TALC

A Sub-Arcsecond FIR observatory

AIM
ASTROPHYSIQUE INTERACTIONS MULTI-ÉCHELLES

DE LA RECHERCHE À L'INDUSTRIE
cea

TALC

What a “single-dish” in space can do…

AIM
ASTROPHYSIQUE INTERACTIONS MULTI-ÉCHELLES

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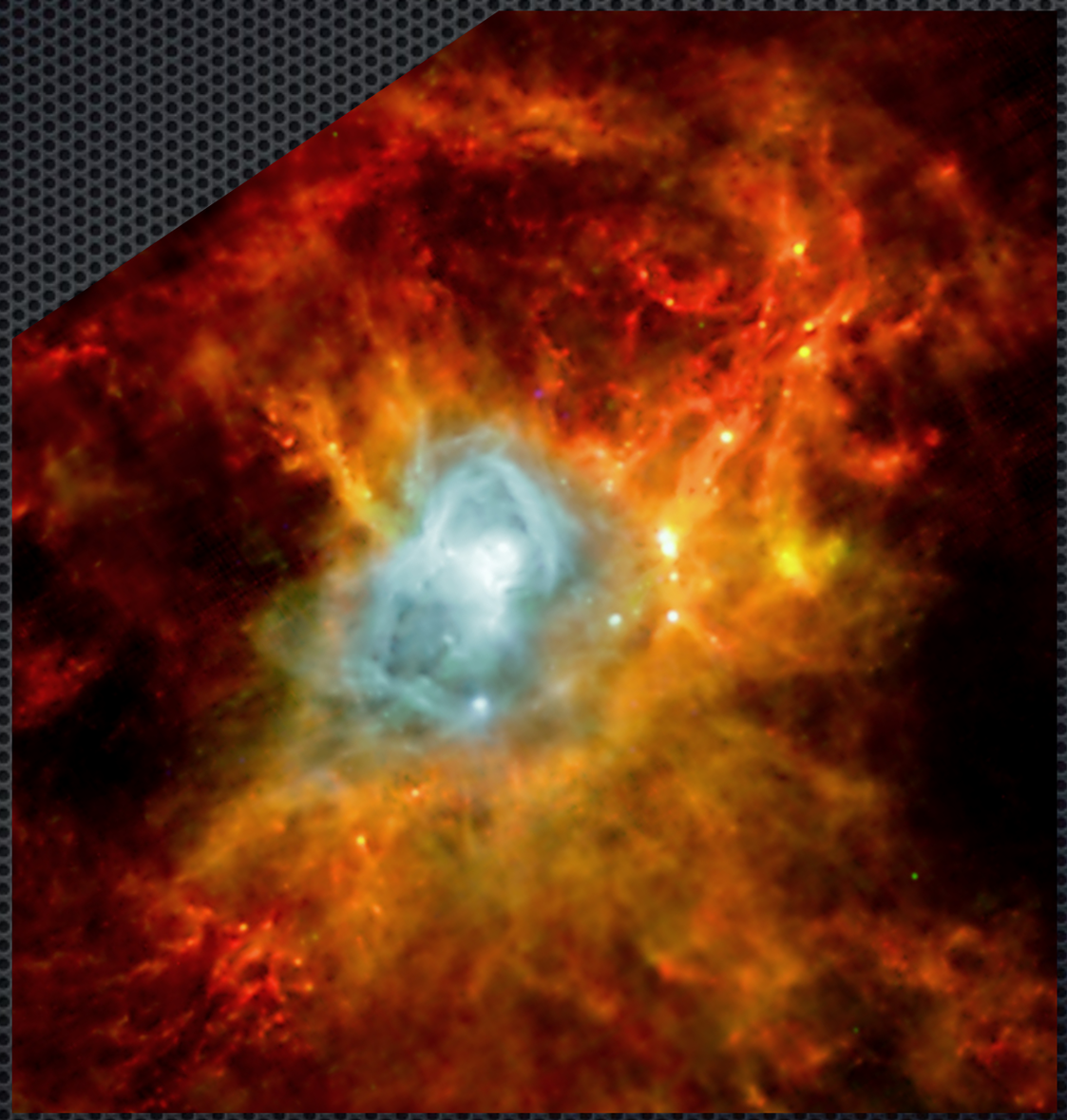
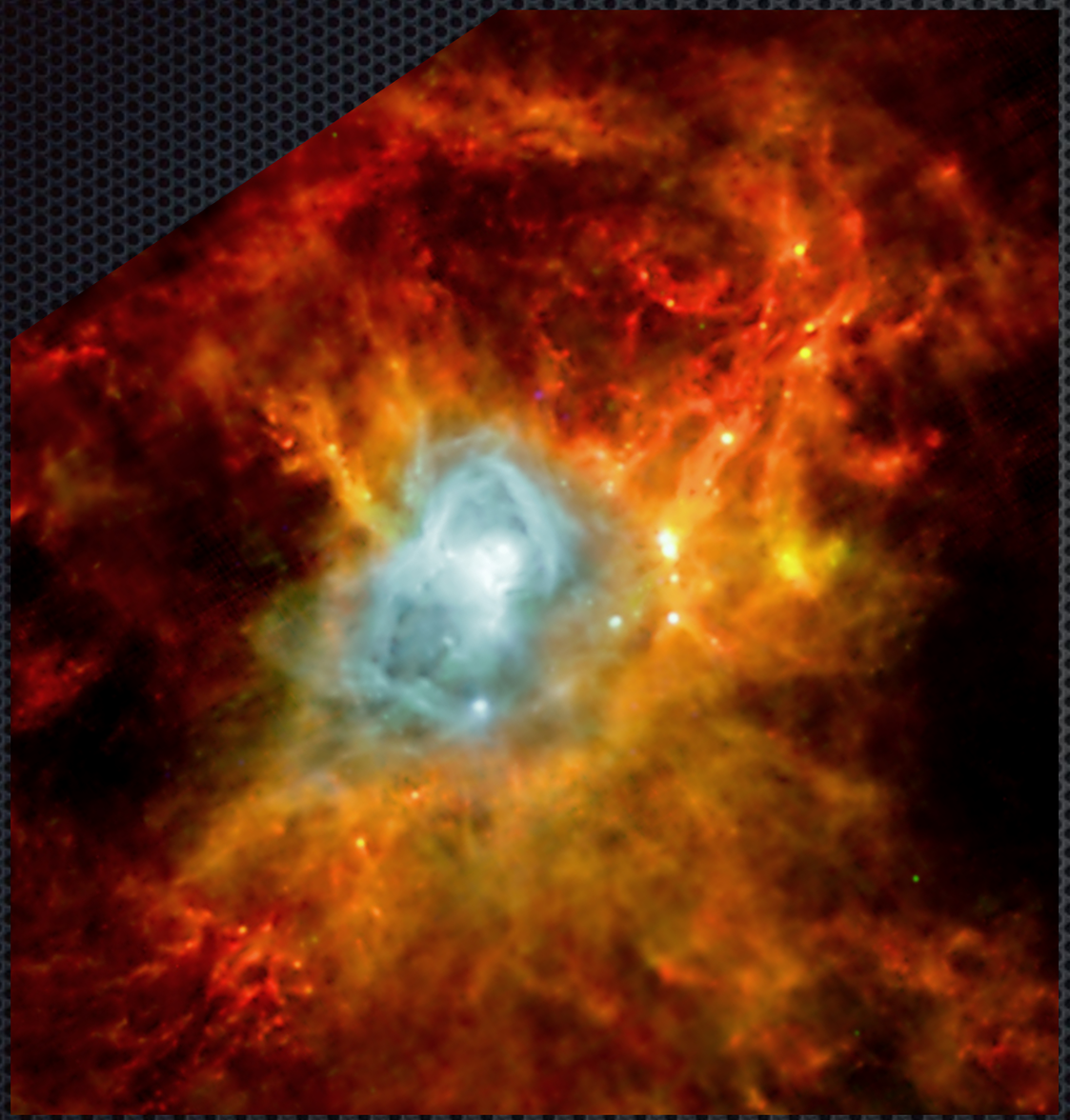
Quantitative analysis from imaging in the FIR



