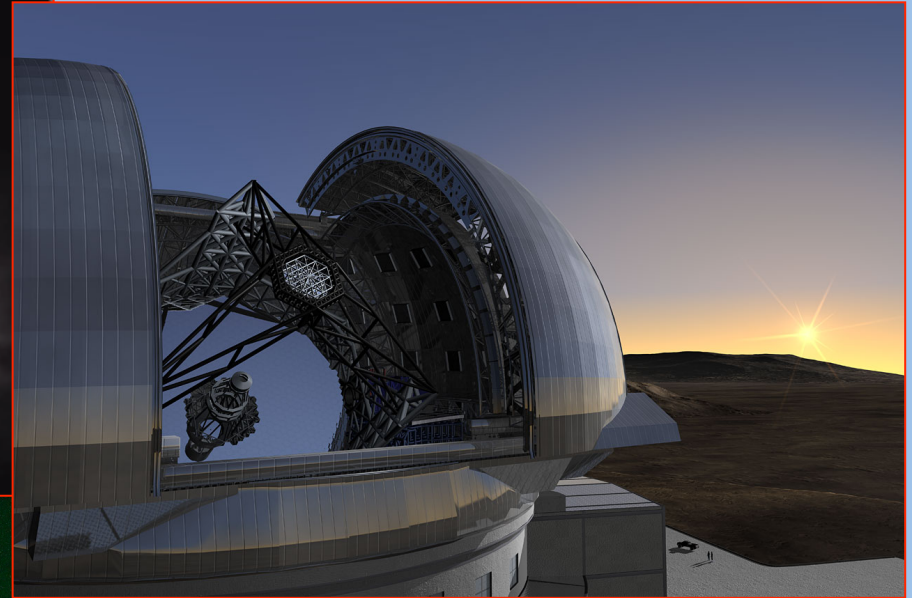




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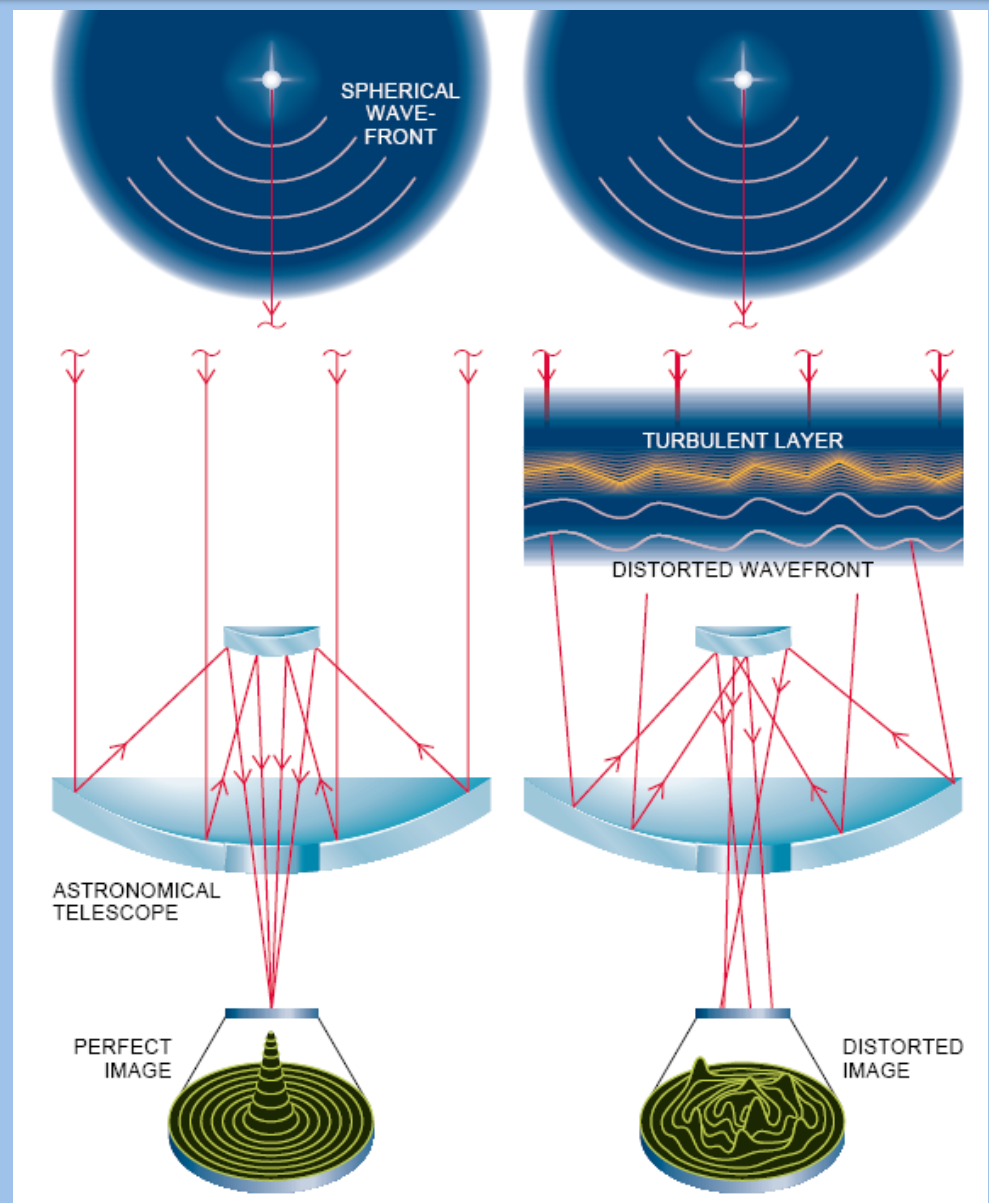
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Addomesticare la luce  
*Roberto Ragazzoni*





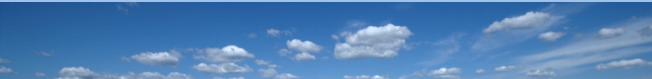
Il problema...



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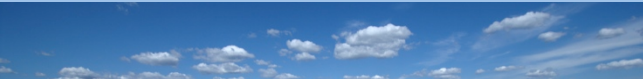
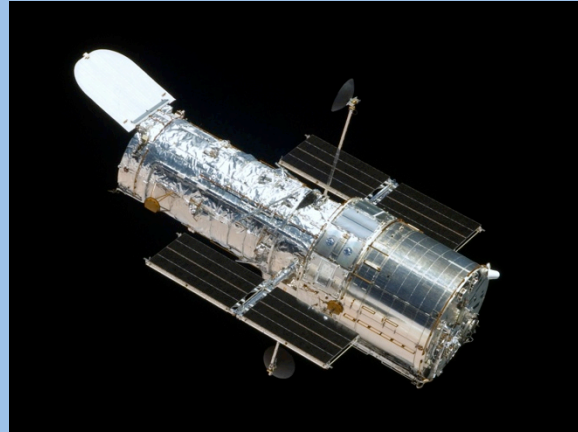


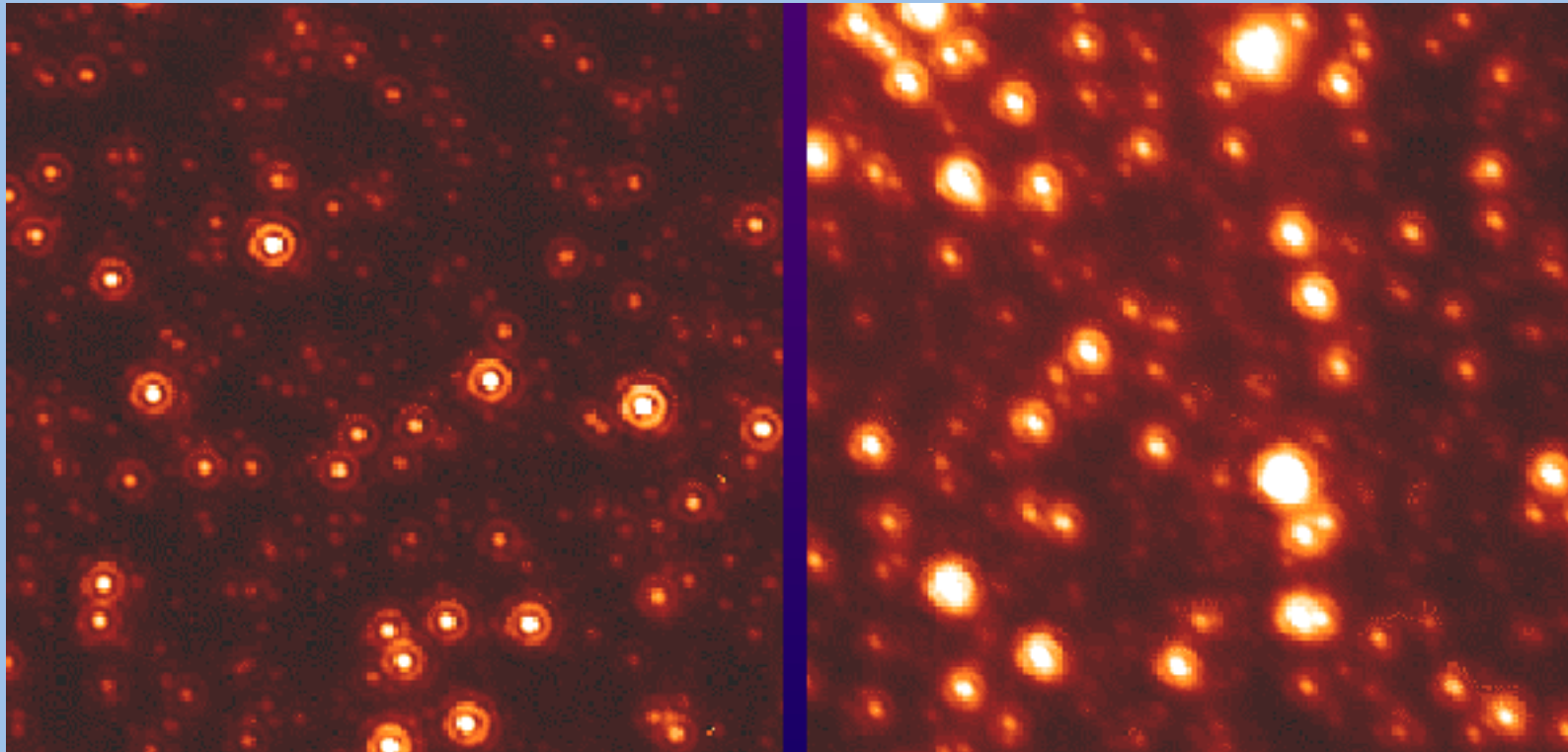


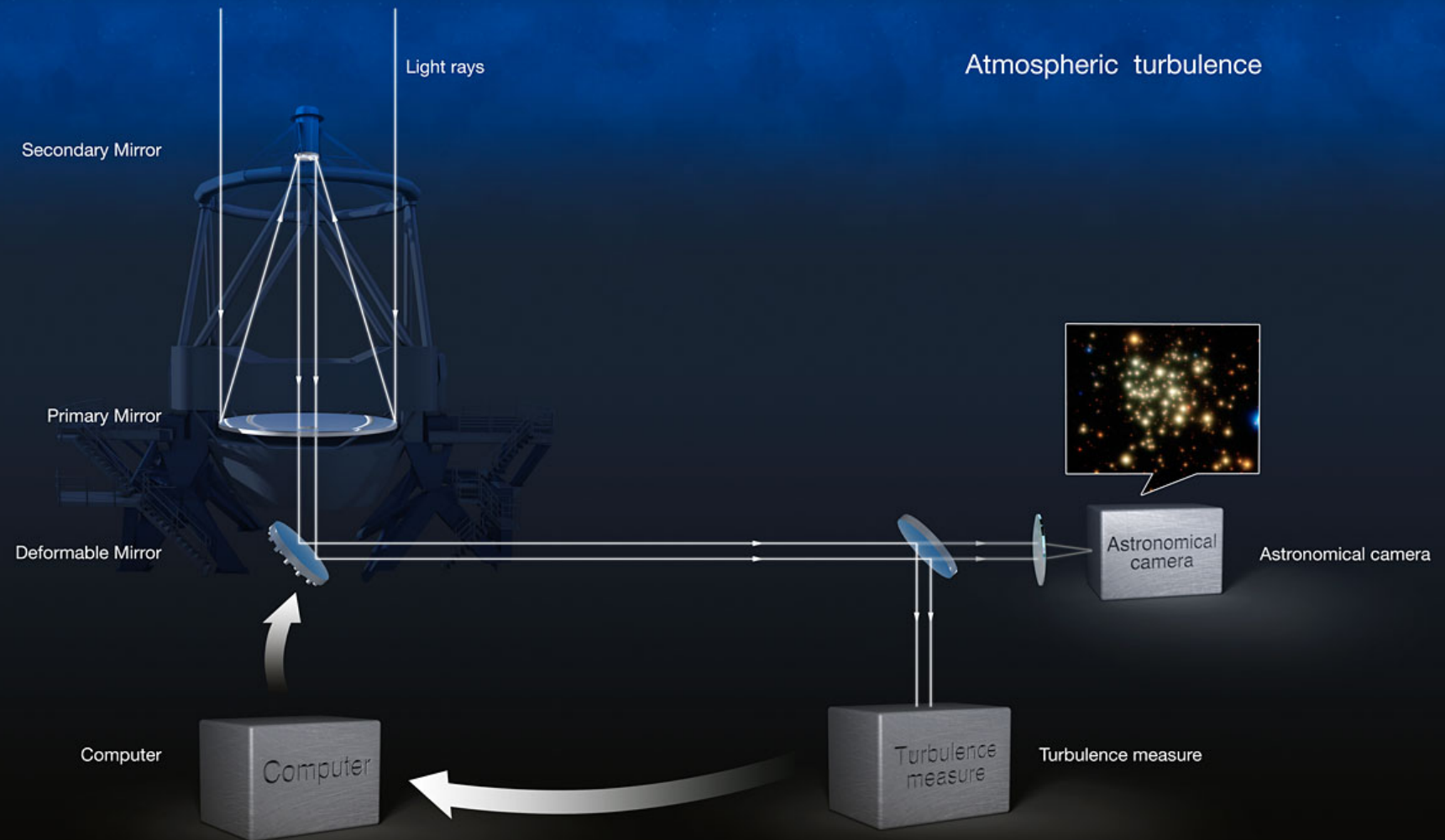
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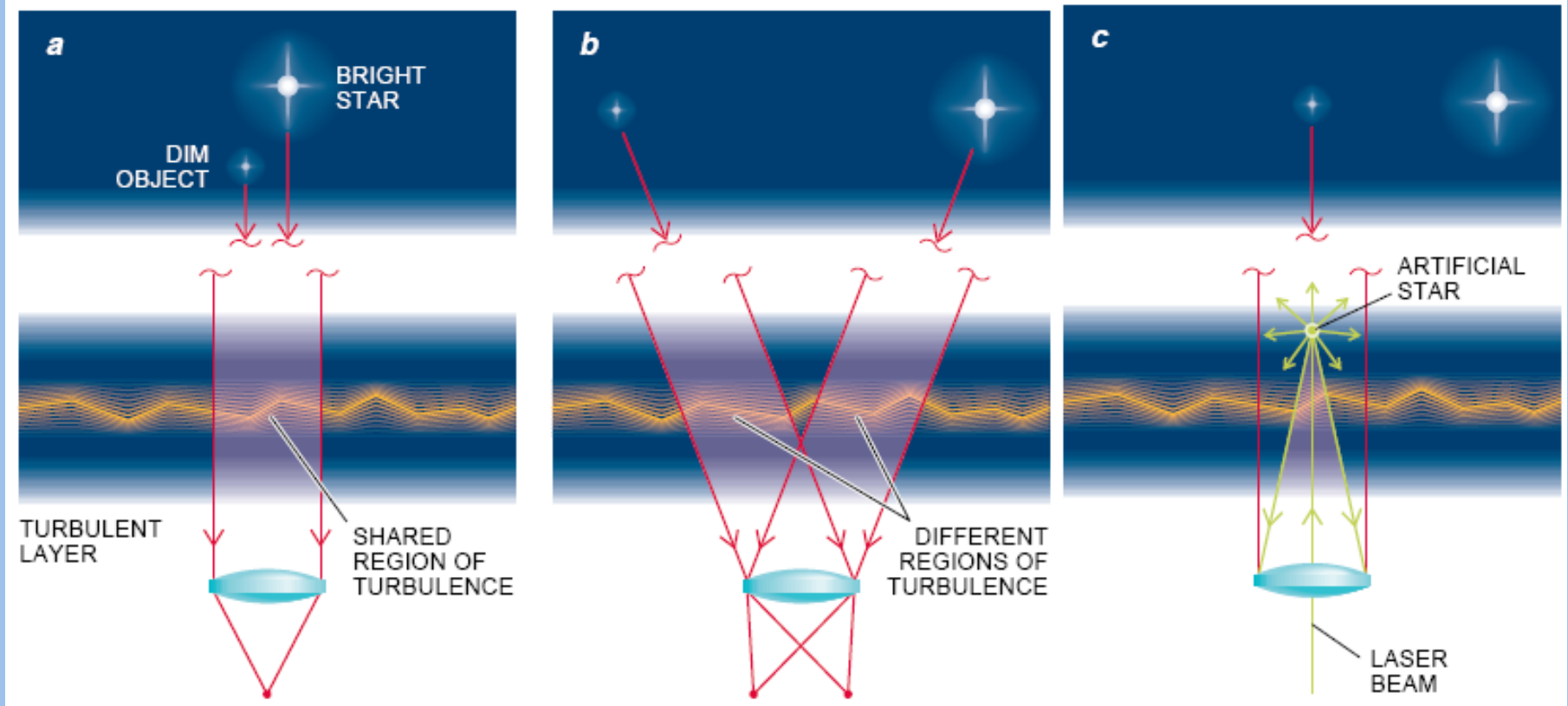
# Addomesticare la luce

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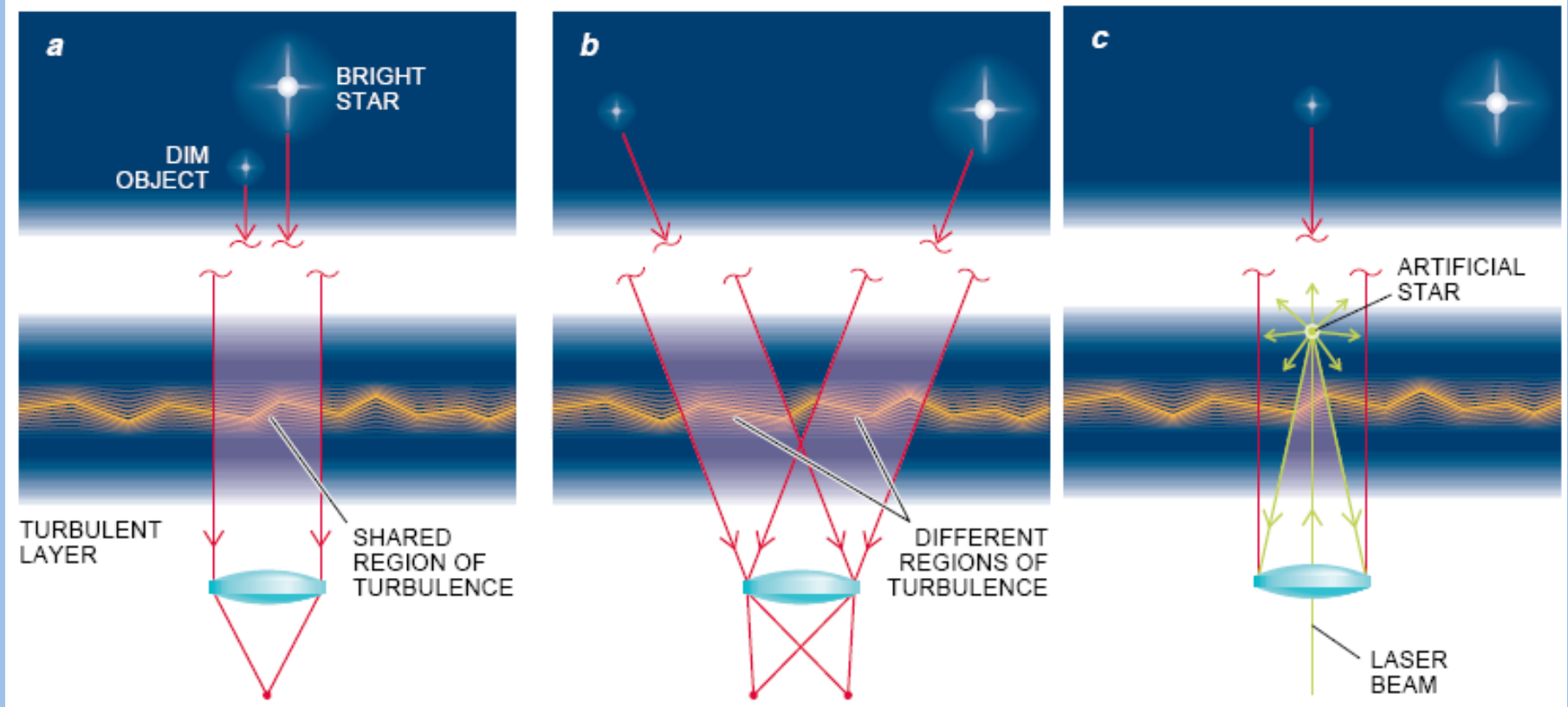




