LAST, POLARIZATION & ISRAEL: DEVELOPMENT OF A NEW POLARIZATION TELESCOPE

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The Large Array Survey Telescope (LAST)
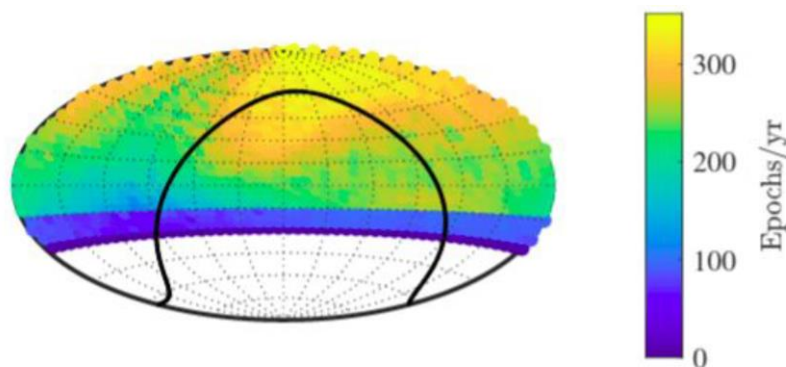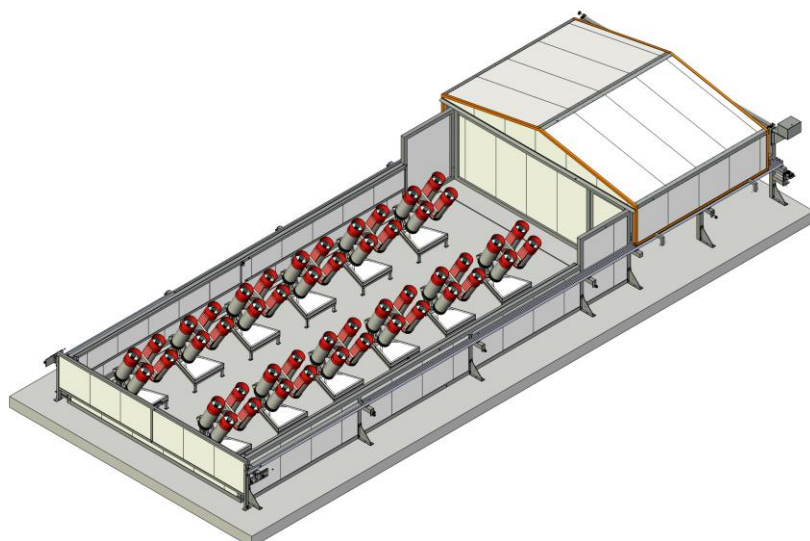
➢ Array of up to 48 telescopes, under construction

➢ 4 telescopes per mount, 8 mounts already installed

➢ Based in Neot Semadar, Israel

➢ High cadence all sky survey

➢ Up to 355 square degree FoV

➢ Modular design – single mounts can be adapted (filters, polarization, observation mode)

➢ Science objectives: GW follow-up, early Sne detection, fast transients, follow-up for ULTRASAT, neutrino follow-up, binaries, WDs, exoplanets, etc…

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Why doing optical polarization with LAST?