Aquila

Quantitative analysis from imaging in the FIR



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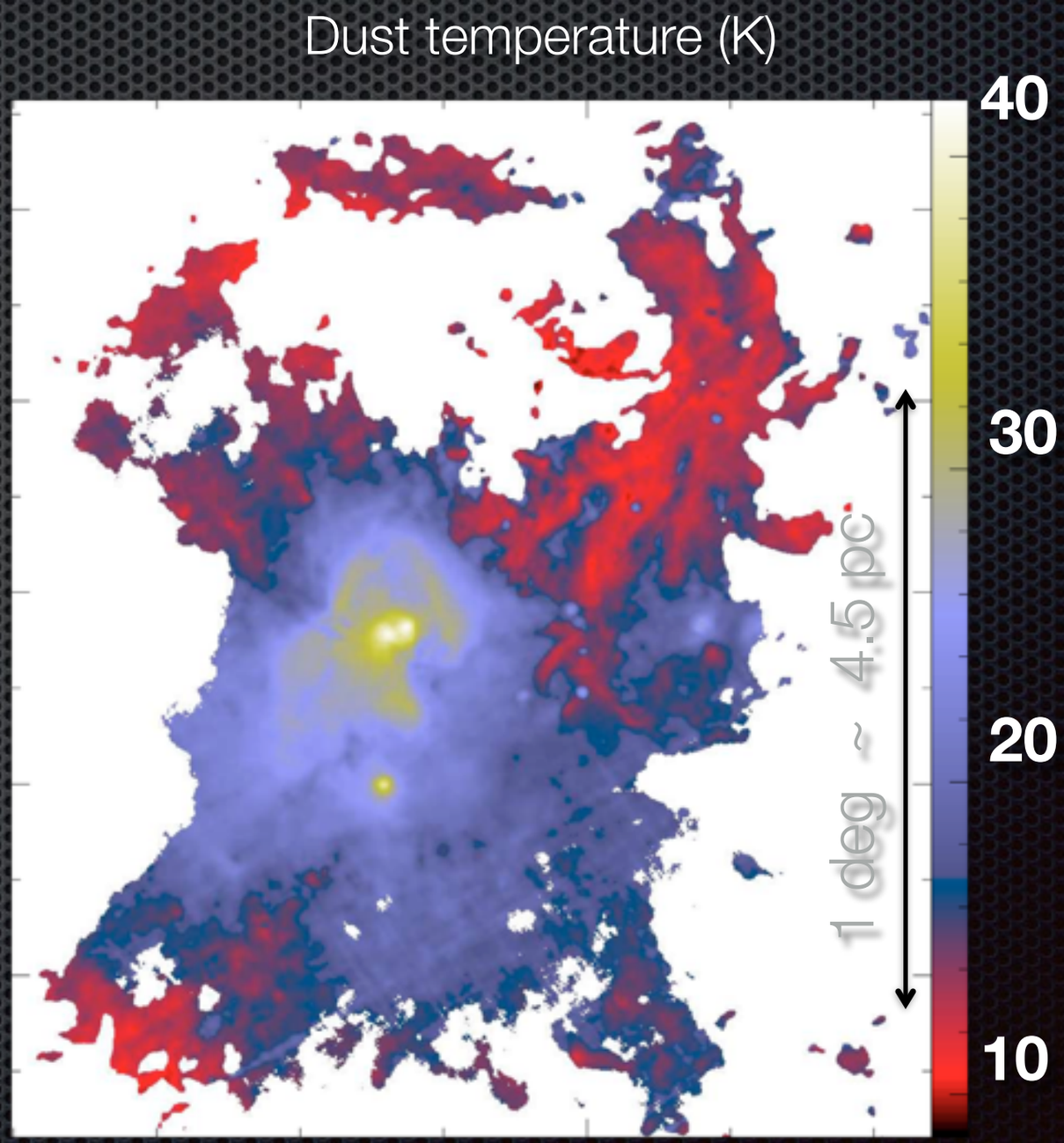
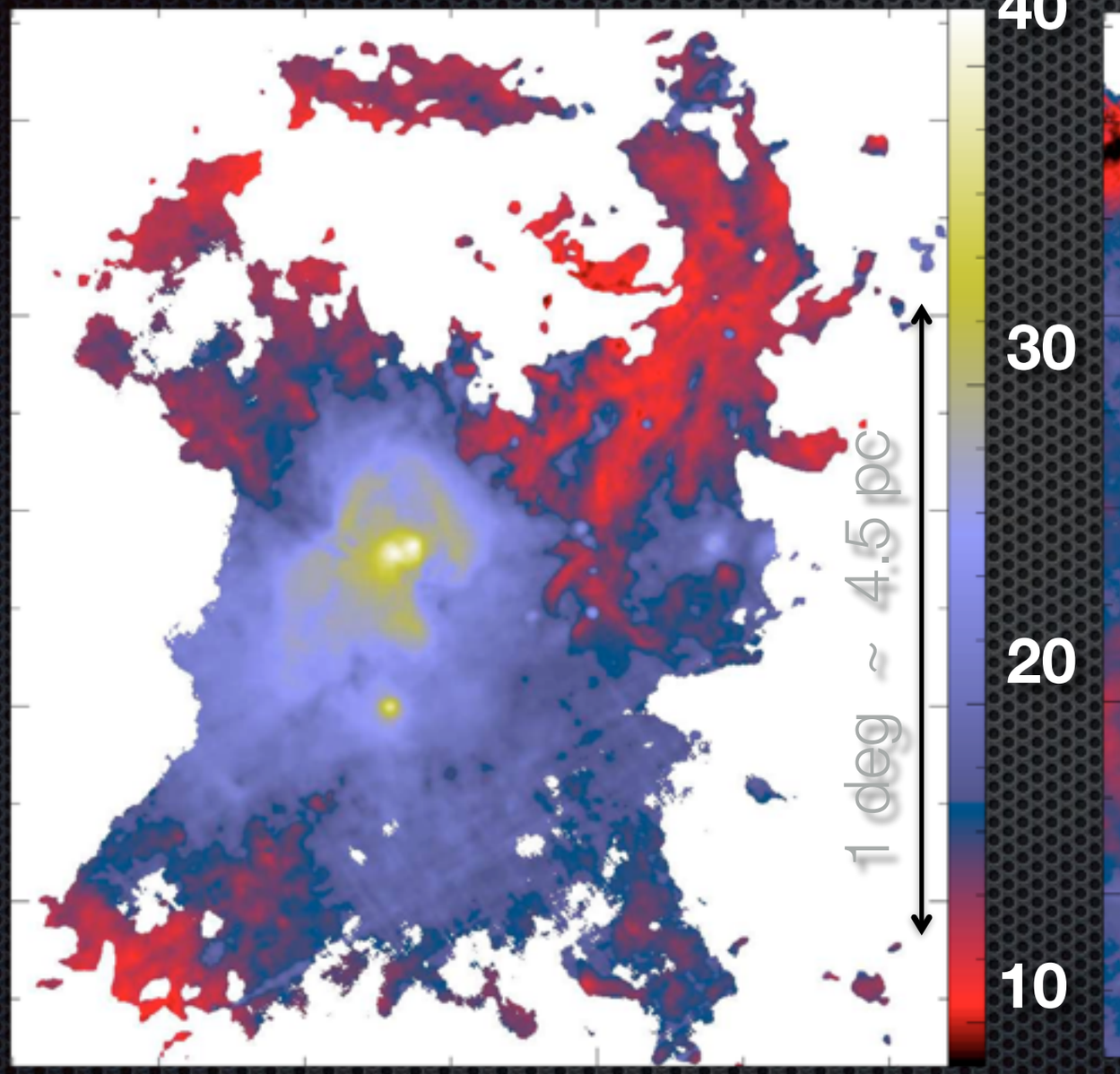
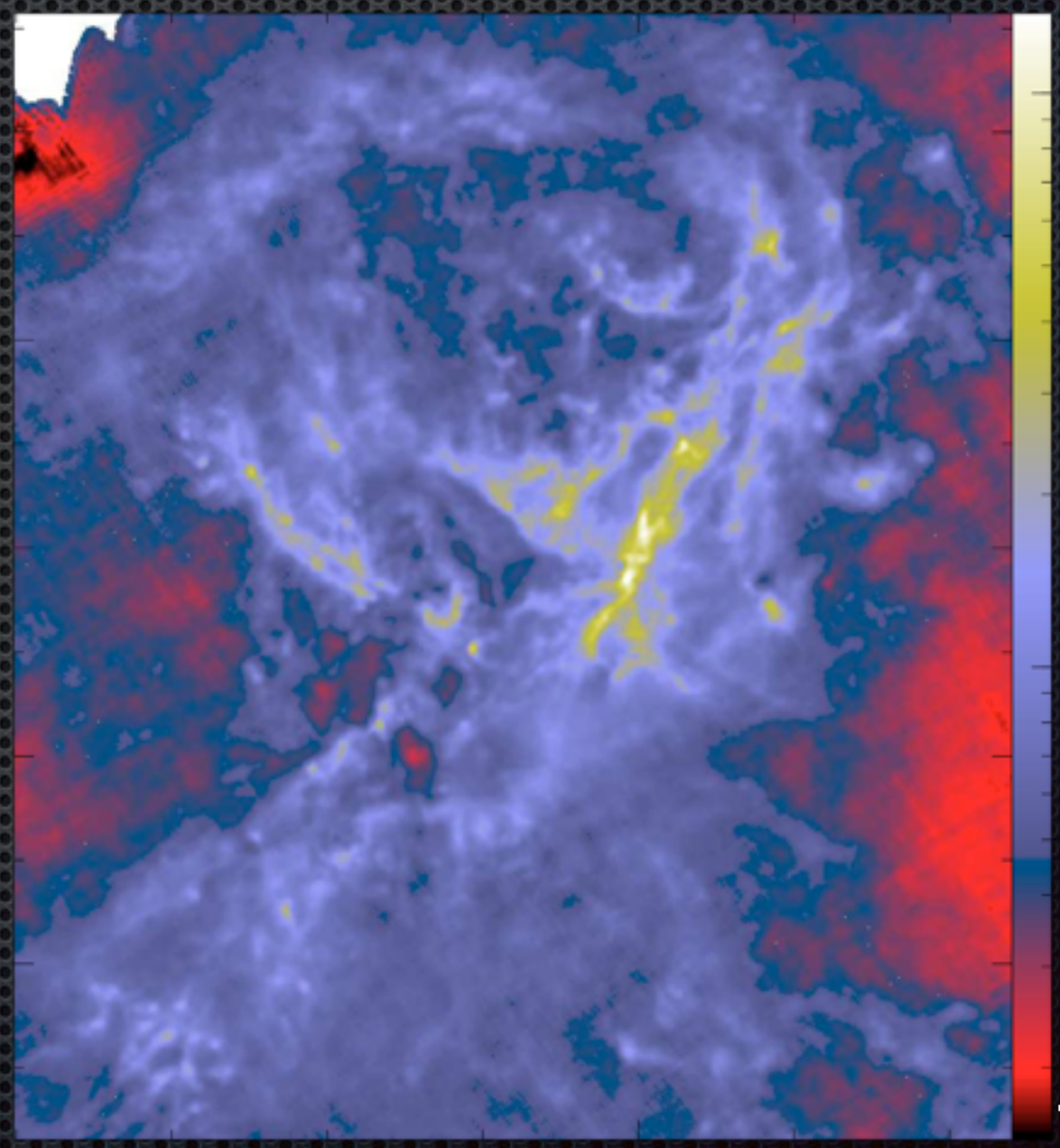


Quantitative analysis from imaging in the FIR

Dust temperature (K)



Column Density (H_2/cm^2)

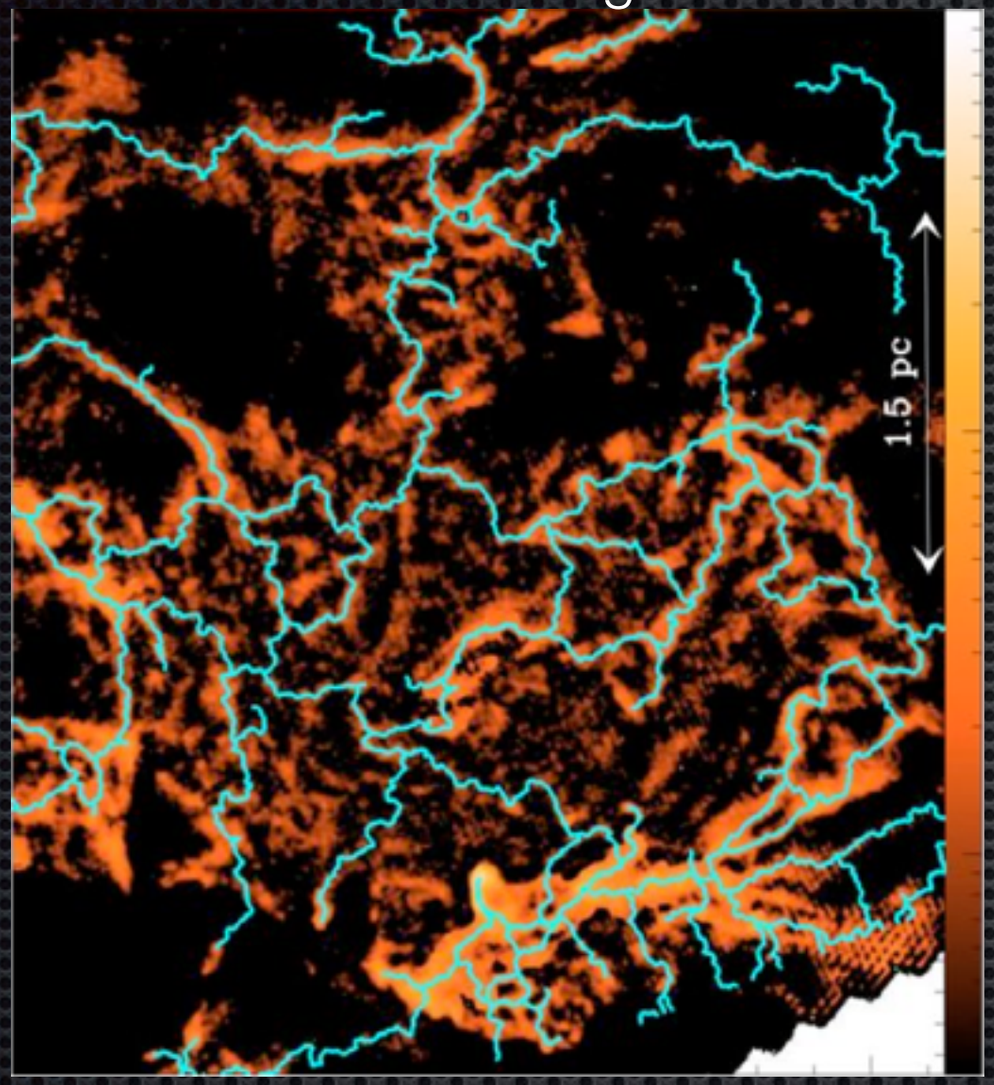


Aquila

Filamentary networks in all observed interstellar clouds

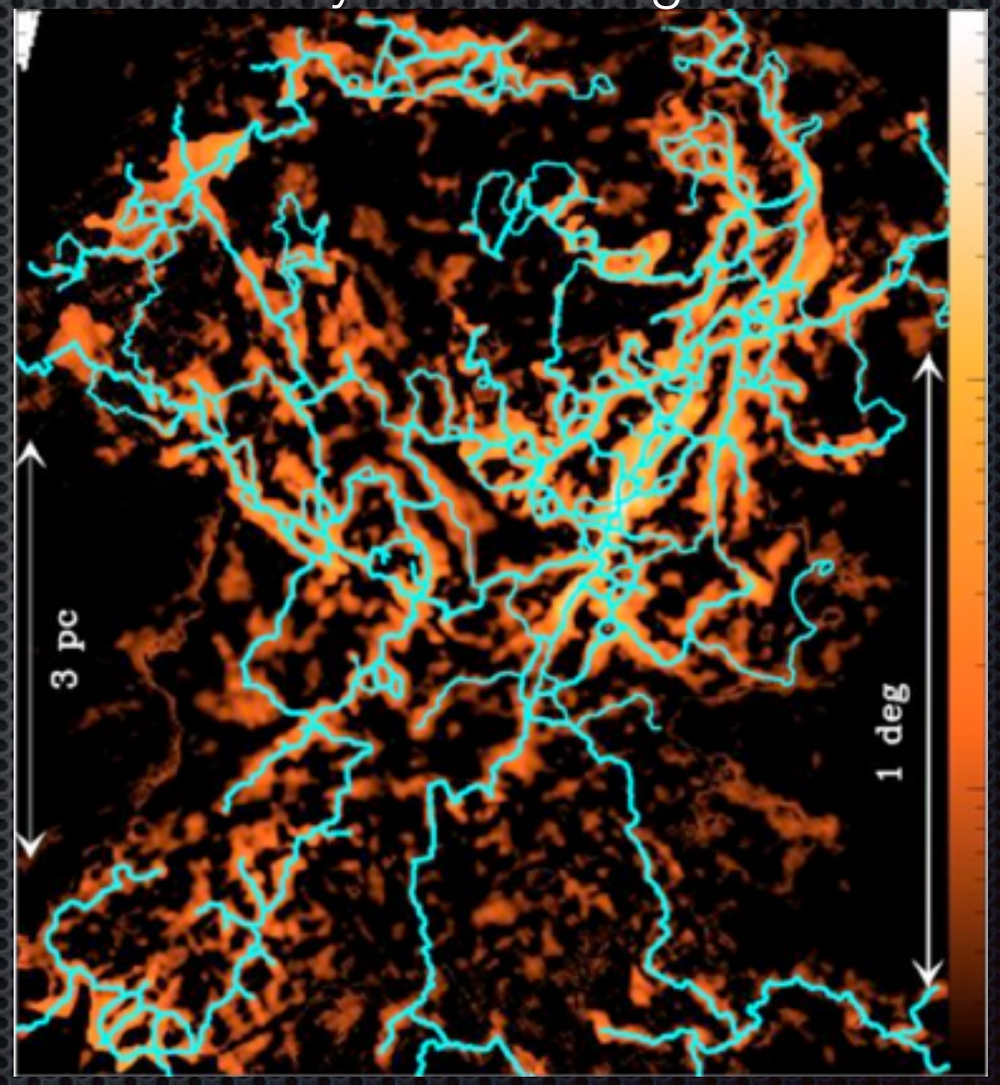
Detection and physical characterization of filaments through mathematical connexion studies

