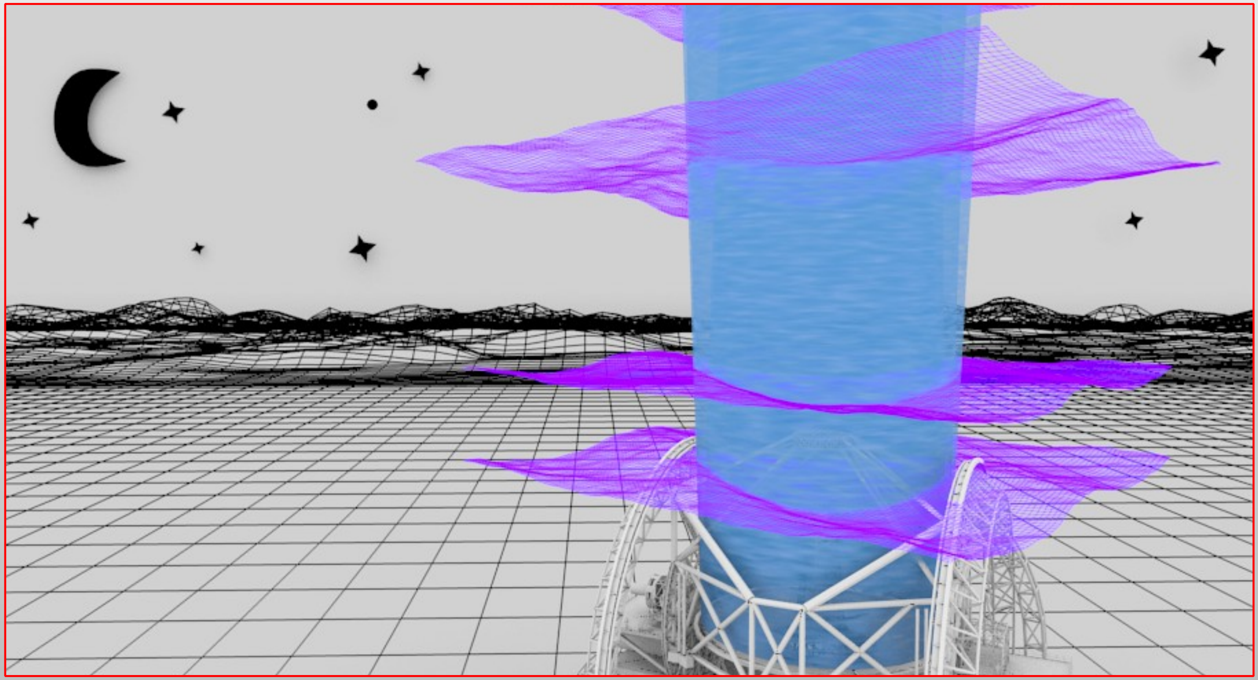
Natural Guide Stars (NGS) only for Adaptive Optics (AO) on ELT



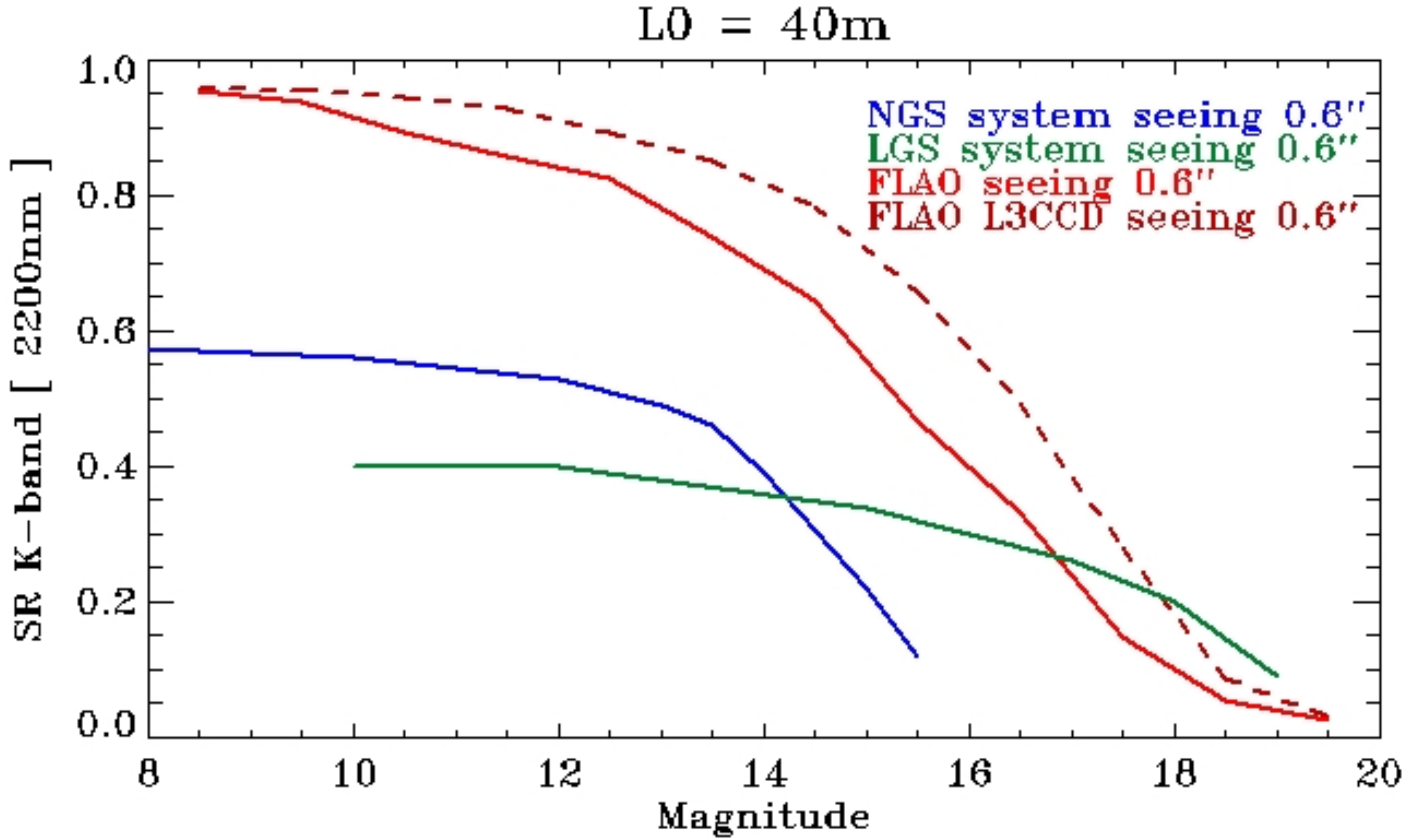
Ismaning - Feb 28th 2013

by R. Ragazzoni, C. Arcidiacono, M. Bergomi, M. Dima, J. Farinato, D. Magrin, L. Marafatto, V. Viotto

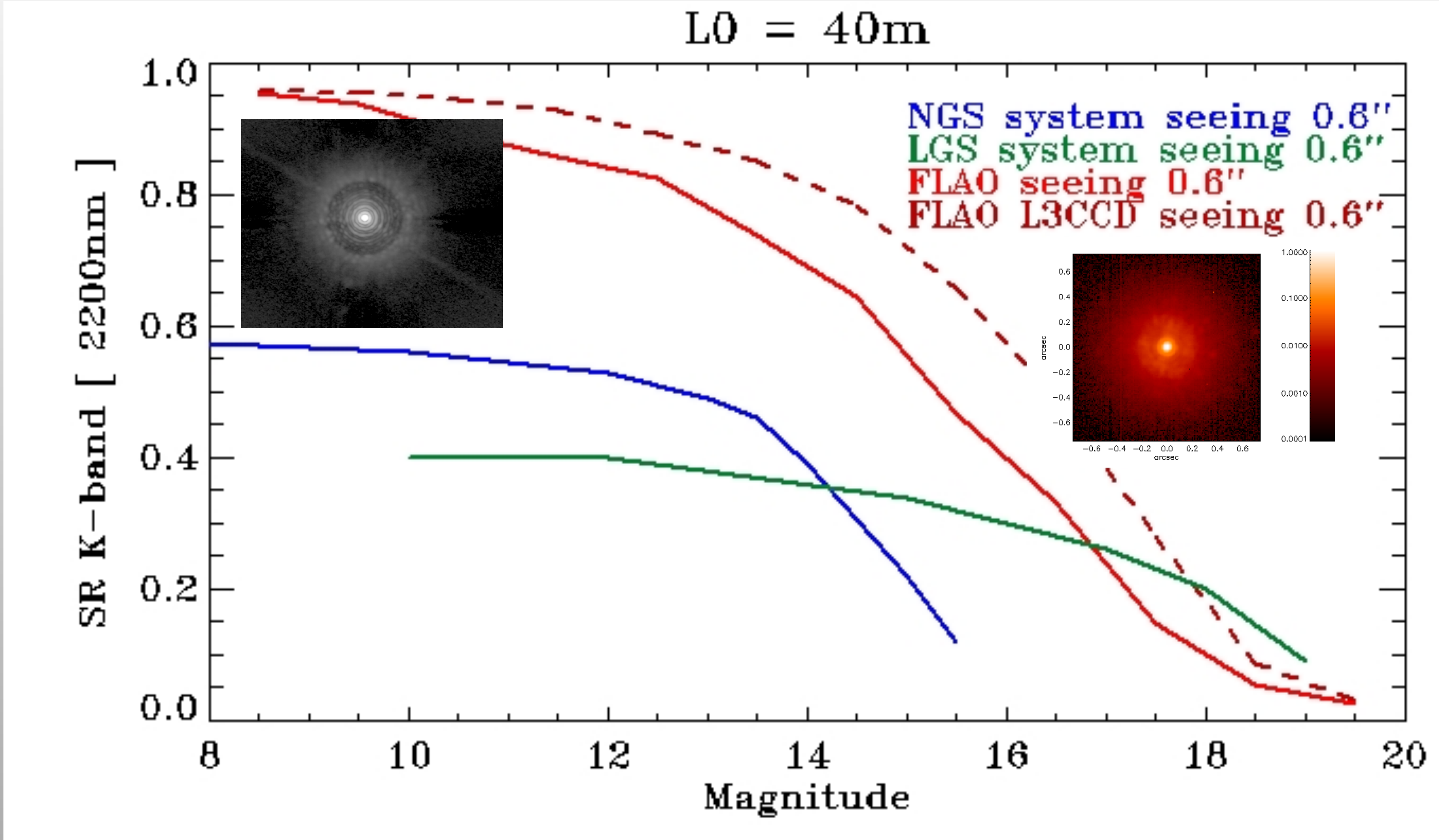
Why NGSs for AO on ELT...?

- Because are cheaper than LGSs
- Because lim mag of Pyramid WFS pushed the limits of AO...
- Because the patrol field of E-ELT is huge
- Because the rays from LGSs will arrive nevertheless from a similarly skewed angle
- Because NGSs are less invasive then LGS
- Because MCAO can be extended a little into Global MCAO and making this true...

Courtesy S. Esposito - Based upon real LBT data



Courtesy S. Esposito - Based upon real LBT data



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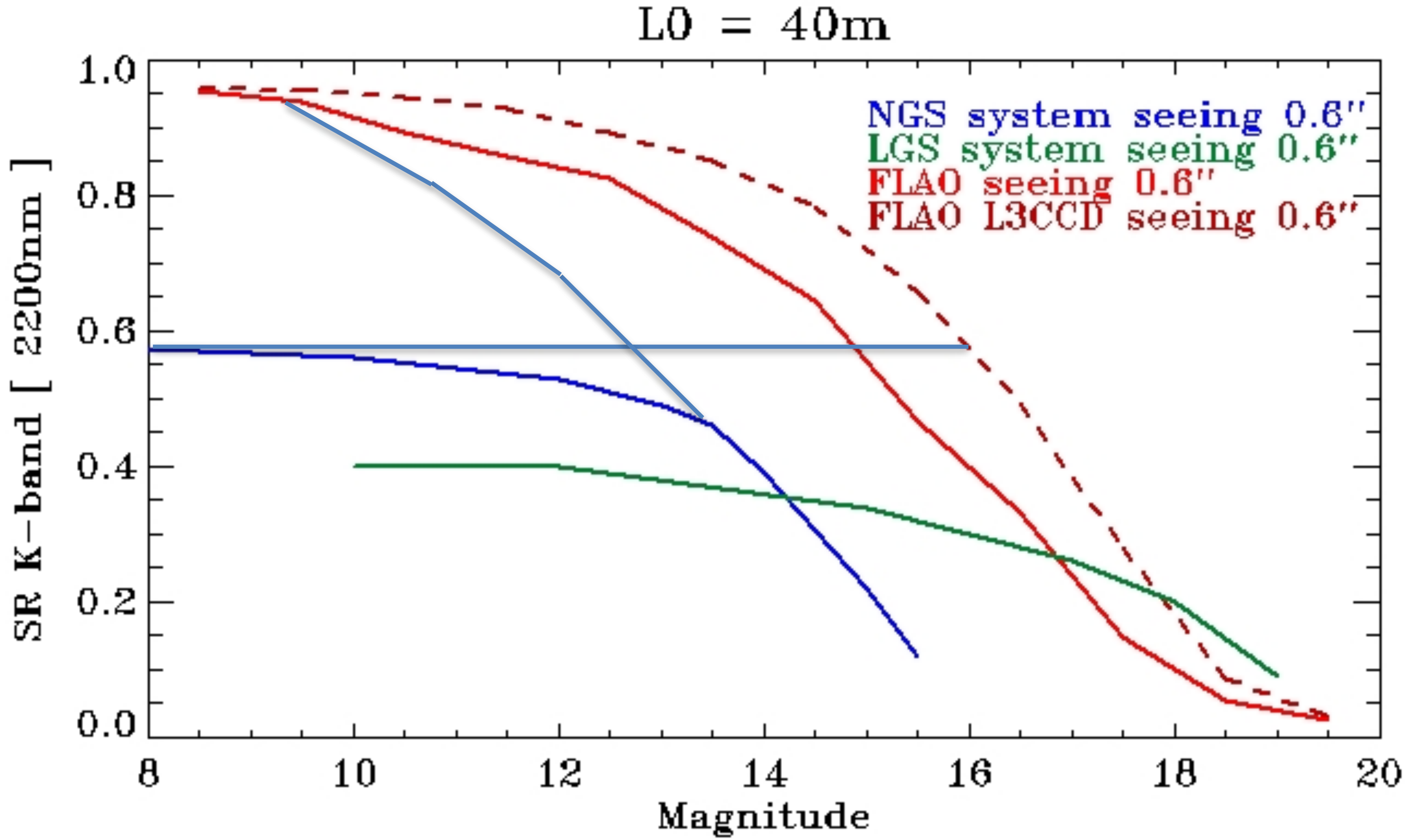

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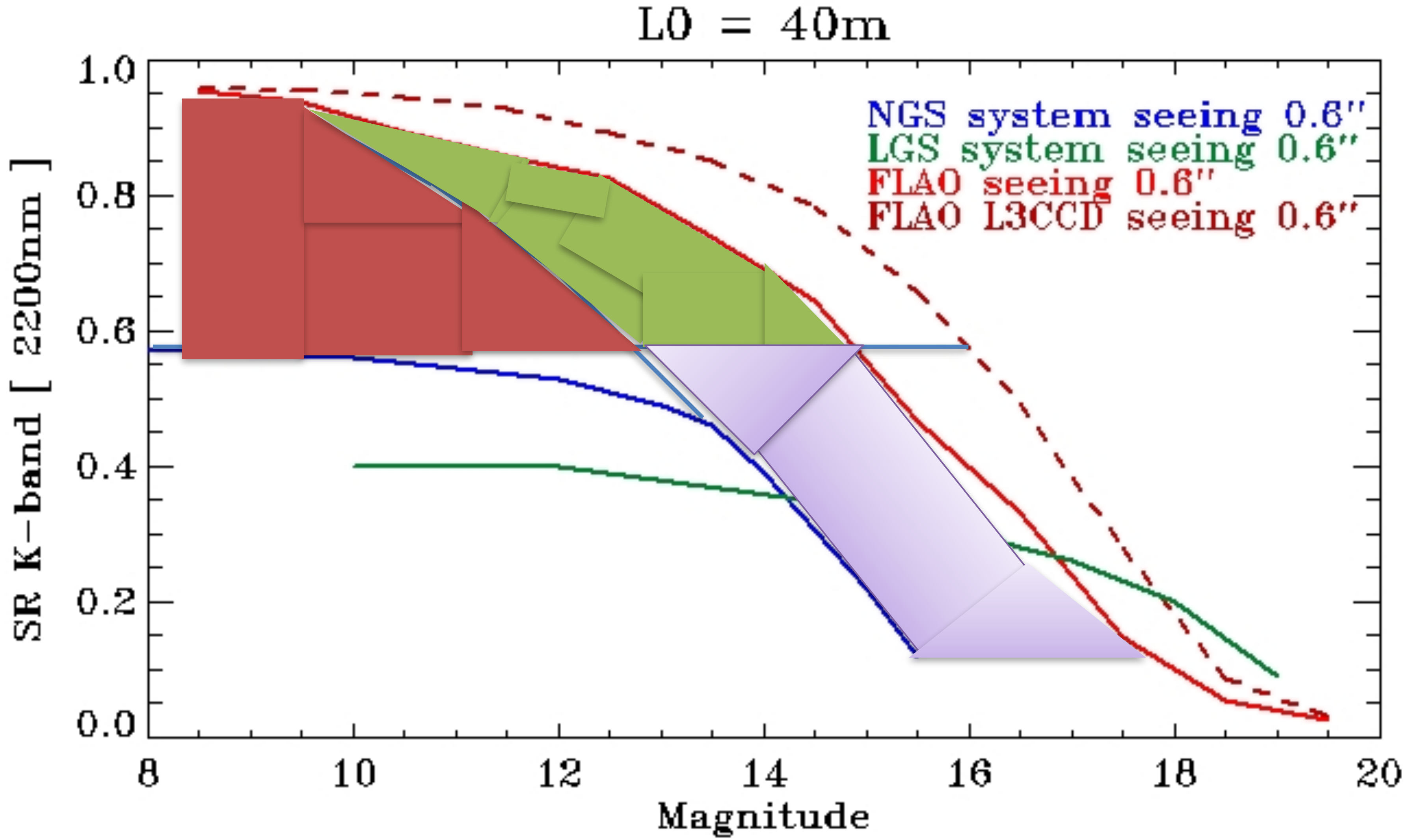

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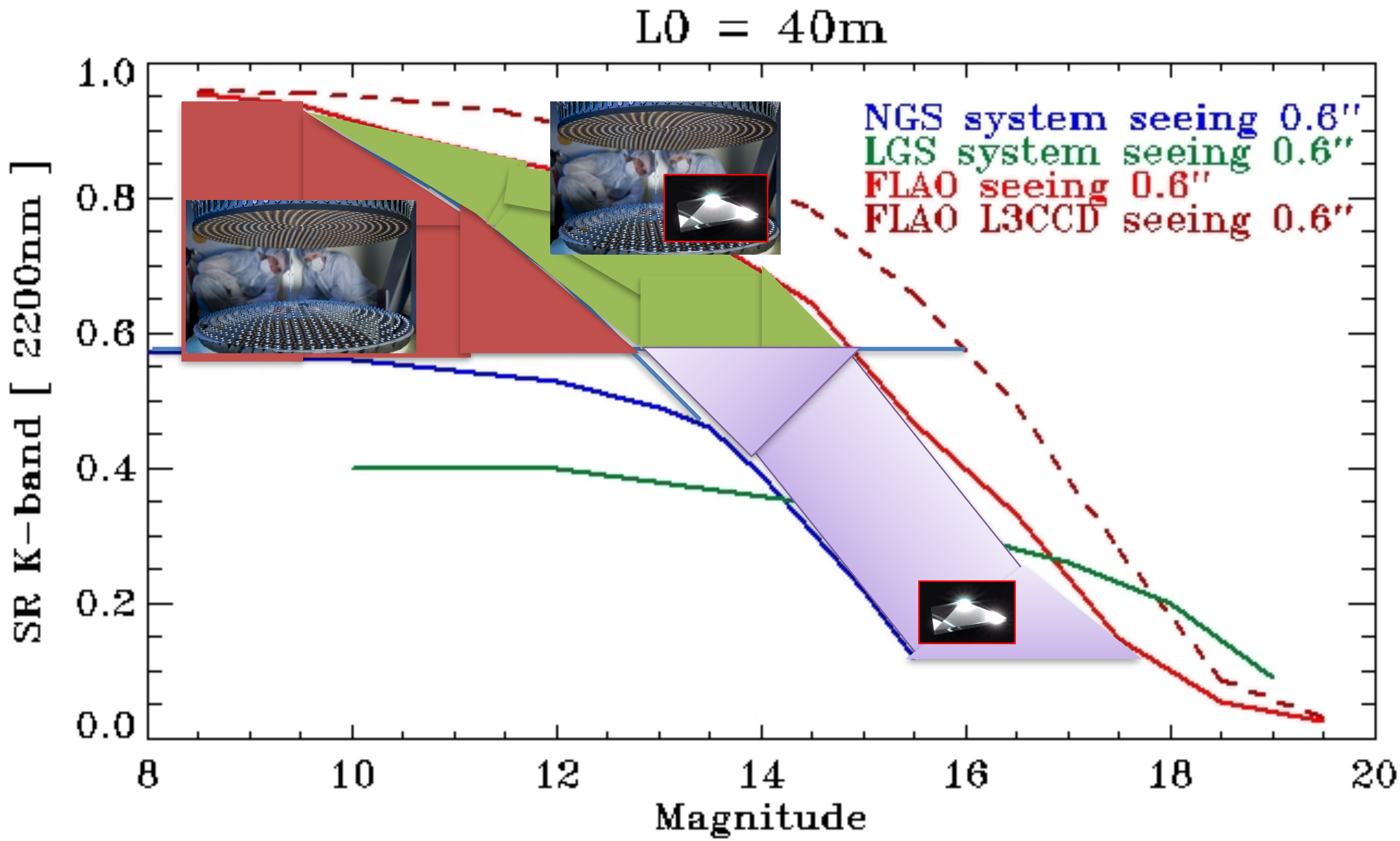

