

Wi-Fi SuperCAT (Wide-Field Super Compact Aplanatic Telescope)

Giovanni Pareschi – INAF/Brera

a new (very) wide field telescope



ARTE E CULTURA

Osservatorio Astronomico Giuseppe Piazzi

da **SONDRIO E VALMALENCO**

condividi | f x

Ponte Valtellina (sondrio)
Inaugurato il **23 ottobre 2009**,



INAF Working Group

INAF

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Small industries involved in the effort:

TECNOTTICA CONSONNI (Calco, Lc, Italy)

Nuclear Instruments (Lambrugo, Lc, Italy)

Marcon Telescopes (s. Donà di Piave, Ve, Italy)

INAF patent request deposited in spring 2026

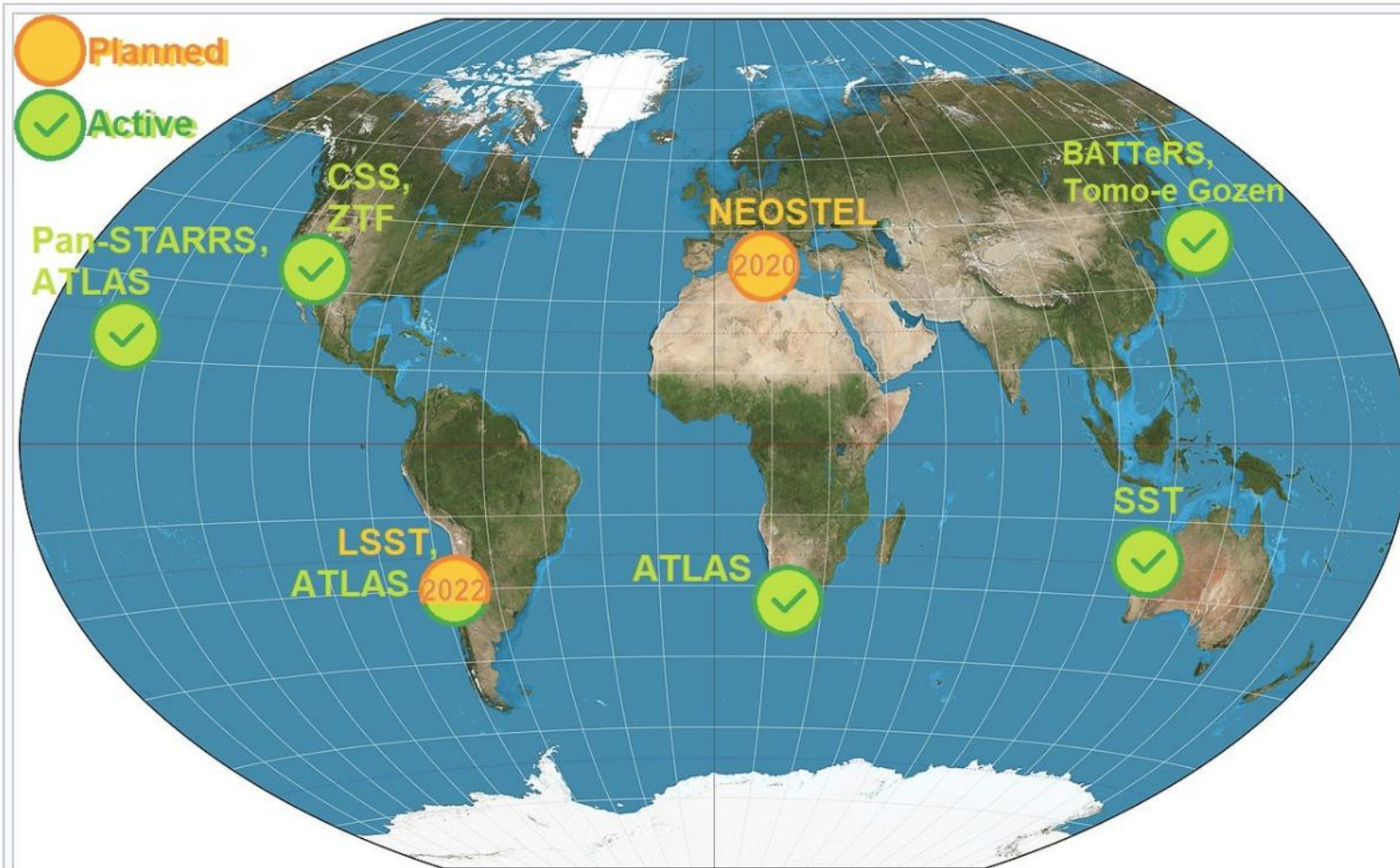
Outline

- Some remarks on current and future wide-field telescopes
- Design guidelines for a new concept **pointing** telescope
- **Wi-Fi SuperCAT (Wide Field Super Compact Aplanatic Telescope)**
Discussion of this new concept, performance and ongoing activities

Small wide-field telescopes for surveying, space surveillance and time-domain astronomy

