Mirrors for CTA telescopes

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INTRODUCTION

In June 2010 Canestrari wrote (SPIE proc 2010, 7739, 12):

"New projects have been started as the European Cherenkov Telescope Array (CTA) […] In this framework, tens of thousands of optical mirror panels have to be manufactured, tested and mounted into the telescopes. Because of this high number of mirrors it is mandatory to develop a technique easily transferable to industrial mass production, but keeping the technical and cost-effectiveness requirements of the next generation of TeV telescopes."

After three years we are very close to that situation and several technologies have been investigated but not all are fully ready to start with that mirror mass production required by CTA.

OUTLINE

- General requirements on mirrors
- Summary on technologies
- Large Size Telescope optics and mirrors
- Medium Size Telescopes optics and mirrors
- Small Size Telescopes optics and mirrors

Due to the huge reflecting surface (up to 400 m^2) and the low requirement in the surface dish error the panel solution is the most suitable for the different size CTA telescopes.

Optical Requirements

- Surface roughness ~ 3 nm rms to avoid diffusive scattering
- PSF on the single mirror ~ 1 mrad.
- Surface error on the panel driven by PSF requirement and optical design (~ 0.1 mm)
- Reflectivity > 85% in the 300-550 nm range to be guarantee for 10 years lifetime

Geometry and size

- Exagonal shape
- Face to face size between 0.5-2 meters
- Curvature radii design dependent (between few meters up to ~ 50 meters)
- Spherical and aspherical surfaces (different radii of curvature in perpendicular directions and monolithic secondary mirrors)

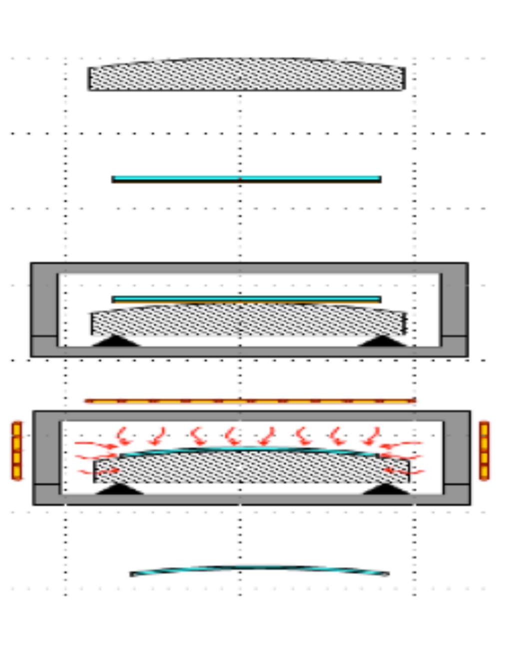
Physical properties

- Weight < 20 kg/m^2 is desirable
- Mirror deformation under gravity must be small enough to maintain the specifications for the PSF and the alignment
- No shape deformation for a 10 years lifetime
- No damage in temperature range between -15° to 60° C
- No significative change in shape in the temperature range between -10° to 30° C

Mirror replica technologies

- Hot slumping mirrors
- Cold slumped glass sandwich mirrors
- Hot slumped glass sandwich mirrors
- Sheet Moulding Compound mirrors
- Open-structure Composite mirrors
- Electroforming for high curvature mirrors
- Thin reflective layers on mould formed sandwich

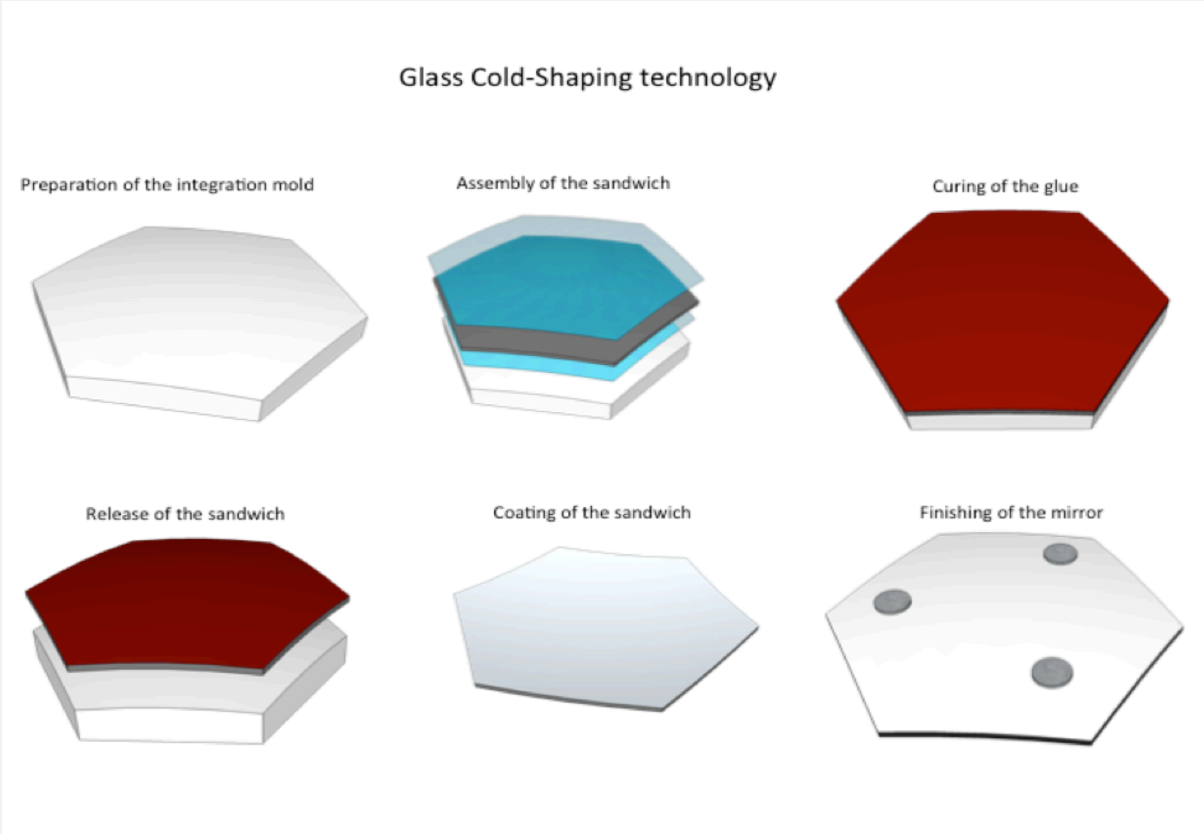
After heating the mould and putting the glass on it at constant pressure and temperature about 650° the mirror will copy the mould's shape. The copy process can be direct or indirect.