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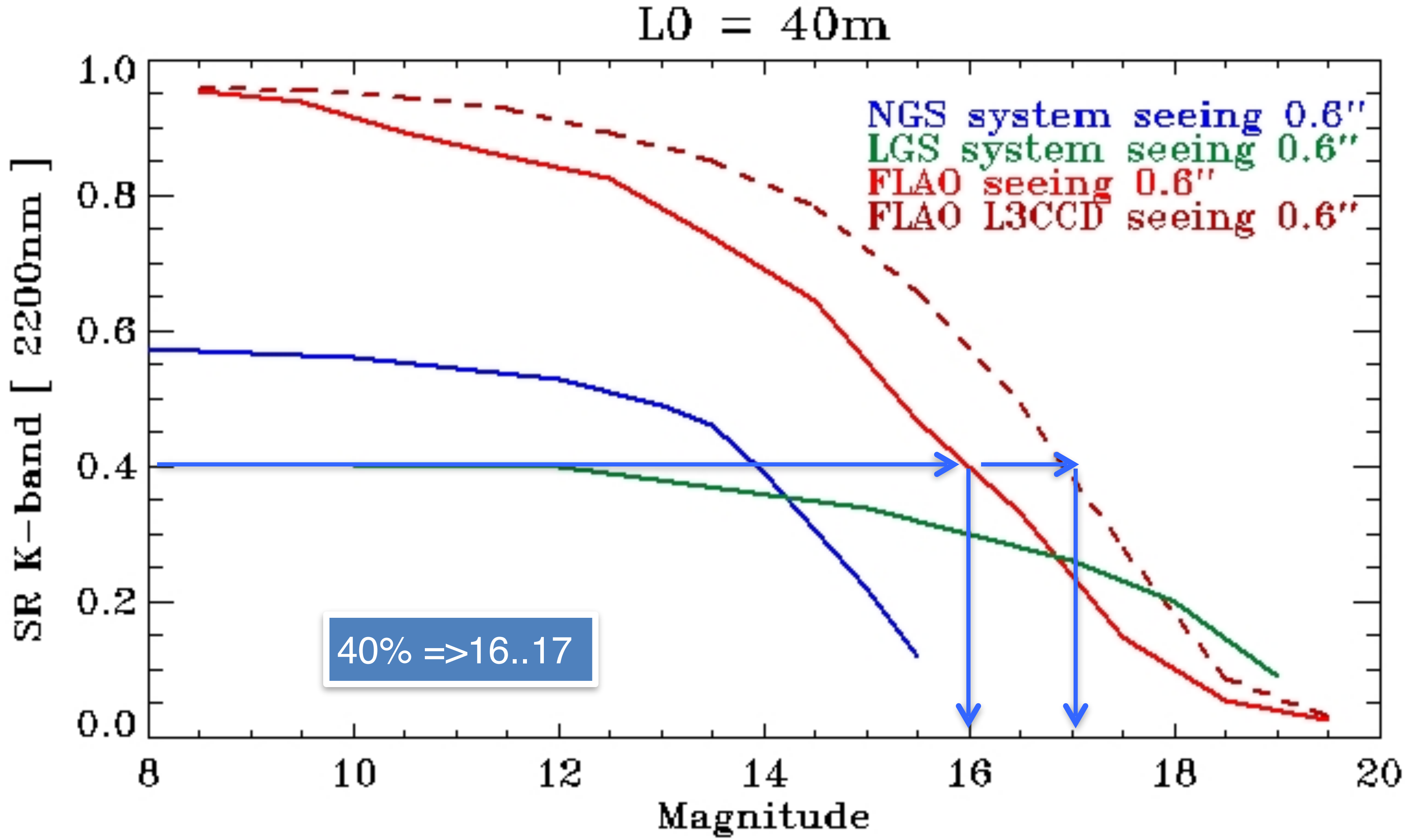
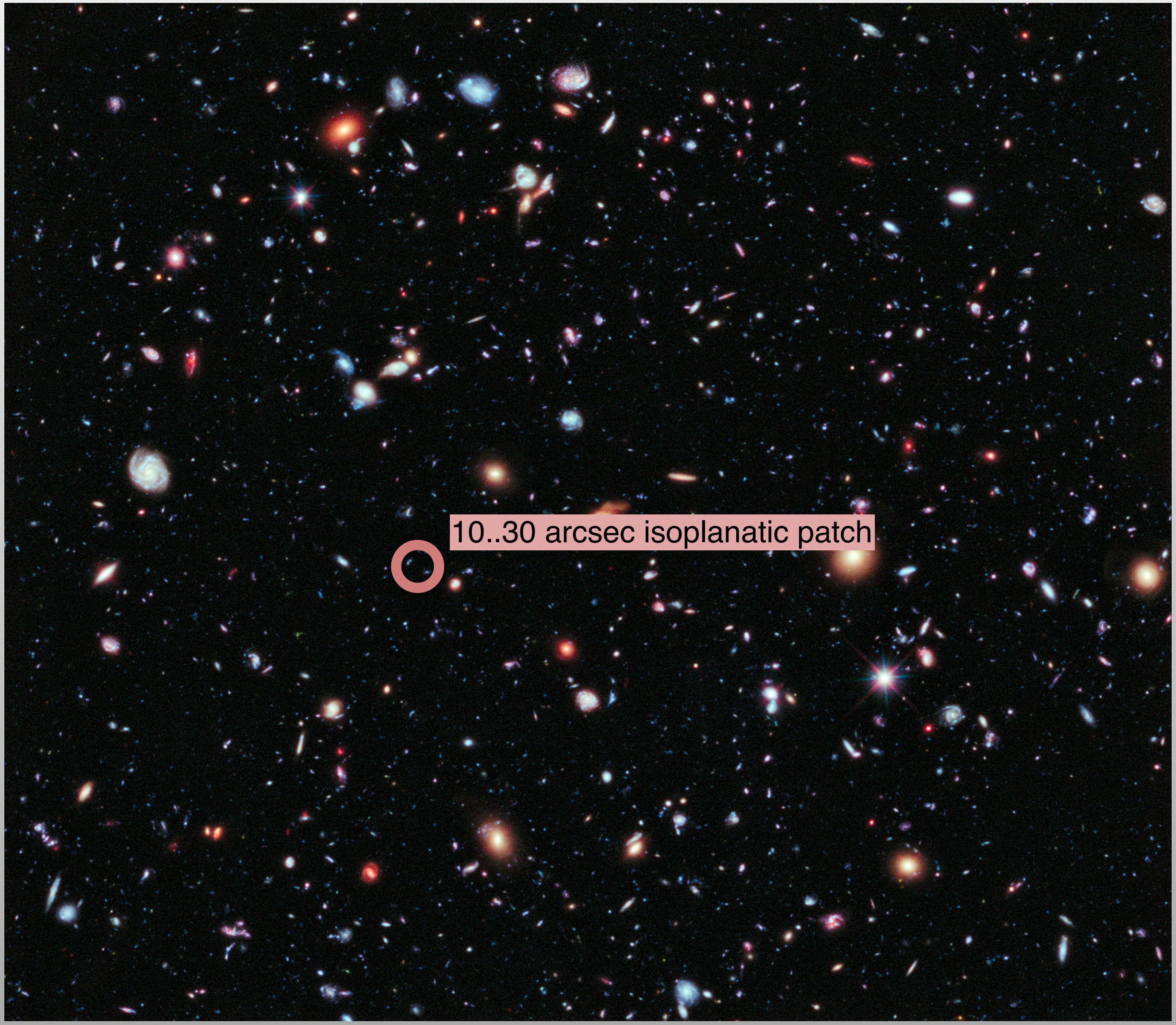


Field of View comparison

Field of View comparison



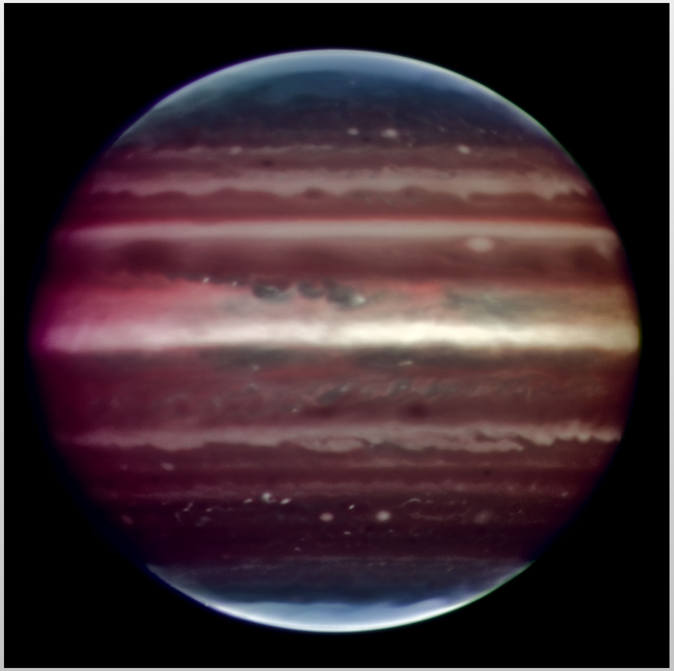
Field of View comparison

Field of View comparison

Field of View

- SCAO: 10..30 arcsec
- MAD-like MCAO 2'
- x 16..144 wrt SCAO
- E-ELT patrol FoV 10'
- x 25 wrt MAD
- x 400..3600 wrt SCAO
- ....and sky coverages goes linearly with for a fixed number of stars (1 for SCAO, 2+ for MCAO likes...)
- Still using 3..5 stars makes a gain of ~100..1000

Field of View



- SCAO: 10..30 arcsec
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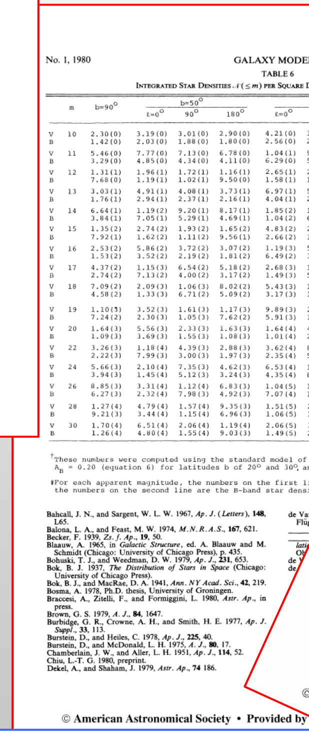
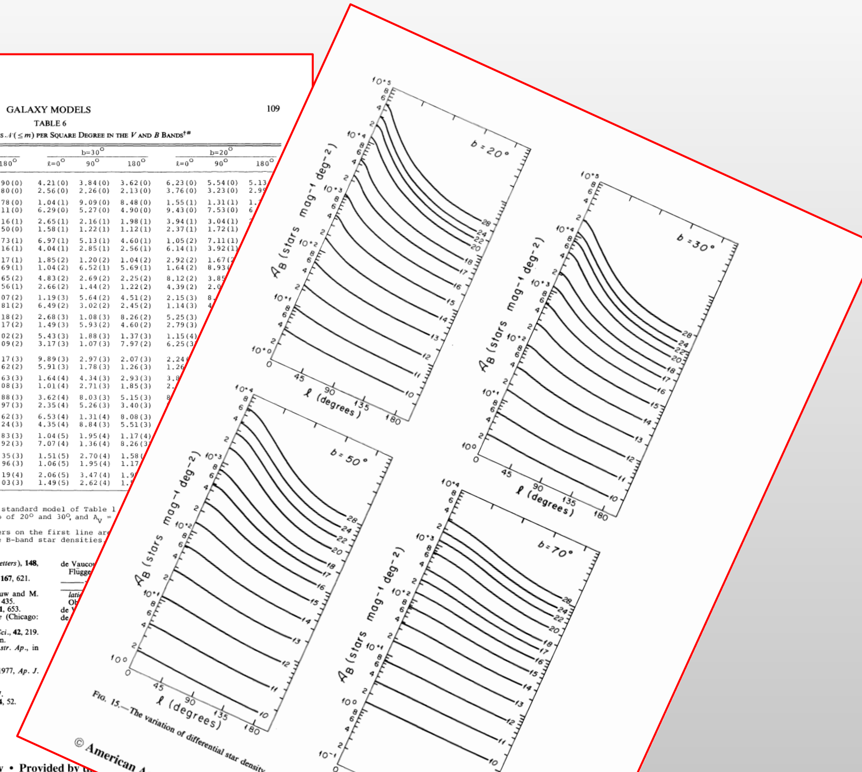
- ....and sky coverages goes linearly with for a fixed number of stars (1 for SCAO, 2+ for MCAO likes...)
- Still using 3..5 stars makes a gain of ~100..1000

V	15	1.35(2)
B		7.92(1)
V	16	2.53(2)
B		1.53(2)
V	17	4.37(2)
B		2.74(2)
V	18	7.09(2)
B		4.58(2)





V=15	V=16	V=17	V=18	Galactic Pole
135	253	437	709	Stars per square deg
1.1	2.2	3.8	6.2	Stars in a 10' diameter
0.3	0.6	0.9	1.6	Stars in a 5' diameter

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B		4.58(2)

No. 1, 1980 GALAXY MODELS 109

TABLE 6

INTEGRATED STAR DENSITIES $\mathcal{N}(\leq m)$ PER SQUARE DEGREE IN THE V AND B BANDS†#

	m	b=90°	b=50° ℓ=0°	b=50° 90°	b=50° 180°	b=30° ℓ=0°	b=30° 90°	b=30° 180°	b=20° ℓ=0°	b=20° 90°
V	10	2.30(0)	3.19(0)	3.01(0)	2.90(0)	4.21(0)	3.84(0)	3.62(0)	6.23(0)	5.54(0)
B		1.42(0)	2.03(0)	1.88(0)	1.80(0)	2.56(0)	2.26(0)	2.13(0)	3.76(0)	3.23(0)
V	11	5.46(0)	7.77(0)	7.13(0)	6.78(0)	1.04(1)	9.09(0)	8.48(0)	1.55(1)	1.31(1)
B		3.29(0)	4.85(0)	4.34(0)	4.11(0)	6.29(0)	5.27(0)	4.90(0)	9.43(0)	7.53(0)
V	12	1.31(1)	1.96(1)	1.72(1)	1.16(1)	2.65(1)	2.16(1)	1.98(1)	3.94(1)	3.04(1)
B		7.68(0)	1.19(1)	1.02(1)	9.50(0)	1.58(1)	1.22(1)	1.12(1)	2.37(1)	1.72(1)
V	13	3.03(1)	4.91(1)	4.08(1)	3.73(1)	6.97(1)	5.13(1)	4.60(1)	1.05(2)	7.11(1)
B		1.76(1)	2.94(1)	2.37(1)	2.16(1)	4.04(1)	2.85(1)	2.56(1)	6.14(1)	3.92(1)
V	14	6.64(1)	1.19(2)	9.20(1)	8.17(1)	1.85(2)	1.20(2)	1.04(2)	2.92(2)	1.67(2
B		3.84(1)	7.05(1)	5.29(1)	4.69(1)	1.04(2)	6.52(1)	5.69(1)	1.64(2)	8.93(
V	15	1.35(2)	2.74(2)	1.93(2)	1.65(2)	4.83(2)	2.69(2)	2.25(2)	8.12(2)	3.85
B		7.92(1)	1.62(2)	1.11(2)	9.56(1)	2.66(2)	1.44(2)	1.22(2)	4.39(2)	2.0
V	16	2.53(2)	5.86(2)	3.72(2)	3.07(2)	1.19(3)	5.64(2)	4.51(2)	2.15(3)	8.
B		1.53(2)	3.52(2)	2.19(2)	1.81(2)	6.49(2)	3.02(2)	2.45(2)	1.14(3)	4
V	17	4.37(2)	1.15(3)	6.54(2)	5.18(2)	2.68(3)	1.08(3)	8.26(2)	5.25(3)	
B		2.74(2)	7.13(2)	4.00(2)	3.17(2)	1.49(3)	5.93(2)	4.60(2)	2.79(3)	
V	18	7.09(2)	2.09(3)	1.06(3)	8.02(2)	5.43(3)	1.88(3)	1.37(3)	1.15(4)	
B		4.58(2)	1.33(3)	6.71(2)	5.09(2)	3.17(3)	1.07(3)	7.97(2)	6.25(3	
V	19	1.10(3)	3.52(3)	1.61(3)	1.17(3)	9.89(3)	2.97(3)	2.07(3)	2.24(	
B		7.24(2)	2.30(3)	1.05(3)	7.62(2)	5.91(3)	1.78(3)	1.26(3)	1.26	
V	20	1.64(3)	5.56(3)	2.33(3)	1.63(3)	1.64(4)	4.34(3)	2.93(3)	3.8	
B		1.09(3)	3.69(3)	1.55(3)	1.08(3)	1.01(4)	2.71(3)	1.85(3)	2.	
V	22	3.26(3)	1.18(4)	4.39(3)	2.88(3)	3.62(4)	8.03(3)	5.15(3)	8	
B		2.22(3)	7.99(3)	3.00(3)	1.97(3)	2.35(4)	5.26(3)	3.40(3)		
V	24	5.66(3)	2.10(4)	7.35(3)	4.62(3)	6.53(4)	1.31(4)	8.08(3)		
B		3.94(3)	1.45(4)	5.12(3)	3.24(3)	4.35(4)	8.84(3)	5.51(3)		
V	26	8.85(3)	3.31(4)	1.12(4)	6.83(3)	1.04(5)	1.95(4)	1.17(4)		
B		6.27(3)	2.32(4)	7.98(3)	4.92(3)	7.07(4)	1.36(4)	8.26(3		
V	28	1.27(4)	4.79(4)	1.57(4)	9.35(3)	1.51(5)	2.70(4)	1.58(		
B		9.21(3)	3.44(4)	1.15(4)	6.96(3)	1.06(5)	1.95(4)	1.17		
V	30	1.70(4)	6.51(4)	2.06(4)	1.19(4)	2.06(5)	3.47(4)	1.9		
B		1.26(4)	4.80(4)	1.55(4)	9.03(3)	1.49(5)	2.62(4)	1.		

†These numbers were computed using the standard model of Table 1 ... A_B = 0.20 (equation 6) for latitudes b of 20° and 30°, and A_V = ...

#For each apparent magnitude, the numbers on the first line are ... the numbers on the second line are the B-band star densities.

Bahcall, J. N., and Sargent, W. L. W. 1967, *Ap. J. (Letters)*, **148**, L65.
Balona, L. A., and Feast, M. W. 1974, *M.N.R.A.S.*, **167**, 621.
Becker, F. 1939, *Zs. f. Ap.*, **19**, 50.
Blaauw, A. 1965, in *Galactic Structure*, ed. A. Blaauw and M. Schmidt (Chicago: University of Chicago Press), p. 435.
Bohuski, T. J., and Weedman, D. W. 1979, *Ap. J.*, **231**, 653.
Bok, B. J. 1937, *The Distribution of Stars in Space* (Chicago: University of Chicago Press).
Bok, B. J., and MacRae, D. A. 1941, *Ann. NY Acad. Sci.*, **42**, 219.
Bosma, A. 1978, Ph.D. thesis, University of Groningen.
Braccesi, A., Zitelli, F., and Formiggini, L. 1980, *Astr. Ap.*, in press.
Brown, G. S. 1979, *A. J.*, **84**, 1647.
Burbidge, G. R., Crowne, A. H., and Smith, H. E. 1977, *Ap. J. Suppl.*, **33**, 113.
Burstein, D., and Heiles, C. 1978, *Ap. J.*, **225**, 40.
Burstein, D., and McDonald, L. H. 1975, *A. J.*, **80**, 17.
Chamberlain, J. W., and Aller, L. H. 1951, *Ap. J.*, **114**, 52.
Chiu, L.-T. G. 1980, preprint.
Dekel, A., and Shaham, J. 1979, *Astr. Ap.*, **74** 186.
de Vaucou...
Flügge...

