Optical Design of the 25m CCAT sub-mm wave Telescope

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Introduction

CCAT is a 25-m class submillimeter wavelength telescope designed to operate down to at least 350 μm (850 GHz). Multiple submillimeter telluric windows are consistently available from the CCAT site on Cerro Chajnantor, located 5600 m above sea level in the Atacama Desert in northern Chile. Coupled with a wide-field camera[1], the CCAT observatory would work in synergy with ALMA, delivering follow up targets to ALMA from large scale survey missions conducted with CCAT.

The optical design of the telescope has evolved throughout the years from initial concept to contract readiness.[2–5] A change in project funding and a desire for a "turnkey" telescope delivered from a reputable vendor necessitated new optical design work. In order to control costs, we explored reducing the 1° field of view to 0.5°or 0.33°and the new instrument space(s) are required to fit within the available space between the telescope's elevation bearings. We investigated solutions involving both Cassegrain, Gregorian and folded Gregorian designs. Here, we present the details of the most promising optical designs for the project, including diffraction limited performance, for the best configurations.

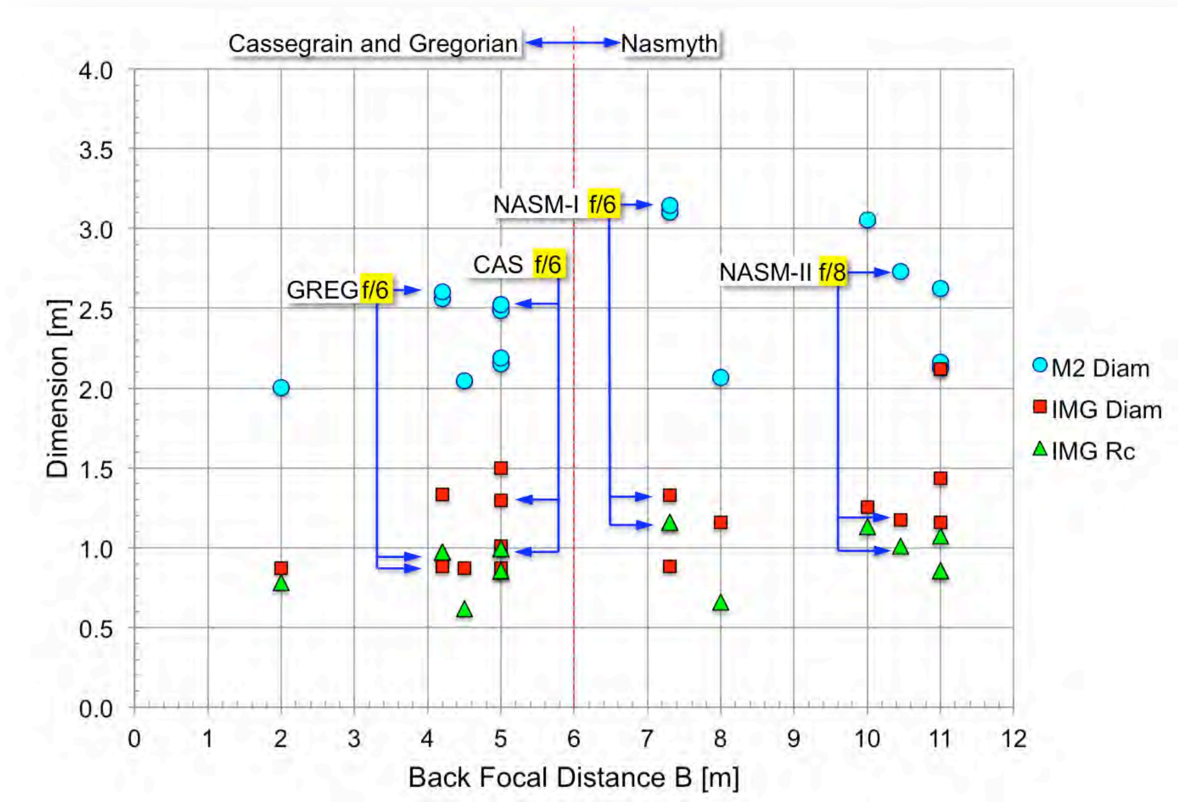

Fig.1 **25-m class sub-mm telescope** optical design tradeoff study: sub-reflector diameter (D_2), Image surface diameter (D_{img}) and radius of curvature of the image surface (Rc_{img}) as a function of back focal distance B for the different optical designs used in the trade-off study. A smaller D_2 is preferred for structural reasons but a larger Rc_{img} is required for the instrumentation to minimize focal plane curvature and take advantage of the full field of view.