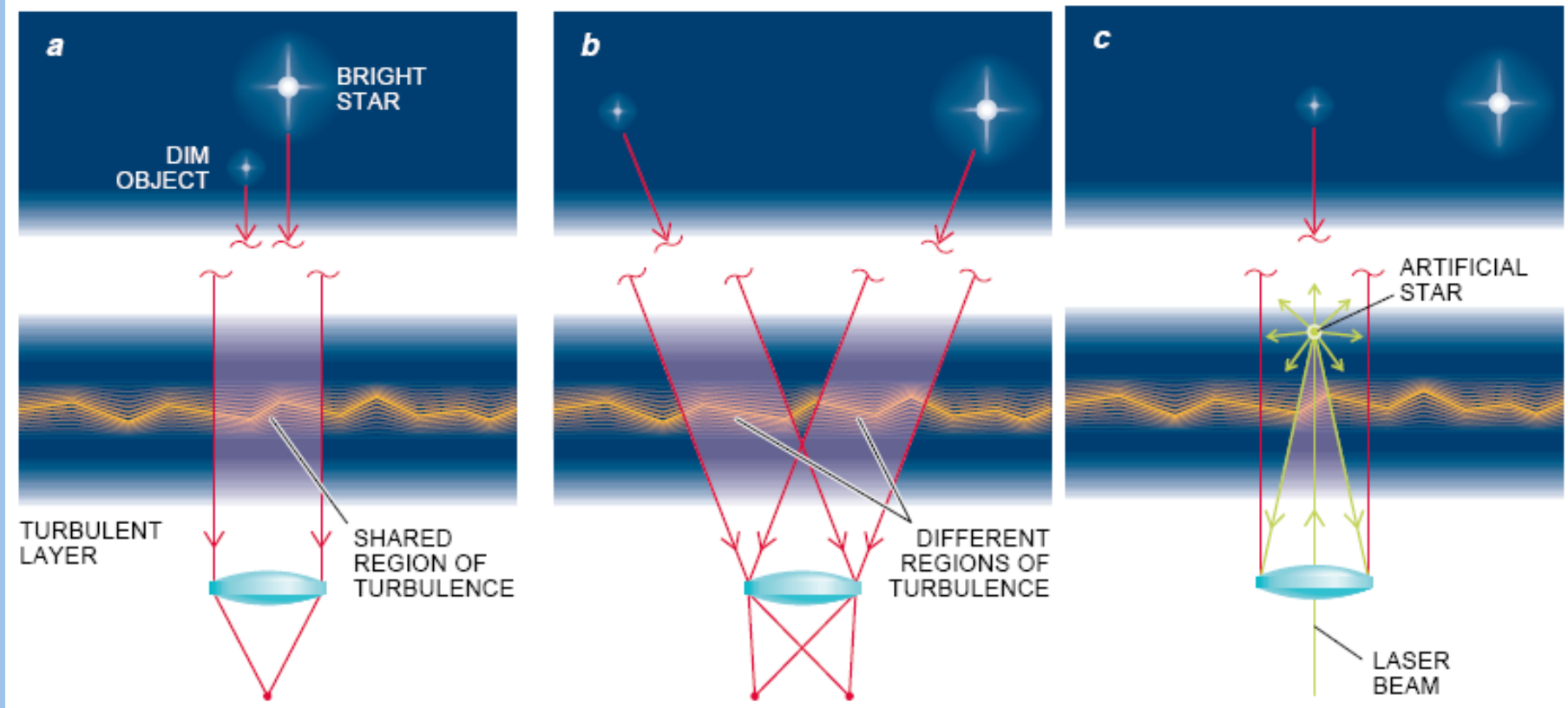








Angolo isoplanatico

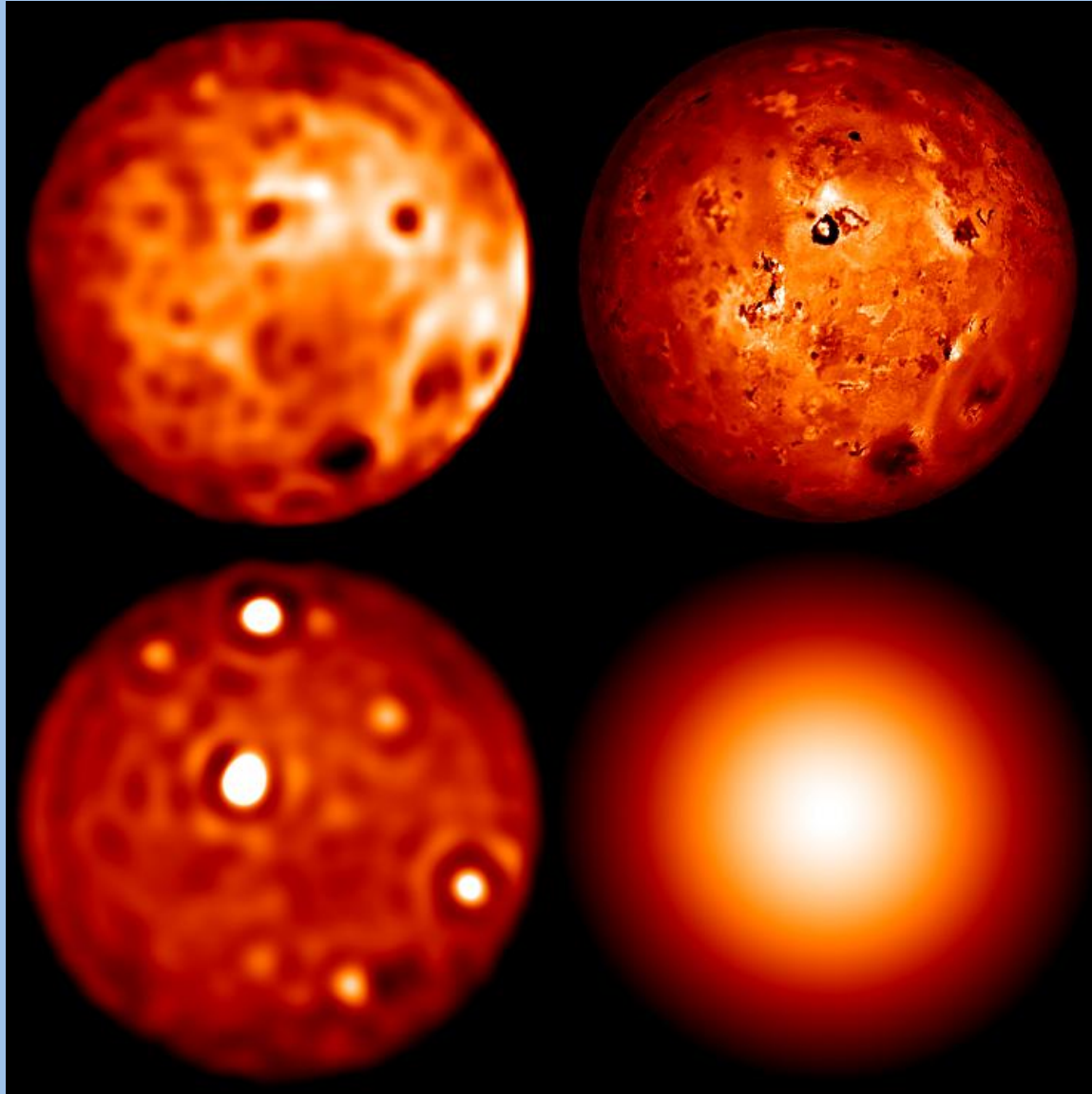


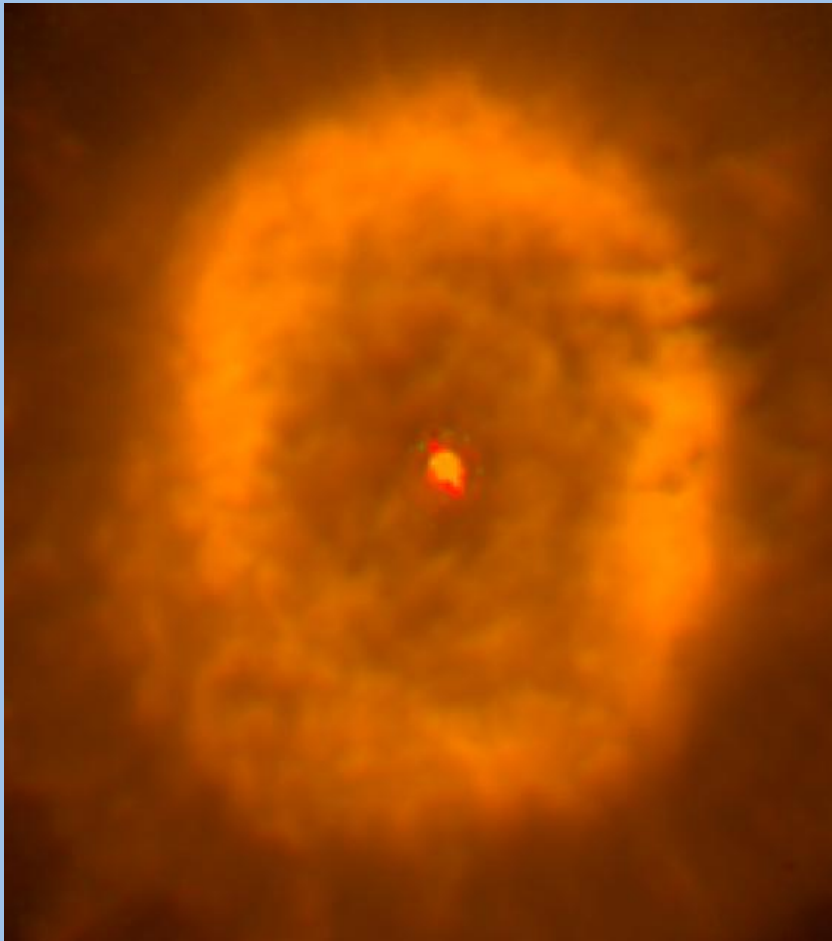
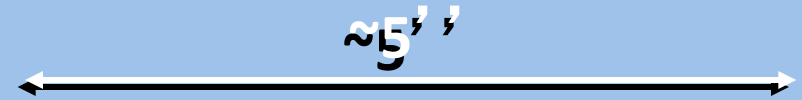
Angolo isoplanatico

Copertura del cielo



# Ottica Adattiva





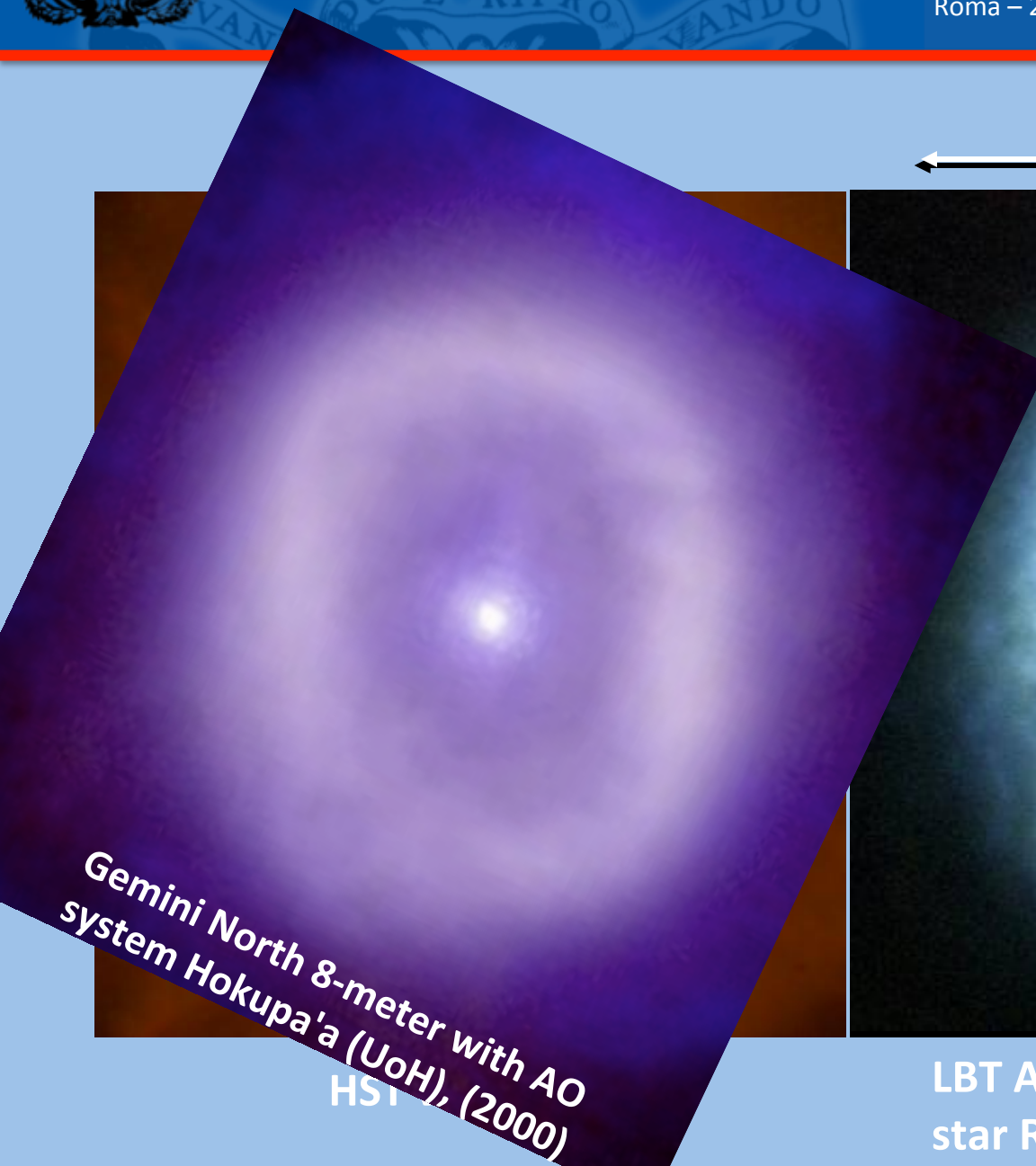
HST visible image



LBT AO, 100s, H2 filter (2.1 $\mu$ m), ref.  
star Rband 11mag, 150modes, 500Hz

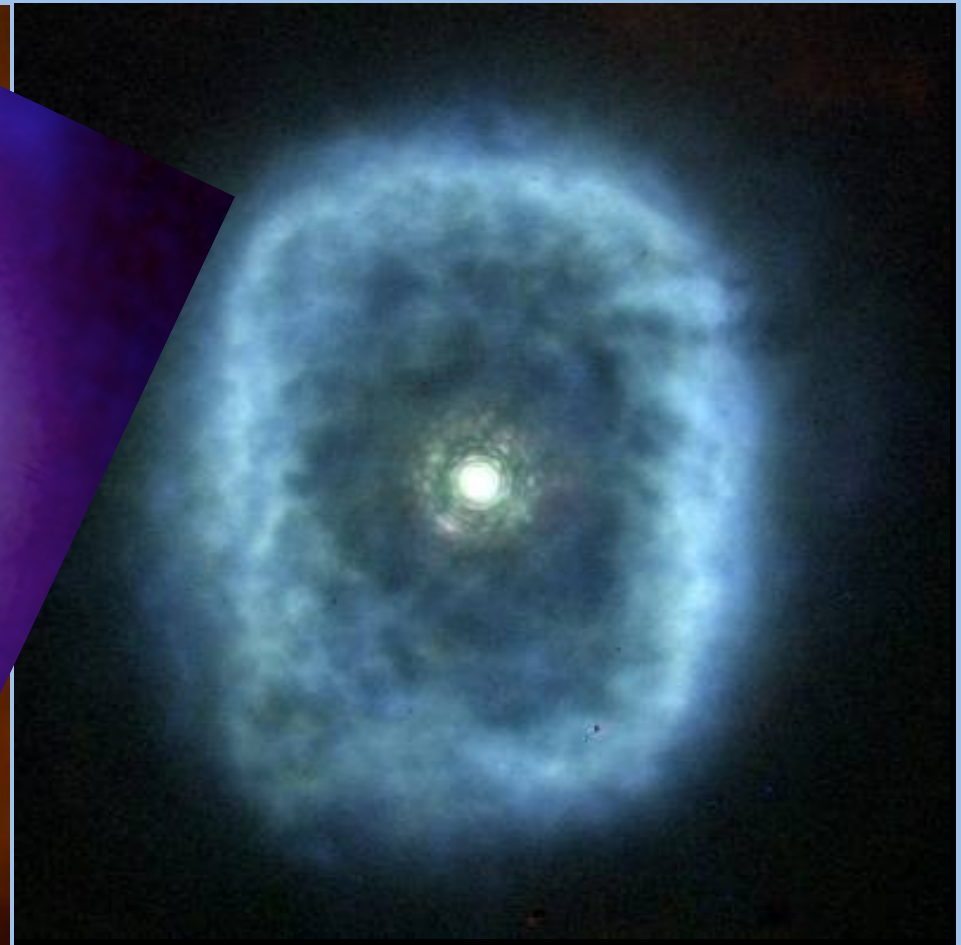


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Gemini North 8-meter with AO  
system Hokupa'a (UoH), (2000)  
HST

≈ 5''



LBT AO, 100s, H2 filter (2.1um), ref.  
star Rband 11mag, 150modes, 500Hz



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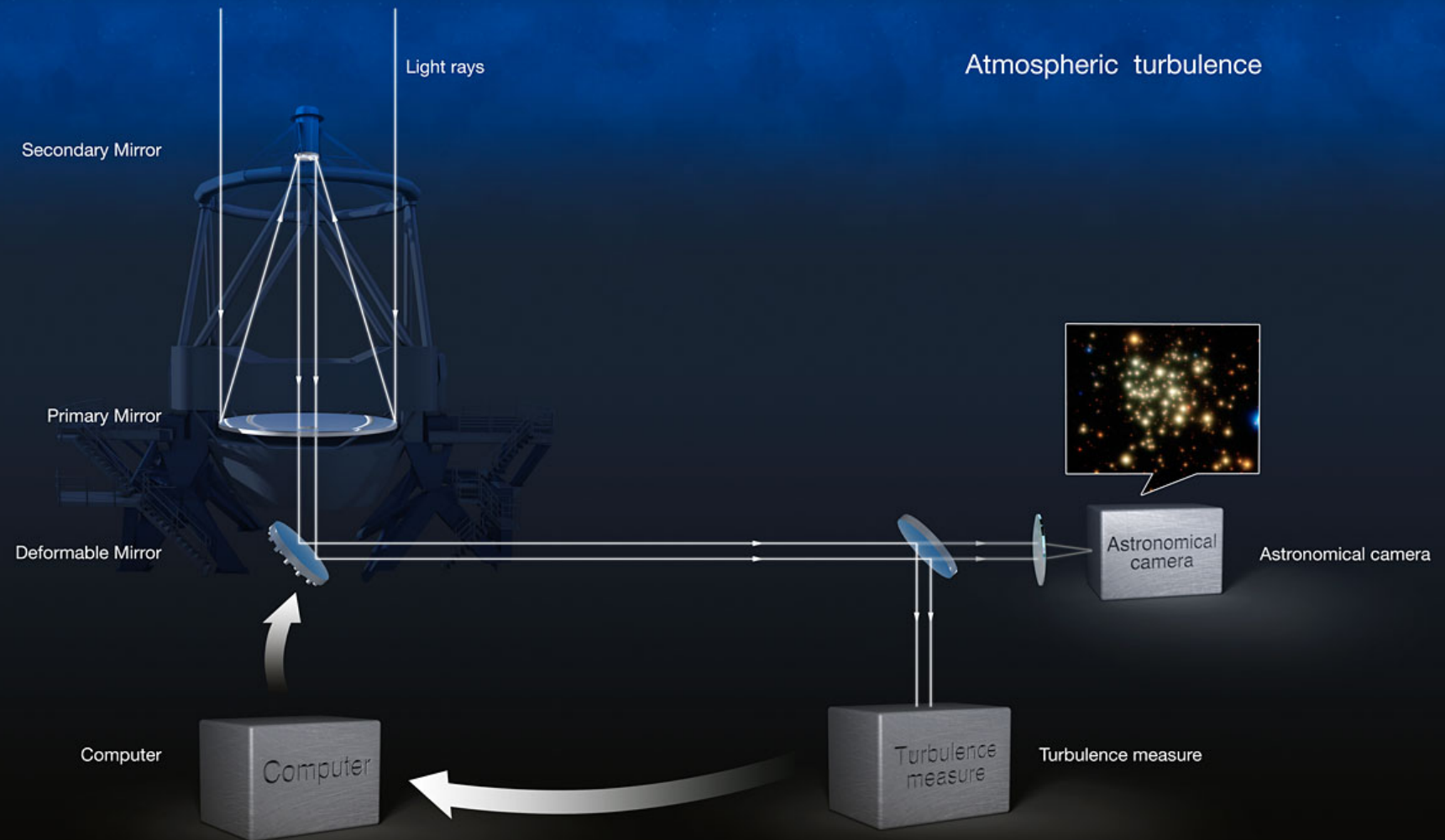
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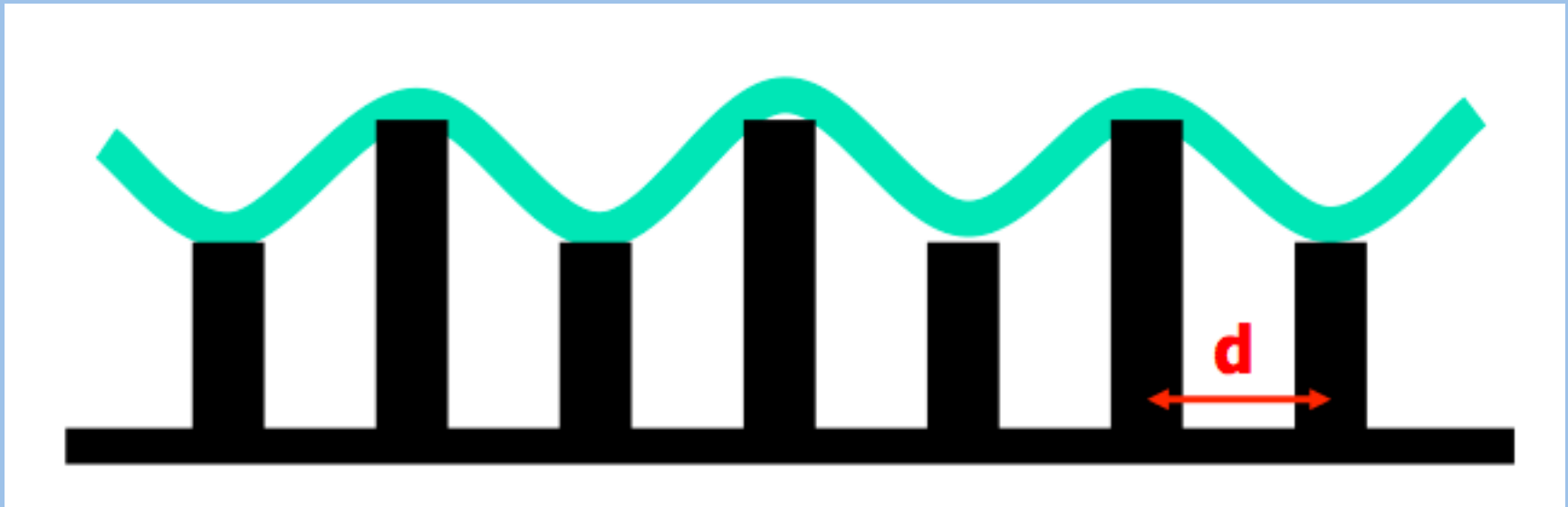
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# Addomesticare la luce

