Concept Design of Fiber-fed Kilo-Objects Spectrograph

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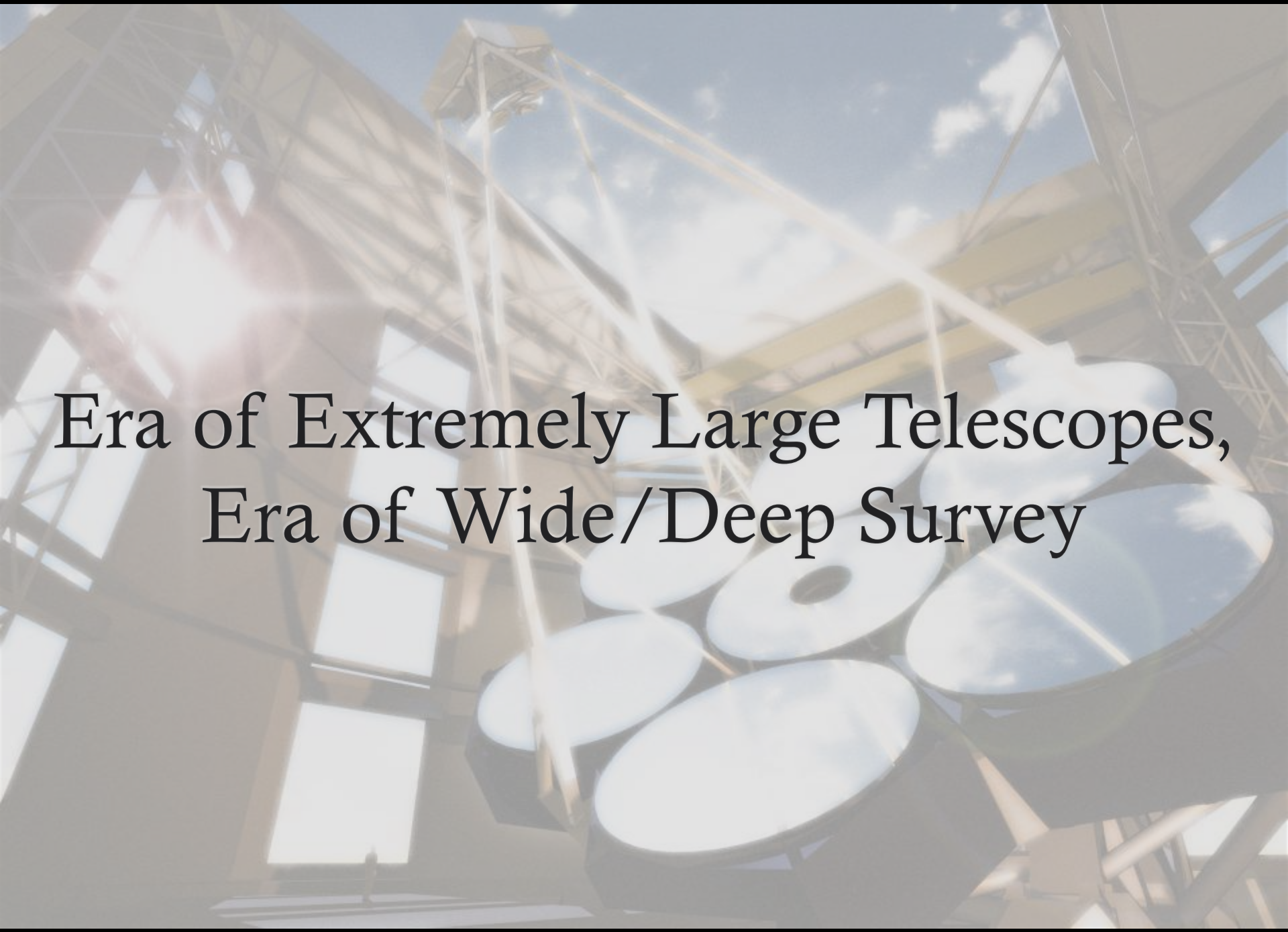
@ CosKASI Workshop, 2017/4/18

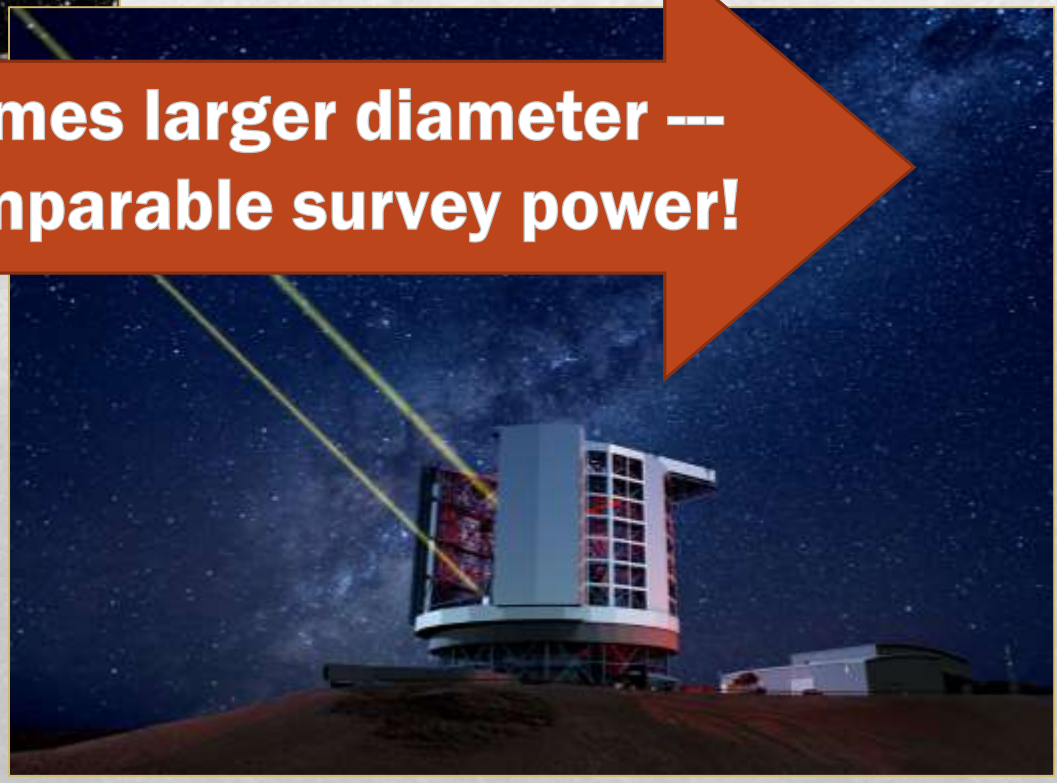


Era of Extremely Large Telescopes, Era of Wide/Deep Survey

LSST

- 8.4m mirror
- 3.5° FoV
- 2023~
- Photometric survey

3-times larger diameter ---
Comparable survey power!