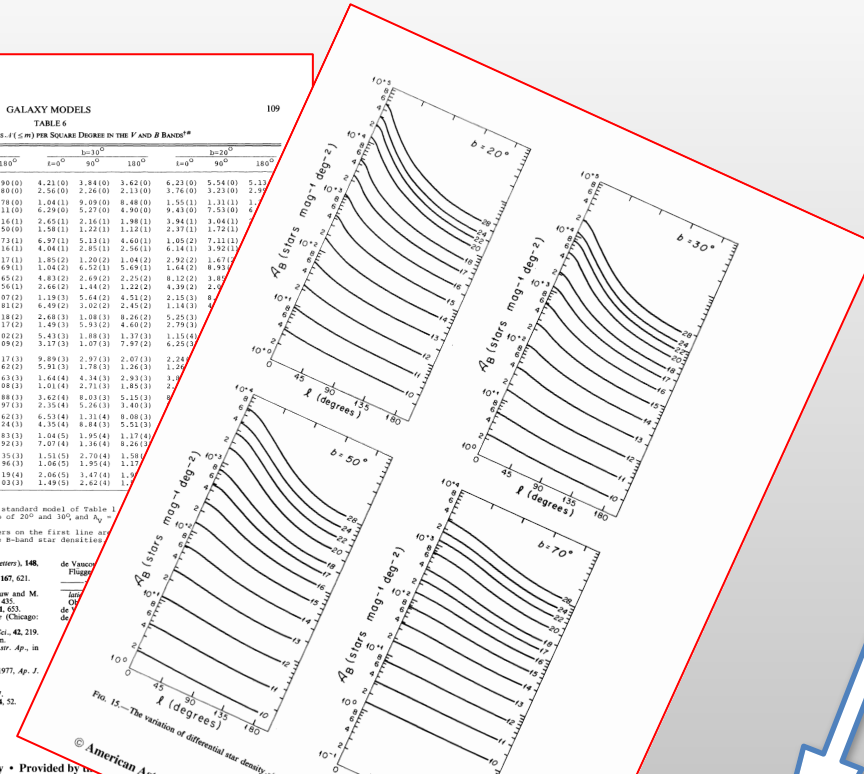
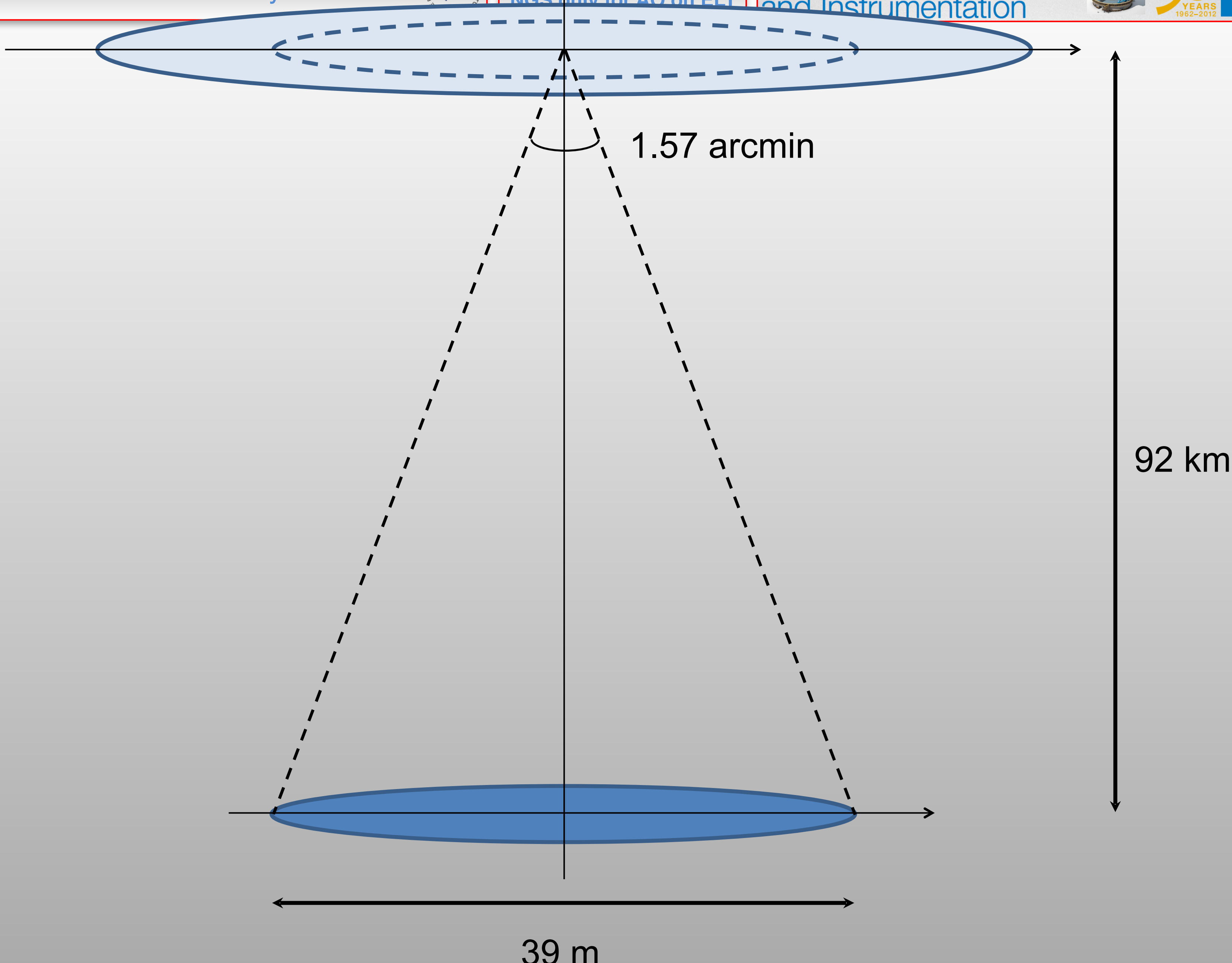
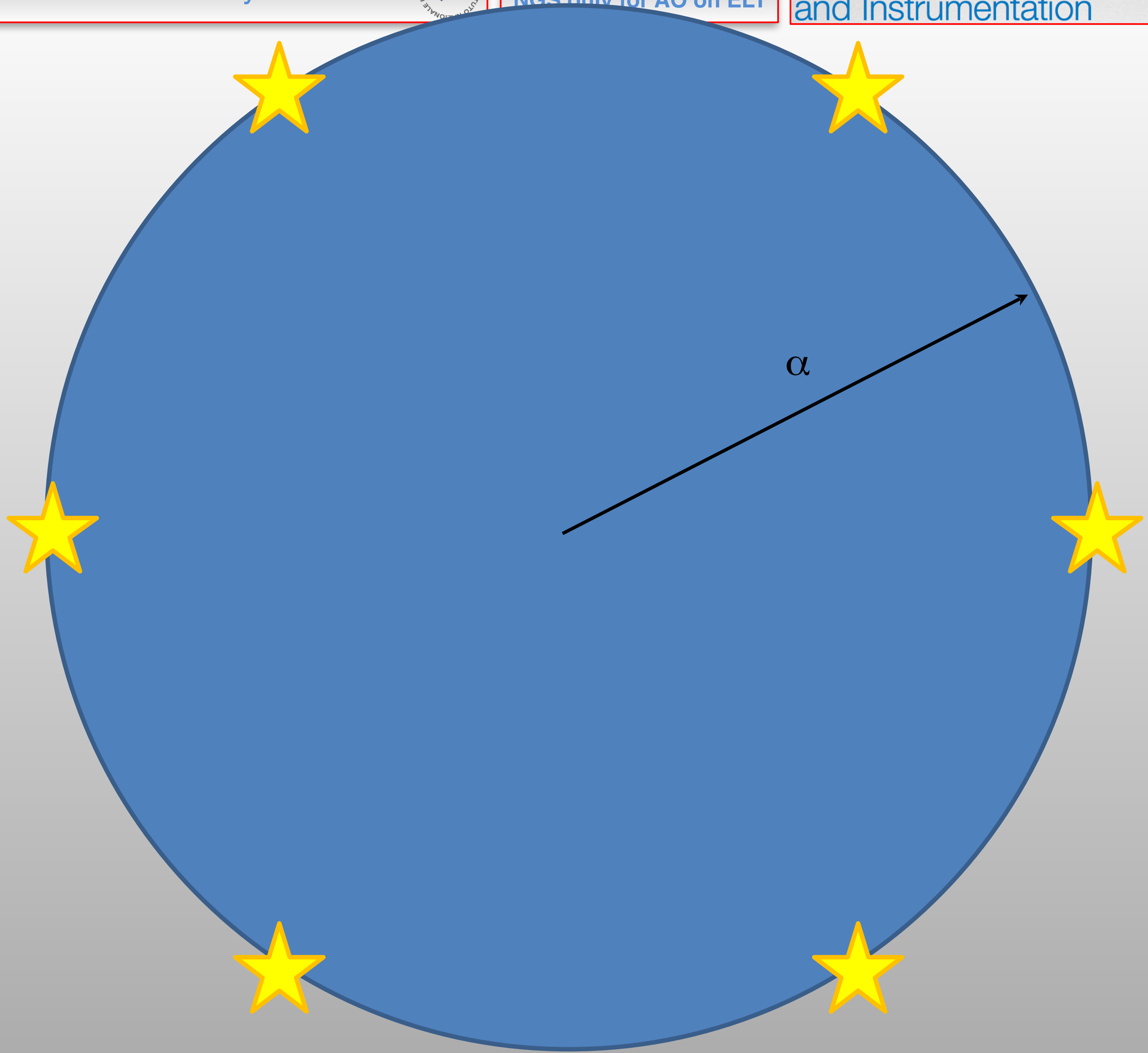
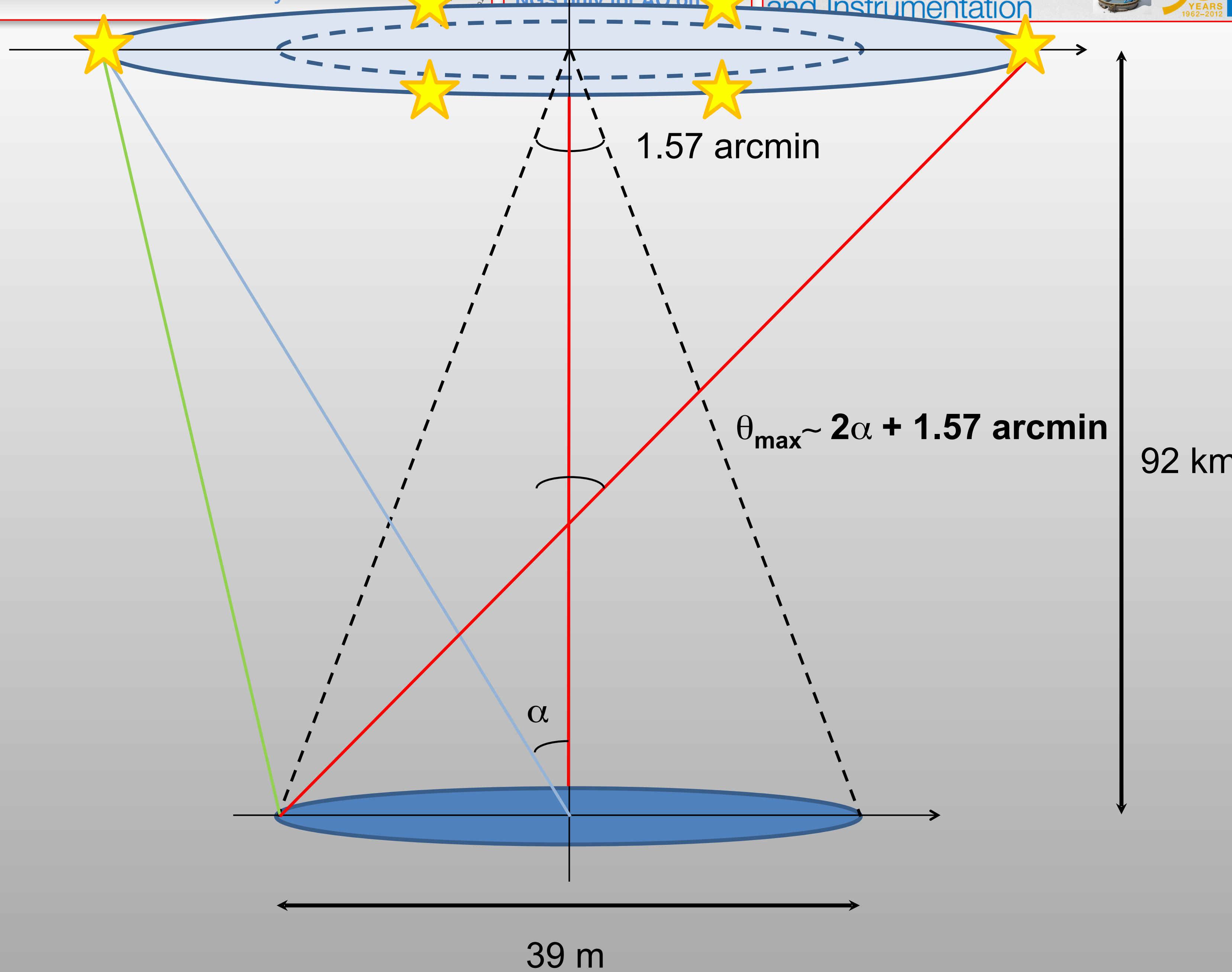


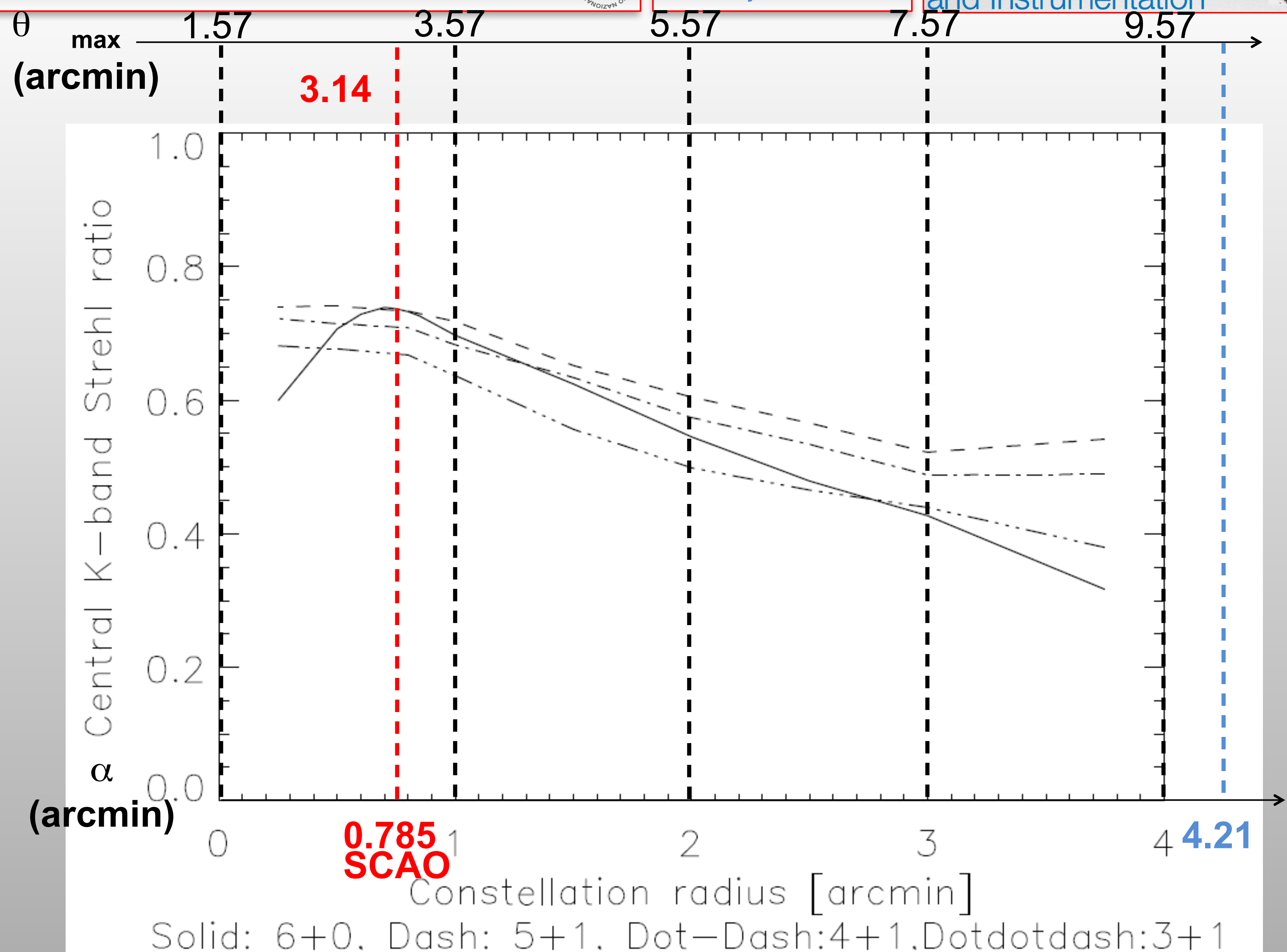
FIG. 15.—The variation of differential star density ...

V=15	V=16	V=17	V=18	Galactic Pole
135	253	437	709	Stars per square deg
1.1	2.2	3.8	6.2	Stars in a 10' diameter
0.3	0.6	0.9	1.6	Stars in a 5' diameter

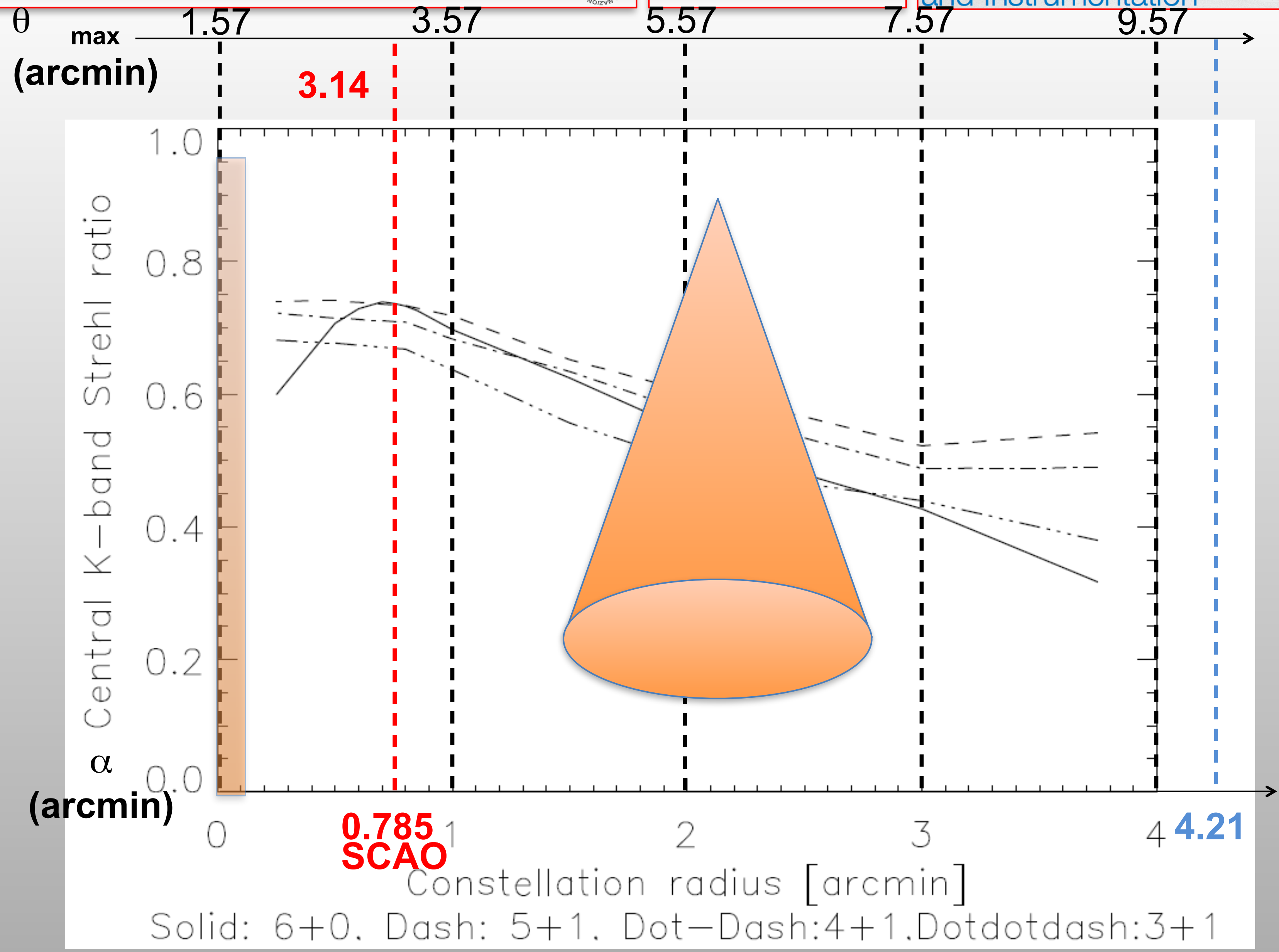

1.57 arcmin
92 km
39 m


α


1.57 arcmin
θmax ~ 2α + 1.57 arcmin
92 km
α
39 m



From M. Le Louarn - ELT AO LGSs simulations



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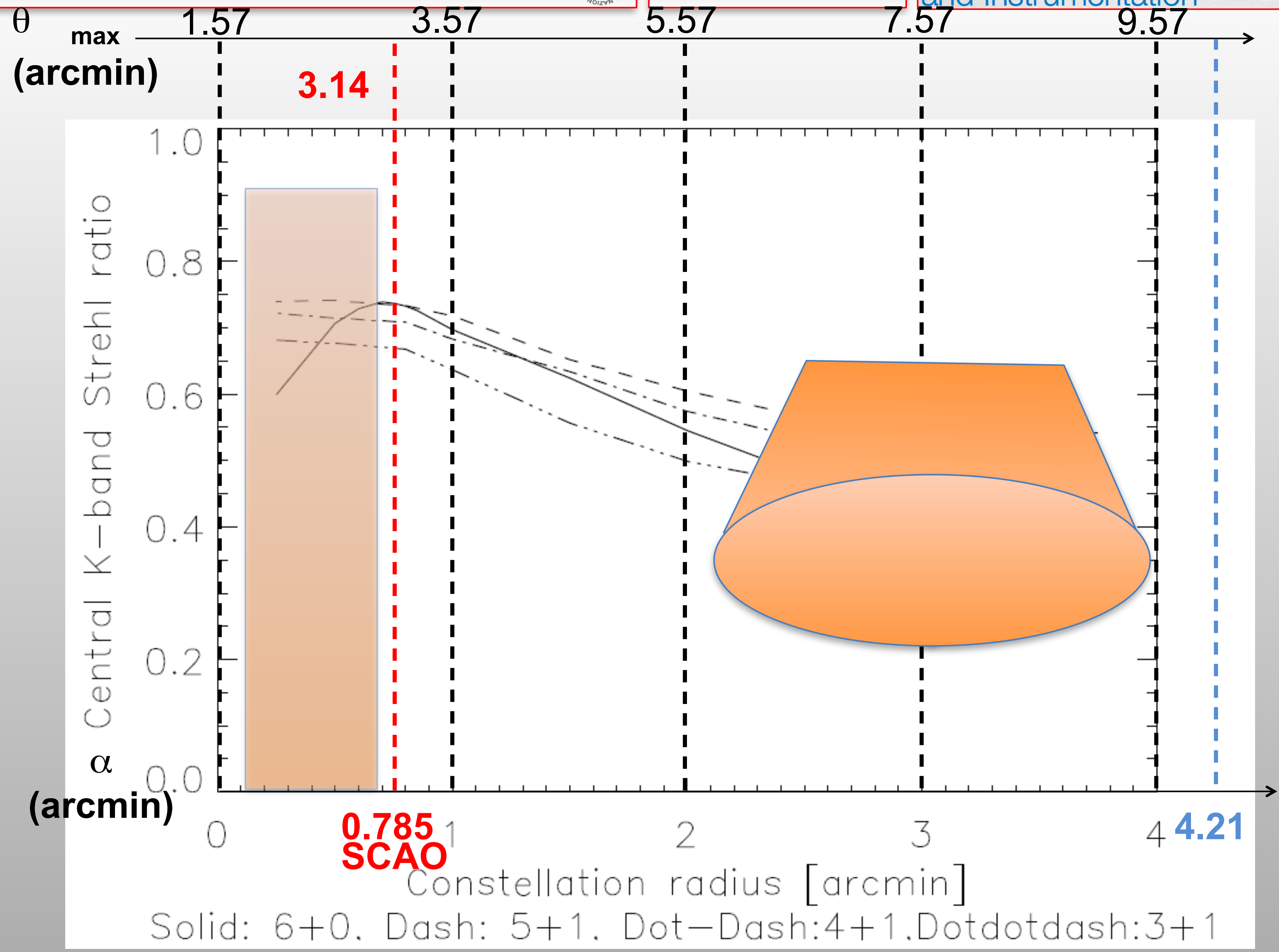

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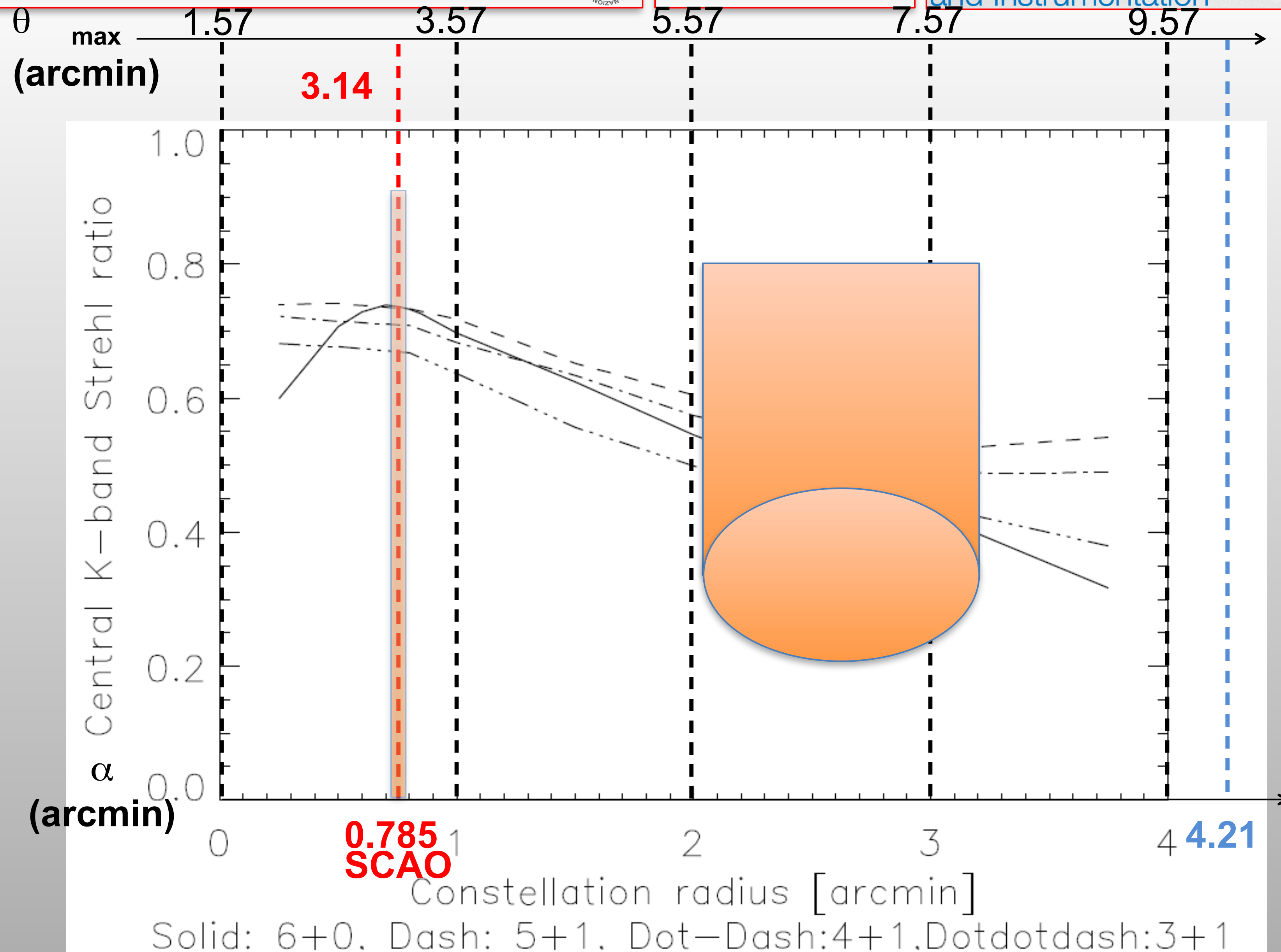