Mag to flux: $I = 10^{-0.4(m - m_{zp})}$

Stokes Q: $\dfrac{I_0 - I_{90}}{I_0 + I_{90}}$

Stokes U: $\dfrac{I_{45} - I_{135}}{I_{45} + I_{135}}$

Pol. degree: $\sqrt{Q^2 + U^2}$

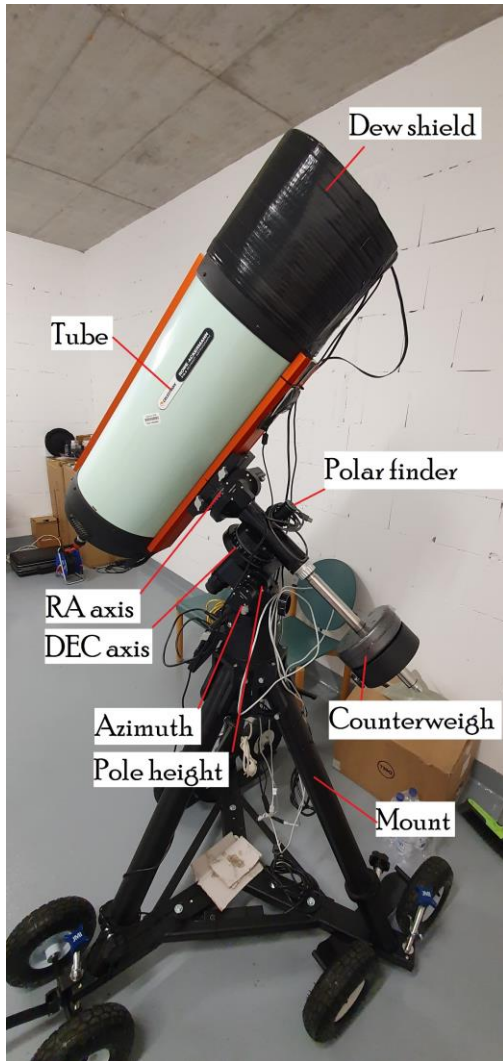Pol. angle: $\arctan \dfrac{U}{Q}$

➤ For polarization information, we need 4 measurements with linear polarization filter at 0, 45, 90 and 135 degree

➤ Combine these 4 photometric information via Stokes formalism to get polarization information

➤ „Other" polarization telescopes have (fast) rotating filter, so limitation to central part of FoV, bright sources

➤ **Benefit of LAST: No moving parts in lightpath, take all data at same time! We can perform polarization measurments over whole field of view!**

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Bochum prototype & why polarization is hard to measure

- ➢ Polarization is hard to measure because of instrumental polarization

- ➢ All optical components in a telescope polarize light partially, plus reflections, stray light, CCD sensitivity, etc..

- ➢ We need good understanding of our telesope + optical components to correct for instrumental polarization

- ➢ Bochum prototype to test setup and filters

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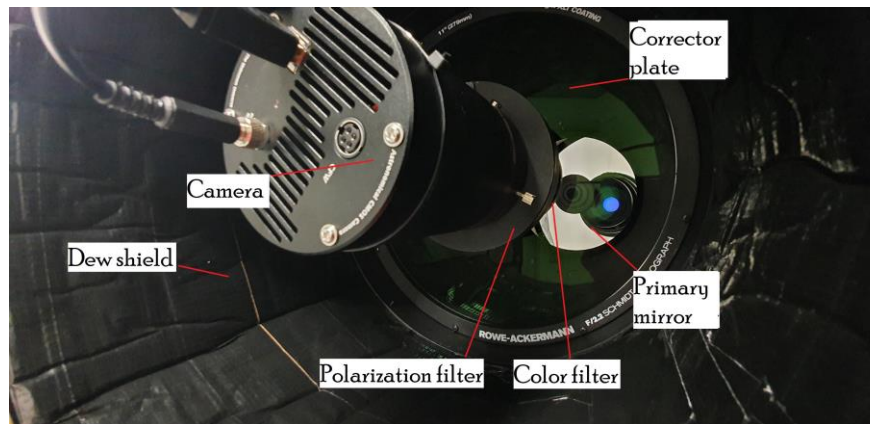
Standard stars & instrumental polarization corrections
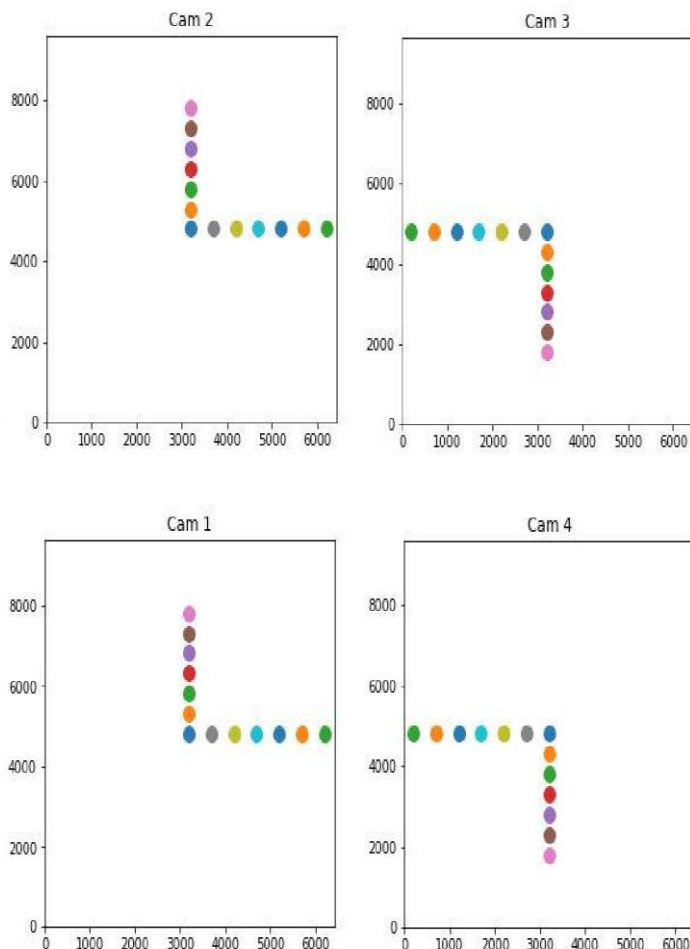
- ➢ Instrumental polarization is changing over FoV

