The moon as a tool for the calibration of infrared sensors

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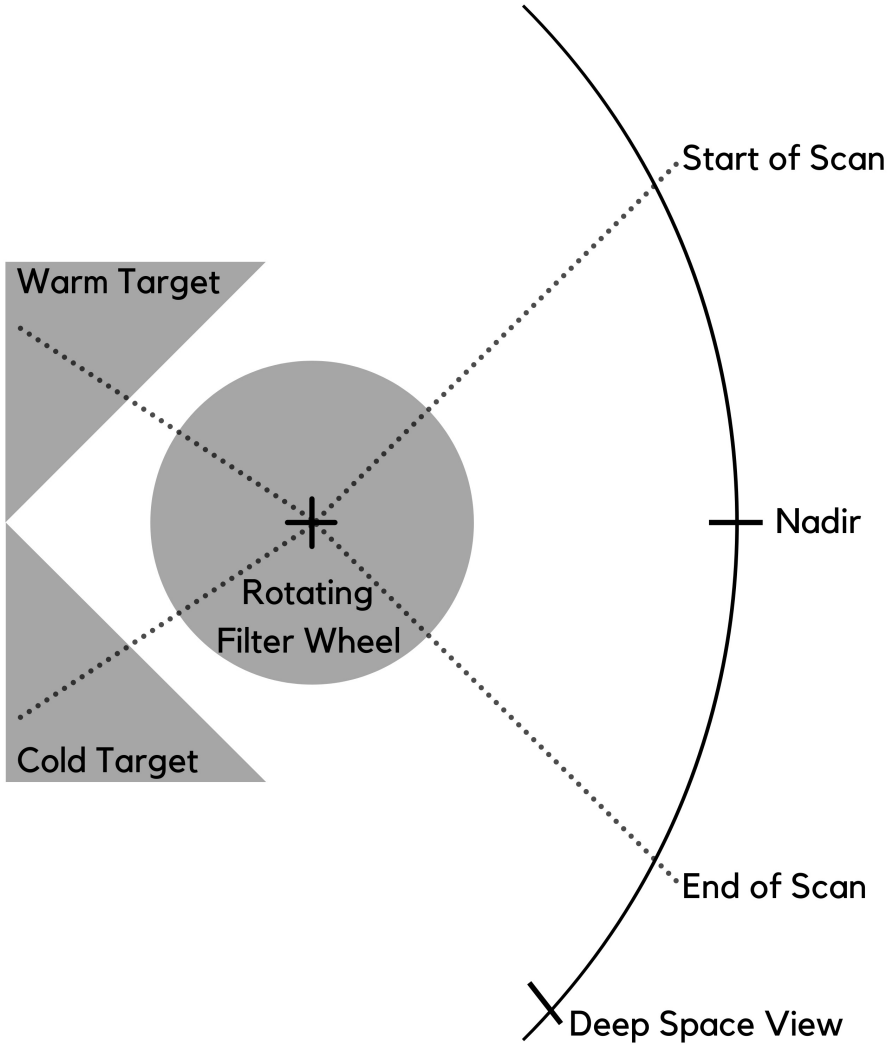
Motivation

„*These studies conclude … that for around a quarter of a century,* ***no existing satellite Earth radiation budget climate data record is of a sufficient standard to partition changes to the Earth from those*** *of un-tracked and changing* ***artificial instrumentation effects***.“ (Grant Matthews, 2018)

- Moon used for calibration in optical and microwave
- Still *not very common* in IR

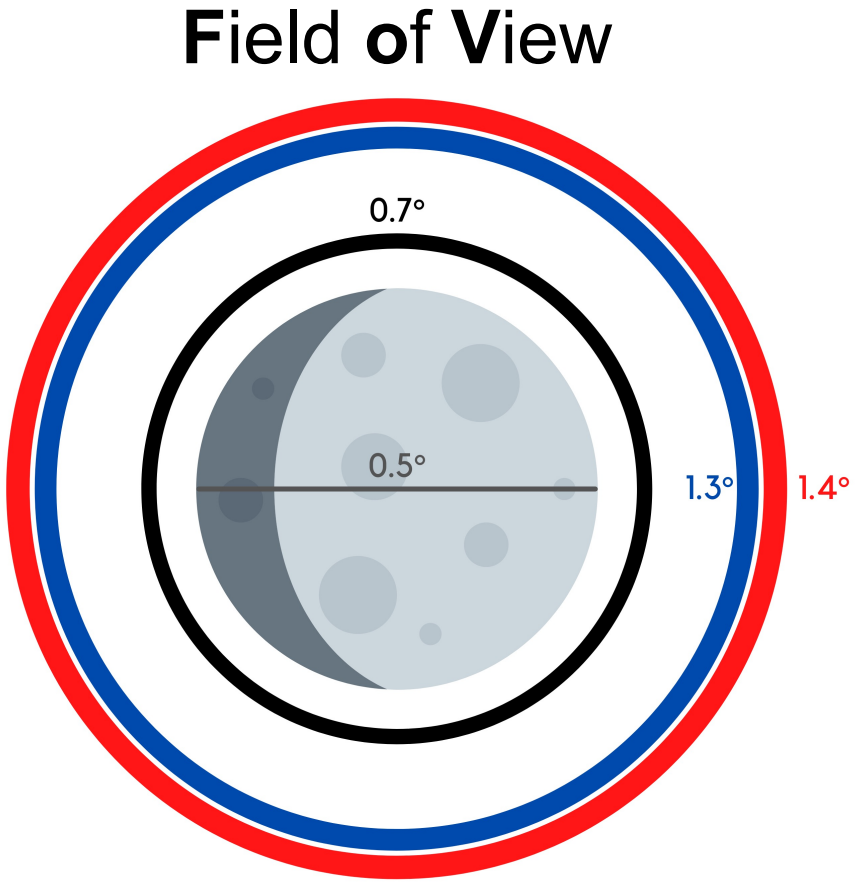
➢ Focus on **H**igh-resolution **I**nfrared **R**adiation **S**ounder water vapor channel 12 at 6.7 μm, which is important for climate research