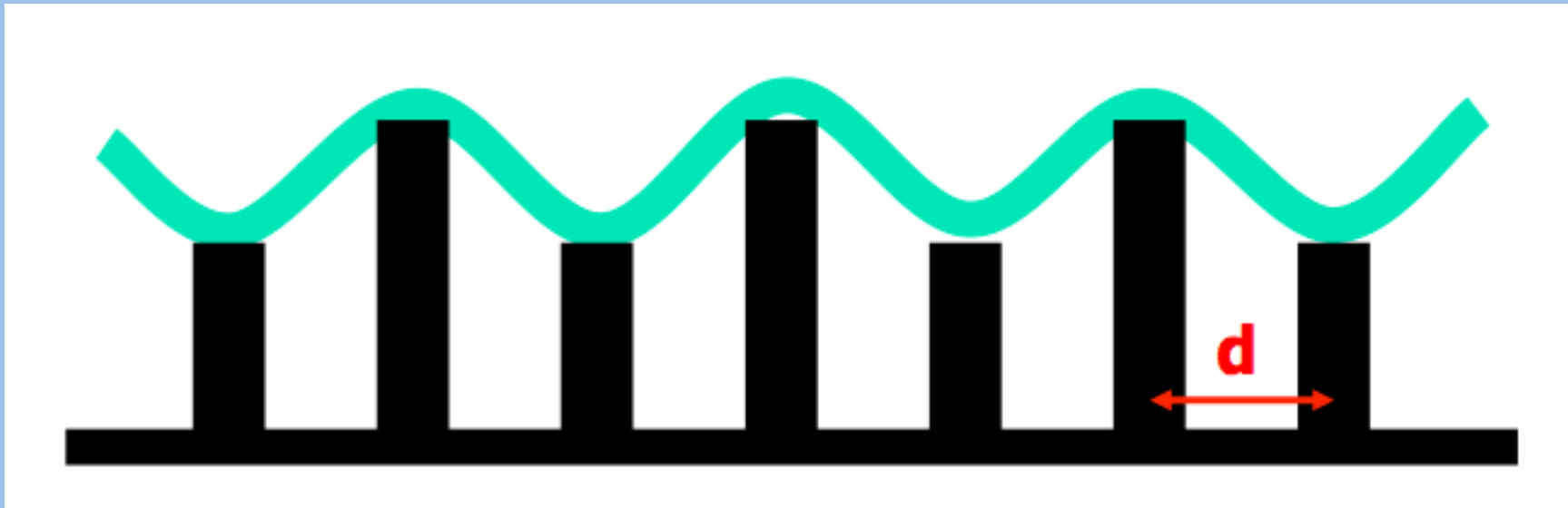
*Roberto Ragazzoni*





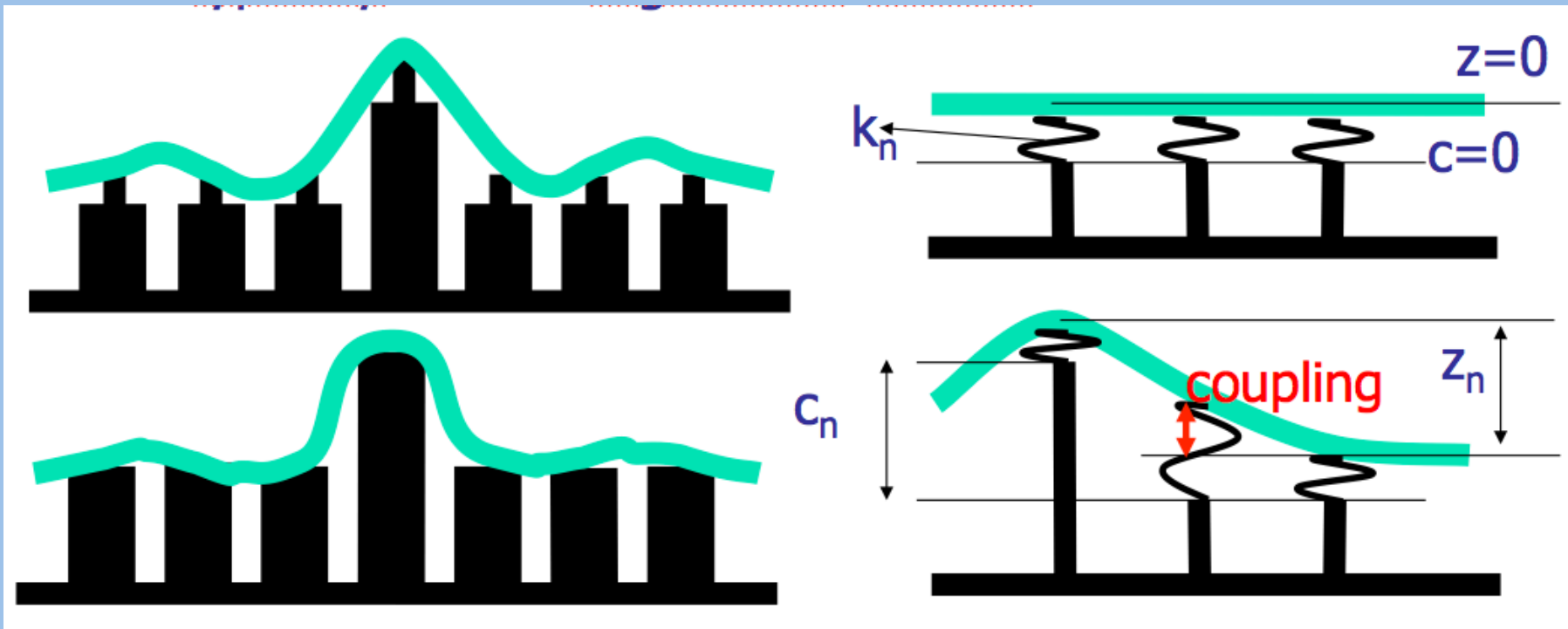


Densità attuatori



Densità attuatori

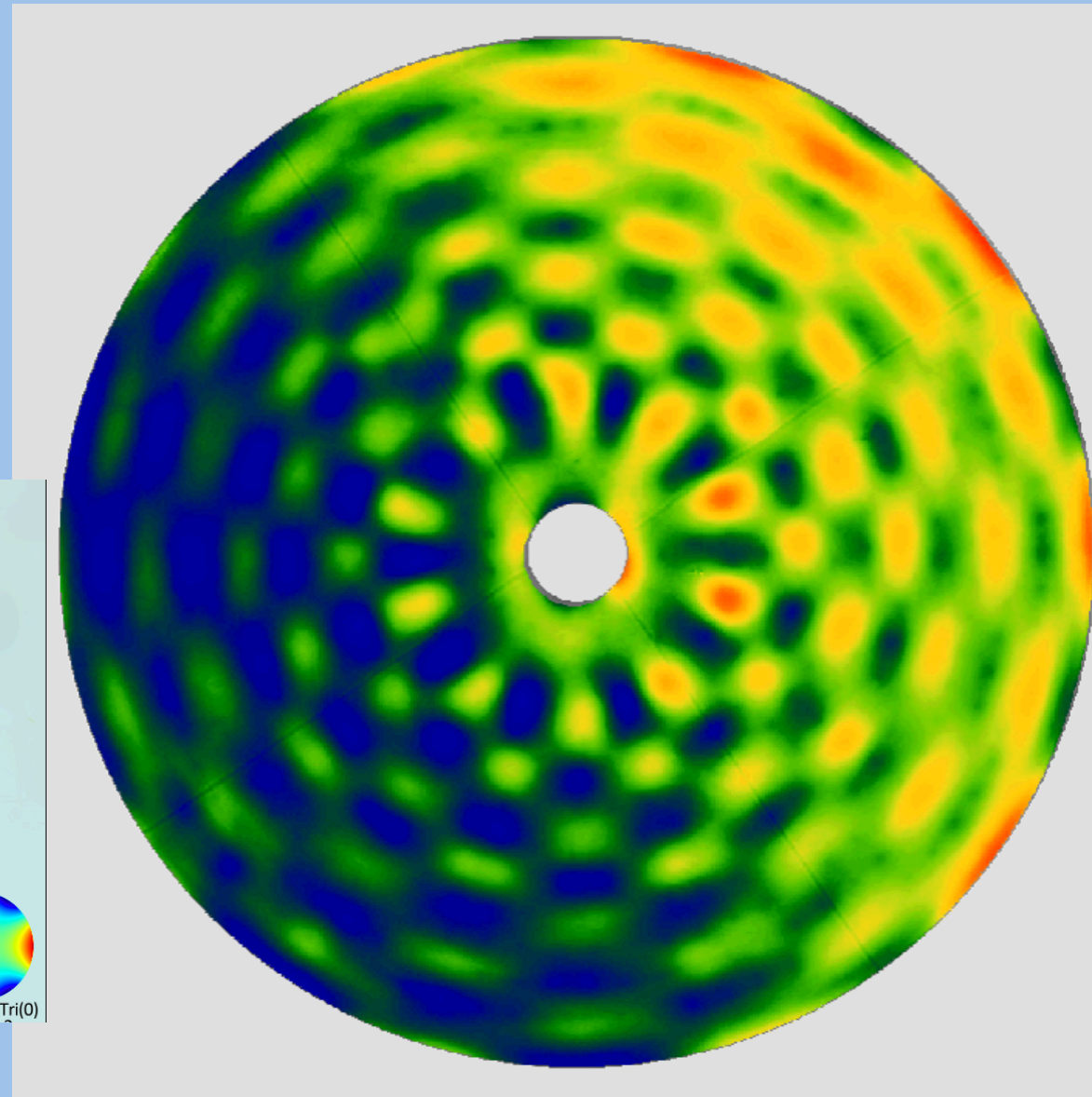
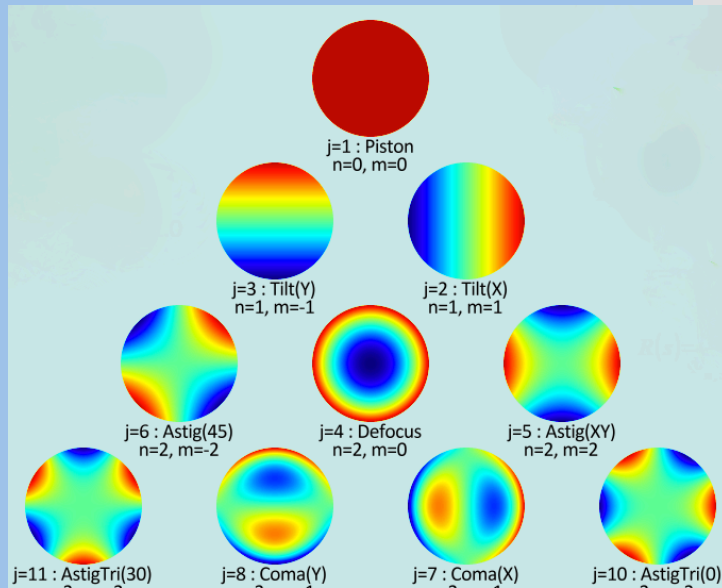
Frequenza temporale



Densità attuatori

Frequenza temporale

Accoppiamento





## *Deformable Mirror*

Rear View

349 Actuators  
on 7 mm spacing



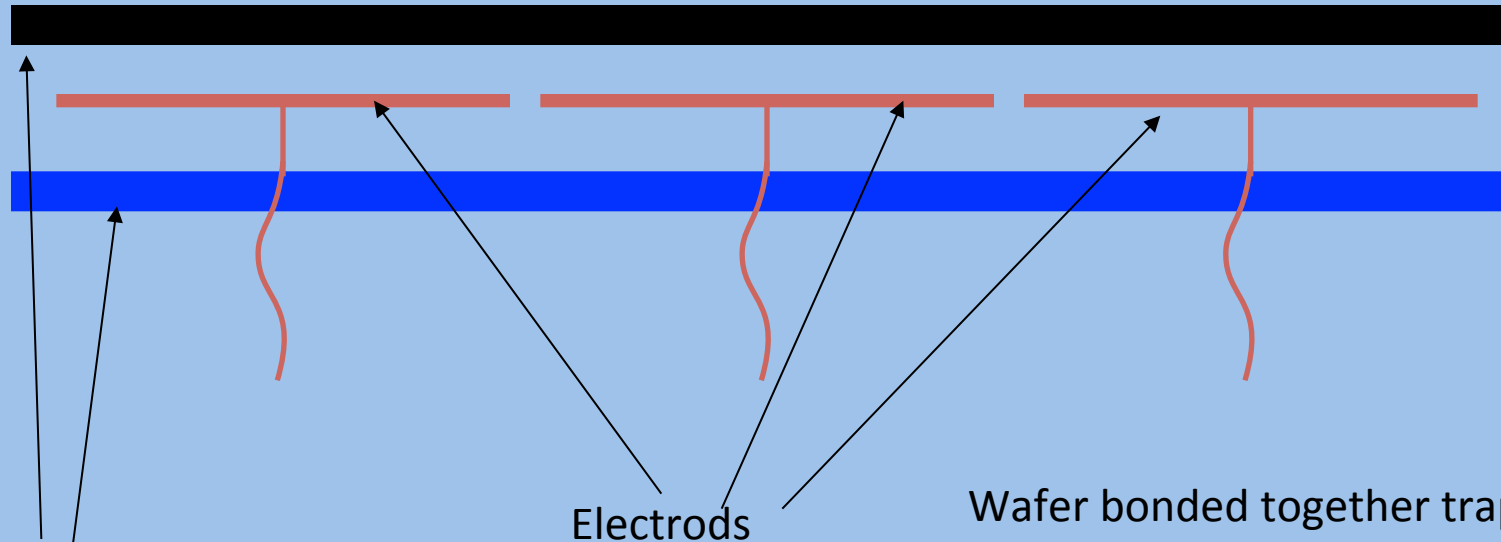
Front View

146 mm diameter  
clear aperture





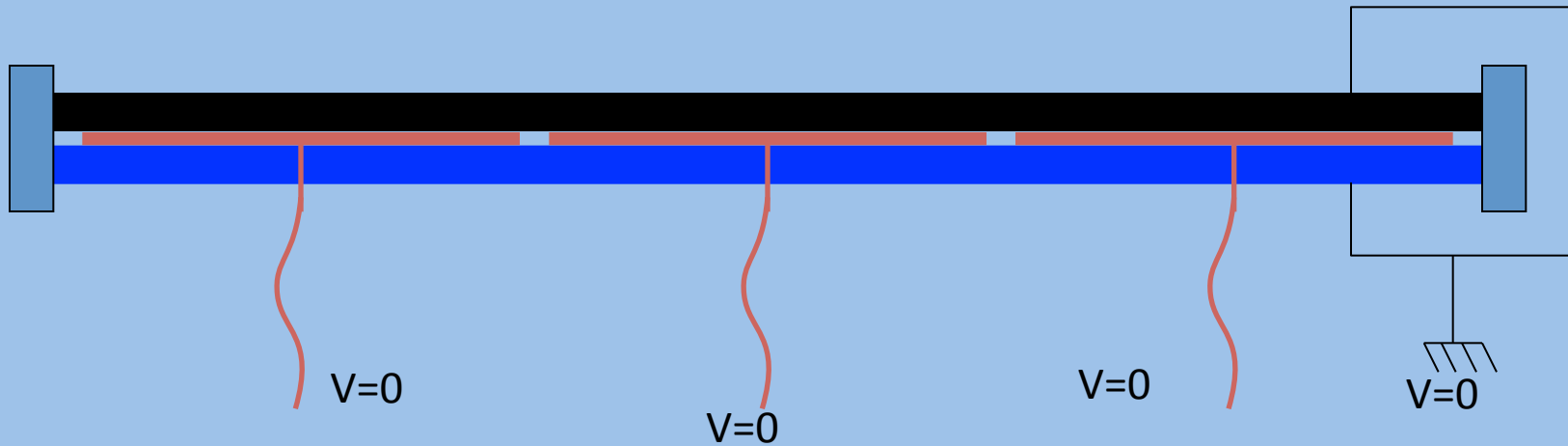
1377 act. Piezo DM for SPHERE  
•  $\pm 5.3 \mu\text{m}$  for  $\pm 400 \text{ V}$   
with its drive electronics



Piezoelectric ceramic wafer  
with opposite polarization

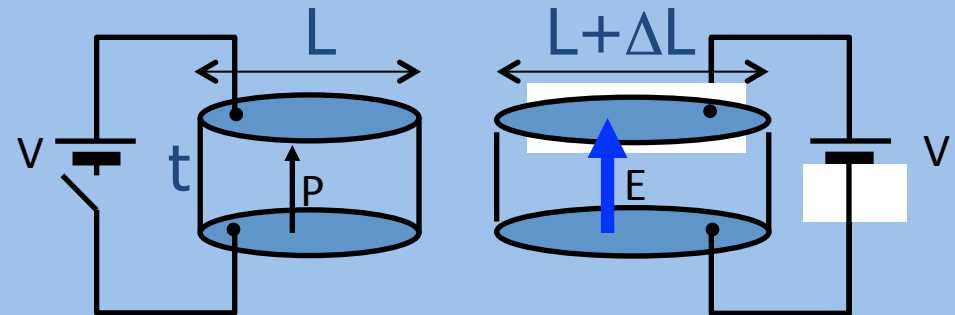
Electrodes

Wafer bonded together trapping  
the electrodes



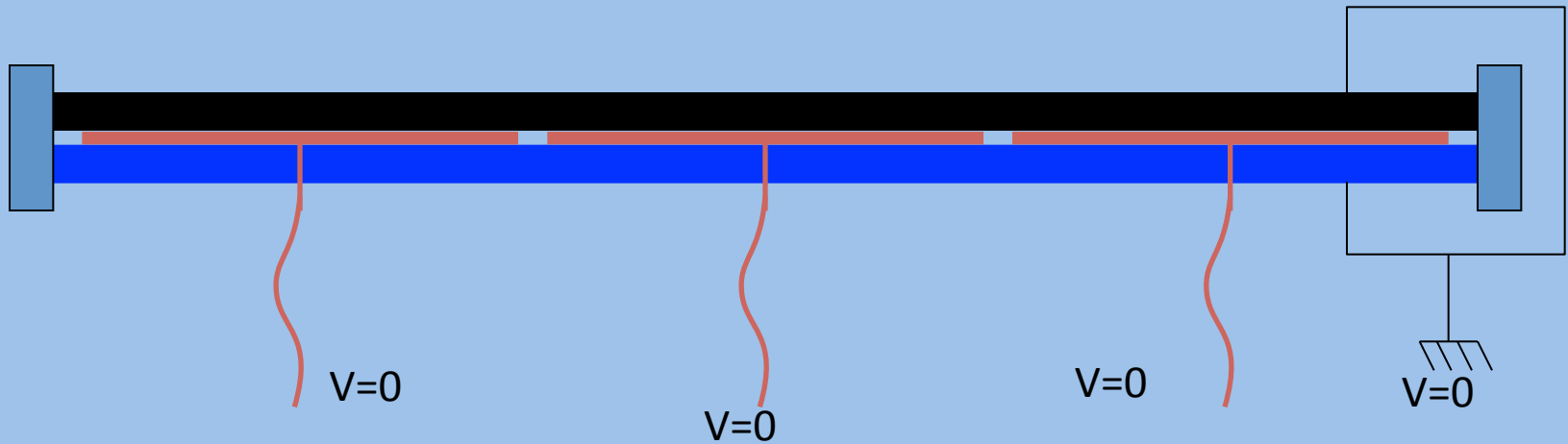
Wafer bonded together trapping the electrodes

External surfaces of the wafers grounded



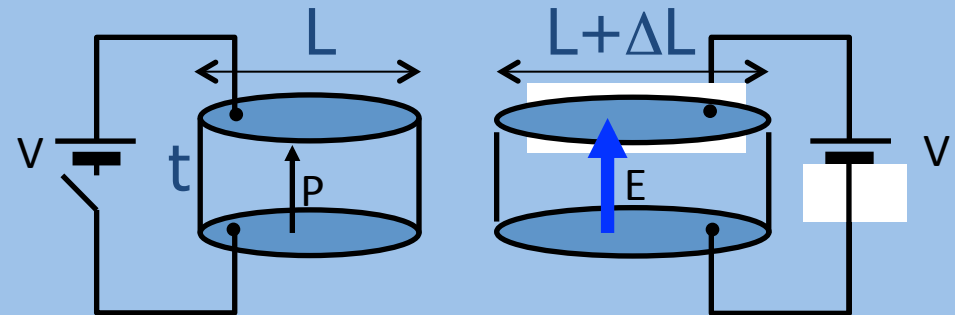
$$\Delta L = (L/t) * d_{31} * V$$





Wafer bonded together trapping the electrodes

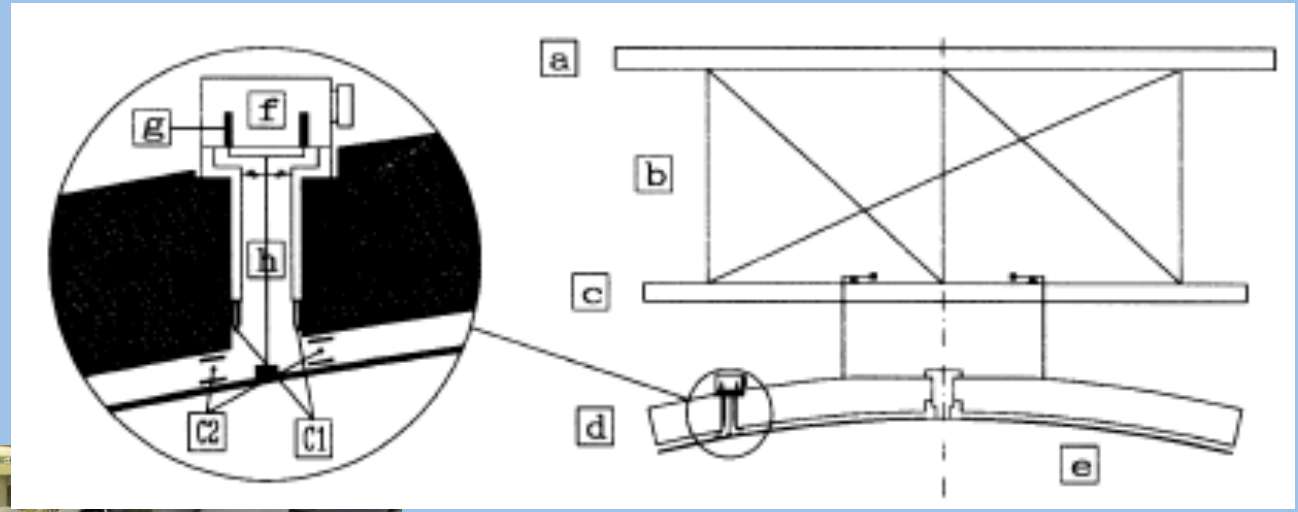
External surfaces of the wafers grounded