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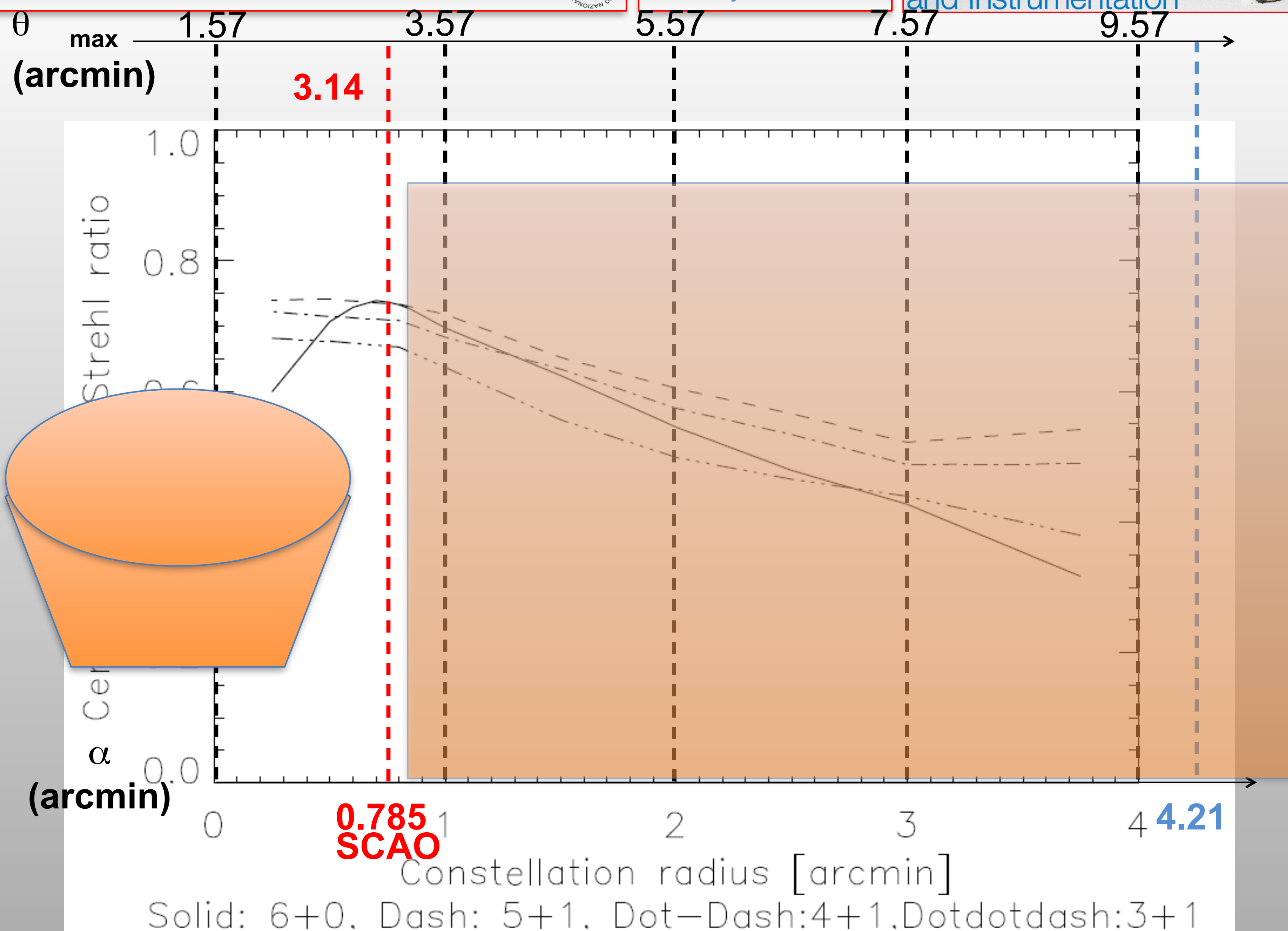

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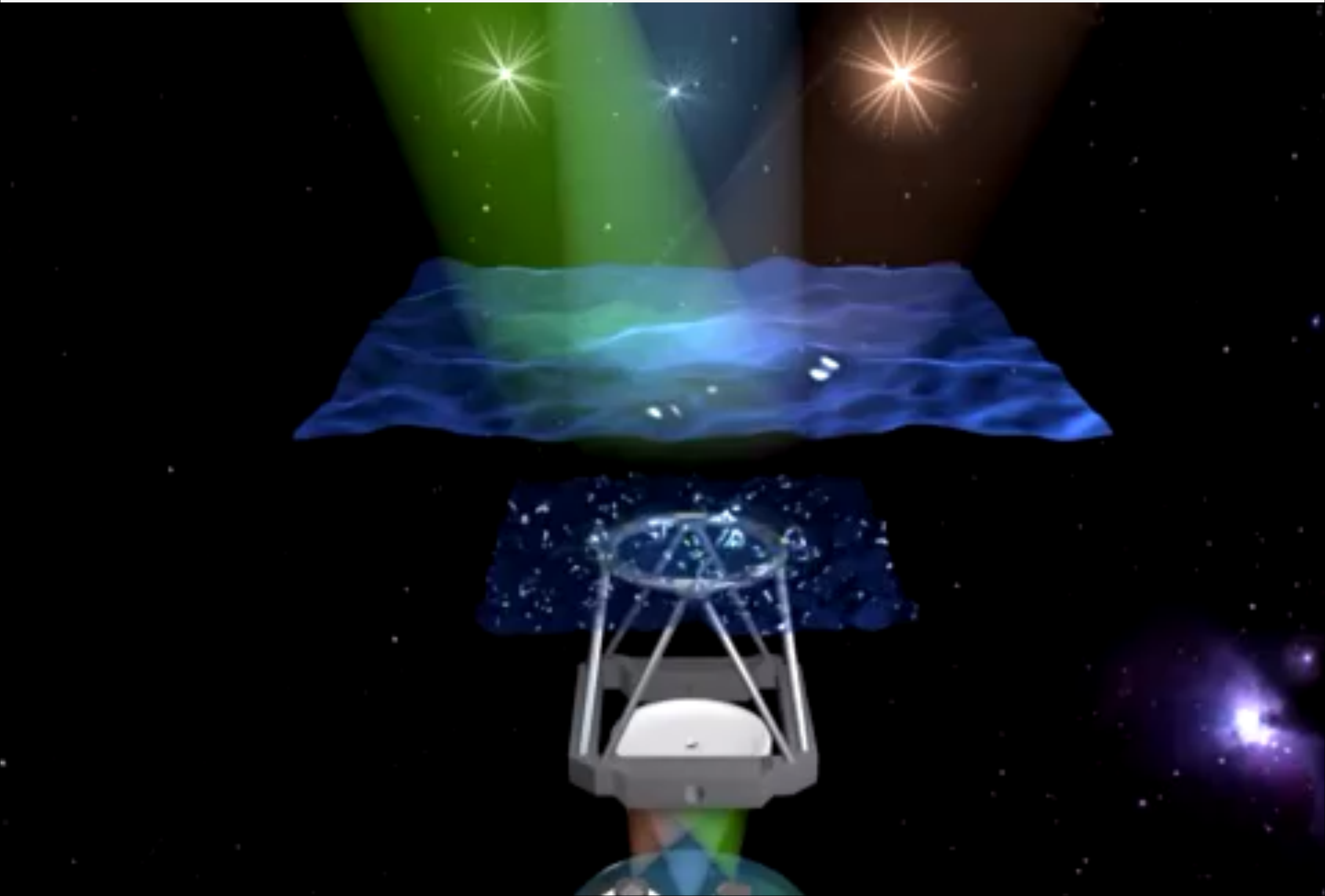
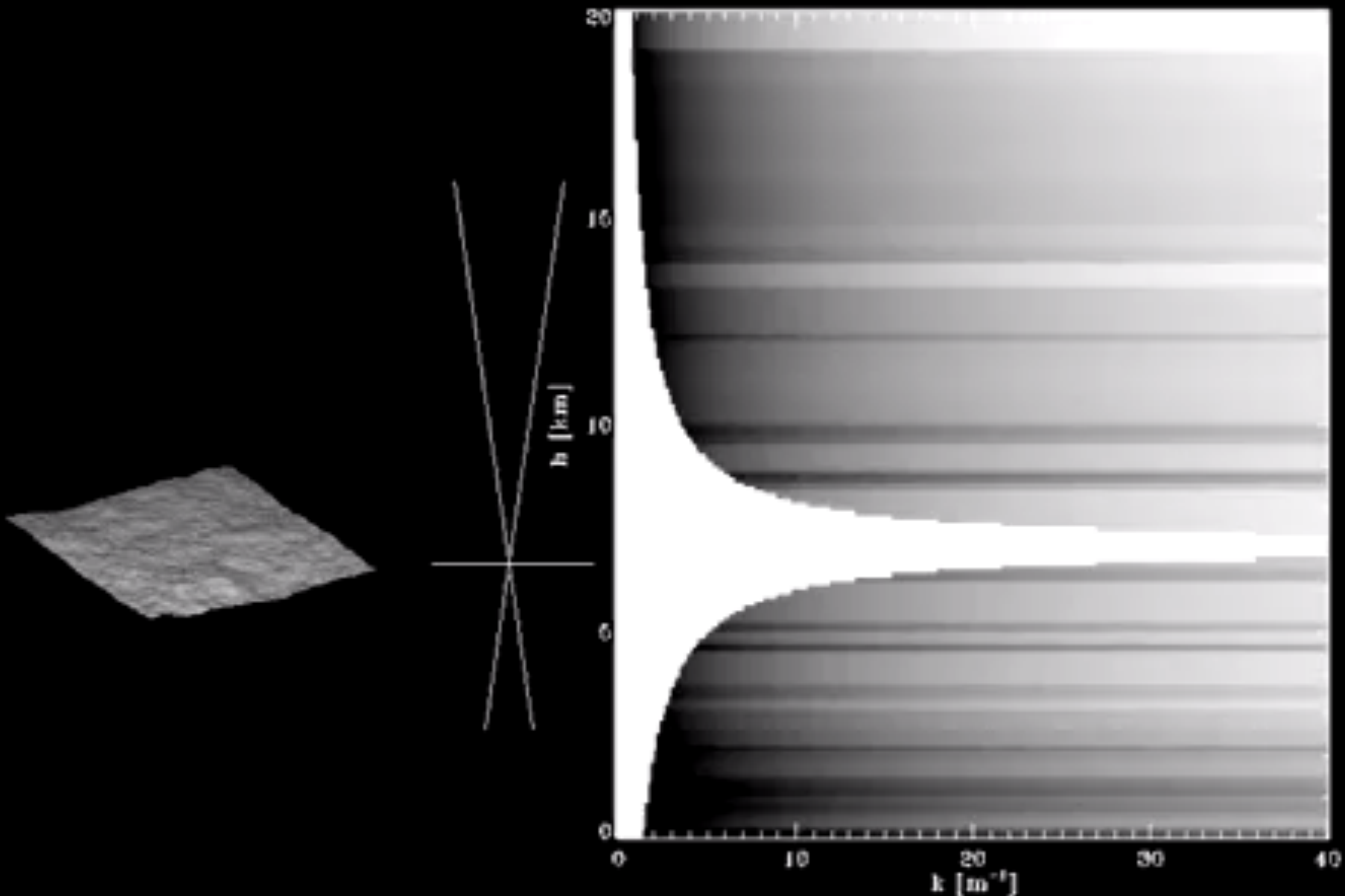
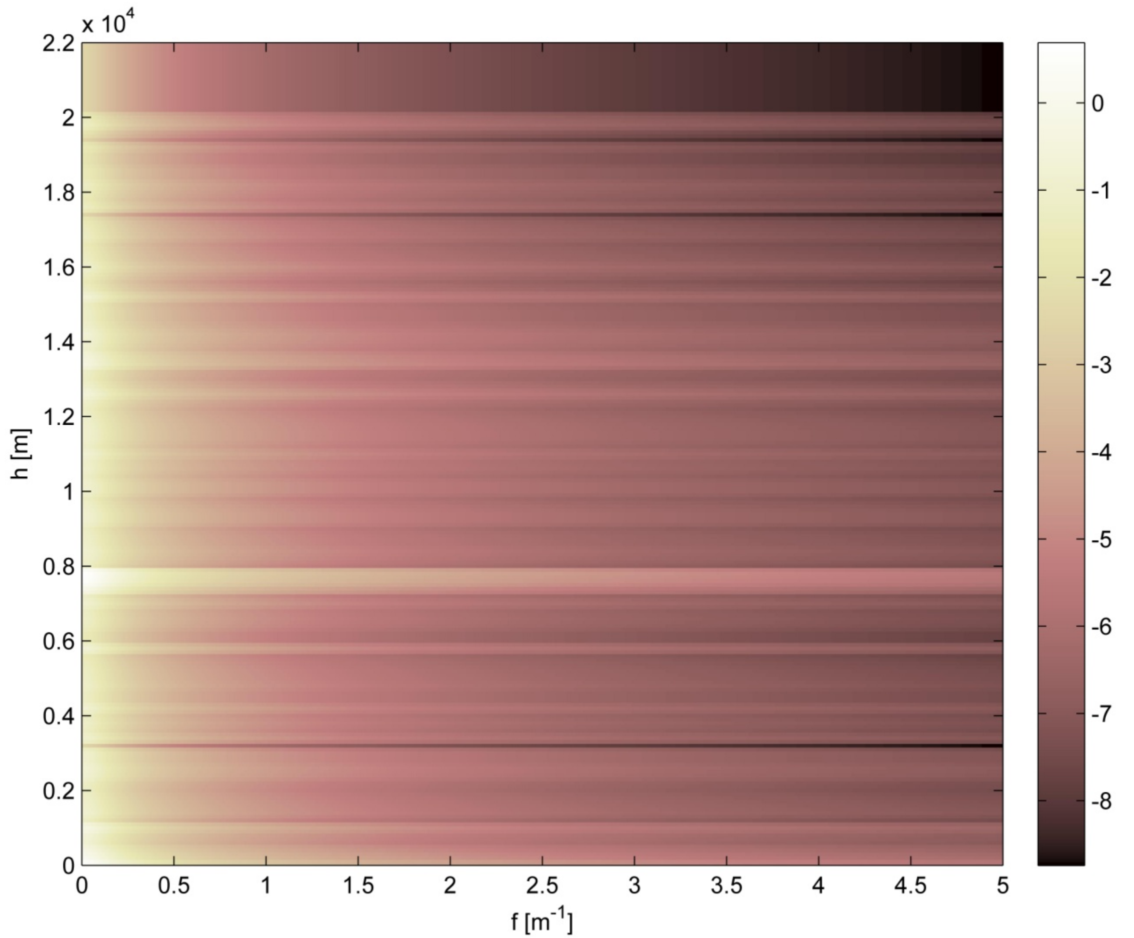


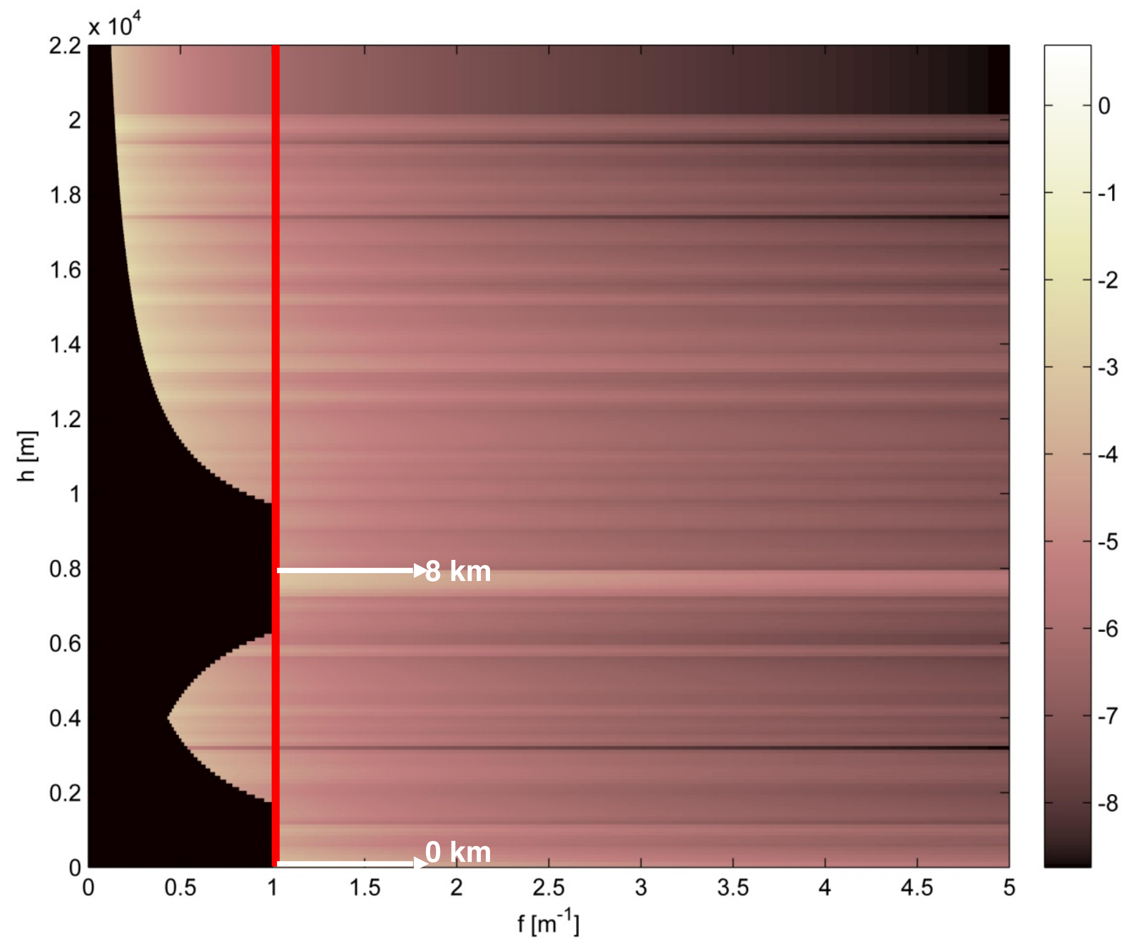

h [km]
0
5
10
15
20
k [m⁻¹]
10
30
40


x 10^4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
h [m]
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
f [m^-1]
0
-1
-2
-3
-4
-5
-6
-7
-8

