8,5) band, mesopause temperature can be estimated with 5-min resolutions and errors up to 3 K.
    - We should check the performance after installation at KHO

- A new monochromatic SWIR camera has been also developed and its optical performance was tested.
  - Target emissions are N_2^+ M (0,0) aurora and OH (5,2) band around 1.1 μm.
  - FOV is slightly wider than that of NIRAS-2 that helps to interpret NIRAS-2 results.
  - PSF is less than 2 pixel at 130-pixel distance and it is the same as optical design.
  - In a test observation, we successfully identified horizontal structures of OH (5,2) band airglow layers with 30-seconds exposures.
  - We have successfully taken aurora images at 1.1 μm with a monochromatic InGaAs imager for the first time (as long as I know)

- NIRAS-2 and NIRAC have been installed at KHO/UNIS, Longyearbyen (78.2°N, 15.6°E) and started continuous observations!
  - I hope that they would keep operations without any problems…