GMT

- 24.5m mirror
- 20’ FoV
- 2024~
- Spectroscopic capability

HectoMAP survey with MMT (6.5m)

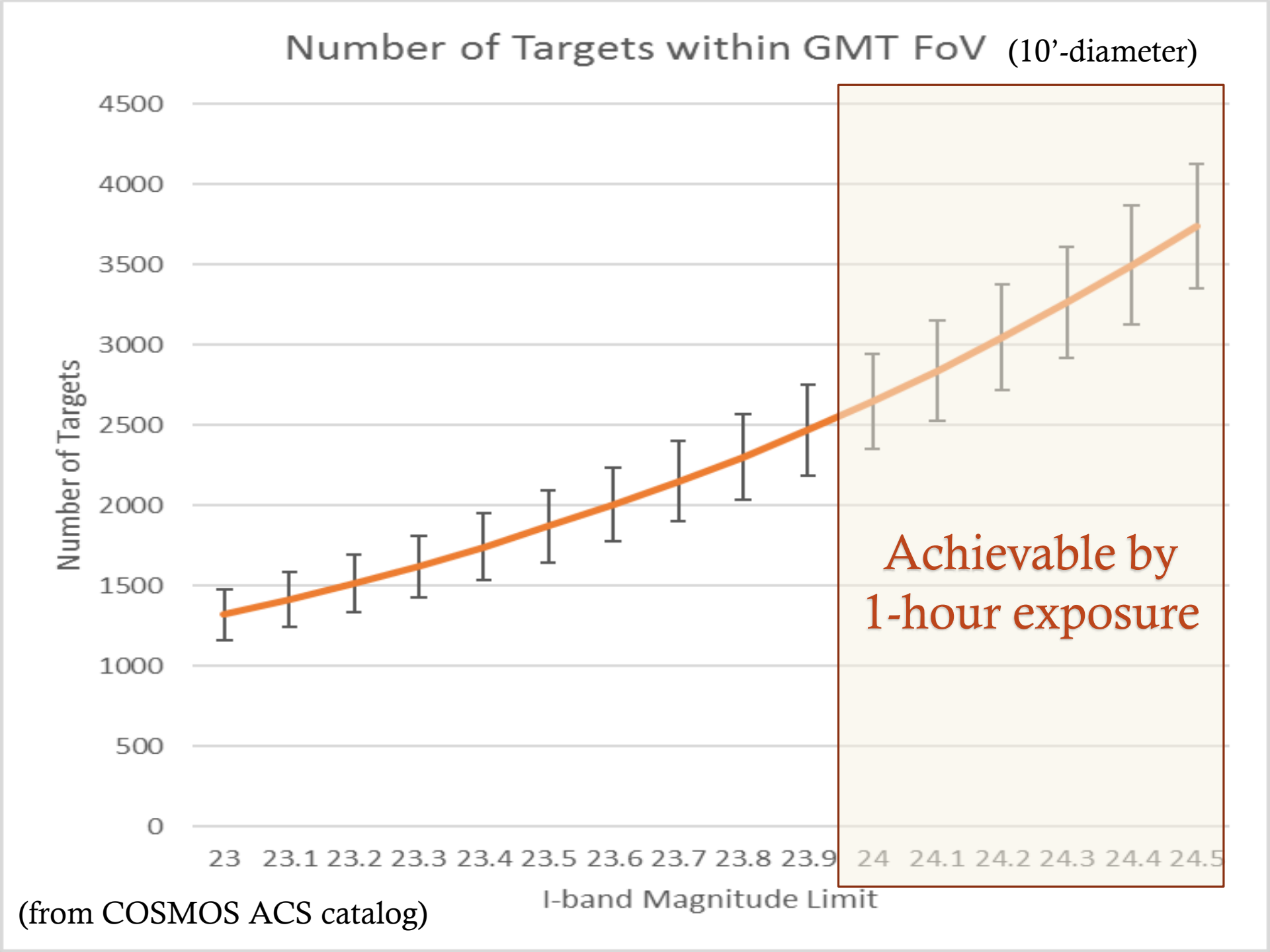
(Geller, Hwang, Sohn+)

Horizon Run Simulation

(Kim, Park+)

Horizon Run Simulation

HectoMAP-like survey with GMT? (24.5m)



(from COSMOS ACS catalog)

Q. Are Extremely Large Telescopes Really Ready for Cosmology?

Proposed GMT Instruments
Limited by budget

Natural Seeing Instruments

	Instrument	Capability	
★	GMACS	Visible Multi-object spect (R~3,000) 4.5' x 9' FoV	Natural
★	G-CLEF	Visible Echelle and precision RV (R ~ 40-100K)	Natural

