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A Small Aperture Synoptic Solar Telescope - Baseline Design

Dirk Soltau

Leibniz-Institut für Sonnenphysik (KIS)

2nd SPRING Progress Meeting February 18th, 2020

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SOLARNET

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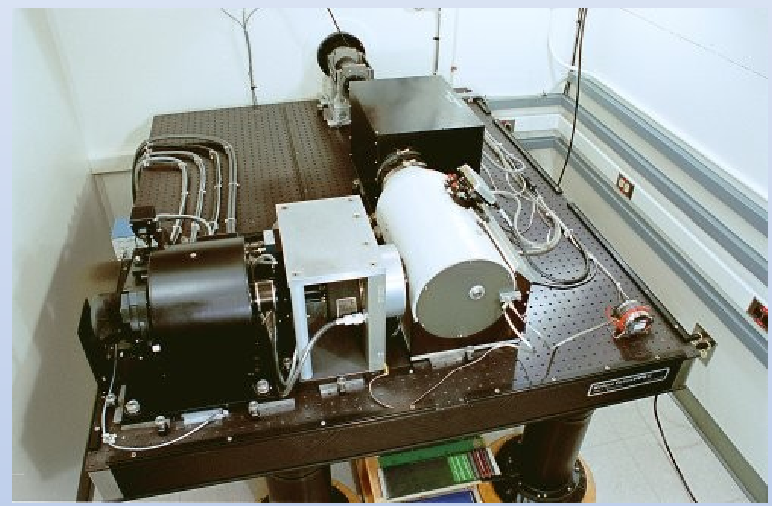
Good old GONG instrument:

Michelson interferometer □ One line only (Ni 6768 Å)



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Legacy:
FP7 SOLARNET2017 WP80

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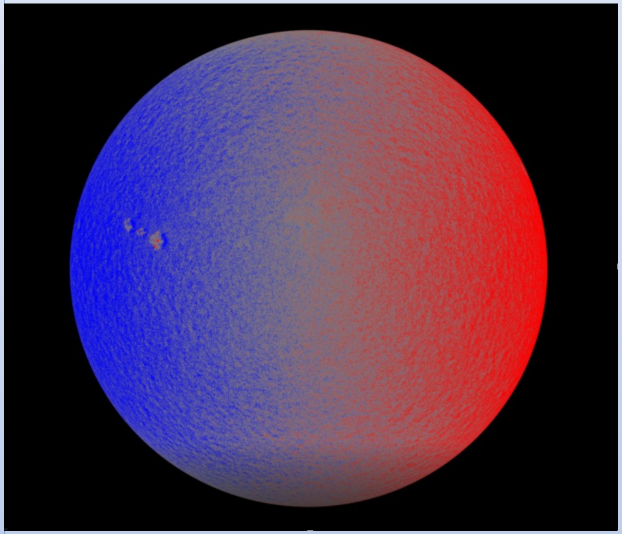
Requirements from WP 80 (SOLARNET 2017) :

- Detector: 4k x 4k
- Spectral resolution: 8 pm
- Cadence: 30 – 60 s
- Velocity sensitivity: 10 m/s
- Magnetic sensitivity: 10 G (los)
- Two types of telescopes:
  - Small (D < 250 mm)
  - Large (D > 500 mm)
- GONG sites (6)



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Many spectral lines (17!) in 3 wavelength bands

S. No.	Spectral line (Å)	Element	Formation Height (km)	SNR required	Q-factor of the line
1	3933	Ca II K		1400	3400
2	3968	Ca II H		1000	4600
3	5173	Mg I b1	595±5	450	10300
4	5250	Fe I		250	18900
5	5434	Fe I	556±25	350	13800
6	5576	Fe I	310±15	350	13300
7	5890	Na I D2	927±35	450	11000
8	5896	Na I D1		550	8500
9	6173	Fe I	276±26	320	14700
10	6301	Fe I	337±23	350	13300
11	6302	Fe I		320	15500
12	6563	H I α	1200-1700	600	8100
13	6768	Ni I		300	16000
14	7090	Fe I	284±32	420	10800
15	8542 (4Å window)	Ca II		800	6000
16	10830	He I		1400	600
17	15648	Fe I		500	9500

Which spectroscopic device can do that?

	Imaging	Multi line	High cadence
Michelson	Yes	No	yes
Grating	No (depends)	Yes	No (depends)
Fabry-Perot	Yes	Yes	Yes

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Design driving parameters:

	Value	Why?
Telescope type	2 mirror	Short Proven concept (SOLIS)
Etalon diameter	120 mm useful diameter	Largest low risk diameter according to ICOS
Detector	Pixel scale: 0.5"/pixel	Resolution

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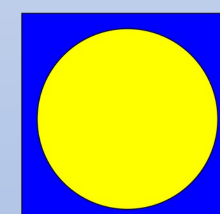
Design driving parameters:

	Value	Why?
Etalon diameter	120 mm useful diameter	Largest low risk diameter according to ICOS
Etalon configuration	Collimated rather than telecentric	More compact
Detector pixel size	12 µm	Andor Balor 17F-12 4k x 4k, 16 bit, low noise, 49.5 x 49.5 mm^2, 18.5 ms readout time, 16 Gb/s
Space	Limited (e.g. Container)	Proven concept

 120 mm < D < = 250 mm

 Pupil size = 120 mm

 focal length = 4300 mm



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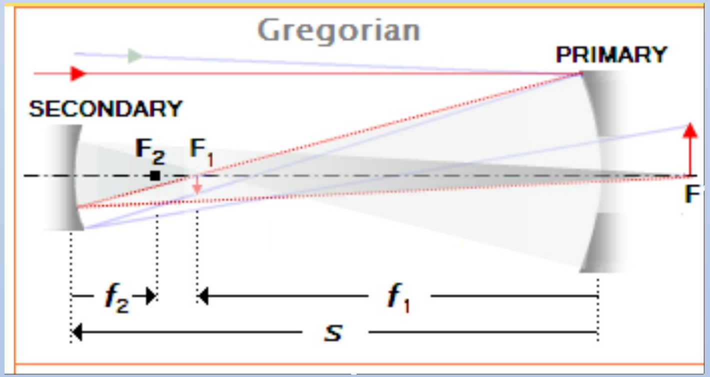
Designing a compact 2 mirror telescope