Vertex and MTM

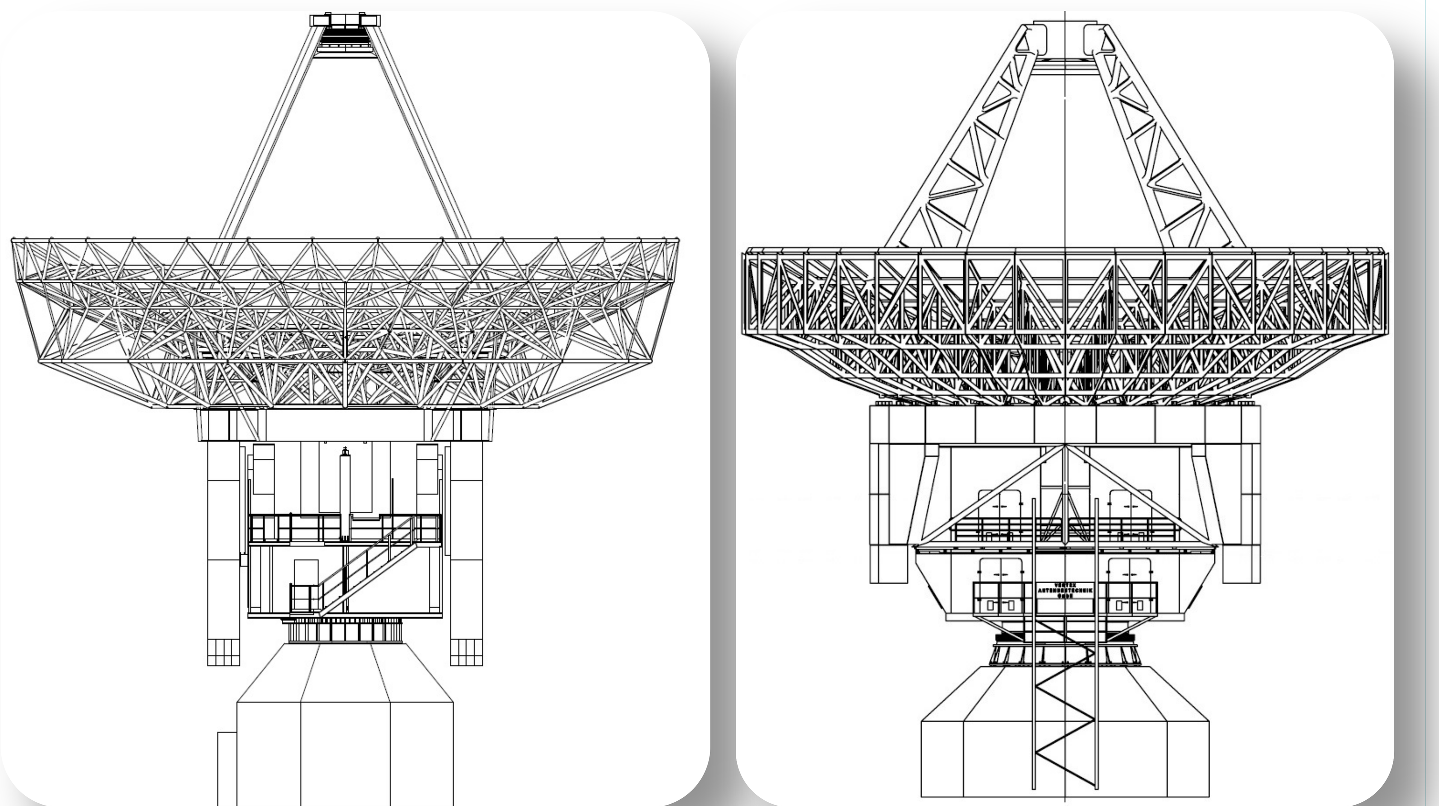

Fig.2 **Structural concepts** for the CCAT 25-m telescope with instrumentation contained within the zone between elevation bearings. *Left*: **MT Mechantronics GmbH, f/6 Gregorian**, (20' FoV). *Right*: **Vertex Antennentechnik GmbH, f/6 Nasmyth-I**, (20' FoV).