$$\Delta L = (L/t) * d_{31} * V$$



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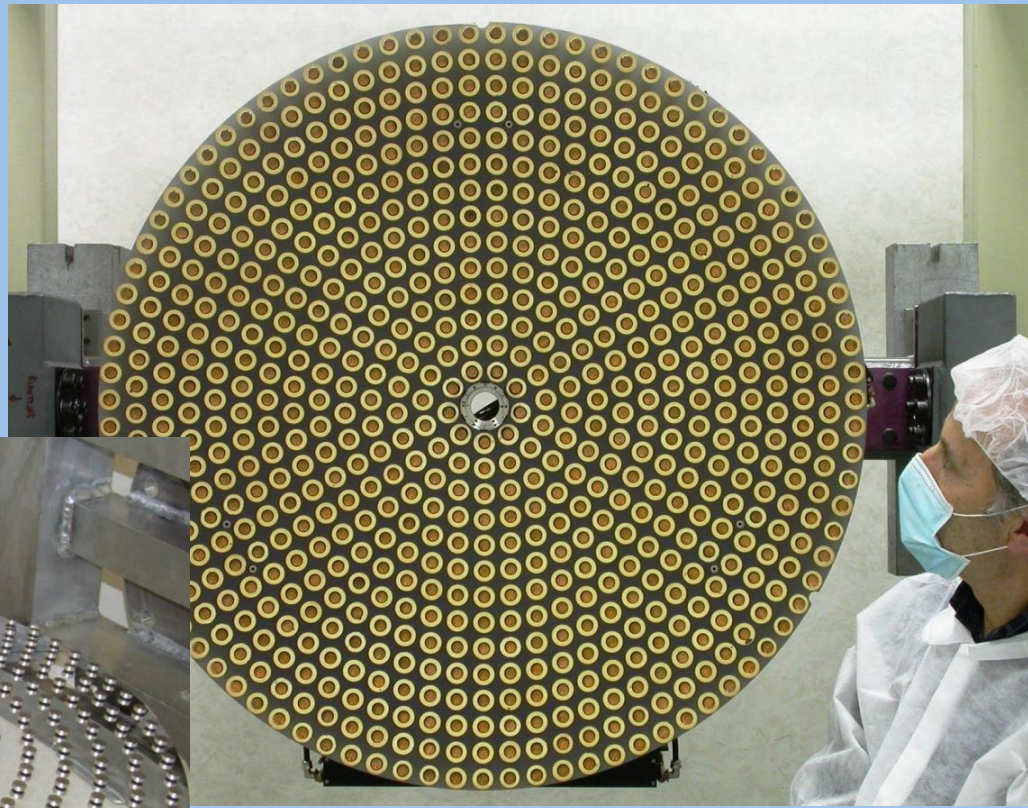
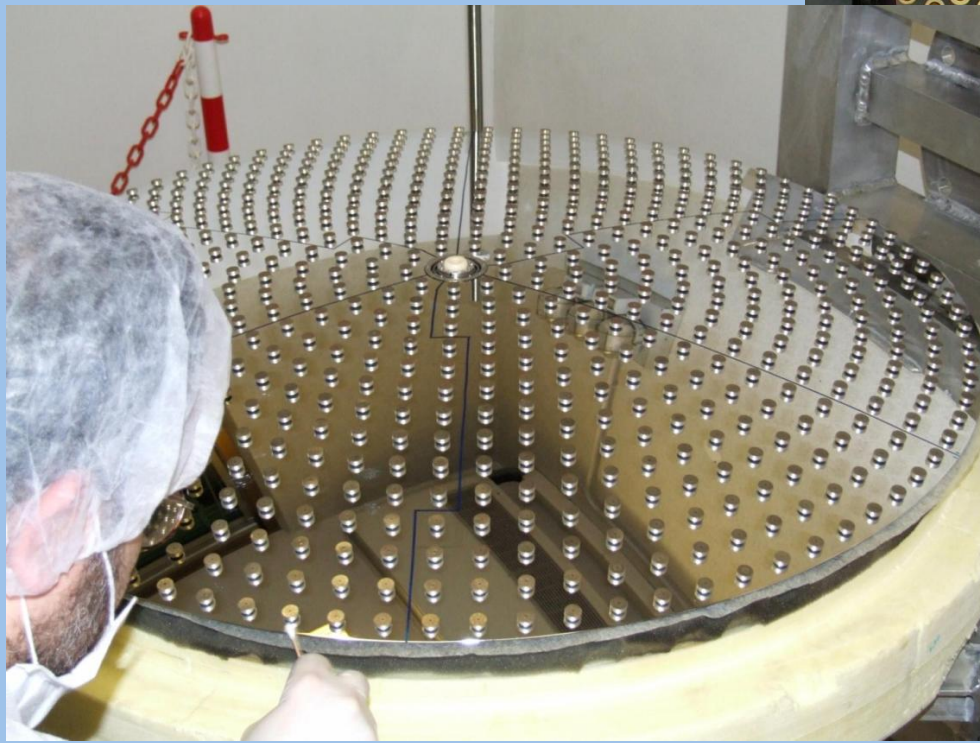




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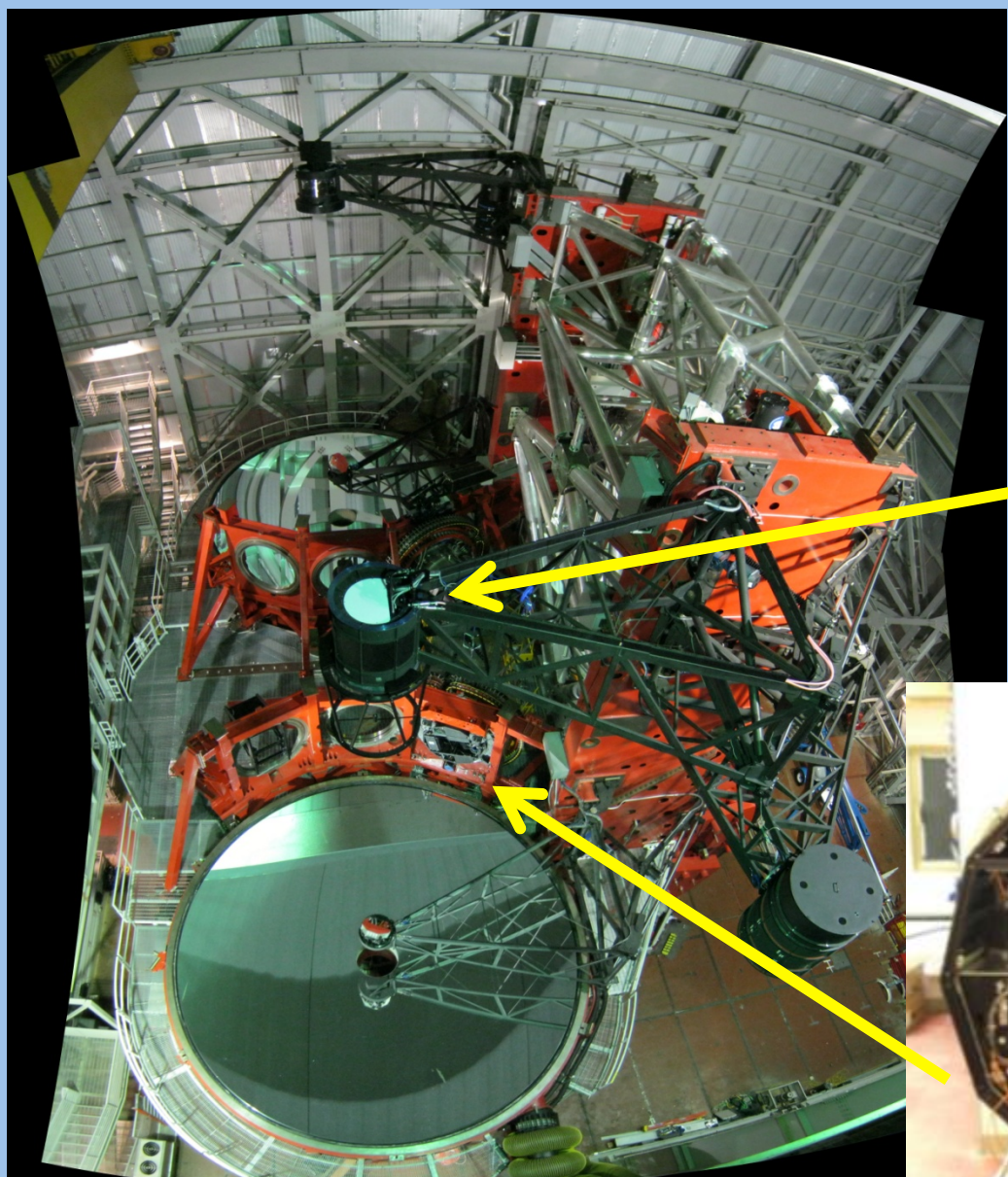
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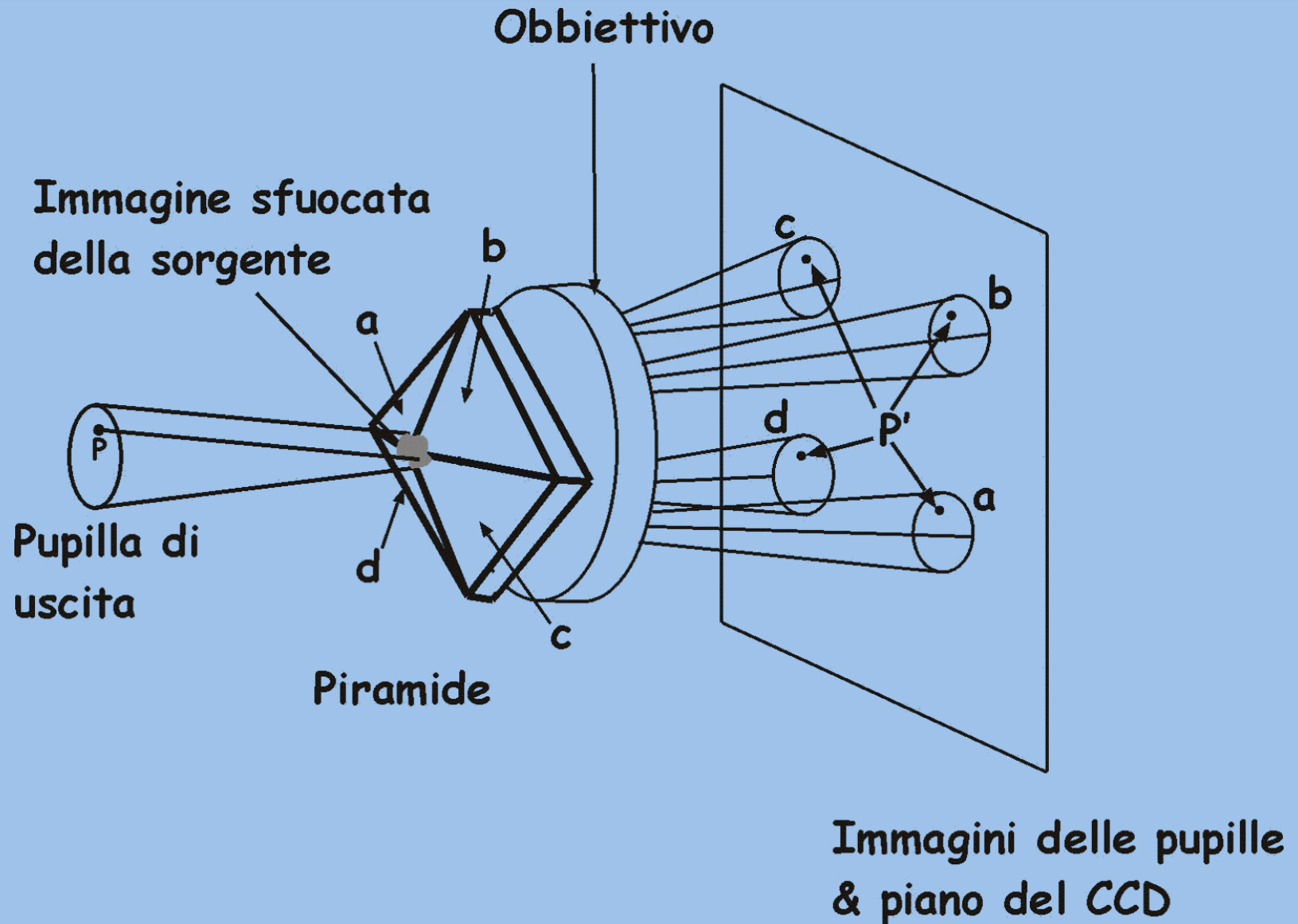
**LBT672a unit**

- 911mm diameter
- 1.6mm thick
- 672 actuators
- Settling time < 1ms
- 30nm WFE



**LBT WFS unit**

- Pyramid sensor
- 30x30 to 5x5 subap.
- Tilt mod.  $\approx 2-6 \lambda/D$
- 1Kfps max [30x30]





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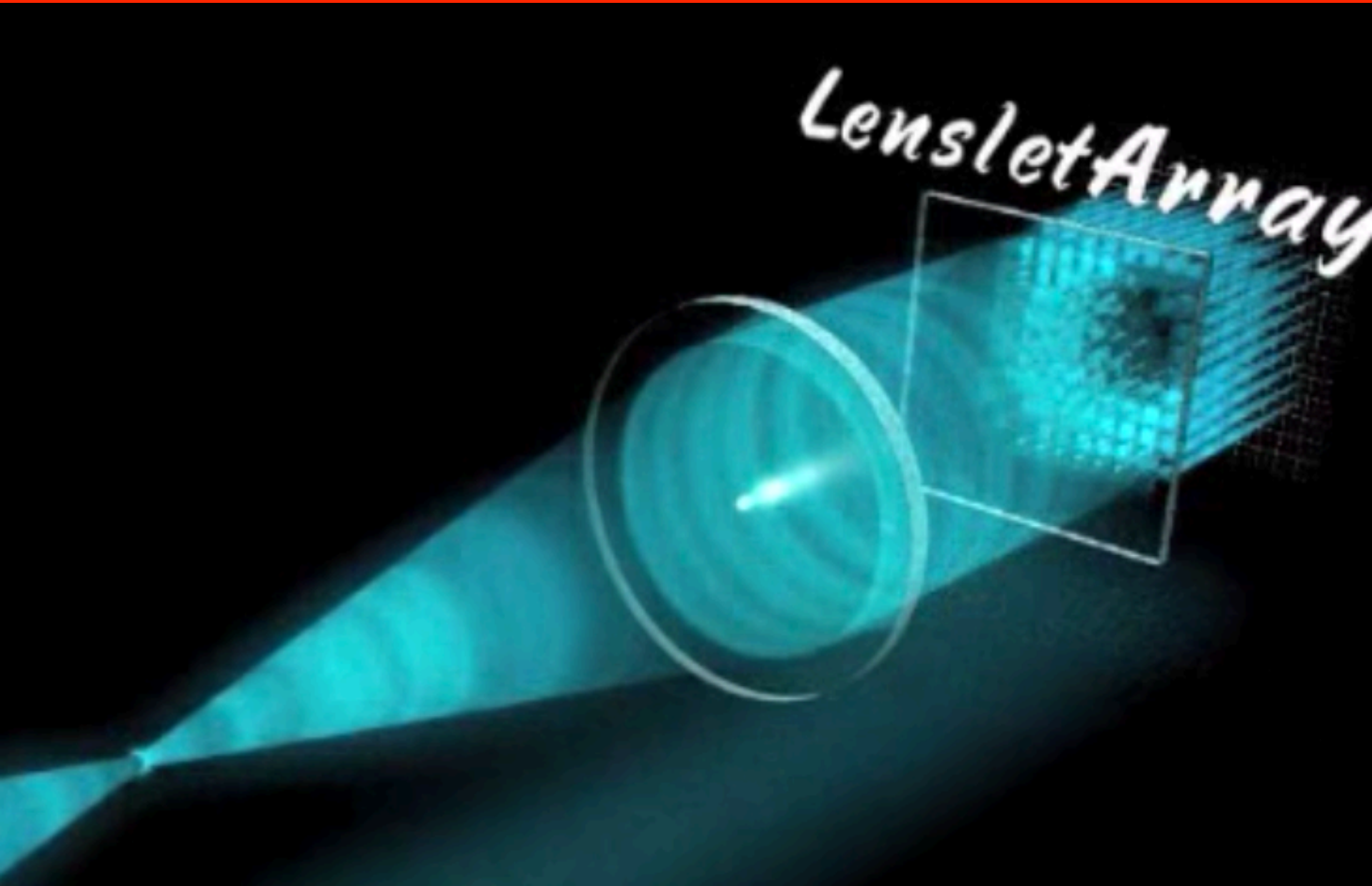
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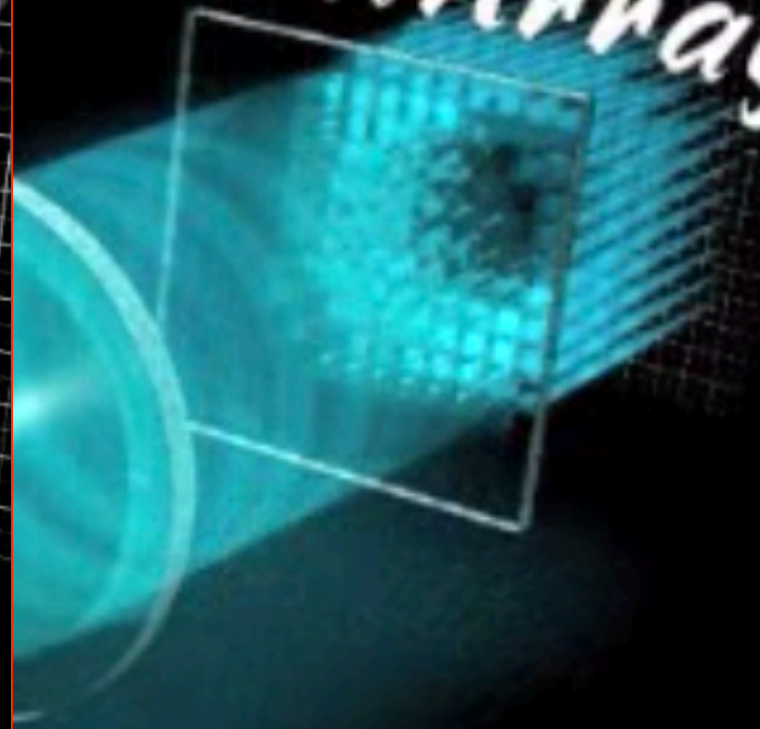
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Lenslet Array





*Lenslet Array*



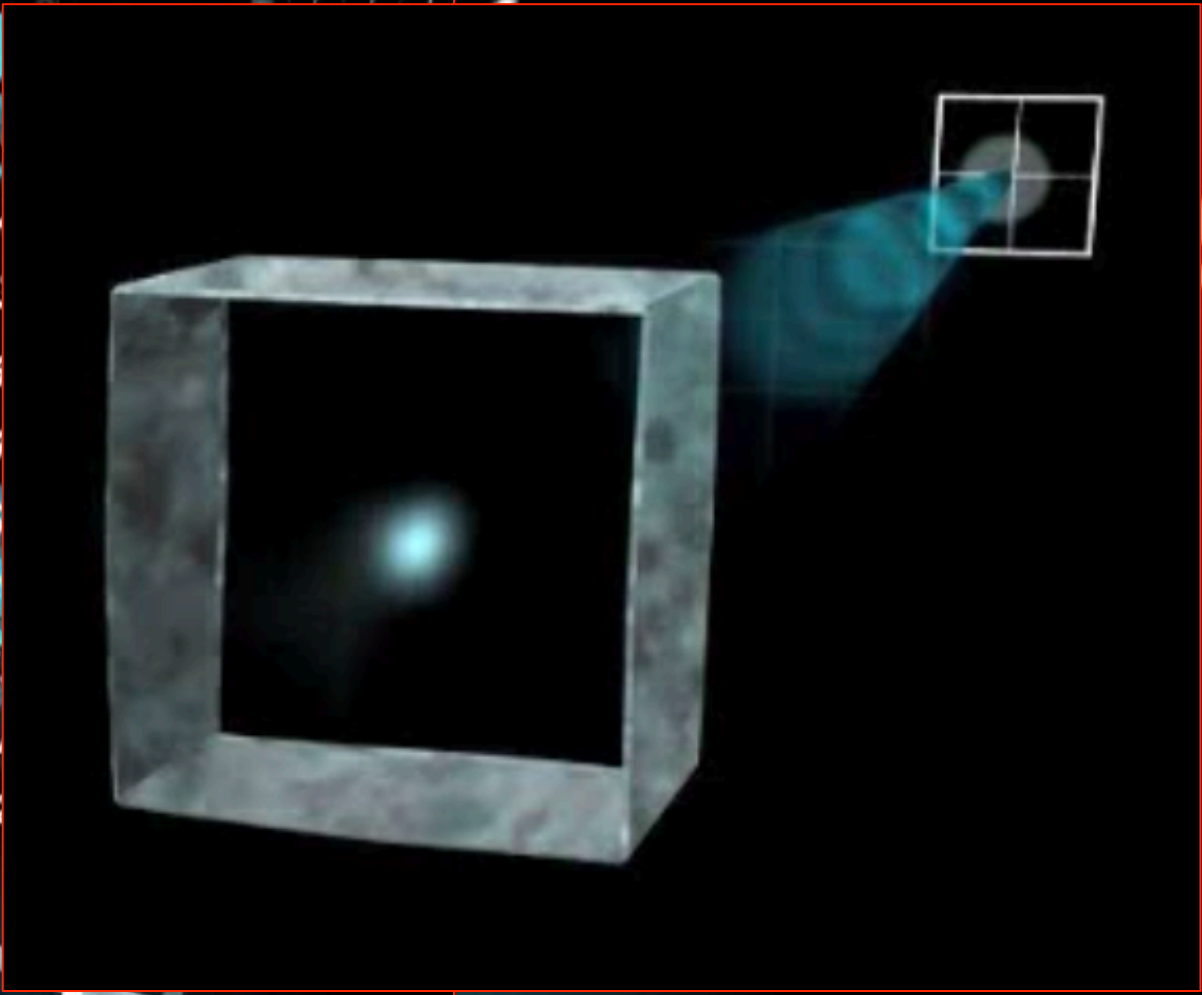




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1 2 3 4 5 6 7 8  
9 10 11 12 13 14 15 16 17  
19 20 21 22 23 24 25 26 27 28  
31 32 33 34 35 36  
39 40 41 42  
45 46 47 48  
51 52 53 54  
57 58 59 60  
63 64 65 66 67 68  
71 72 73 74 75 76 77 78 79 80  
83 84 85 86 87 88 89 90 91 92  
93 94 95 96 97 98 99 100