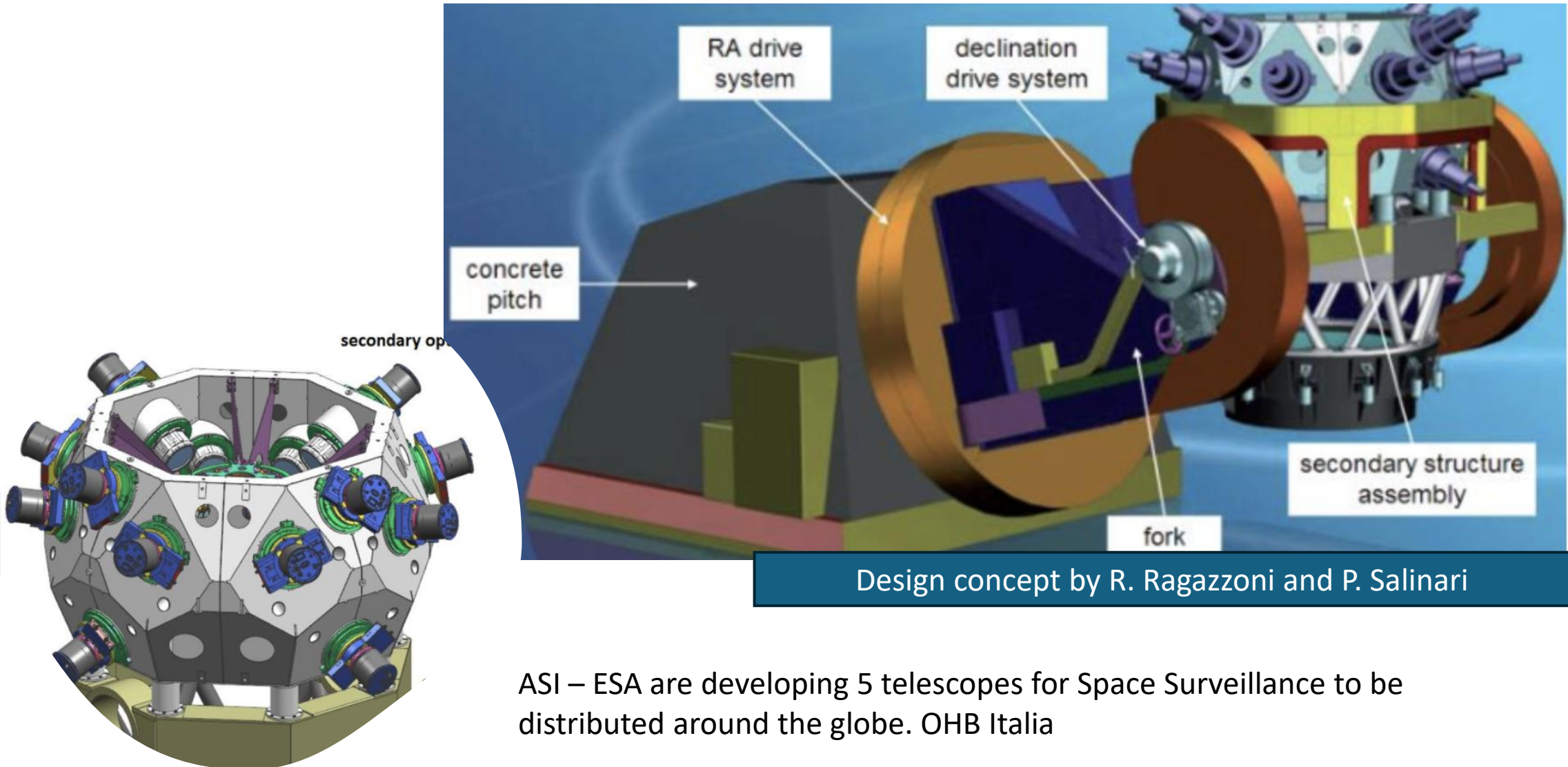
a few general considerations

- Wide-field optical telescopes are fundamental to modern astrophysics, enabling the study of the “transient” Universe.
- Internationally, the largest facility currently operational in the Northern Hemisphere is the Zwicky Transient Facility (ZTF) at the Palomar site in California, equipped with a wide-field Schmidt camera with a 47-square-degree field of view.
- With the support of ASI, ESA, and INAF, Italy is developing the FLYEYE/NEOSTED prototype in Matera, with plans to relocate it to Sicily.
- Other smaller facilities are already running



Now complete, the Chile and South Africa ATLAS sites have filled in the previous lack of coverage in the [Southern Hemisphere](#) (see [Asteroid impact prediction](#)). Sited around 120° (8 hours) east of existing surveys, the ATLAS South Africa telescope (and the planned [NEOSTEL](#) in Sicily) also provide warnings during the Hawaiian/Chilean and California daytimes. The latter mostly matters for small asteroids which become bright enough for detection for at most a day or two.

Fly-Eye Concept



ASI – ESA are developing 5 telescopes for Space Surveillance to be distributed around the globe. OHB Italia

From: «Flyeye Telescope: design upgrade and development status», Gregori, P., et al, (2023)

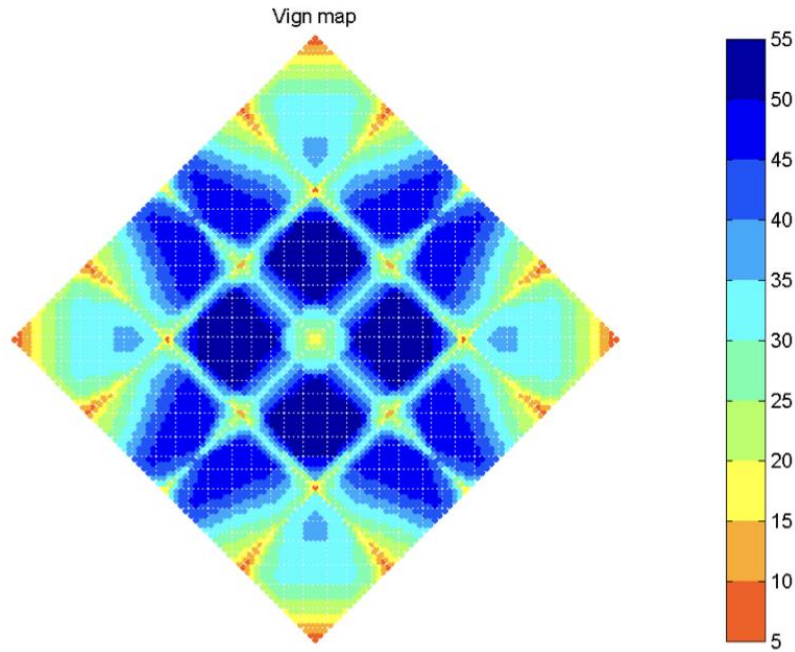


*Figure 22. Vignetting map of the entire FoV in the ideal case.
The color-map gives the percentage of un-vignetted light.*

