

A dark grey arrow points to the right from the left edge of the slide. Below it, several thin, curved lines in shades of blue and grey sweep across the left side of the slide.

# Low Resolution



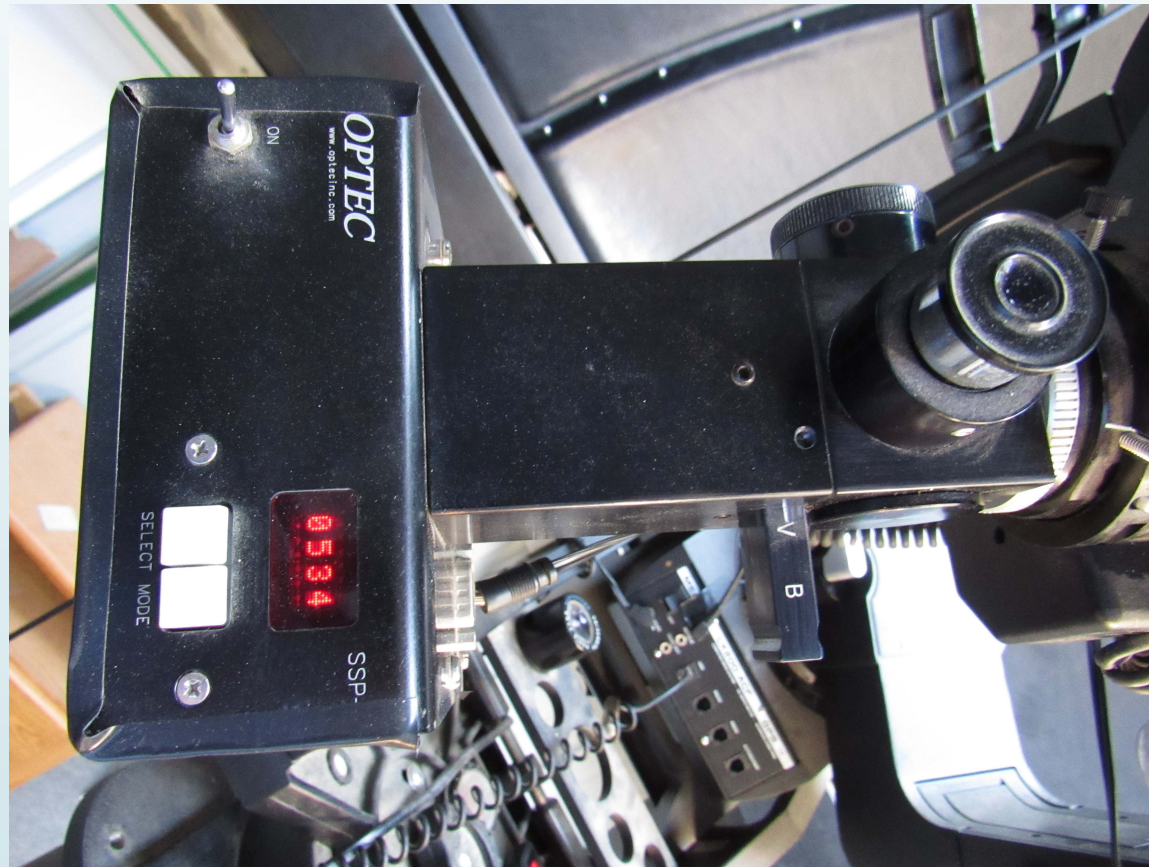
# Spectroscopy

# Aurora on Uranus

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# Photometry



# Photometric Parameters

- ▶ Optec SSP-3 solid state photometer
- ▶ 0.25m LX-200 telescope
- ▶ Blue and Green filters, transformed to Johnson B, V
- ▶ Differential photometry, compared to HD 11257
- ▶ Precision: 0.002-0.006 mag B and V
- ▶ (B-V) mean 0.563,  $\sigma$  0.004, 12 determinations

# Spectroscopy



# Spectrometry Parameters

- ▶ Low Resolution Spectroscopy
- ▶ Objective Grating, Star Analyzer SA-100, 100 lines/mm
- ▶ 150mm telephoto lens
- ▶ Canon D60a, 4.3 $\mu$ m pixels
- ▶ Analysis performed using RSpec, Field Tested Systems
- ▶ Net effective dispersion: 2.88 Angstroms/pixel
- ▶  $\beta$  Ari used for calibration
  - ▶ Spectroscopic binary with A5v primary
  - ▶ Approx. same airmass as Uranus

# Background

- B, V photometry of Uranus since 2003
- Photometry reported to Association of Lunar and Planetary Observers
  - Remote Planets Section
- Occasional anomalies in (B-V) color
- Sub-Earth latitude range  $-17^\circ$  (2003) to  $+41^\circ$  (2018)
- More anomalies as north polar region swings toward Earth
- No correlation with longitude in any apparition
- Uranus “shines” by reflecting sunlight and is usually characterized by absorption lines corresponding to methane and ammonia in its atmosphere