Non star-forming cloud



Filament network in Polaris

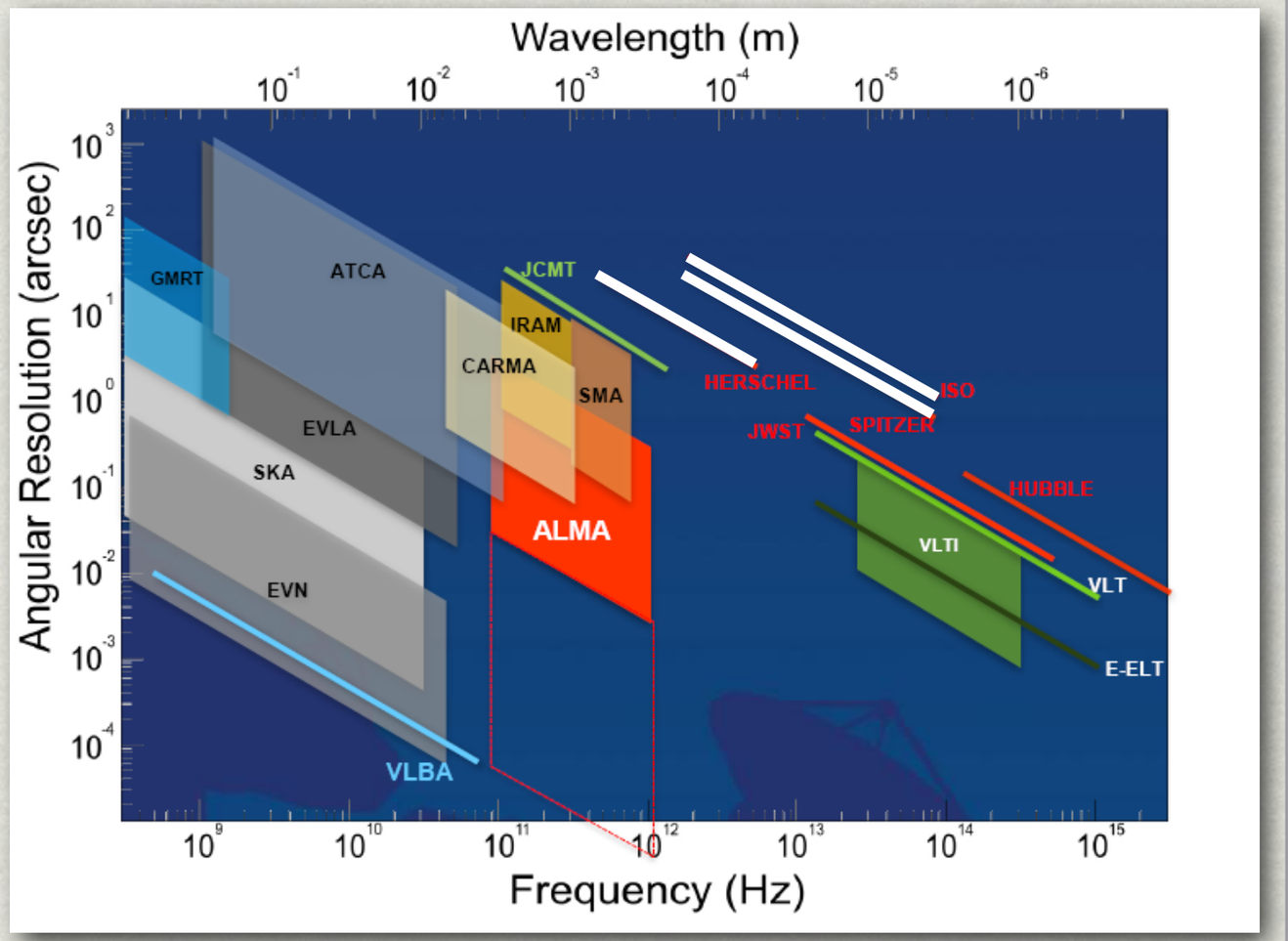
Actively star forming cloud



Filament network in Aquila

The sub-arcsecond imperative

- The FIR gap:
- 1" is a critical scale to build appropriate paradigms for:
  - planet formation and habitability,
  - galaxy evolution,
  - star formation.



1" is..	100 AU at 100 pc	0.1 pc at 20 kpc	100 pc at 20 Mpc	1 kpc at 200 Mpc
	"Kuiper" belt radius in Fomalhaut	star forming filament anywhere in the Galaxy	Narrow Line Region in AGN	Star-forming complex in luminous IR galaxies

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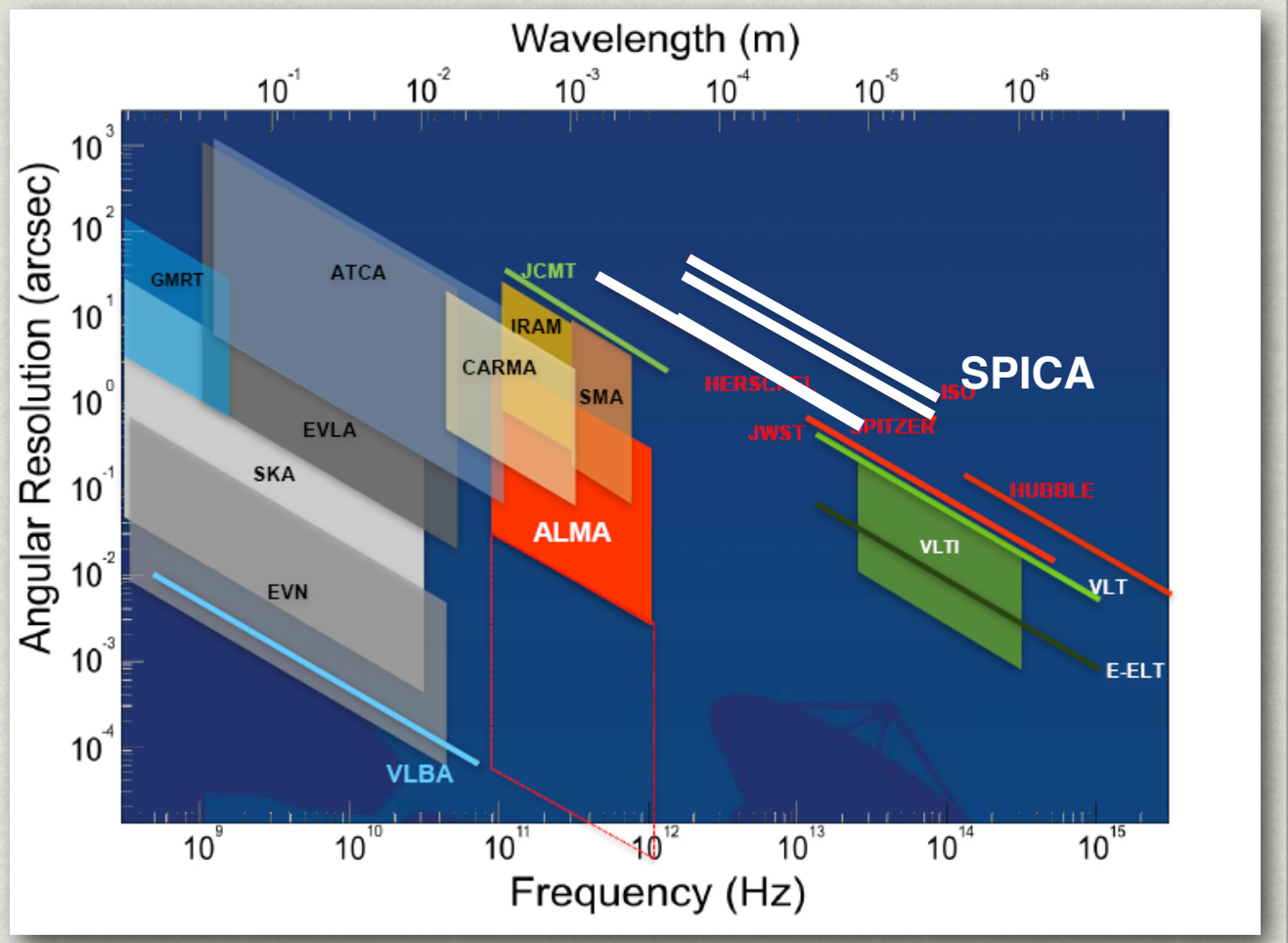

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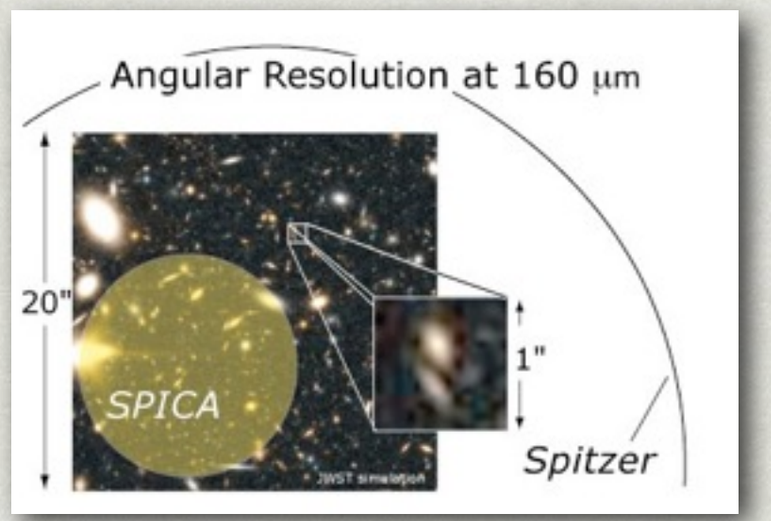
SPICA could bridge the gap in sensitivity, but
(1) its mirror is the same size as Herschel's and
(2) it now competes for M4



How does one create a large aperture in space?

Geometrical constraints

- For monolithic mirrors, the size limit is given by the fairing's width, at ~4m.
  - Note: in Europe, for the time frame beyond 2020, launcher will likely be Ariane 6, rather than Soyouz or Ariane 5.
  - According to CNES Launchers Division, Ariane 6 will accommodate similar fairings as Ariane 5, but will be less powerful.
- Solutions for large "aperture" are:
  - Folding mirrors.
  - Extendable structures.
  - Free-flying elements.
- Current folding concepts (JWST, RadioAstron, Millimetron) still have their diameter limited by one dimension of the fairing (its total length).

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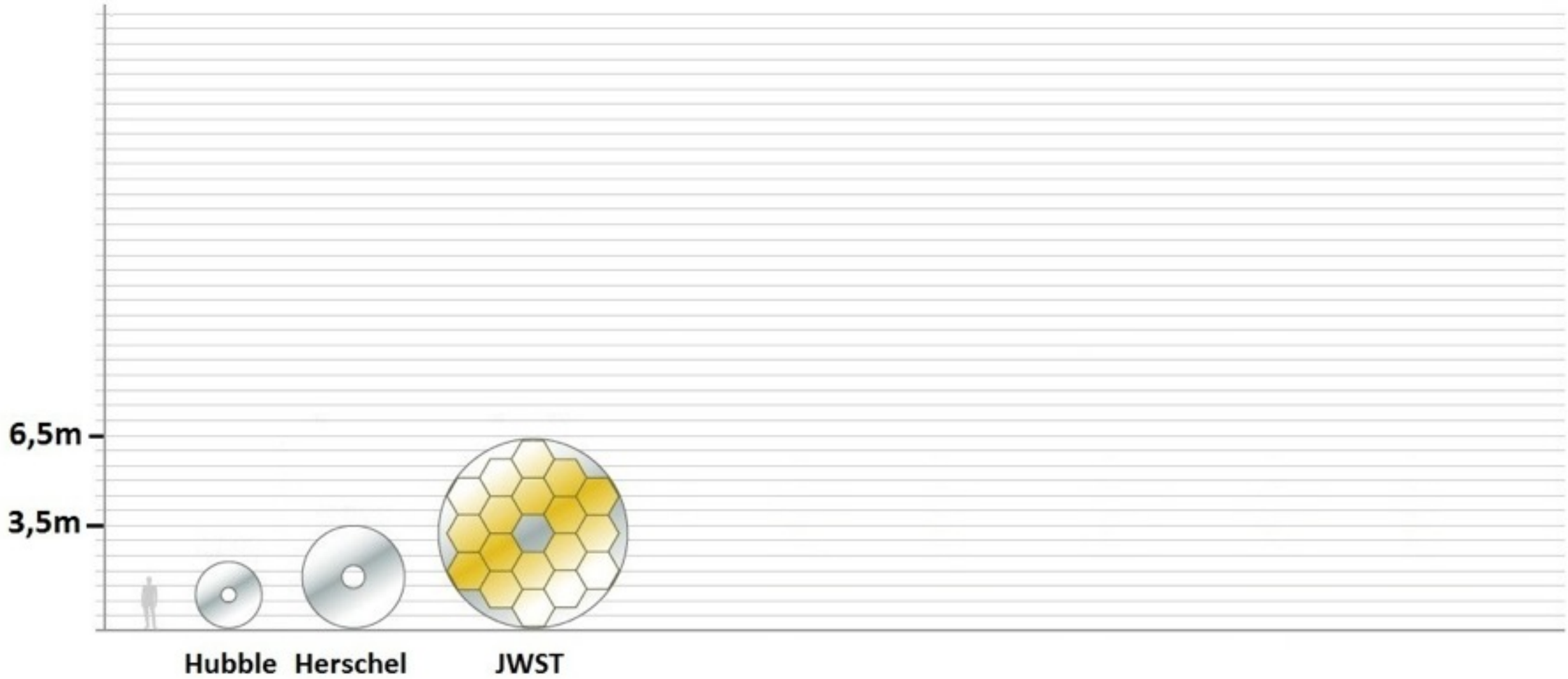
TALC is a radical departure from these concepts where the mirror diameter is no longer defined by the fairing's length.