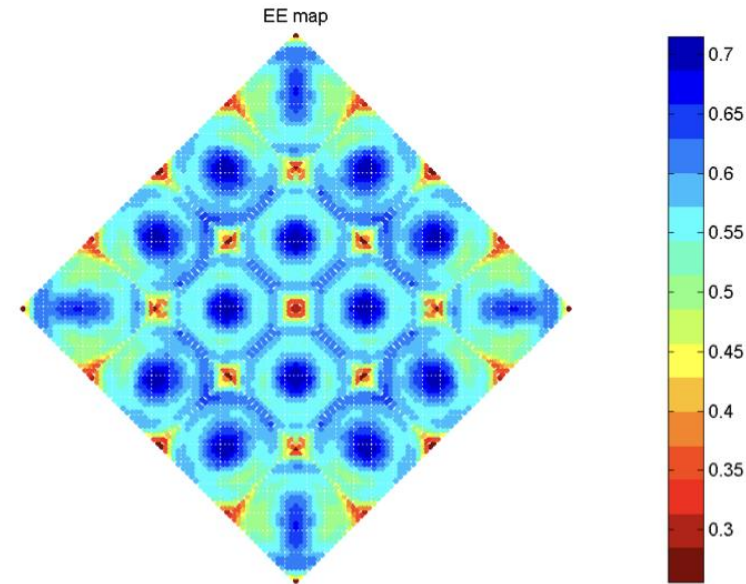
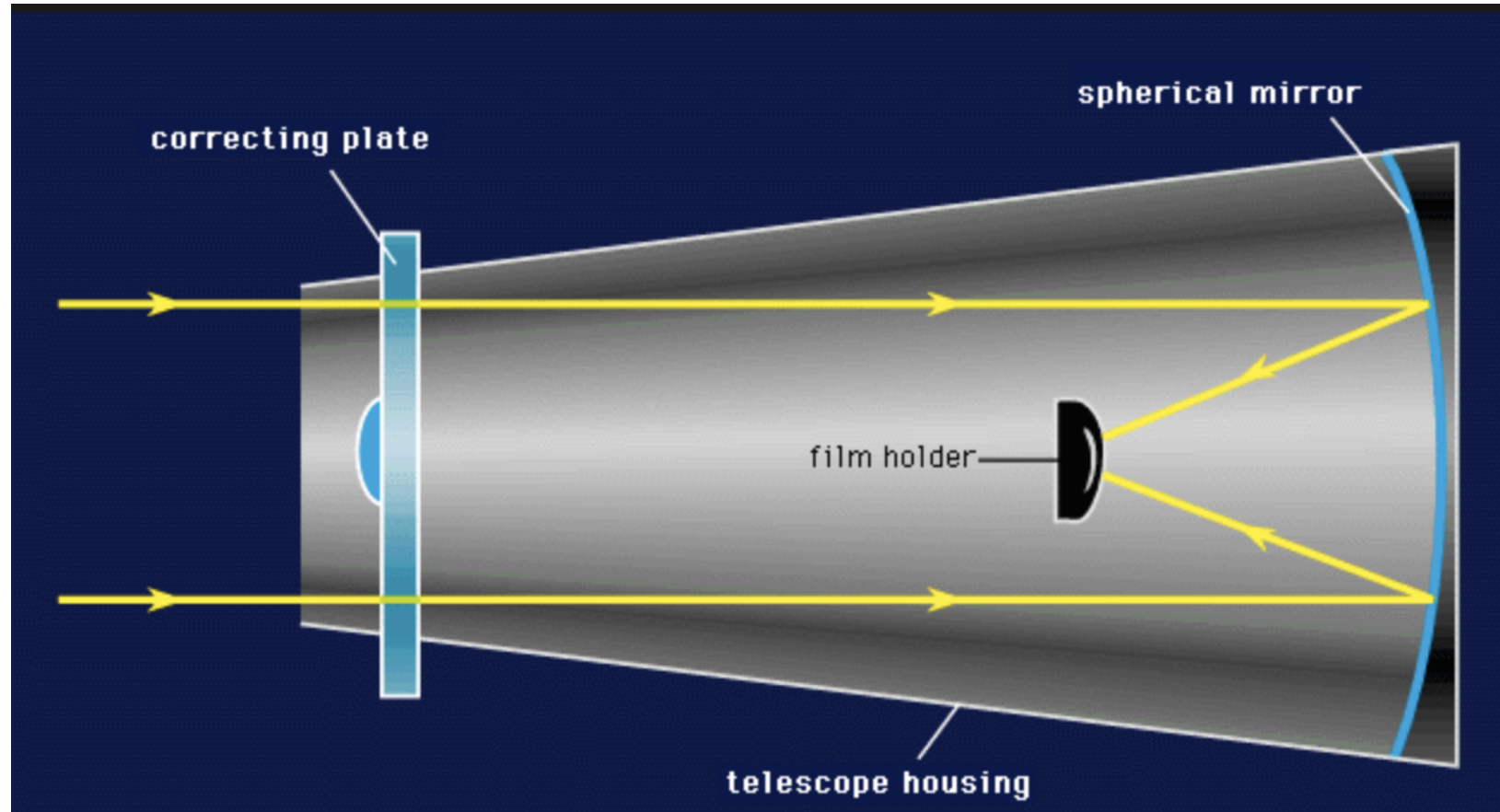
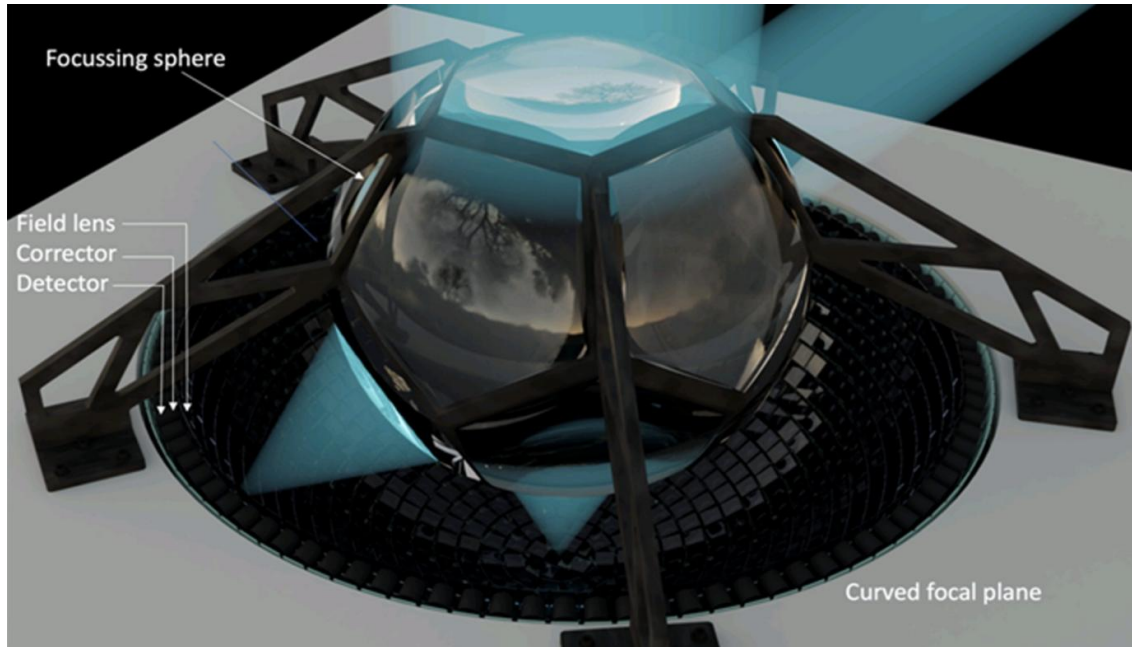


*Figure 23. Ensquared energy map in the ideal configuration,
exposure time set at 40s.*