- ➢ Observe sources on different grid positions

- ➢ 4 tubes are not perfectly aligned, so simultaneous observations not possible

- ➢ To measure instrumental polarization we observe standard sources: Low-pol and high-pol stars, with **known** and **constant** polarization

- ➢ There are systematics like atmosphere, moon light, temperature, focus, etc.., therefore many measurements needed to beat system by statistics

Observation runs in Israel
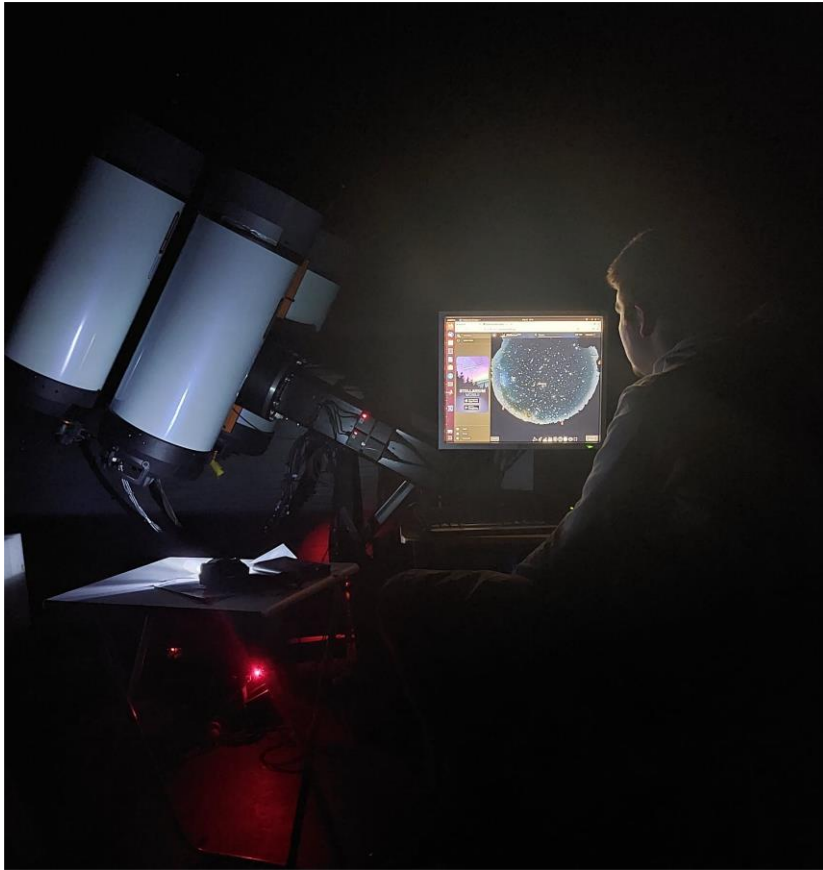
- Equiped one mount with polarization and R color filters, FoV about 2.2 square degree

- 3 observation runs done: May 2022 (Anatolii, Jowita, Ruslan, Sven), November 2022 (Simone) and March 2023 (Sven)