INAF – Rodolfo Canestrari - rodolfo.canestrari@brera.inaf.it

COLD SLUMPED GLASS SANDWICH

The mirror will copy the mould's shape with a possible spring back effect that can be used to obtain different curvature radii from the same mould.
Dust and imperfections on the surface will be replicated on the mirror.



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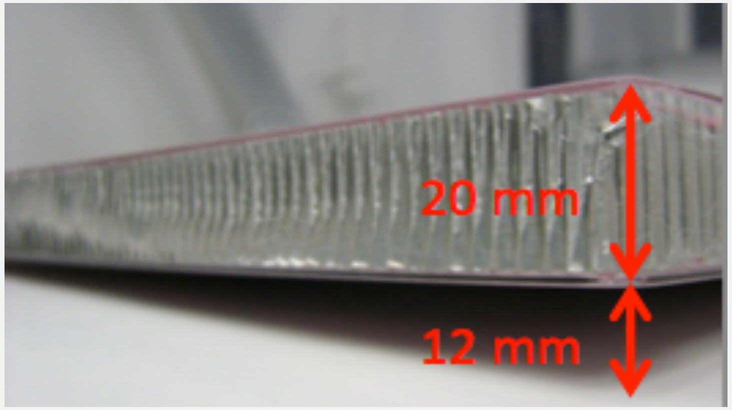
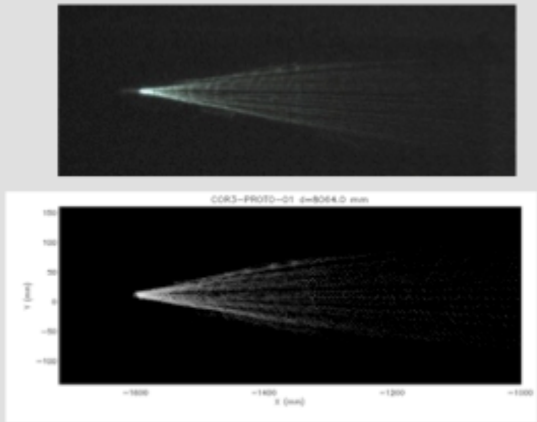
This technology is similar to the previous one but the thin glasses are modeled with hot slumping before to be assembled with sandwich. In this way a small correction can be applied to the hot pre-shaped surface.





Comparison between optical measurement and ray-tracing from surface measurement

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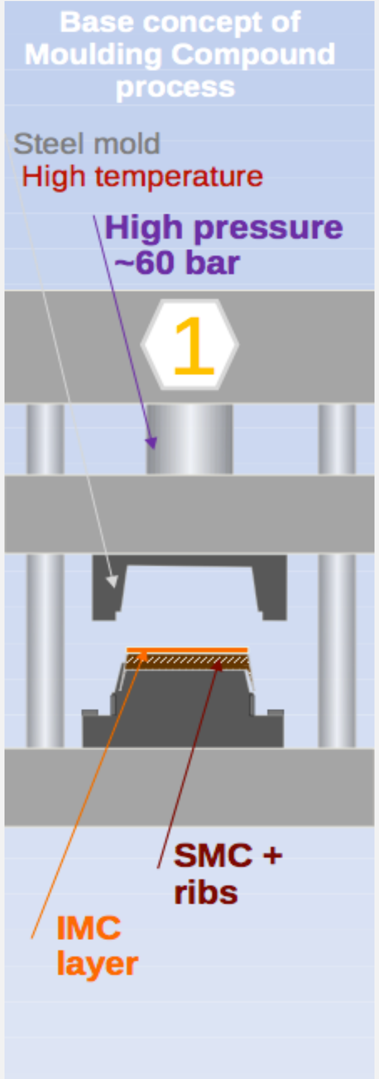
SHEET MOULDING COMPOUND MIRRORS

- Material: carbon fibre SMC composite
- In Mould Coating (IMC)
- Either one-part mirror (ribs on back side for stability) or additional honeycomb
- Different options for the reflective surface