TALC basic concepts

- To reach high sensitivity and high spatial resolution, *fast*, we need a large collecting surface, and a large outer diameter.



TALC basic concepts

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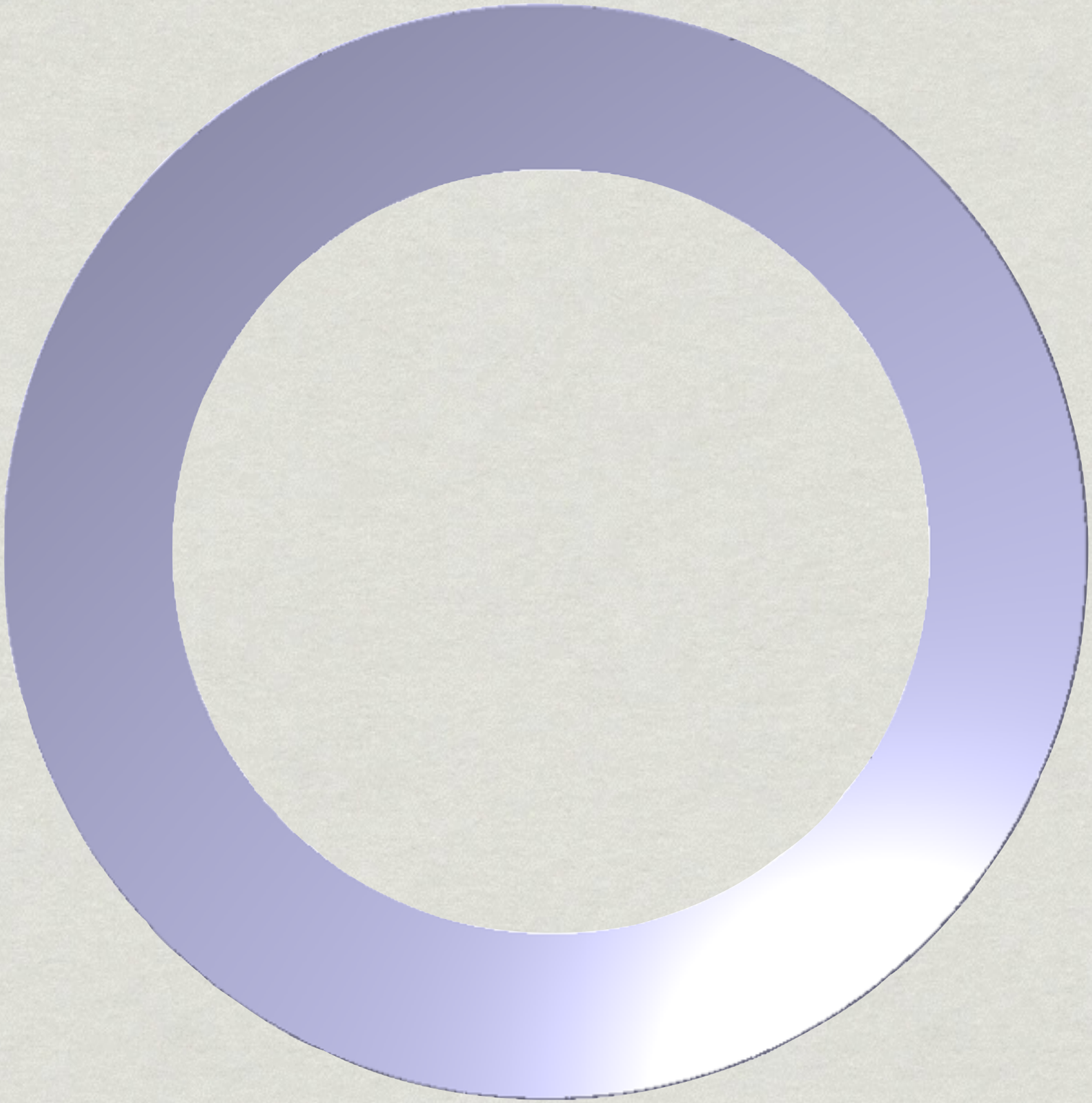
- We do not need a filled aperture…

How to fold a 20m ring…



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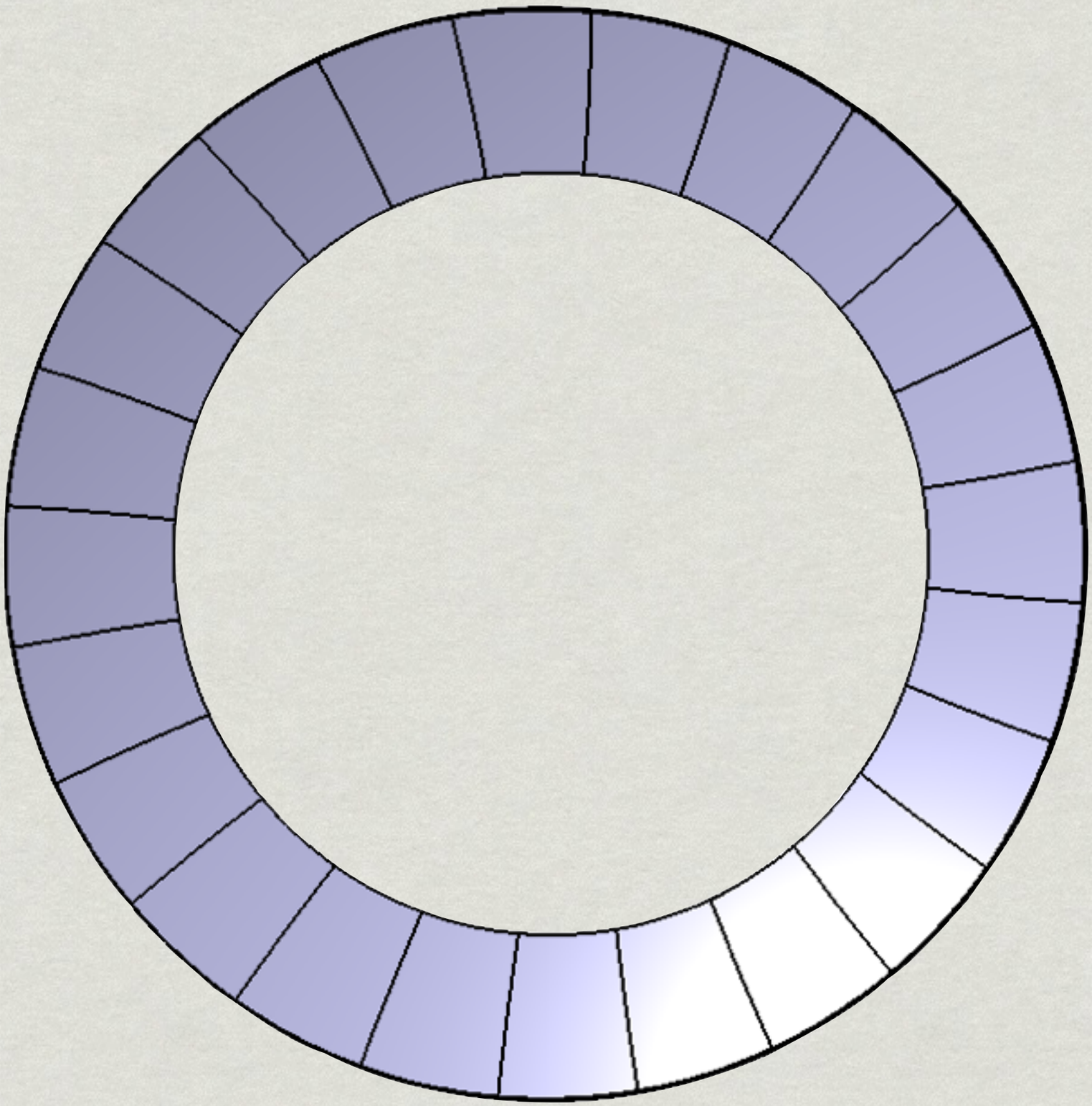

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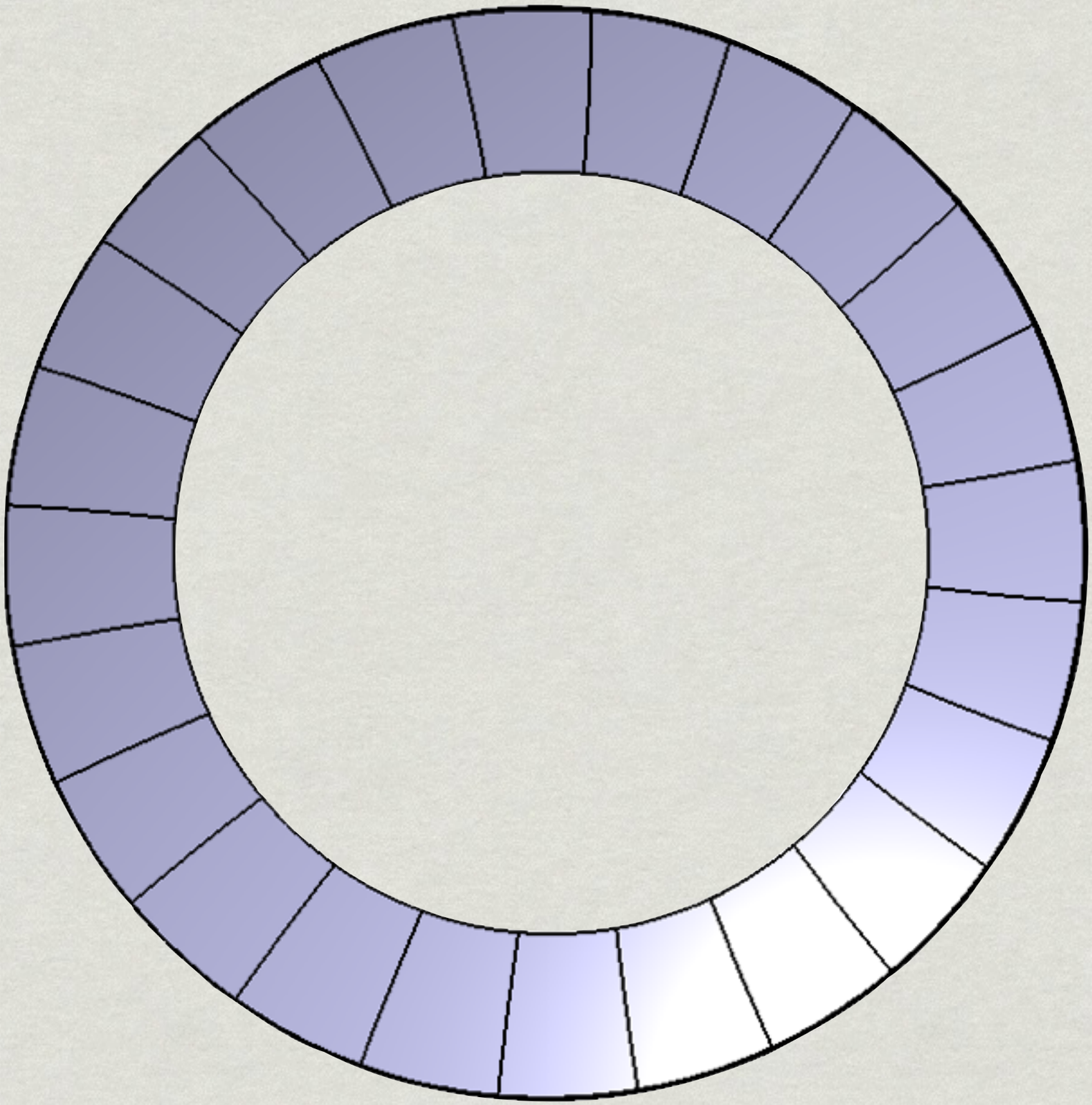