Moon in the FoV of HIRS



Simplified from Koenig et. al. (1979)

HIRS/2
HIRS/3
HIRS/4



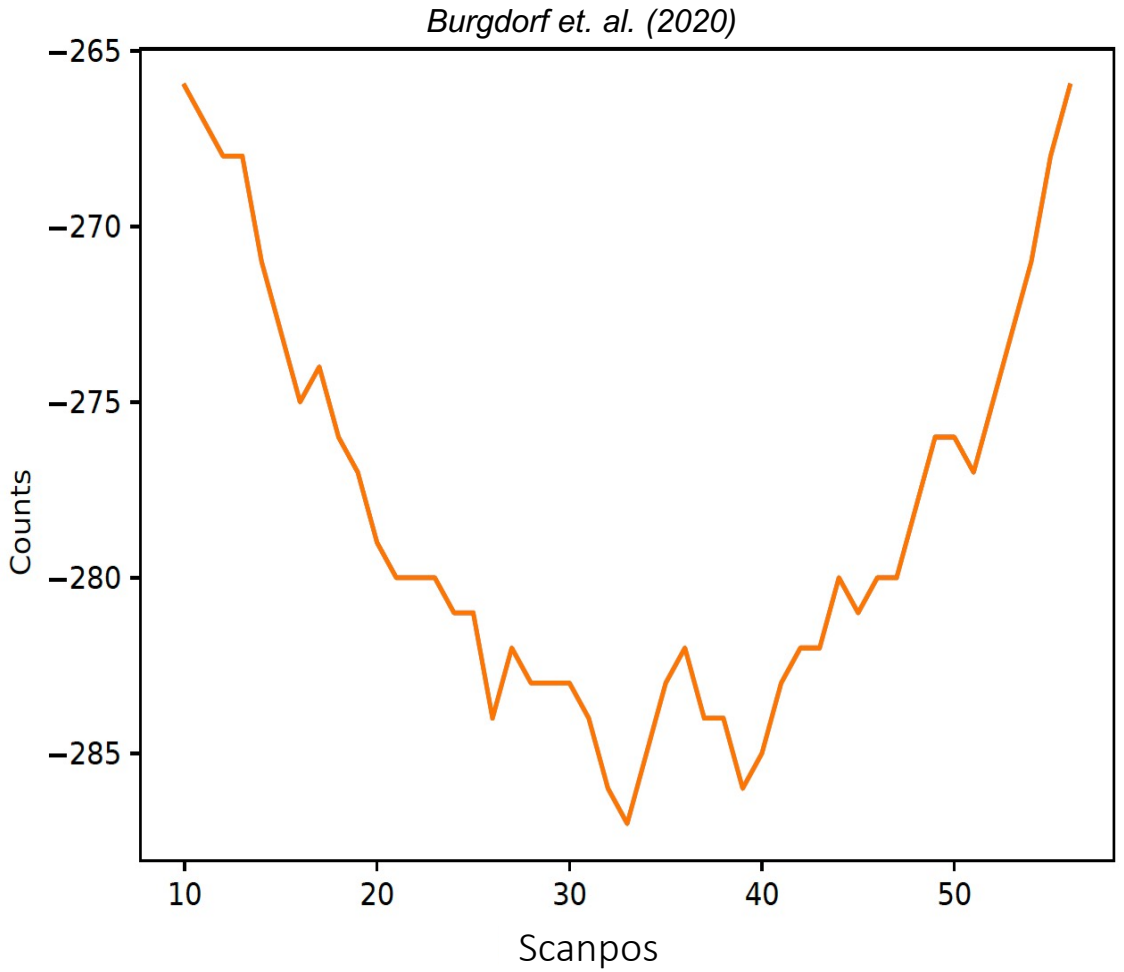
Not to scale

Values from Burgdorf et. al. (2020)

Moon with HIRS

High-resolution **I**nfrared **R**adiation **S**ounder (1975-today)

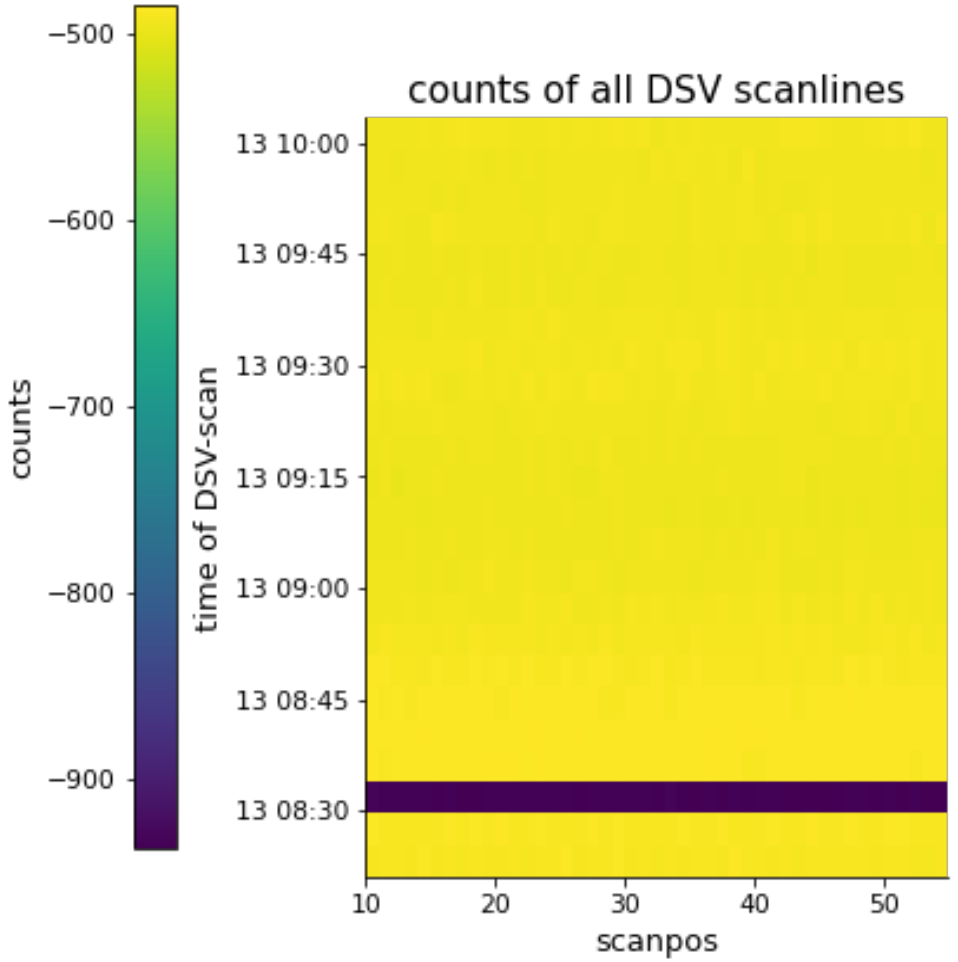
- Polar Orbit
- 20 channels:
  - 1 visible (0.69 μm)
  - 7 **s**hort**w**ave IR (3.7 to 4.6 μm)
  - 12 **l**ong**w**ave IR (6.5 to 15 μm)