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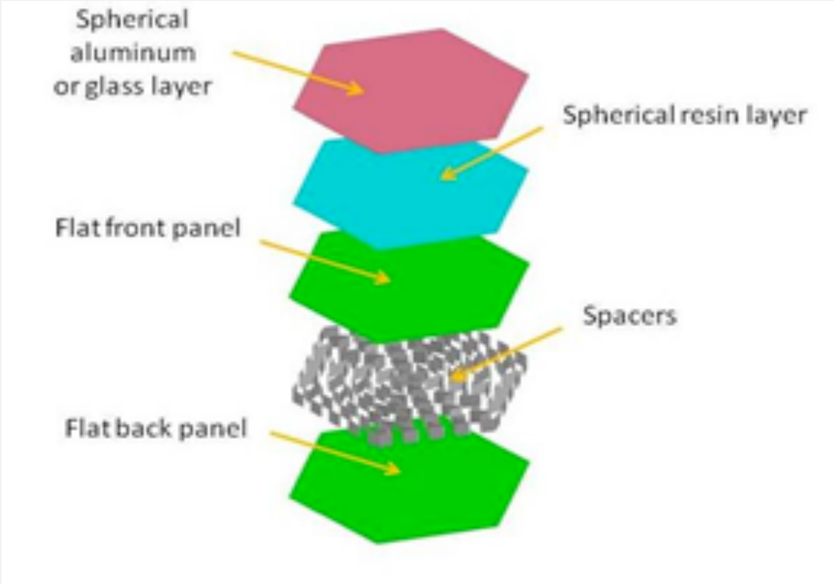
OPEN-STRUCTURE COMPOSITE MIRRORS

- open structure, not sealed front and back panels of structure are flat
- curved front surface is formed by spherical epoxy layer
- front layer can be very thin



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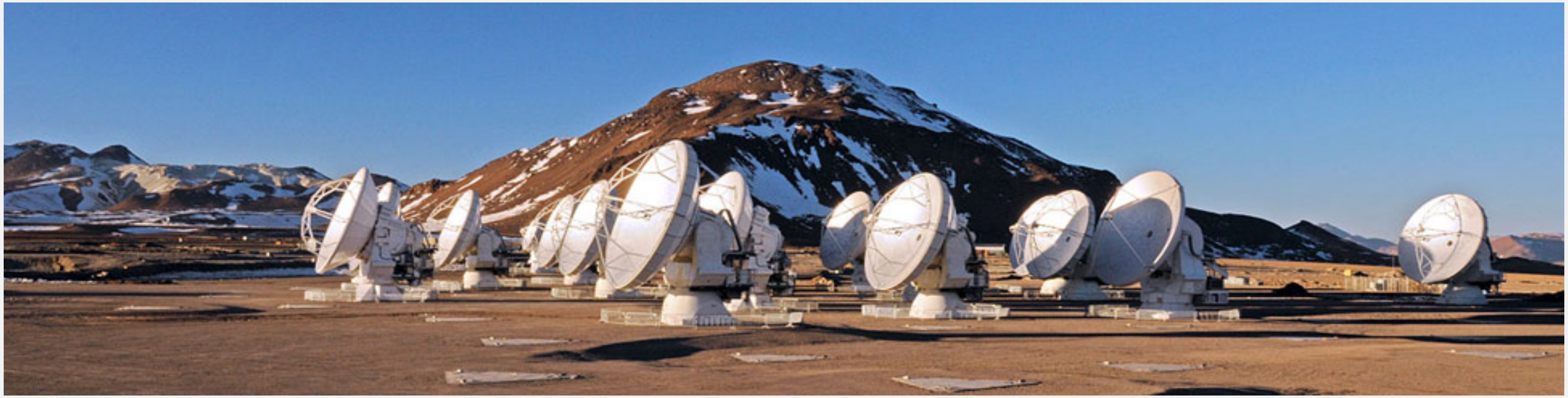
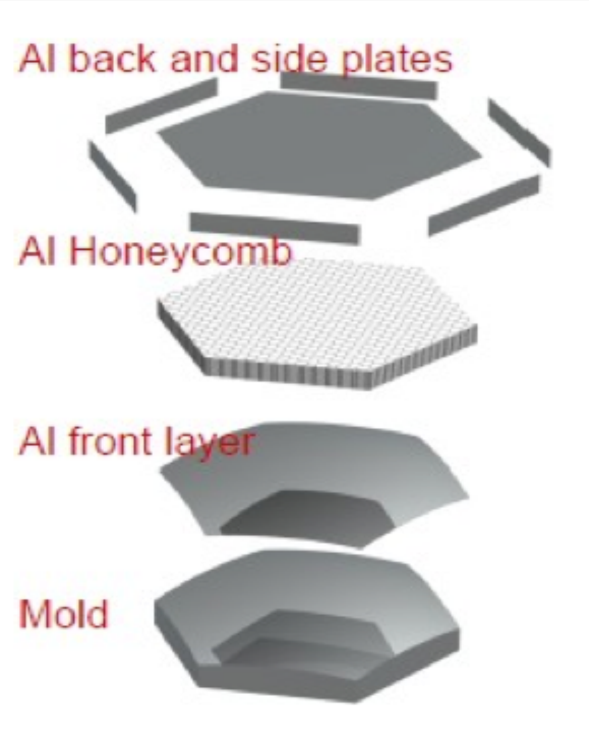
Electroforming

In the electroforming process, the mould is submerged in a chemical (Nickel Cobalt) bath and a thin (1 mm) shell is deposited on the mould by passing a current through the bath with suitably placed electrodes. This technique produces high-quality, curved mirrors for X-ray astronomy so that the surface roughness can be limited to values of 2-3 nm. The CTA mirror figures are not a challenge, but the expense of the mould is a concern. This process has been used in panel productions of ALMA telescopes (Media Lario Technologies). Application followed by University of Alabama – UAH – Valerie Connaughton - valerie@nasa.gov



