THE CALAR ALTO SCHMIDT-LEMAITRE EXPLORER:

AN INNOVATE CONCEPT FOR TRANSIENT SEARCH & DETECTION

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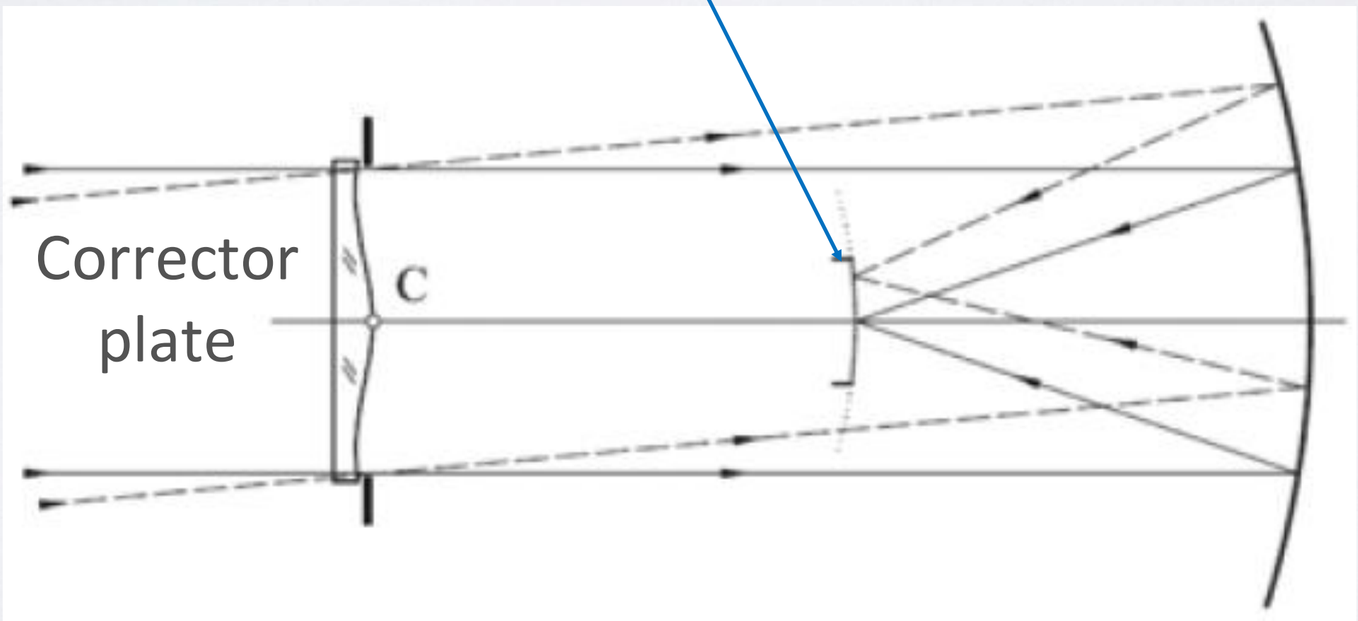
Seminar @TS2020
02.04.2021

WIDE FIELD ASTRONOMY

Wide field optical system (typically Schmidt designs):
observation of transients, planets, …

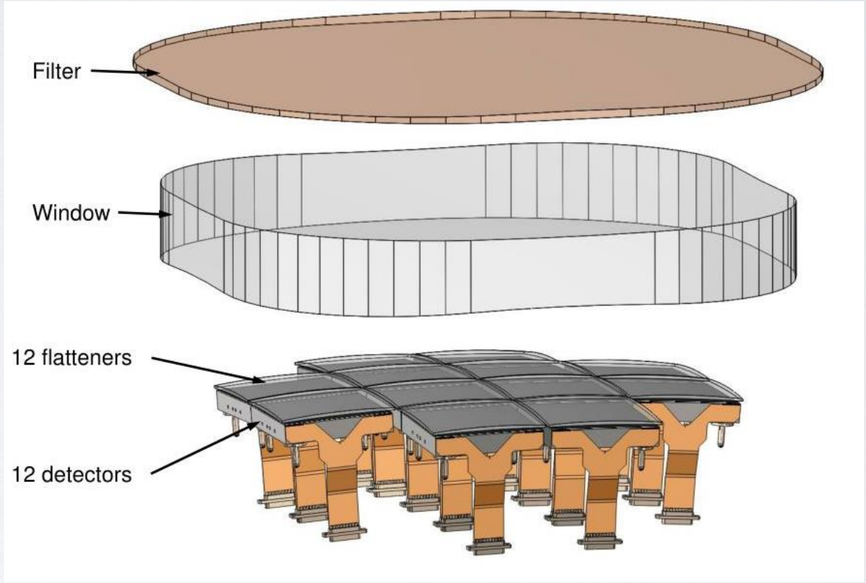
CURVED FOCAL SURFACE



WIDE FIELD ASTRONOMY

CURVED FOCAL SURFACE → Additional field flatteners

Kepler focal plane,
42 flat CCDs



ZTF focal plane

- **Degraded trasmissivity**
- **Degraded performances** (aberrations, etc.)

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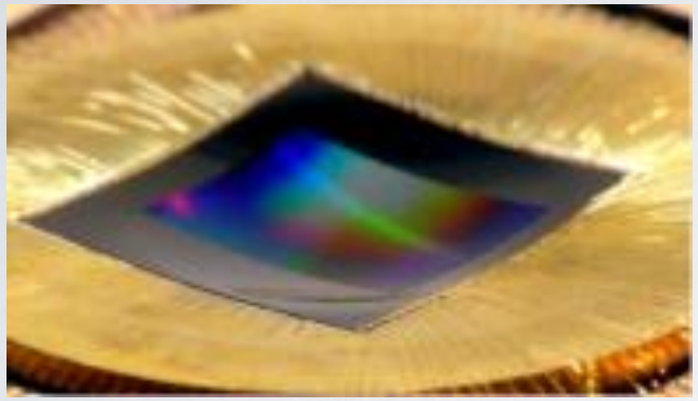
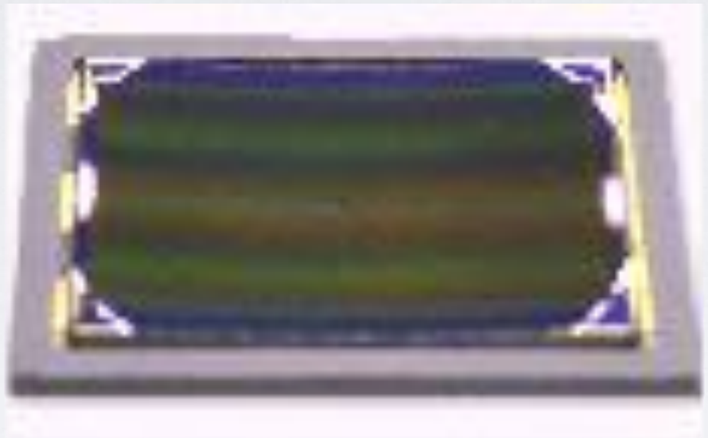
CURVED DETECTORS DEVELOPMENT