**N=12**



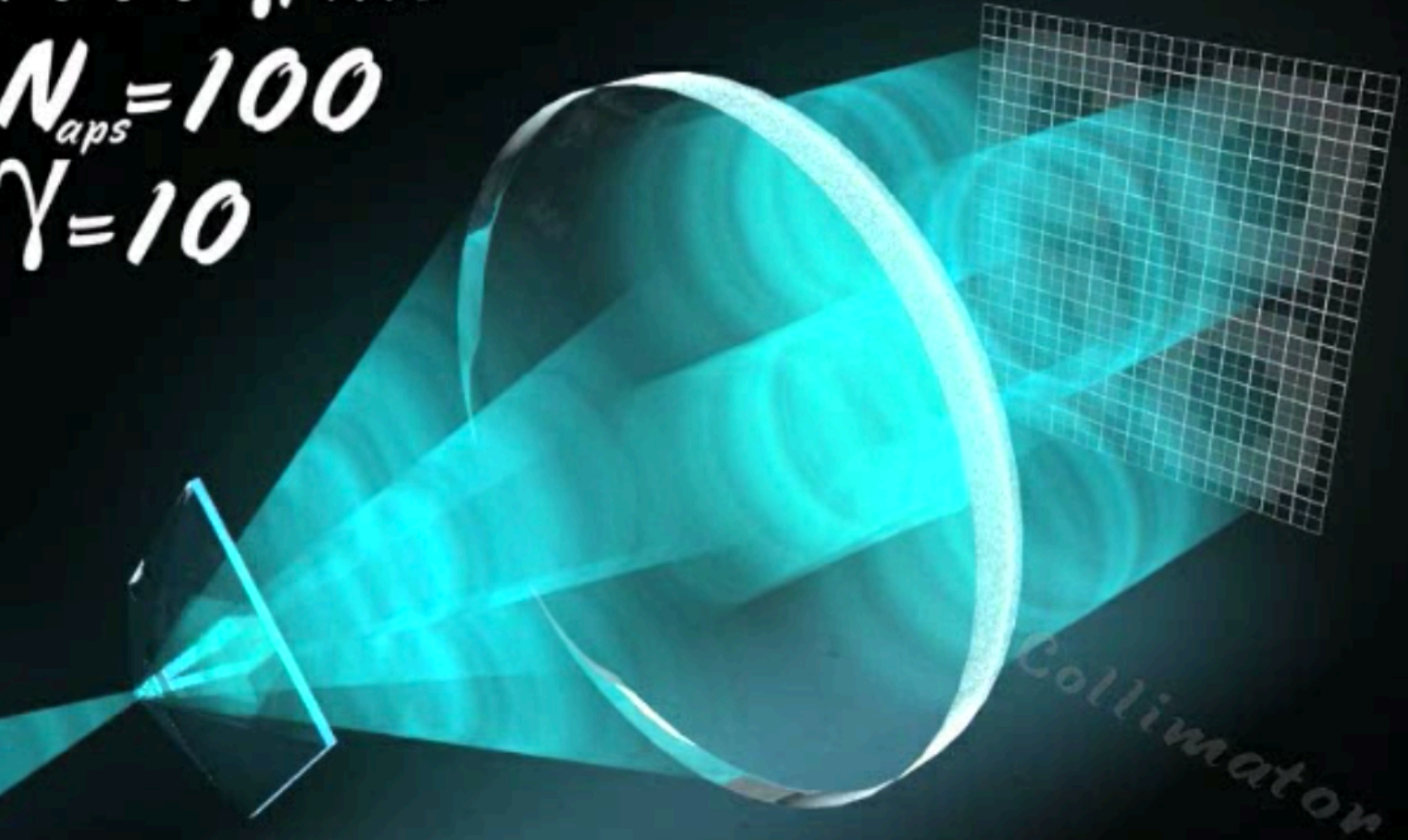


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# Addomesticare la luce

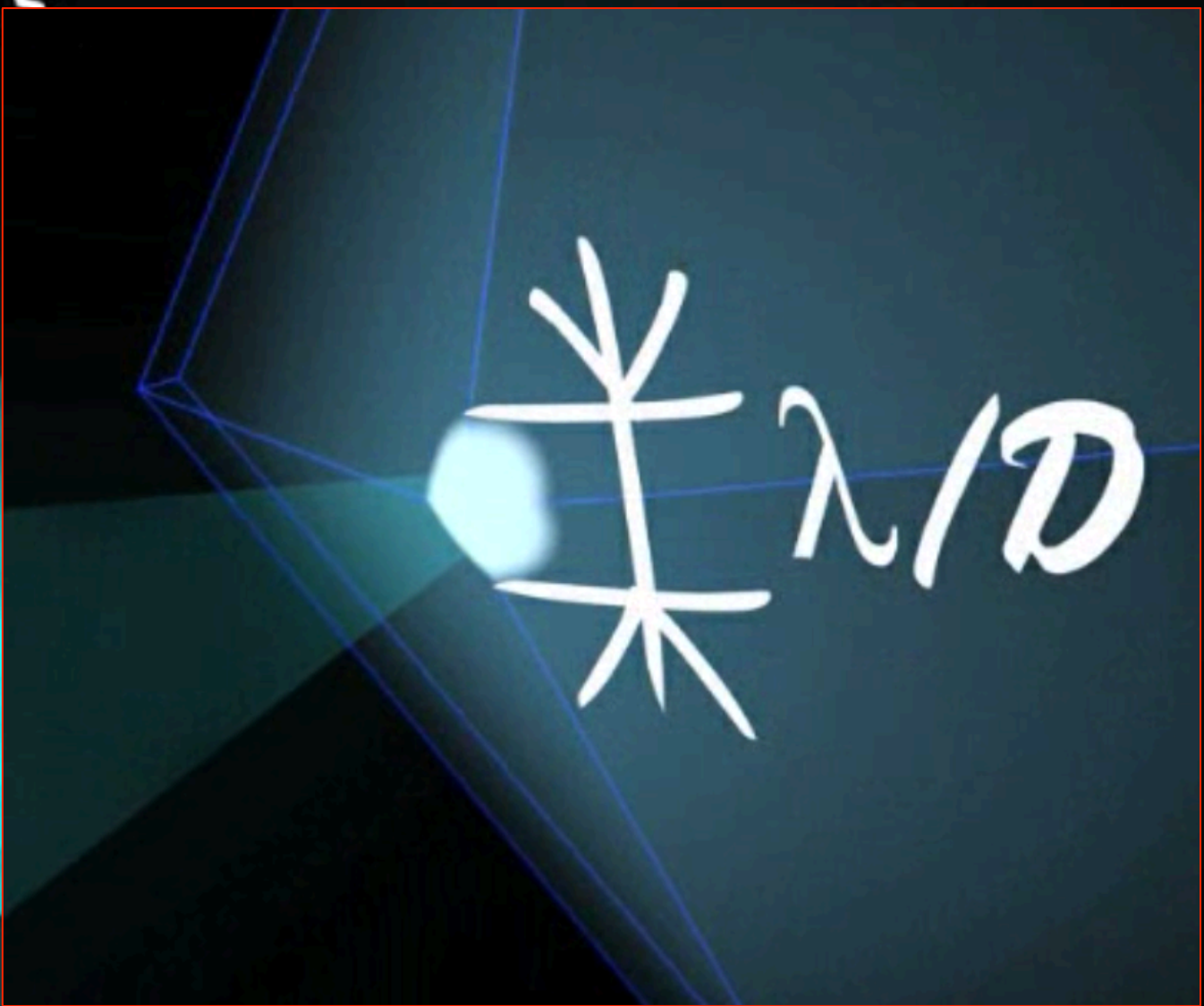
Roberto Ragazzoni

1000  $\mu$ m/s  
 $N_{aps} = 100$   
 $\gamma = 10$





1000 SIM  
 $N_{aps} = 100$   
 $\gamma = 10$

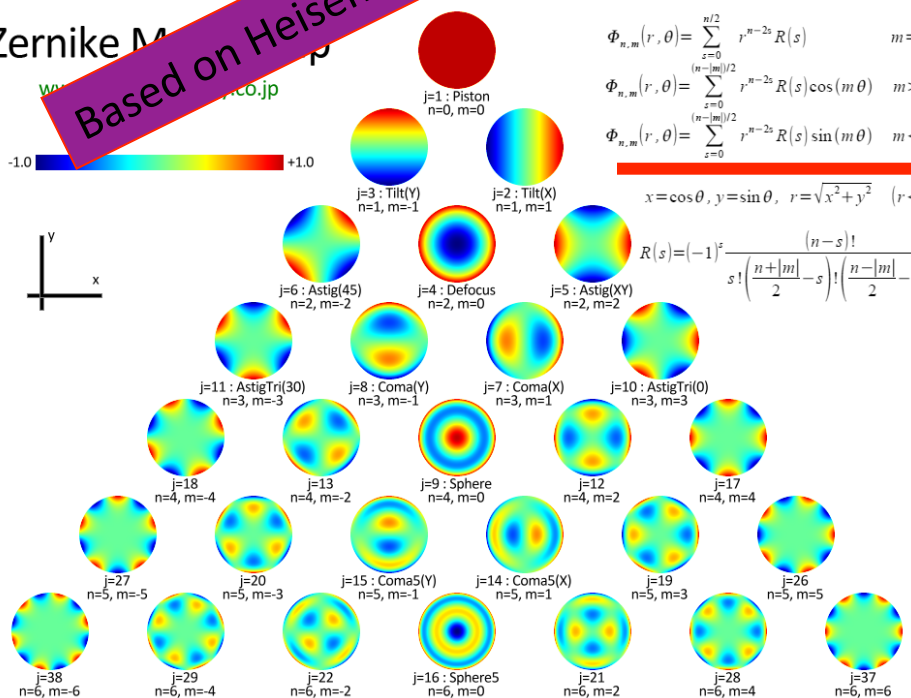




Based on Heisenber uncertainty principle...

Zernike M

-1.0 +1.0



$$\Phi_{n,m}(r, \theta) = \sum_{s=0}^{n/2} r^{n-2s} R(s) \quad m =$$

$$\Phi_{n,m}(r, \theta) = \sum_{s=0}^{(n-|m|)/2} r^{n-2s} R(s) \cos(m\theta) \quad m >$$

$$\Phi_{n,m}(r, \theta) = \sum_{s=0}^{(n-|m|)/2} r^{n-2s} R(s) \sin(m\theta) \quad m <$$

$$x = \cos \theta, y = \sin \theta, r = \sqrt{x^2 + y^2} \quad (r <$$

$$R(s) = (-1)^s \frac{(n-s)!}{s! \left(\frac{n+|m|}{2} - s\right)! \left(\frac{n-|m|}{2} - s\right)!}$$

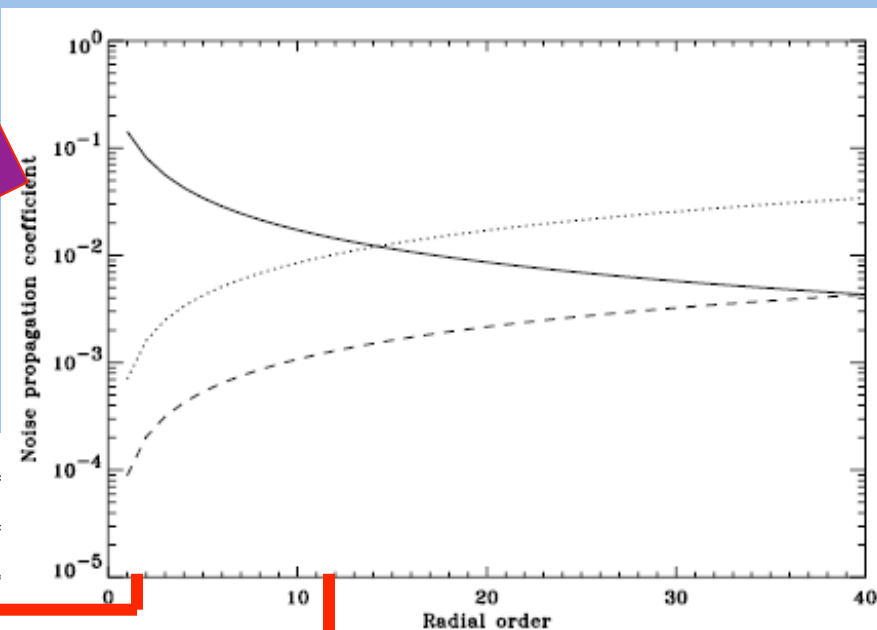


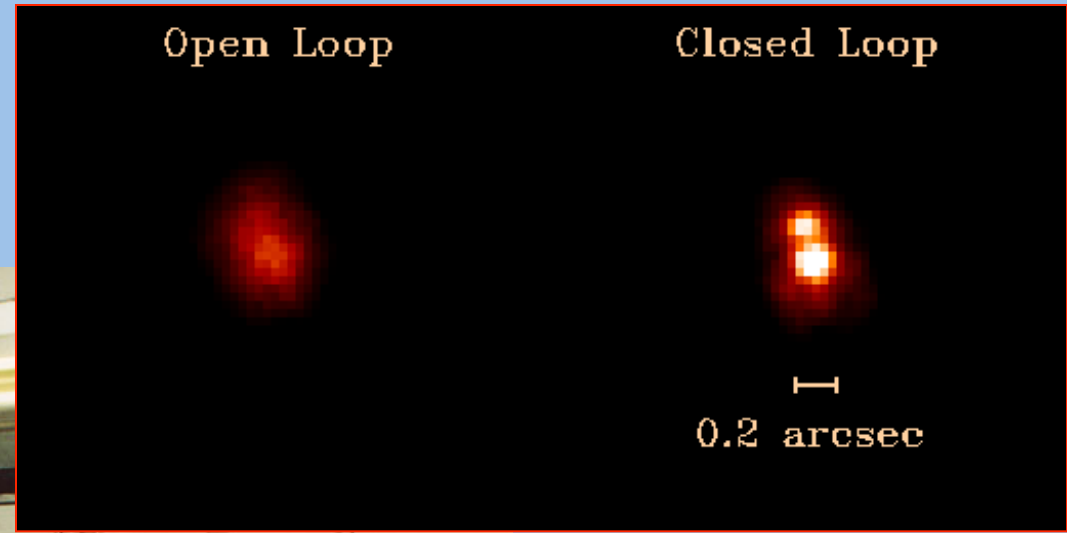
Fig. 3. Solid line:  $p_i$  vs. the radial order  $q$  for the SH case; dotted line: the same for the pyramid case; dashed line: the same scaled in order to have the same integral area for the WF residual error.



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# Then, in the night between 5 and 6 September 2001...



We also made a very rough experiment at TNG oscillating the pyramid by the “SH” amount...



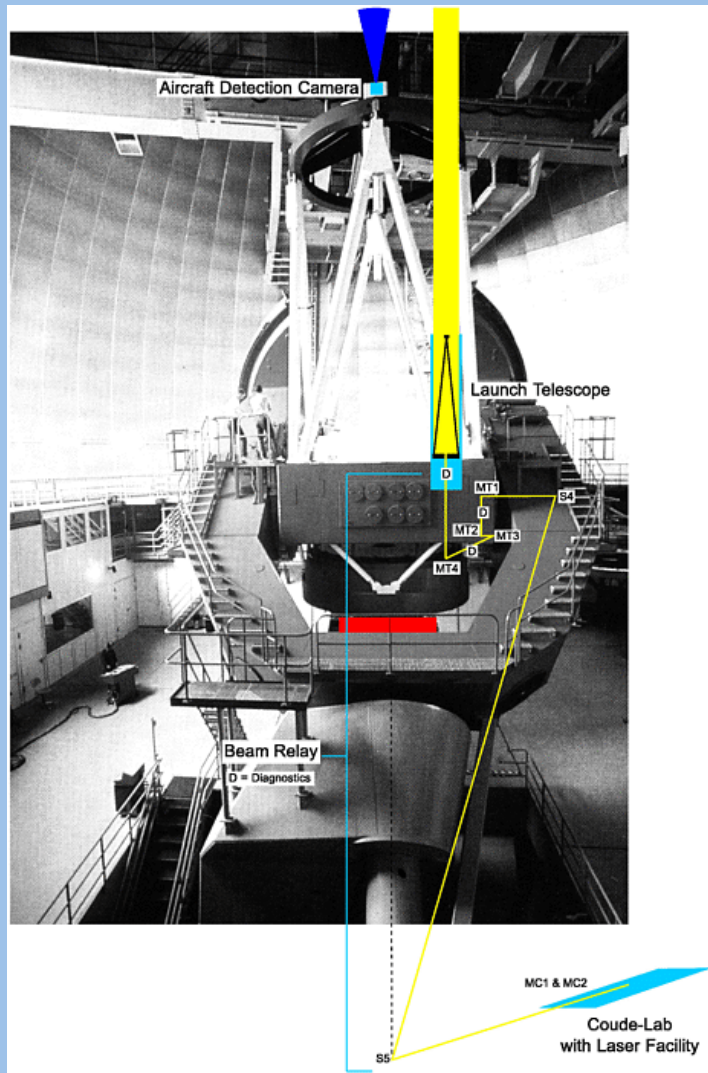
Table 1. Known Airglow Emissions for the Earth<sup>a</sup>

$\lambda$ (Å)	Emitter State	Day Intensity	Height (km)	Process	Twilight Intensity	Height (km)	Night Intensity	Height (km)	Process	$g$ (s <sup>-1</sup> )	$d$ (source)	$h_q$ (km)	Remarks
304	He <sup>+</sup>	Present		R			(4.8)			$1.1 \times 10^{-4}$			Nightglow radiation could be either or both
584	He	Present		R			(12)			$1.7 \times 10^{-5}$			
834	O <sup>+</sup>	Present		R									
1025	HL $\gamma$ - $\beta$	Present	200 to 10 <sup>4</sup>	R			10 R	200	R	$2.6 \times 10^{-6}$			
1200	N( <sup>4</sup> P)	400 R	180	R?									
1216	HL $\gamma$ - $\alpha$	6 kR	100 to 10 <sup>5</sup>	R			2 kR	100 to 10 <sup>5</sup>	R	$2.1 \times 10^{-3}$	( $4.5 \times 10^{-8}$ [H <sub>2</sub> ])		
1302, 1304, 1306	O( <sup>3</sup> S)	7.5 kR	190	eFR						$1.0 \times 10^{-4}$			
1356	O( <sup>3</sup> S)	350 R	140	e									
1300–1500	N <sub>2</sub> ( $\alpha$ <sup>1</sup> $\Pi_g$ )	Present		e									Lyman–Birge–Hopfield
1493, 1744	N	Present		e									
2000–4000	N <sub>2</sub> (A <sup>3</sup> $\Sigma_u^+$ )	Present		e									Vegard–Kaplan
2160, etc.	NO(A <sup>3</sup> $\Sigma^+$ )	1 kR	70–150	R						$4.0 \times 10^{-6}$			$\gamma$ bands; $g$ for 1–0 band
3371, etc.	N <sub>2</sub> (C <sup>3</sup> $\Pi_u$ )	900 R	$\geq 130$	e									2nd Positive
2600–3800	O <sub>2</sub> (A <sup>3</sup> $\Sigma_u^+$ )						600 R	90	C				Herzberg
3466	N( <sup>2</sup> P)	Present		e									
3889	He( <sup>3</sup> P)			R	1 R	>400?				0.1			Scatterer is He( <sup>3</sup> S)
3914, etc.	N <sub>2</sub> <sup>+</sup> (B <sup>2</sup> $\Sigma_u^+$ )	2.0 kR	150	RF	200–500 R	300	<1 R			0.050	10 <sup>-8</sup> [N <sub>2</sub> ]	46	1st Negative
3933.68	Ca <sup>+</sup> ( <sup>2</sup> P)				<100 R	80–200				0.3, 0.15			
4368	O( <sup>4</sup> S)				1 R								
5200	N( <sup>2</sup> D)	90 R	~200	I	10 R		1 R	~250	I	( $6 \times 10^{-11}$ )		~200	Also quenched by electrons
5000–6500	NO <sub>2</sub> ?						1 R/Å	~90	C				Continuum
5577	O( <sup>1</sup> S)	3.0 kR	90, 175	Ce	400 R	200?	250 R	90, 300	C, I	( $1 \times 10^{-11}$ )	$3 \times 10^{-8}$ [O <sub>2</sub> ]	94	2972 Å (5%)
5893	Na( <sup>2</sup> P)	30 kR	92	R	1–4 kR	92	20–150 R	~92	C	0.80		40	
6300, 64	O( <sup>1</sup> D)	2–20 kR	250	FIe	1 kR	300	10–500 R	300	I	( $4.5 \times 10^{-10}$ )	$5.8 \times 10^{-6}$ [O <sub>2</sub> ]	340	
6563	H( <sup>3</sup> P)						3 R	200	F	$2.6 \times 10^{-6}$			
6708	Li( <sup>2</sup> P)				10–1000 R	~90				16			May be of artificial origin
7619, etc.	O <sub>2</sub> ( <sup>1</sup> $\Sigma$ )	300 kR	40–120	RFT			6 kR	~80	C	$6.3 \times 10^{-9}$	$<5 \times 10^{-3}$ [O <sub>2</sub> ]	90	Atmospheric
7699	K( <sup>2</sup> P)				40 R	~90				1.67			
7774, 8446	O	1.6, 1.1 kR	~150	e									
10510, etc.	N <sub>2</sub> (B <sup>3</sup> $\Pi_g$ )	900 R	150	e								37	1st Positive
10830	He( <sup>3</sup> P)				3 kR	500				16.8		~400	Scatterer is He( <sup>3</sup> S); $h_q$ for its destruction
11036, etc.	N <sub>2</sub> <sup>+</sup> (A <sup>2</sup> $\Pi_u$ )	4 kR	150	RF						0.042	$2.8 \times 10^{-8}$		Meinel; $g$ , $d$ for 1-0 band (9200 Å)
12700, etc.	O <sub>2</sub> ( <sup>1</sup> $\Delta$ )	20 MR	50	F	5 MR	80	80 kR	90?	C?	( $9.4 \times 10^{-11}$ )	$9.5 \times 10^{-3}$ [O <sub>2</sub> ]	75	IR atm; 0-1 band 1.58 $\mu$ m; Noxon bands 1.9 $\mu$ m
2800, etc.	OH( $\nu < 9$ )	4.5 MR		C			4.5 MR	90	C				Meinel; 4.5 $\mu$ m to 3816 Å

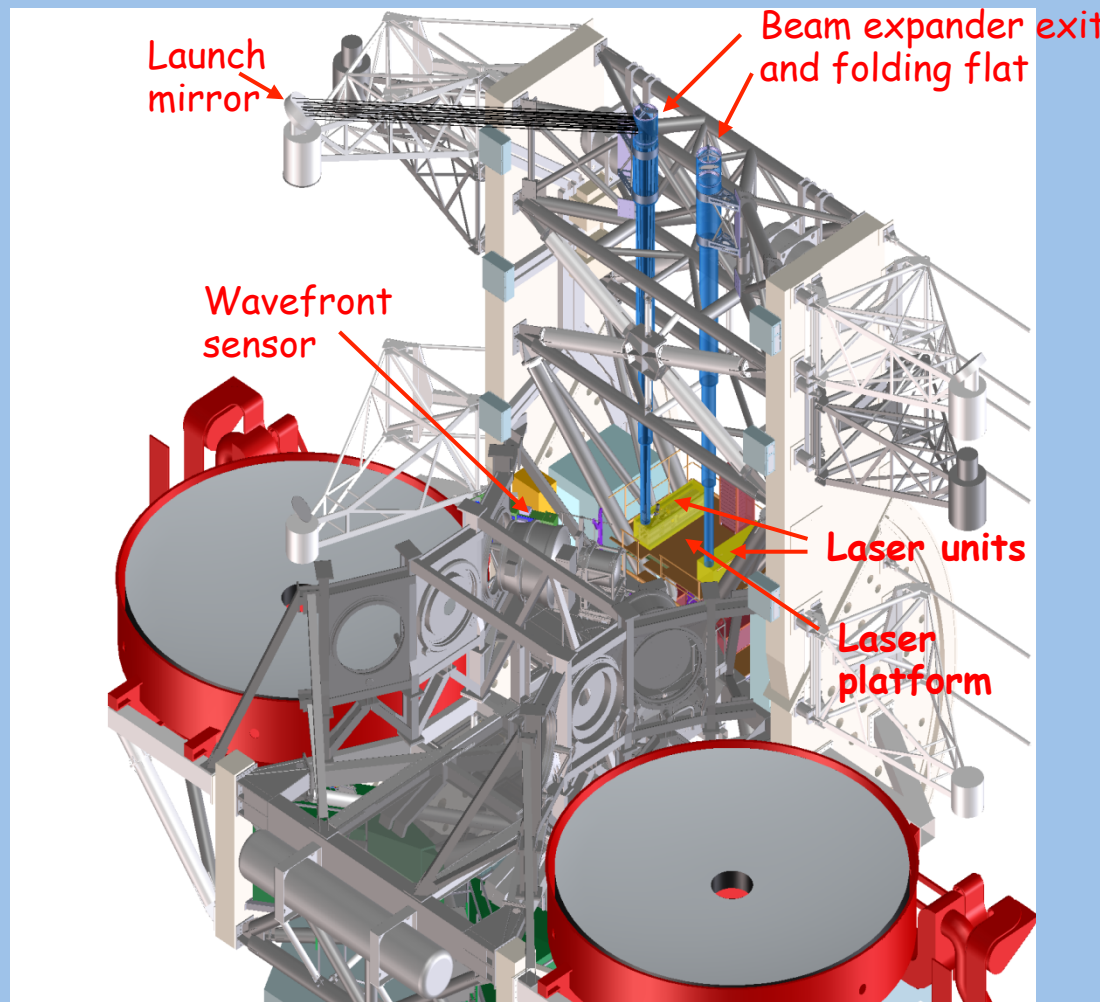
<sup>a</sup>From Ref. 20. Production processes are R, resonance scattering; F, fluorescence; C, chemical association; I, ionic reactions; e, photoelectrons; T, excitation transitions. Production rate factors are  $g$  and  $d$ ;  $h_q$  is the quenching height.