Thin reflective layers on mould formed sandwich

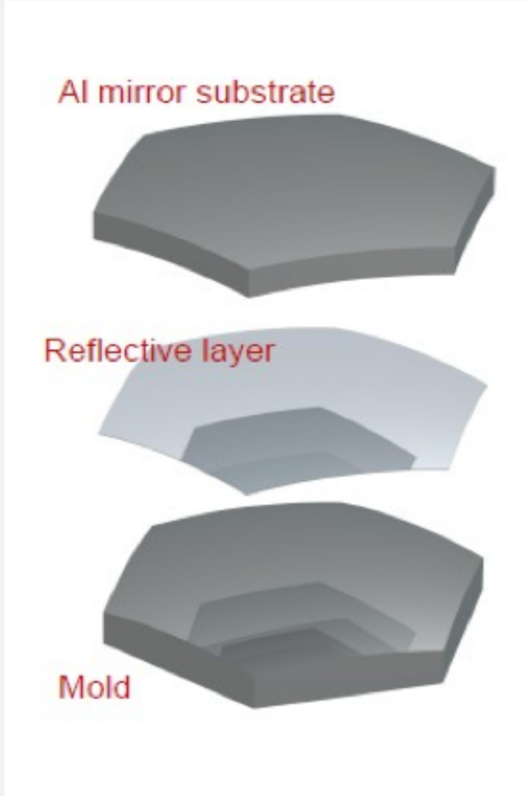


Sandwhich

- Al Backplane
- Al honeycomb inside
- Al substrate

Reflecting surface (current goal in feasibility study):

- thin front coated glass sheets
- reflective foil from 3M



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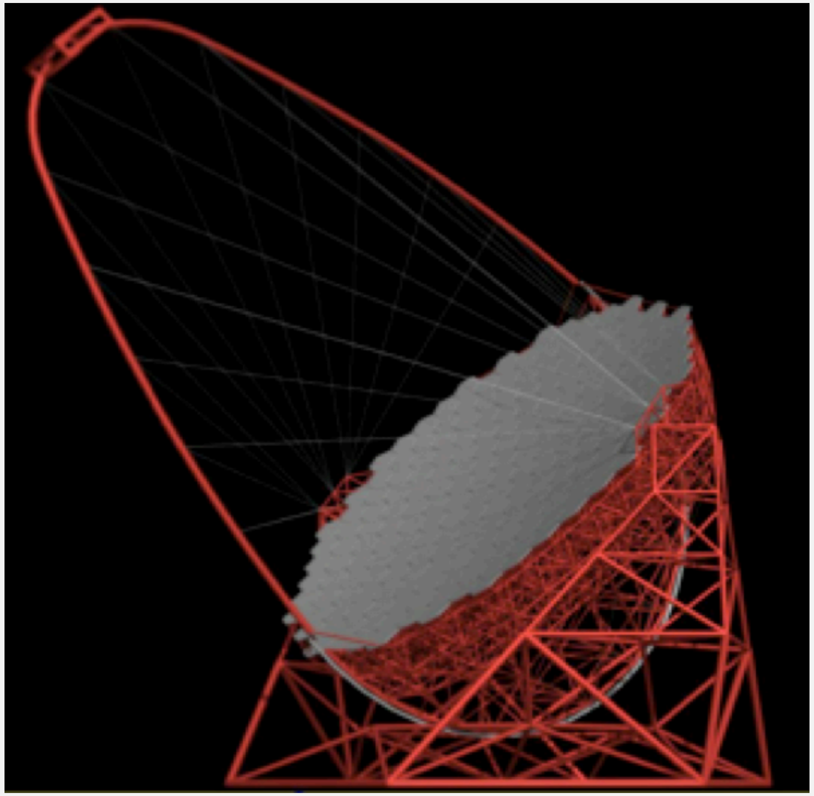
LST Optical configurations

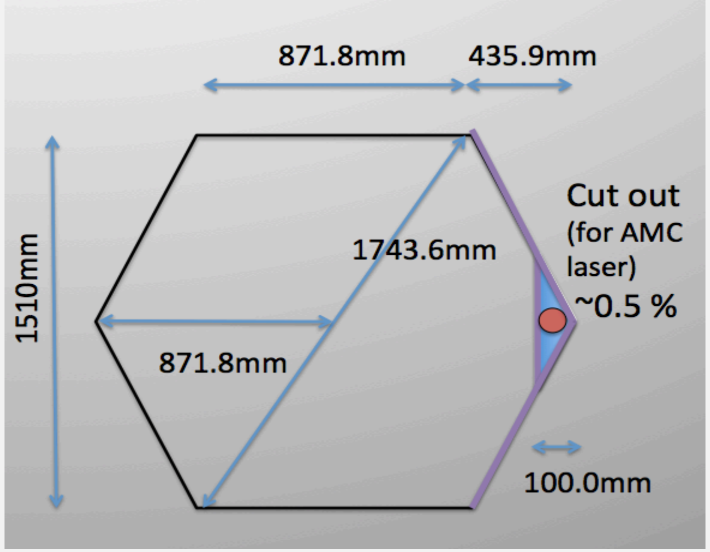
- One dish telescope
- Diameter: 23 m
- Dish area: 389 m^2
- F = 28 m parabolic
- # panels = 198
- D80:10mm(1/5 pixel)