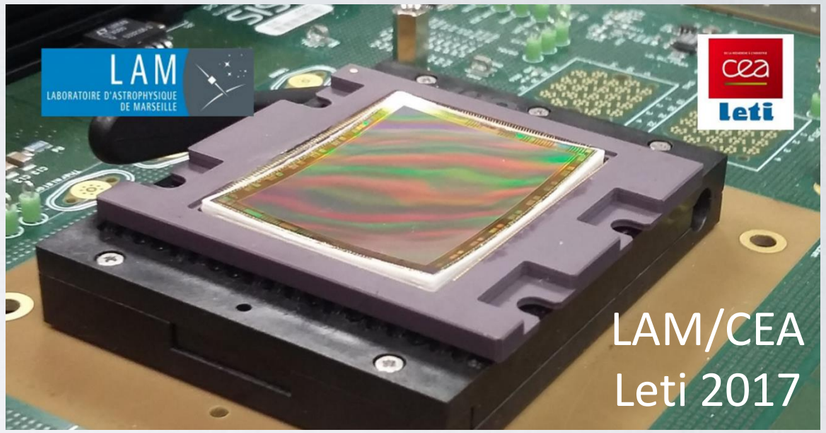
A new way of solving the problem



Microsoft 2017

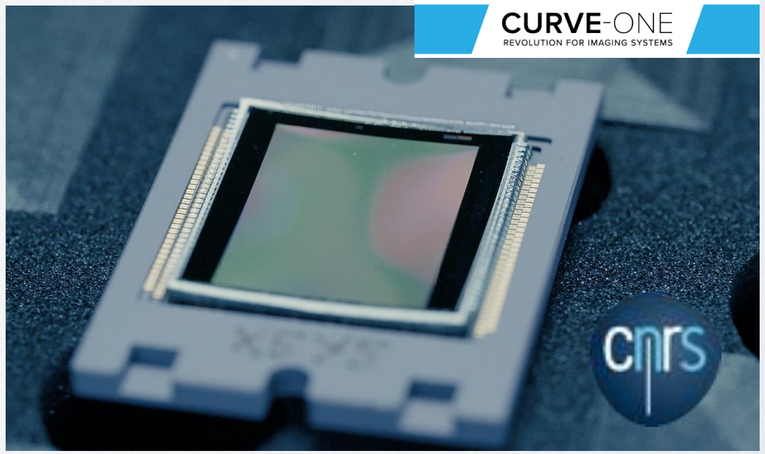


Sony 2014



Many advantages:

- smaller and **more compact systems**
- **better throughput**



LAM-CNRS
2019

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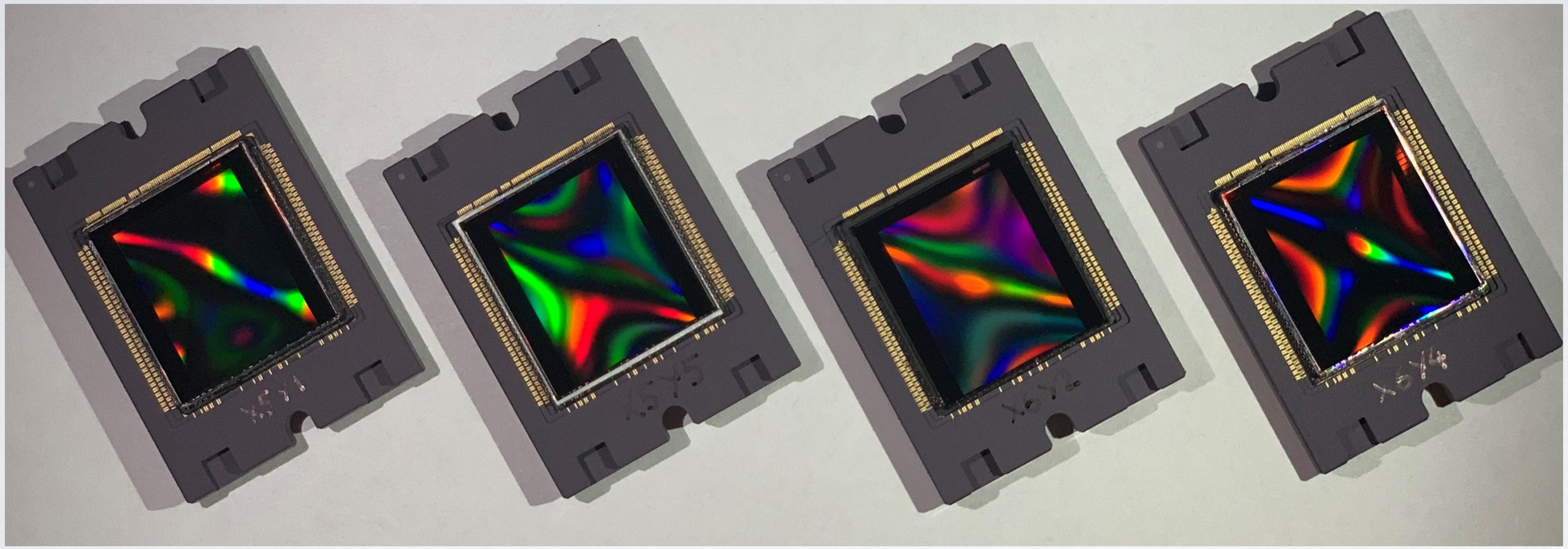
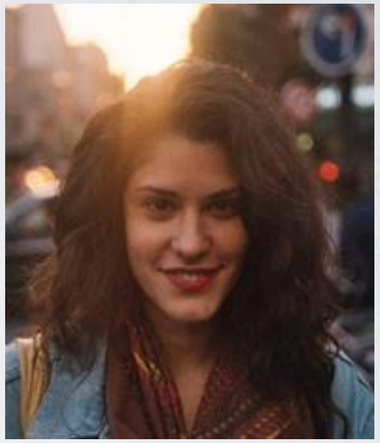
DE MARSEILLE

PROTOTYPES FROM LAM (2019) CURVEONE STARTUP

CMV12000 CMOSIS 4096x3072 pixels of 5.5 µm



PhD student
Kelly Joaquina



New curving method for better control on the shape and improved performances

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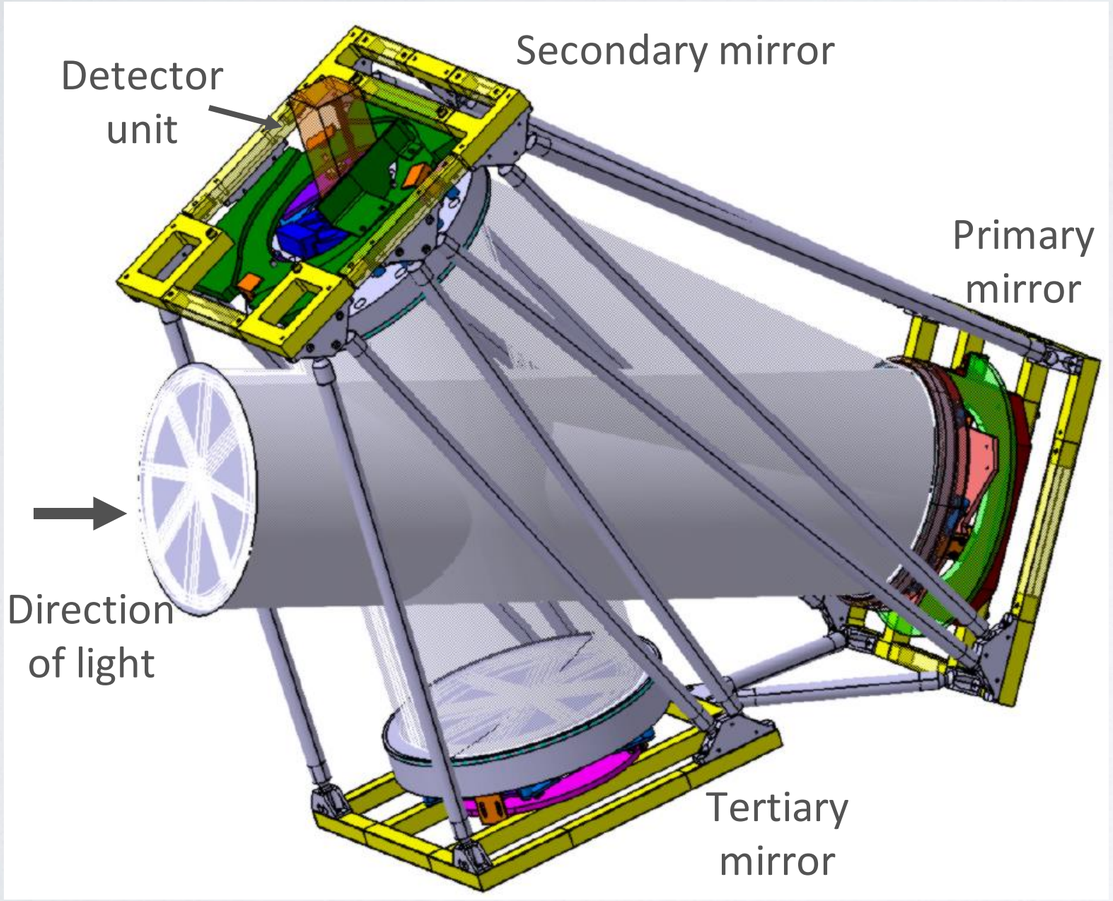
CASTLE DESIGN