Cassegrain and Gregorian

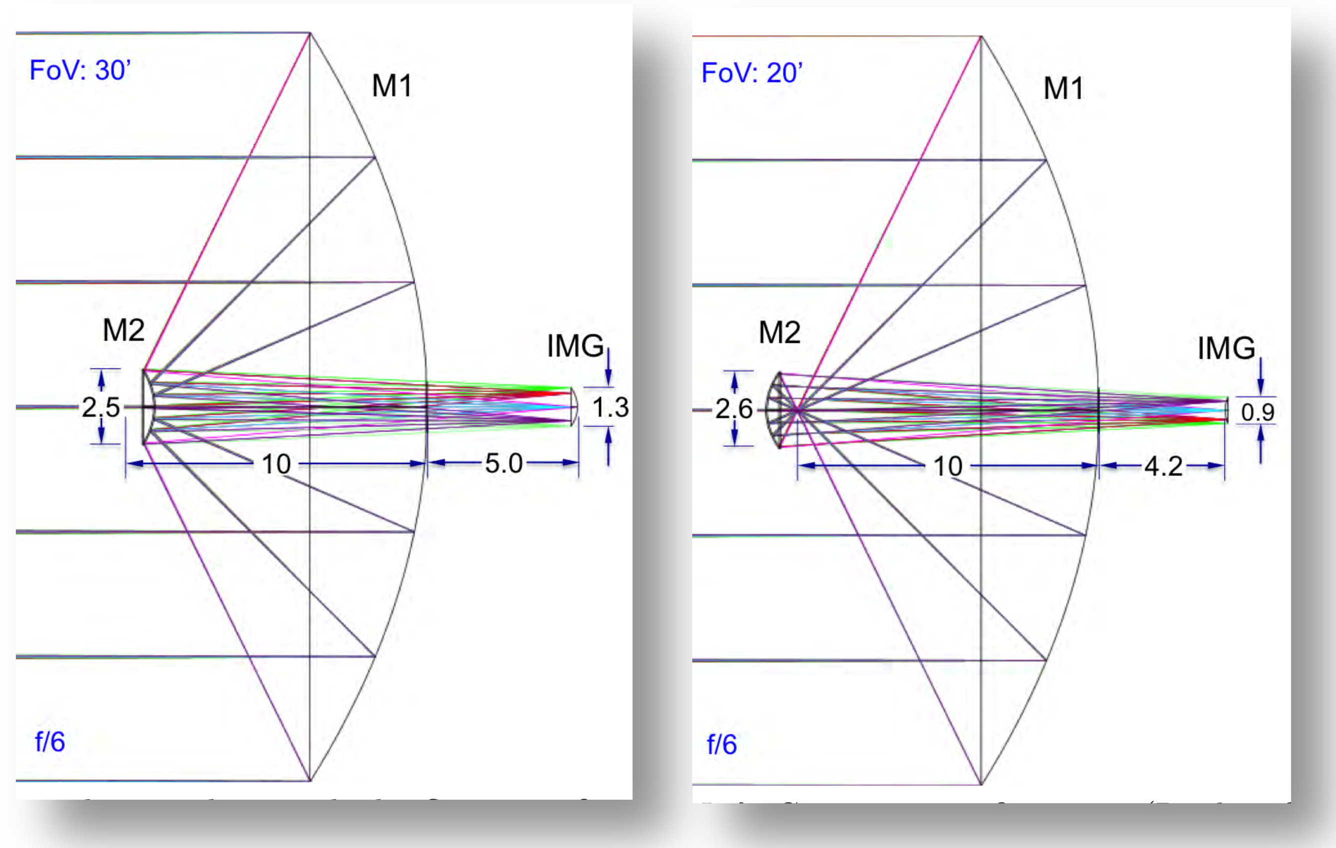

Fig.3 **Dual reflector** configurations for 25-m class sub-mm telescope *Left:* **Cassegrain configuration** (Ritchey-Cretien) for a 0.5°FoV. *Right:* **Gregorian Configuration (Aplanatic)** with a 20' FoV. The Cassegrain option was eventually discarded due to the difficulty of figuring such a large convex optic, and emphasis was given to Gregorian options.