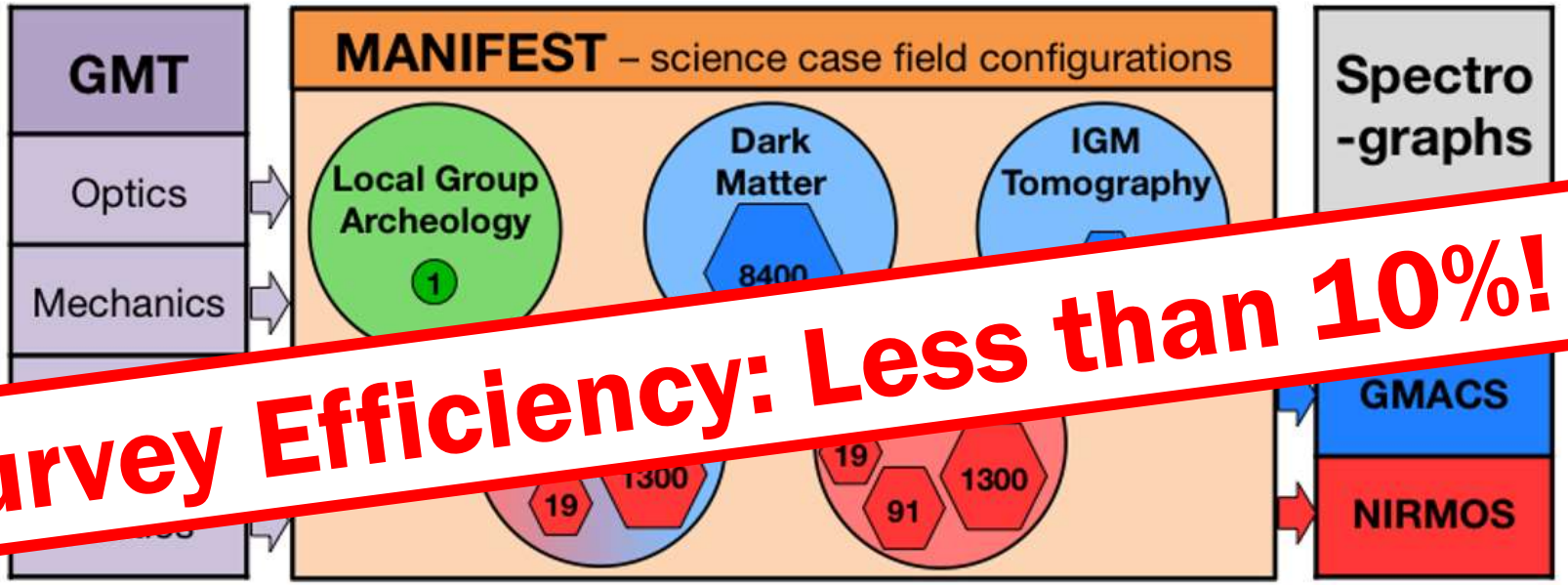
AO Instruments

	Instrument	Capability	
★	GMTNIRS	JHKLM Echelle (R=50-100K)	LTAO, NGSAO
★	GMTIFS	JHK Integral Field Spectrograph / Imager (R=5-10K)	LTAO, NGSAO

Plus a robotic fiber feed: MANIFEST (AAO)

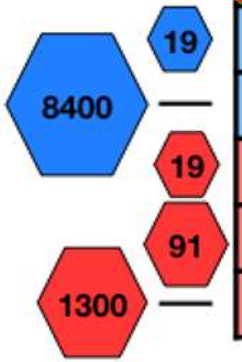
★ Included in implementation plan under development

MANIFEST Science



Survey Efficiency: Less than 10%!

Reduced by 1/4!



spectro -graph	# starbugs/IFUs in configuration	# fibres per starbug or IFU	field of view of starbug/IFU	
G-CLEF	43/4	1	0.7”	Initial available configurations
GMA[illegible]	420	19	1.0”	
GMACS	1	8400	23”	
NIRMOS	65	19	1.25”	Potential additional configurations
NIRMOS	14	91	2.75”	
NIRMOS	1	1300	9”	

How about Other ELTs?

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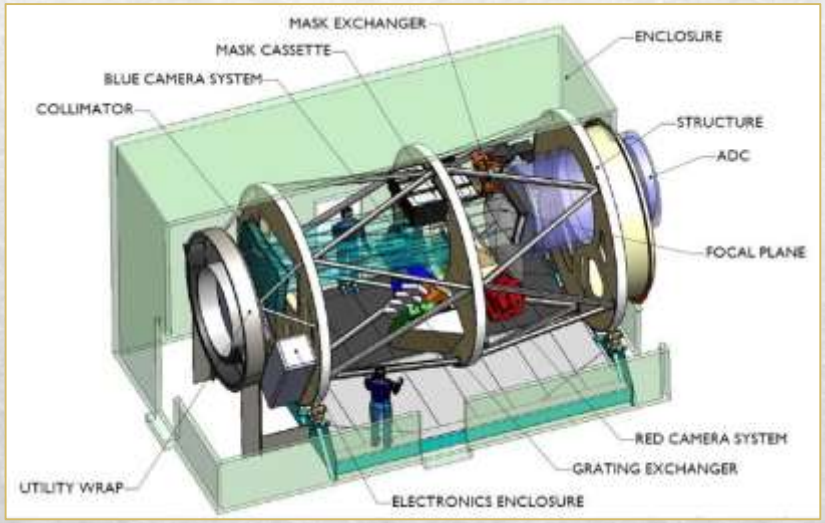


WFOS @ TMT

- FoV: 40.3 arcmin^2
- Multiplex: 200

MOSAIC @ E-ELT

- FoV: 32 arcmin^2
- Multiplex: 200

© E-ELT Consorthium

GMT: 4 countries (Korea, US, Australia, Brazil)
TMT: 5 countries (US, India, China, Japan, Canada)
E-ELT: 15 European countries

Current facility instruments
of upcoming ELTs are not suitable
for cosmological survey!

→ How about making a visiting instrument?

Objectives

- High Multiplexing ($N_{target} \sim 10^3$)
  - For maximum utilize of GMT's large mirror size
- Mid-Spectral Resolution ($R \sim 2{,}000$)
  - For more than just the redshift survey
- Low Cost & Technology
  - For making this project doable

Preliminary Concept: Key Parameters

Multiplex	952
Fiber FoV	0.4″
Wavelength Range	3,650A ~ 9,000A (2CH)
Spectral Resolution	1,240 ~ 2,394
Magnitude Limit	$I_{AB} = 24.5$ mag (1 hour exp.; S/N=5)
Total Cost	< 10M USD