Fully reflective Schmidt design to be installed in Calar Alto (robotic telescope)



Telescope parameter	Value
Field of view	$2.^{\circ}36 \times 1.^{\circ}56$
F/#	2.5
Diameter	356 mm
Detector shape/radius of curvature	Convex/$\sim$800 mm
Total throughput	$> 40\%$ $\lambda \in [400, 600]$ nm $> 50\%$ $\lambda \in [600, 1000]$ nm
Detector parameter	**Value**
Pixel size on sky	$1''$
Quantum Efficiency	>80% @520 nm
RON	<2 e^-
fps	>100
Site parameter	**Value**
Seeing	$1''$
Sky background V band	22.01 mag arcsec^{-2}
Clear hours for observations/year	70%
Photometric nights/year	30%

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LOW SURFACE BRIGHTNESS UNIVERSE

Duc et al., 2018

Extended objects with brightness < background (21-22 mag/arcsec^2)

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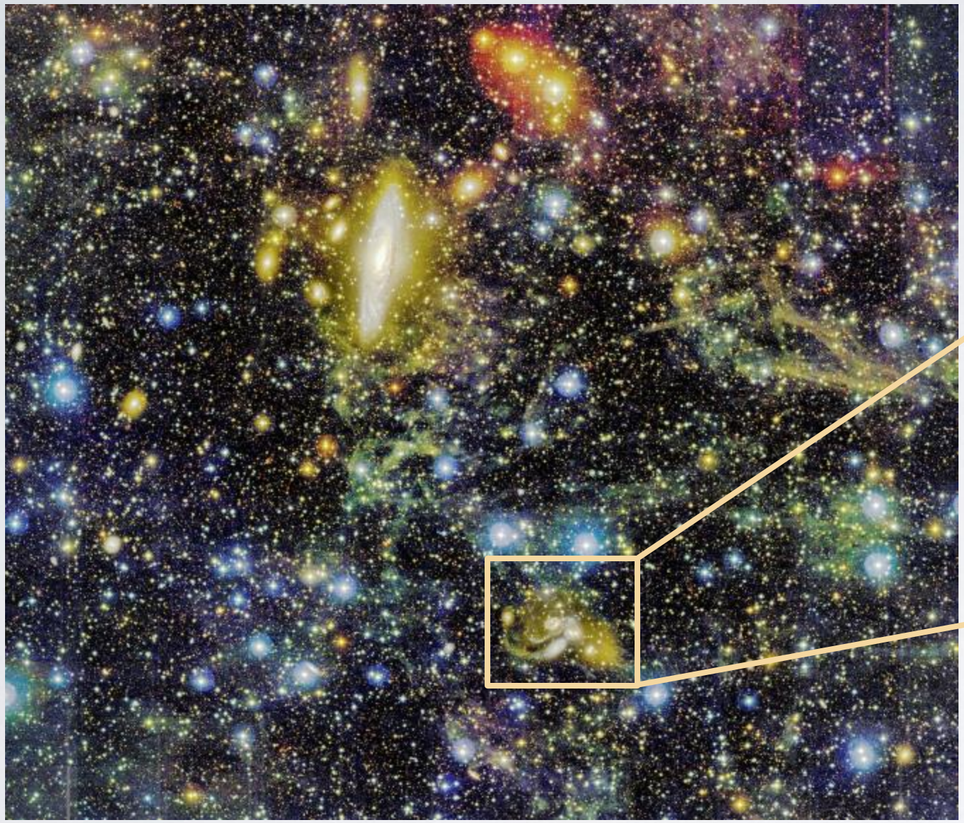
SCIENCE CASE III: LOW SURFACE BRIGHTNESS UNIVERSE



Duc et al., 2018

26 mag/arcsec^2

Duc/Cuillandre/CFHT/Coleum (2012)

INFORMATION ON GALAXY FORMATION AND EVOLUTION

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BRIGHT STAR IN THE FIELD

NGC 474 Image credit: CFHT/Coelum

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CURRENT SURVEYS

- **Large telescopes**: not optimized (ghosts, complex pipeline)
- **Smaller telescopes/off-the-shelf**: more difficult to customize

Survey name	SDSS[1]	CFHT[2]	Burrell Schmidt[3]	Dragonfly[4]
Primary diameter(m)	2.5	3.6	0.9	0.143 (48 elements array)
Field of view	$3^{\circ}.0$	$0^{\circ}.96 \times 0^{\circ}.94$	$1^{\circ}.65 \times 1^{\circ}.65$	$2^{\circ}.6 \times 1^{\circ}.9$
Pixel size	$0''.396$	$0''.197$	$1''.45$	$2''.8$
SB(mag arcsec^{-2})	26.4	28.5	28.5	29.8
Filter	g	g	V	g

[1] Kniazev et al. (2004), [2] Duc et al. (2015), [3] Mihos et al. (2017), [4] Danieli et al. (2020).