Optical Performance I

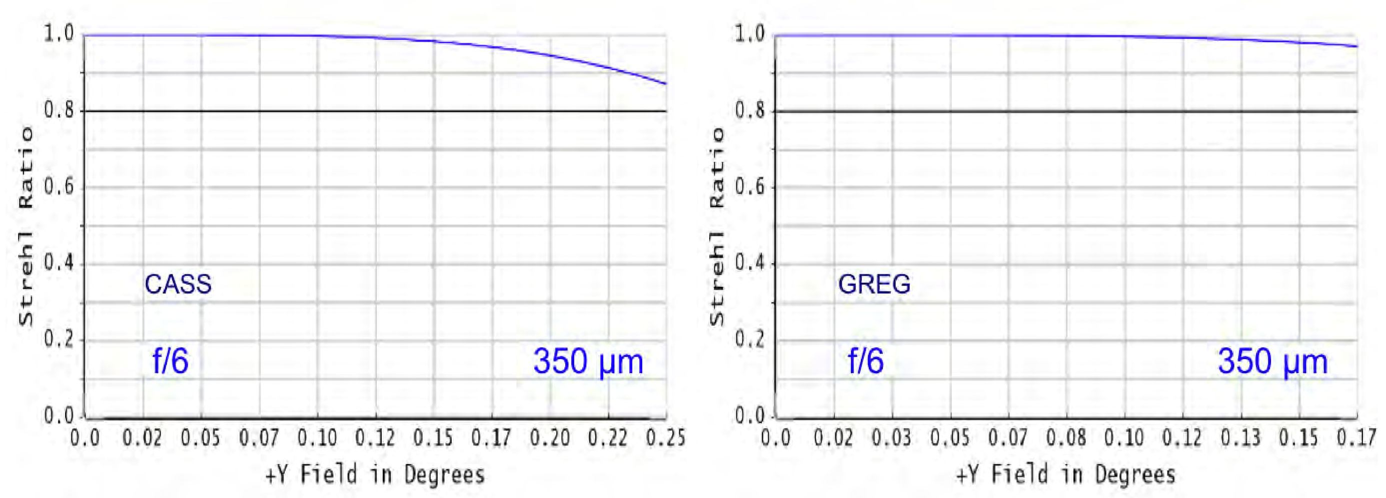

Fig.4 **Strehl ratio** as a function of field of view radius at 350 μm. (The horizontal line indicates the diffraction limit) *Left*: **f/6 Cassegrain** configuration, (30' FoV). *Right*: **f/6 Aplanatic Gregorian** configuration, (20' FoV). Both configurations show acceptable performance.