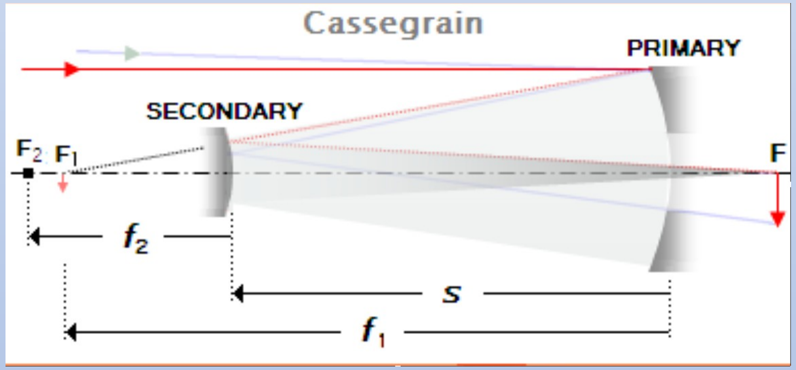
Gregorian

pro	con
Real focus in F1	Long
	Alignment tolerance
	FOV

Cassegrain (RC)

pro	con
compact	baffling
Alignment more tolerant	
FOV	





Images taken from https://www.telescope-optics.net/two-mirror.htm

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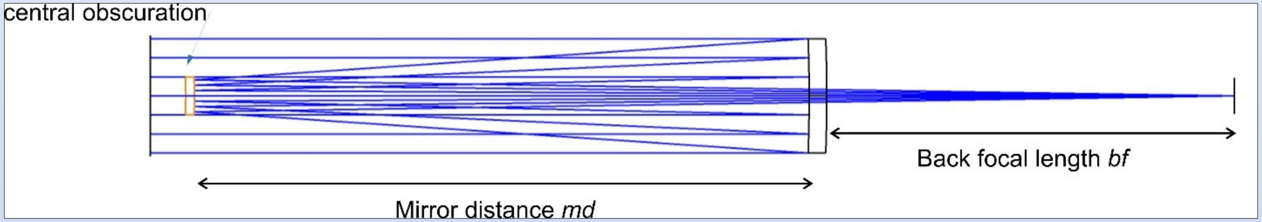
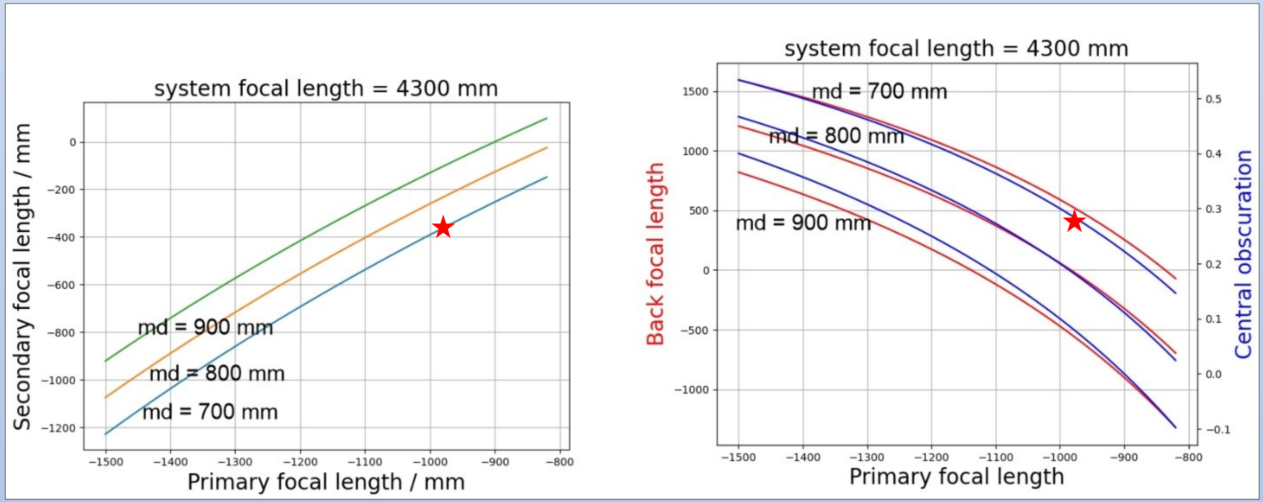
Designing a Cassegrain telescope

Given: f = 4300, appr. Length = 1000 mm



Important parameters:

- Back focal length
- Central obscuration



Images taken from https://www.telescope-optics.net/two-mirror.htm

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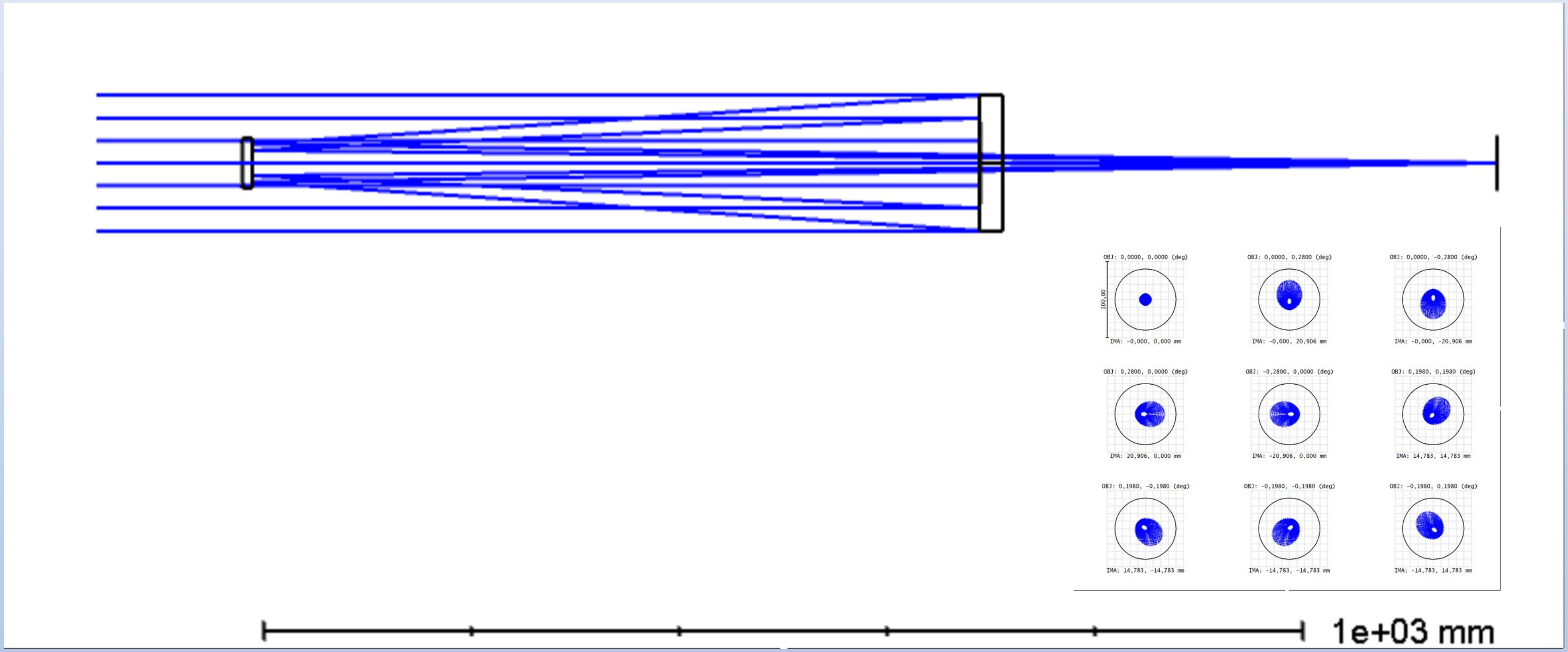
Designing a Cassegrain telescope

Given: f = 4300, appr. Length = 1000 mm



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Approach I: One telescope, three etalons Teaming with AMOS

- D = 180 mm
- f = 4300 mm
- Etalon size = 120 mm
- Collimated configuration
- One telescope, three etalons (500 nm, 850 nm, 1560 nm)
- Space for calibration unit
- Space for dual beam polarimeter
- Tip tilt sensing/correction

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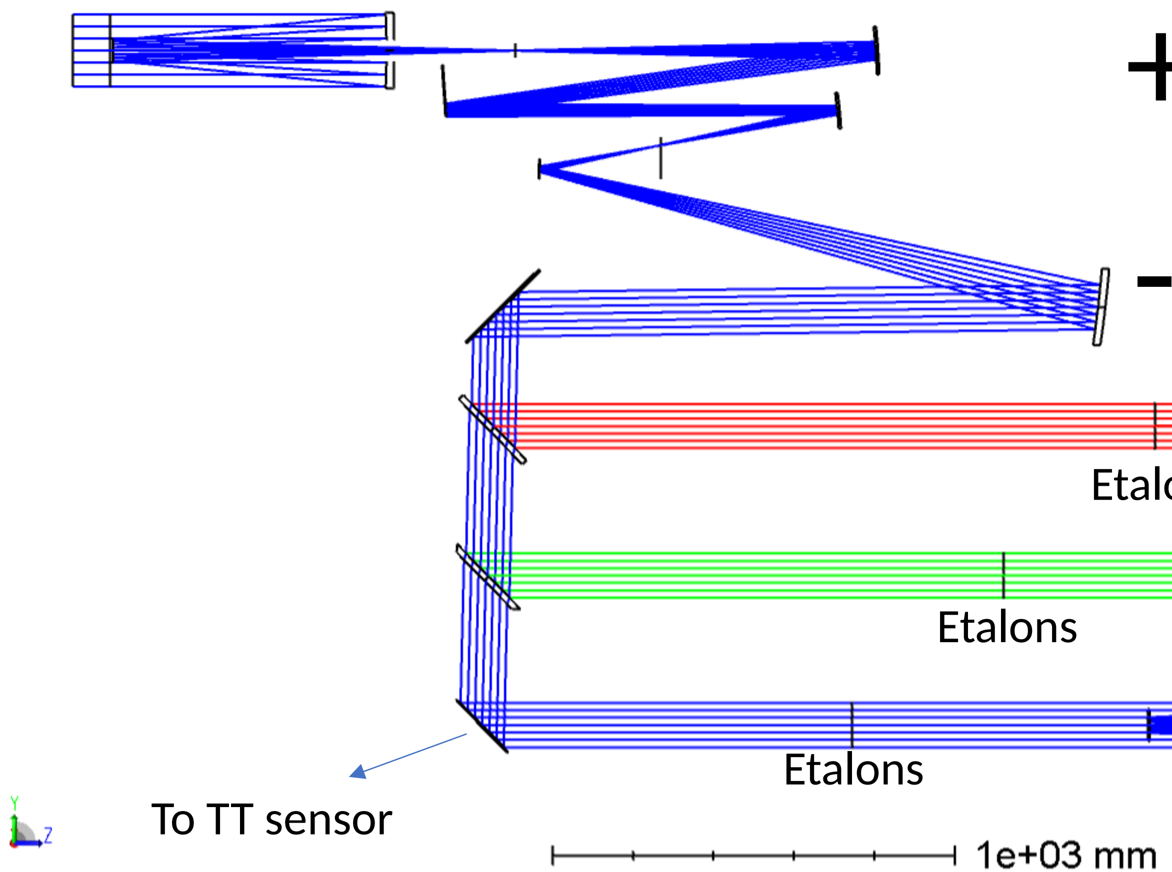
AMOS design Vers 3.0