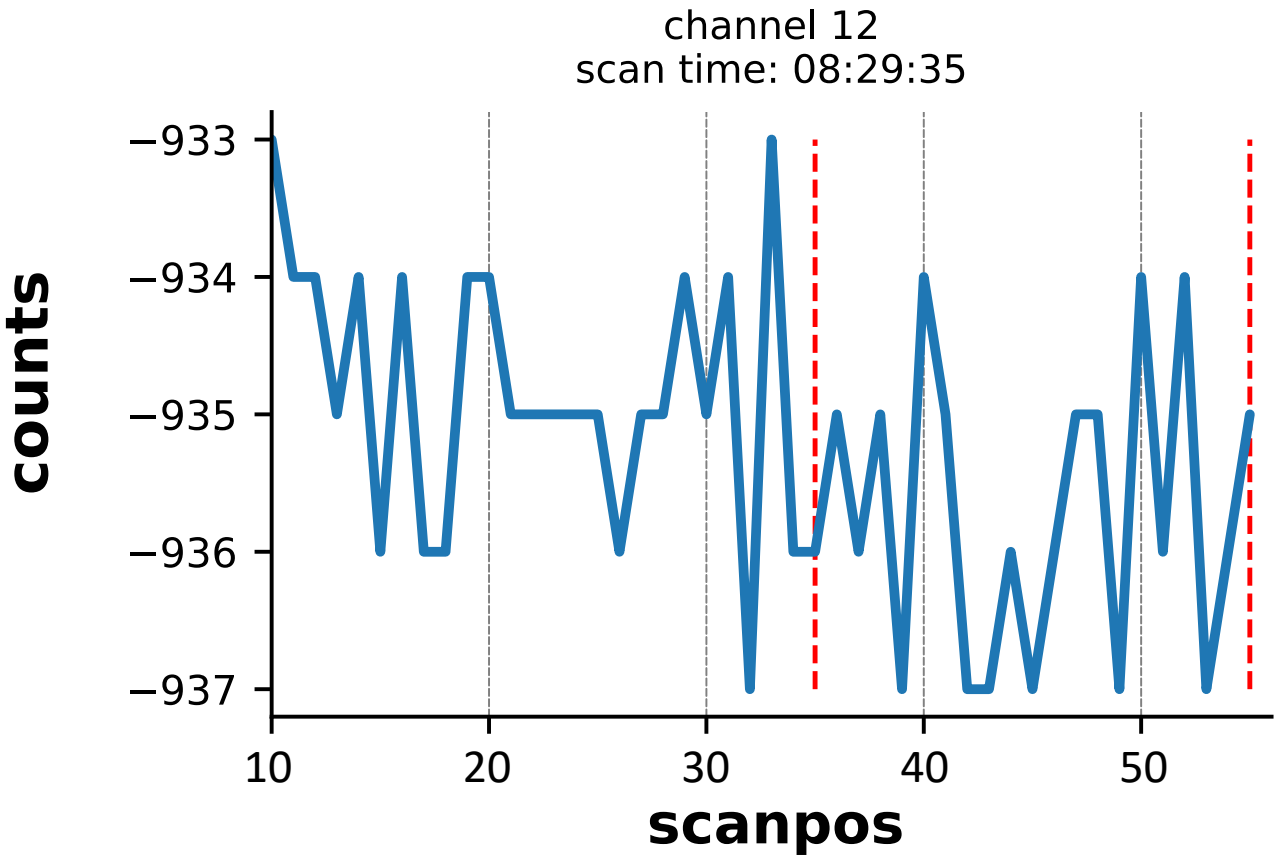
Observed with NOAA-19
at 12.5 μm 04.03.2012 05:07

Finding Moon observations with HIRS

- Loop through all observation files
- Check if gradient between **D**eep **S**pace **V**iews > 50 counts
- Find scanline with minimum average counts = moon „intrusion“