D_{tel} = 8 m
N. DMs = 2
N. actuators = 8
Field of View = 2 arcmin

$$R = \sum_H \int_F \Phi_\varphi^{2D}(f)\,df$$

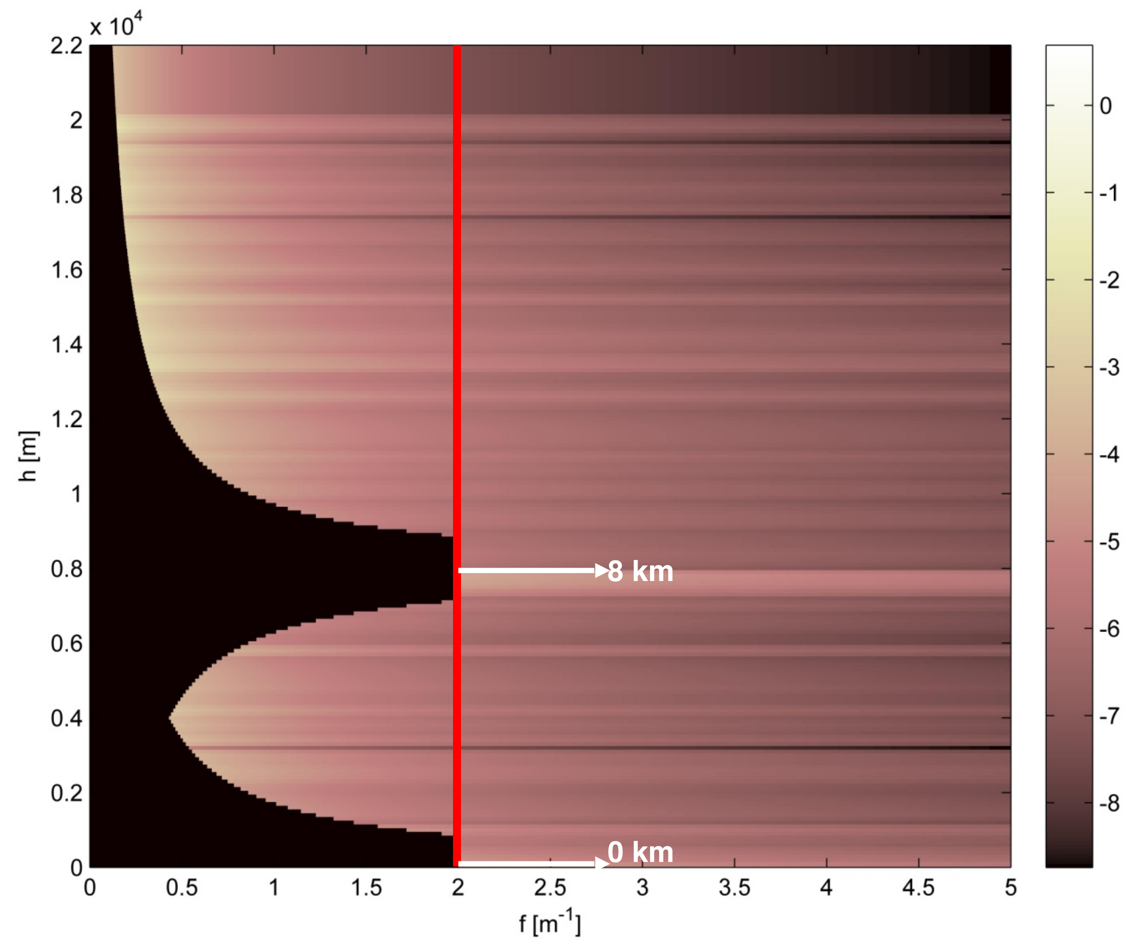
$R_{MAD\text{-}8m} = 0.0262$



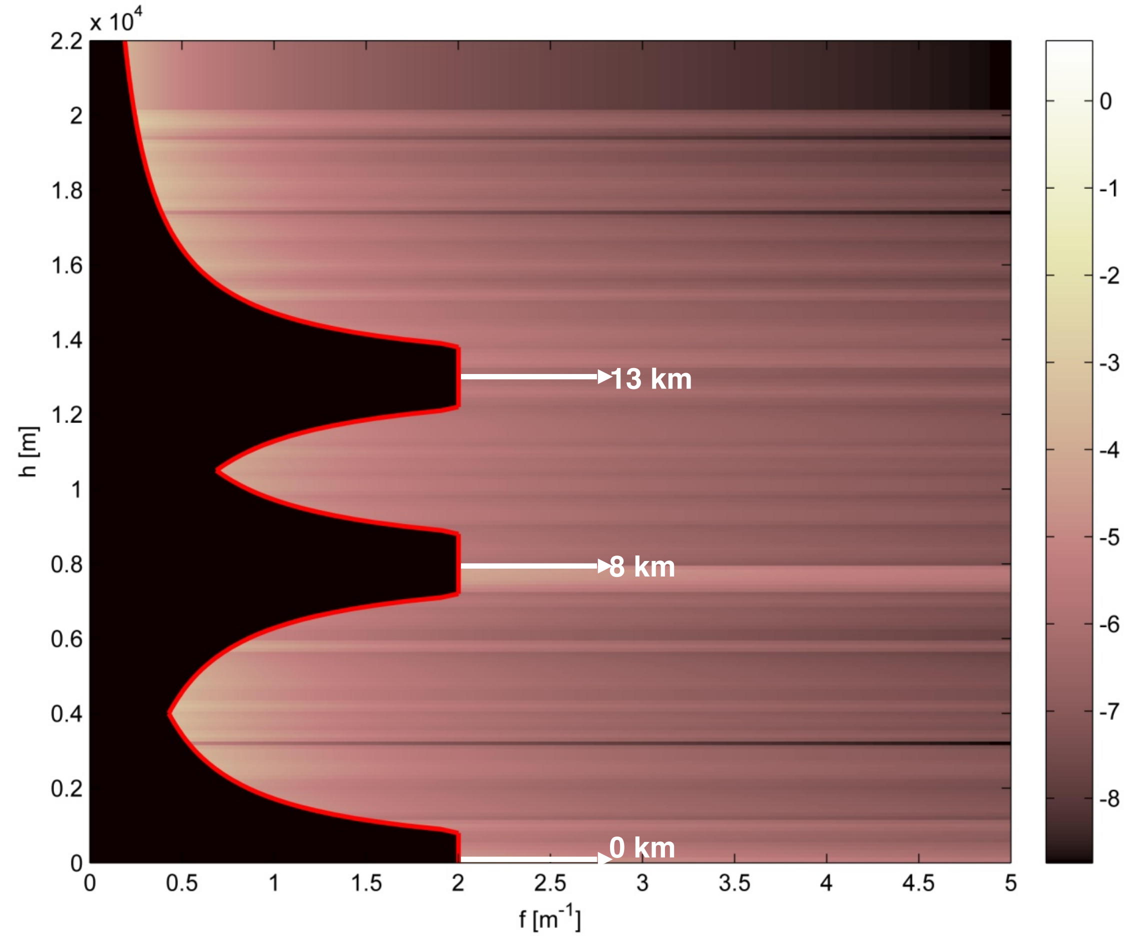
D_{tel} = 40 m
N. DMs = 2
N. actuators = 80
Field of View = 2 arcmin

$$R = \sum_H \int_F \Phi_\varphi^{2D}(f)\,df$$

$R_{MAD\text{-}40m}$ = 0.0239

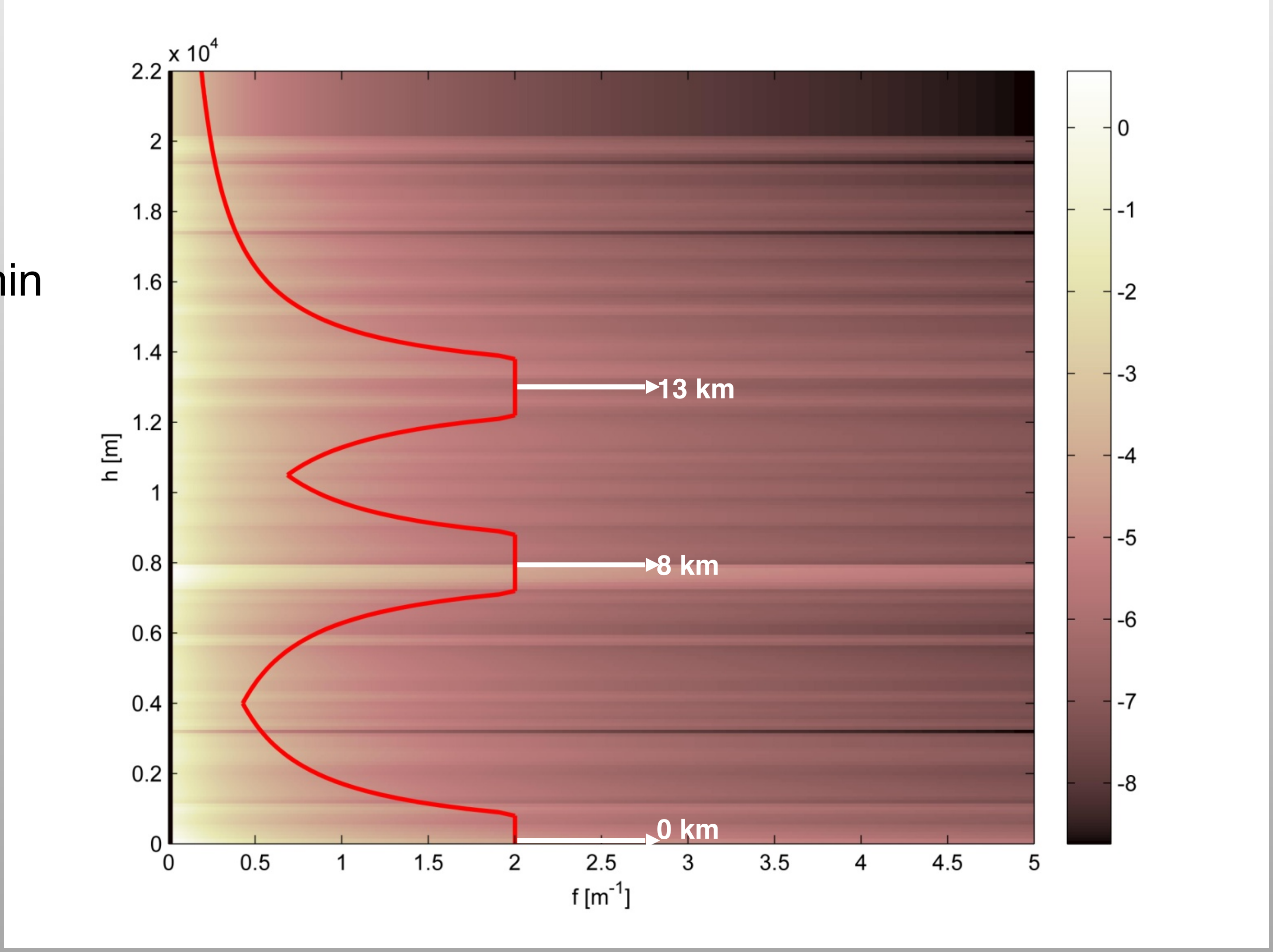


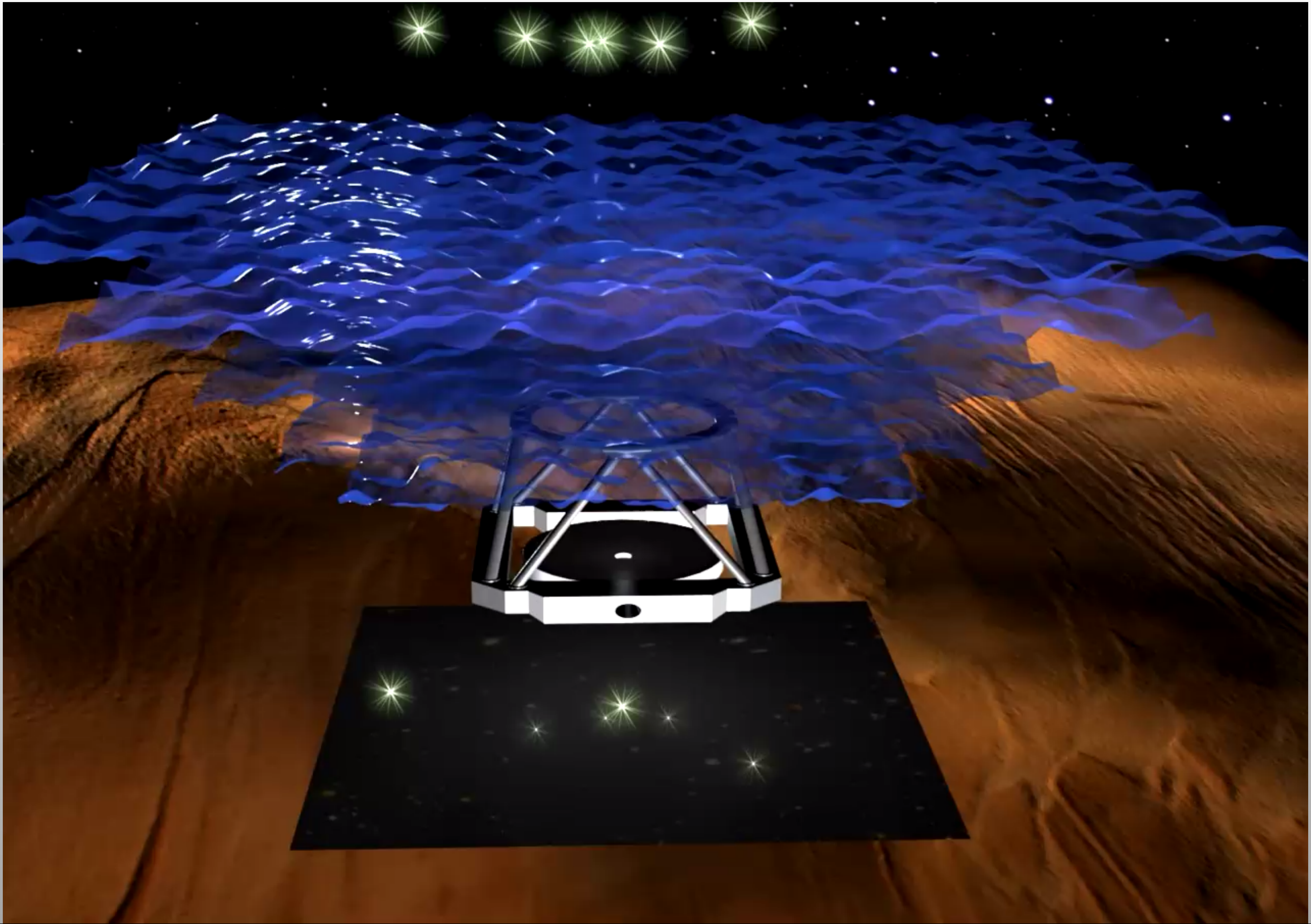
D_{tel} = 40 m
N. DMs = 3
N. actuators = 80
Field of View = 2 arcmin



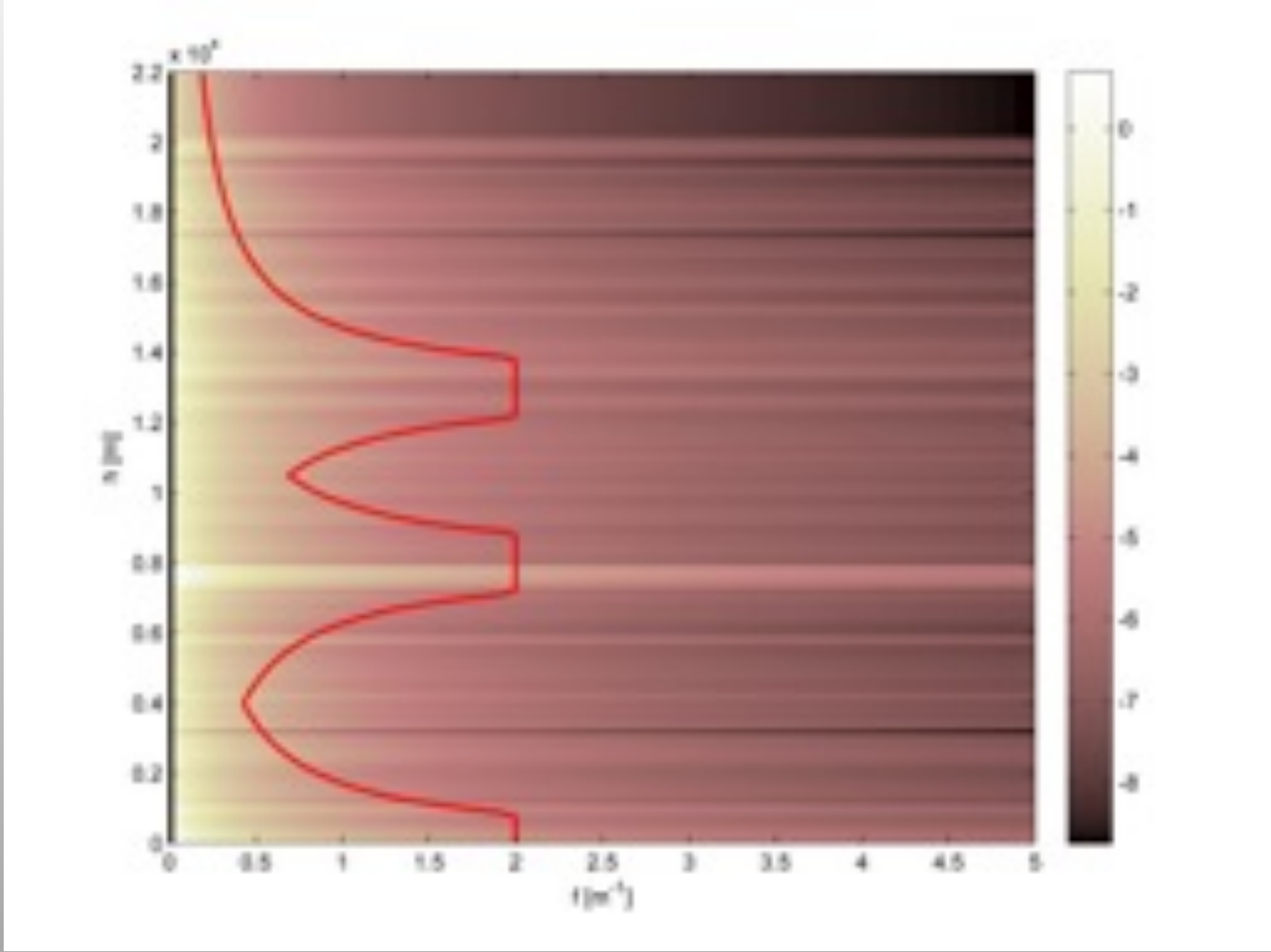
D_{tel} = 40 m
N. DMs = 3
N. actuators = 80
Field of View = 2 arcmin

N.VDMs = 0

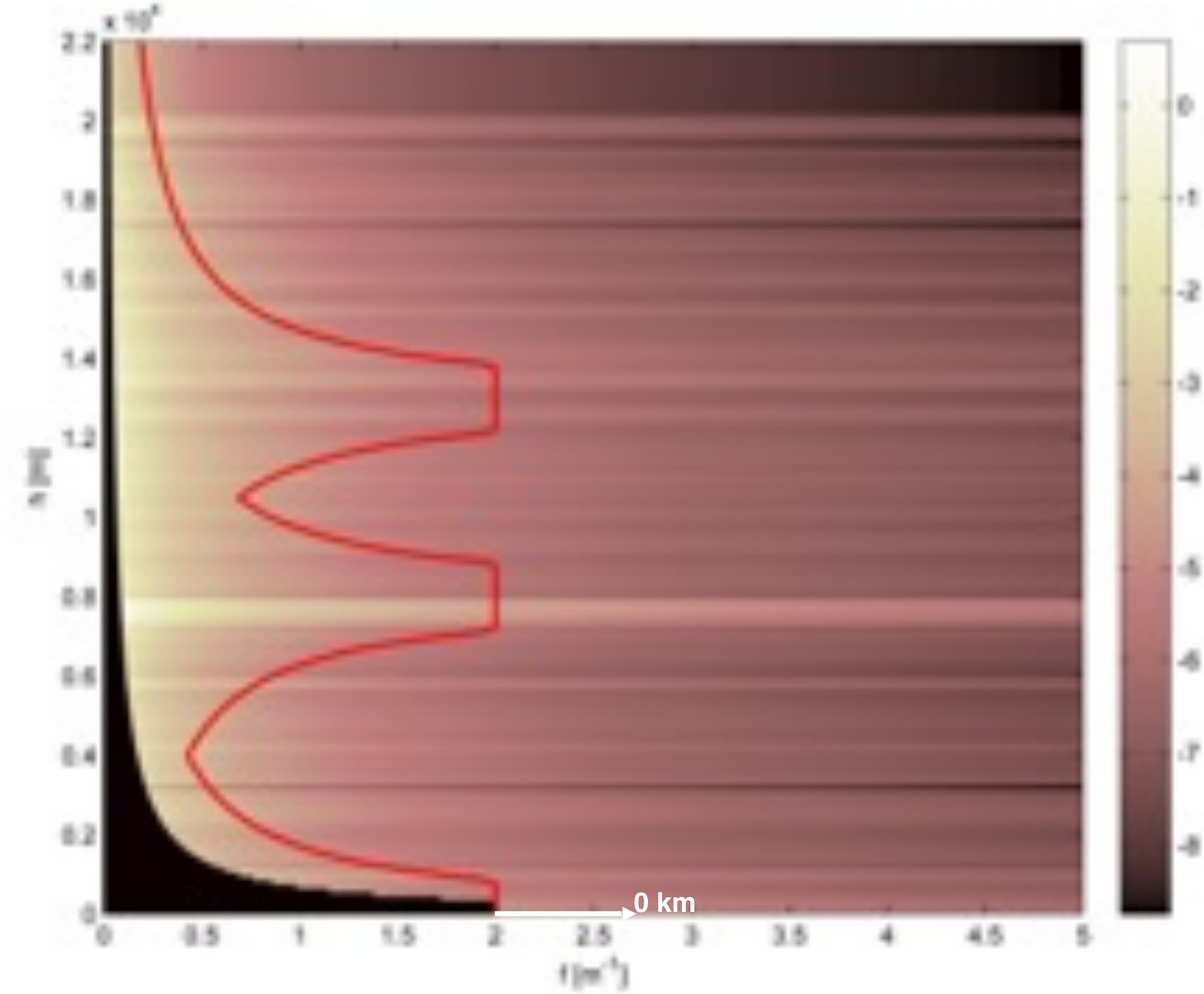




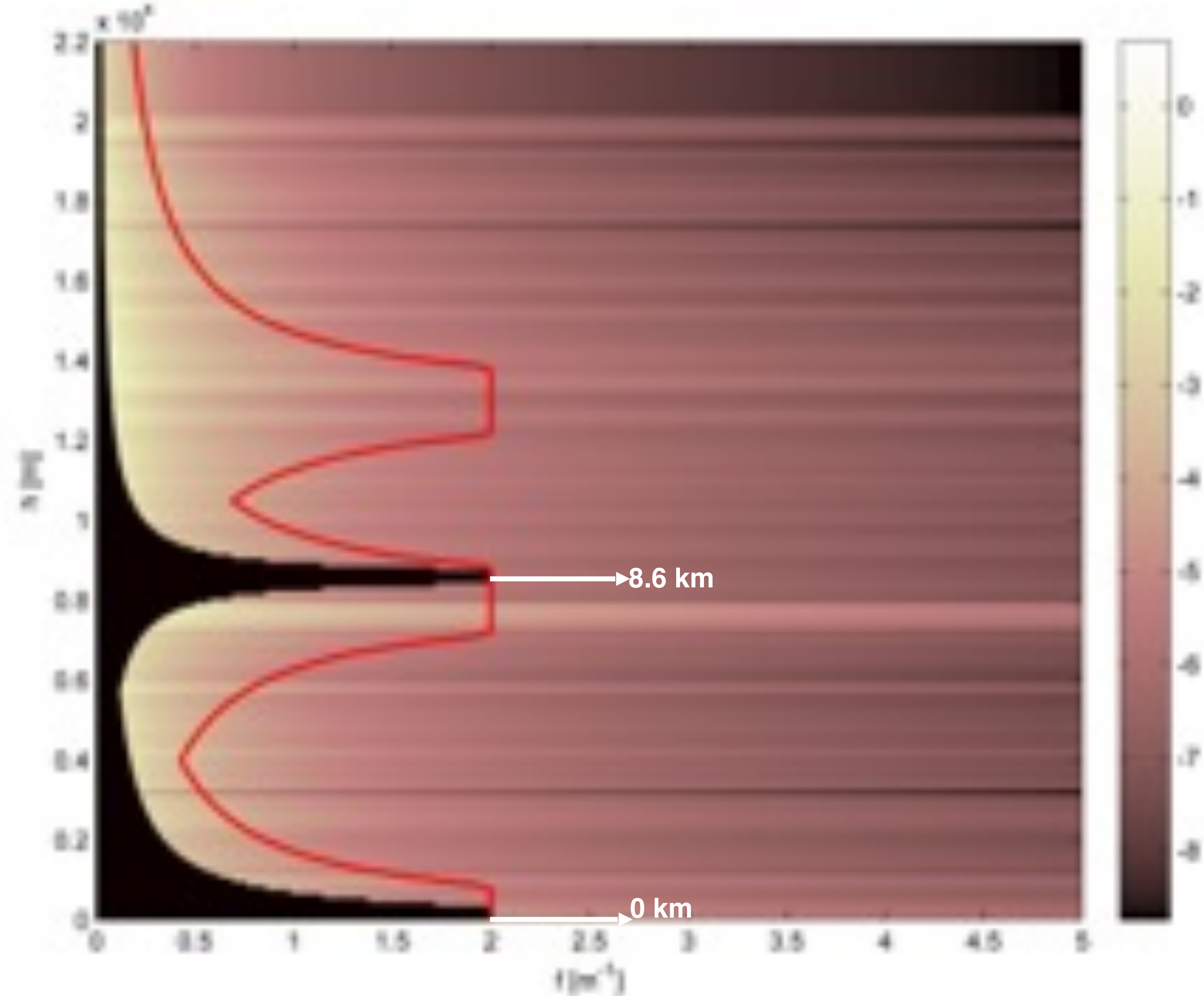
Ground VDM FoV = 5 arcmin
VDMs FoV = 10 arcmin