+

Space for
- Calibration unit
- Polarimeter

-

- optical performance not sufficient

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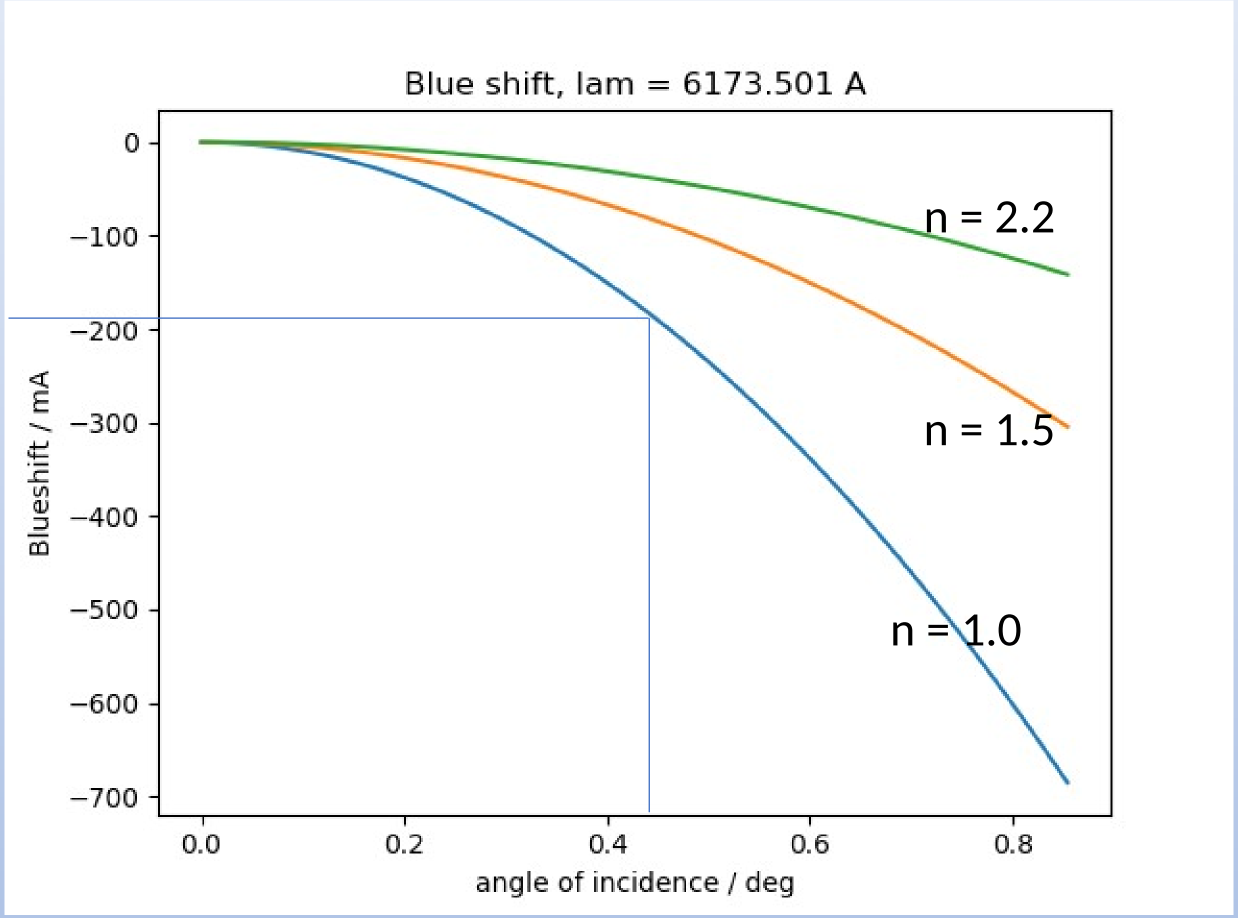
Blue shift because of angle of incidence

190 mÅ

FOV/2 = 0.28°



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Approach II: One telecope, one etalon, one wavelength band

Sacrifice	Gain
Aperture: 180 mm 120 mm (Etalon diameter)	Simplicity: no relay optics, 6 mirrors less
One telescope, 3 etalons = easier handling	Much more compact
	Design polarization free (no calibration unit(?))
	Better optical performance
	blue shift = 70 mÅ (smallest possible) gain in cadence