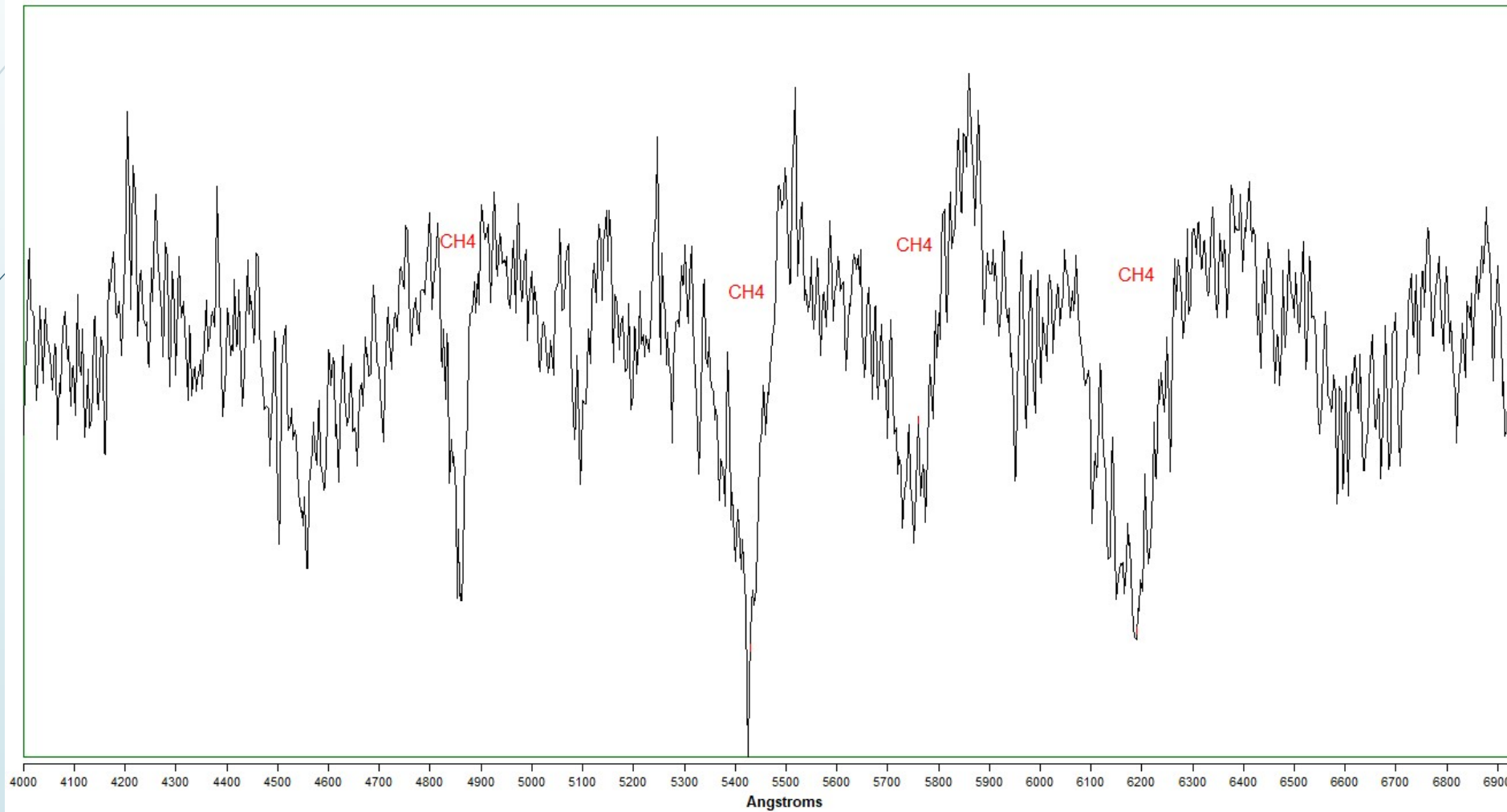


# Summary of Measurements

Uranus Summary					
Apparition 2018-2019		(B-V) mean 0.563 dev .004			
UT Date	JD	(B-V)	(B-V) Deviation	Sub-Earth Longitude	Spectrum
	2458000+				
10/11/2018	402.7146	0.583	+5 $\sigma$	176	Not Available
10/28/2018	419.666	0.565		32	Interference
10/29/2018	420.6743	0.566		177	Normal
11/4/2018	426.6618	0.553		297	Normal
11/26/2018	448.6111	0.567		137	Normal
11/28/2018	450.616	0.565		62	Normal
12/21/2018	473.6097	0.563		64	Normal
12/25/2018	477.6021	0.558		265	Normal
12/31/2018	483.5771	0.567		19	Normal
1/4/2019	487.5813	0.594	+8 $\sigma$	225	Emmision @ 452.8, 527.8 nm
1/20/2019	503.5694	0.559		317	Not Available
1/24/2019	507.5799	0.565		167	Normal
1/25/2019	508.5889	0.581	+5 $\sigma$	313	Emission @ 557.7 nm [O I]?
1/26/2019	509.5979	0.561		98	Normal
1/31/2019	514.5819	0.565		97	Normal
2/8/2019	522.5965	0.57		132	Normal