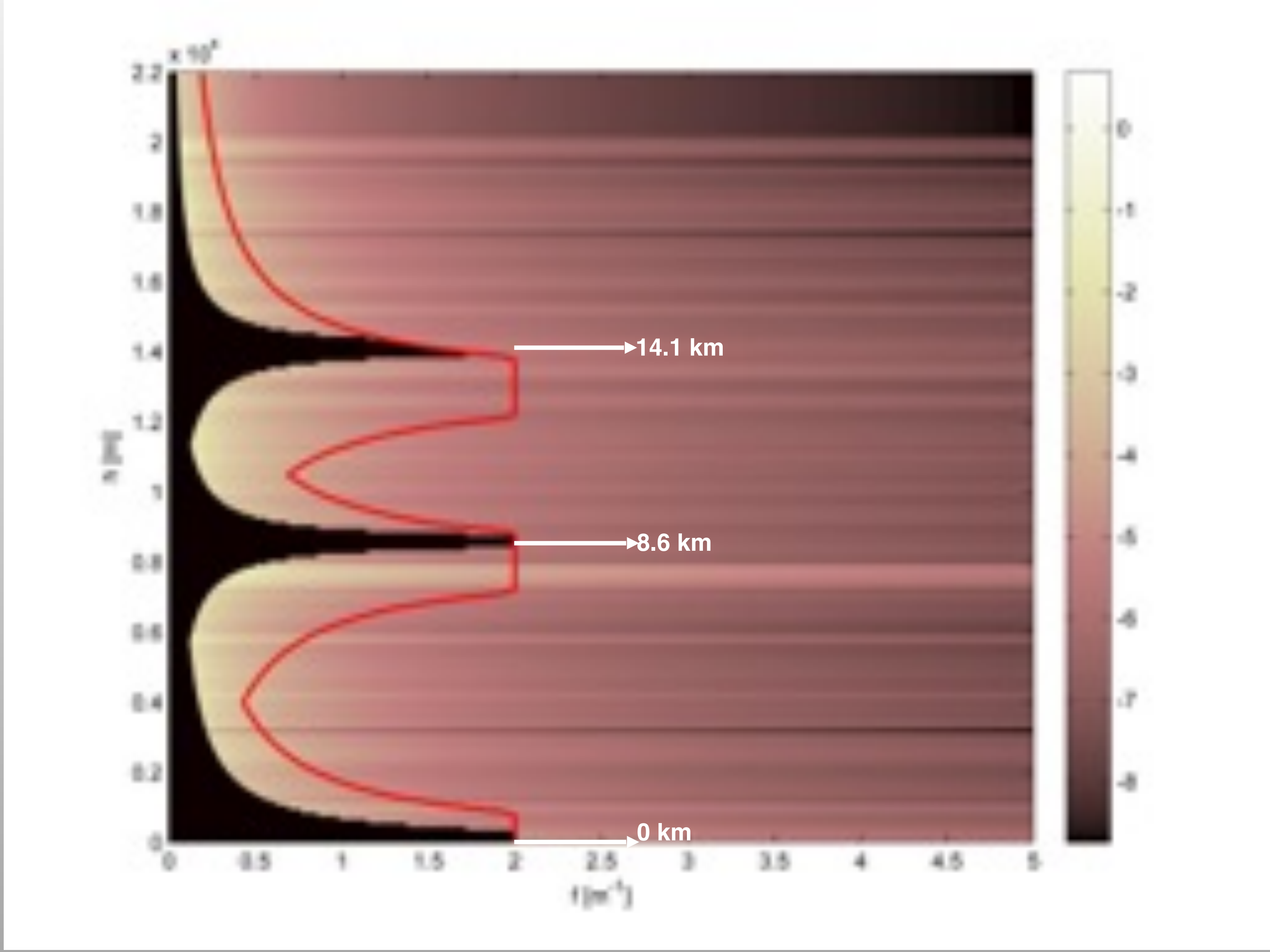
Ground VDM FoV = 5 arcmin
VDMs FoV = 10 arcmin



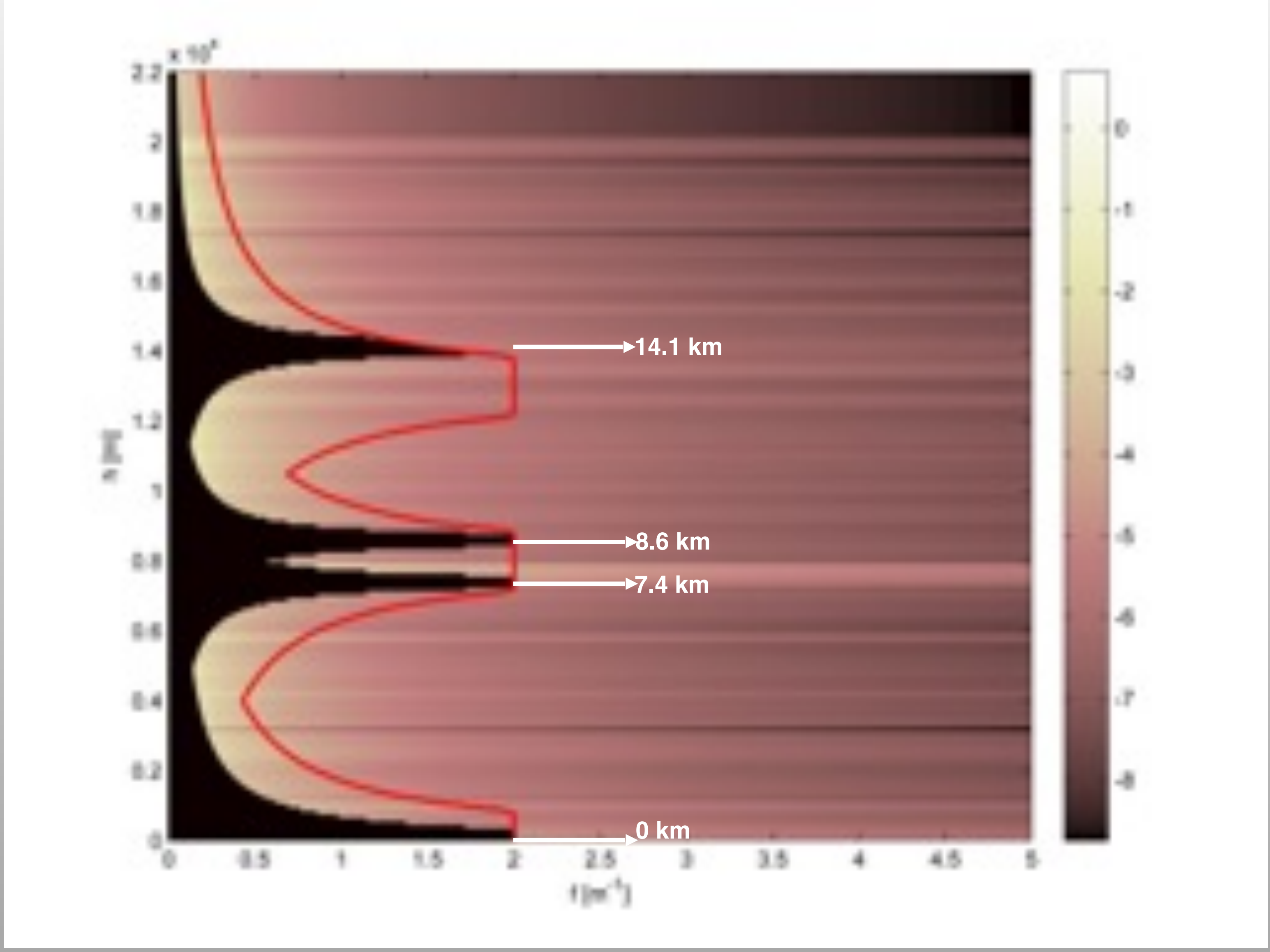
Ground VDM FoV = 5 arcmin
VDMs FoV = 10 arcmin



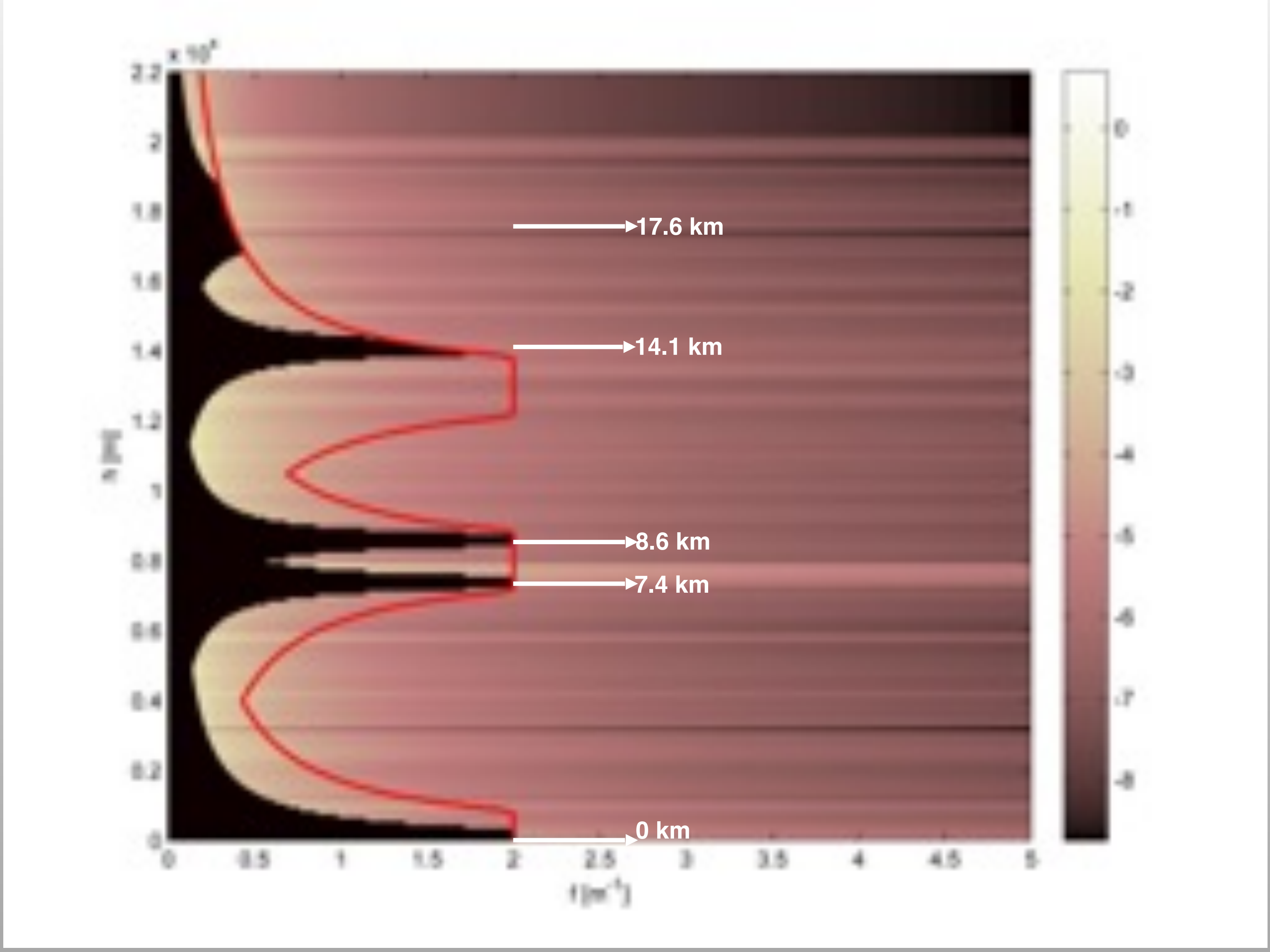
Ground VDM FoV = 5 arcmin
VDMs FoV = 10 arcmin



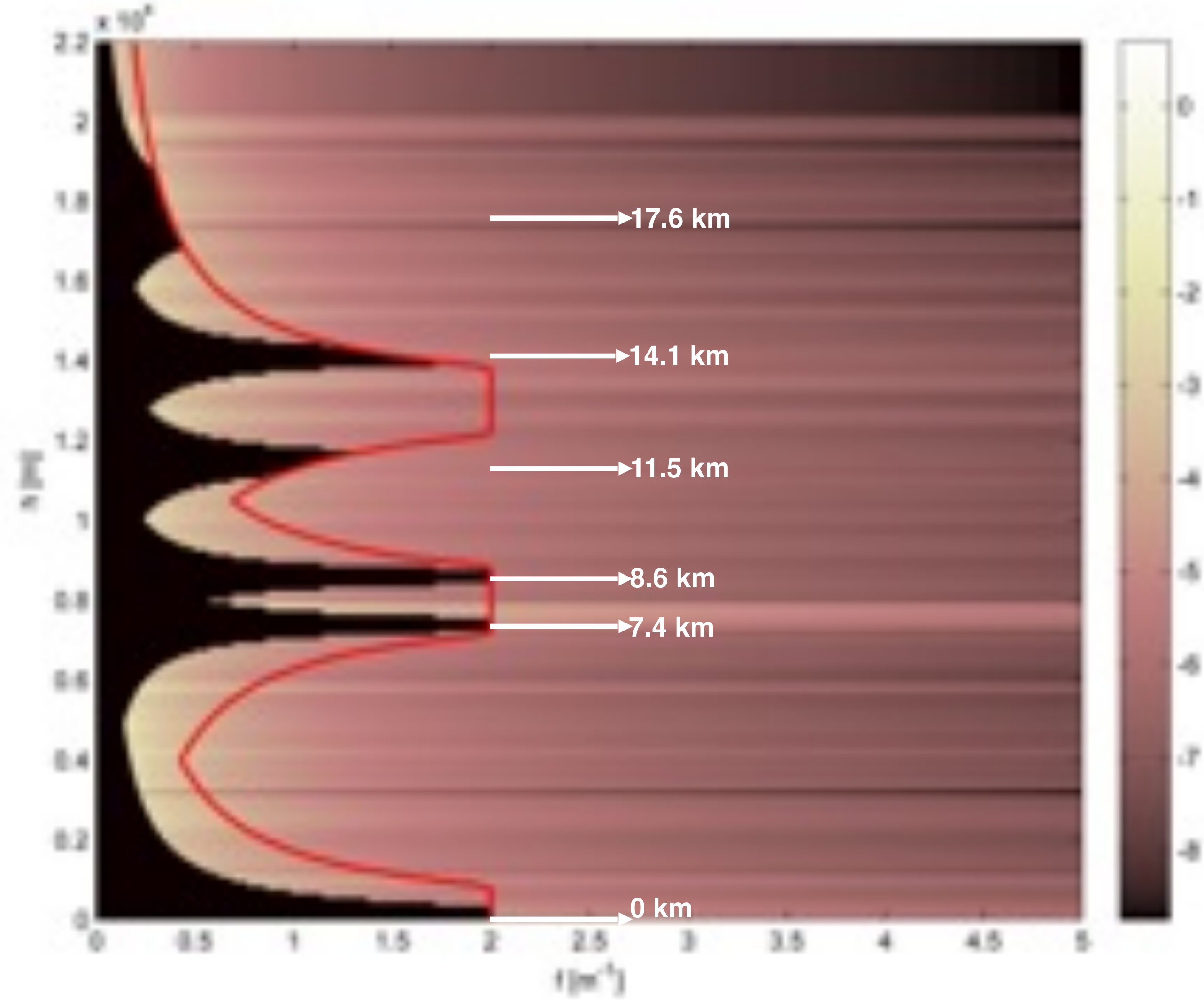
Ground VDM FoV = 5 arcmin
VDMs FoV = 10 arcmin



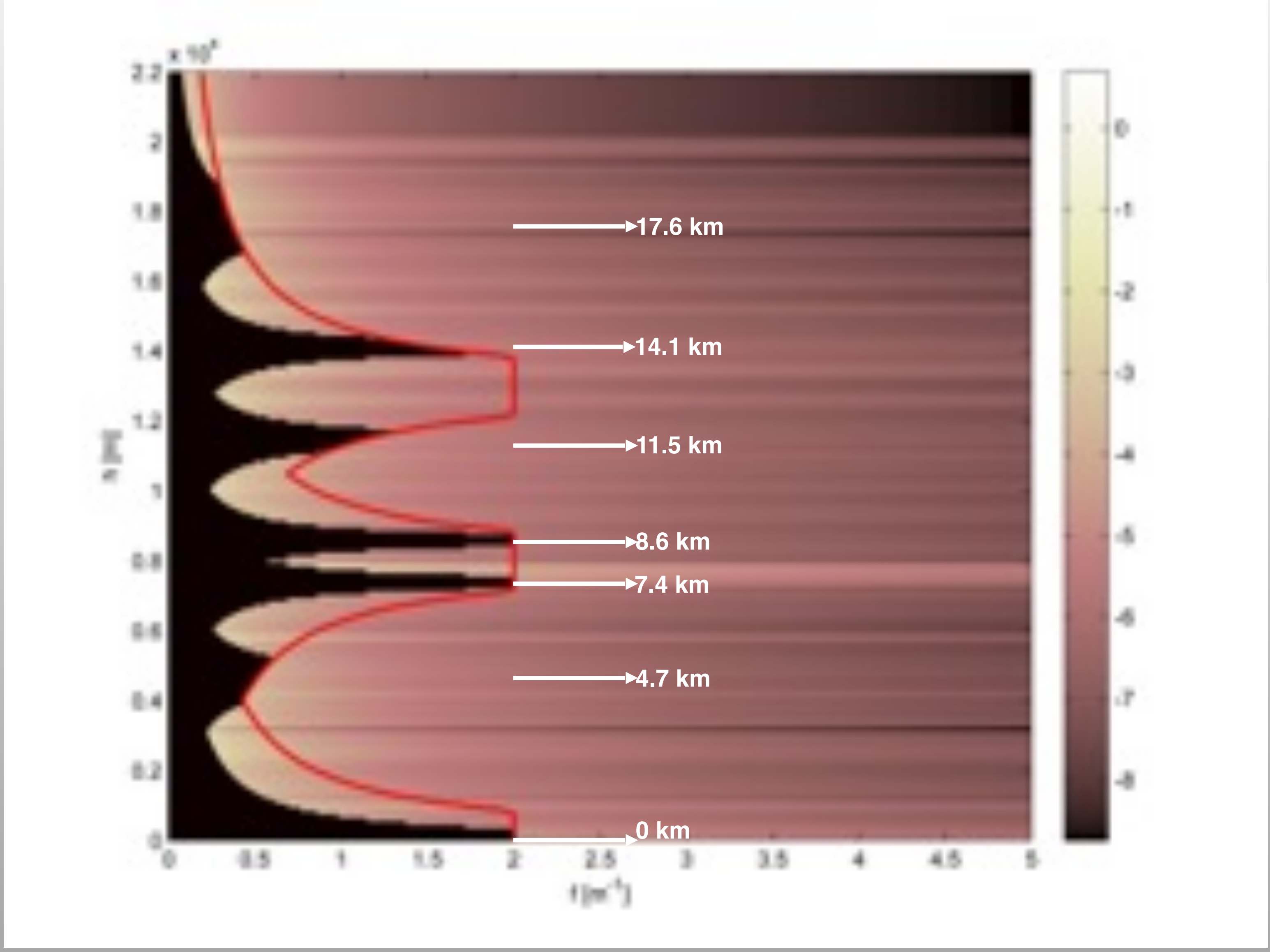
Ground VDM FoV = 5 arcmin
VDMs FoV = 10 arcmin



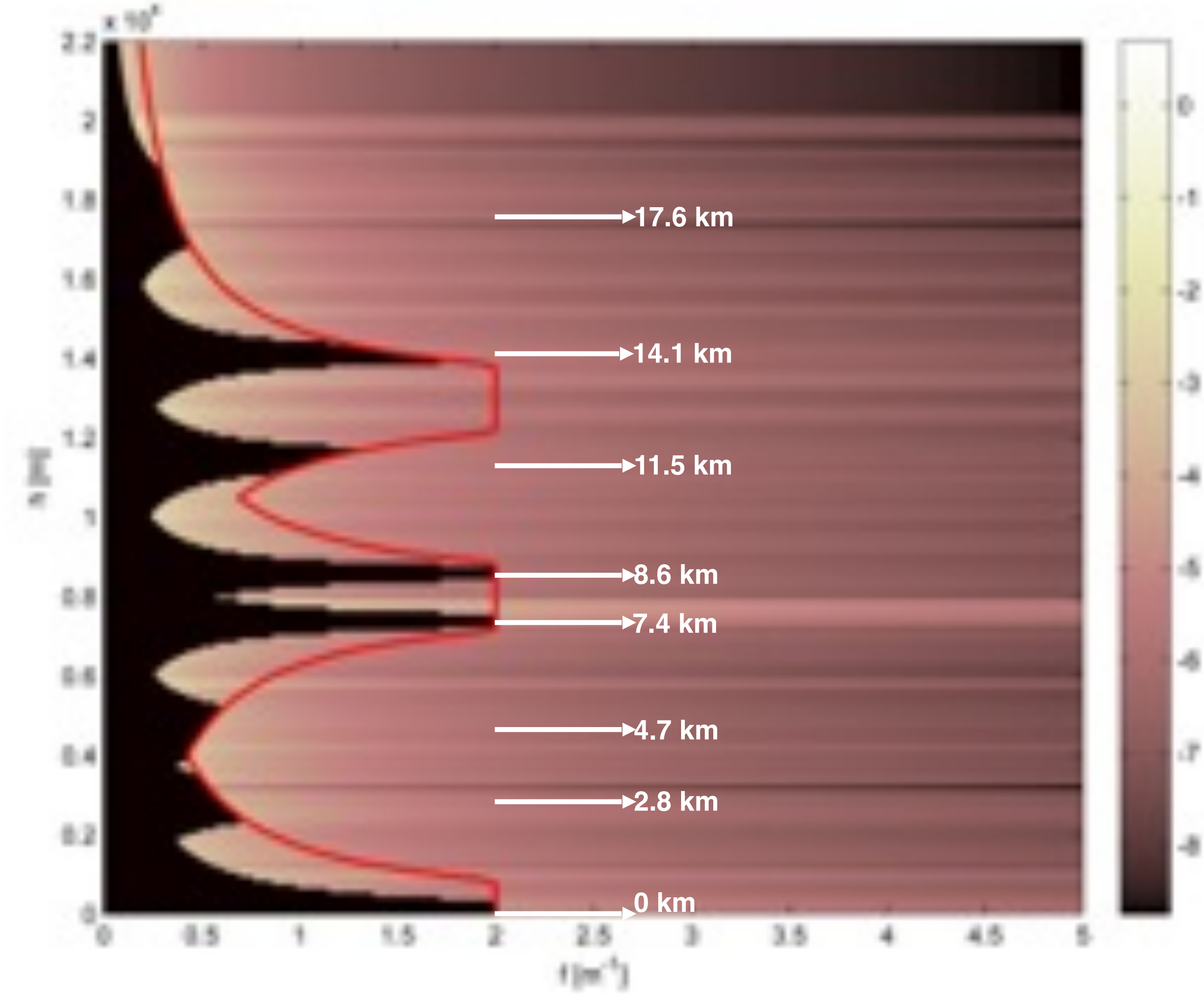
Ground VDM FoV = 5 arcmin
VDMs FoV = 10 arcmin