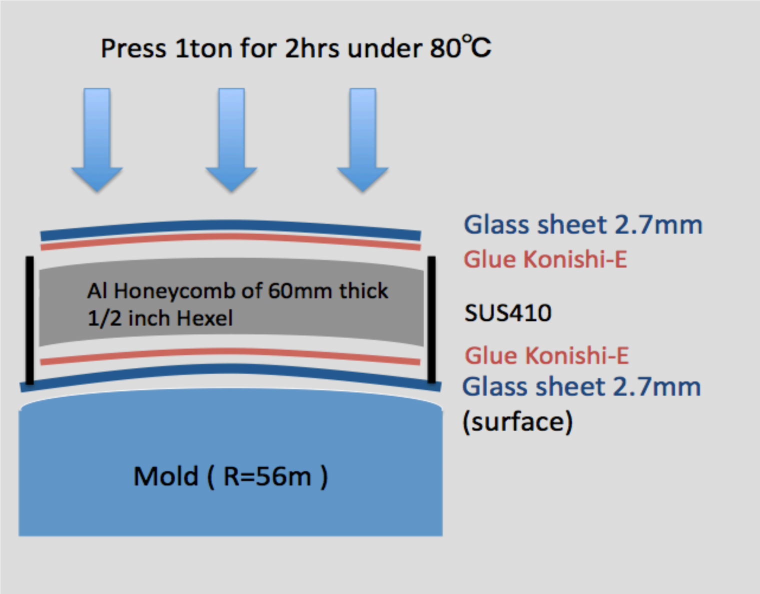


MPI Munich – University of Tokyo - Mashairo Teshima – masahiro.teshima@mppmu.mpg.de

LST MIRRORS

- Cold slumping technology
- 1.5 meter size face to face
- 65 mm thickness
- 56 meters curvature radius
- Weight ~ 45 Kg





MODIFIED DAVIES-COTTON MST

- One dish telescope
- Diameter: 12 m
- Dish area: 105 m^2
- F = 16 m
- # panels = 84
- D80: 4 cm

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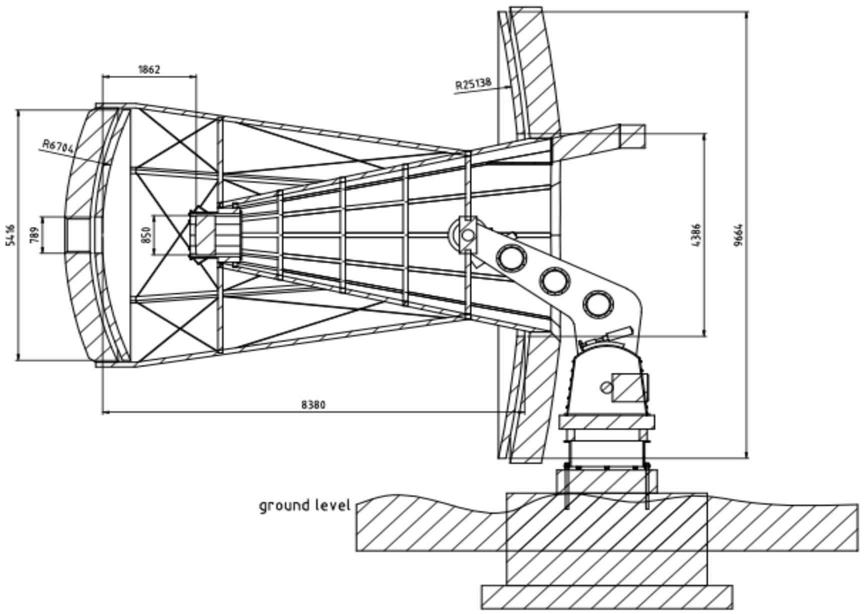
MST MIRRORS

- Cold slumping technology
- 1.2 meter size face to face
- various thickness depending by the technology adopted
- 32 meters curvature radius
- Weight ~ 15 Kg

Schwarchild couder MST

- Two mirror telescope
- Aspherical mirrors
- Primary diameter: 9.5 m
- Secondary diameter: 5.4m
- F = 5.6 m
- # primary panels = 48
- # secondary panels = 24
- D80: 3 mm



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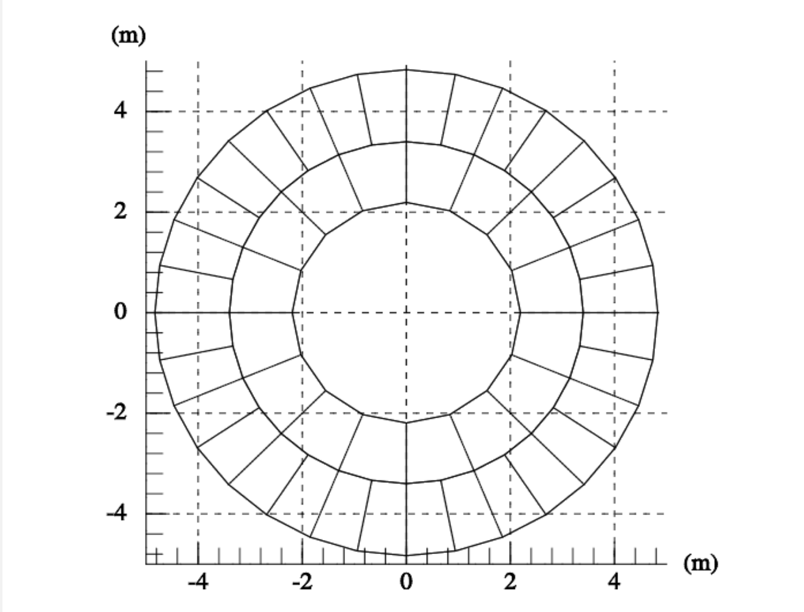
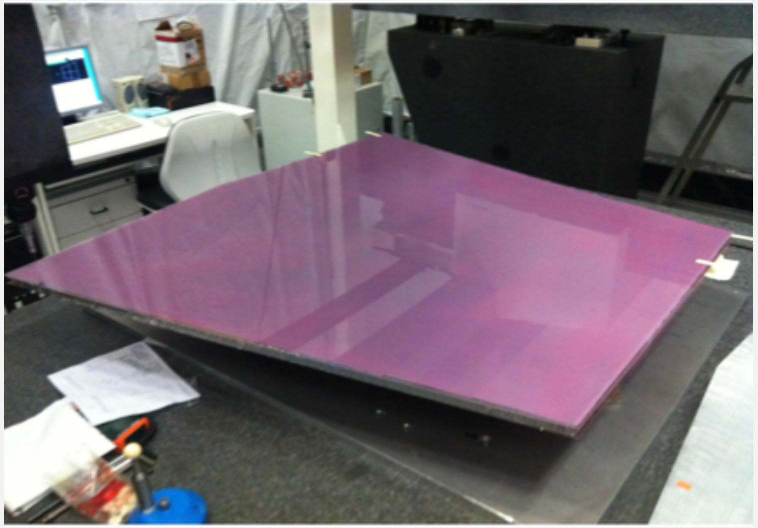
SC MST MIRRORS