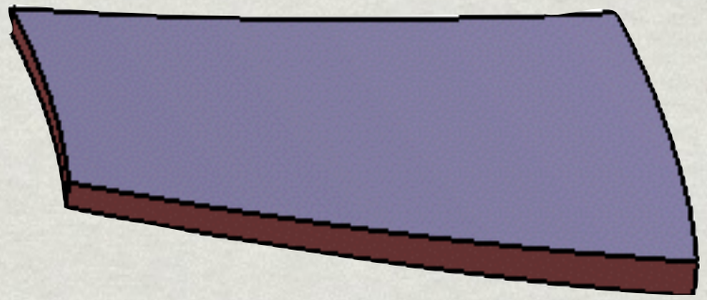

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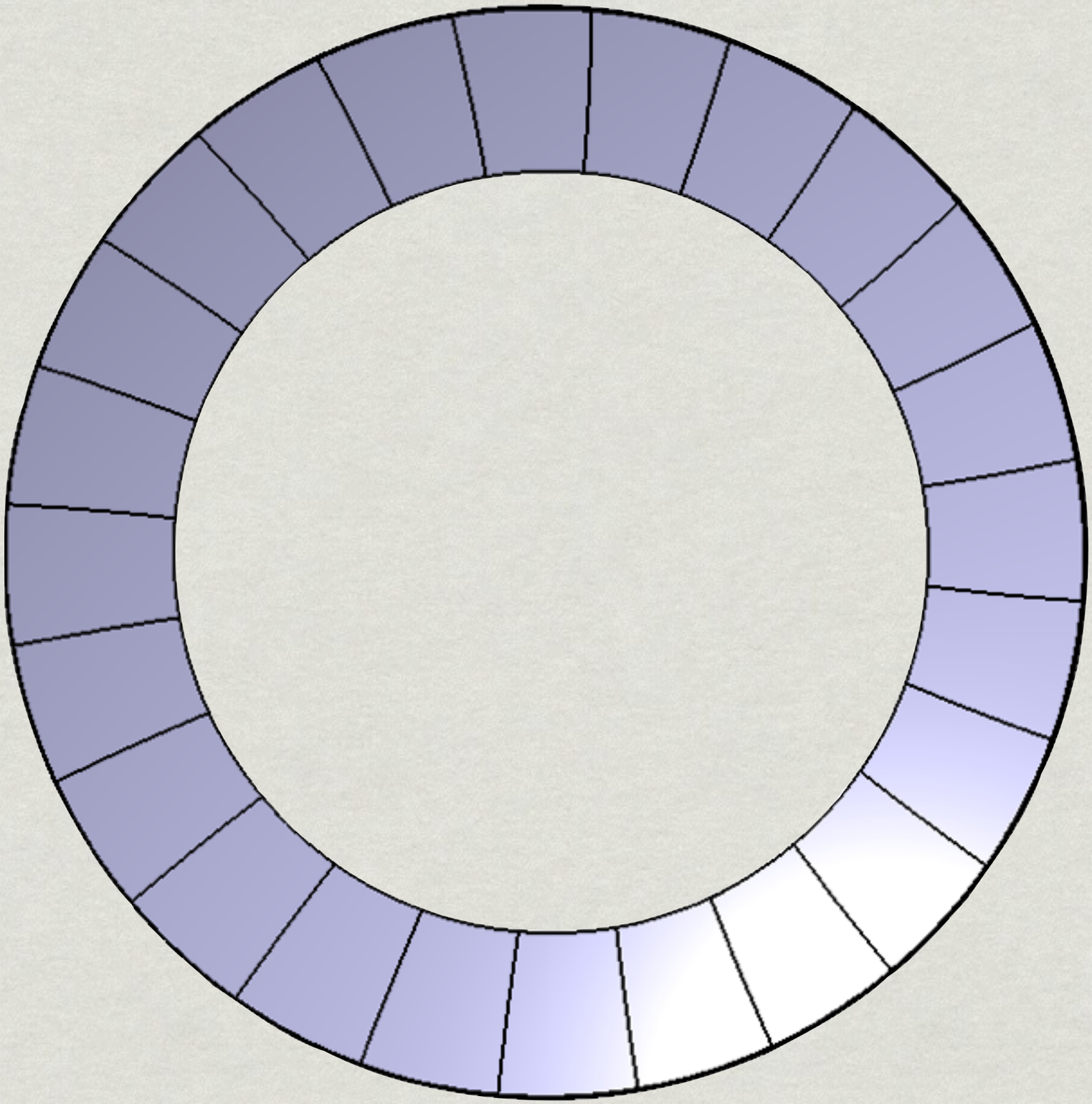