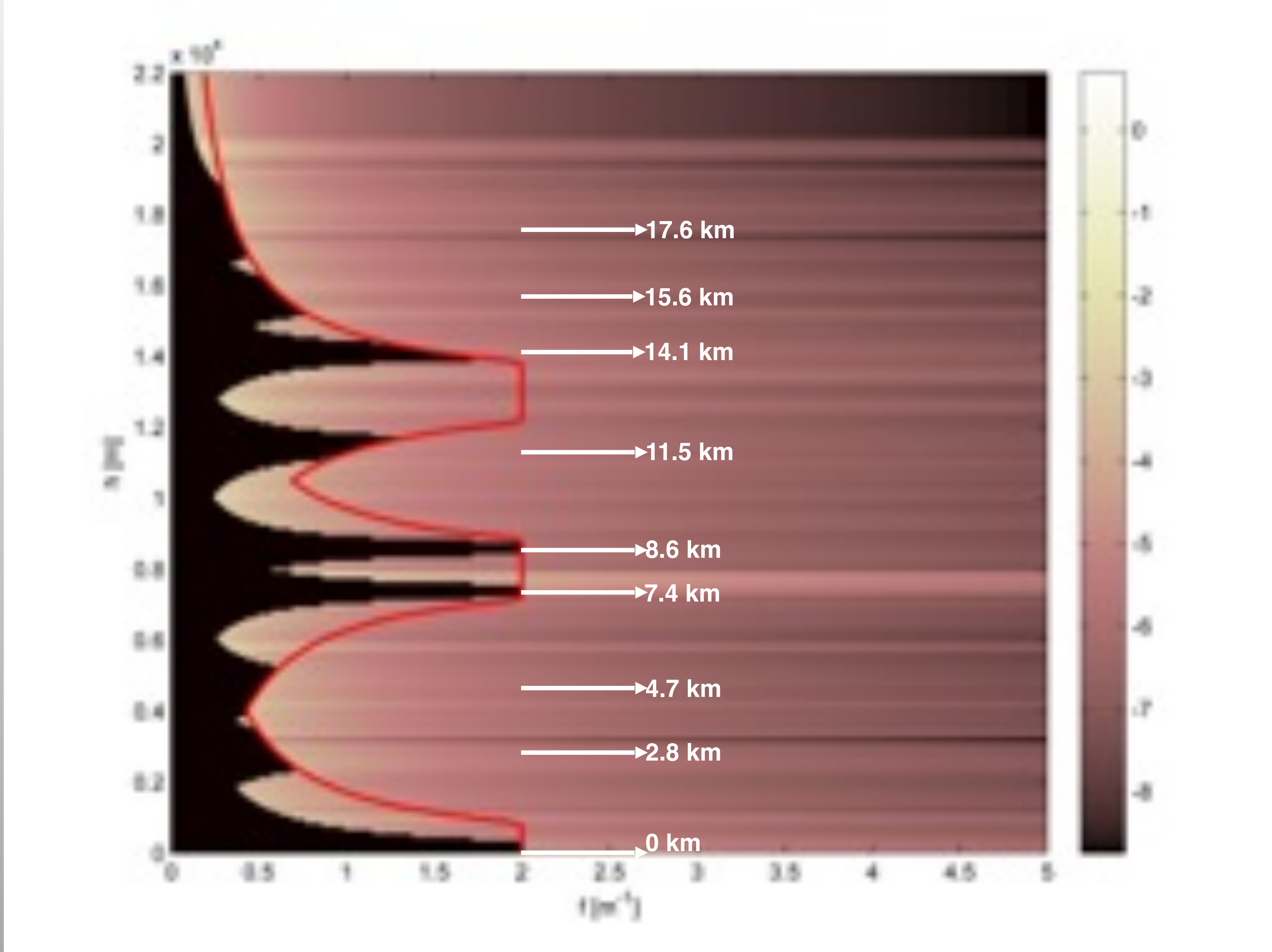
Ground VDM FoV = 5 arcmin
VDMs FoV = 10 arcmin



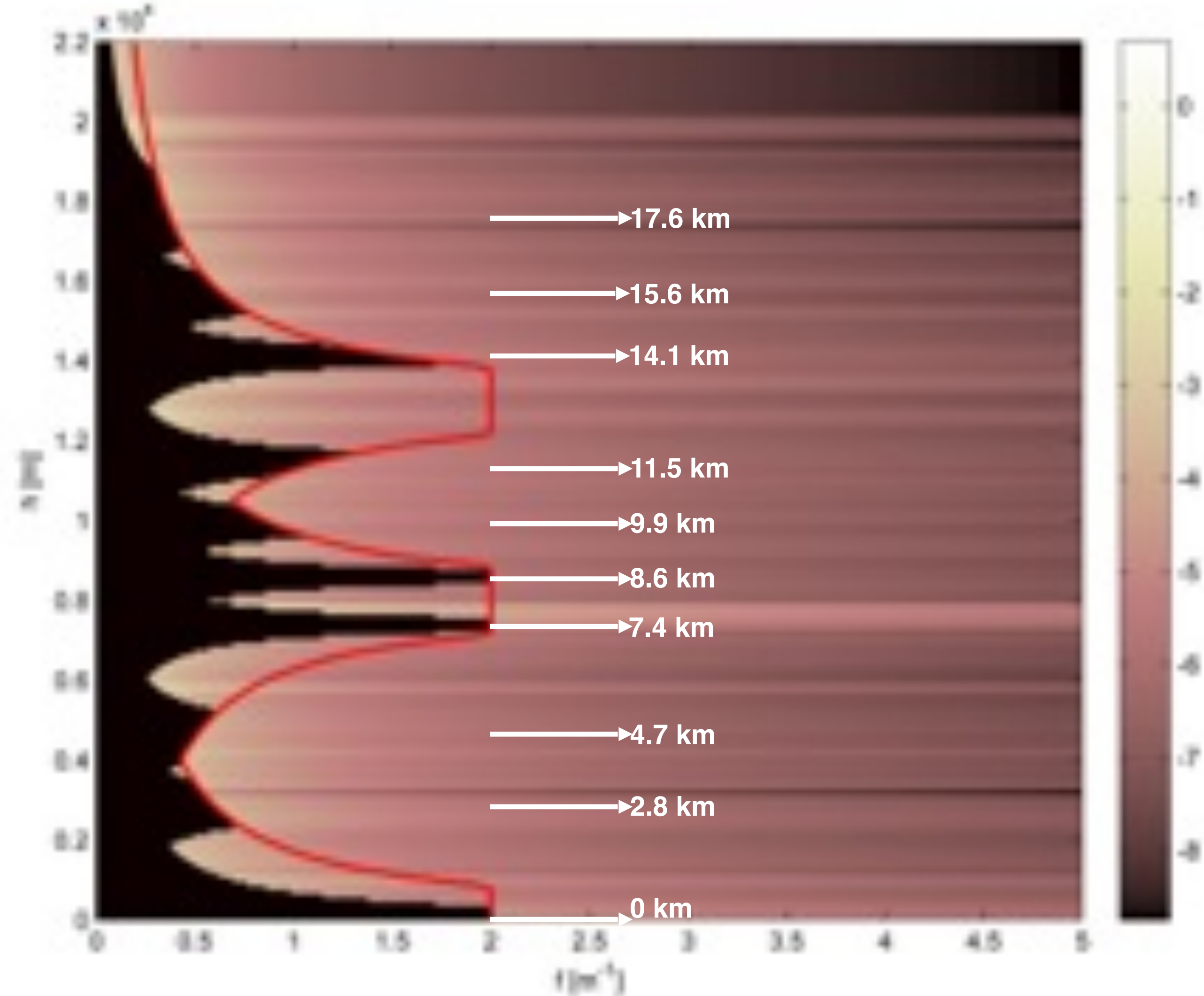
Ground VDM FoV = 5 arcmin
VDMs FoV = 10 arcmin

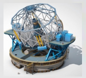


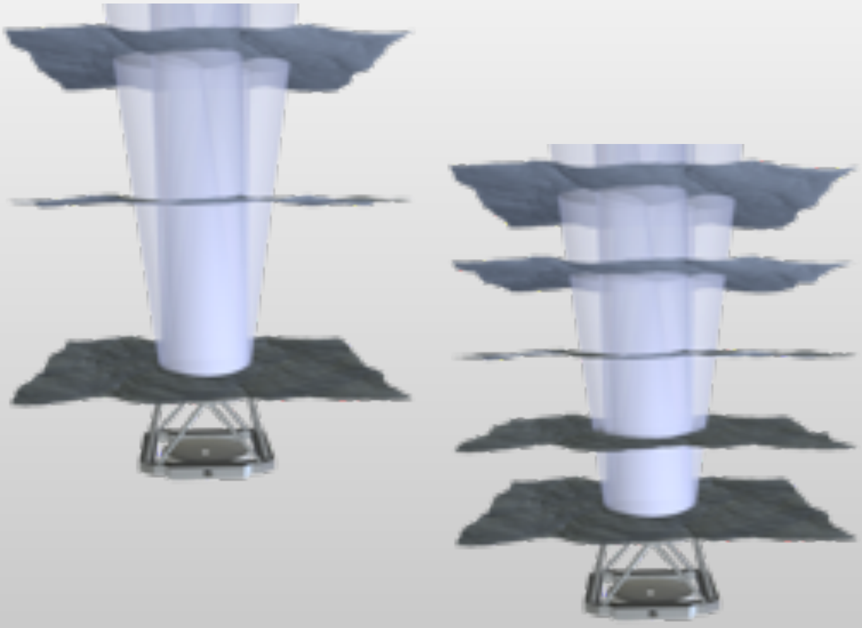
Ground VDM FoV = 5 arcmin
VDMs FoV = 10 arcmin



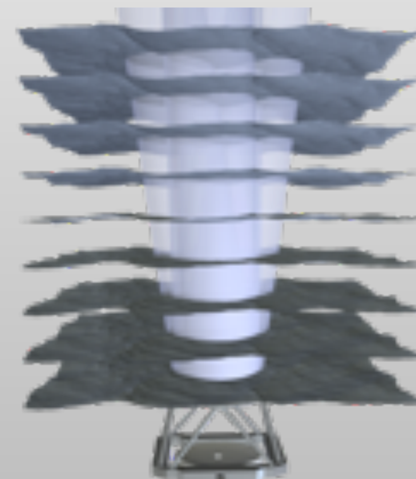
Ground VDM FoV = 5 arcmin
VDMs FoV = 10 arcmin

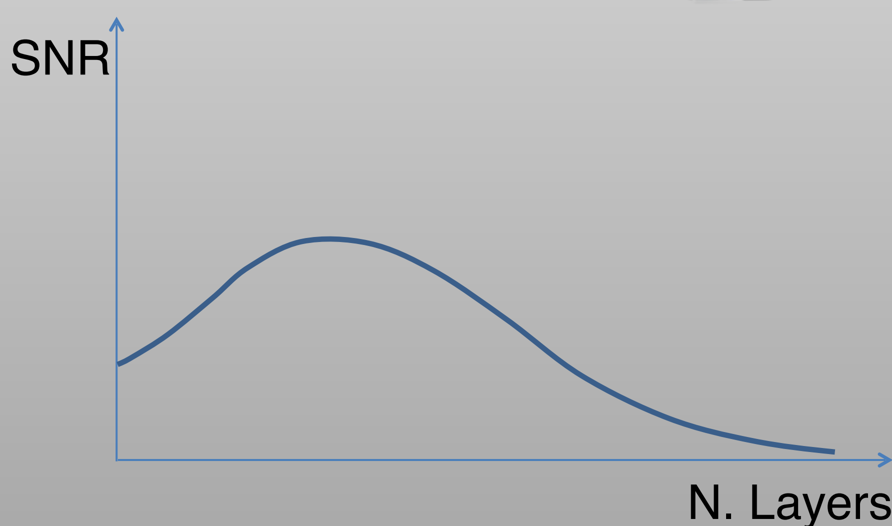






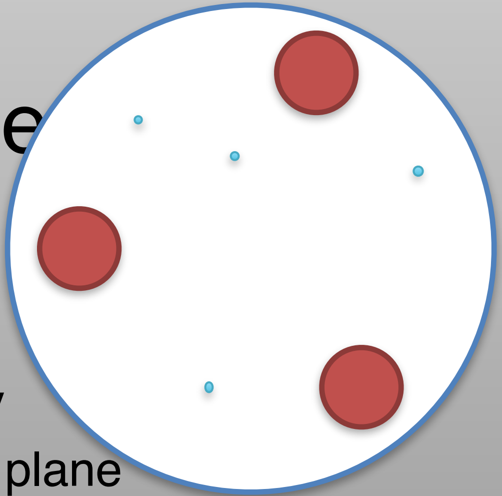
- The more the considered layers, the more precise the turbulence reconstruction
- The more the reconstructed layers, the more the noise from single measurments

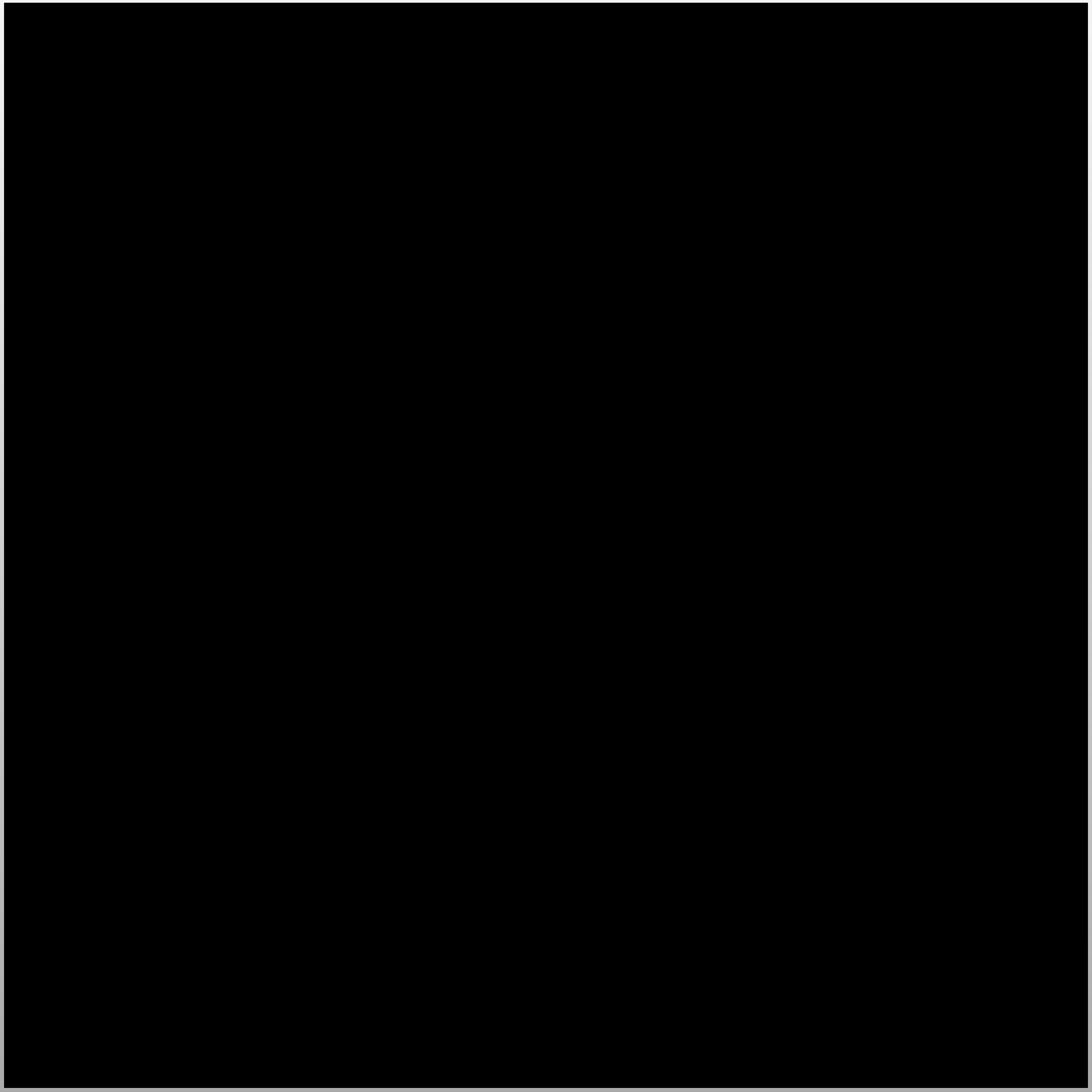


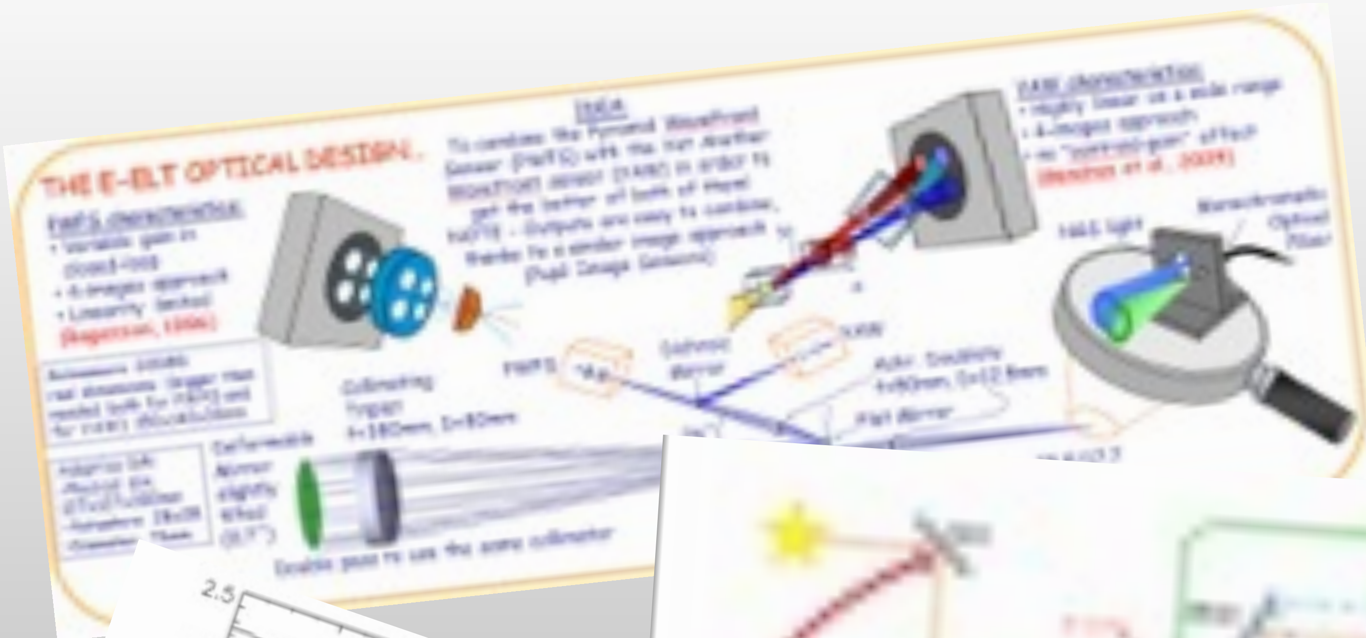


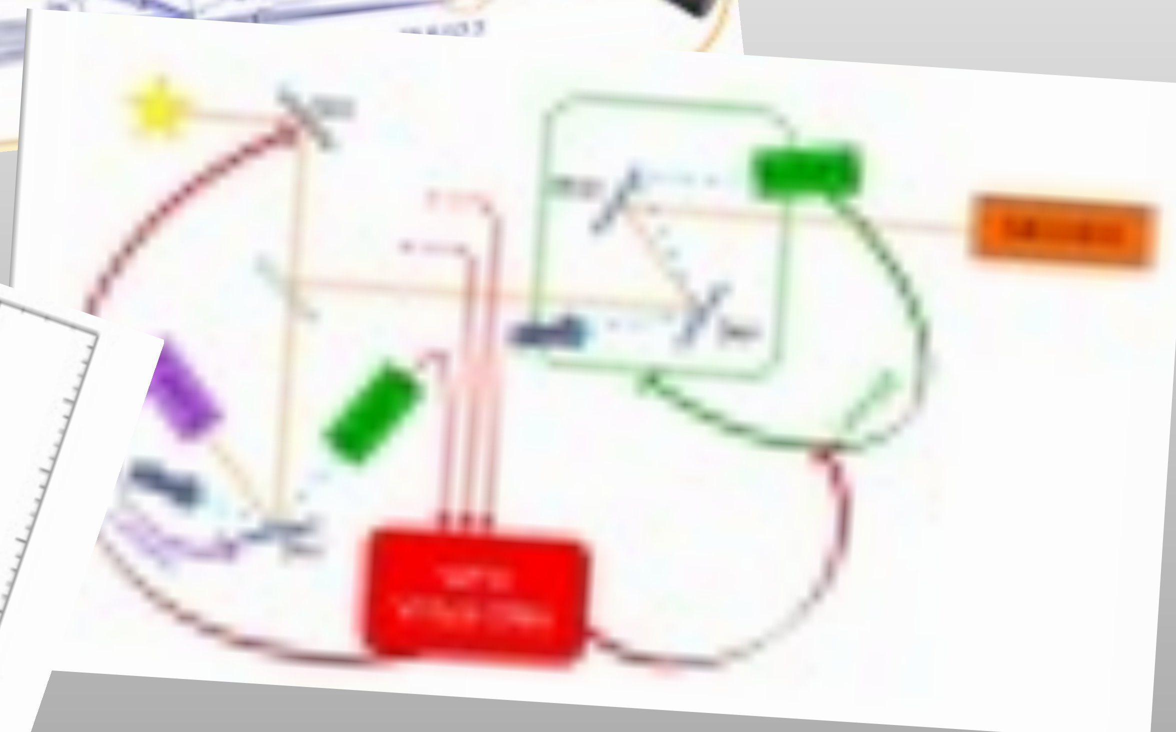
Technology is at hands...