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DSAZ 3.5 m Telescope and the ALFA LGS-System





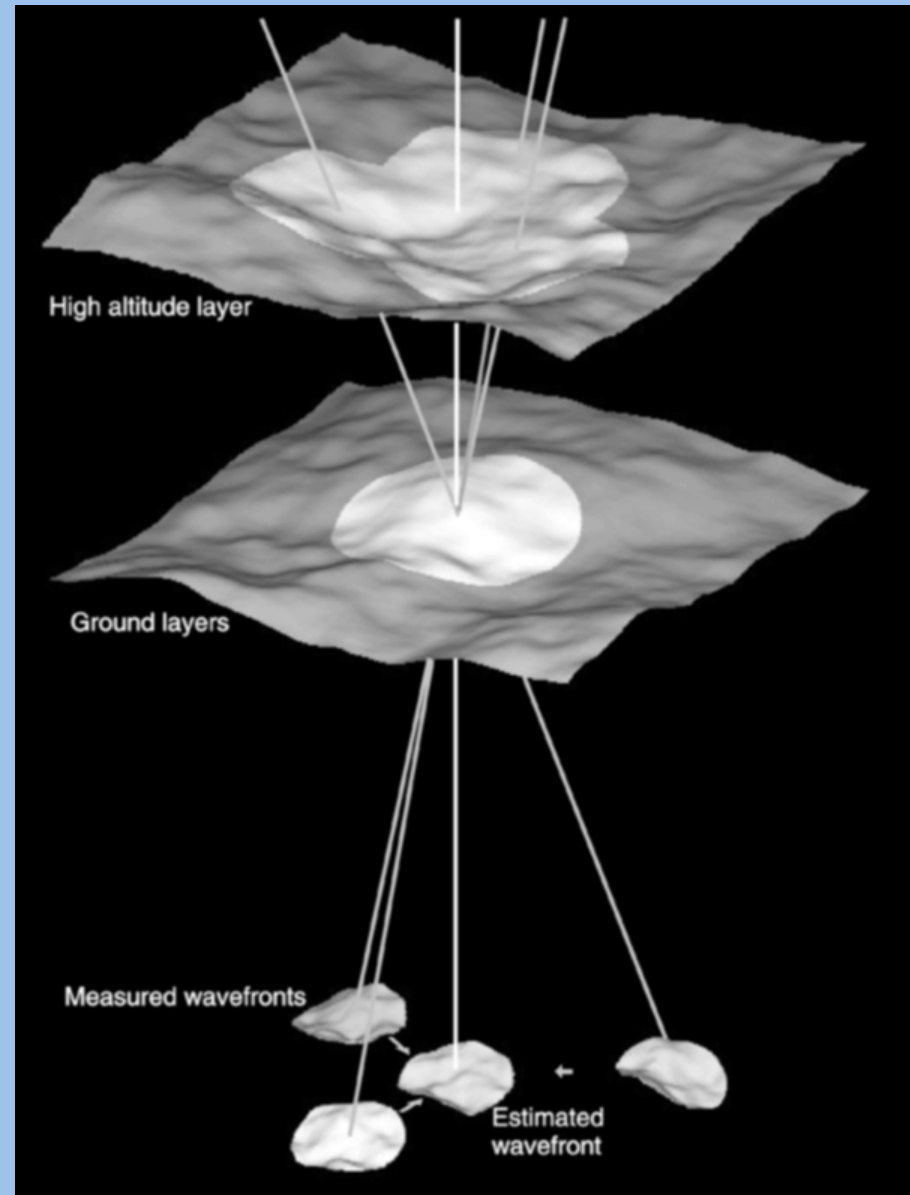
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# Tomografia





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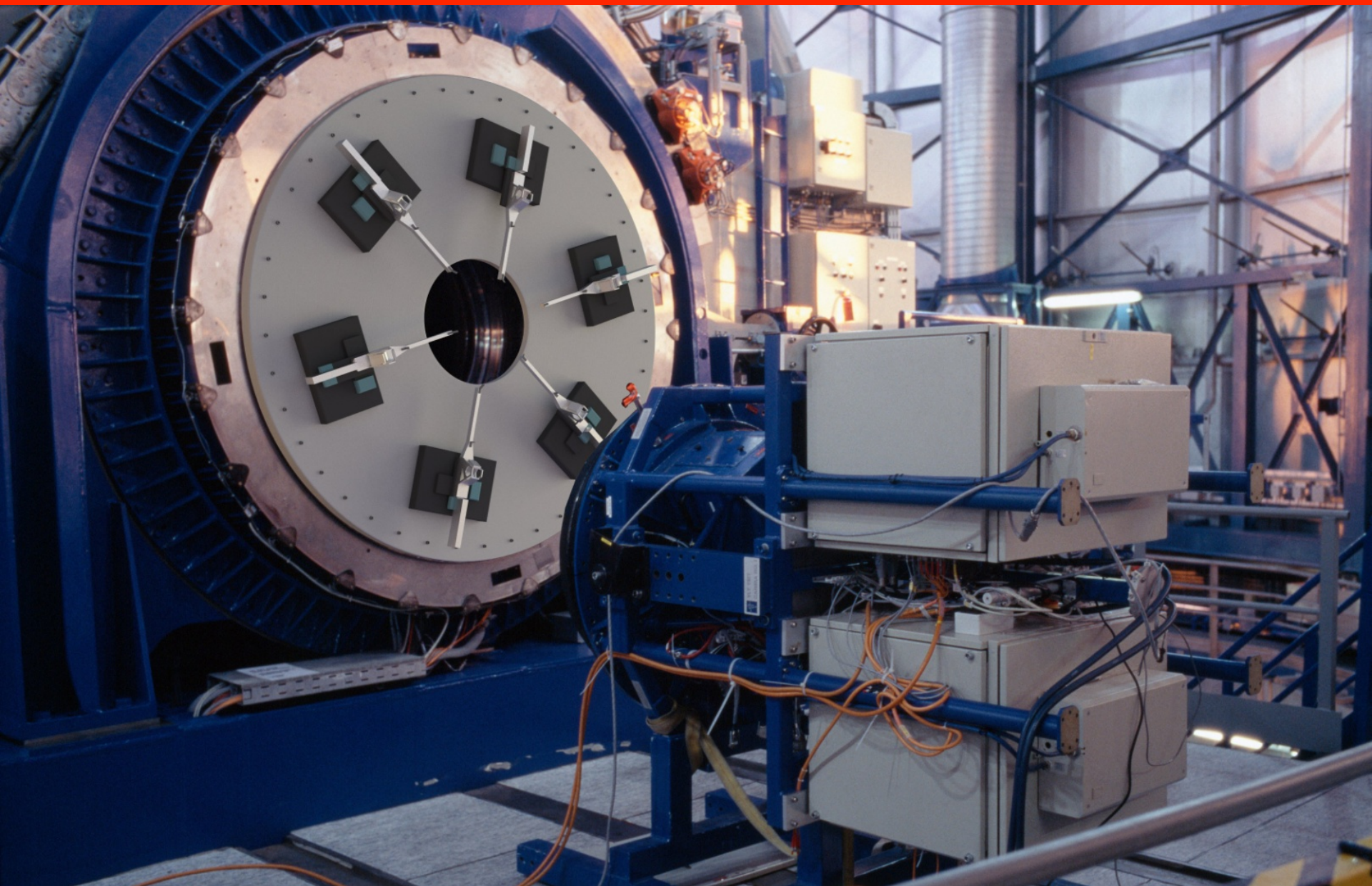


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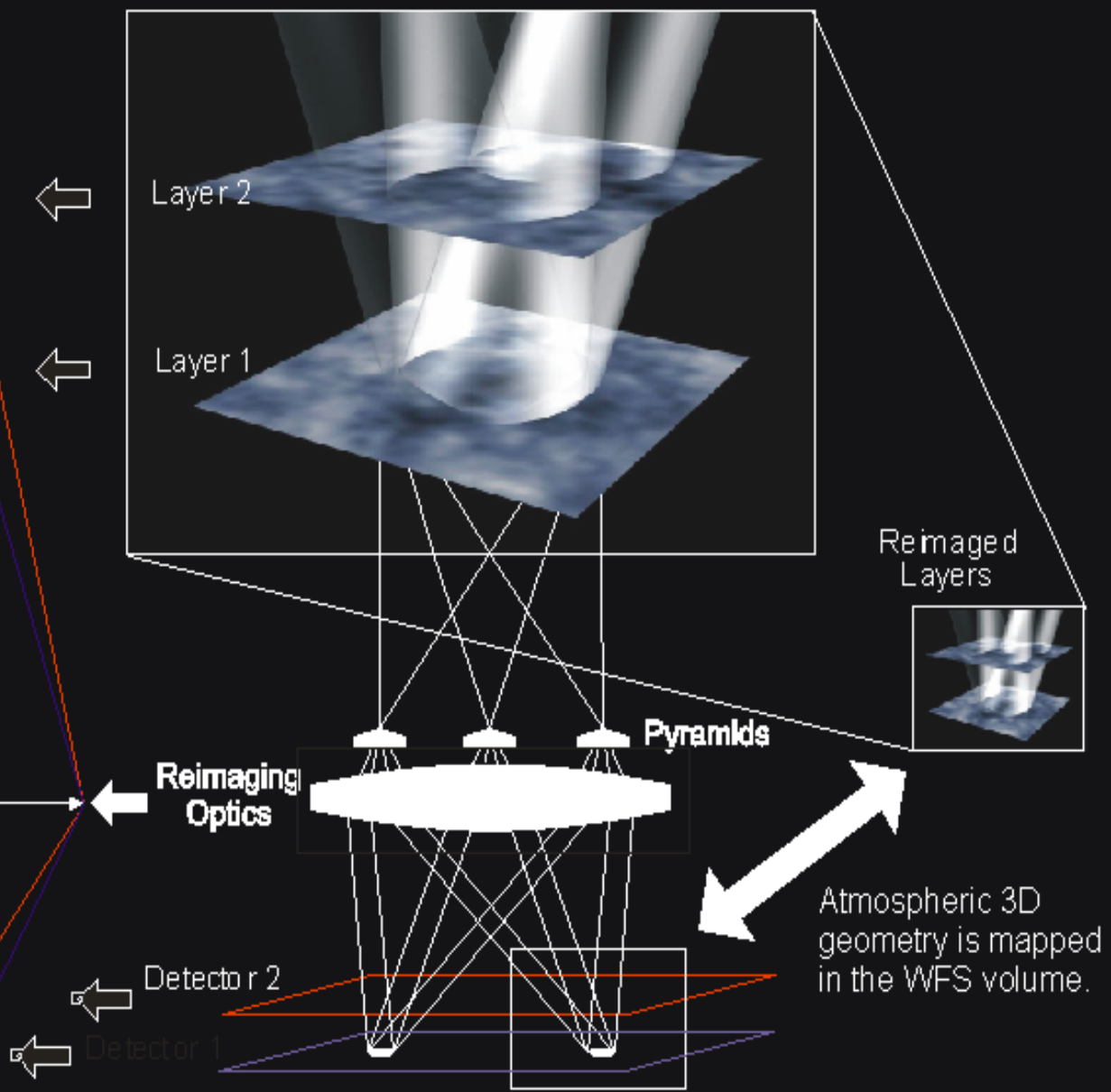
Addomesticare la luce  
*Roberto Ragazzoni*





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Pyramid WFS based system easily complies with such an approach. Complexity scales mostly with the number of sensed layers rather than with the number of references.



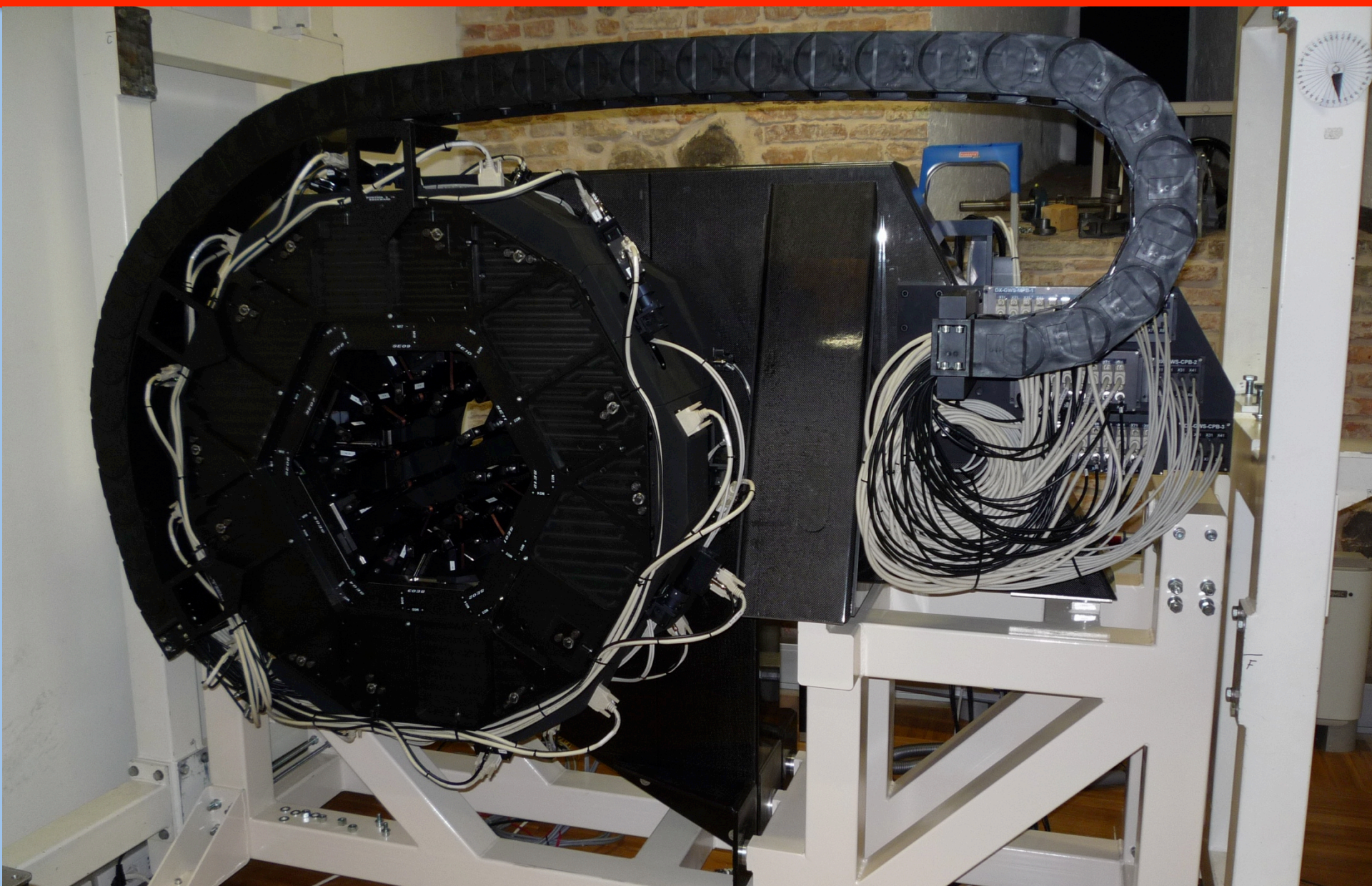
Atmospheric 3D geometry is mapped in the WFS volume.





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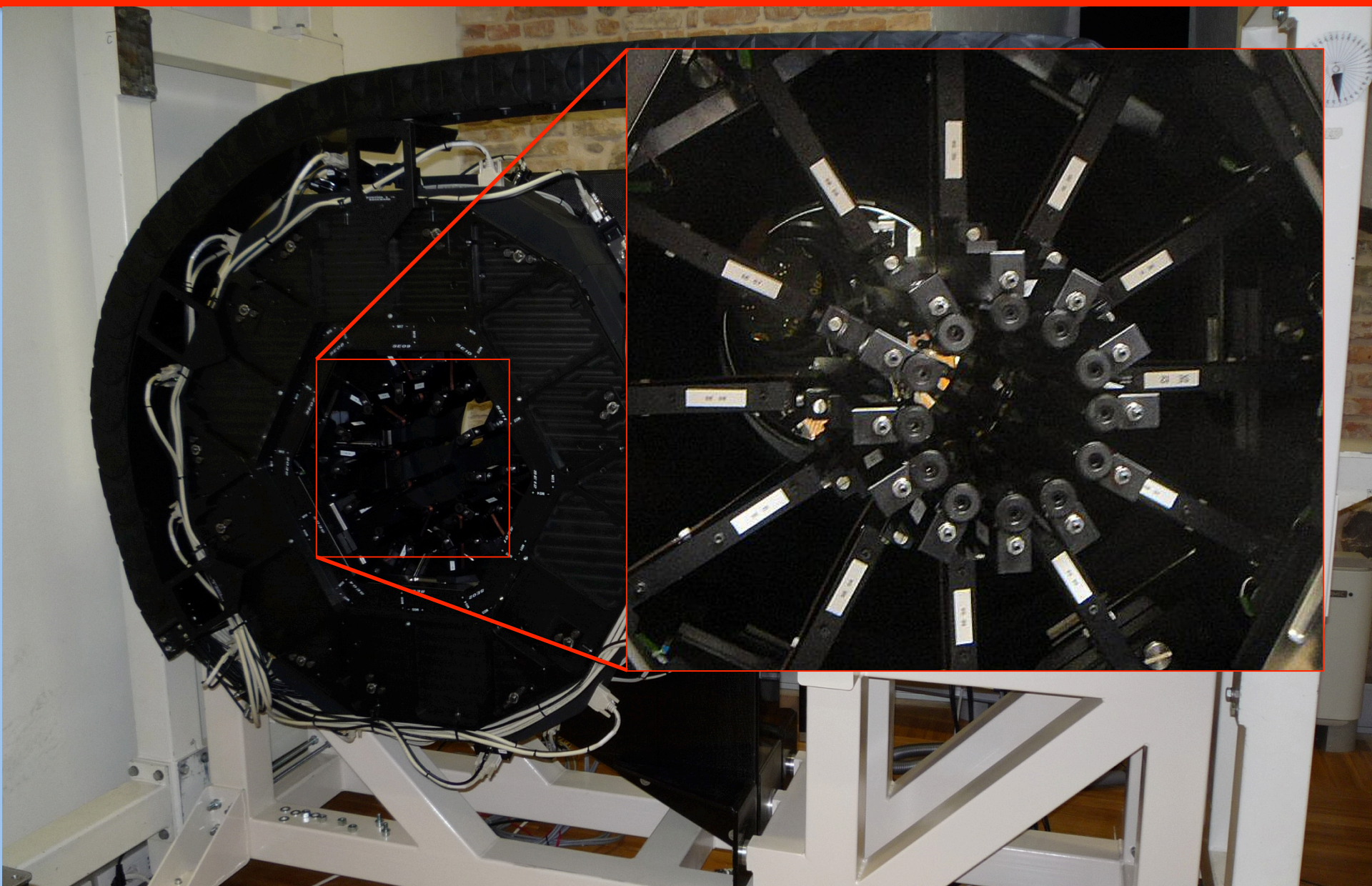




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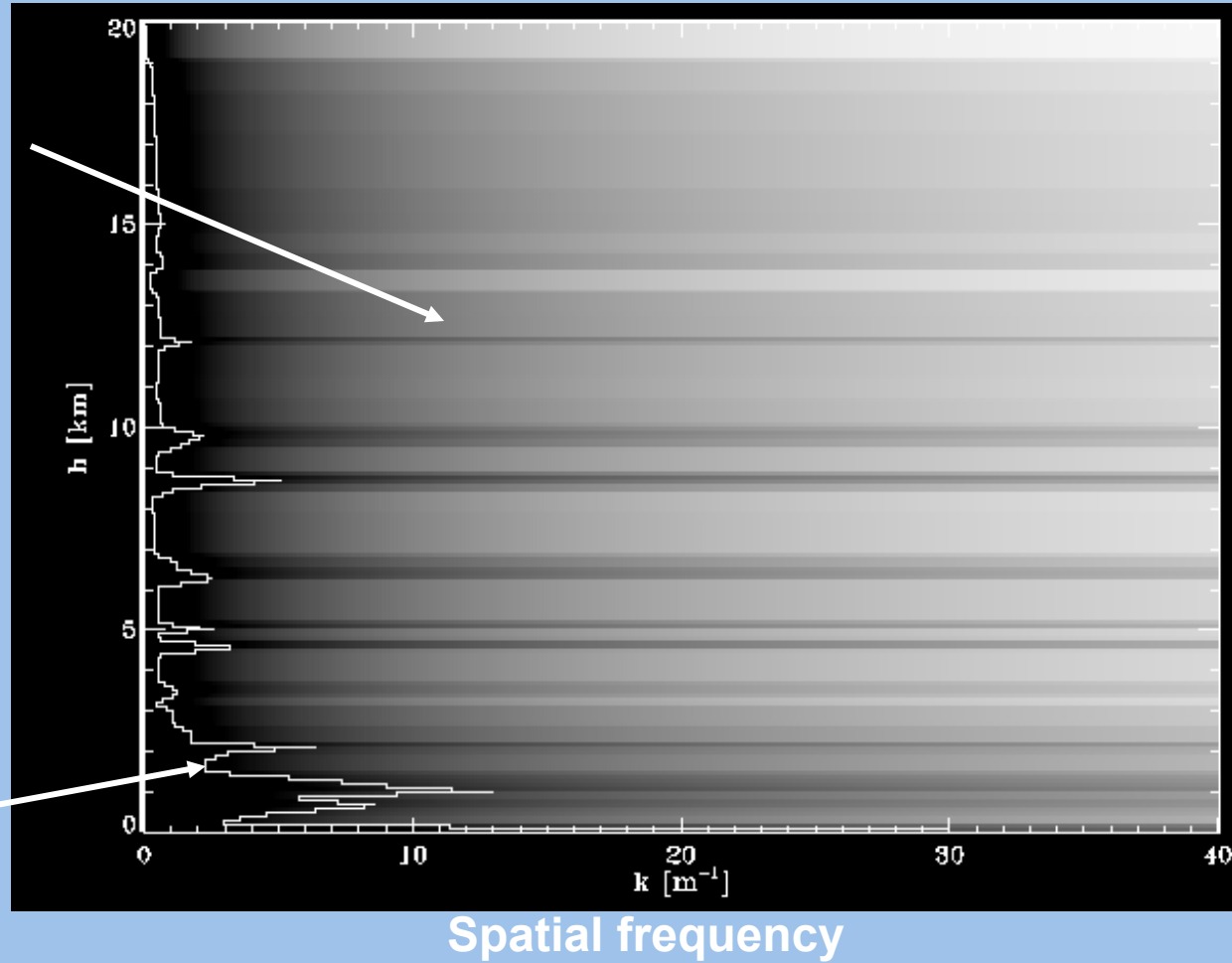