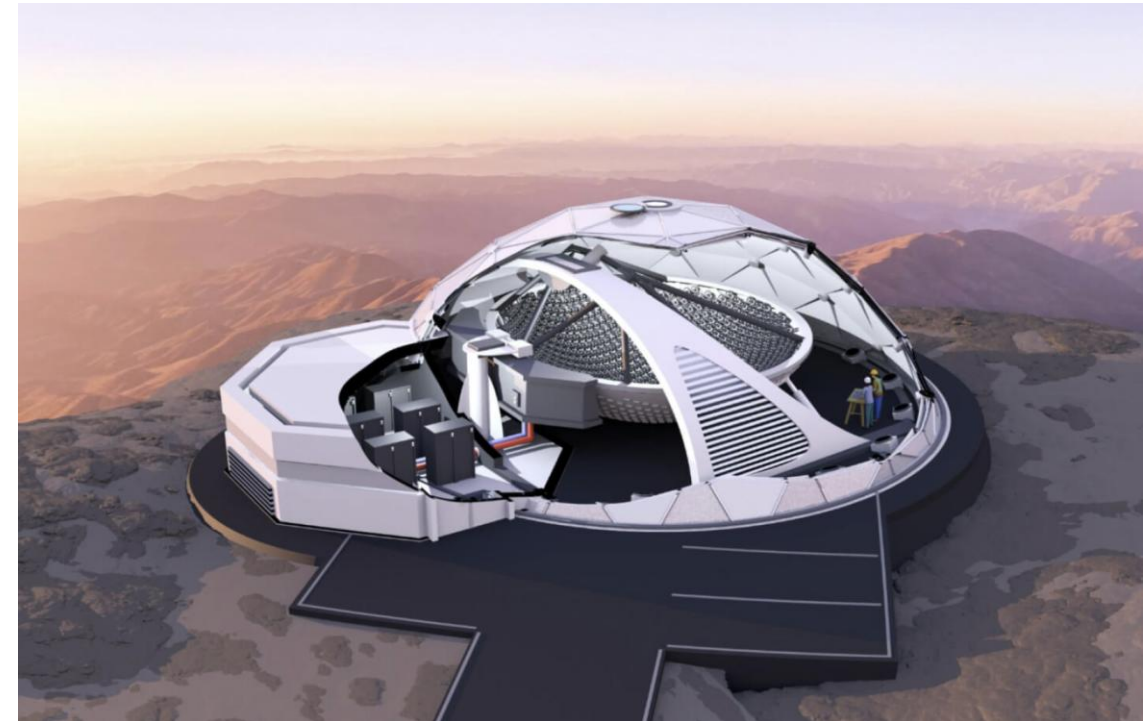
Schmidt Concept



Extremely large «fixed-mount» monitoring systems under development



Mezzo Cielo- INAF , R² & Guys



ARGUS – Eric & Wendy Schwartz Foundation

Small Wide-field pointing telescopes for space surveillance and time-domain astronomy

- ~~Wide field optical telescopes are fundamental to modern astrophysics~~

Drawbacks:

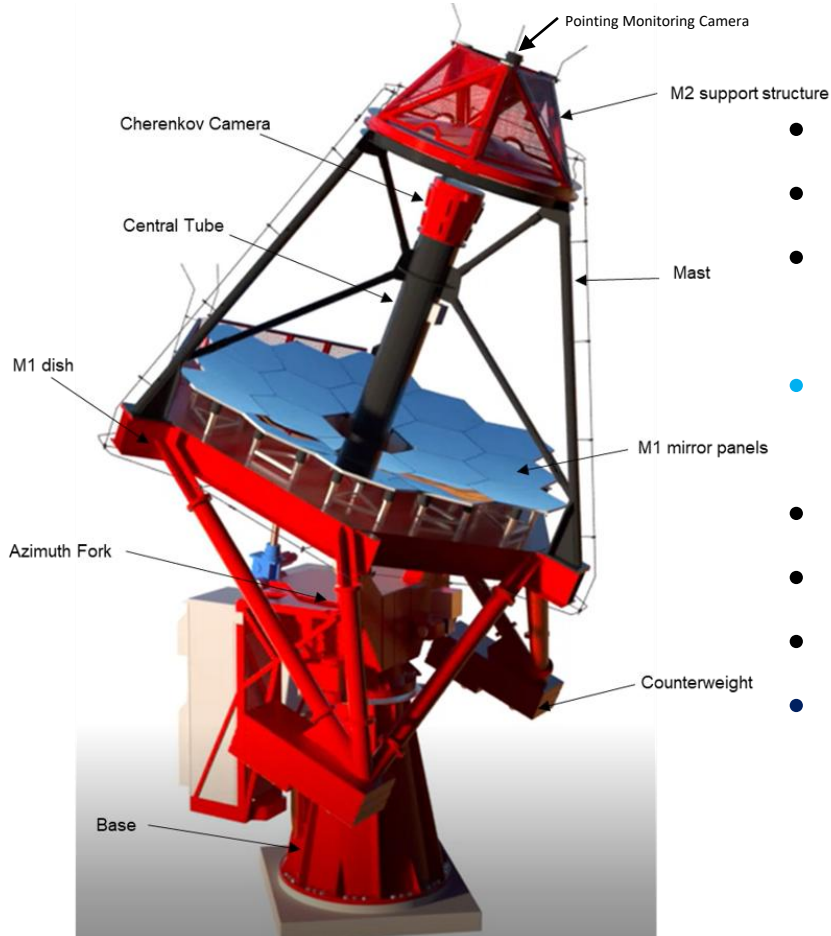
- 1) high cost,
 - 2) large number of optical elements (e.g. for Fly Eye),
 - 3) just equatorial mount → large volume and high power consumption
 - 4) no derotation,
 - 5) no fast repointing
- Italy, with the support of ASI and ESA, and with the support of INAF, is developing the **FLYEYE/NEOSTED** prototype in Matera, with a planned transfer to Sicily, plus 4 other telescopes to be distributed around the globe for large sky coverage → **47 – 35 square degrees**