Comparison to GMACS-1ARM

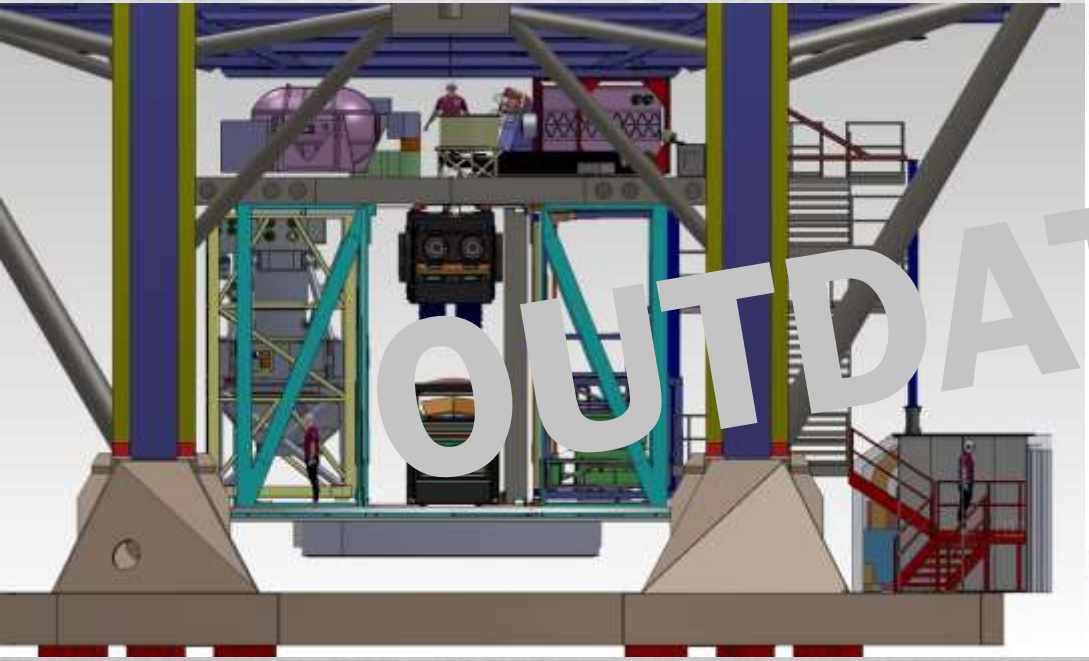
	GMACS	GMACS +MANIFEST	Ours
Slit Width / Fiber FoV	0.7″	0.25″	0.4″
Wavelength Range (A)	[3700, 8800]	[3700, 8800]	[3650, 9000]
Spectral Resolution	1,300 ~ 6,000	3,800 ~ 18,000	1,240 ~ 2,394
Multiplex	≤ 100	105 (19 fibers/IFU)	952

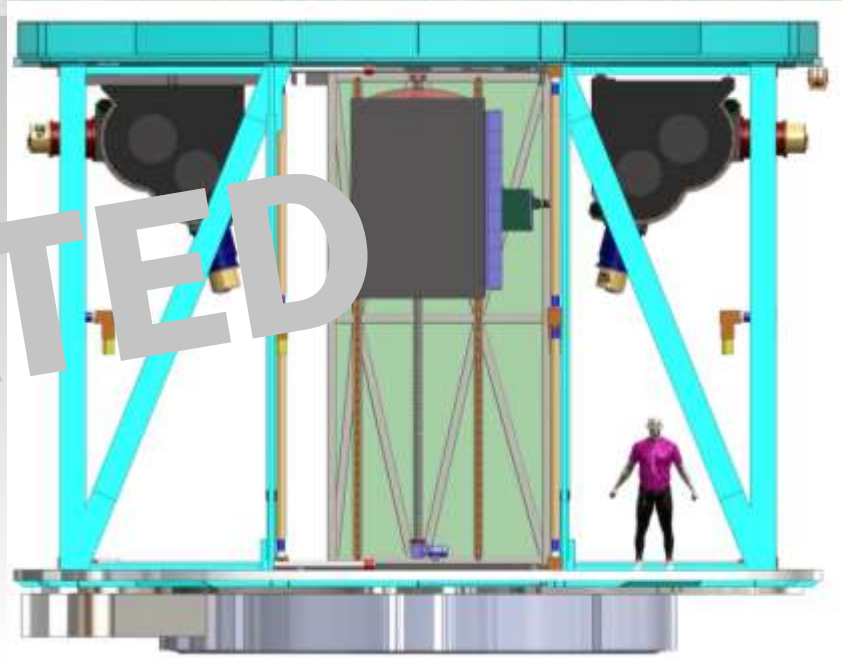
Restriction on GMT

- Large plate scale (1″/mm)
  - Fiber diameter is increased
  - Spectral resolution and number of fibers per spectrograph are reduced @ the same CCD size
  - >~ 10 spectrographs are required
    → Needs enough volume!

Restriction on GMT

- Not enough room for instrument below the GMT rotator
  - Need additional room to store spectrographs
  - >~ 20m fiber cable is required…?