# A bi-dimensional representation Of the atmospheric turbulence

Power spectrum is  
kolmogorov profiled

Altitude



Profile as from  
Hubin et al.  
SPIE 4007, 1100  
(mean Paranal)

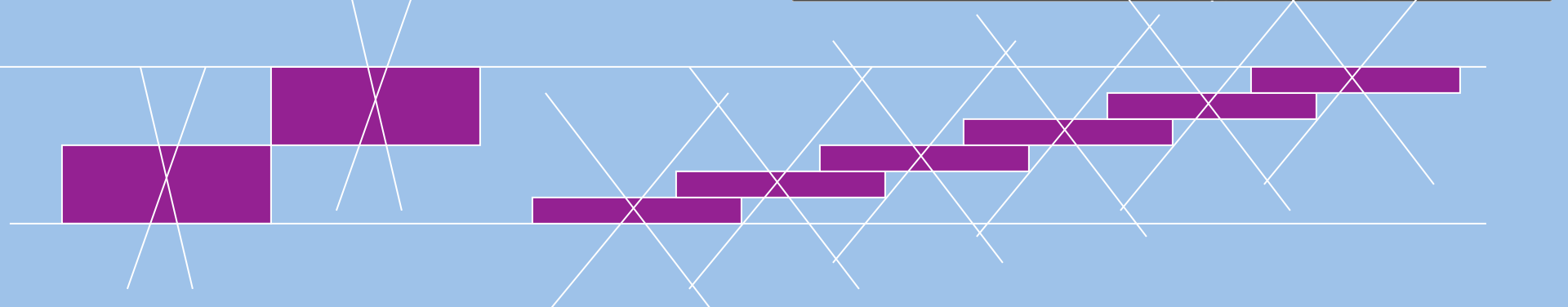
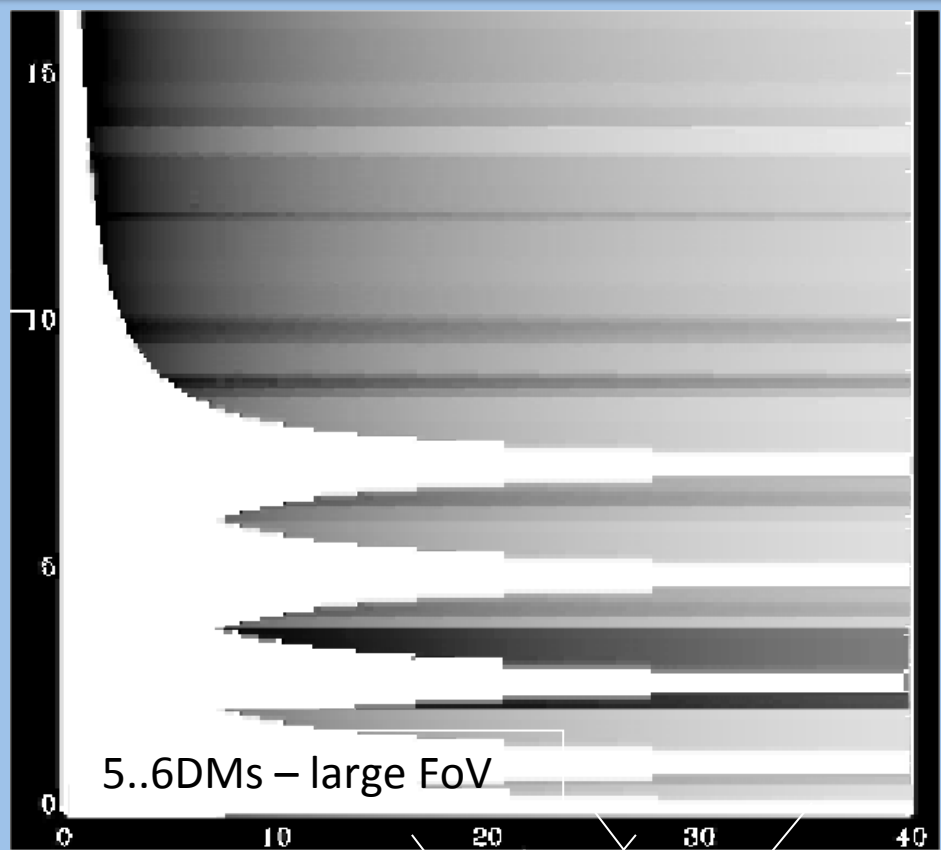
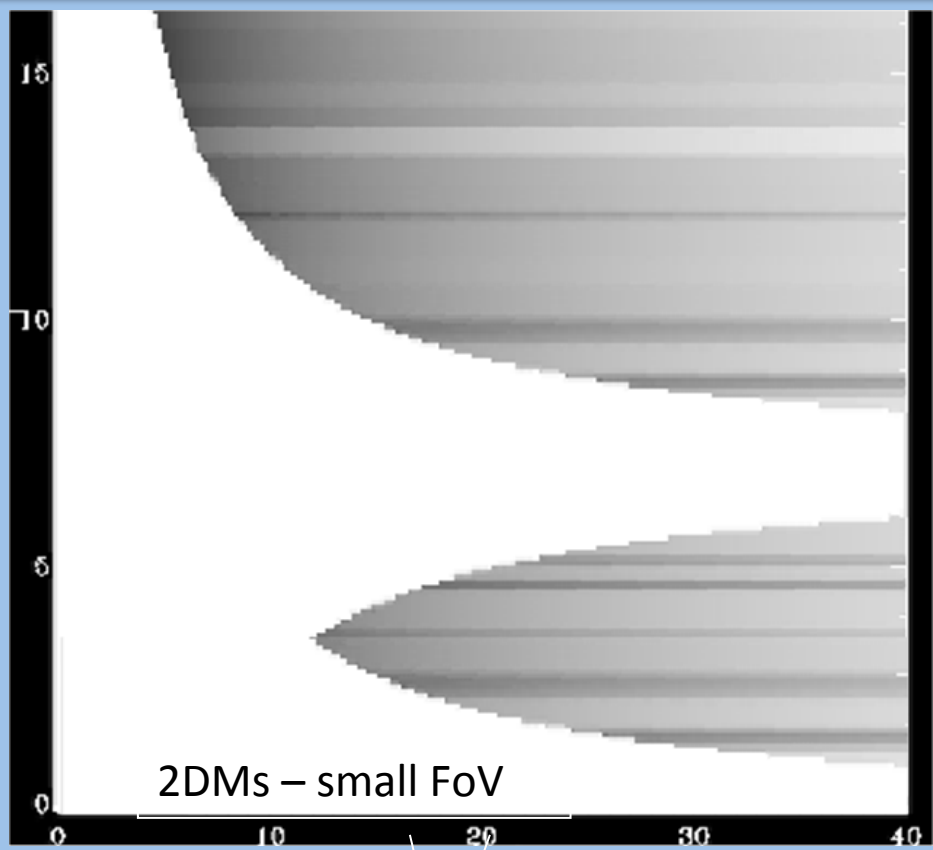


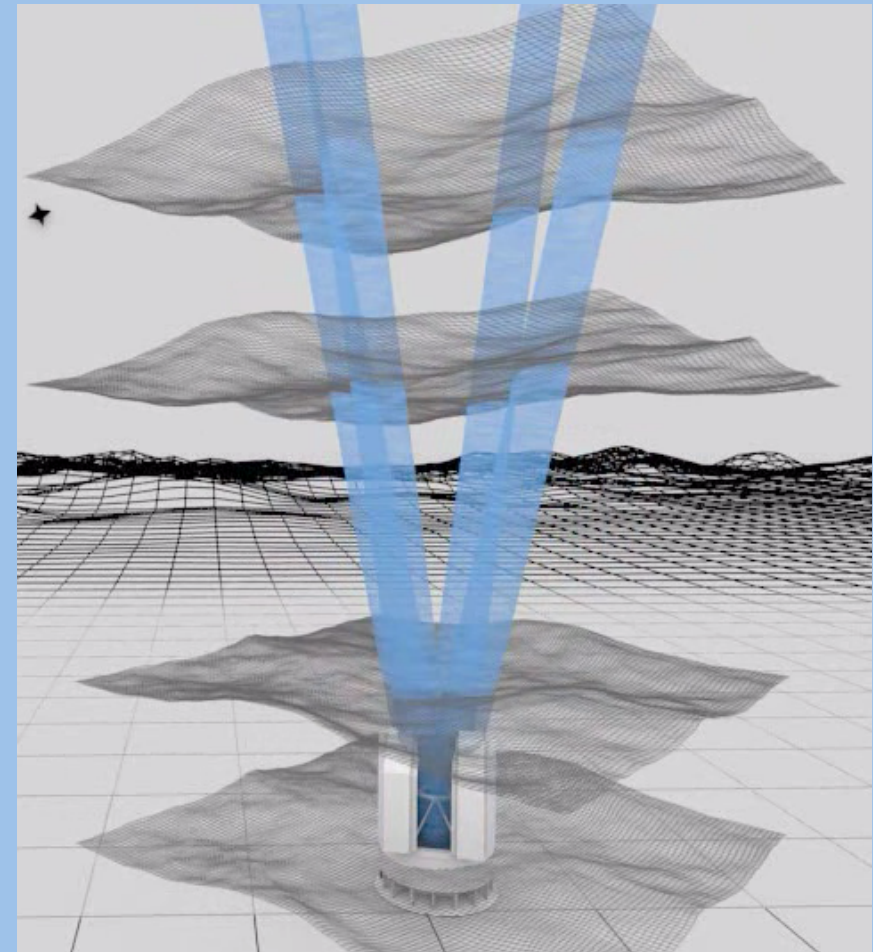
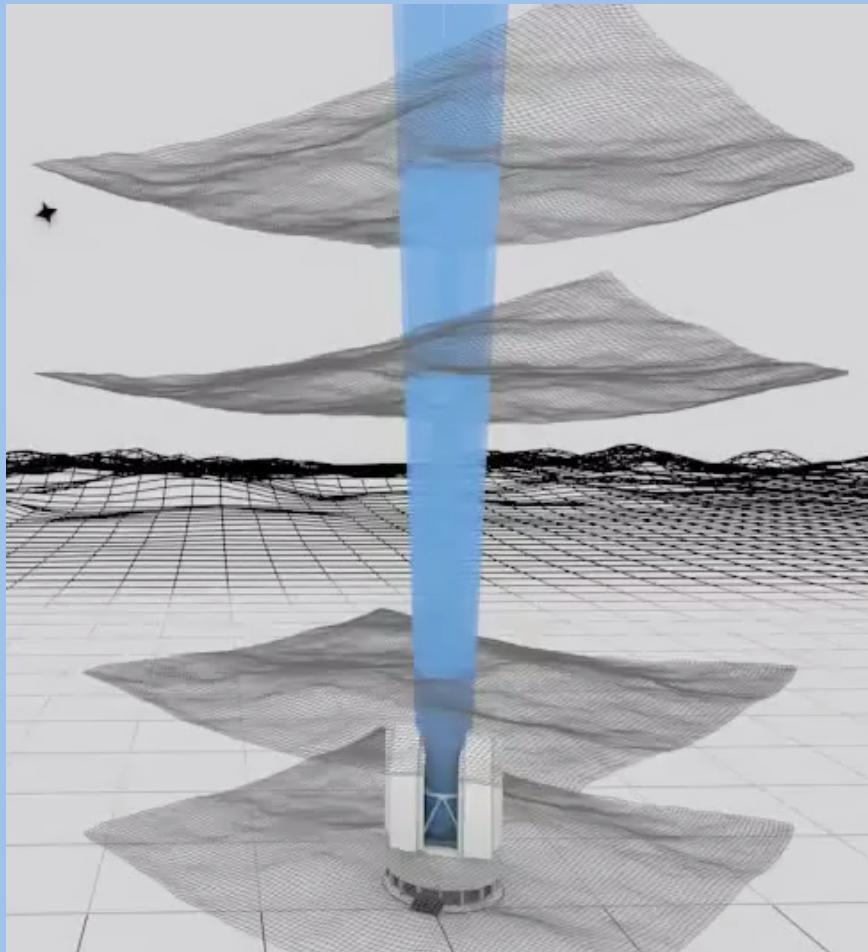


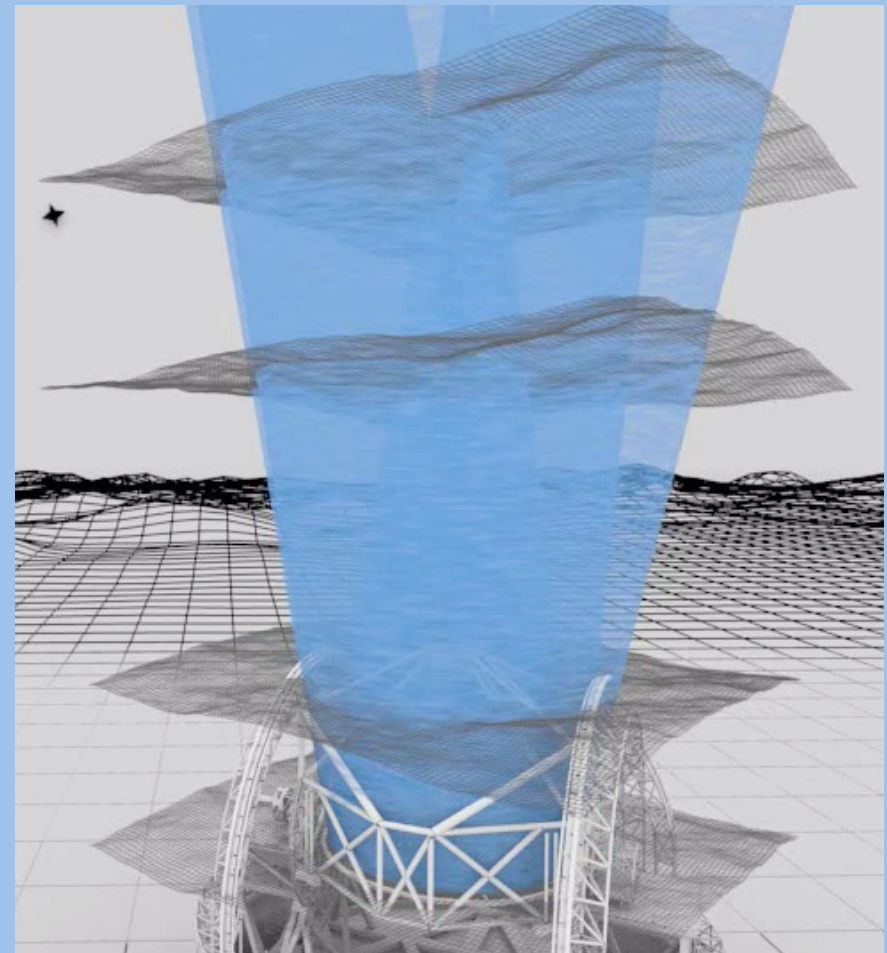
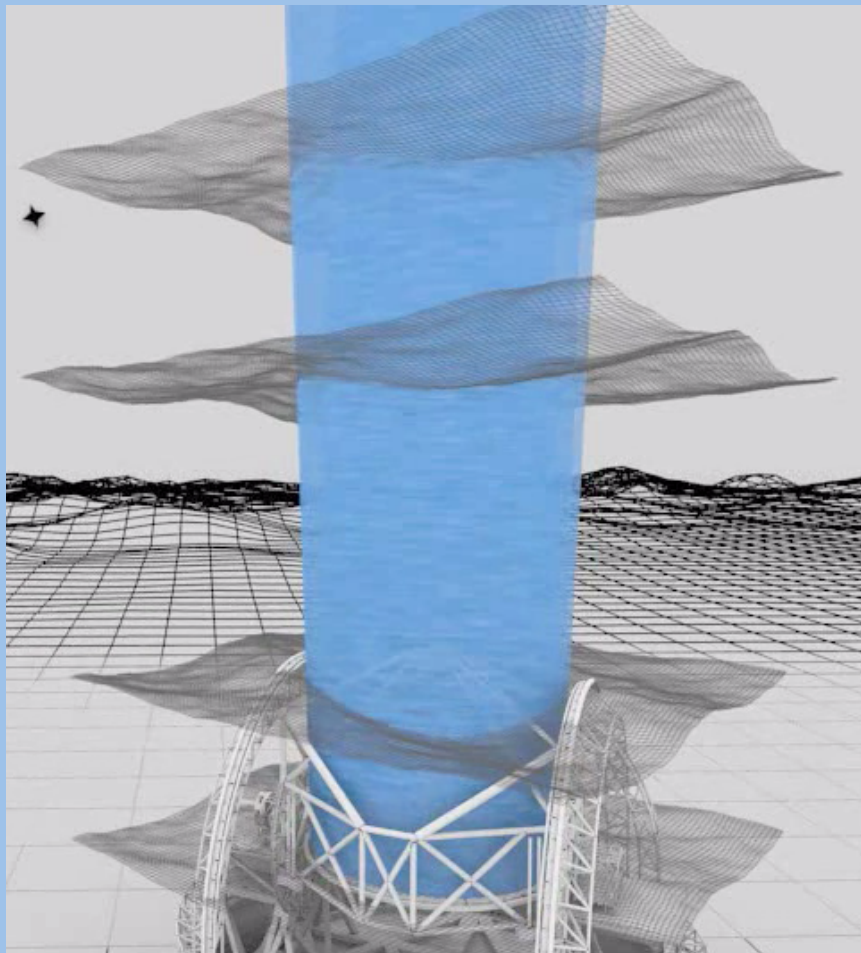
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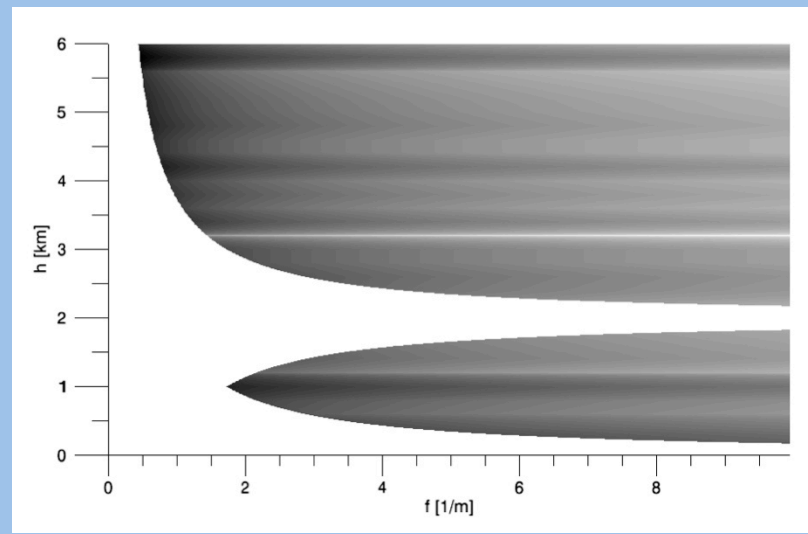
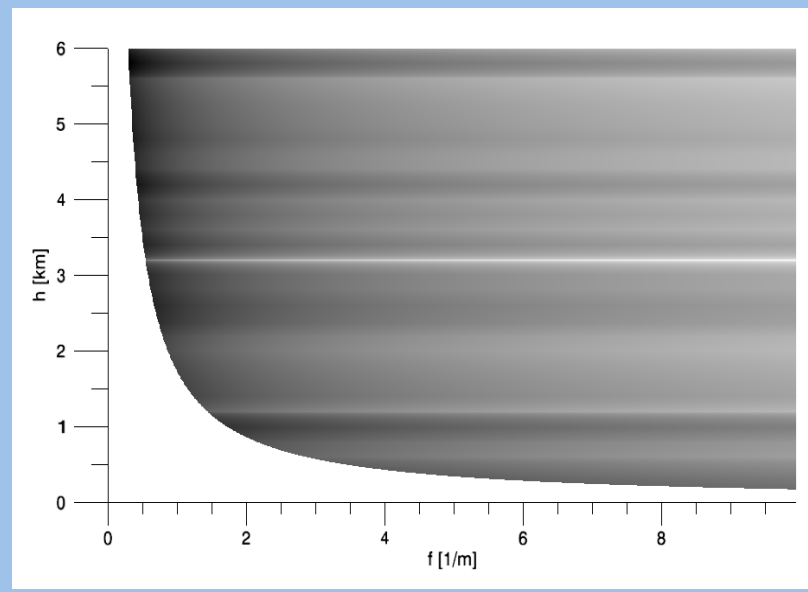
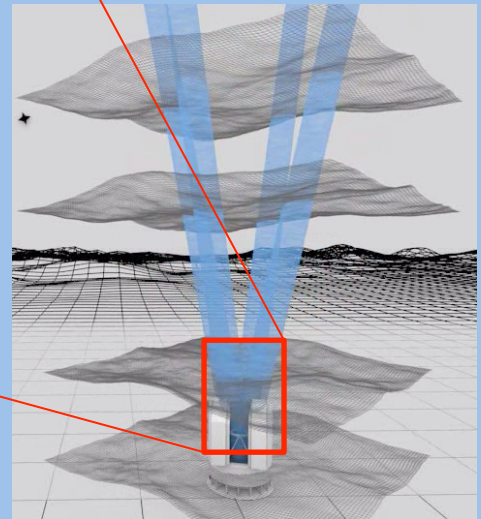
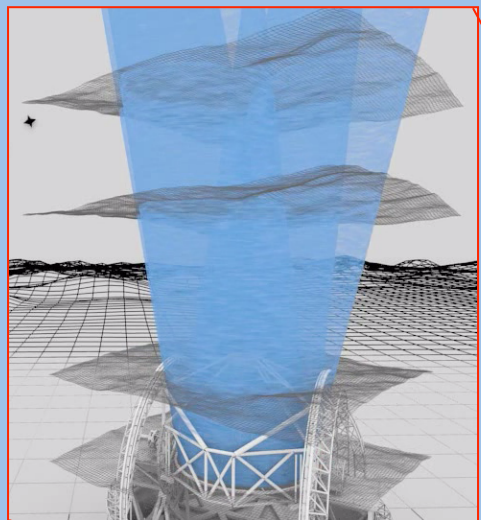