A possible change of perspective

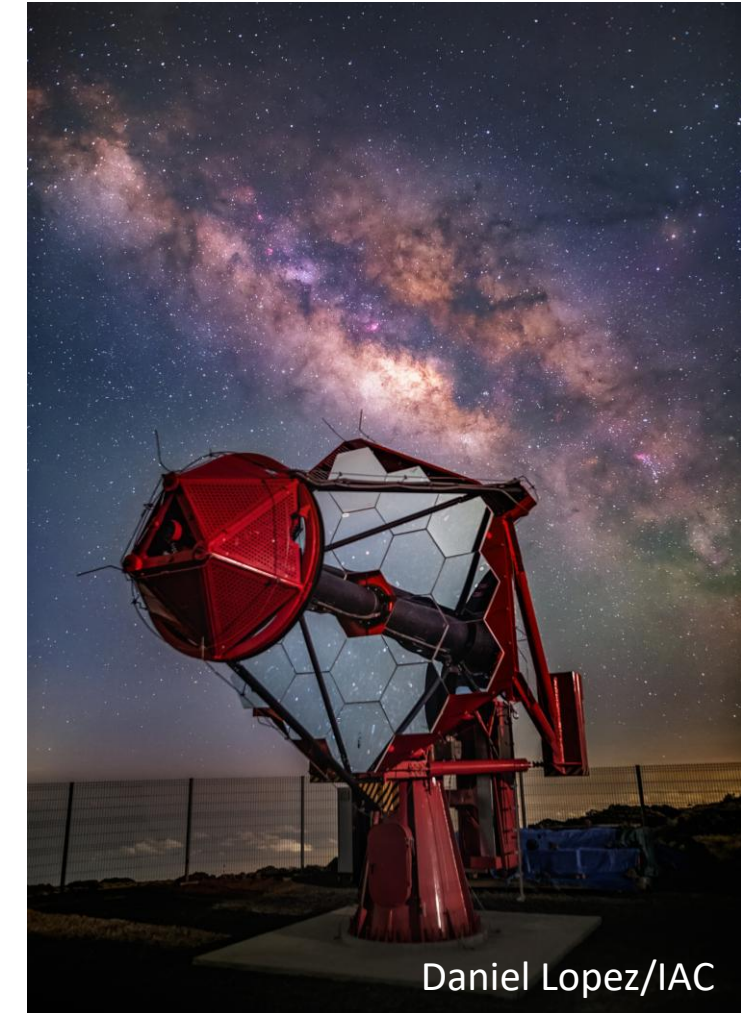
- CMOS technologies already available:
 - Small pixels (2–10 microns)
 - Large arrays (10k x 10k pixels per camera)
- Very compact aplanatic telescopes (**F# 1 or less**)
- AZ mount
 - **Reduced space requirements**
 - **Fast re-pointing**
 - **Interchangeable filters**
- Single camera (possibly mosaic)
 - Small Vignetting and uniform PSF across the entire field
 - Low Power reduction
- **Near-infrared camera possible**

ASTRI Mini-Array telescopes

Contribution to opto-mechanics design and production from several companies:
DAL BEN SpA, EIE Group Srl, Media Lario Srl, Flabeg, Vetrolamp, Cilas, ZAOT



- Alt-azimuthal mount
- Total weight: 17.5 tons
- Dimensions: 8.6 m pointing at zenith, 7.5 m pointing at the horizon
- **Modified Schwarzschild-Couder configuration**
- Primary Mirror: 4.3 m (18 segments)
- Secondary Mirror: 1.8 m (monolithic)
- Average effective area $> 5.0 \text{ m}^2$
- **F-number: 0.5**



Daniel Lopez/IAC

The Schwarzschild Aplanatic Telescope

1905: Karl Schwarzschild solved the Seidel 's equations for **spherical** aberration and **coma** finding a relation between parameters capable to make a telescope **aplanatic**. (*Couder 1926 → also correction of **astigmatism** with curved focal plane*)



Vladimir Vassiliev, UCLA

“For any geometry, 2 aspheric mirrors allow the correction of SI and SII to give an aplanatic telescope”

Schwarzschild telescope



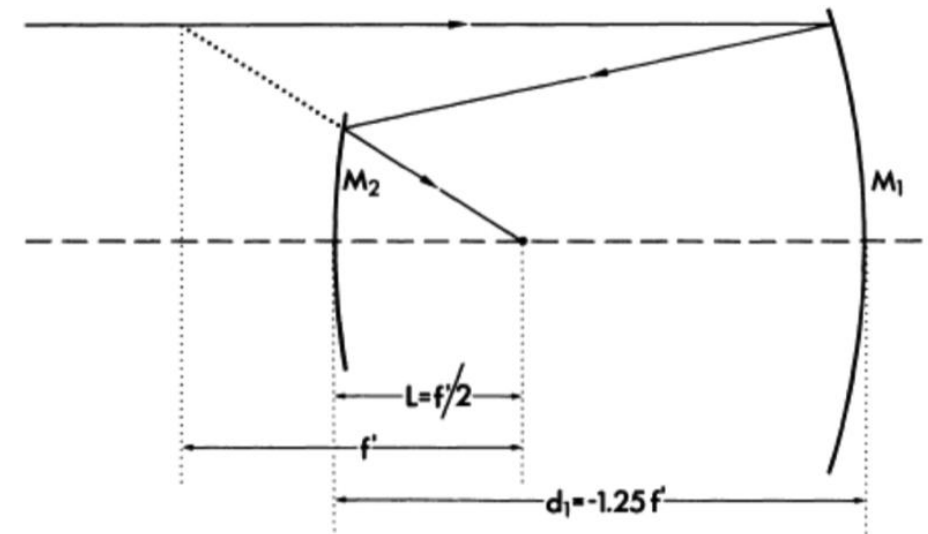
KS: f/3.0

$b_{S1} = -13.5$ (Hyperbola)

$b_{S2} = 1.963$ (Spheroid)

FoV: 2.8 deg

$RMS_{edge} \sim 12''$



Technological challenge: Aspherical Optics manufacturing + large secondary mirror

X-ray and Cherenkov Aplanatic Polynomyal Telescopes



Paper

29 September 1999

X-ray optics for the WFXT telescope

Oberto Citterio, Sergio Campana, Paolo Conconi, Mauro Ghigo, Francesco Mazzoleni, Heinrich W. Braeuninger, Wolfgang Burkert, Andreas Oppitz

[Author Affiliations +](#)

Proceedings Volume 3766, X-Ray Optics, Instruments, and Missions II; (1999)