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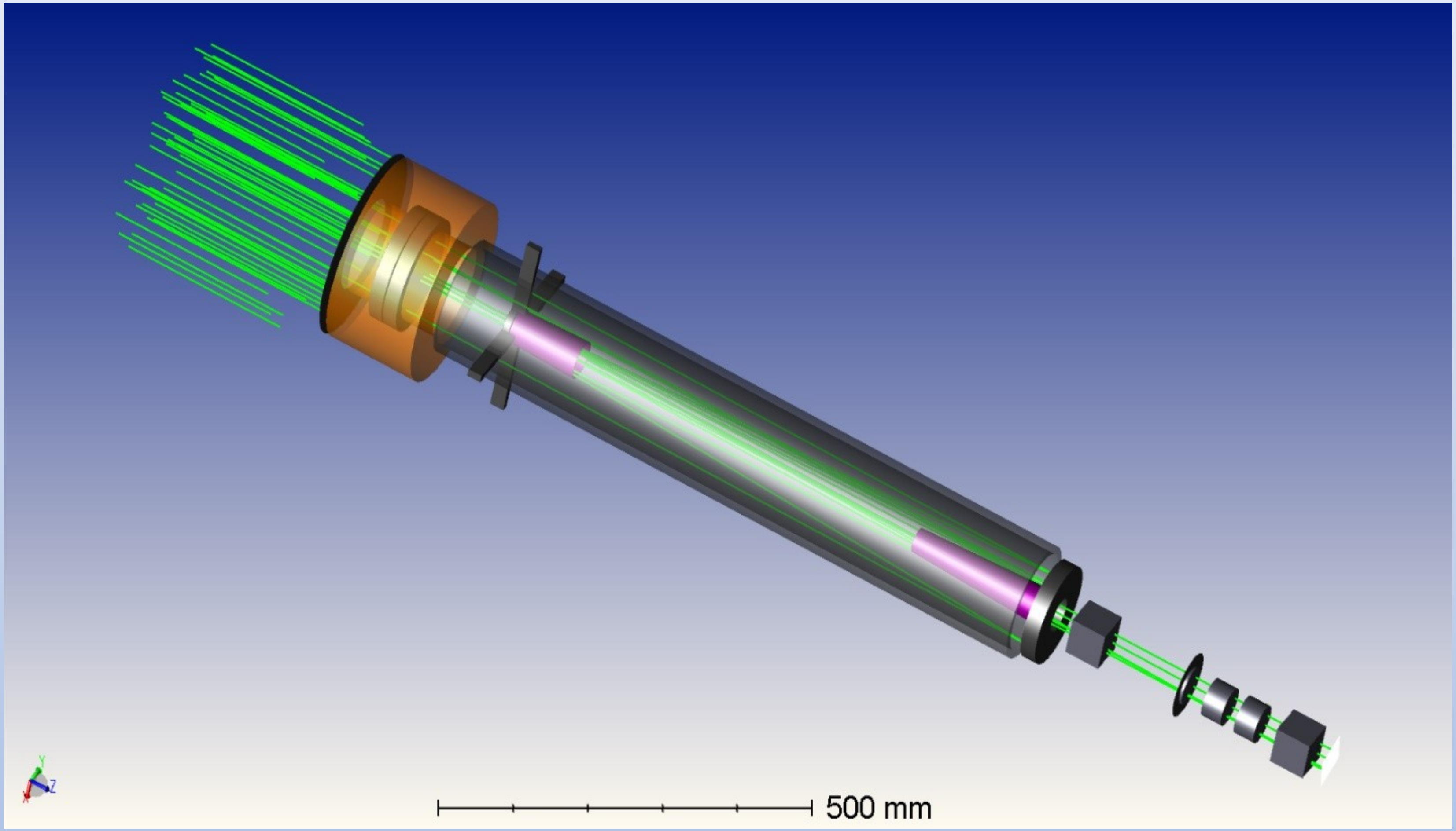
Telescope with etalon(s) in front



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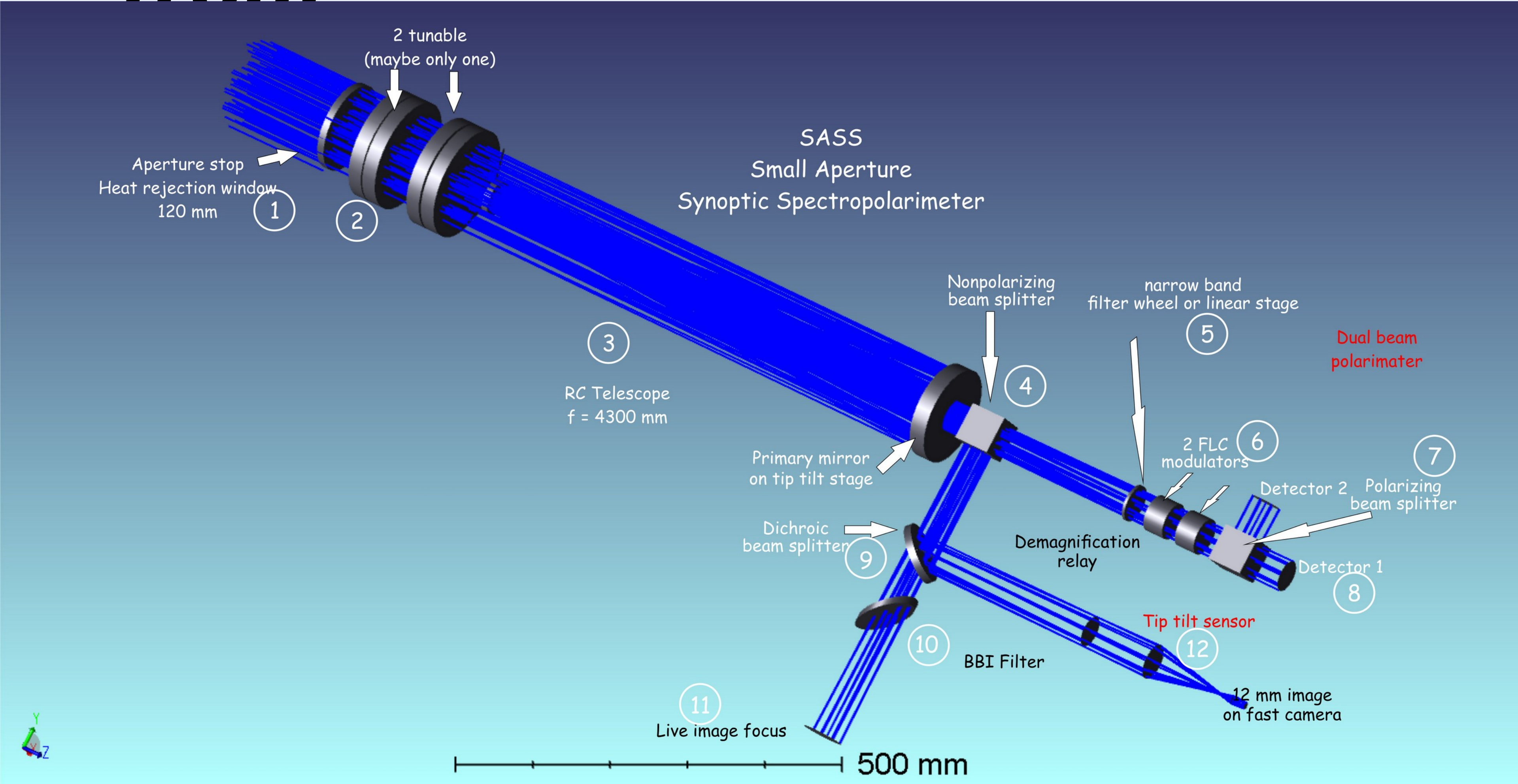
Telescope with etalon(s) in front