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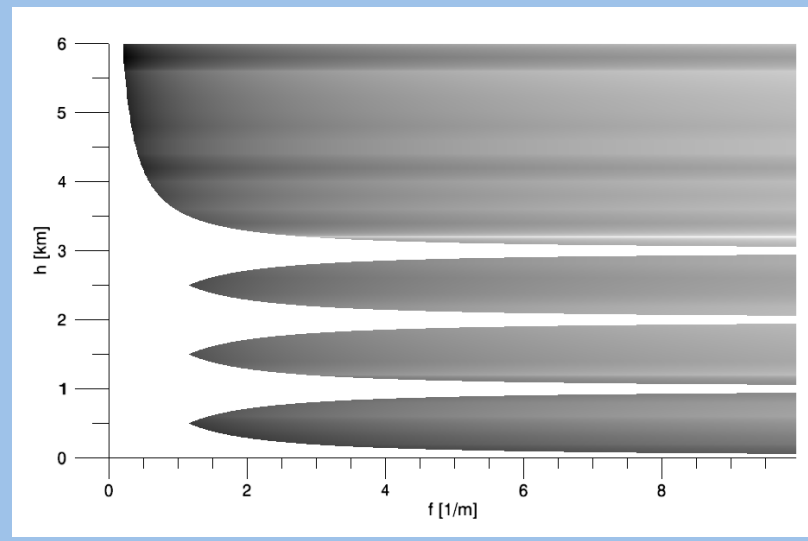
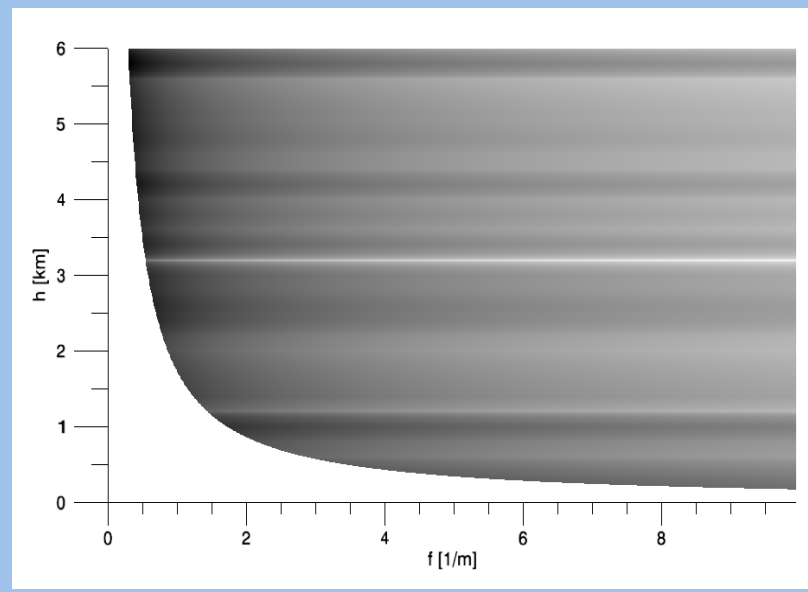
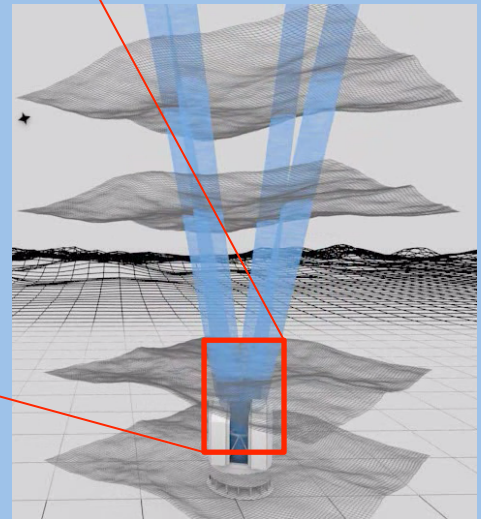
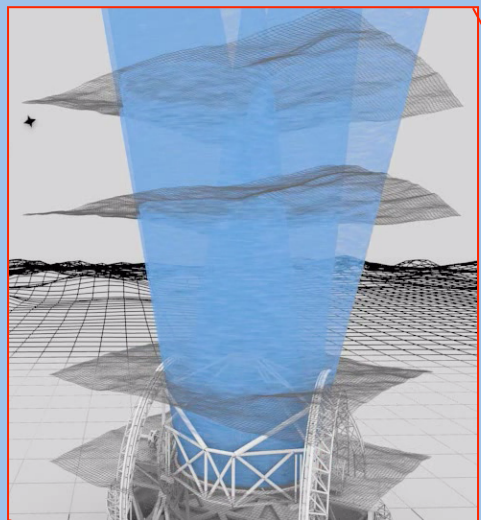
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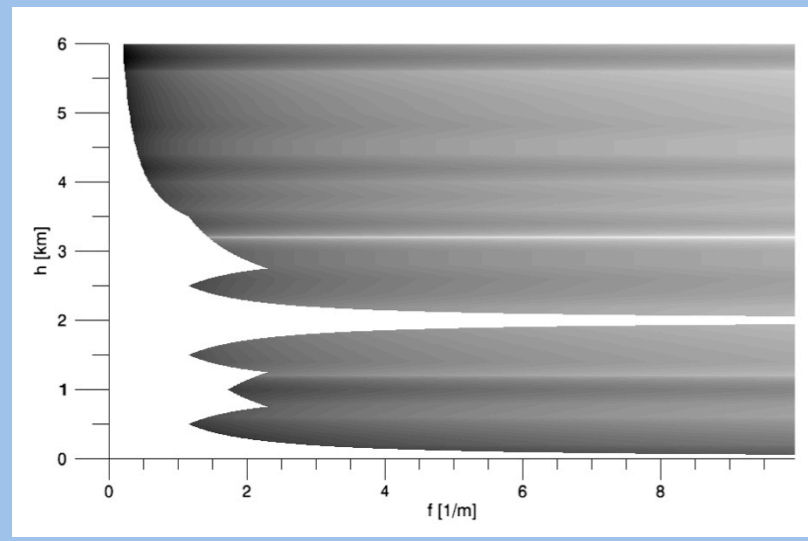
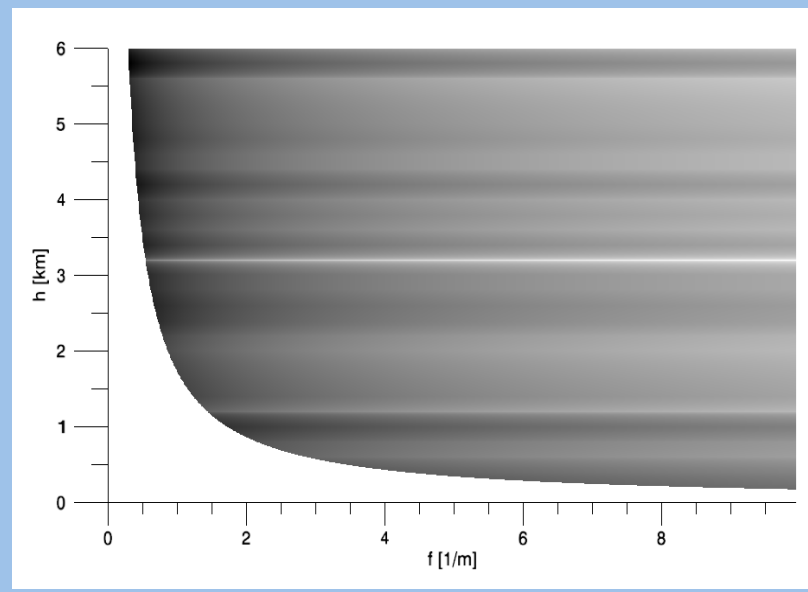
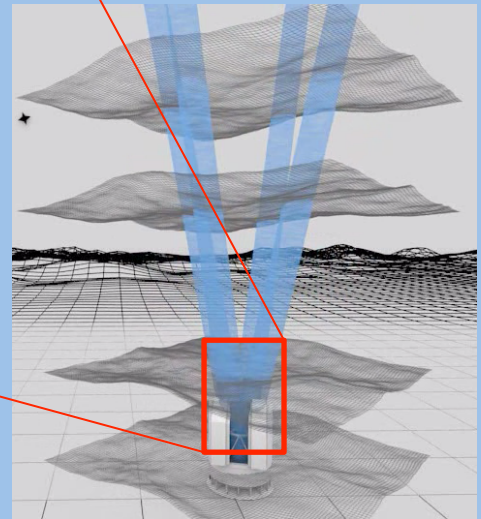
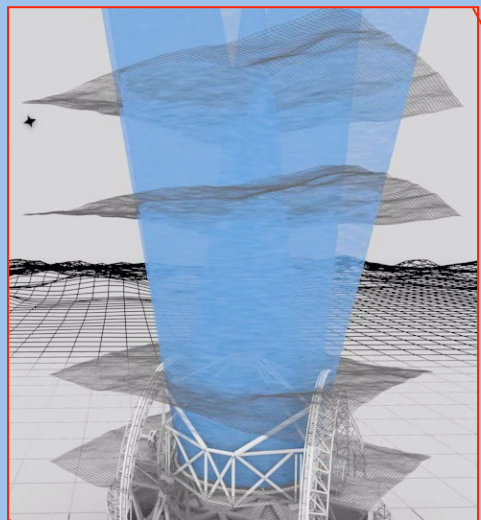


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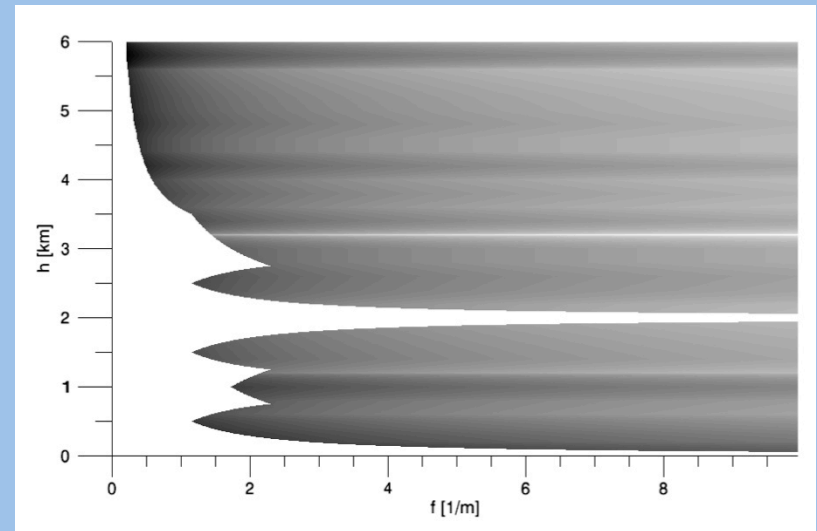
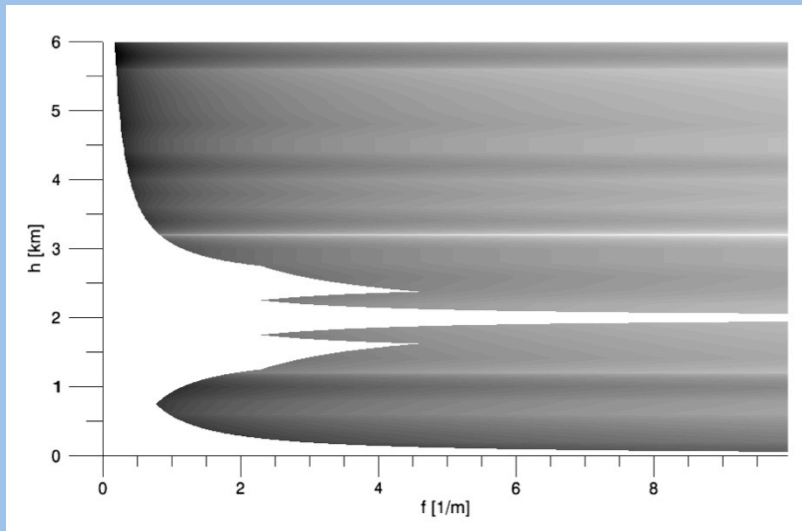
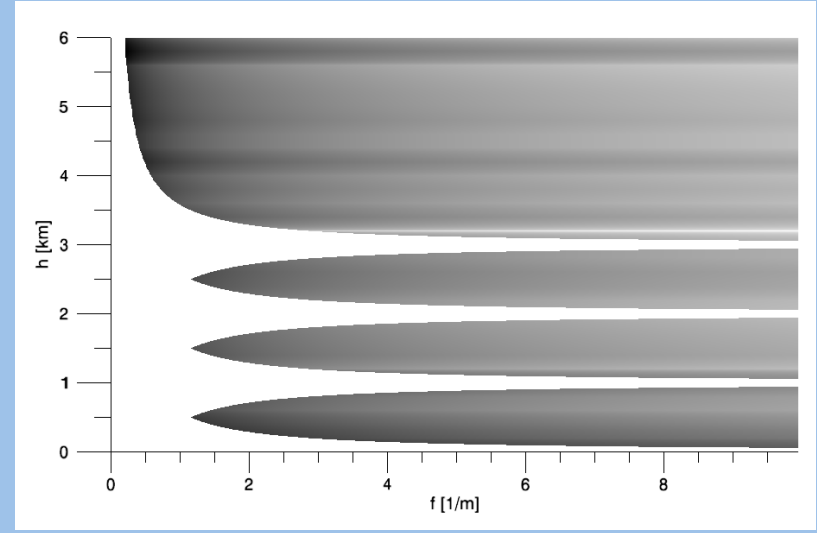
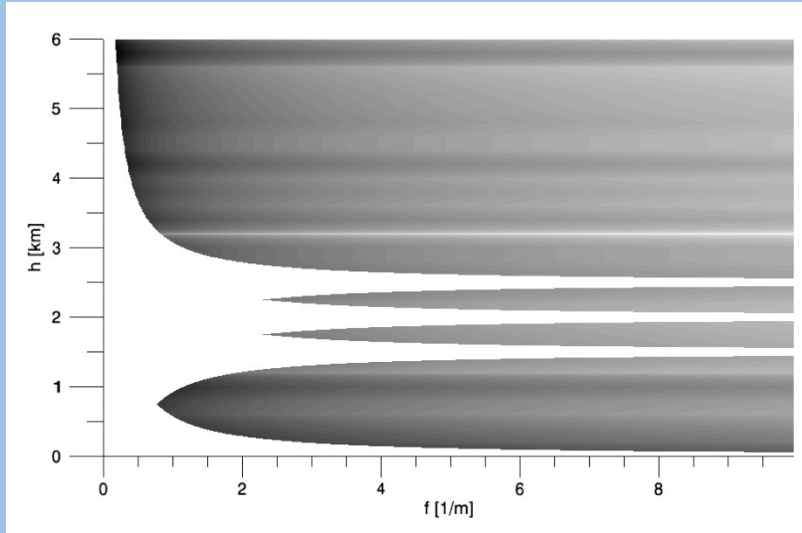


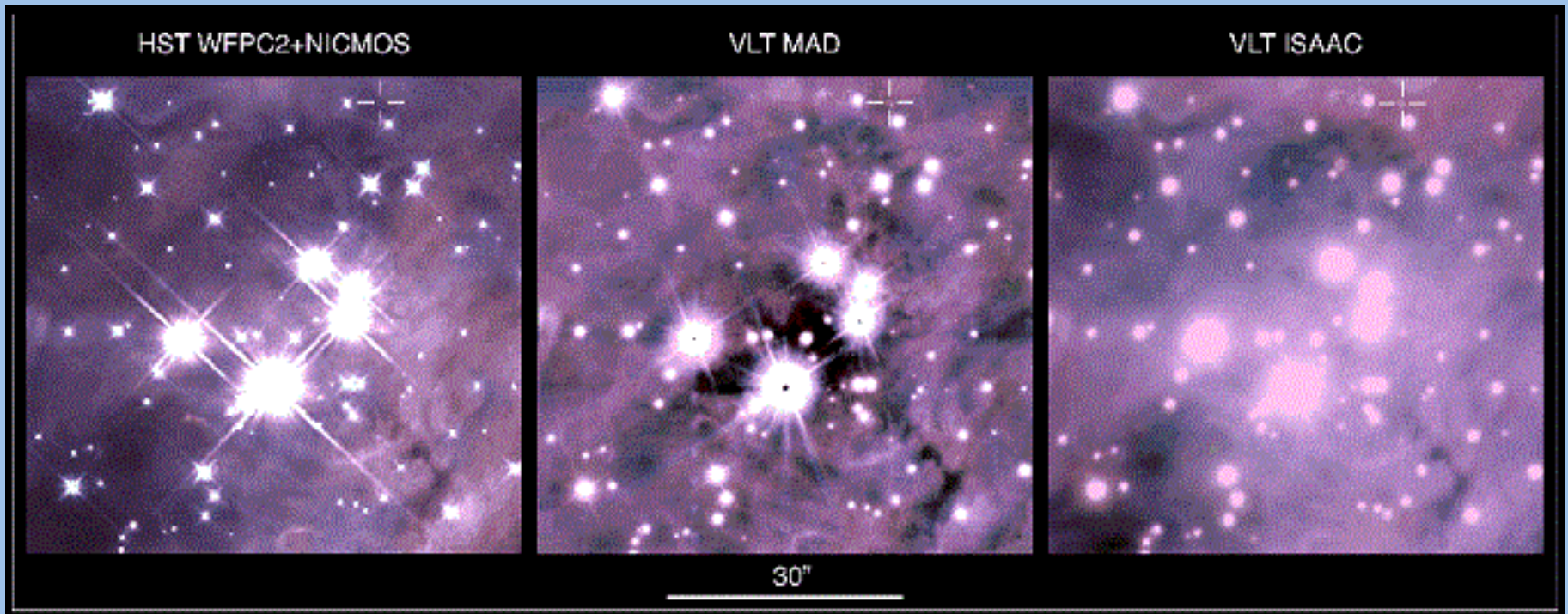


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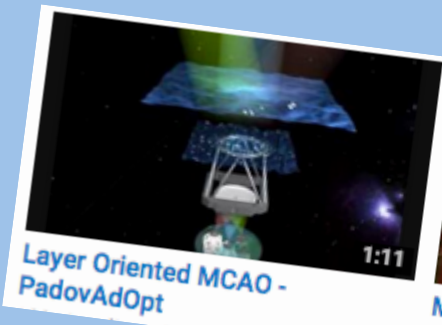




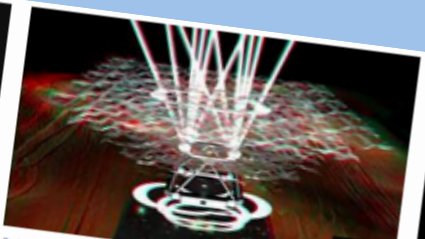
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Canale: *PadovAdopt*



Layer Oriented MCAO - PadovAdOpt 1:11



MCAO with virtual DMs - 3Dmovie - PadovAdOpt 1:40



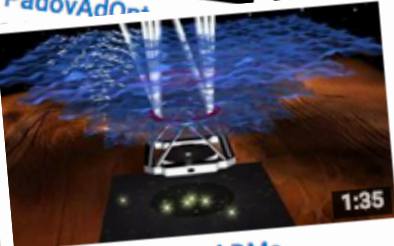
Virtual DM - PadovAdOpt 1:15



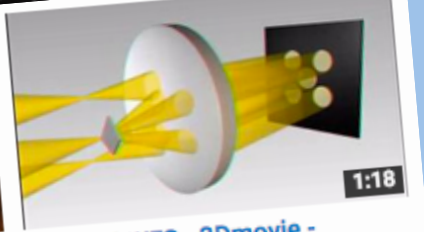
Referencing an MCAO system - 1:10



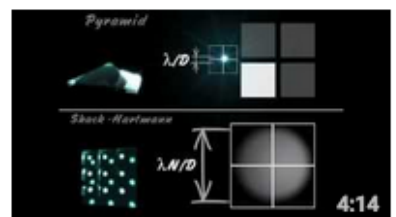
A very linear WaveFront Sensor - PadovAdOpt 0:54



MCAO with Virtual DMs - PadovAdOpt 1:35



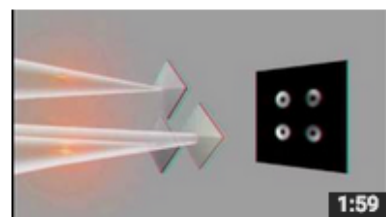
Pyramid WFS - 3Dmovie - PadovAdOpt 1:18



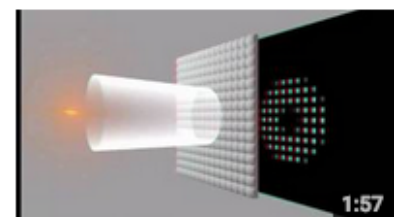
Pyramid vs Shack-Hartmann: the gain in sensitivity 4:14



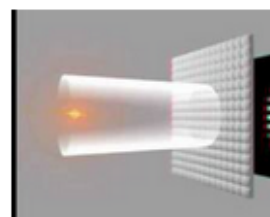
MOAO vs. MCAO - 3Dmovie - PadovAdOpt 1:25



Pyramid vs. Shack-Hartmann - 3Dmovie - PadovAdOpt 1:59



Pyramid and SH dealing with tilt - 3Dmovie - PadovAdOpt 1:57

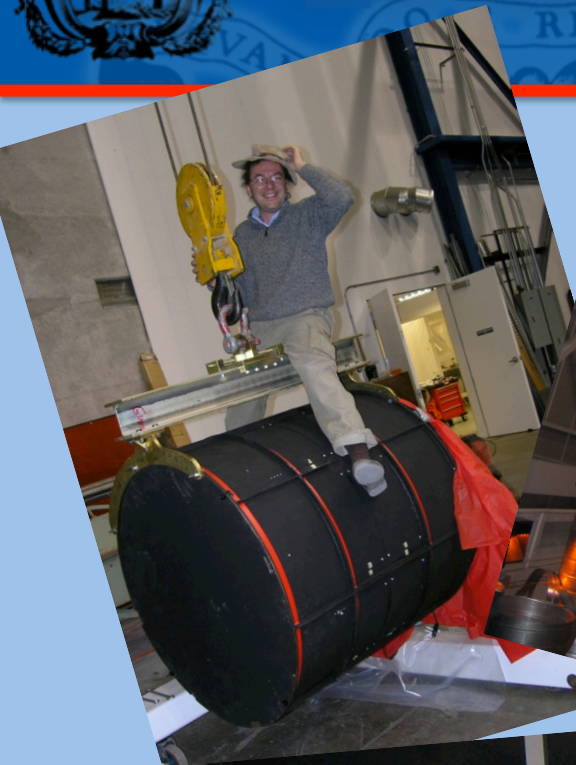


Pyramid and SH dealing with defocus - 3Dmovie - PadovAdOpt



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*Grazie dell'attenzione*

