Development of an integral field unit for a NIR-MOS camera: SWIMS

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Collaborator

- ✓ **SWIMS team in TAO project**
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  - ▪Ken Tateuchi
  - ▪Soya Nishijima

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  - ▪Shinobu Ozaki

- ✓ **Kyoto-Sangyo Univ.**
  - ▪Tomohiro yoshikawa

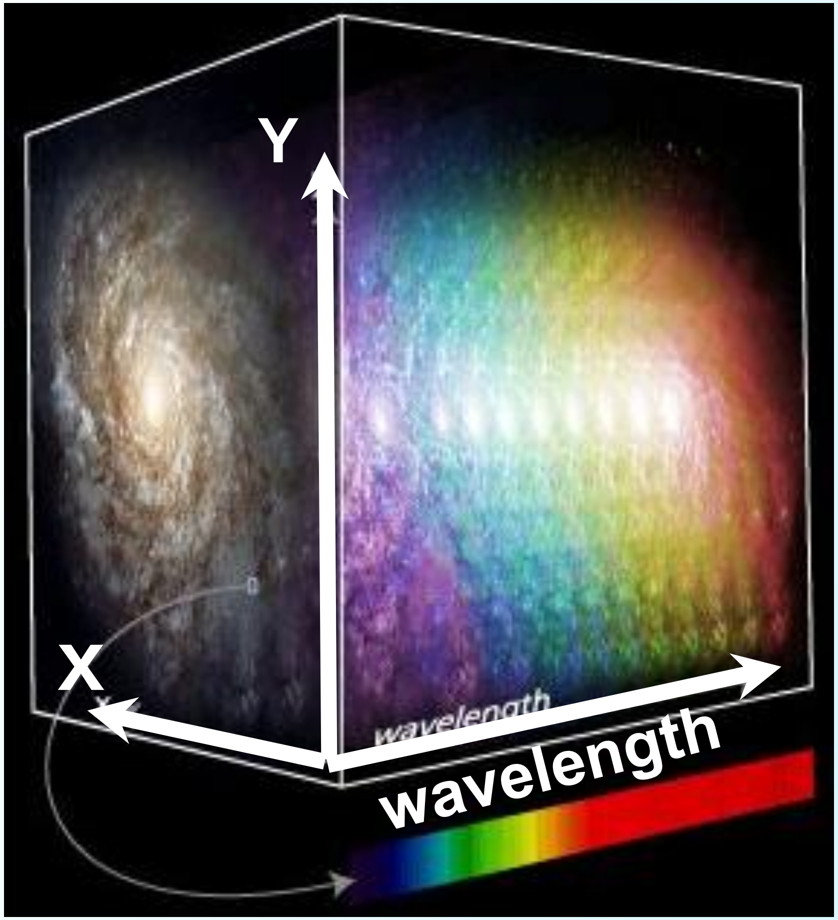
*Advanced Technology Center

Outline

- ✓ **Introduction**
  - – **What is an IFS?**
- ✓ **Development of SWIMS-IFU**
  - – **concept**
  - – **mechanical/optical design**
- ✓ **Towards the future**
  - – **next generation instruments with IFU**
- ✓ **Summary**

What is an integral field spectrograph?

✓IFS enables to obtain spectra over a 2D field- of- view



"Data Cube"

2D spacial info. = (RA, DEC)