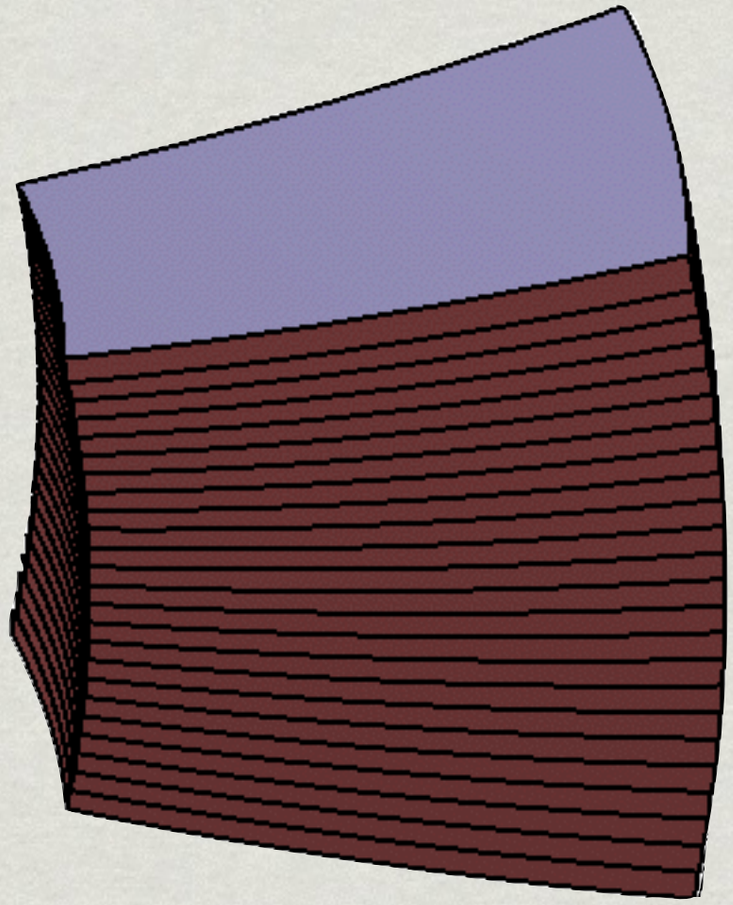

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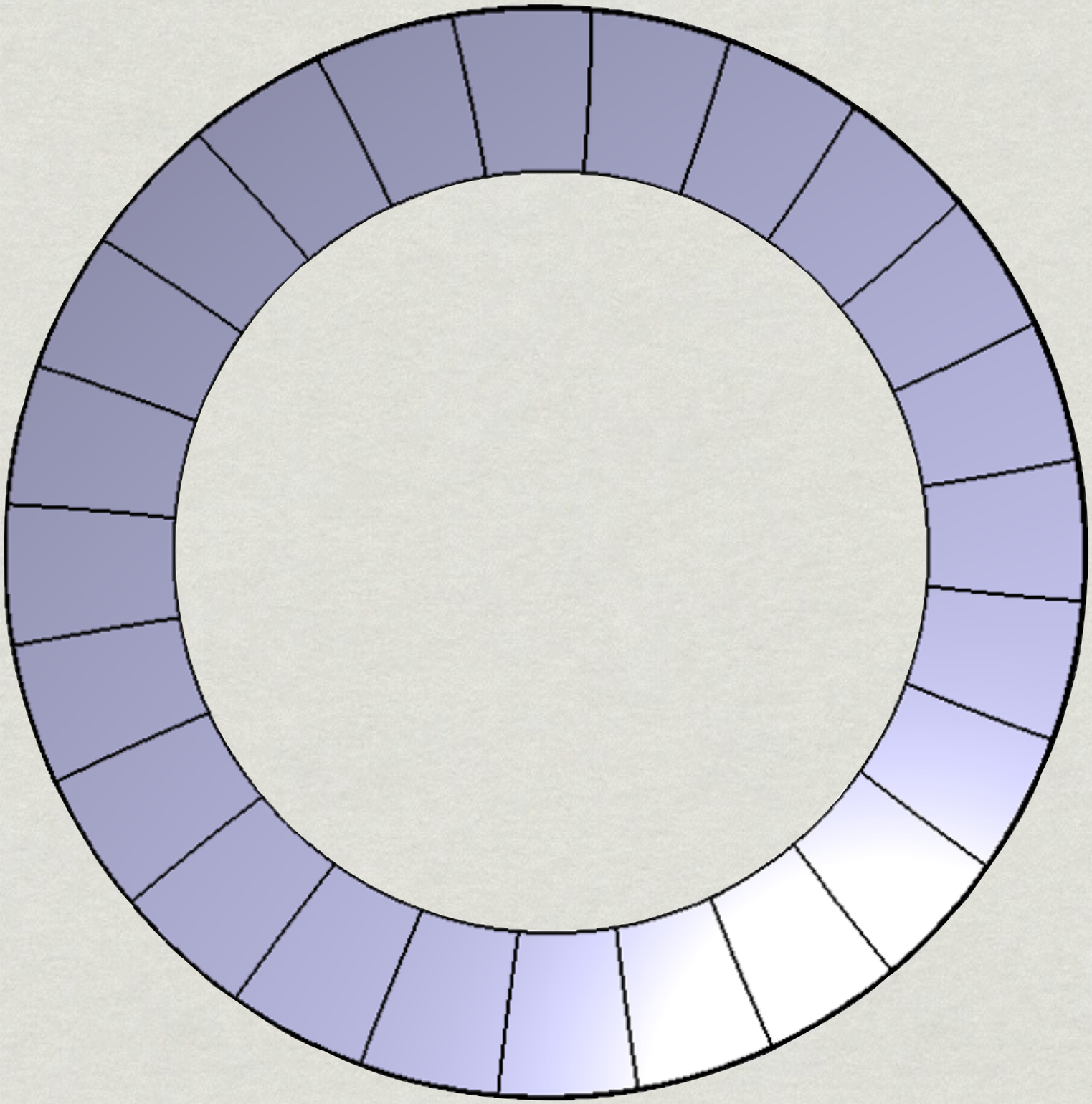
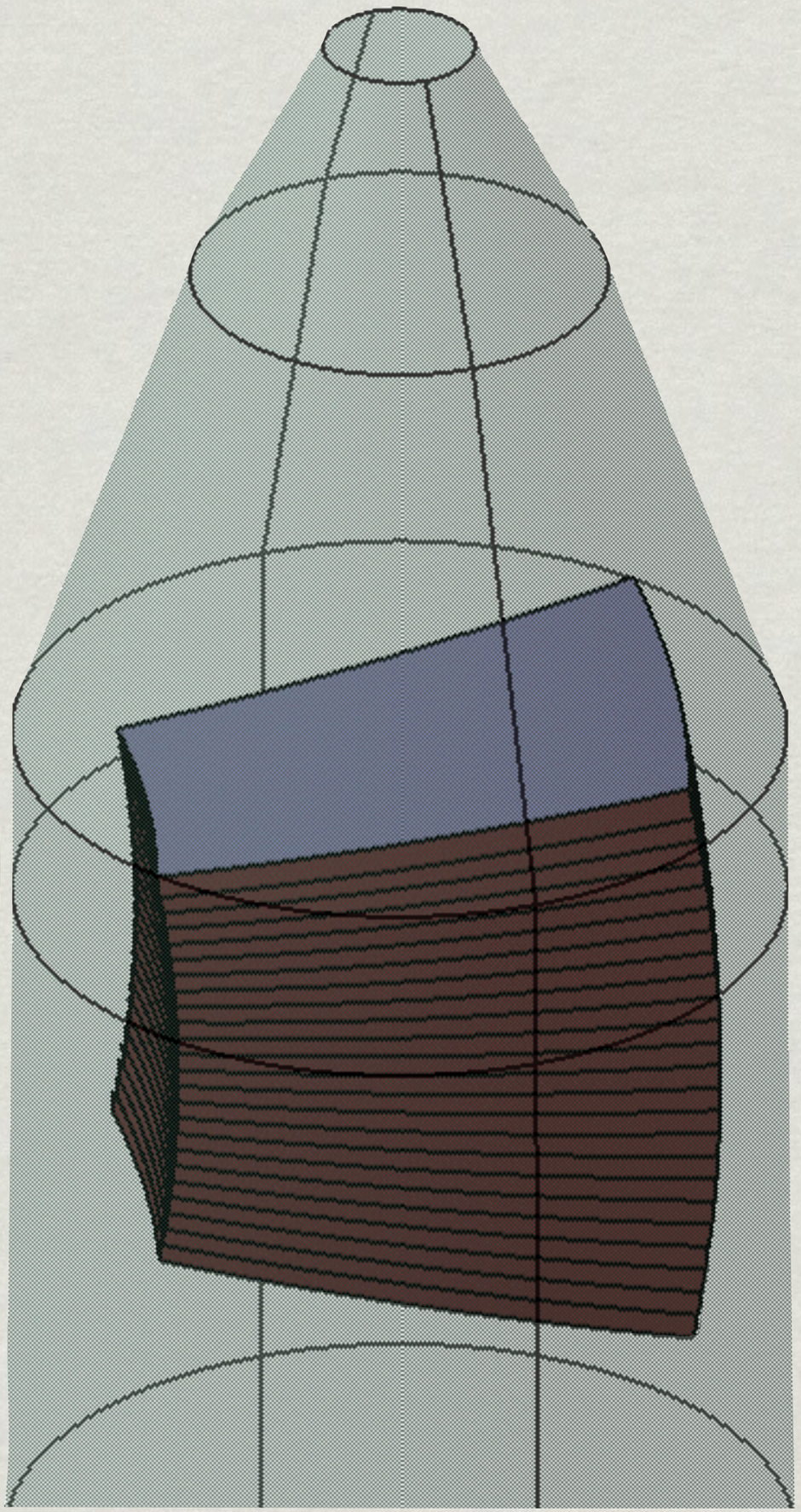
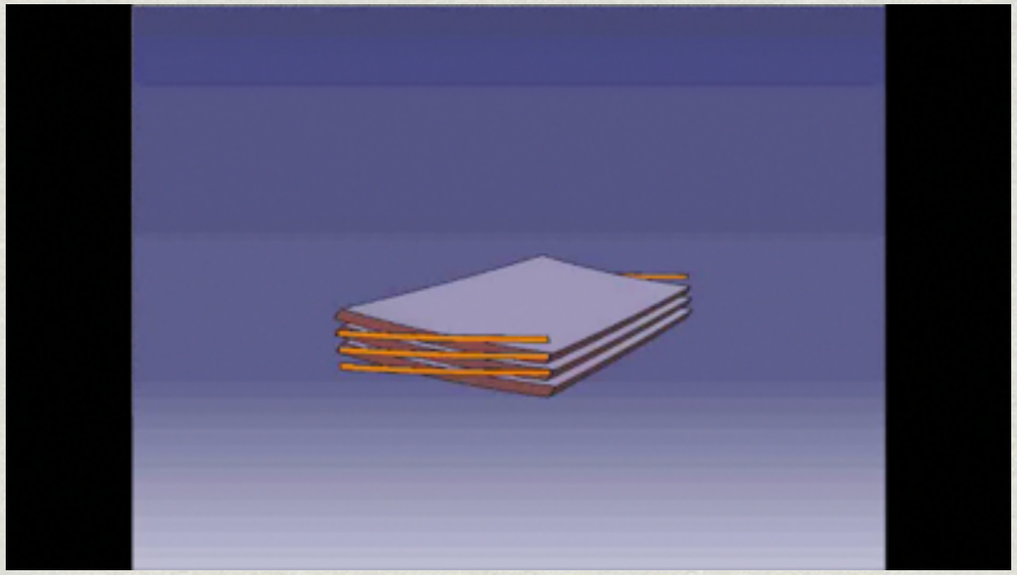
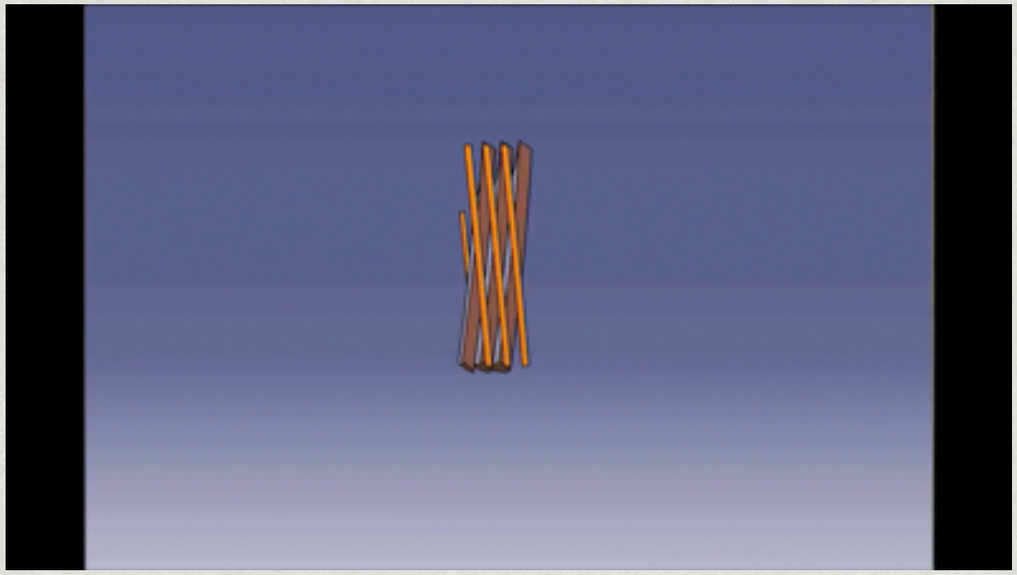
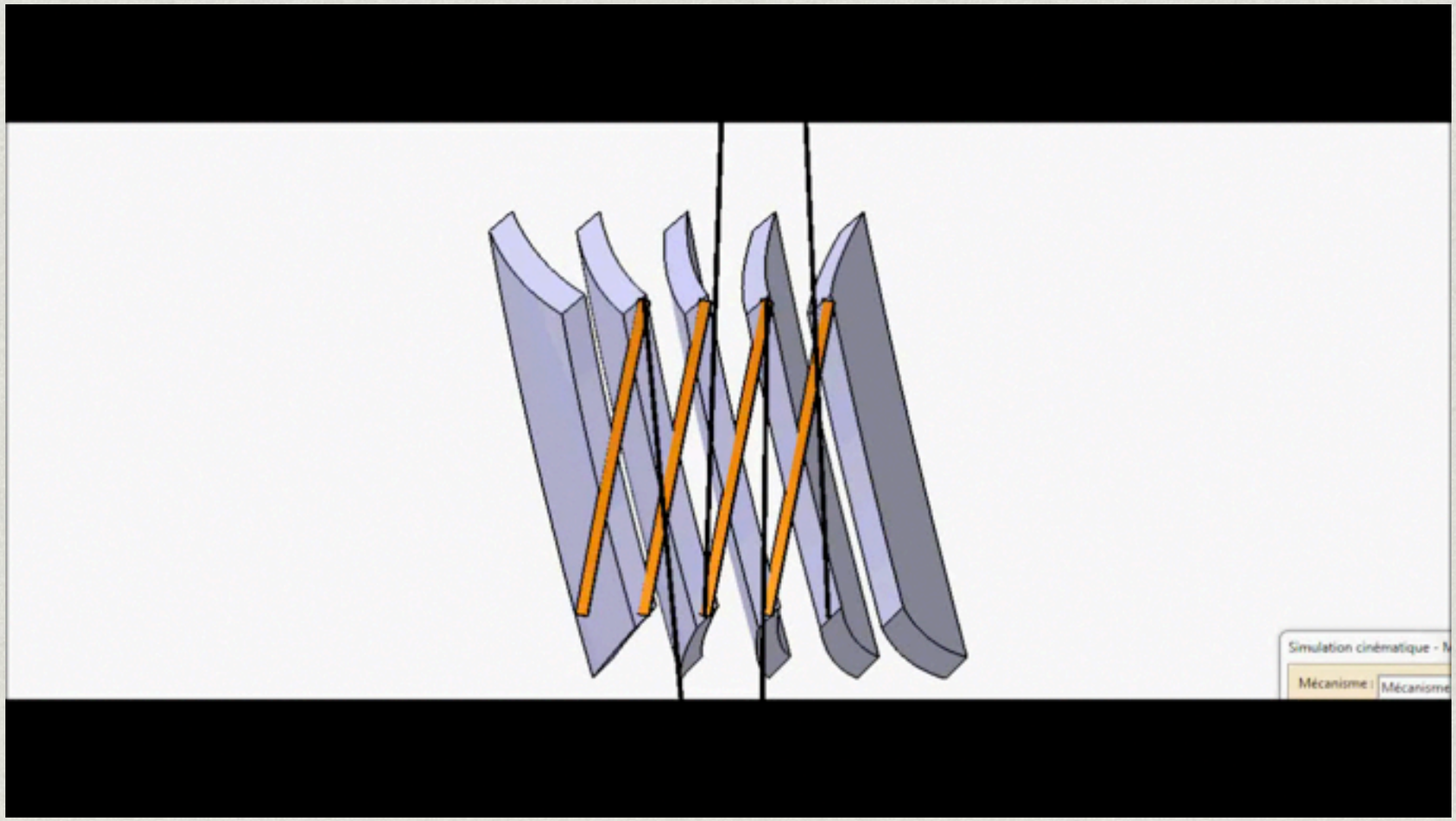




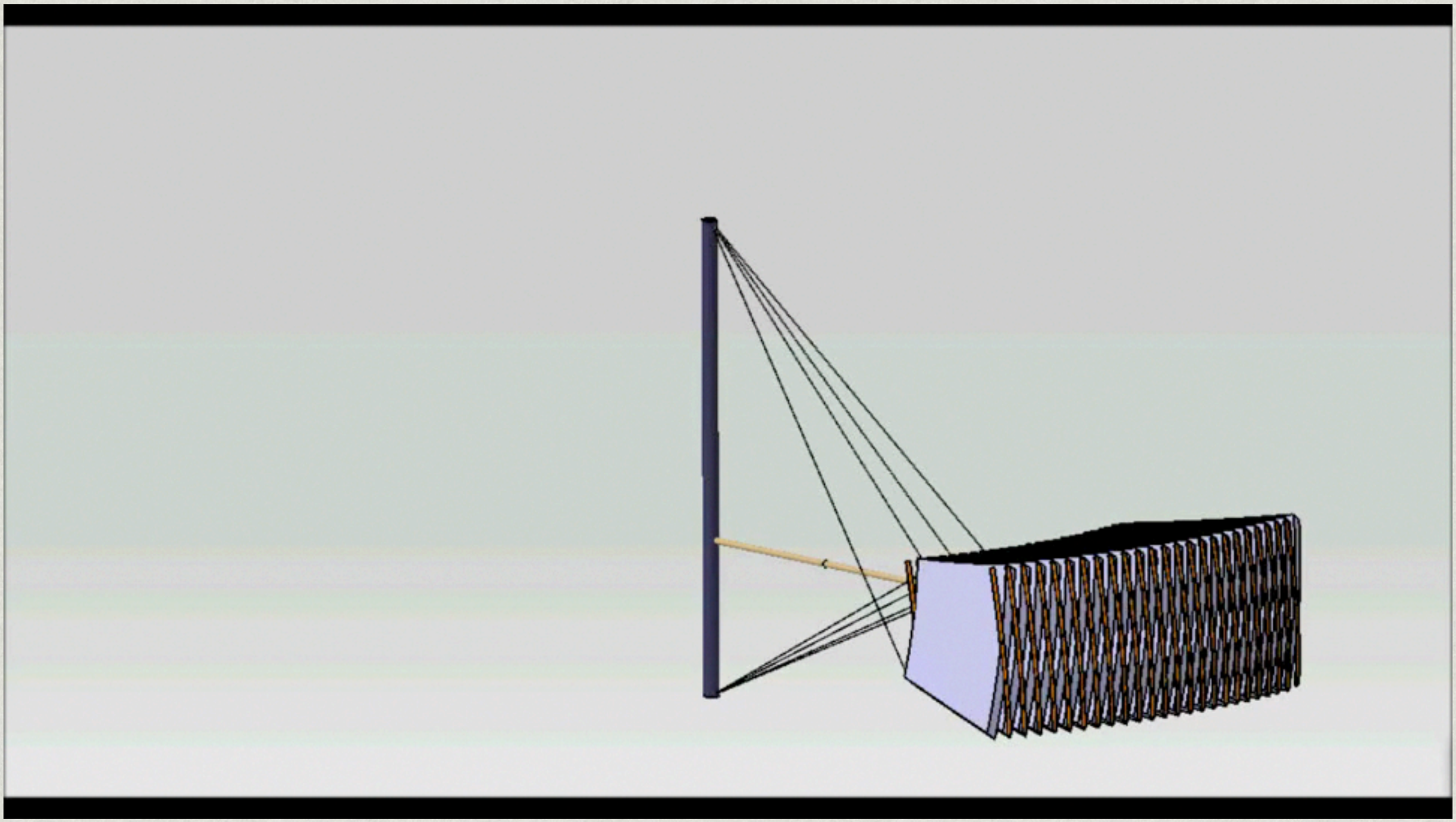
How to unfold a 20m ring..