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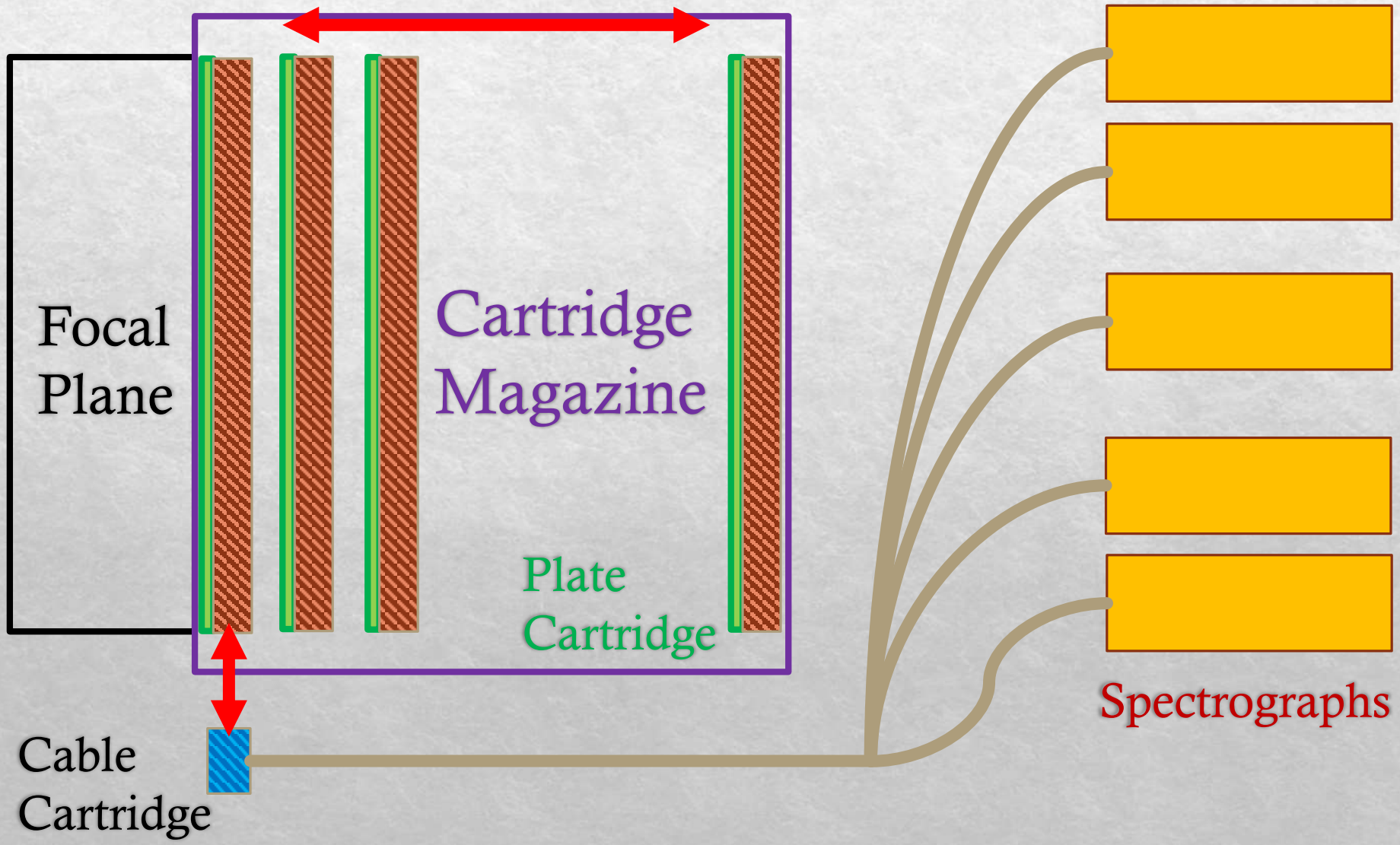
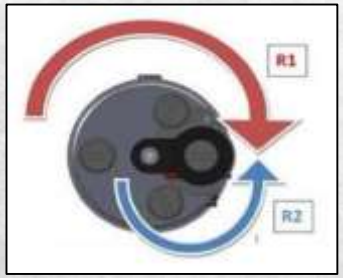
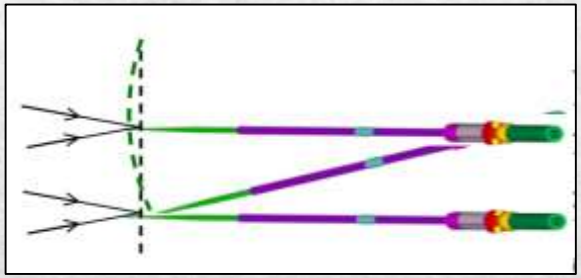
Overall Structure

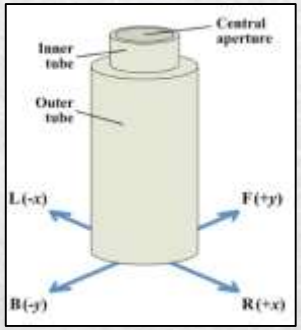


Automatic Target Allocation?

- Robotic Fiber Positioner



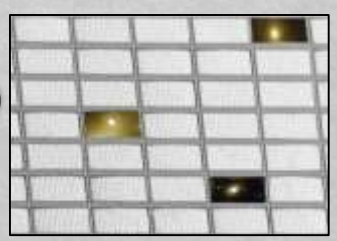


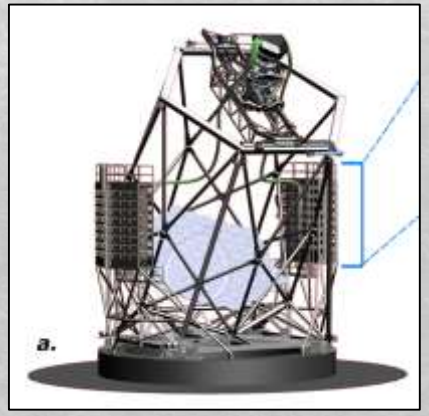


  - LAMOST, DESI, Subaru…
  - Heavy loads at the focal plane
  - Too expensive for visiting instrument?

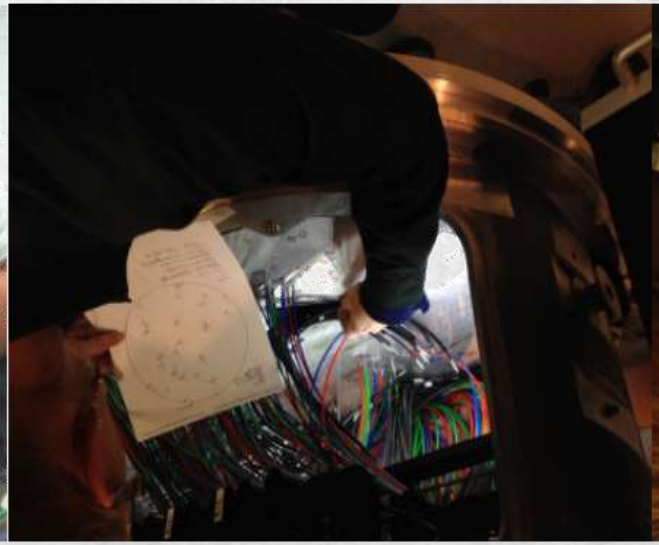
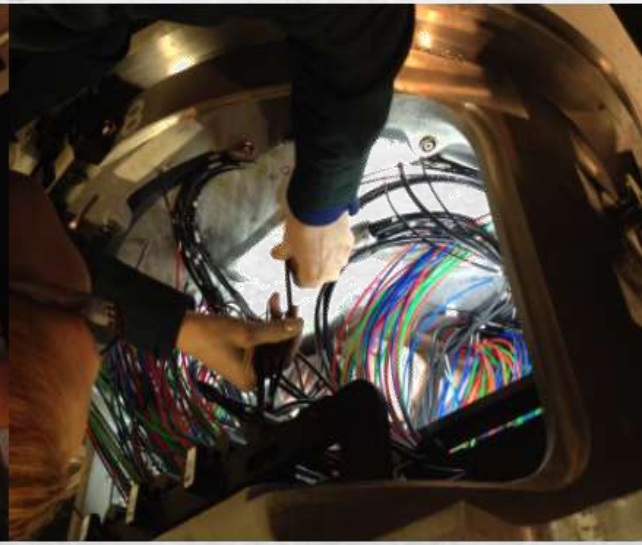
- Rasterized Fiber Array