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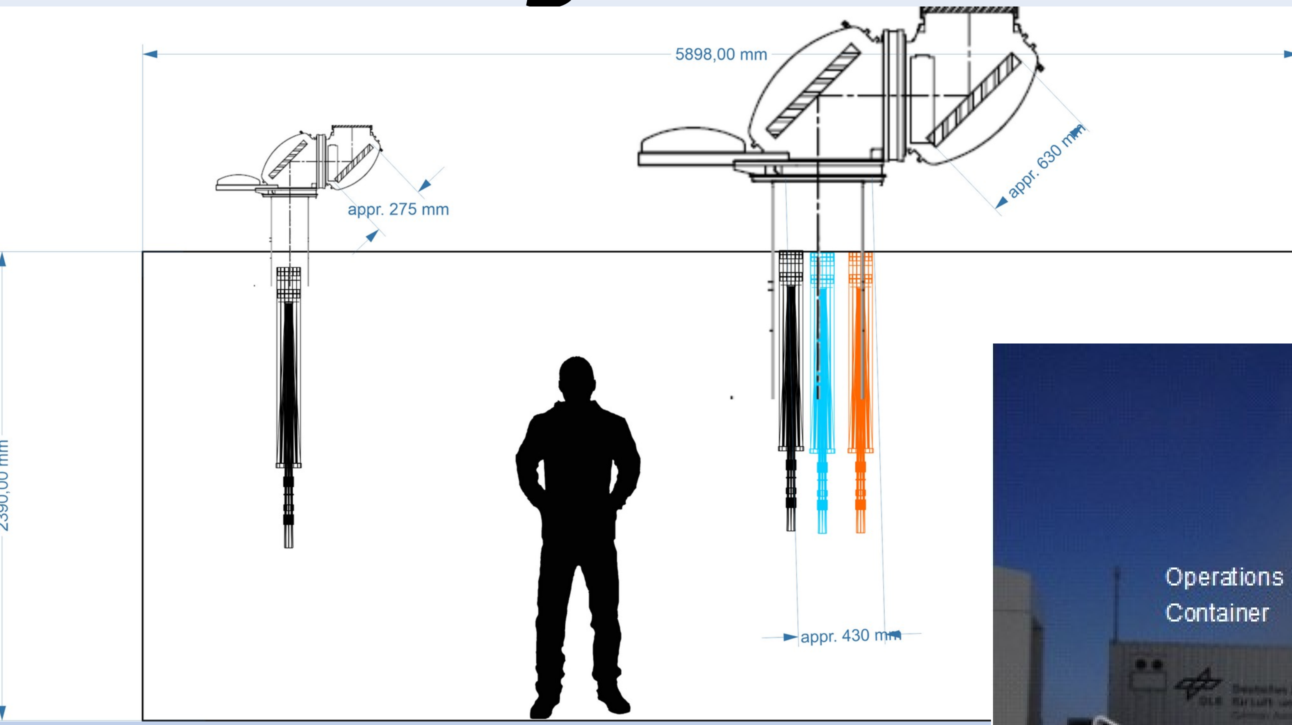
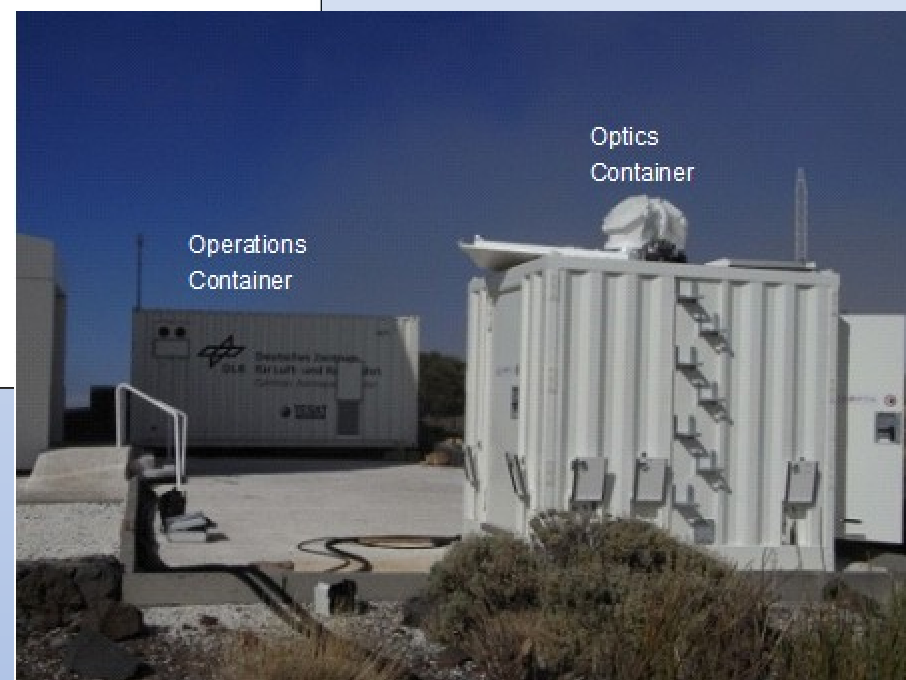
Housing





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Issues

- **Etalon performance**
  - **What will be the Finesse?**
  - **One etalon or two?**
- **Thermal management**
  - **Heat rejection window**
  - **Vacuum in turret?**
- **Image stability**
  - **Tip tilt correction**
- **False light**
  - **Day blindness**
  - **Ghosts**
- **S/N**
  - **Photon flux**

All these issues are under investigation …
…but only experiments and measurements will give reliable answers.