Moon intrusions with HIRS



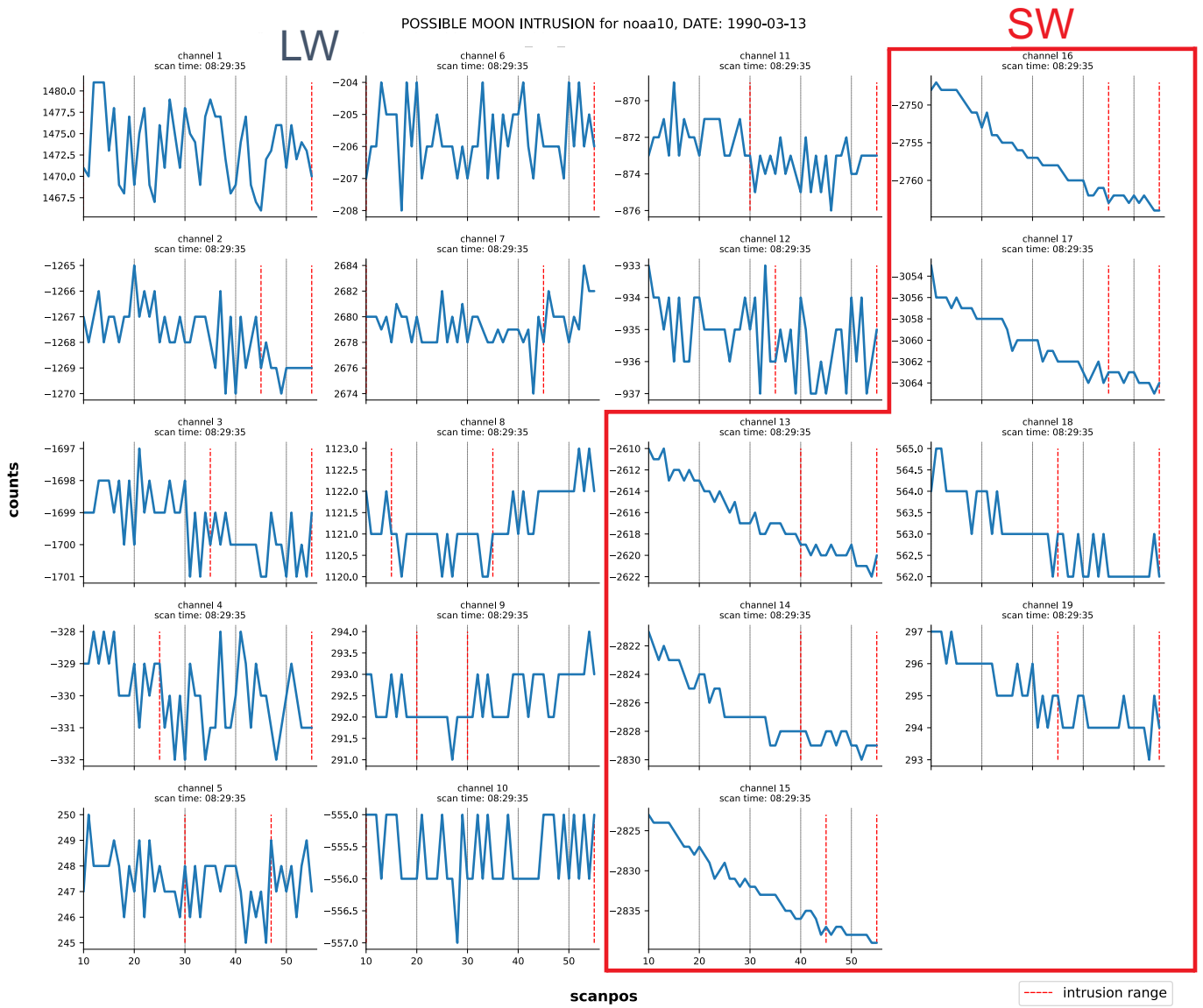
Constant region with lowest counts

Moon intrusions with HIRS

Ideally: For all channel the same region

SW (3.7 to 4.6 μm): Moon is moving inside the FoV

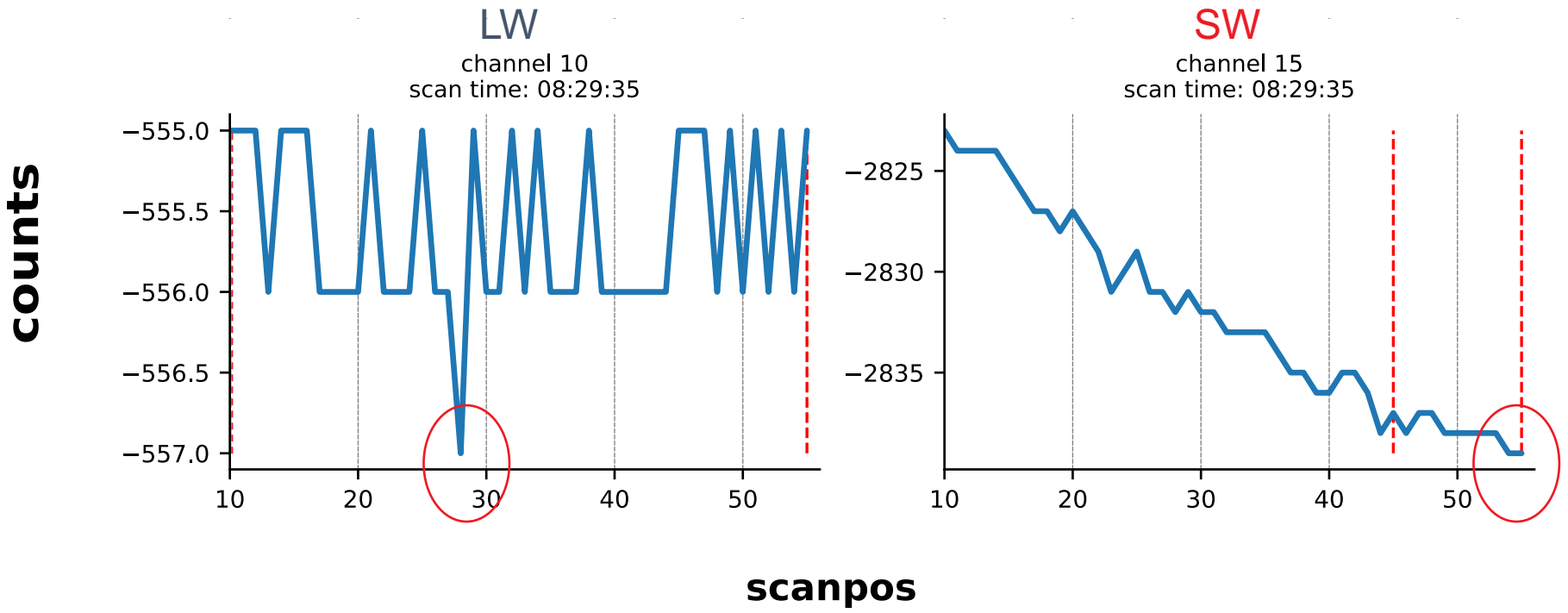
LW (6.5 to 15 μm): Moon is in the middle of the FoV