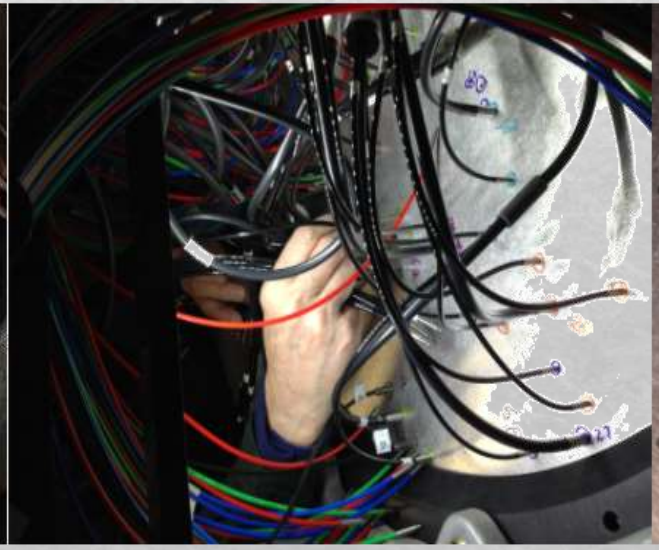
  - NIRSpec (JWST), VIRUS (HETDEX)
  - Need tons of spectrograph or complicated optical switch



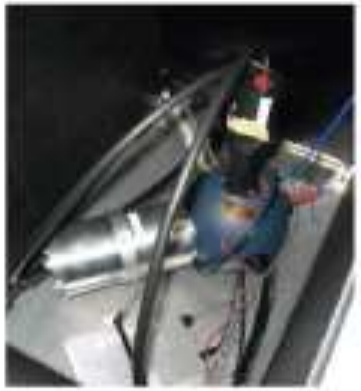


Manual Fiber Plug-in




Connection to Distant Spectrographs - Gang Connector

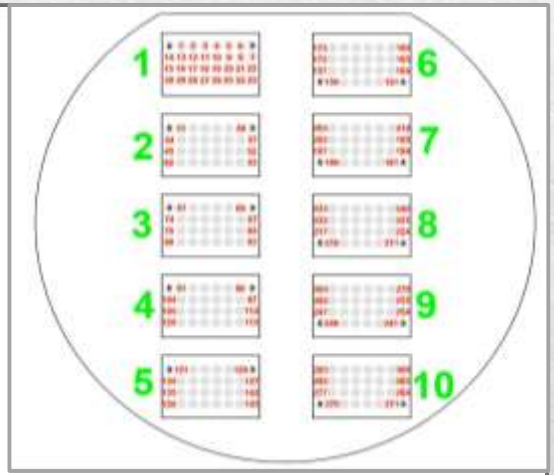


Integrating sphere

- ThAr HCL
- UNe HCL
- Quartz flat
- Shutter on output port
- Choice of 'dense' or 'sparse' packed fibers to instrument

Calibration

Telescope



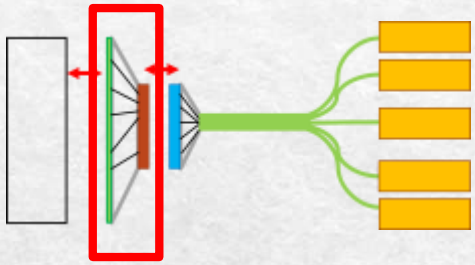
Simultaneously connect (10) US Conec custom MTP 30-fiber connectors

'Gang Connecctor'