We need a testbed and a prototype

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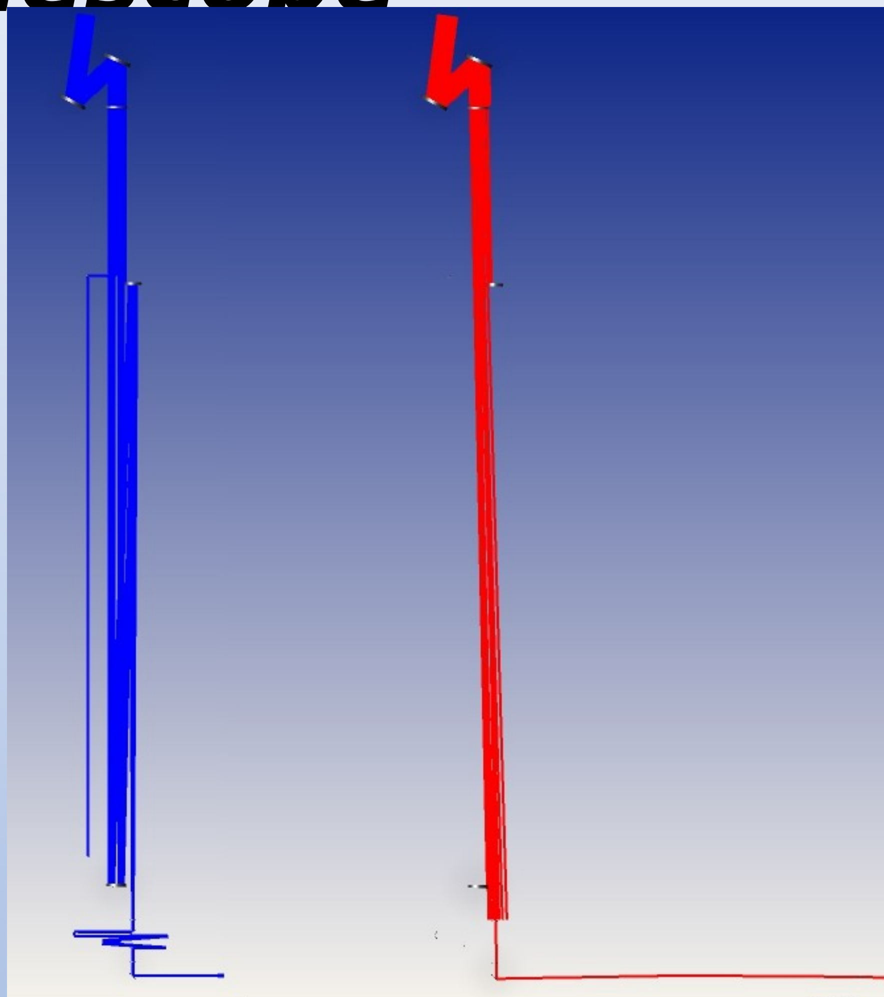
VTT as testbed for a full disk telescope



Bypass the telescope mirrors and feed the optic lab directly

Useful e.g.

- **To test etalons**
- **To test tiptilt sensor**
- **To test flatfielding strategies**

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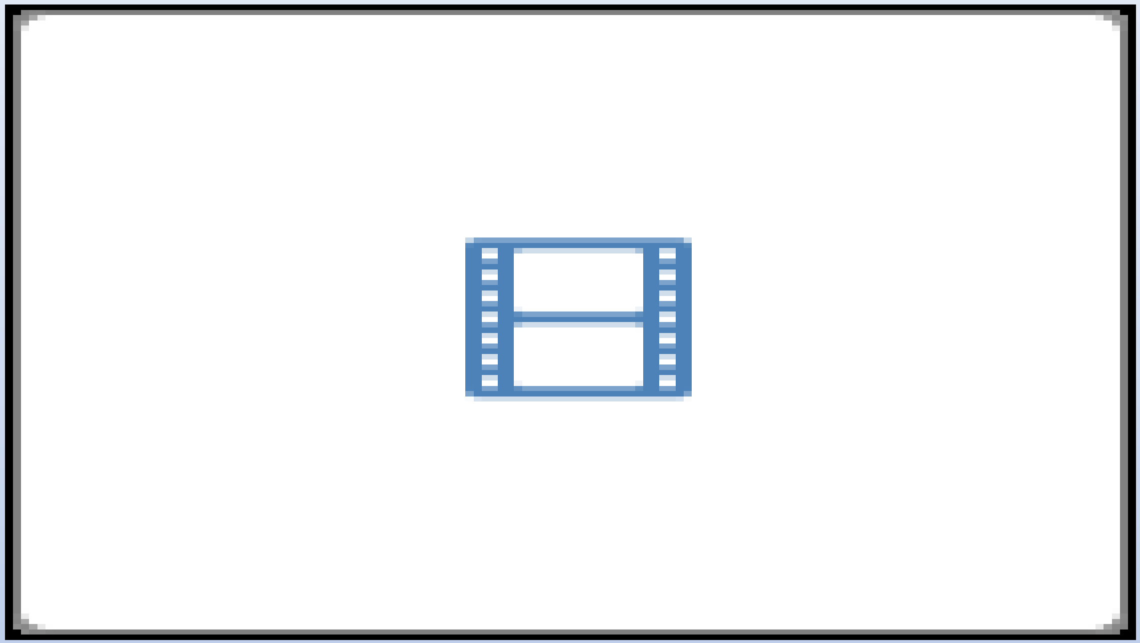
First Full Disk HELLRIDE observations (25.08.2020)