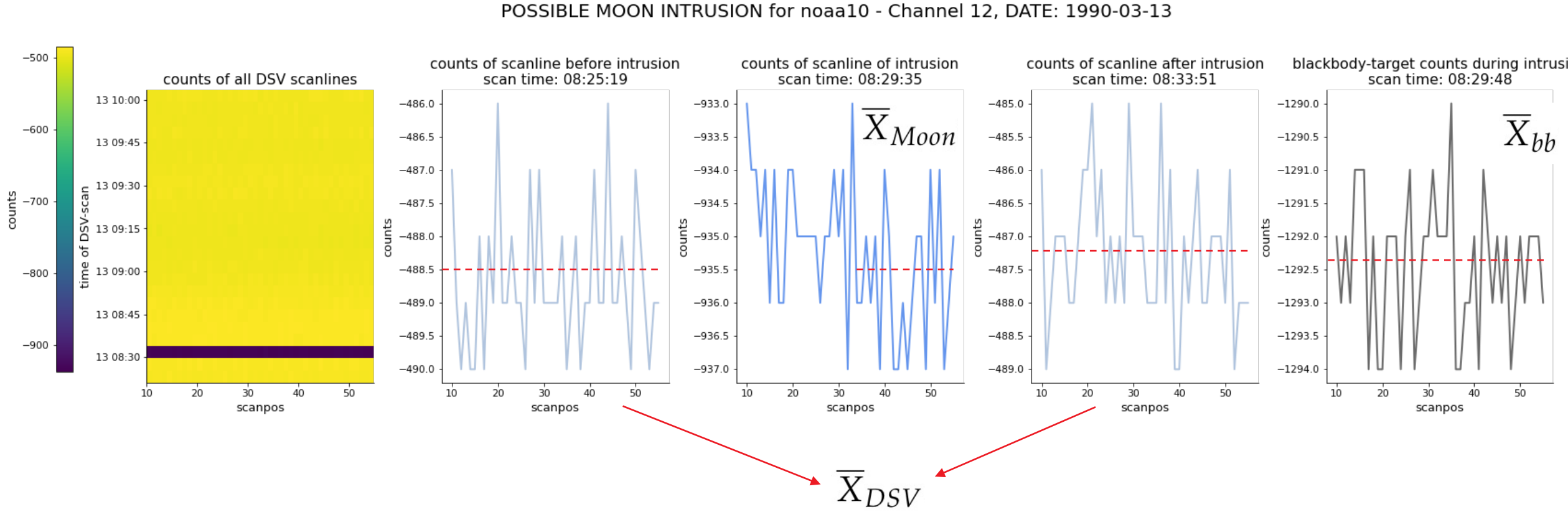
Caracterisation: Pointing accuracy

Minimum of scan position for all channels is not the same!

NOAA-10 with HIRS/2: FoV = 1.4°, Moon 0.5°



Moon intrusions with HIRS



$\overline{X}_{Moon}$: Average counts from space target with moon in FOV

$\overline{X}_{bb}$: Average counts from blackbody

$\overline{X}_{DSV}$: Average counts from deep space view

Calculation of Radiance of the Moon

$$R_{Moon} = \left(\frac{R_{bb}}{\alpha^2} + \frac{R_{bb} \cdot (\overline{X}_{Moon} - \overline{X}_{bb})}{\alpha^2 \cdot (\overline{X}_{bb} - \overline{X}_{DSV})} \right) \cdot \frac{FOV^2}{0.97}$$