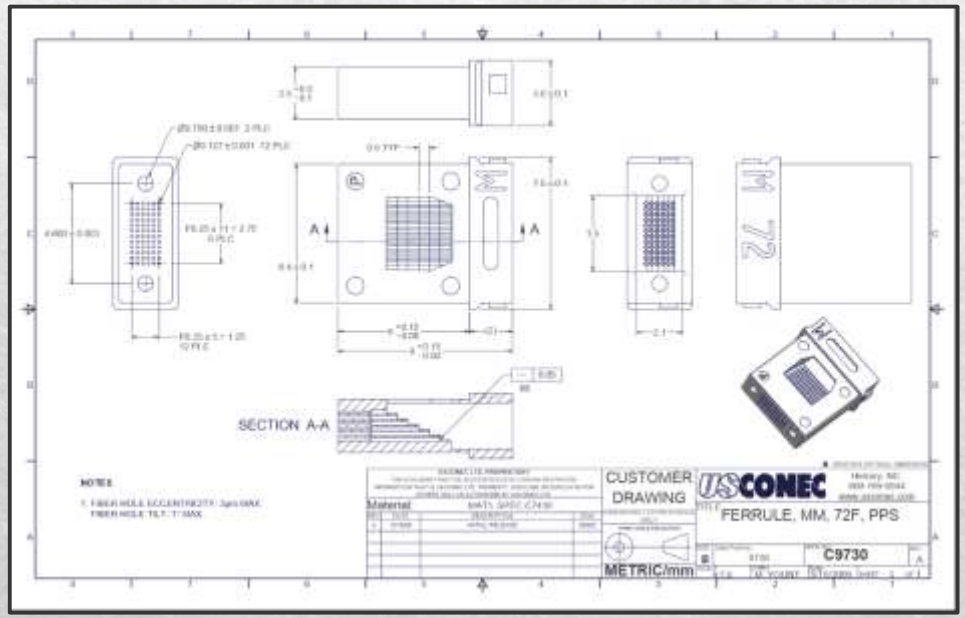
40-m

10 sets of 30 fibers from instrument

Instrument Slit Head

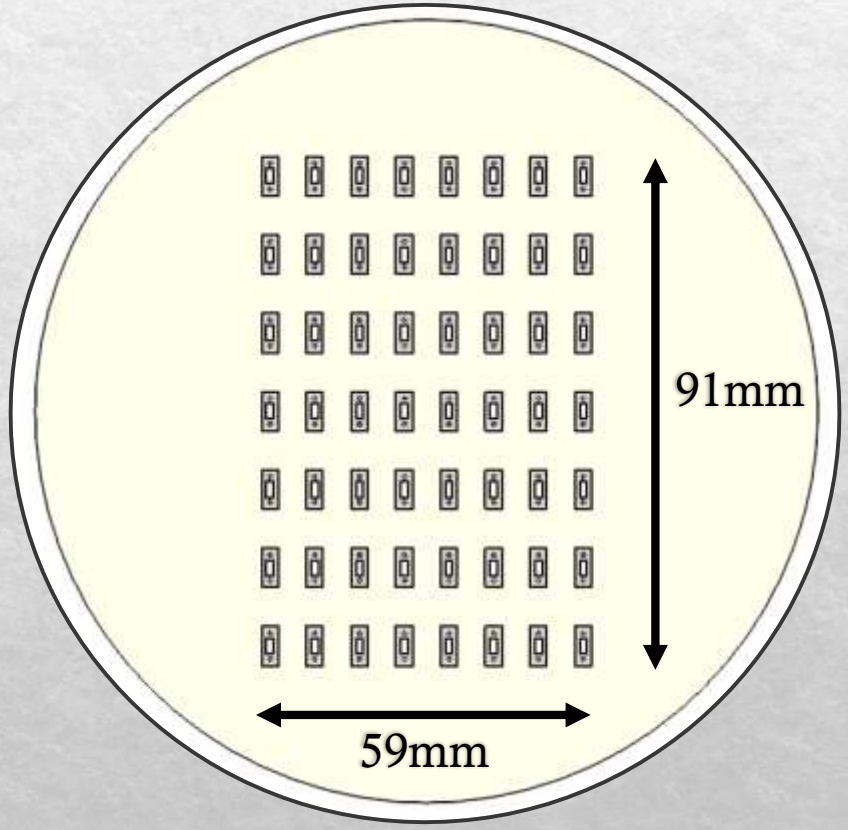


Gang Connector



MTP ferrule (US Conec Ltd.)

- Connect 72 fibers at once
- 0.2dB typical insertion loss
- $31.2ea



Configuration example
with 56 ferrules (4032 fibers)

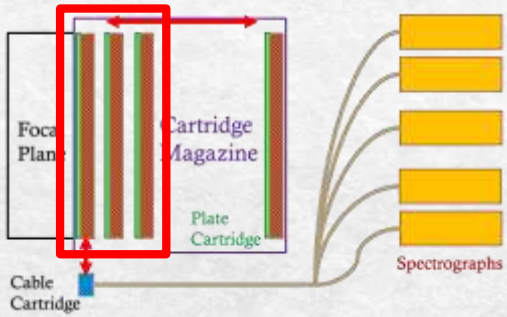


Plate Cartridge

Gang Connector

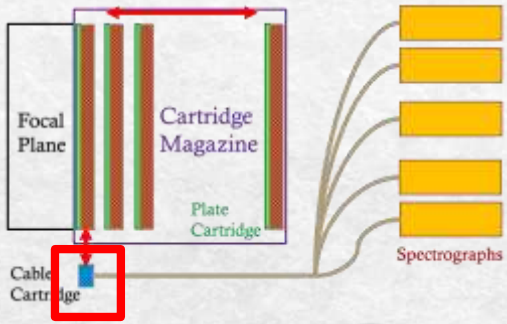
Focal Plate

600mm (10′)

Case

FRONT

BACK



Cable Cartridge

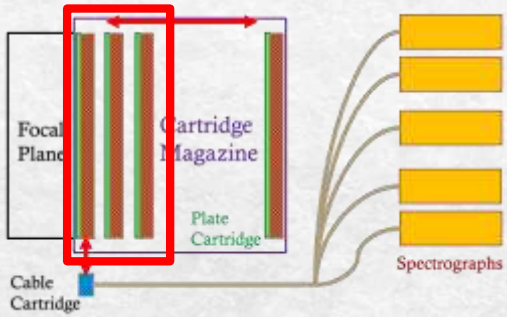
Gang Connector

Fiber Cable

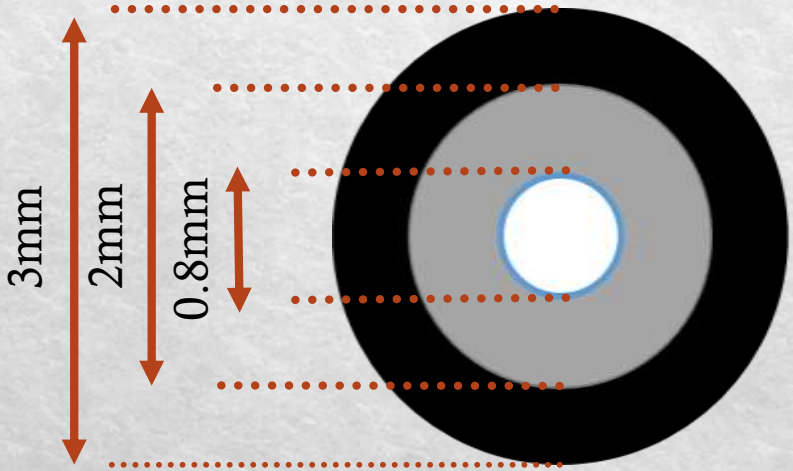
Plate Cartridge

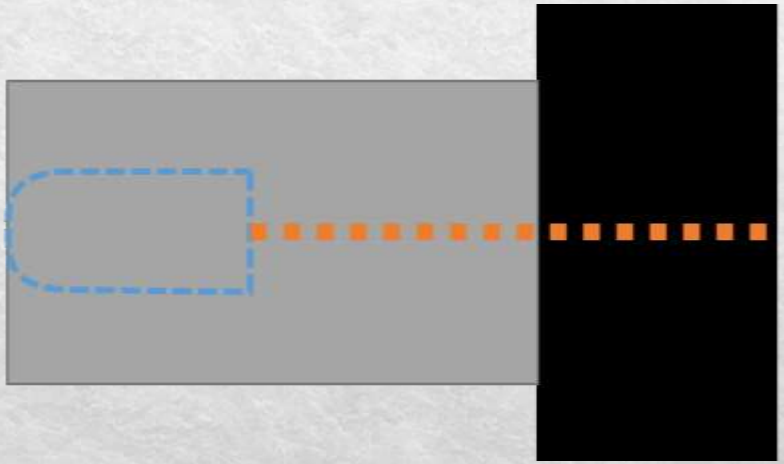
Case

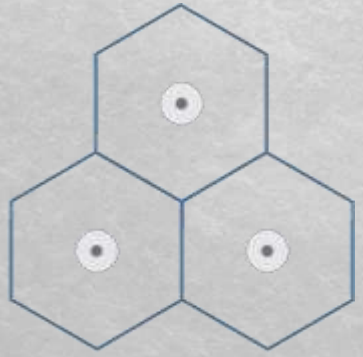
Screw locking?