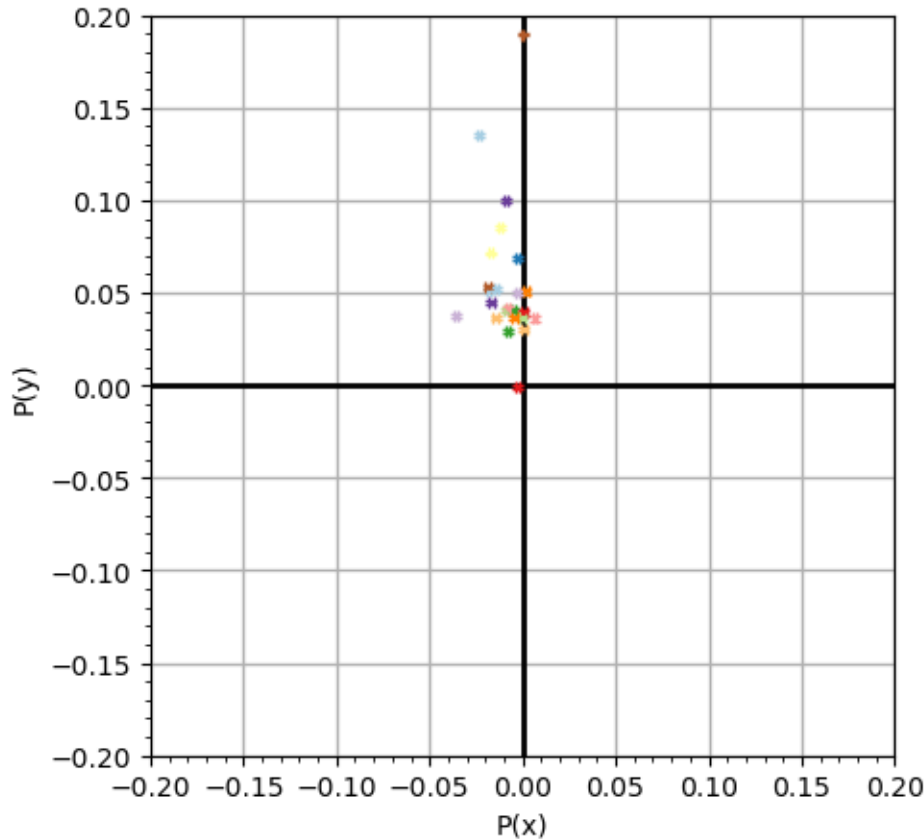- In principle very simple task: We need data data data data data data data data data data data data data data data data data data data aaaaand data!

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Guest rooms

Mount 1 (polarization)

Desert & Scorpions

Data analysis & quality cuts

	date	time	exptime	name	aperture_set	letters	sky	fwhm	ellipticity	value2	value3	mag	mag_error	status
0	2022-11-19	17:19:21.276	5.0	HD19820_r0-0002-p000.fit	OBJECT_O_BAD	BL	4.2	2.85	0.025	16.7	11.0	11.3584	0.0018	OK
1	2022-11-19	18:34:19.325	5.0	HD19820_r0-0003-p000.fit	OBJECT_O_BAD	BL	4.0	2.85	0.074	58.3	11.0	11.3011	0.0018	OK
2	2022-11-19	16:20:09.867	5.0	HD19820_r1-0001-p000.fit	OBJECT_O_BAD	BL	3.9	2.77	0.037	119.7	11.0	11.3827	0.0018	OK
3	2022-11-19	17:22:44.215	5.0	HD19820_r1-0002-p000.fit	OBJECT_O_BAD	BL	3.7	2.91	0.011	3.2	11.0	11.3638	0.0018	OK
4	2022-11-19	18:37:47.741	5.0	HD19820_r1-0003-p000.fit	OBJECT_O_BAD	BL	3.5	3.52	0.119	74.3	11.0	11.2953	0.0018	OK
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2218	2022-11-01	01:38:31.589	60.0	NGC1275_r0-0002-p090.fit	OBJECT_O_BAD	BL	59.1	6.57	0.051	164.9	11.0	14.4949	0.0127	OK
2219	2022-11-01	00:37:09.595	60.0	PKS0735+17_r0-0001-p090.fit	OBJECT_O_BAD	BL	44.8	2.61	0.006	114.4	11.0	16.2914	0.0514	OK
2220	2022-11-01	01:03:47.093	5.0	NGC1275_r0-0001-p135.fit	OBJECT_O_BAD	BL	5.5	3.36	0.100	0.0	11.0	17.2007	0.0861	NEGATIVE_PIXELS
2221	2022-11-01	01:40:54.752	60.0	NGC1275_r0-0002-p135.fit	OBJECT_O_BAD	BL	67.1	5.42	0.056	99.9	11.0	14.3358	0.0127	OK
2222	2022-11-01	00:39:16.657	60.0	PKS0735+17_r0-0001-p135.fit	OBJECT_O_BAD	BL	51.9	1.73	0.010	34.2	11.0	16.0381	0.0500	OK

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Data analysis & quality cuts

Low pol data points at central CCD position of HD42182 without filtering from Simones observation run.