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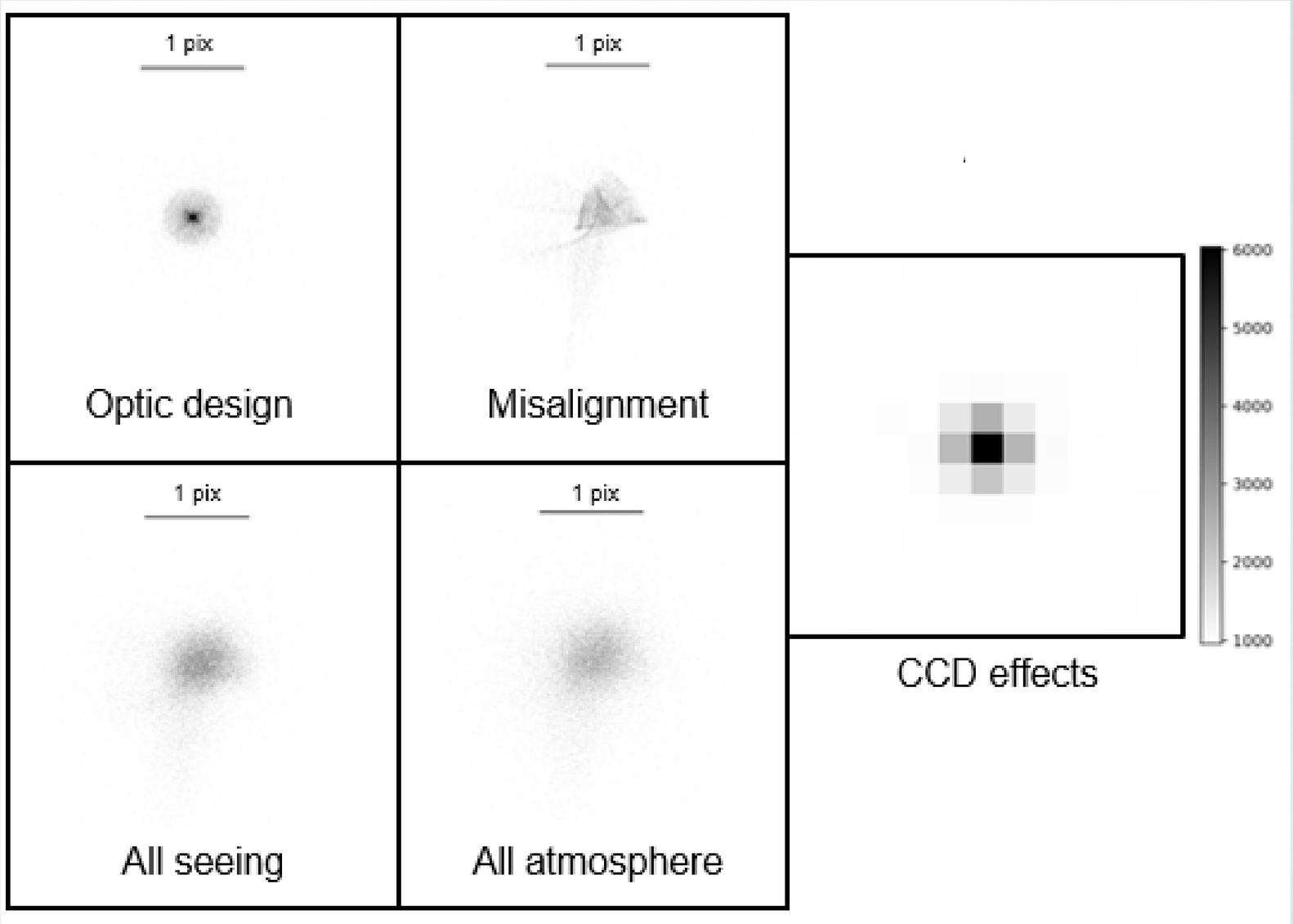
SINGLE STAR AT THE CENTER OF THE FIELD OF VIEW

1 pix = 2.32”
FoV 1.6°x2.6°

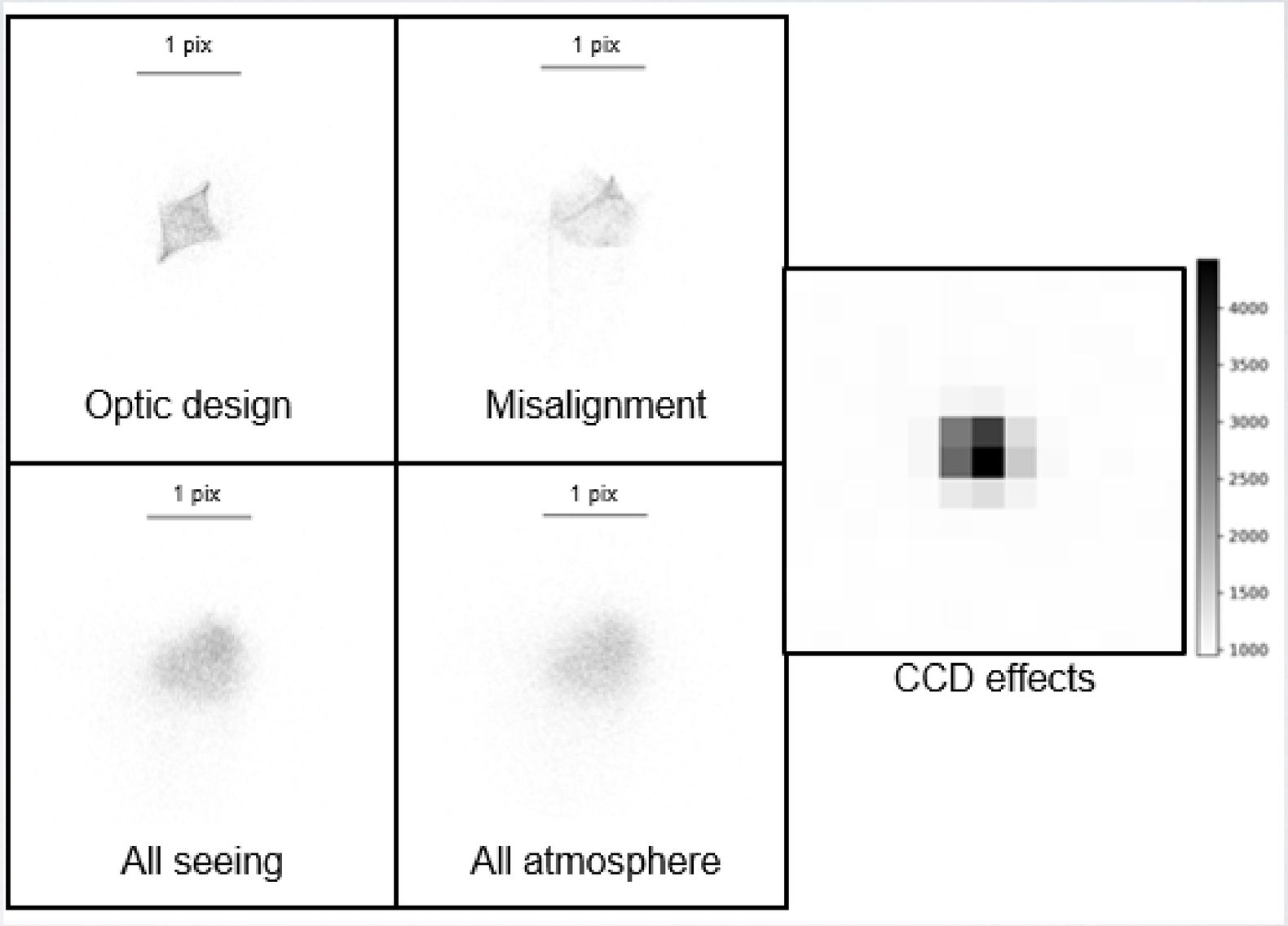
Peterson et al., 2015, PhoSim
https://www.lsst.org/scientists/simulations/phosim