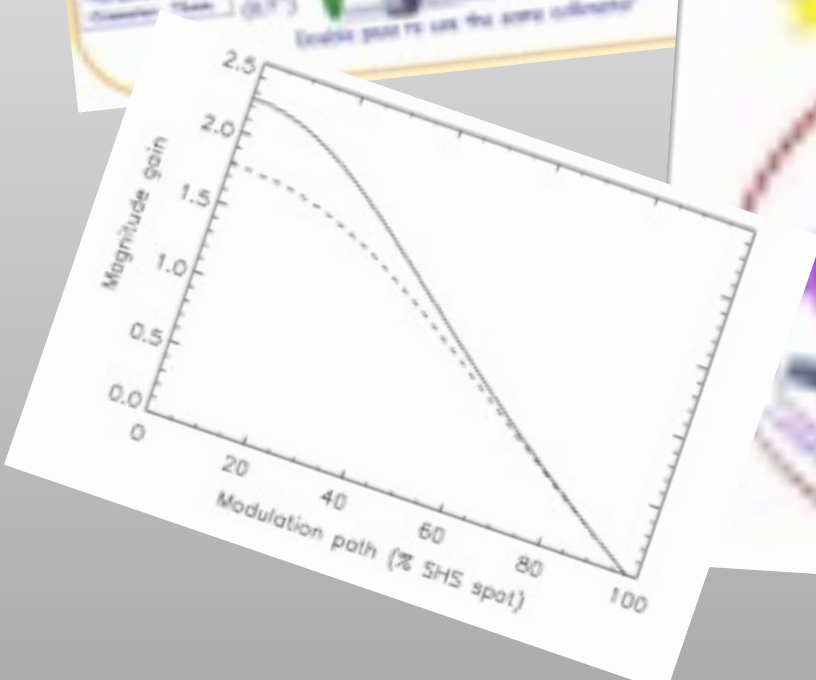
- Locally closed loop WFSs makes Pyramids working in (almost) closed loop
- These devices (we called Very Linear VL-WFSs) works around non zero
- Concpetually is exactly the same problem as MOAO
- NGSs are less invasive in the focal plane





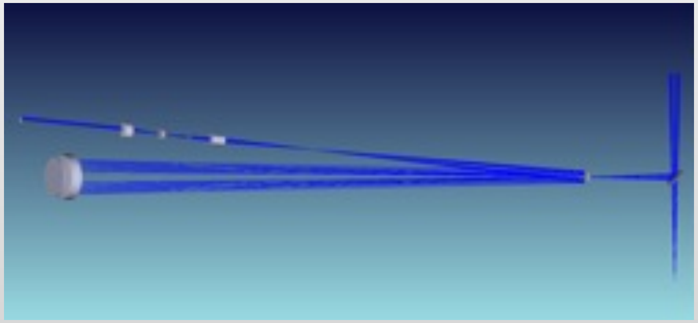

THE E-ELT OPTICAL DESIGN

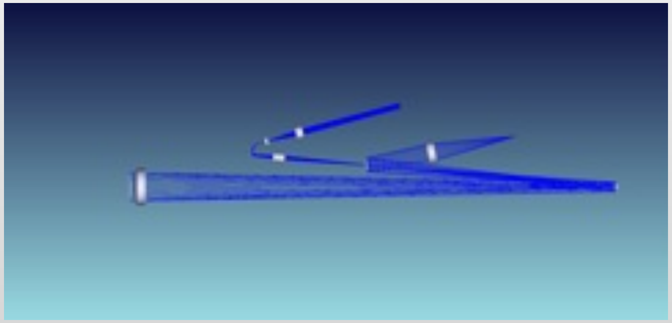


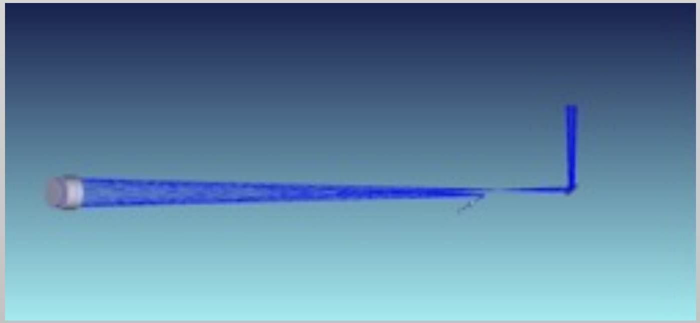

2.5
2.0
1.5
1.0
0.5
0.0
Magnitude gain
0
20
40
60
80
100
Modulation path (% SHS spot)

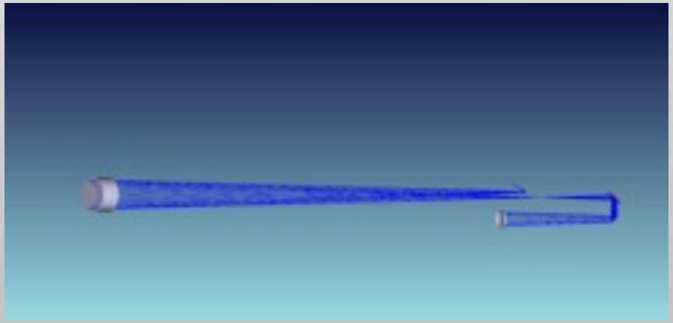
We are evaluating pro and cons of several different optical designs …

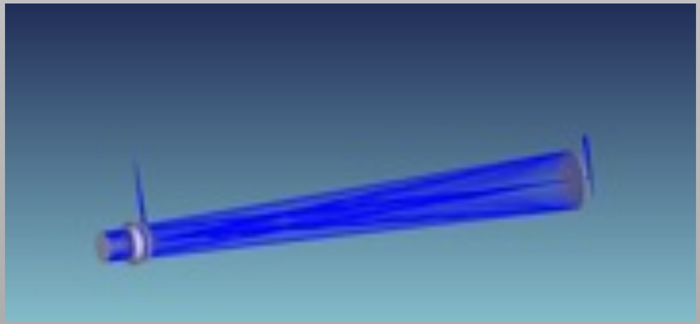
work in progress

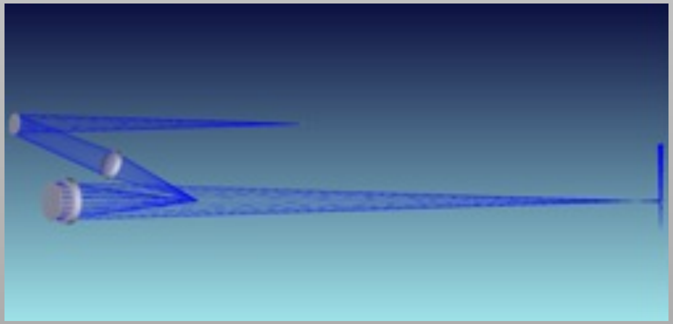


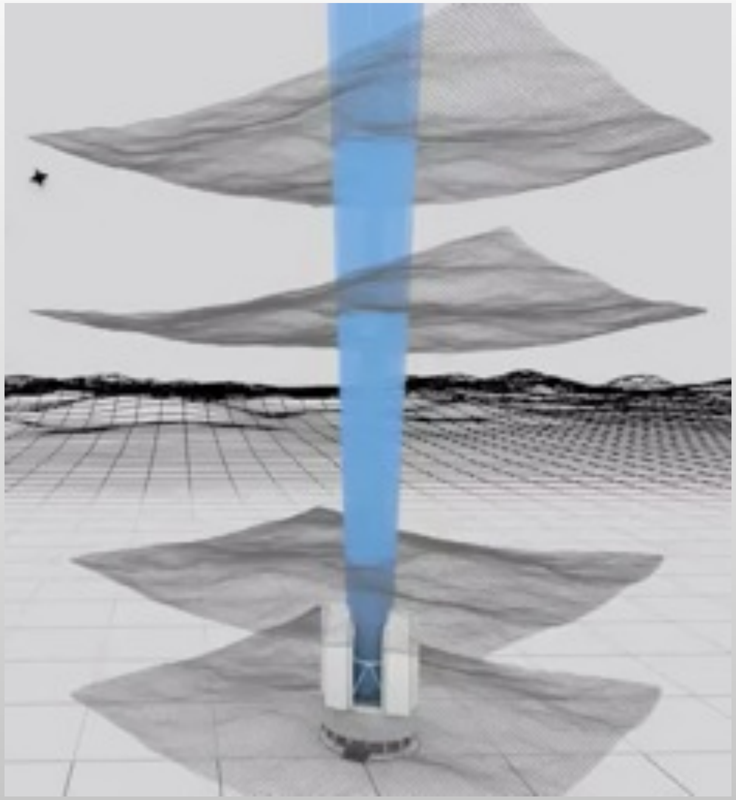




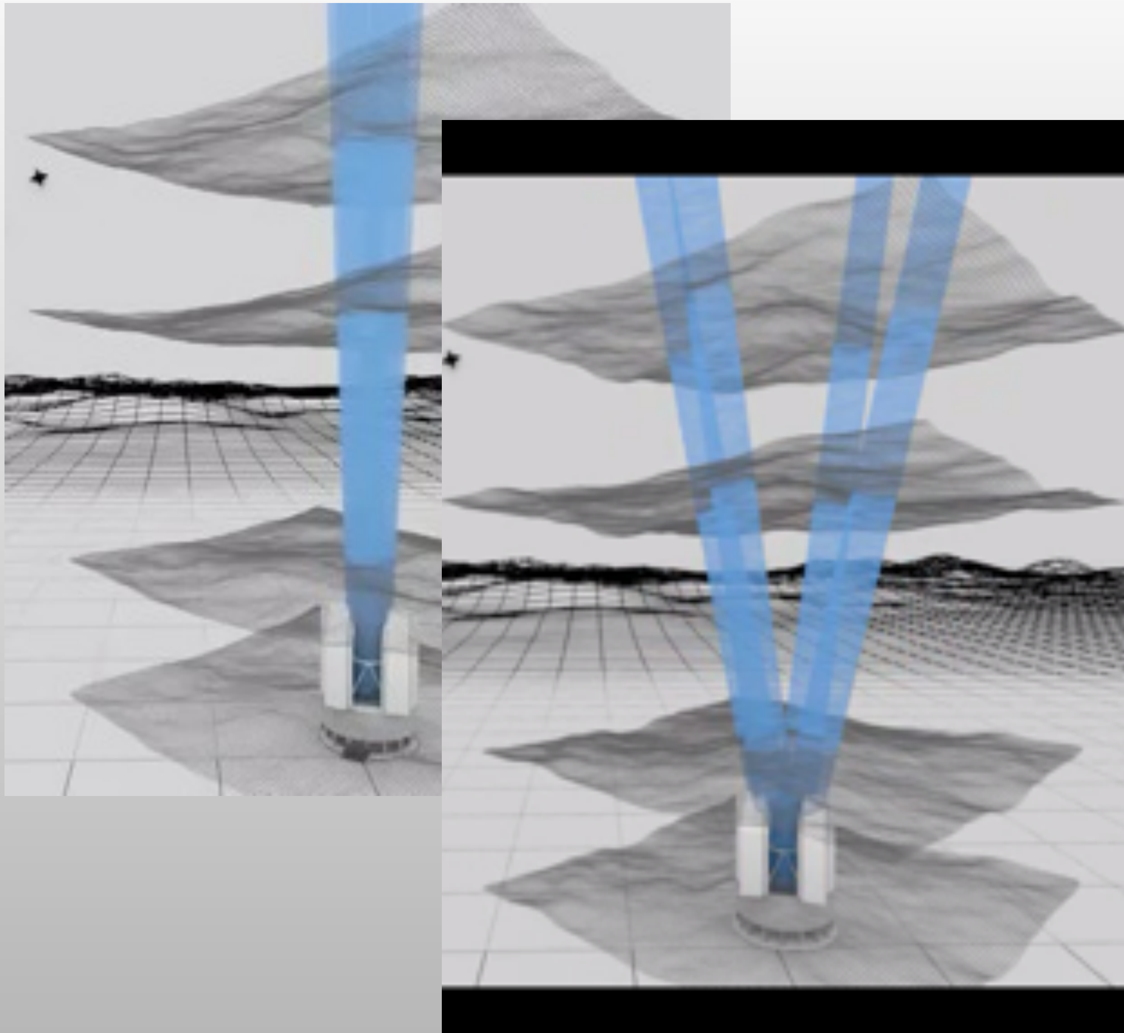




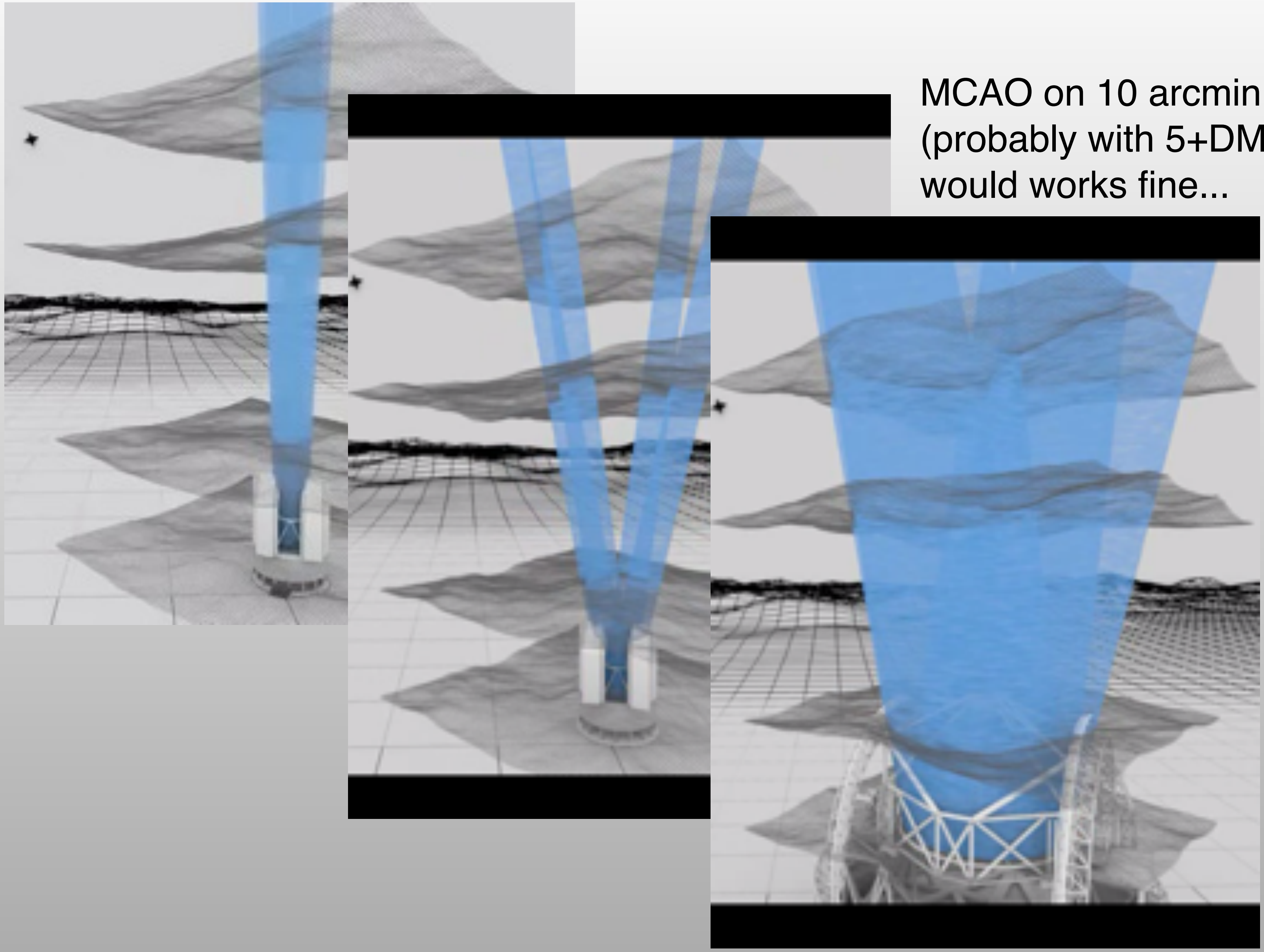




MCAO on 2 arcmin at an 8m

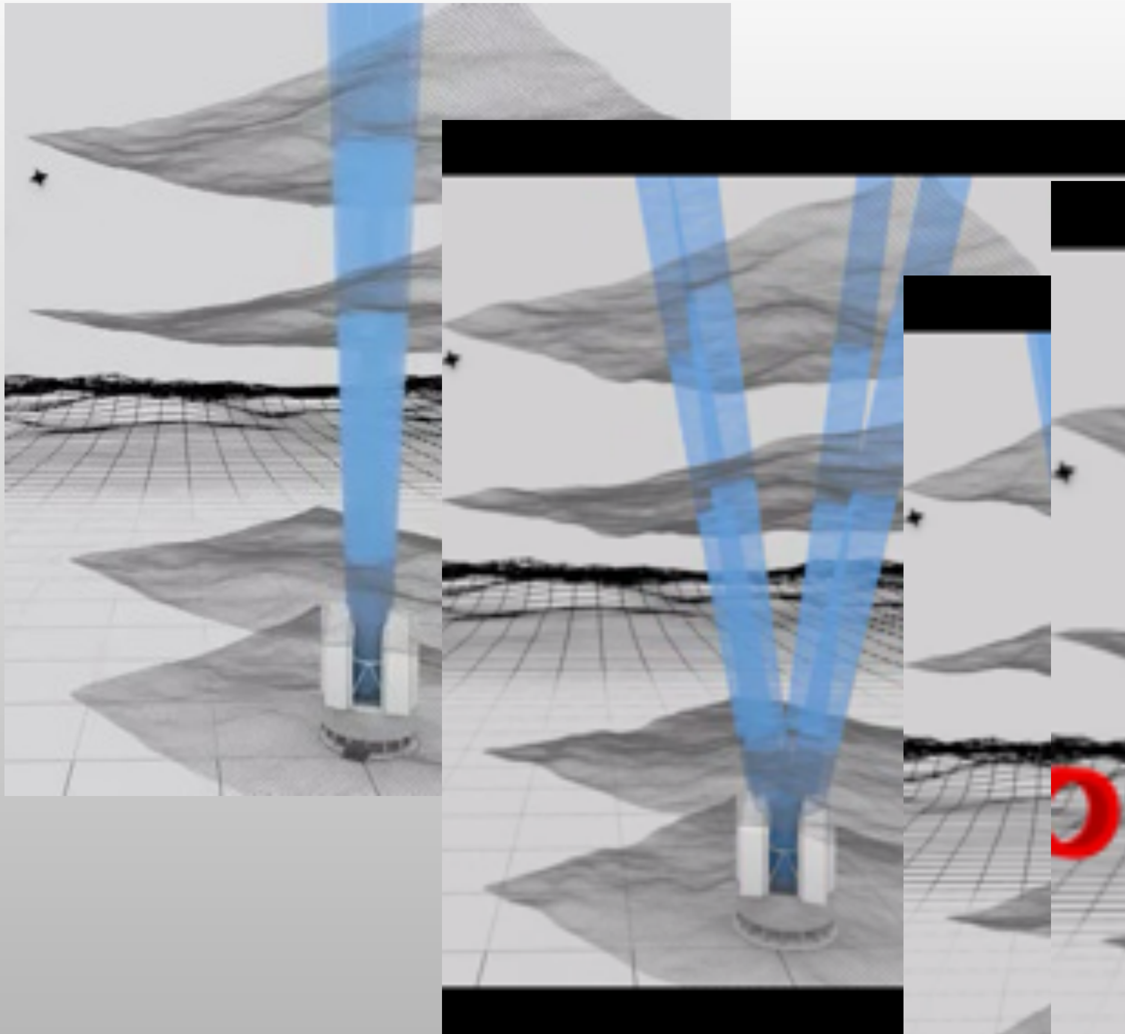


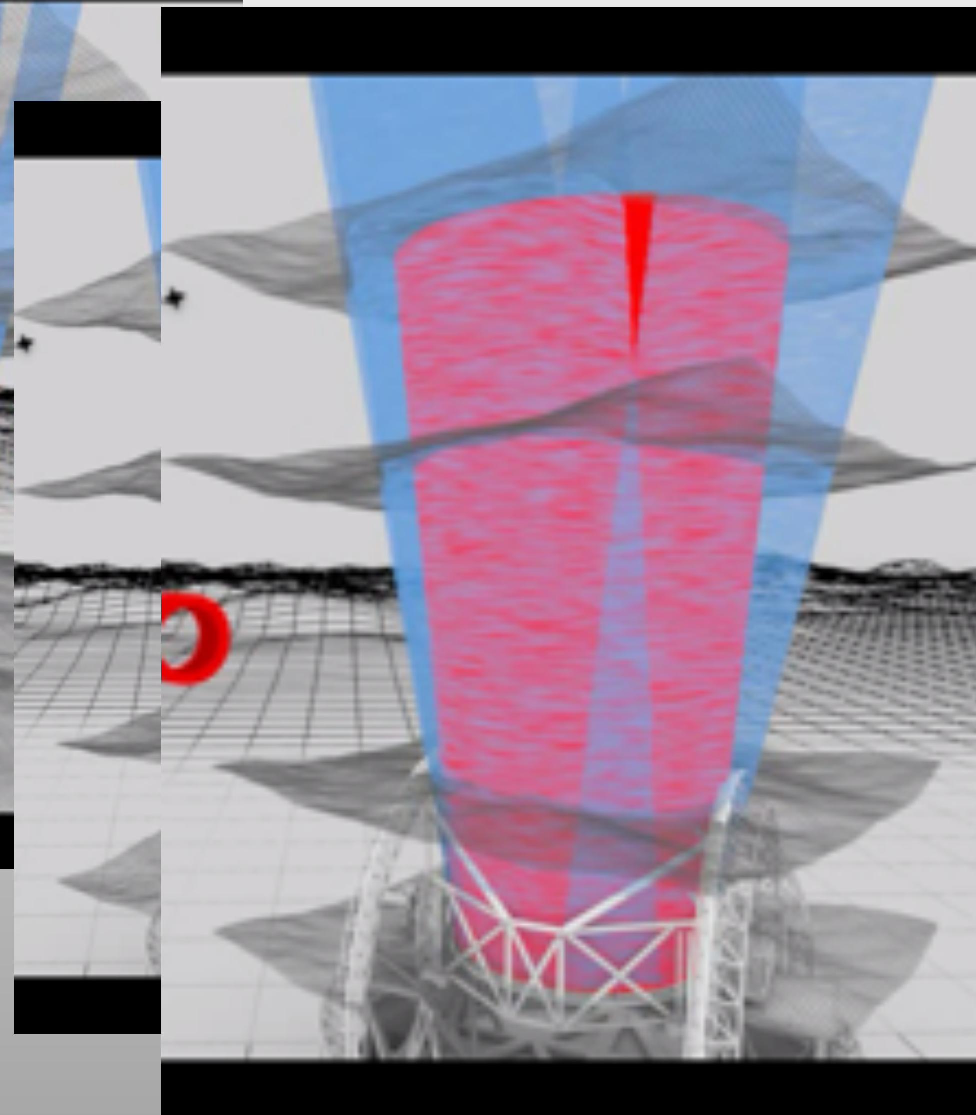
MCAO on 10 arcmin at an 8m would not give advantages other then for GLAO...



MCAO on 10 arcmin (probably with 5+DMs) would works fine...

GMCAO on 10 arcmin compensating only the central 2 arcmin...!!!





Conclusions

- GMCAO can be used as back-up plan or...
- ...as performance mitigator (cyrrus, LGS failure...) and can coexists with LGSs.
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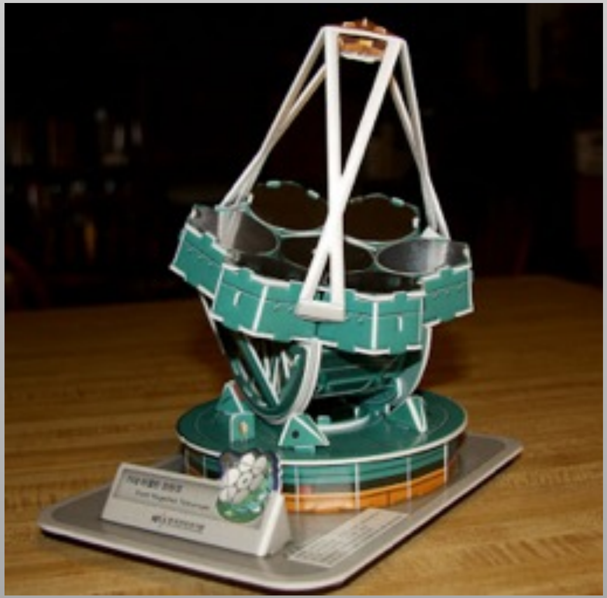

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