+

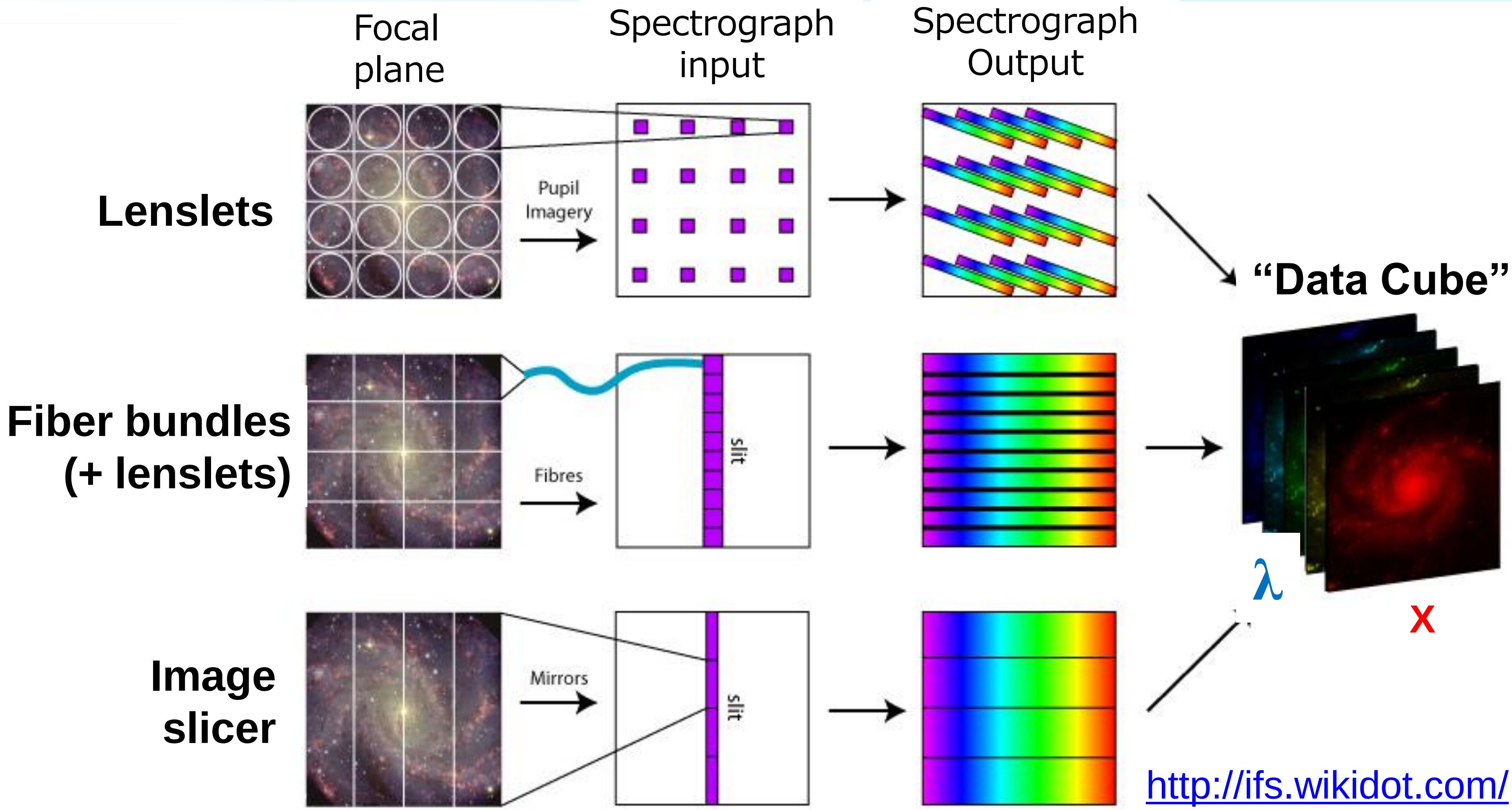
1D spectral info. = λ or v

http://sciencewise.anu.edu.au/

Introduction (2)