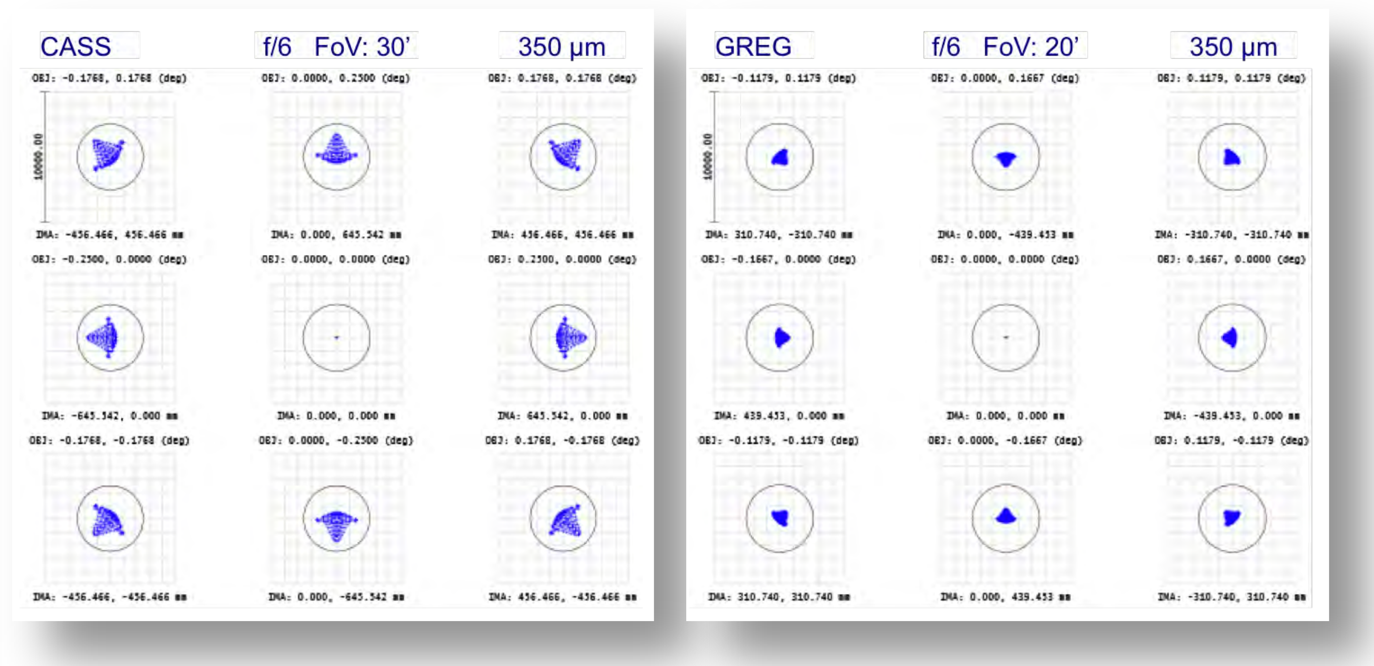

Fig.5 **Spot diagrams** in the field of view of the Cassegrain and Gregorian configurations. The Airy spot size at 350 μm is indicated by the circle. *Left*: **f/6 Cassegrain** configuration, (30' FoV). *Right*: **f/6 Aplanatic Gregorian** configuration, (20' FoV). Again, both configurations show acceptable performance across the field of view.