➢ The sampled datapoints show a large spread in the Stokes Q-U-plane

➢ All datapoints of an unpolarized stars should cluster at a fixed position in this phase space, which then gives the instrumental polarization

➢ We had to develop quality cuts and basically go through all of our data by hand

➢ We filter for hot pixels inside aperture, sky, FWHM, saturation + sorted out suspicious data points by hand

Data analysis & quality cuts
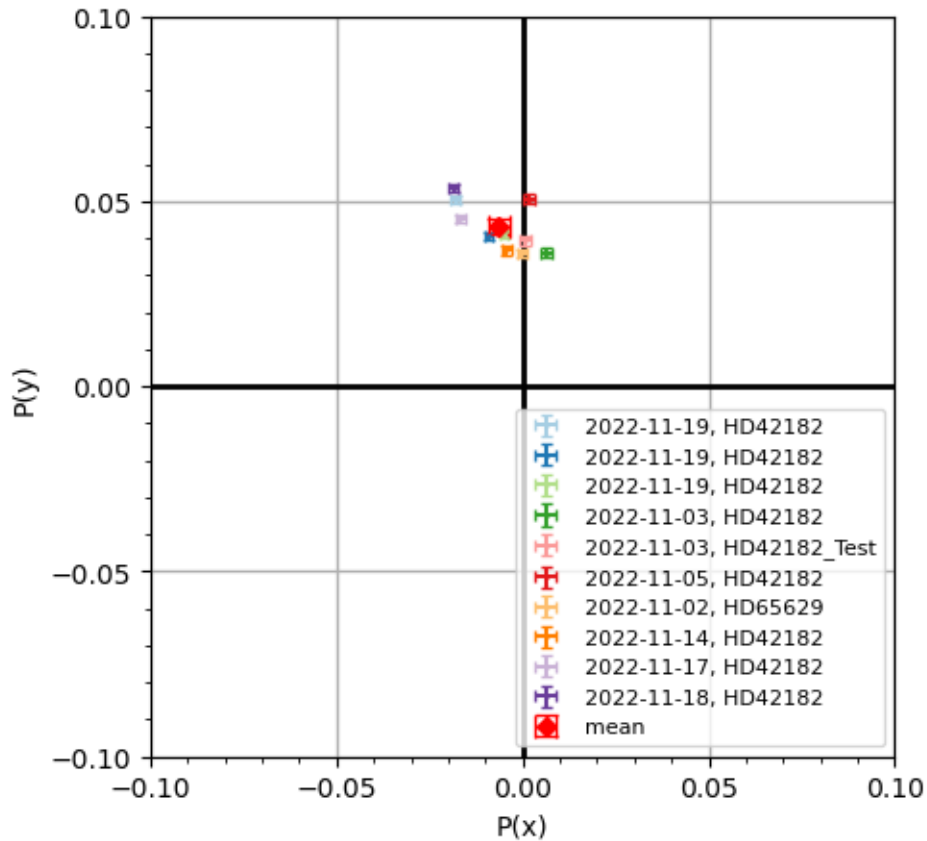
Data points that survived that quality cut

- Data points that survived quality cut cluster for a given star and position at a certain point in phase-space

- This is the true instrumental polarization at this CCD/FoV position

- Then correct all good data at this position with the average Q and U values and calculate the polarization degree and angle

- Currently we are implementing an absolute photometry to get absolute polarization values