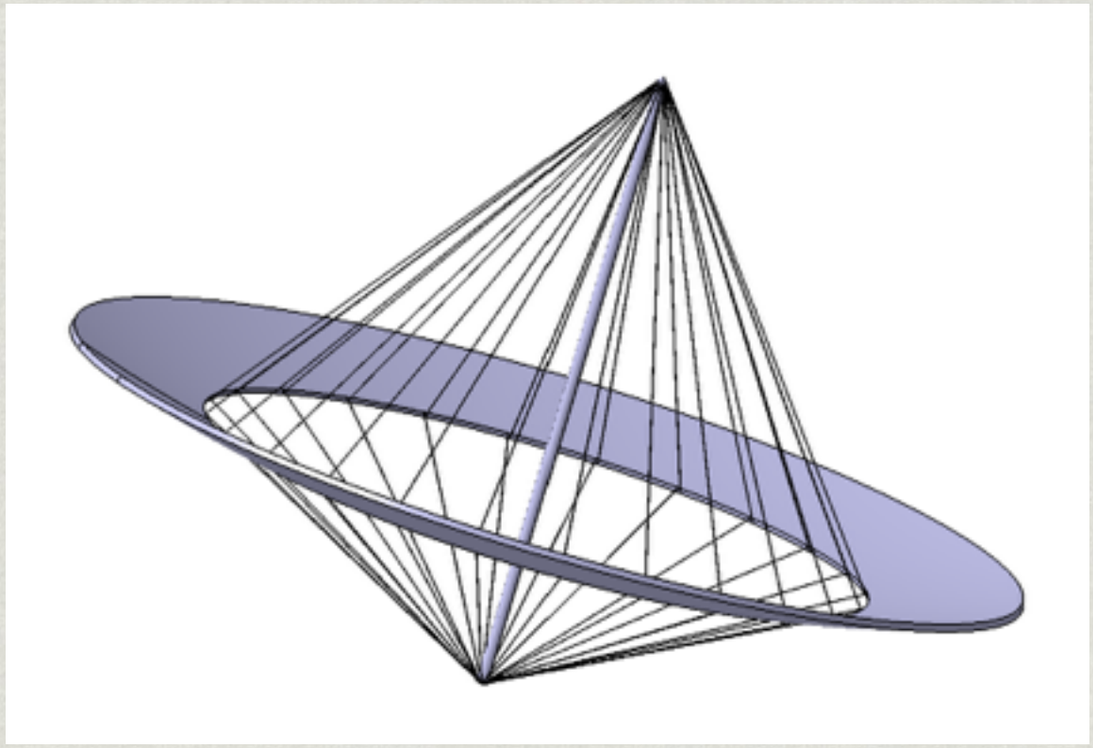




Complete ring dynamical simulation



Strength through tension and compression



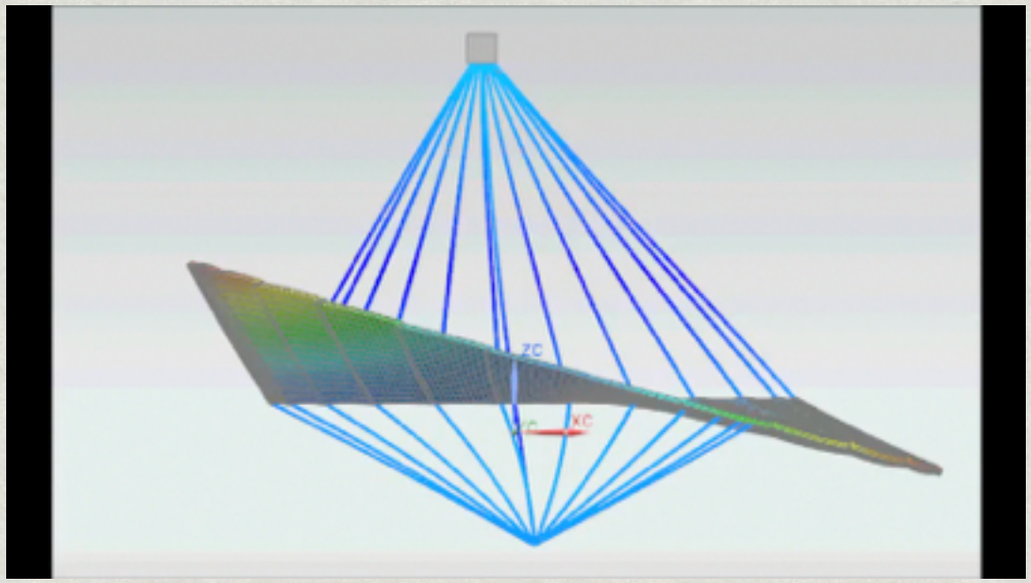
Singapore Flyer Wheel (150m diameter)

Tension of the cable structure leads to compression of the inner ring of the mirror, leads to global stiffness of the structure.

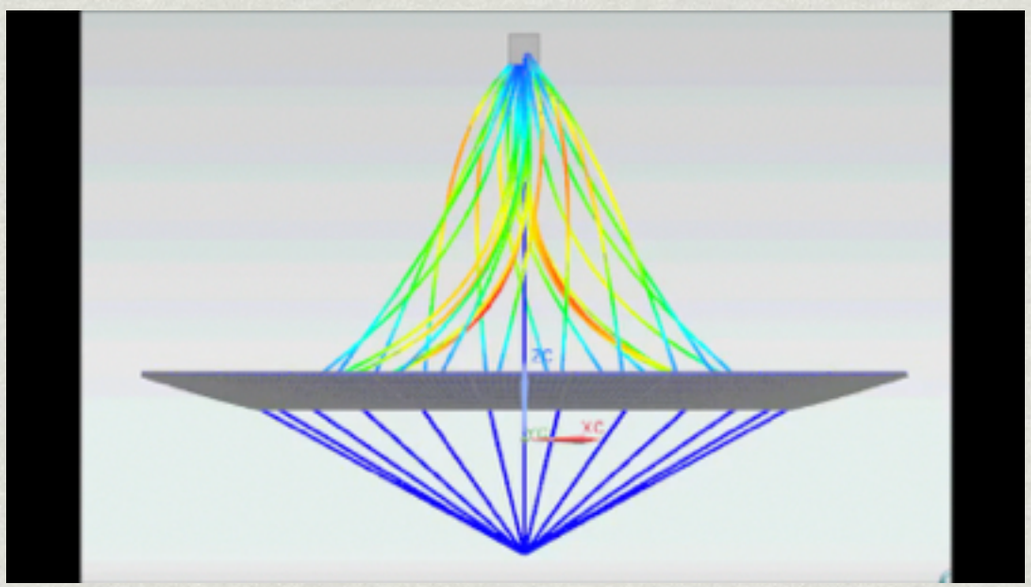
TALC's innovation: the same cable structure provides deployment and rigidity.

Stiffness demonstrated through vibration studies

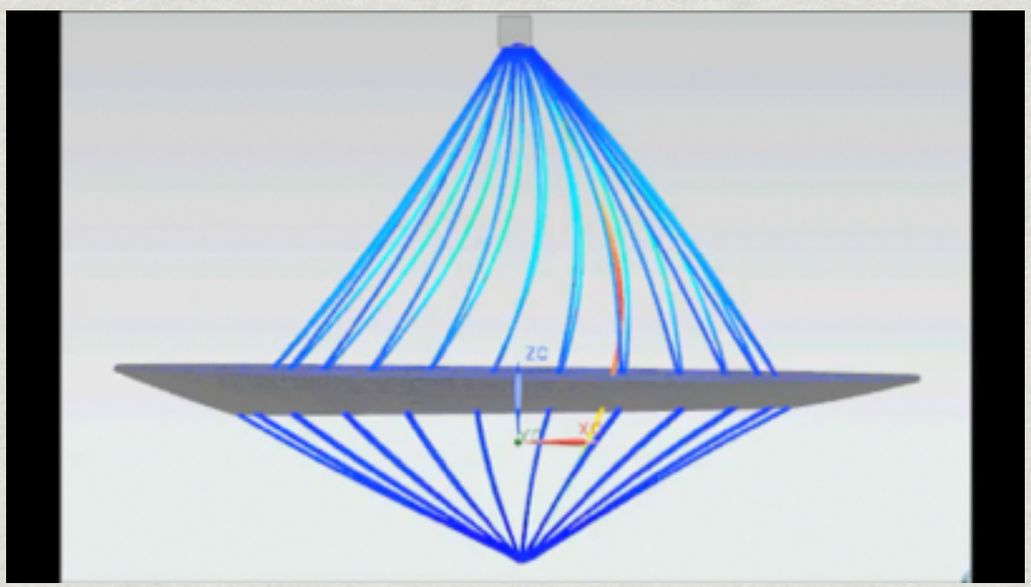
3.2 Hz



Vibrations can be dampened/controlled via the cables' tension, and the length of the mirror connecting rods.



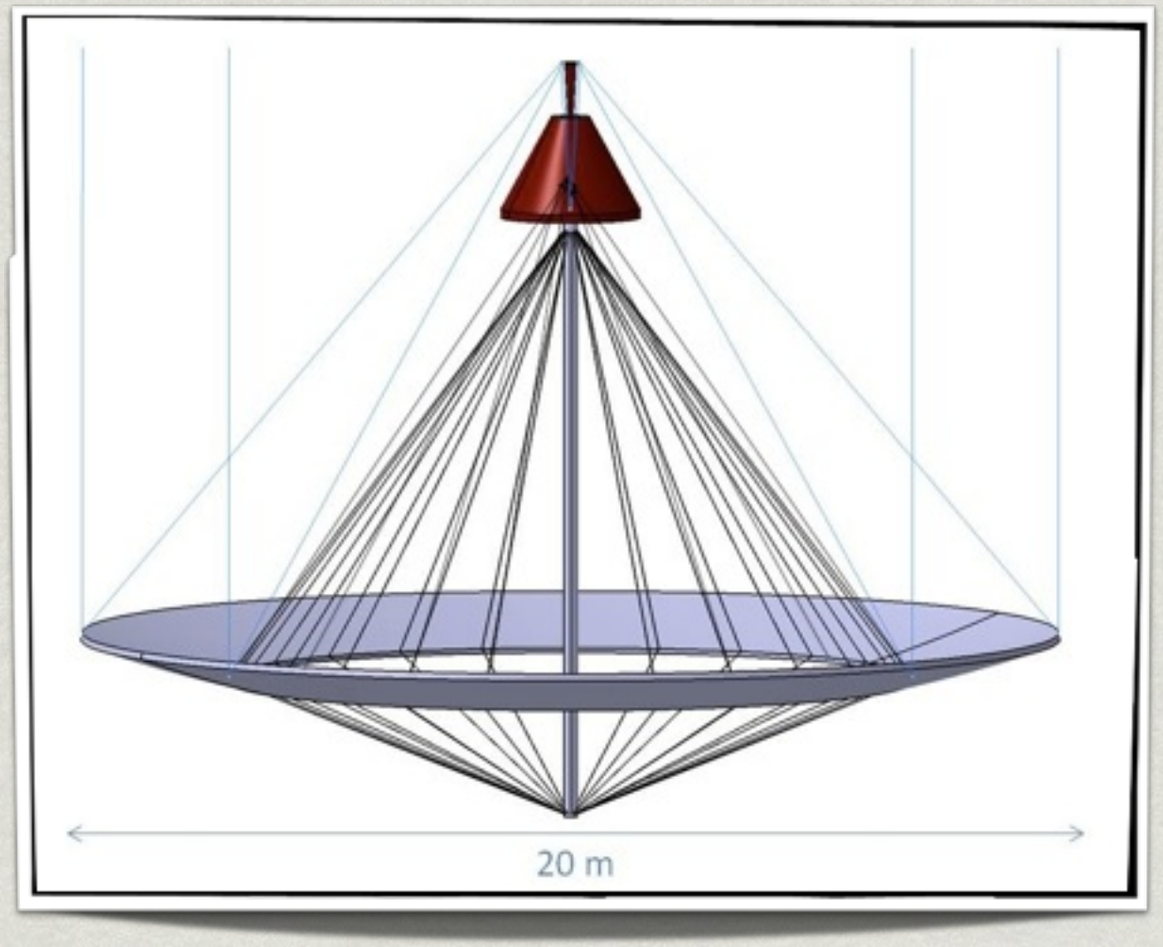
6.2 Hz



6.5 Hz

TALC in brief

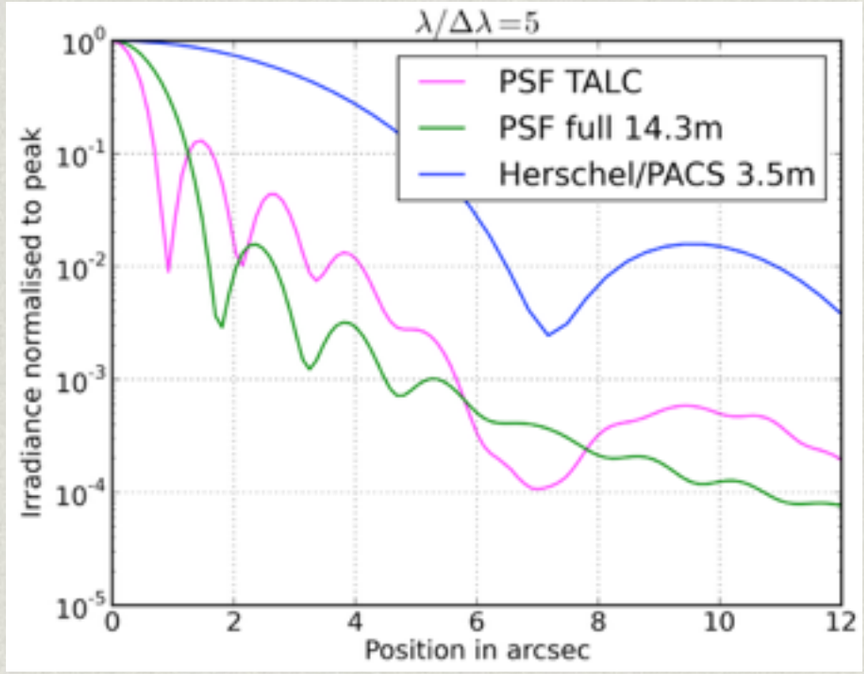
- **TALC stands for Thinned Aperture Light Collector**
- **Properties:**
  - 20m external diameter.
  - As much collecting area as a 14m filled telescope (16xHerschel)
  - Passively cooled, preliminary studies give T~50K.
  - Significant physical space for instrument bay.
  - Good optical quality on a 120" radius away from the optical axis
  - 0.9" main beam resolution @100μm (equivalent to JWST@30μm).
- **Constraints:**
  - Segmented light-weight mirror needs active global shape control (but no active surface control).
  - Only 30% of the beam's total energy is in the main beam -> Data processing.