R_{Moon}: Radiance of the moon

R_{bb}: Radiance of the blackbody

$\overline{X}_{Moon}$: Average counts from space target with moon in FOV

$\overline{X}_{bb}$: Average counts from blackbody

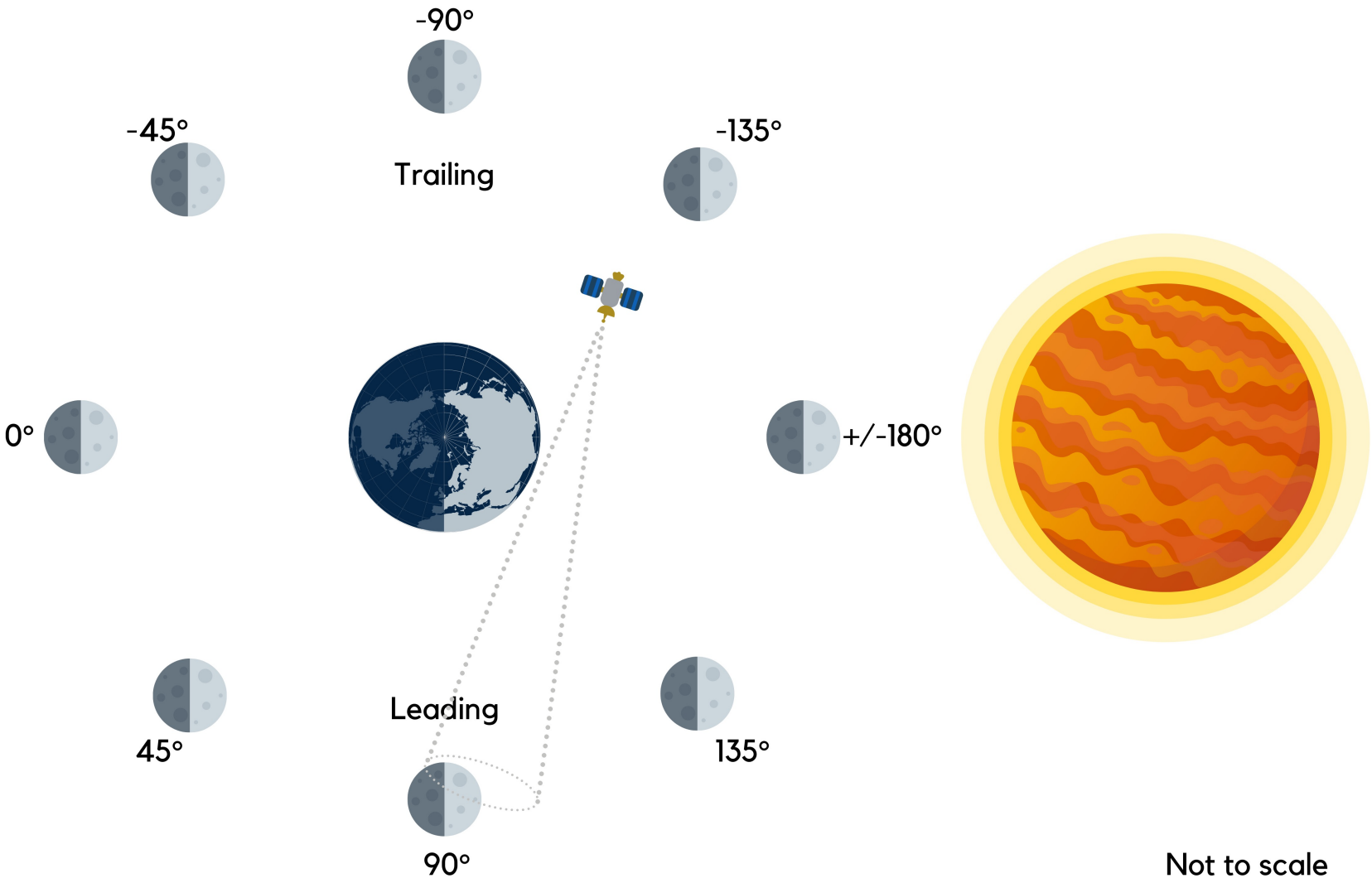
$\overline{X}_{DSV}$: Average counts from deep space view

$\sigma_{\overline{X}_{bb}}$: Standard deviation of the blackbody counts

α: Angular diameter of the moon

FOV: Field of view

DSV away from Sun

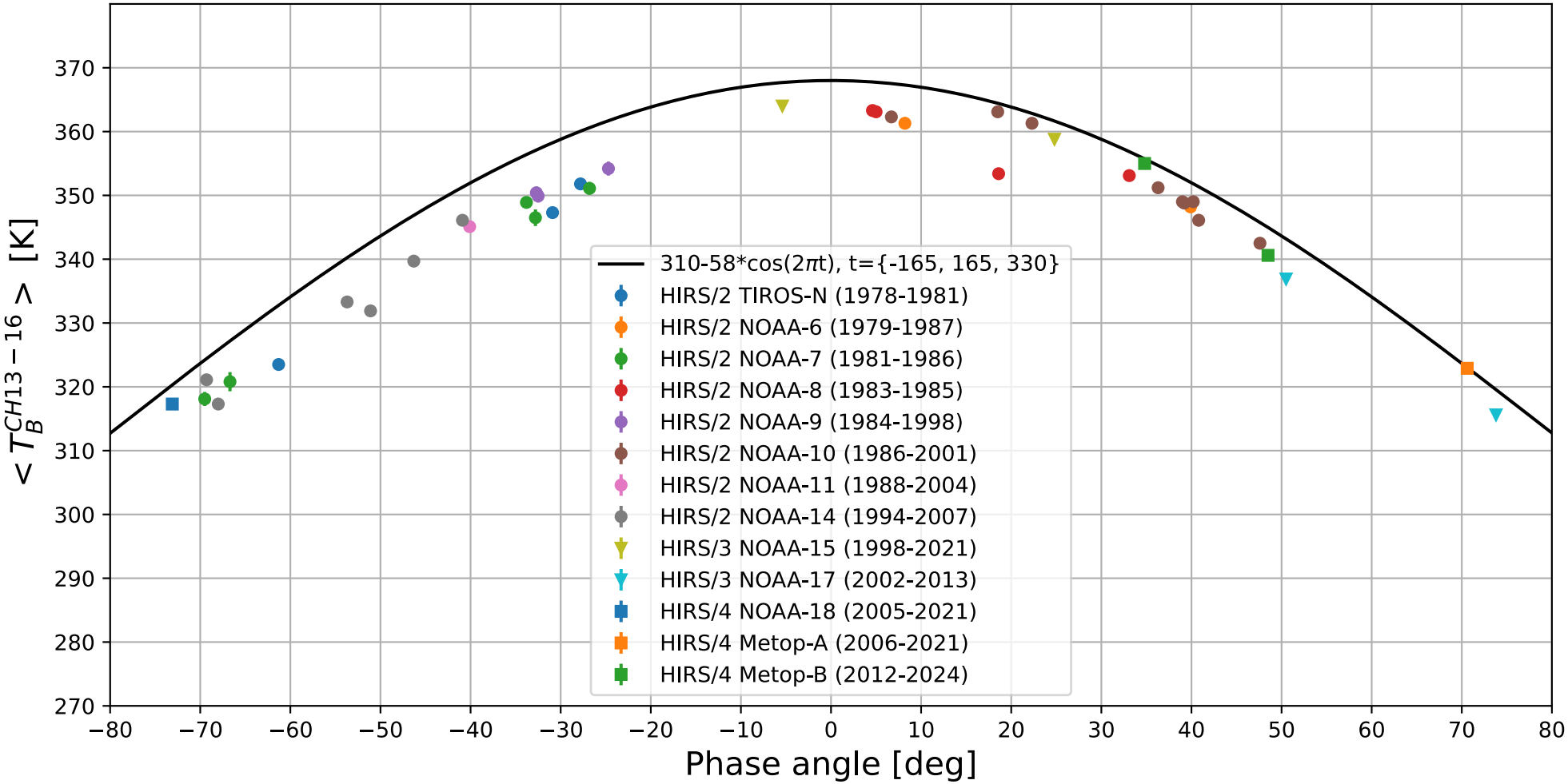


Inspired from illustration on (https://www.astronomynotes.com/nakedeye/s13.htm, 09.03.2022)