<https://doi.org/10.1117/12.363636>

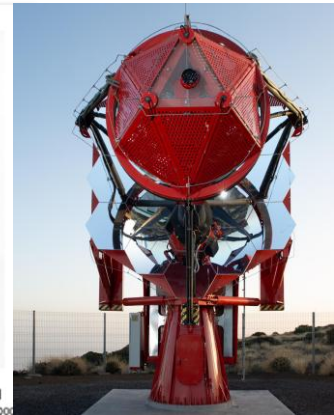
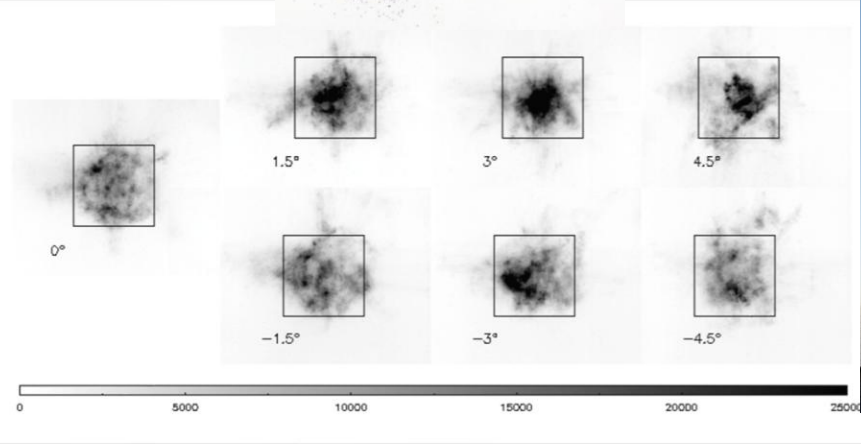
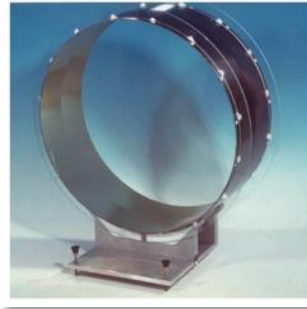
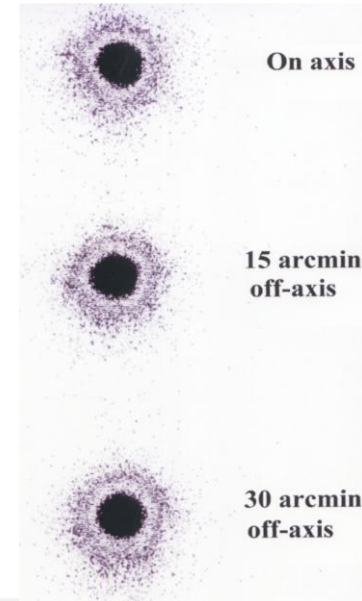
Event: SPIE's International Symposium on Optical Science, Engineering, and Instrumentation, 1999, Denver, CO, United States

A&A 608, A86 (2017)
DOI: [10.1051/0004-6361/201731602](https://doi.org/10.1051/0004-6361/201731602)
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**Astronomy
&
Astrophysics**

First optical validation of a Schwarzschild Couder telescope: the ASTRI SST-2M Cherenkov telescope

E. Giro^{1,2}, R. Canestrari², G. Sironi², E. Antolini³, P. Conconi², C. E. Fermino⁴, C. Gargano⁵, G. Rodeghiero^{1,6},
F. Russo⁷, S. Scuderi⁸, G. Tosti³, V. Vassiliev⁹, and G. Pareschi²

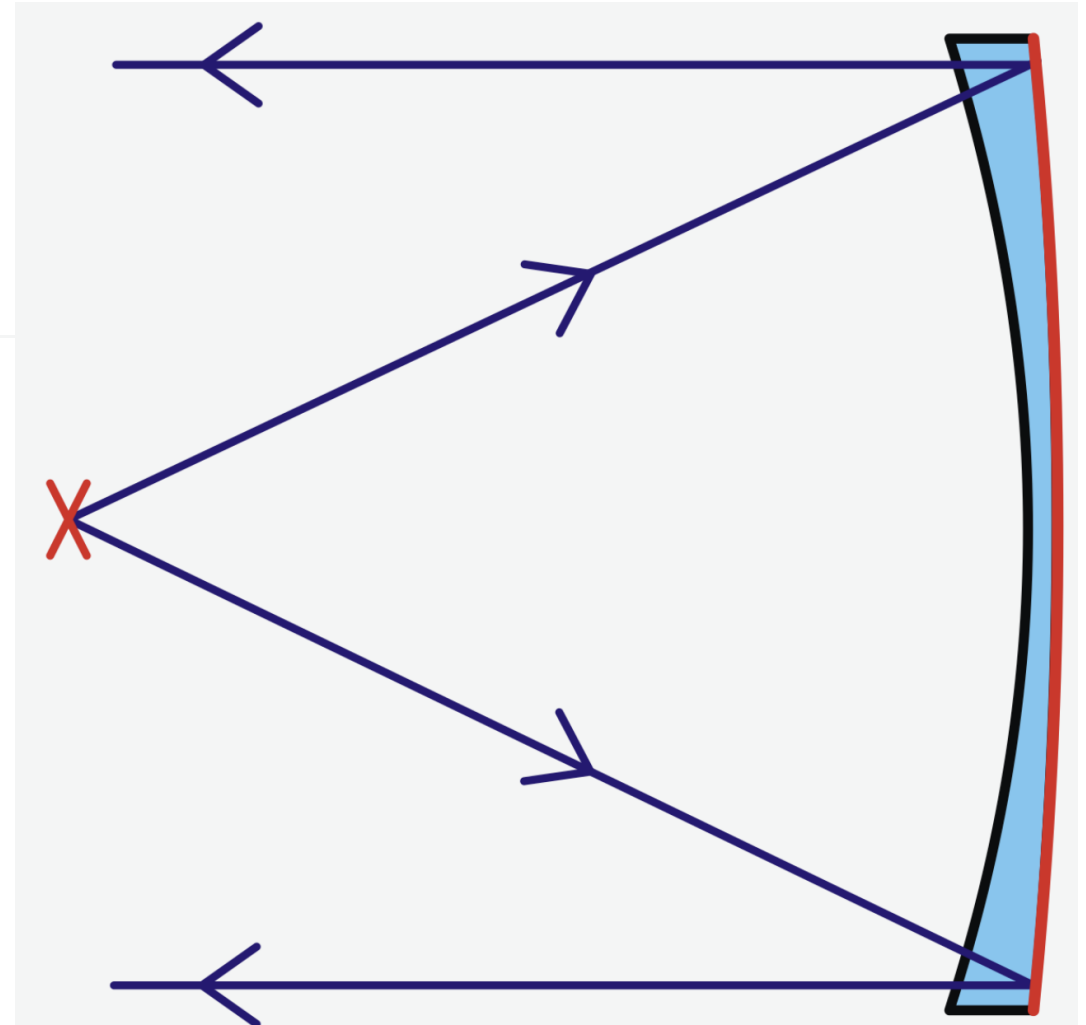


SAME OPTICAL DESIGNER (Paolo Conconi, INAF Brera)