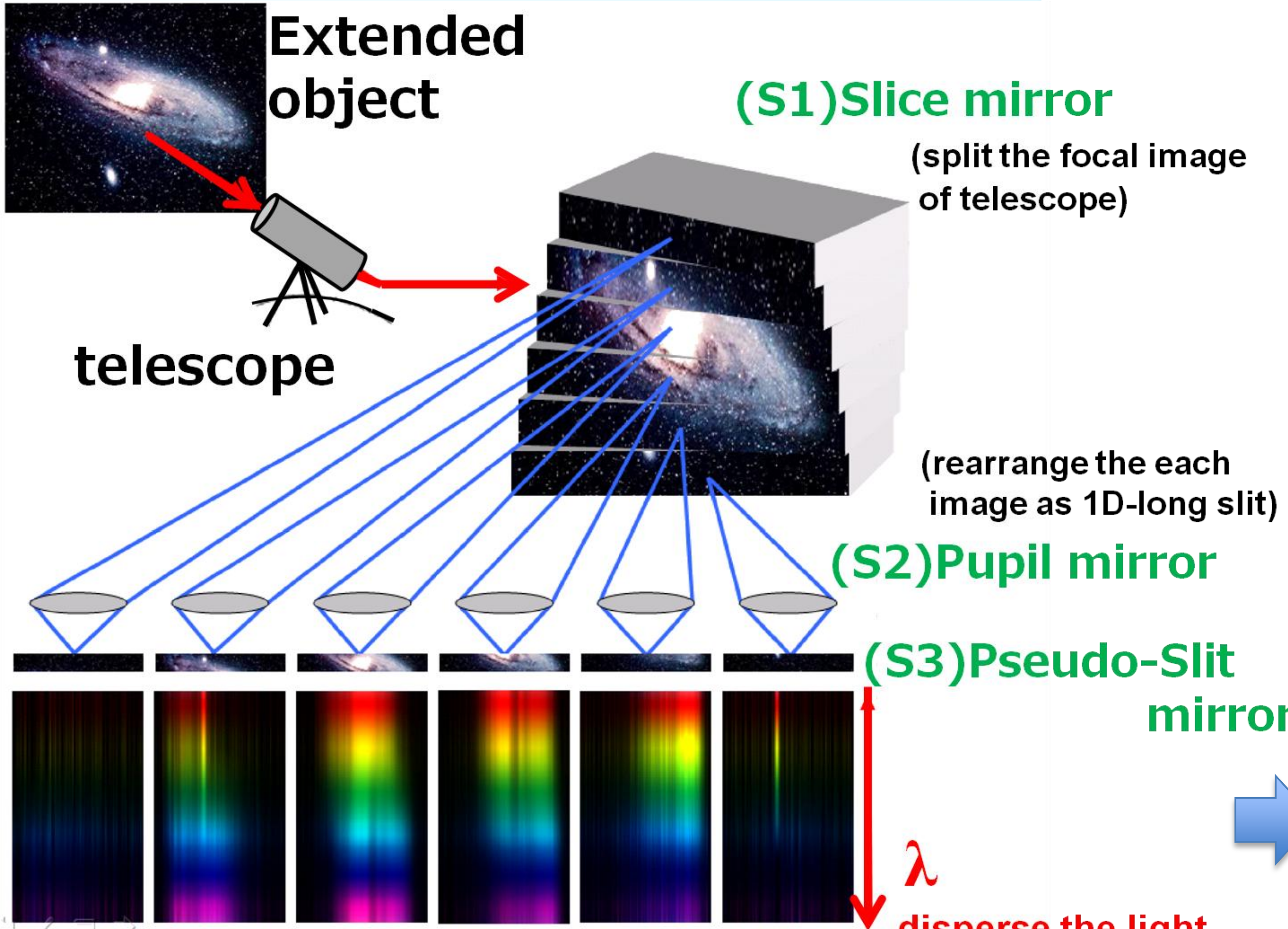
Main IFS techniques

The 3 types of Integral Field Unit (= IFU)

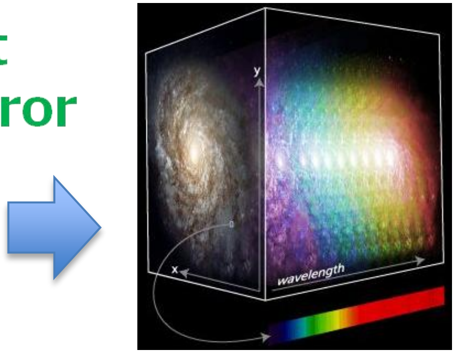


http://ifs.wikidot.com/

The concept of Advanced image slicer



Vives & Prieto ,SPIE (2006)