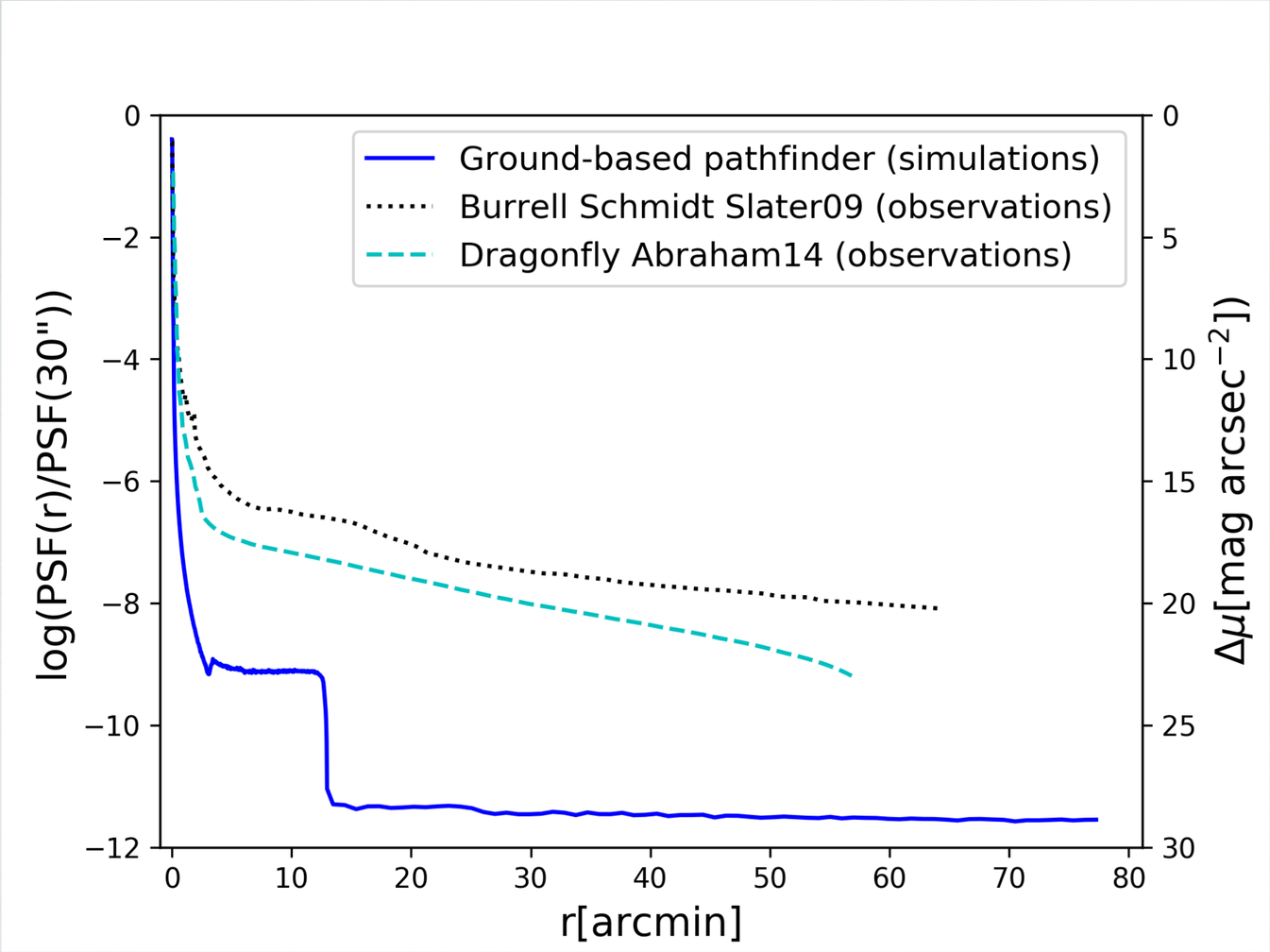
SINGLE STAR AT THE CORNER OF THE FIELD OF VIEW

1 pix = 2.32”
FoV 1.6°x2.6°

The image in the focal surface is uniform in the full field!



SINGLE STAR SIMULATION



Lombardo et al., MNRAS, 2019

Data binned every 2.32”

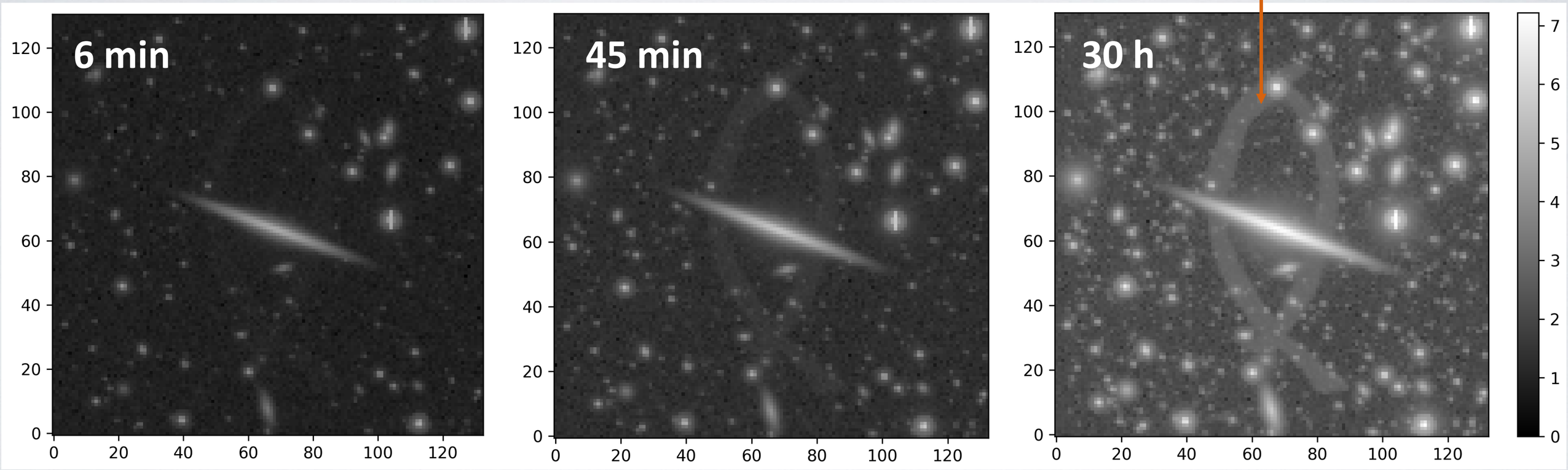
Star at the center of FoV

VERY LOW PSF WINGS IN FULL FOV

U-LSB OBJECTS SIMULATION

Dimension of field: 5’x5’
Max star mag: 30 mag
Min star mag: 15 mag

Loop: 29 mag/arcsec^2



Lombardo et al., MNRAS, 2019

CASTLE ALSO FOR TRANSIENTS

- **Large field of view** 2.36 °x1.56°
- **Pixel size ~1”** on sky
- **Robotic** telescope

Ideal for transient search and detection!
(GW EM counterpart, neutrino counterpart, GRBs, etc.)