# “Normal” Uranus Spectrum

Uranus 1-26-19 "Normal"



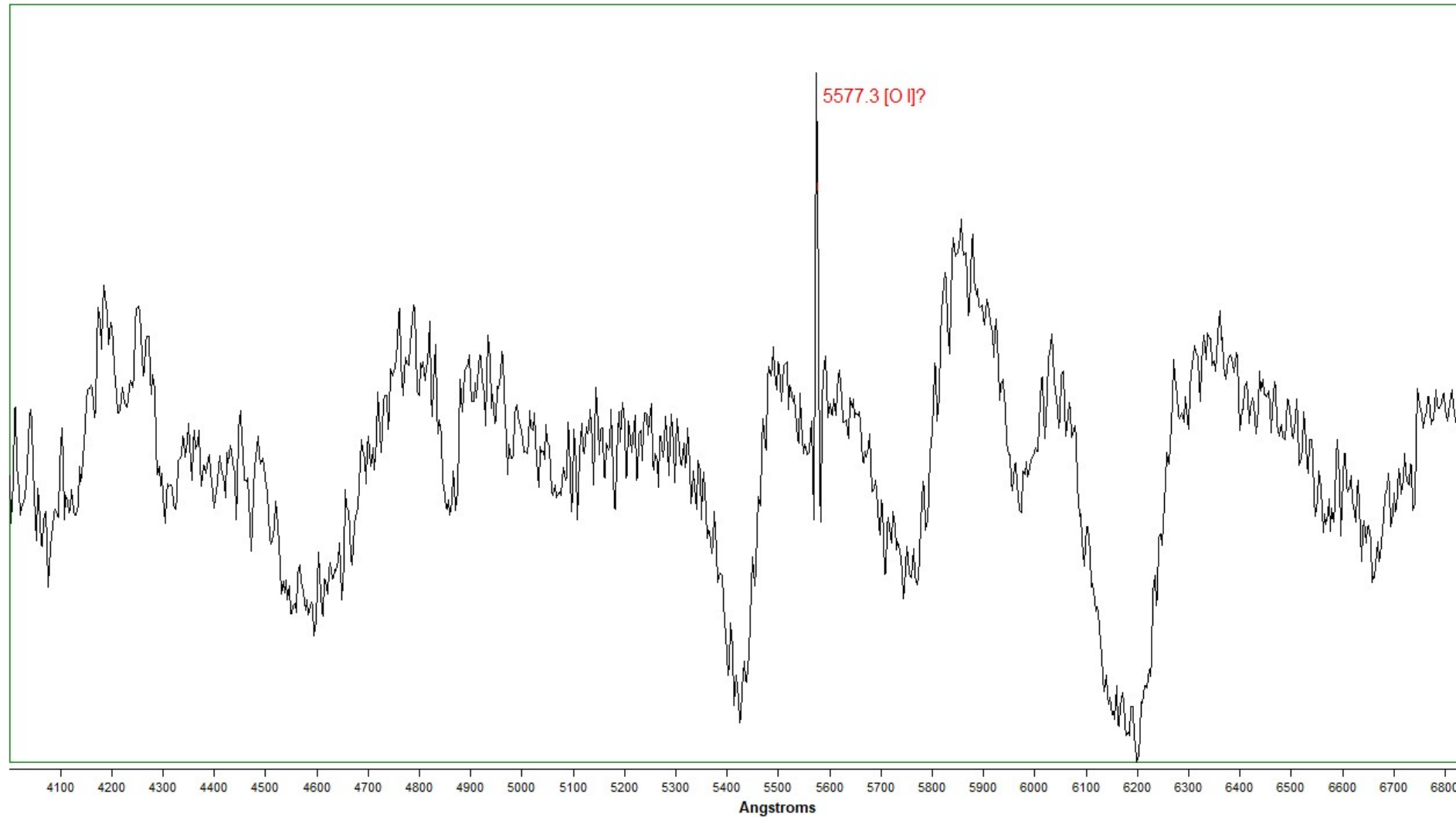
# Uranus Emission Lines 4 January 2019

Uranus 1-04-19 Emissions



# Uranus Emission Lines 25 January 2019

Uranus 1-25-19 Emission



# Conclusions

- ▶ Aurorae can be detected by either (B-V) color or low resolution spectrography as various atmospheric moieties are ionized
- ▶ Aurorae are relatively short lived, less than 24 hours (see 24, 25, 26 January, 2019 data)
- ▶ Aurorae will likely become more frequent and stronger as Uranus' north pole points more directly toward Sun and Earth over the next decade
- ▶ Insufficient data (so far) to determine if magnetic pole coincides with rotational pole of Uranus
- ▶ Larger instrument may find similar spectral evidence of aurorae on Neptune