□ = 630.2 nm

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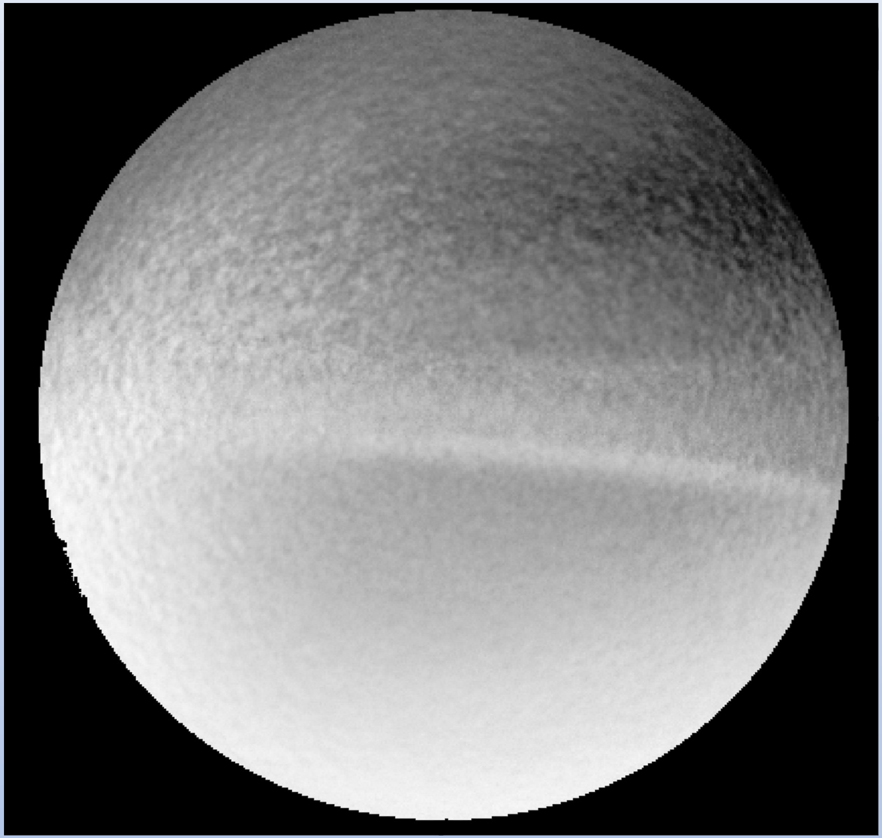
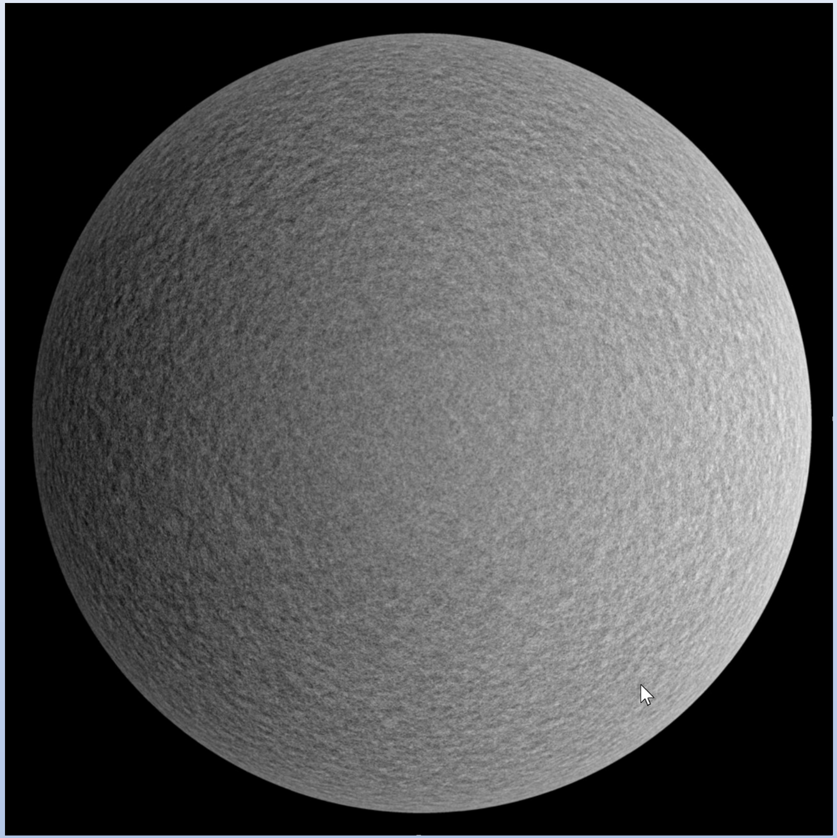
VTT: First Full Disk Doppler map with HELLRIDE (25.08.2020)



VTT



HMI

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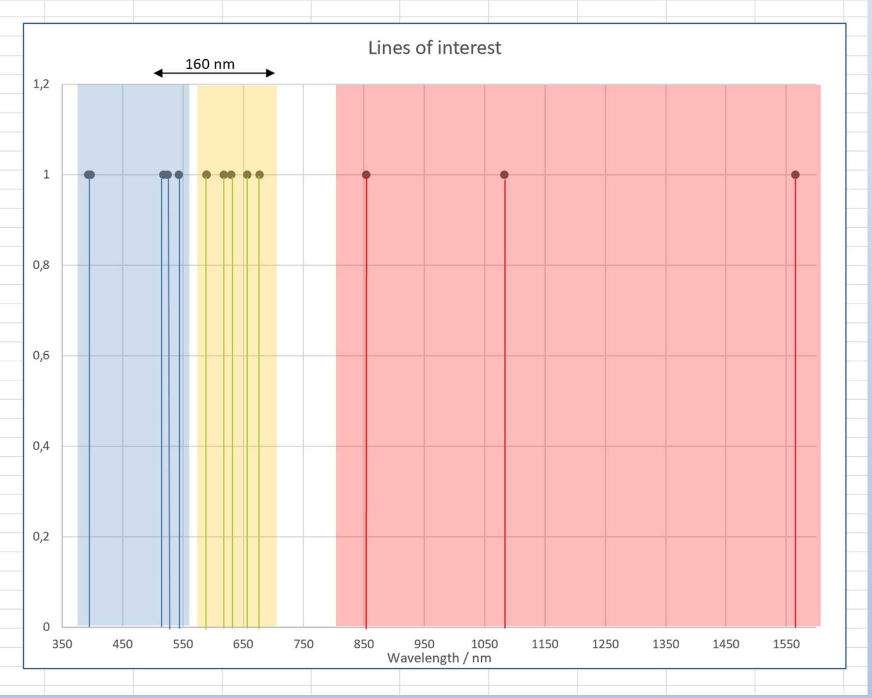
Prototype

- Ongoing design work together with AMOS
- Deliverable: Optomechanical design study



One band between 510 nm and 680 nm covers 9 lines (of 17)

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Timeline

- Optomechanical design is deliverable by end of WP8.1
- Further full disk experiments at VTT in summer 2021
- Next steps to plan:
  - Purchase a prototype etalon and test it at the VTT testbed
  - Test a full disk tiptilt sensor
  - Build a prototype telescope

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