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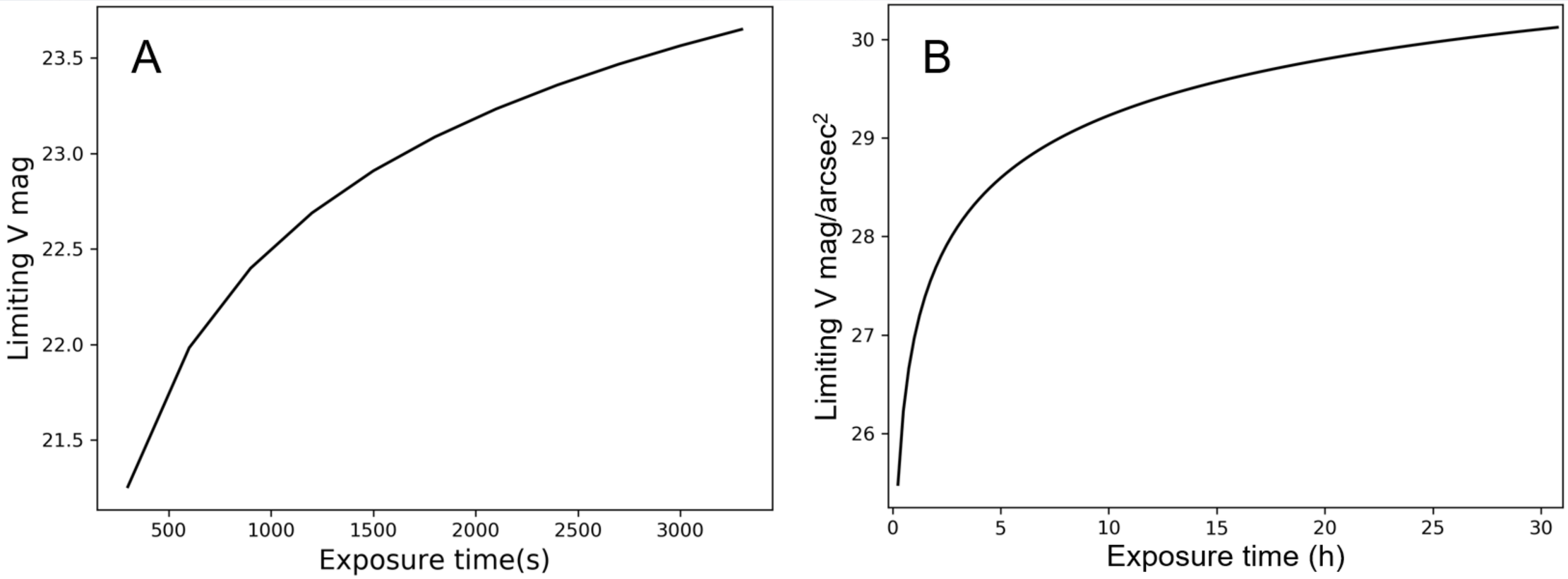
CASTLE: EXPECTED S/N



AVAILABLE ROBOTIC TELESCOPES IN SPAIN (MAINLAND)

- **Many off-the-shelf** (very wide field of view, small entrance, large pixels)
- **Often in bright sites**
- **Some large telescopes** (small field of view)

CASTLE fill in the gap!

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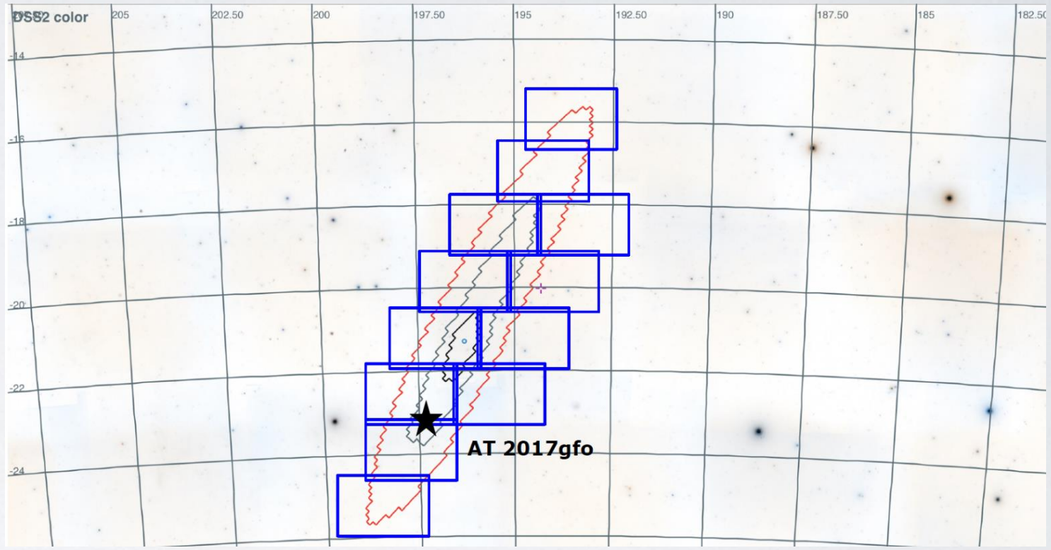
GW OPTICAL COUNTERPART

- Typical error region 50-100 square degree
- >17 mag in V
- ~100 events/year expected
- CASTLE: 15-30 pointings, probe up to 230 Mpc



AT 2017gfo observed by CASTLE

TRANS NEPTUNIAN OBJECTS

CASTLE will observe also TNO and Trojans

the witnesses of the solar system origin

- 24 objects/year
- 16.5 – 18 mag
- 10-30 min per objects
- single frame exposure times from 1 to few seconds

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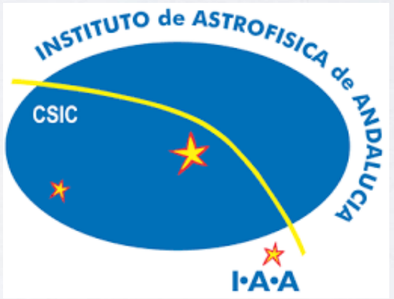
CASTLE COMMUNITY

- White paper Lombardo et al. 2020, **arXiv:2006.13956**

→ Gathering a science group

→ More science cases appeared, e.g. TNO



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CASTLE: OBSERVING TIME ALLOCATION

Table 3: Science cases summary and approximate time allocation for observations.

Science proposed	Available observing time
Ultra-low surface brightness	40%
Transient search & detection + solar system	25%
Opened to the community	20%

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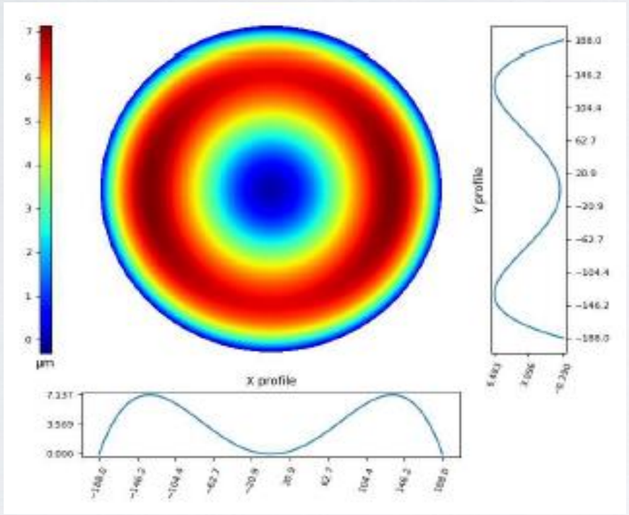
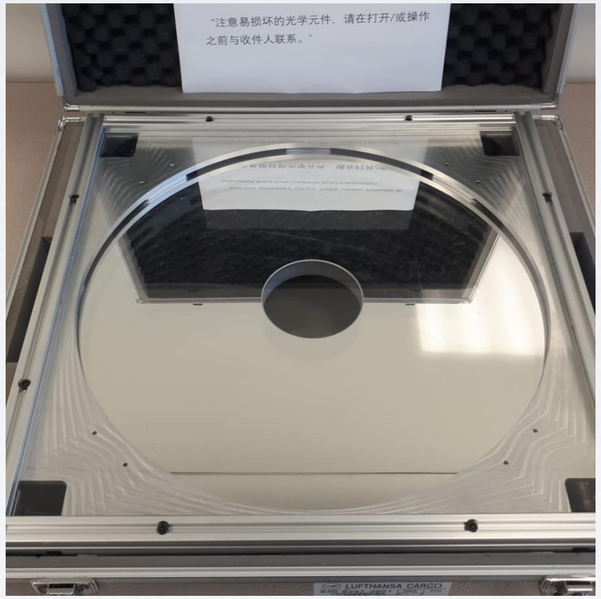
STATUS: OPTICS