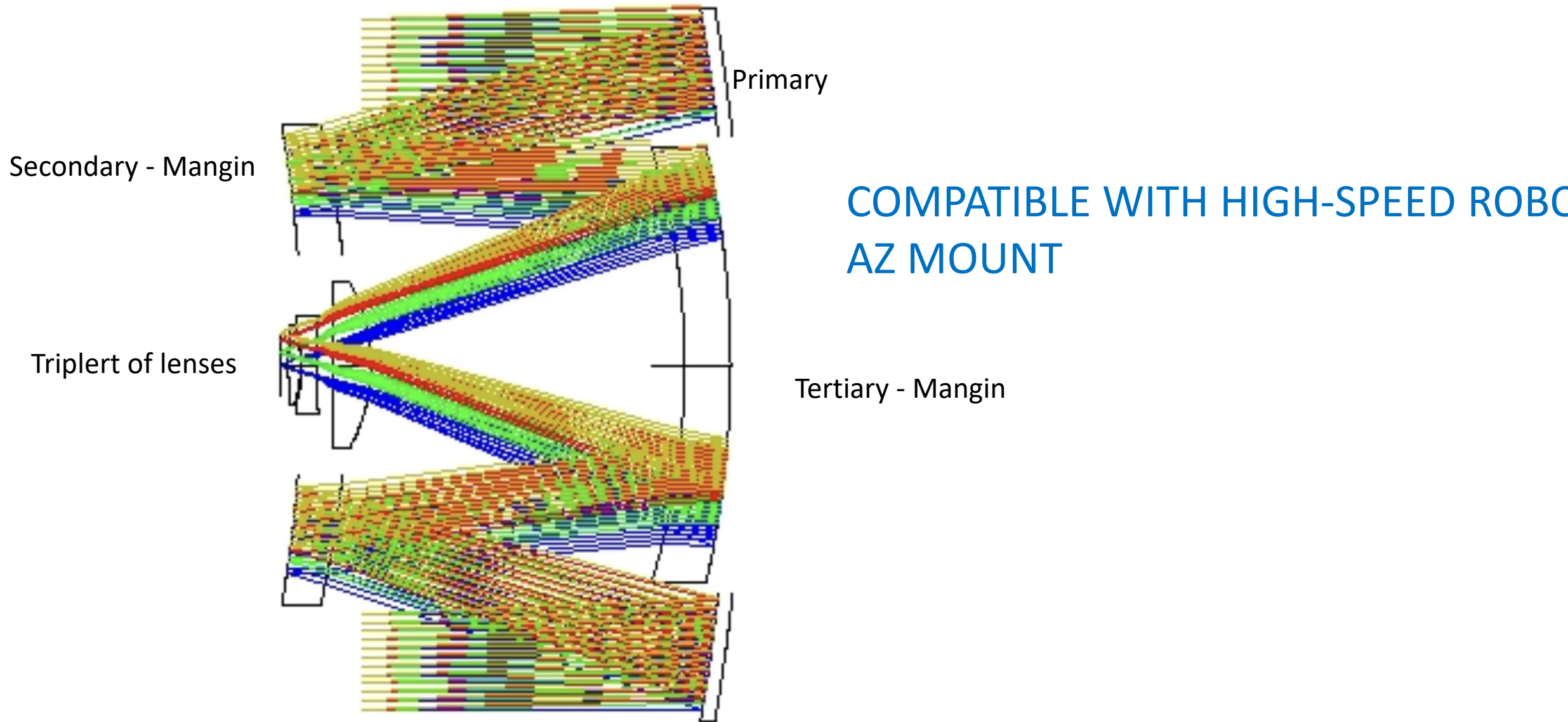
Mangin Mirror – invented in 1874



Alphonse Mangin



An extremely compact system (homothetic)



Possible geometries for the prototype of the innovative three-mirror system

at least one Mangin + corrector plate or at least two Mangin elements

Lamina	M1	M2	M3	Campo Φ	F#	r.m.s.	xpf	Note
Si	Mangin	Sphere	Sphere	10°.5	1,1	3 μ	13	1
Si	Mangin	Sphere	Sphere	8°.5	1,3	2.7 μ	17	2
No	Aspher	Mangin	Mangin	10°.5	0,95	2.0 μ	7	3
No	Mangin	Mangin	Aspher					4
No	Mangin	Asphere	Mangin					5
Si	Aspher	Asphere	Mangin	10°.5	1,1	1.2 μ	22	6

Note: The maximum diameter achievable in configuration No. 3 is 1.5 times that of configurations 1 and 2. Configurations 1 and 2 are limited to the maximum diameter obtainable for the Schmidt lamina

Mirrors and lenses:

realizable using modern optical polishing technologies and associated metrology



Presentazione INAF



Mirrors and lens manufacturing

The Ion Beam Figuring vacuum facility



Oven for hot forming of thin glass foils

The Zeeko polishing machine



Ultrasonic 5 axis WorkCentre

REM (Rapid Eye Mount)