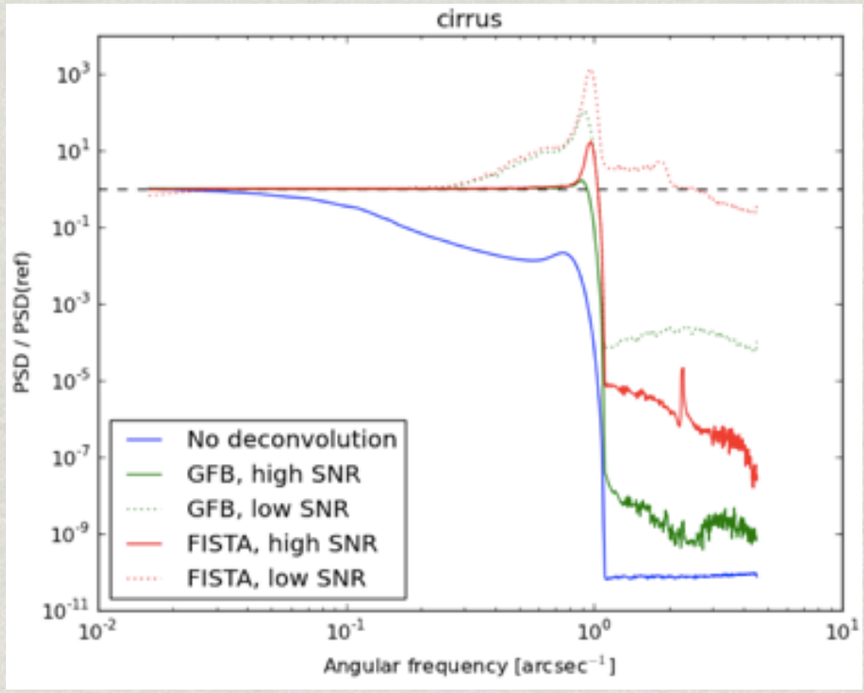
Optics and Processing

- Thanks to the annulus, TALC's main beam is that of a 27m single dish telescope.
- Because of the partially-filled pupil, TALC's main beam contains only 30% of the energy.
- To fully exploit the angular resolution, we need to account for this in the data processing:
  - Use a method taking into account the sparse nature of the astronomical signal (*Compressed Sensing*).
  - Model the complete acquisition process and invert the system taking into account the actual TALC PSF.
  - Unlike classical compression/decompression systems, methods based on compressed sensing separate the acquisition model from the inversion process. Both can be optimized in time.
  - Current methods show promising image restoration performance close to the main beam scale.

Operating a partially-filled pupil telescope close to its optimal resolution is perfectly feasible



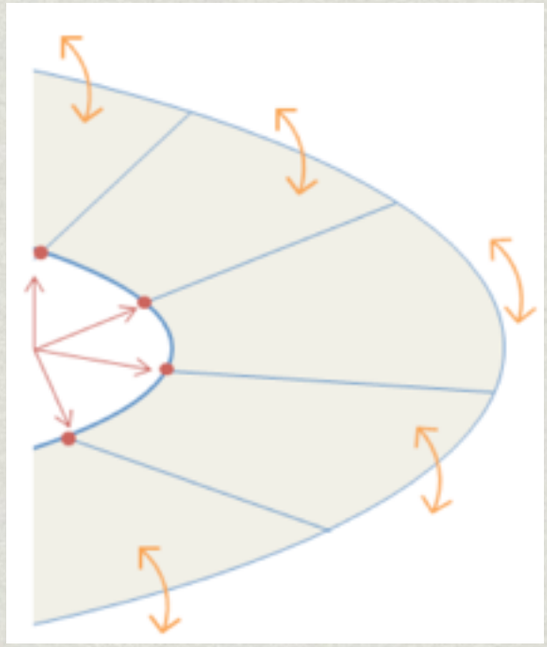
Beam profile for TALC (pink), a filled telescope of identical collecting area (green) and Herschel PACS, for a 100 µm filter of R=5.



A comparison of the measured-to-original power spectrum of spatial structures in a simulated cirrus field. In blue, without any signal processing, in red and green with different inversion algorithms and for two cases of mean signal to noise.

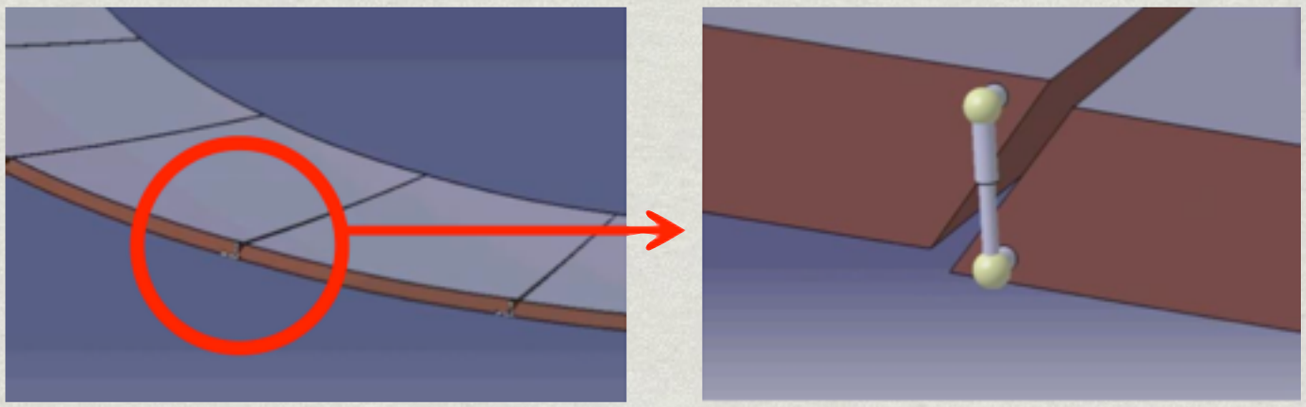
Active Surface Control

- Key assumption: mirror segments are manufactured at the required shape and surface accuracy (no active mirror surface needed).
  - This is a 10μm RMS accuracy over a mirror segment (approximately 3mx3m, achieved for the Herschel mirror).
  - Development of active light-weight mirrors are ongoing (AHMs, Hickey et al. 2010).
  - These errors are included in our simulations.
- Control required to bring the assembled surface in the correct shape:
  - Adjust cable tension/length (position/shape or the inner edge of the mirror).
  - Adjust mirror relative positioning (orientation/shape of the mirror surface).
  - The large number of actuators and the interdependency of actuation actions make the system highly redundant.
  - With realistic errors, our simulation show we can recover the optimal shape with these actuators.



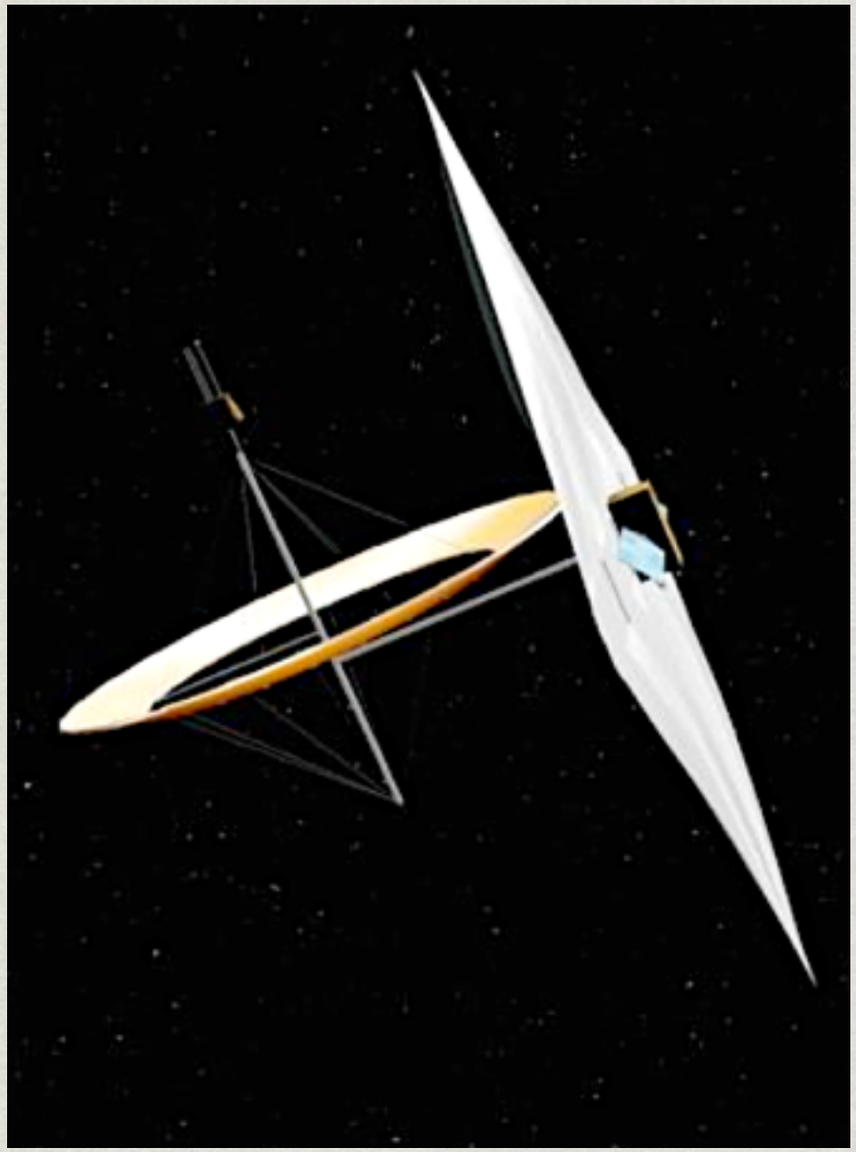
A sector of the mirror showing (in red) connection points (spherical joints) between segments on the inner edge where the cables are attached. Cable lengths control the shape of this inner edge leaving a rotating degree of freedom (orange arrow) for the mirror petals.

A sector of the mirror showing the external edge. The relative position of a mirror with respect to its neighbors can be modified. In the simulation it is represented by a piston but this can be achieved by playing on the length of the crossbars connecting each mirror it neighbors.



Sunshield

- TALC is a FIR telescope and must be shielded from the sun.
- We plan to operate TALC in a fashion similar to Herschel:
  - The sunshield plane is perpendicular to the sun's direction
  - TALC points on a line of sight that is coplanar with the sunshield (i.e. it can access a great circle whose plane is perpendicular to the suns's direction.
  - Dimensions of the sunshield should be optimized regarding the aspect ratio of the deployed TALC system.
- We currently assume a simple sunshield (i.e. not the complex JWST v-grooved sunshield).
  - Light-weight structure.
  - can be deployed with an inflatable system (CNES suggestion).
- The sunshield, while wider, should not make a relative mass contribution as large as that of the JWST.



A computer-rendering of TALC in space showing the proposed configuration for the mirror and sunshield.
The sun's direction is perpendicular to the sunshield plane. The satellite can rotate freely around the axis pointing to the sun, maintaining the solar aspect angle nearly constant.

A Mission scenario for a TALC-like telescope

- Mission assumptions:
  - Mass of the order of 6 tons (half of it is the mirror).
  - Observing from L2.
  - No cryogenic fluid losses.
- Mission constraint:
  - No slot left on the L-class, one had to rely on an “Ariane-6” class.

The CNES has been working with TAS and Astrium on versatile electric propulsion modules for exploration missions.

- “Chemical” launch into low-earth orbit.
- “Fast” electrical push phase to escape the danger zone (space debris), 2-3 weeks.
- “Slow” push phase to L2, <2yrs.

Added benefit: the module can host a number of service functions (power supply, telecommunication, even part of the AOCS).

AIR&COSMOS

Dec. 2013

OPTIQUE

La Darpa prépare son télescope spatial espion

A l'instar des concepts GO3S et Hoasis étudiés par Astrium et Thales Alenia Space pour des systèmes d'observation en continu à haute résolution et en temps réel depuis l'orbite géostationnaire (cf. A&C n° 2365), la Darpa poursuit ses travaux sur sa propre approche du problème avec le programme Moire (Membrane Optical Imager for Real Time Exploitation), basé sur une technologie d'optique en membrane polymère. Creusée de microsillons concentriques, d'une largeur décroissante de quelques centaines de microns à 4 µm du centre vers l'extérieur, cette membrane agirait à la manière d'une lentille de Fresnel, utilisant la diffraction plutôt que la réflexion pour concentrer la lumière vers le capteur. Les développements réalisés par la Darpa et Ball Aerospace ont permis de faire passer le rendement optique de telles membranes de 30 % à 55 %, contre 90 % pour le verre. Ball vient de réaliser en prototype un huitième d'un miroir annulaire segmenté de 5 m de diamètre. A résolution égale, la masse est divisée par sept par rapport à une optique traditionnelle.

VIDÉO. A terme, la Darpa envisage un miroir annulaire segmenté de 20 m de diamètre, replié au lancement dans un volume inférieur à 6 m de diamètre. Une fois déplié sur orbite, il formerait l'optique principale d'un télescope capable de fournir une imagerie continue de la Terre à 1 m de résolution sur une zone d'observation de 100 km², au rythme d'une image par seconde. ■ SB

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