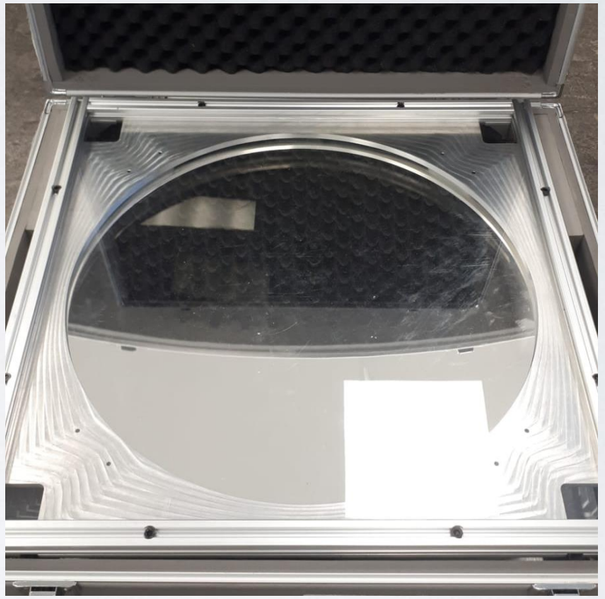
M1 freeform finished @ Winlight



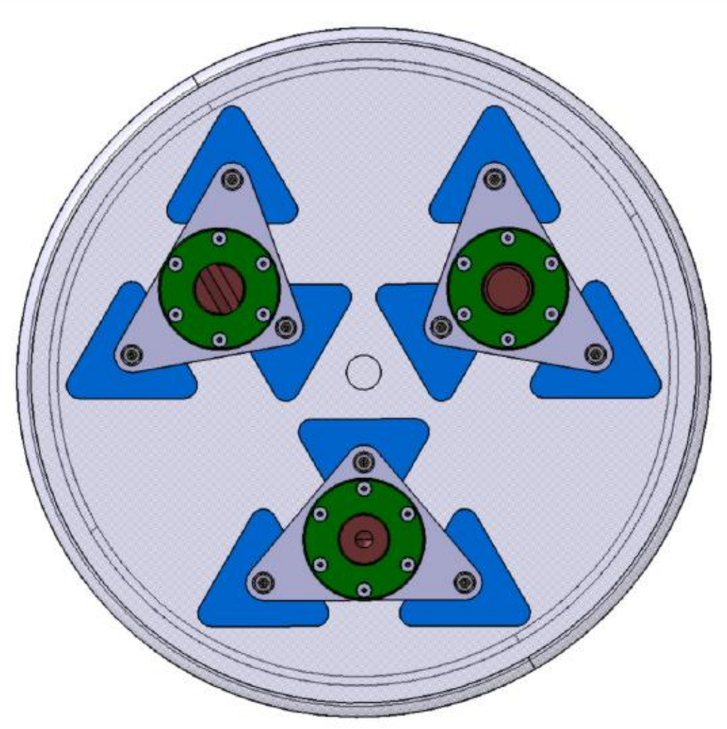
M2 folding flat with central hole

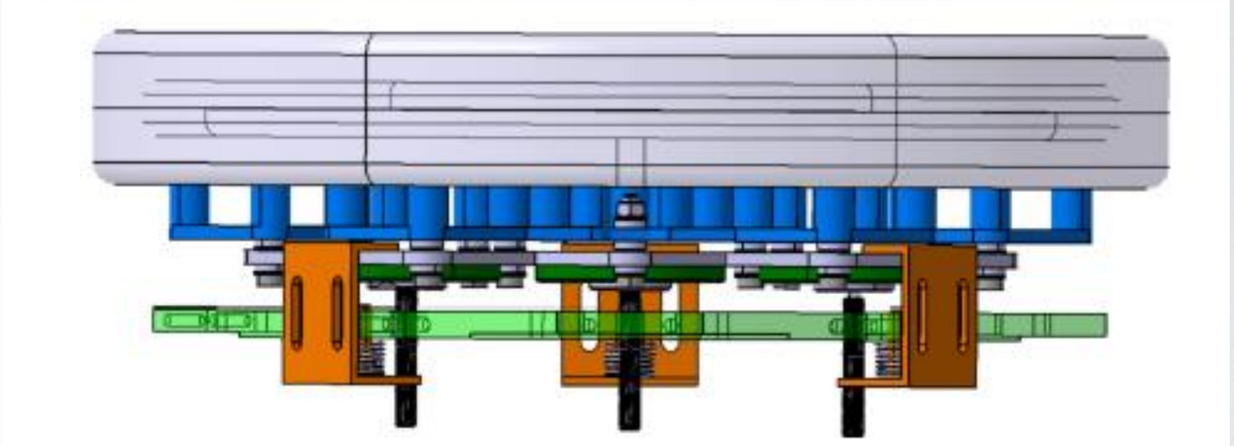


M3 Spherical collimator = Schmidt camera



STATUS: MECHANICS





Mirror's cells design
27 points whiffle tree for gravity compensation

- Mirror cell design finished
- Complete design under evaluation
- FEA planned

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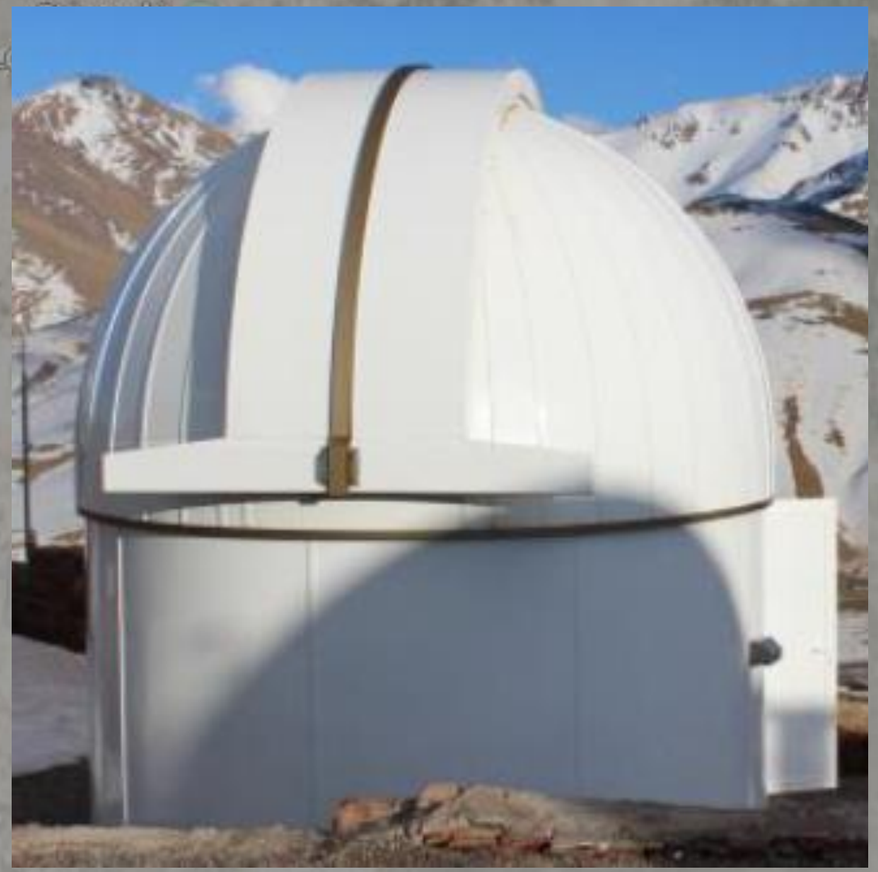
STATUS: DOME

STATUS: DOME

Dome ordered (Gambato)
to be installed in Summer 2021



TIMELINE: DETECTOR + FILTERS

- Curved sensors production funded by ERC ICARUS (StG) and ERC CURVE-X (PoC)

- Detector selected: BSI CMOS from PYXALIS, similar performances to scientific graded CCDs.