Optical Fiber @ Plate Cartridge



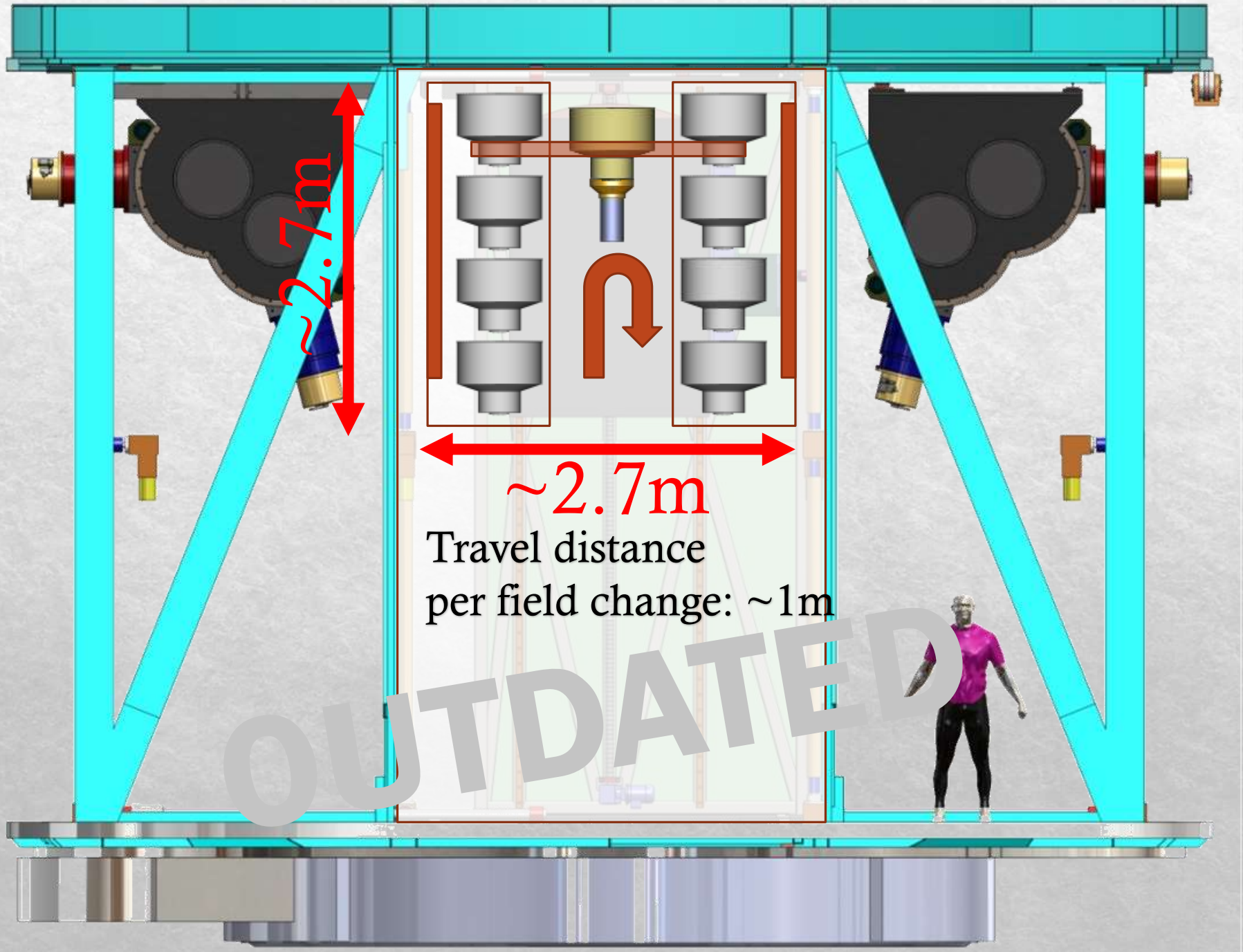




Microlens @ focal plate
- F/8.2 → F/1.26

(IFU option may be available)

MTP ferrule
@ gang connector


~2.7m
~2.7m
Travel distance
per field change: ~1m
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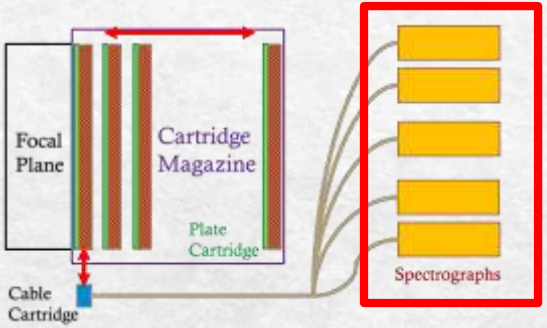

Spectrographs

	Blue channel	Red channel
Camera F/#	F/1.5	
CCD	E2V CCD44-82 2048 x 4096 pixels 15 μm/pix	
Wavelength (A)	3,650 ~ 6,000	6000 ~ 9,000
Spectral Resolution	1,240 ~ 2,038	1,596 ~ 2,394
# Fibers per Spectrograph	204	
# Spectrographs	14	

(additional grating may be available to increase spectral resolution ~2x)

Summary

- Upcoming ELTs naturally lead us to wide and deep cosmological survey
- However, any facility instrument of ELTs are not suitable for such cosmological survey
- We propose 10^3-multiplex, mid-resolution, optical-band, low-cost spectrograph for GMT