G-Nasmyth I and G-Nasmyth-II

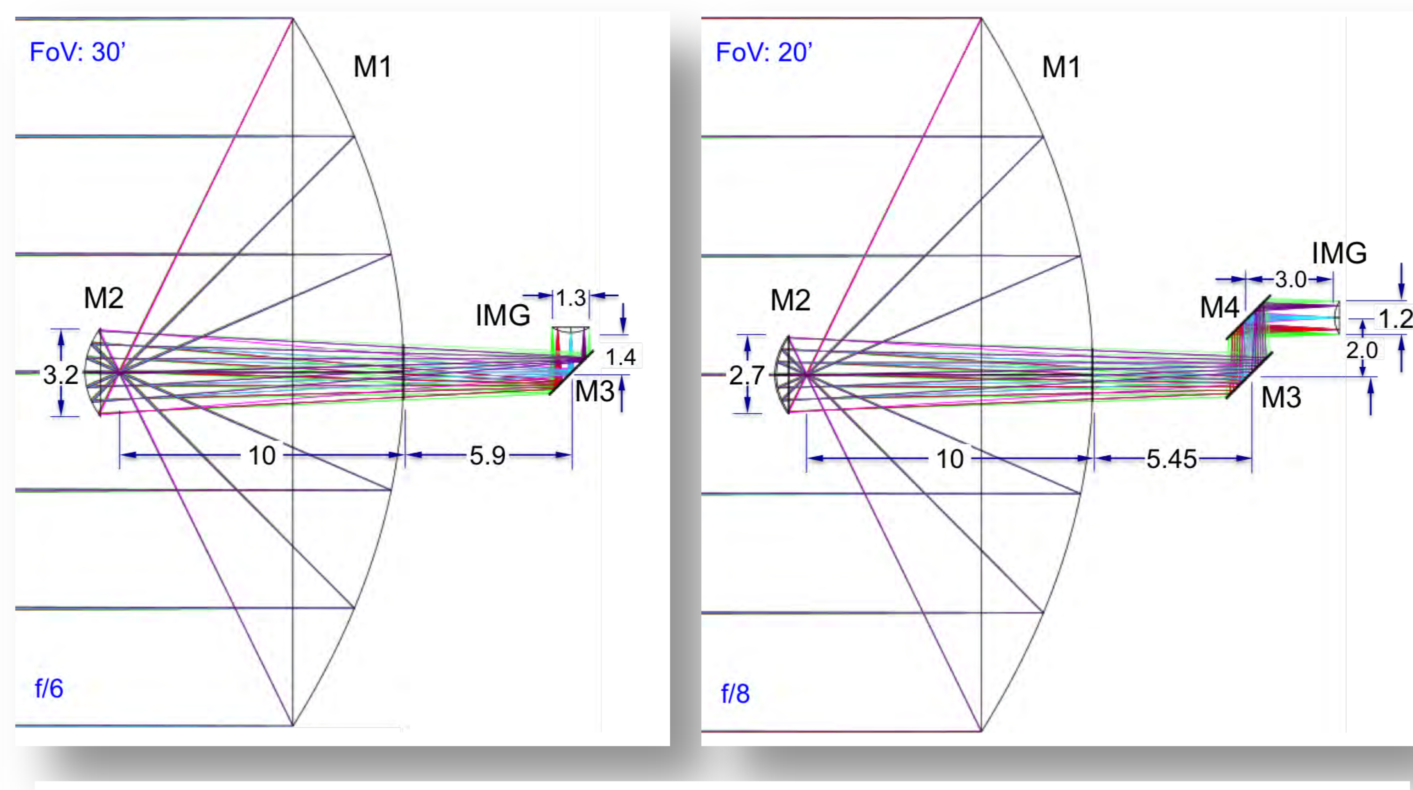

Fig.6. **Gregorian Aplanatic design for two Nasmyth** configurations: *Left*: **Nasmyth-I** with a tertiary flat elliptical mirror **M3**. *Right*: **Nasmyth-II**, with two additional **M3 and M4** flat elliptical mirrors.