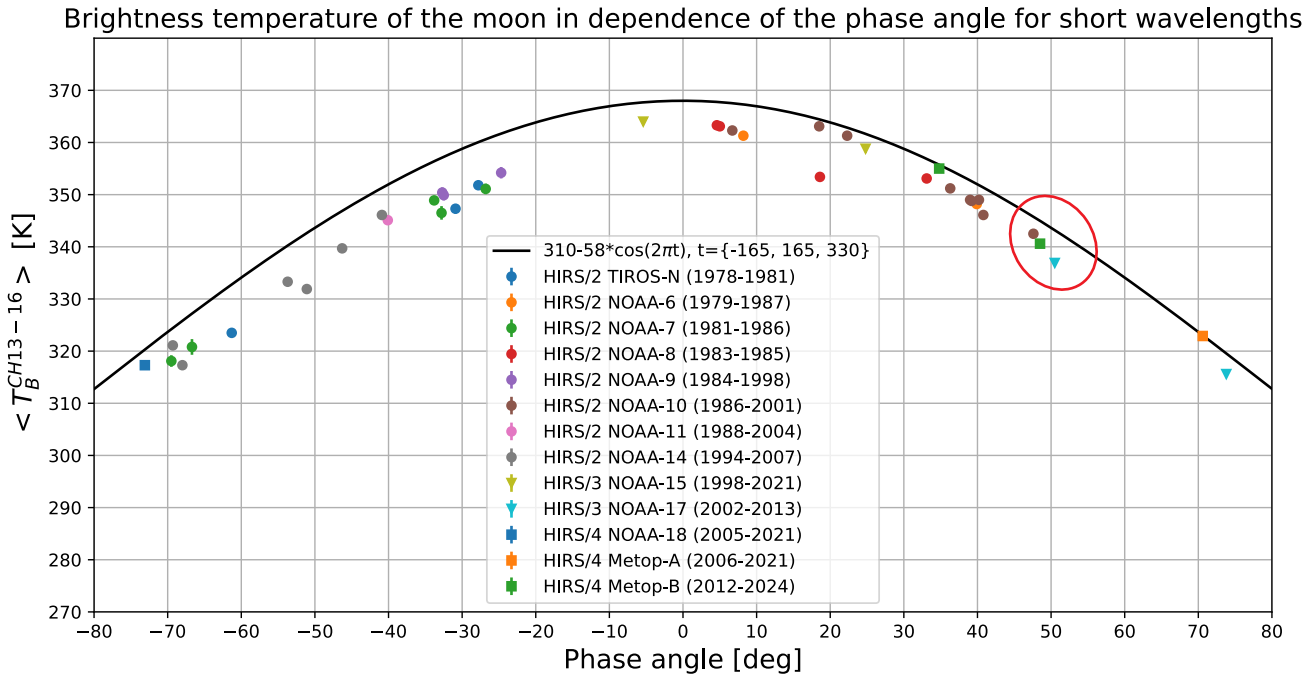
Preliminary Results

$$< \lambda^{CH13-16} > = (4.50 \pm 0.06)\mu m$$

Brightness temperature of the moon in dependence of the phase angle for short wavelengths