La Silla (Cile), operated since 2003 by INAF/Brera



Mount AZ, 60 cm diam., Ritchey-Chrétien

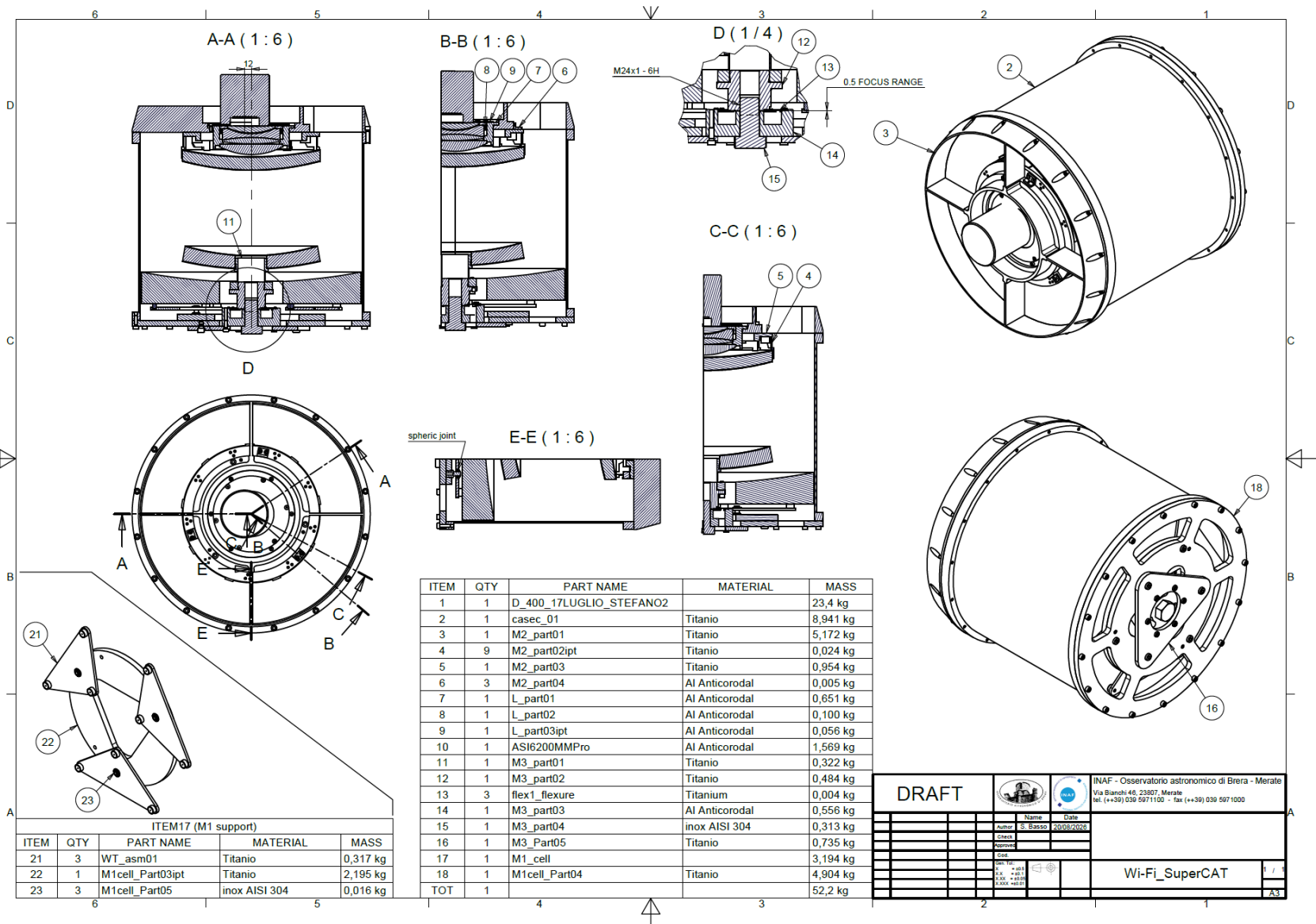
Pointing velocity $\rightarrow 10^\circ/\text{s}$

Commercial AZ Robotic Mount

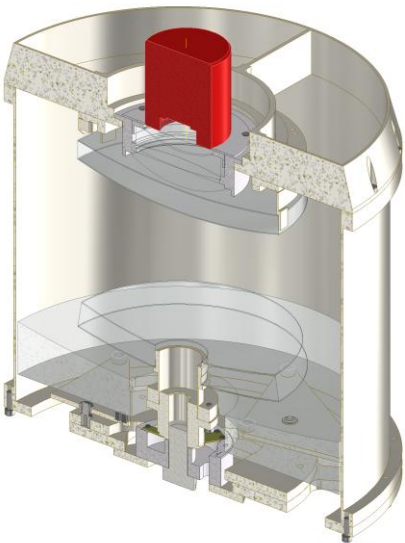


See e.g.: <https://www.astelco.com/products.htm>

Pathfinder under development – preliminary mechanical design



M1 = 40 cm
FOV = 7.5°

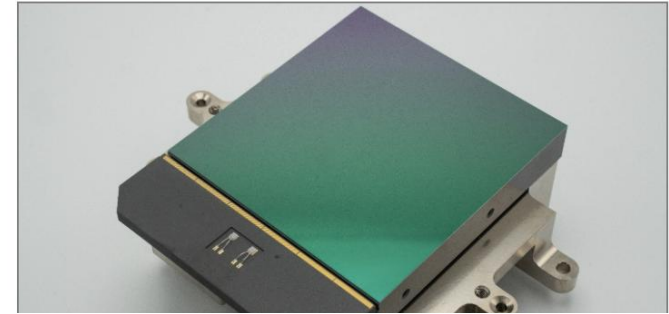


Mosaic of large-format, small-pixel CMOS arrays

Leveraging Teledyne Imaging's extensive heritage of producing imaging sensors, the CIS300 family of sensors are large-area CMOS image sensors designed to meet the demanding requirements of astronomy and scientific imaging. The two sensors currently available, CIS301 and CIS302, feature high sensitivity, excellent image quality, and a flexible design. CIS302 utilizes HiRho technology to enhance the NIR wavelength response.

Key Features:

- 9,000 columns and 8,600 rows of $10\mu\text{m} \times 10\mu\text{m}$, selectable dual gain pixels
- Multiple read-out modes available including rolling shutter, global shutter, staircase mode, and High Dynamic Range (HDR) Operation
- 3 side buttable Silicon Carbide and Ceramic package allowing multiple sensors to be mosaiced together to form even larger area pixel arrays with minimal dead space between individual sensors.
- Selectable 12-bit or 14-bit operation (effectively extendable by HDR)
- High frame rates from 12 CML outputs each running at 2Gbit/s allowing for full image area frame rates of up to 8 frames per second.
- High Quantum Efficiency of over 90% due to back-thinning processing
- Designed for use over a wide range of temperatures- room to cryogenic
- Onboard Temperature Sensors



Wi-Fi Super-CAT Vs. current/near future telescopes

Table 1. Comparison among Wi-Fi SuperCAT and other aplanatic telescopes.

PARAMETER	Wi-Fi SuperCAT	FlyEye/Neosted	ZTF
Diameter (m)	1.5	1	1.2
Optics Configuration	3 mirror/pseudo-catadioptric	Spherical (+ 16 correcting objectives)	Schmidt catadioptric
F#	0.9	2	2.5
Mount	AZ (equatorial possible)	equatorial	equatorial
Rapid re-pointing	YES	NO	NO
# of cameras	1	16	1
FOV (square degrees)	80	44	47
N Pixels (billions)	0.91	0.26	0.60
Gaps in the field	Minimal	No, but low uniformity	Minimal
(E)ntendue (Ster x cm ²)	0.02437	0.00674	0.01359
Pixel Size	1.0 arcsec/pixel	1.5 arcsec/pixel	1.0 arcsec/pixel
Limit Magnitude V (30 sec)	22.5	21.5	20.6



Wi-Fi SuperCAT possible operating mode

- The WI-FI SuperCAT system would combine a relatively small telescope with a very powerful large camera.
- A major feature of the telescope is its large 10° field of view - about 20 times the diameter of the full moon.
- With this system, the entire night sky visible from a northern site (e.g., the Canary Islands) can be imaged with about 350 separate (with opportune overlap) telescope pointings (single-filter exposures).
- At 30 seconds per exposure, plus 5 seconds readout, the telescope can scan 50% of the sky four times per night with a single filter.
- One could scan the whole sky twice each night, reaching a magnitude of 22.5.
- FAST REPOINTING UPON EXTERNAL TRIGGERS (GRB, GW, Novae...) imaging a huge FOV of 80 square degrees