Optical Performance II

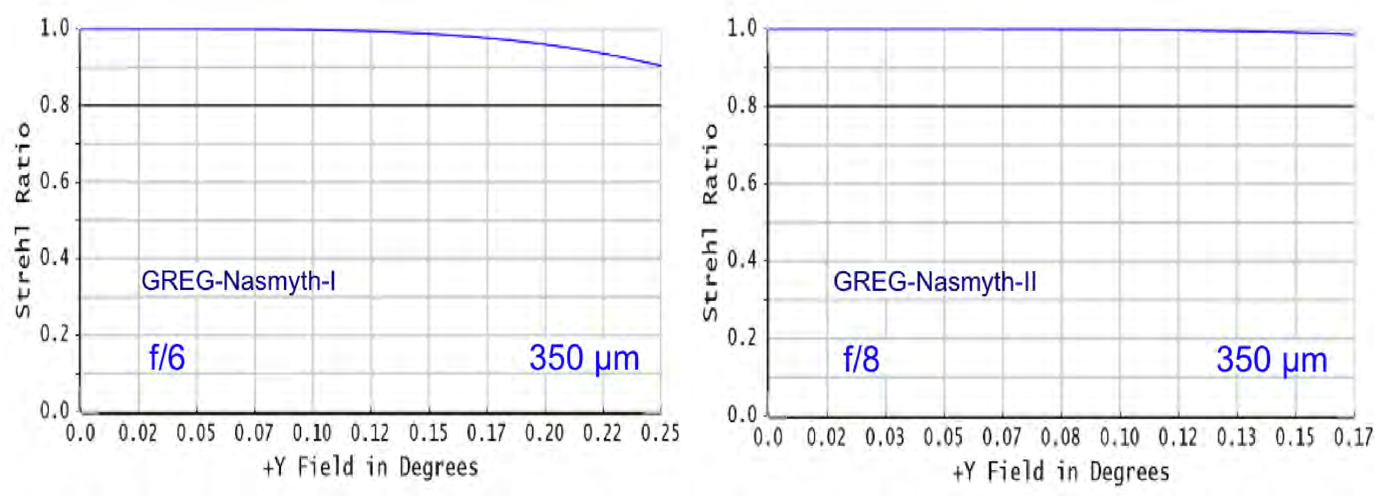

Fig.7 **Strehl ratio** as a function of field of view radius at 350 μm for both planatic Gregorian Nasmyth configurations. (The horizontal line indicates the diffraction limit) *Left*: f/6 Nasmyth-I, (30' FoV). *Right*: f/8 Nasmyth-II, (20' FoV).