Results: Low pol stars and instrumental polarization

➤ For non-polarized stars we get a instrumental polarization of about 4.3±0.2% in center, on edge of usable FoV about 4.8%
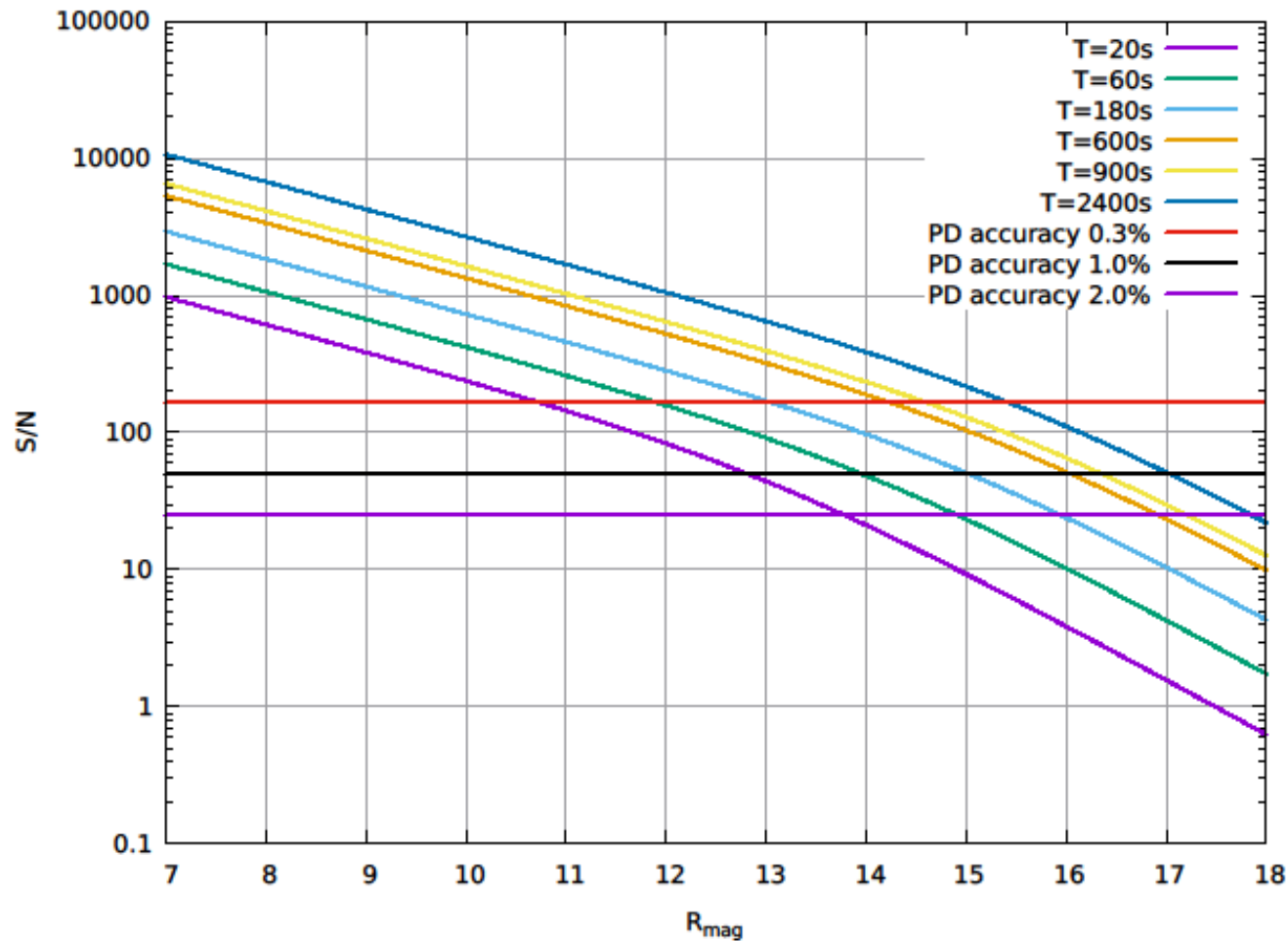
➤ System is working great ! ☺
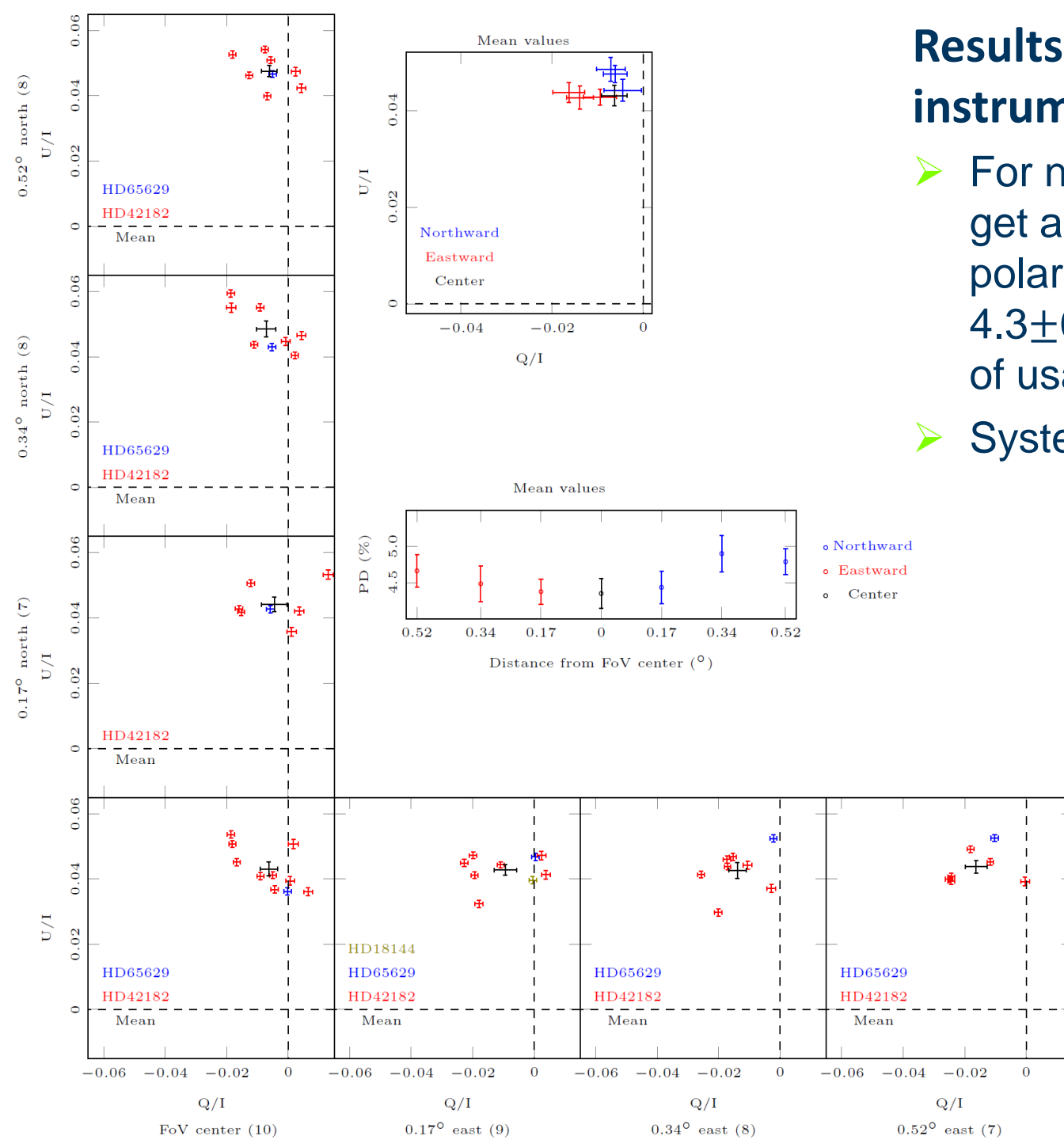
Results: High polarization star HD204827

➤ We observed high polarization standard star HD204827 using 5s exposure (SNR>385)

➤ After subtracting instrumental polarization we are in agreement with other polarization measurments by high-precision instruments

Instrument	Center of FoV		0.54° of center	
	Pol. degree	Pol. angle	Pol. degree	Pol. angle
LAST	5.32±0.19%	59.6±1.58°	5.09±0.19%	60.1±1.64°
NOT (DIPol-UF)	5.085±0.003%	59.21±0.02°	We have no datapoints here Only LAST can do it's magic here ☺	
NOT (ALFOSC)	4.893±0.029%	59.10±0.17°		
RoboPol	5.29±0.06%	61.1±0.3°		

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System limits – simulations based on observational data

What to do next?

➢ We are constructing new test telescope with 4 cameras and self-designed adapters for larger full FoV filters in Bochum right now

➢ Take science data for a nice publication!