- Full detector unit integration winter2021 (Joaquina's PhD)
- Filter sets, g and r and luminance filter ordered (Astrodon)

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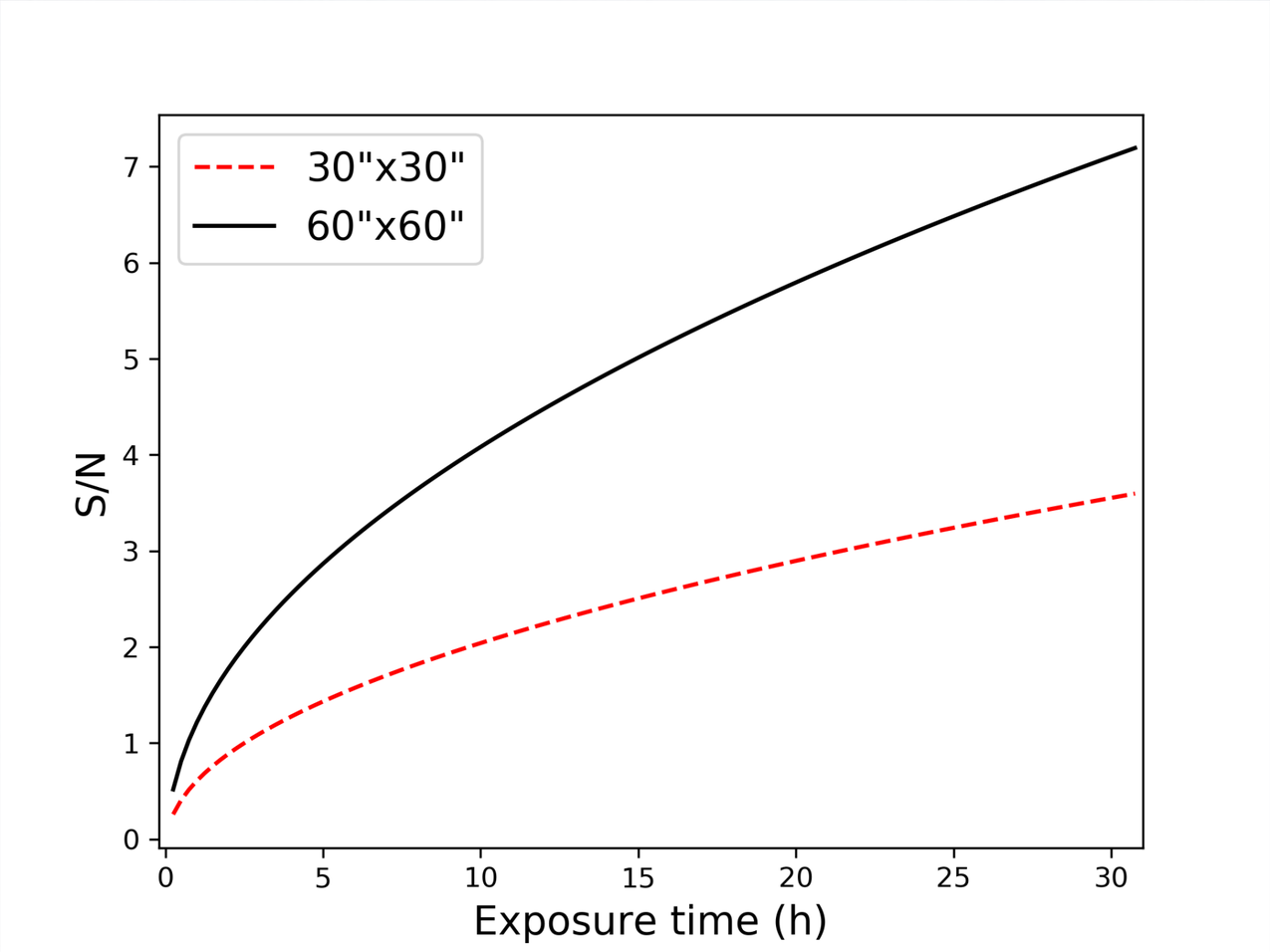
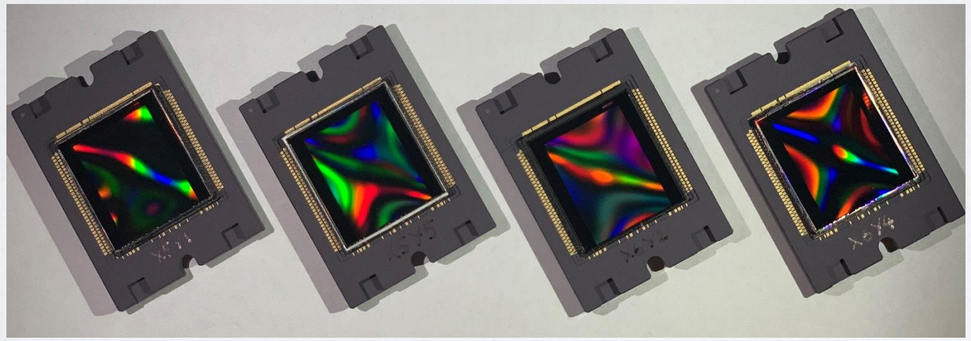
UPGRADE: Hα FILTER

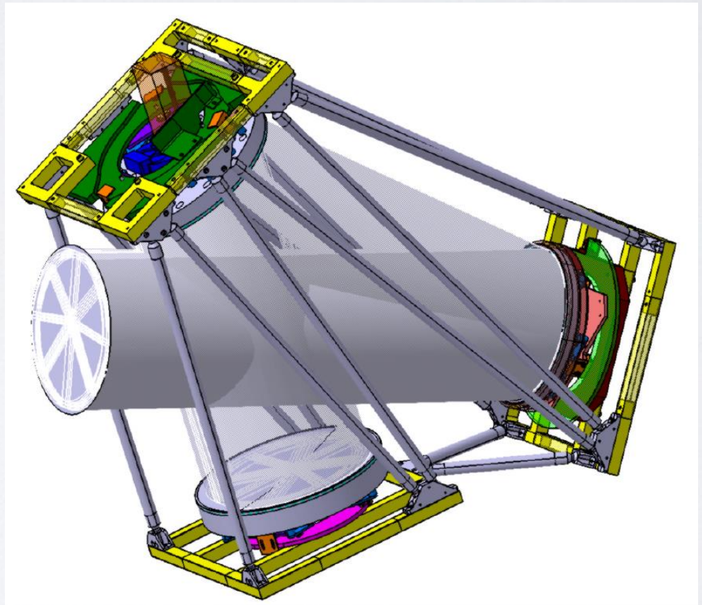


Maybe a i-band filter too!

NEXT STEPS

- Telescope **integration** and lab tests by **fall 2021**
- Commissioning on-site mid-**2022**
- Implementation of automatic observing mode and **robotic facility fall 2022**





Contact me if you are interested:

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THANK YOU!

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