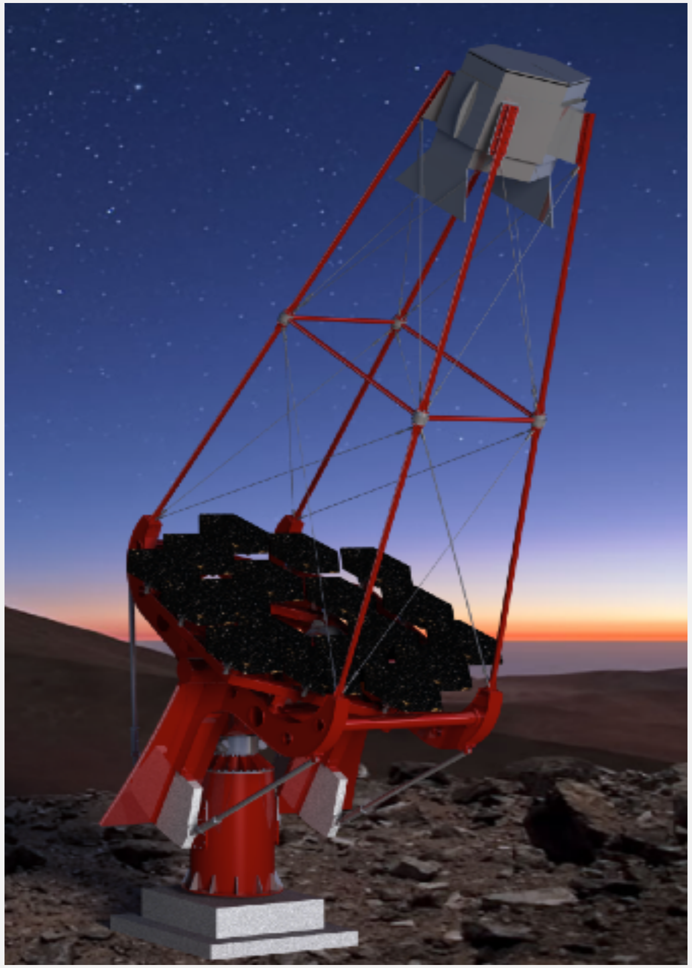
- Cold slumping technology for primary
- Electroforming or hot slumping for secondary (sag of several cm)
- Size < 1 m
- Primary mirror thickness of 30 mm
- primary: 25 meters curvature
- secondary: 6.7 meters curvature radius





Davies-Cotton SST

- One dish telescope
- Diameter: 4 m
- Dish area: 9.4 m^2
- F = 5.5 m
- # panels = 18
- D80: 2.1 cm



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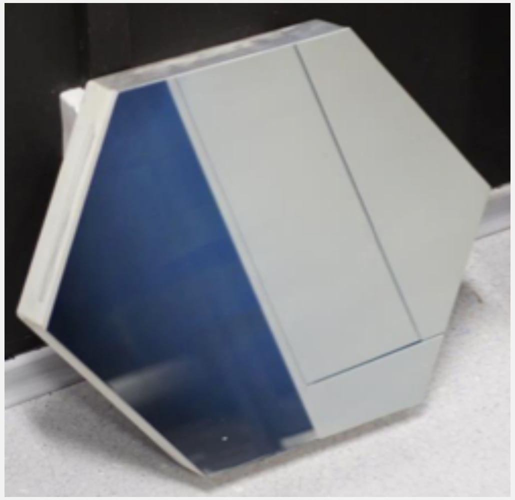
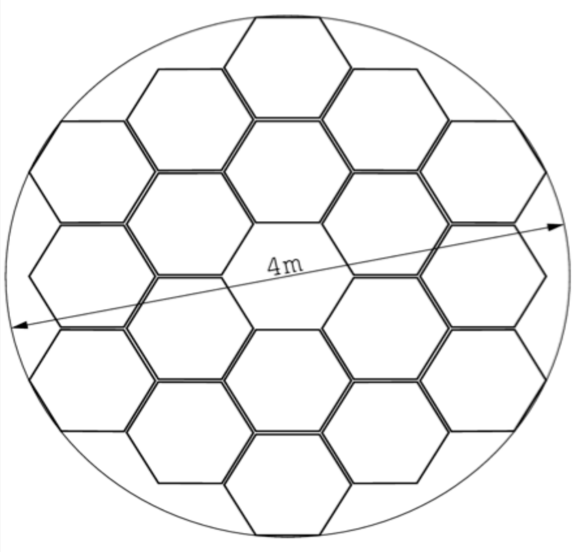
Davies-Cotton SST Mirrors