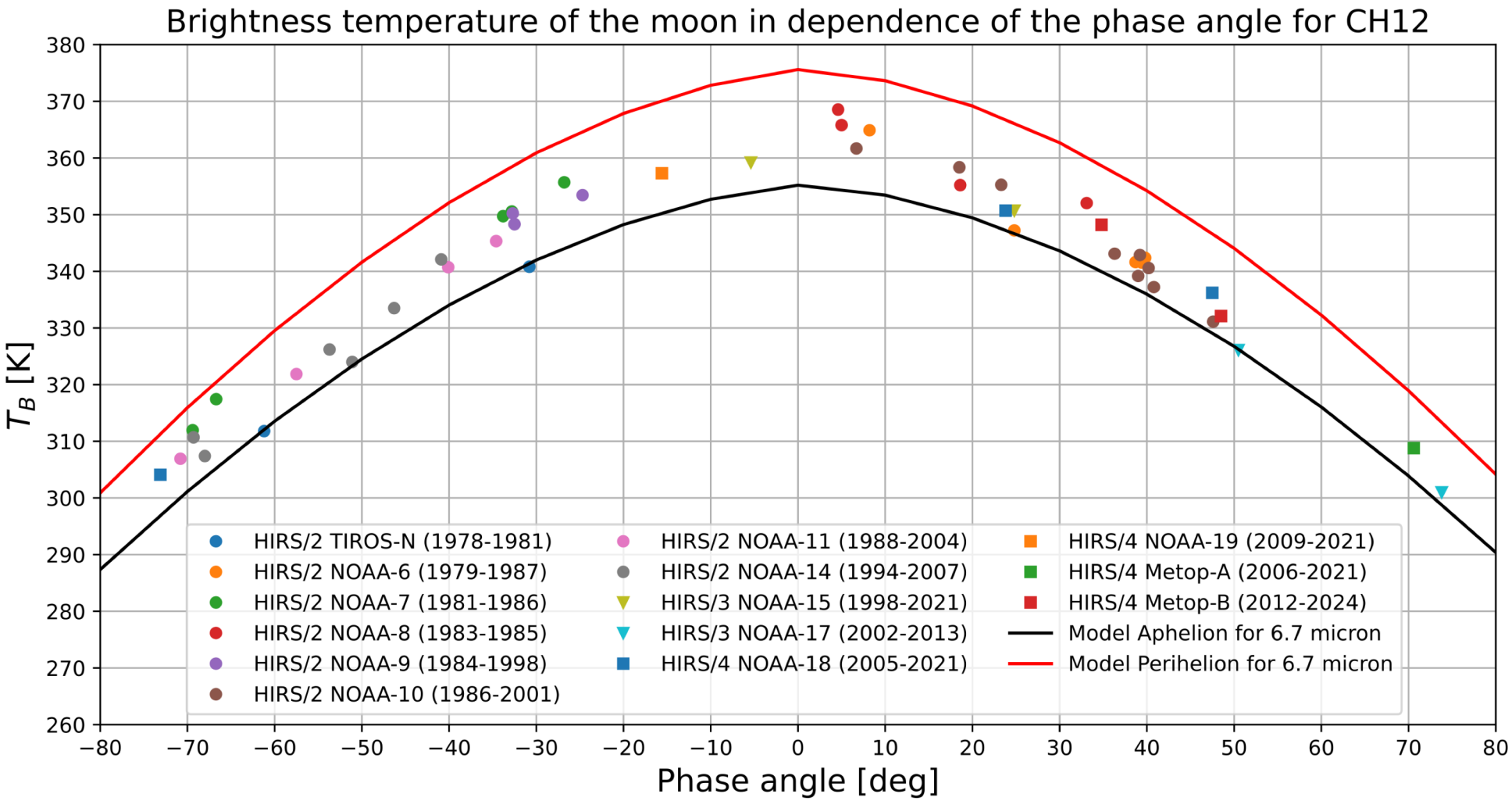
Reprensentativity of Results



$$< \lambda^{CH13-16} > = (4.50 \pm 0.06)\mu m$$

Instrument	Satellite	Date	Phase angle [deg]	T_B [K]
HIRS/2	NOAA-10	30.08.1988	47.6	342.5 ± 0.6
HIRS/3	NOAA-17	26.09.2002	50.5	336.9 ± 0.3
HIRS/4	Metop-B	21.07.2019	48.5	340.6 ± 0.2

Comparison with model *by Thomas Müller*



Center frequency of CH12:

HIRS/2: 6.72 µm

HIRS/3: 6.52 µm

HIRS/4: 6.52 µm

Source of values: https://nwp-saf.eumetsat.int/site/software/aapp/aapp-overview/hirs-2/

Summary

- Calibration of HIRS with the Moon requires no spacecraft maneuvers and spans operational lifetime
- Possible to estimate pointing accuracy
- Good agreement of results over all HIRS versions
- Comparison with thermo-physical model for validation

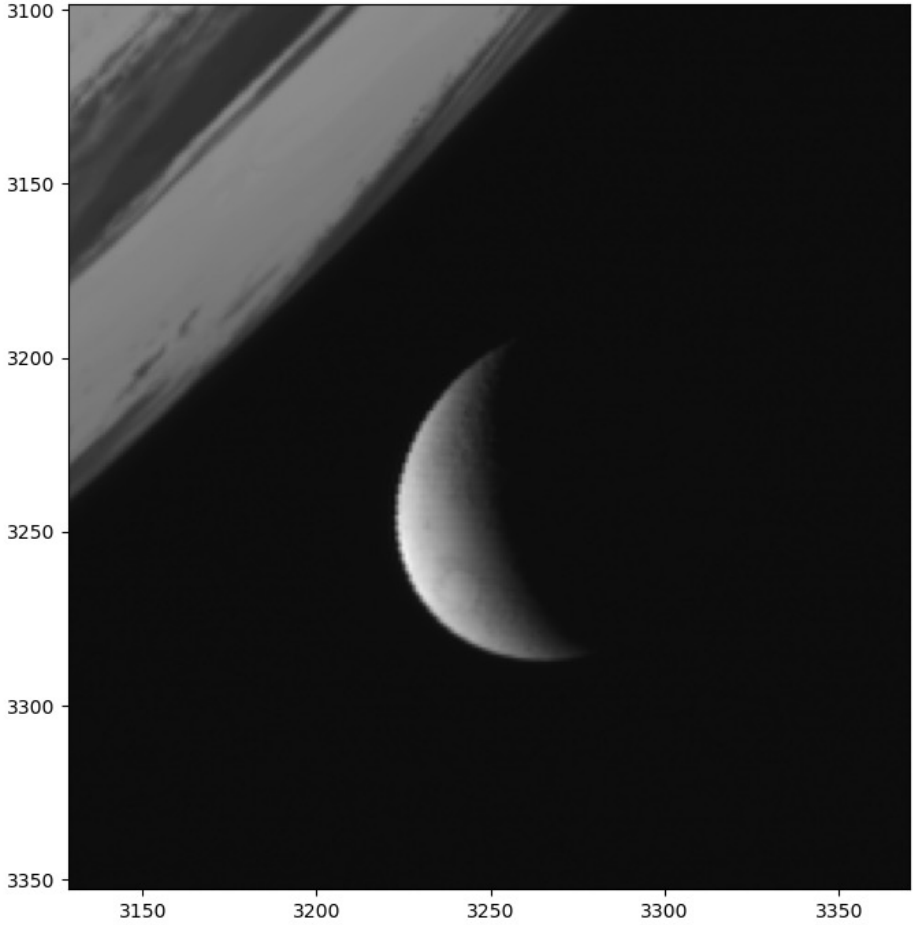
Outlook: Moon with Imager SEVIRI

Spinning **E**nhanced **V**isible
Infra**R**ed **I**mager (2002-today)

- Geostationary Orbit
- 12 channels:
  - 1 visible (0.6 to 0.9 μm)
  - 11 IR (0.6 to 13.4 μm)

➢ Possible to observe moon at phase angles >90°

➢ Intercomparison with HIRS in the IR (3.7 to 15 μm)



Observed with METEOSAT-10 L1.0 (EUMETSAT)
at 8.7 μm 29.07.2017 04:00

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