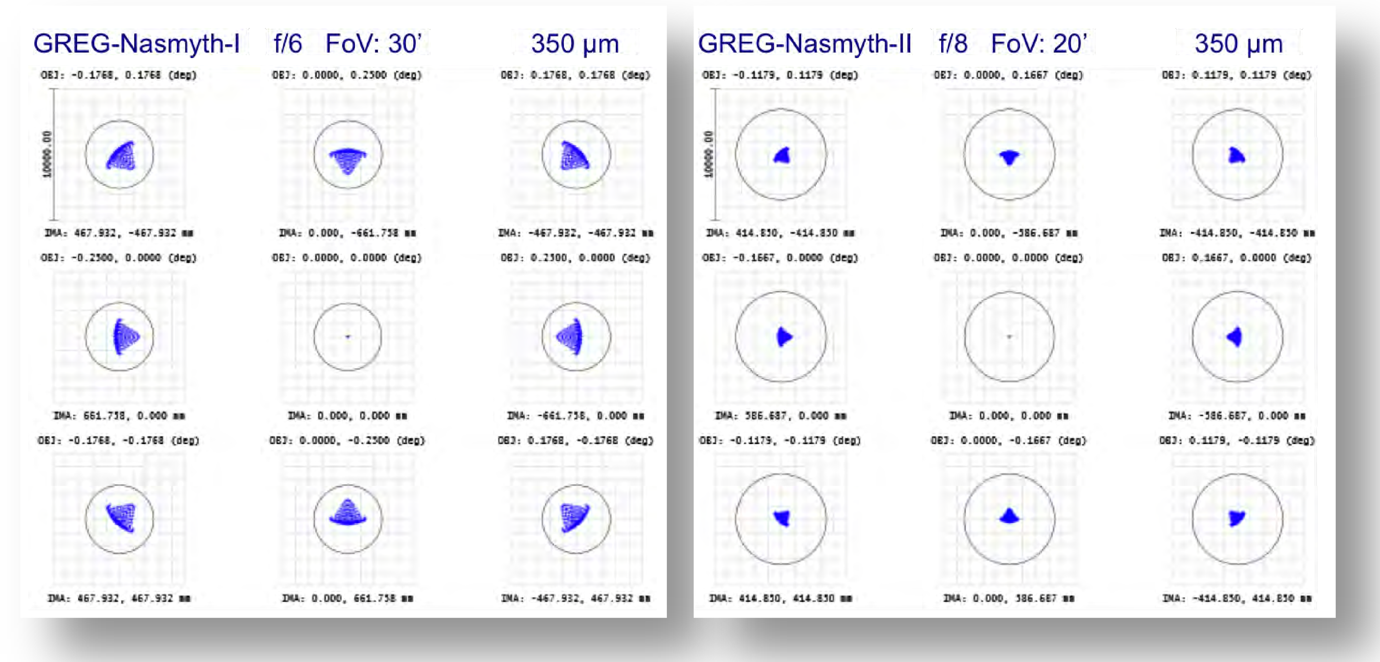

Fig.8 **Spot diagrams** in the field of view for the aplanatic Gregorian Nasmyth configurations. The Airy spot size at 350 μm is indicated by the circle. *Left*: **f/6 Nasmyth-I**, (30' FoV). *Right*: **f/8 Nasmyth-II**, (20' FoV)..

Conclusions

The four final configurations from an optical design study for the CCAT telescope have been presented. Dual reflector Cassegrain and Gregorian systems are possible, as are Gregorian Nasmyth and quasi-Nasmyth options. All configurations deliver diffraction limited performance at 350 μm within a relatively compact arrangement, compatible with available telescope structural options, and enabling the placement of facility instrumentation within the elevation bearings. Thus reducing cost and complexity for the project while still providing strong scientific potential..

REFERENCES

[1]Stacey, G, Parshley, T. Nikola, G. Cortes-Medellin., Parshley, S., Stacey, G., Dowell, D., McKenney, C., Golwala, S. "SWCam: the short wavelength camera for the CCAT observatory". SPIE International Sympo- sium on Astronomical Instrumentation. Vol VII Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation for Astronomy, 91532Z (July 23, 2014).

[2]Woody, D., Padin, S., Chauvin, E., Clavel, B., Cortes, G., Kissil, A., Lou, J., Rasmussen, P., Redding, D., and Zolkower, J., "The CCAT 25m diameter submillimeter-wave telescope", Ground-based and Airborne Telescopes IV. Proc. SPIE 8444, Ground-based and Airborne Telescopes IV, 84442M (Sep, 2012).

[3]Padin, S., Hollister, M., Radford, S., Sayers, J., Woody, D., Zmuidzinas, J., Cortes-Medellin, G., Sebring, T., Stacey, G. "CCAT Optics". SPIE International Symposium on Astronomical Instrumentation, Proc. SPIE 7733, Ground-based and Airborne Telescopes III, 77334Y (August 05, 2010).

[4]Cortes-Medellin, G. and Herter, T., "Optical Design of CCAT", SPIE International Symposium on Astro- nomical Instrumentation. Orlando, FL. Proc. SPIE 6267, Ground-based and Airborne Telescopes, 62672F (June 23, 2006).

[5]Cortes-Medellin, G., "Optical Design of the Cornell-Caltech Large Sub-Millimeter Atacama Telescope CCAT", 2005 IEEE Antenna and Propagation Symposium, Washington DC, July 2005.*e*

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