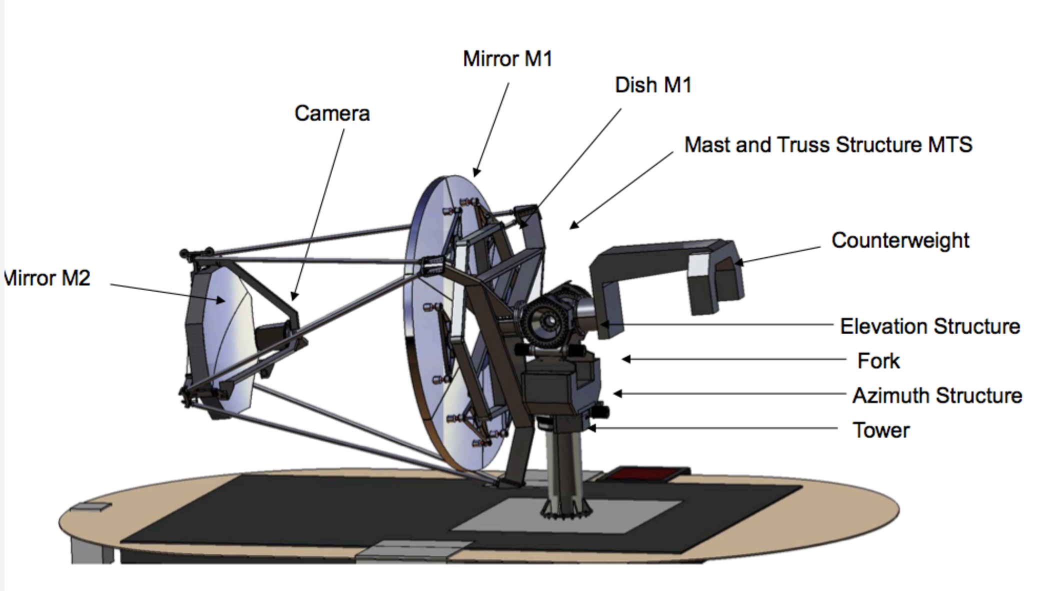
- Glass mirrors as baseline
- Investigation on composite mirrors and cold slumping
- 0.78 meter size face to face
- various thickness and weight depending by the technology adopted
- 11.2 meters curvature radius





GATE TWO MIRRORS TELESCOPE

- Two mirror telescope
- Aspherical mirrors
- Primary diameter: 4 m
- Secondary diameter: 2 m
- F = 2.28 m
- # primary panels = 24
- # secondary panels = 9 or monolithic
- D80: < 4 mm



Gate Consortium – Delphine Dumas
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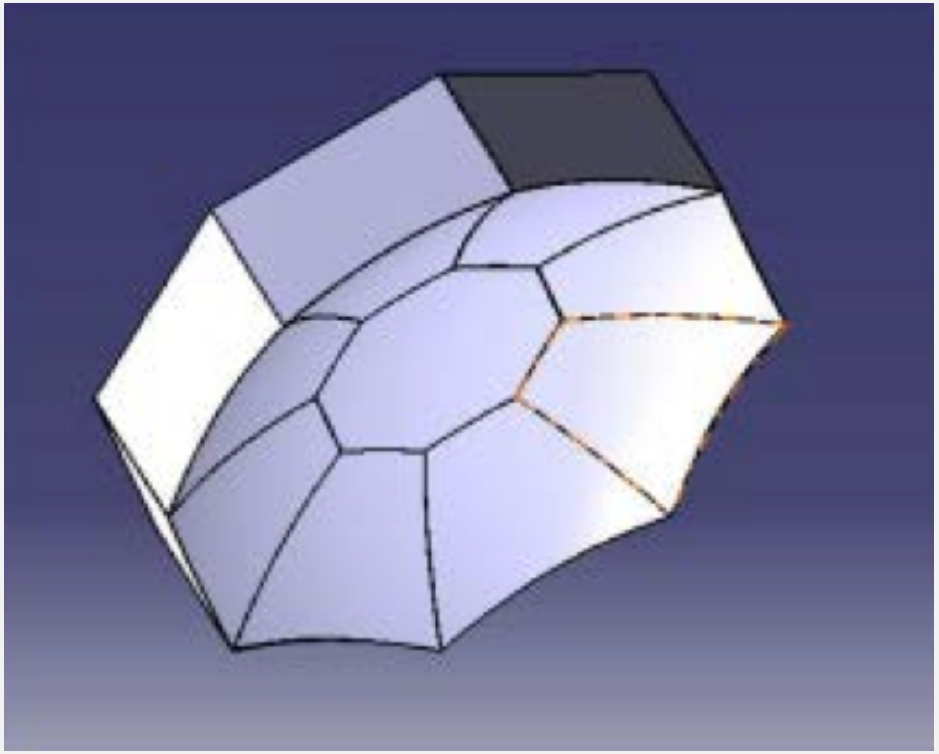
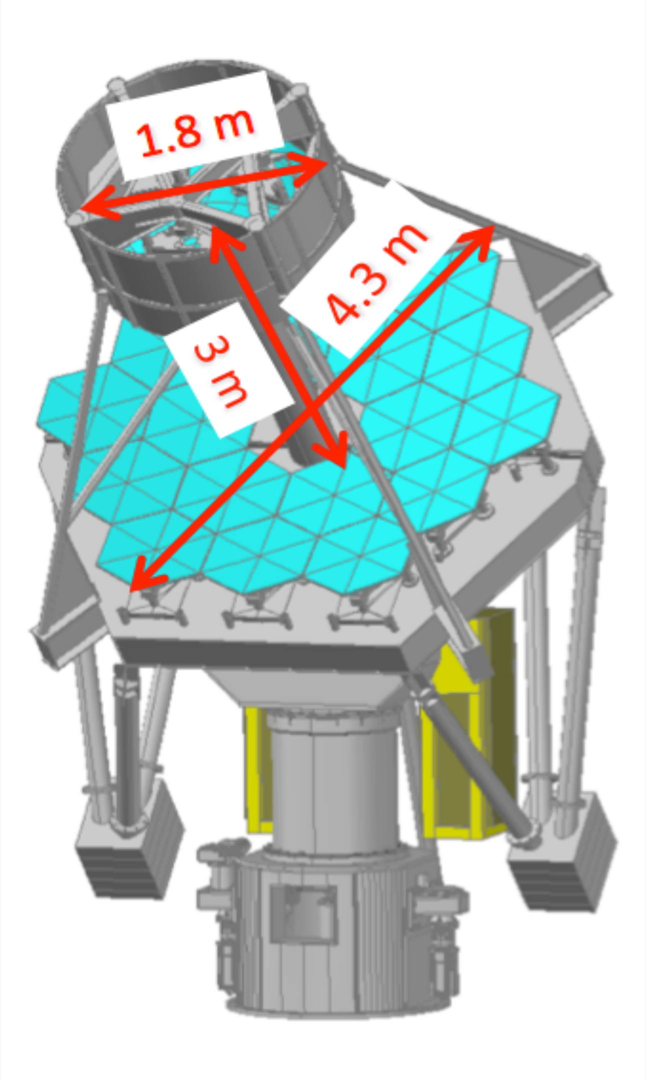
- Al Blank manufacturing + polishing for primary
- Cold slumping on reinforced glass for secondary, backup solution as primary
- primary: 9.7 meters curvature radius
- Size 1 – 2 m
- secondary: 2.1 meters curvature radius



ASTRI TWO MIRROR TELESCOPE

- Two mirror telescope
- Aspherical mirrors
- Primary diameter: 4.3 m
- Secondary diameter: 1.8 m
- F = 2.15 m
- # primary panels = 18
- secondary monolithic
- D80: < 6 mm



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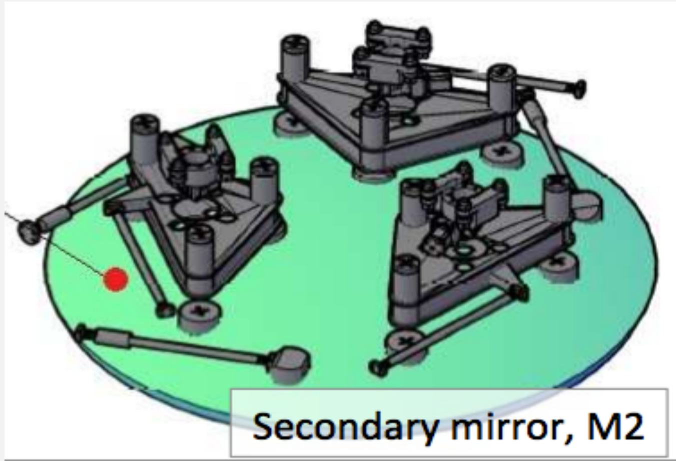
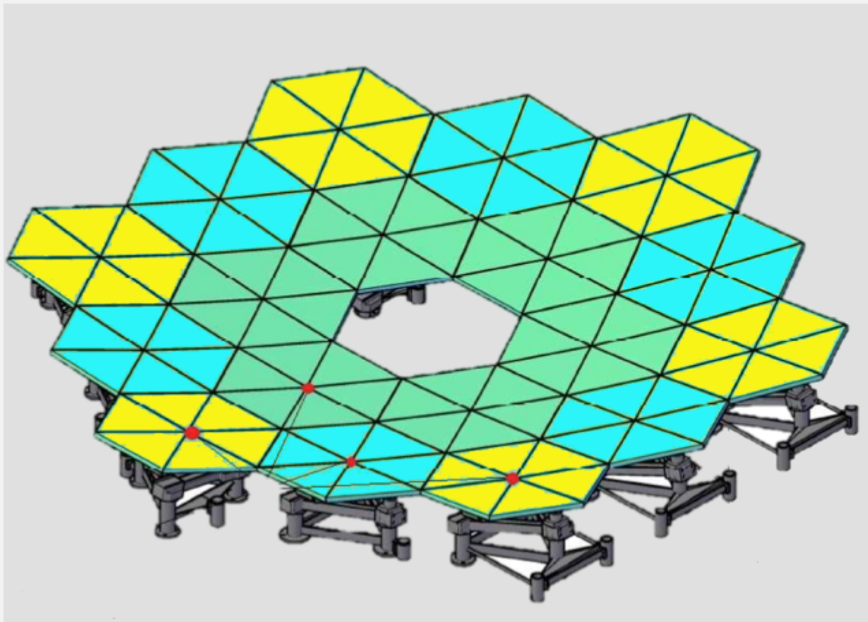
ASTRI TELESCOPE MIRRORS

- Hot slumping or hot pre-shaping + cold integration for primary and secondary
- primary: 8.2 meters curvature radius
- Size 0.85 m face to face
- secondary: 2.1 meters curvature radius
- Primary panels thickness = 10 mm
- Secondary panels thickness = 20 mm





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