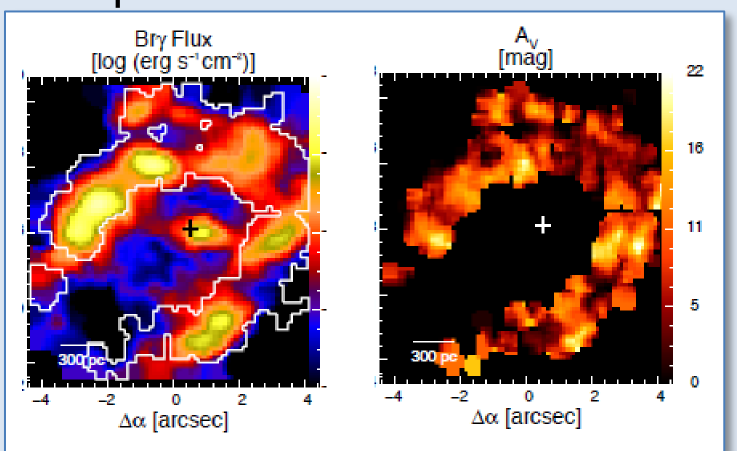
near-IR Integral Field Spectroscopy

✓ The need for near-IR spectroscopy

(1) Less affected by dust obscuration (e.g. dusty starbursts)

(2) At z>1most of the key spectral features are redshifted in the near-IR

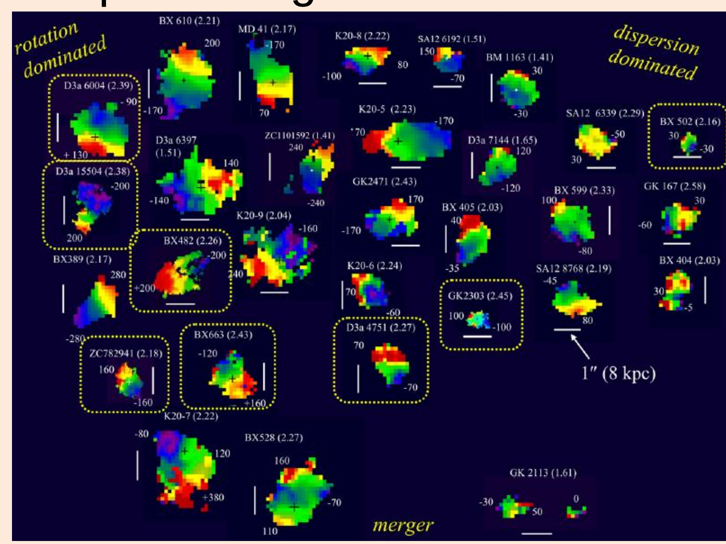
▪ Samples in the local universe



LIRG (z=0.01) with high spatial resolution (~0.3kpc)

J. Piqueras Lopez et al. (2013)

▪ Samples at high redshift



Forster Schreiber et al. (2009)

Introduction (5)

near-IR Integral Field Unit

✓ current near-IR IFUs of the 8-10m class telescopes

telescope	VLT (8.1m)	Keck (10m)	Gemini (8.1m)
NIR-IFU	SINFONI	OSIRIS	NIFS
IFU-type	slicer	lenslets	slicer
λ [um]	1.1-2.45	1.0-2.4	0.94-2.4
R=λ/Δλ	2000-4000	~3800	5000-6000
Spatial element size	0.0125" x 0.025" 0.050" x 0.10" 0.125" x 0.250"	0.020" , 0.035" 0.050" , 0.100"	0.104"x0.04"
Field of view	0.8"×0.8" 3" ×3" 8" ×8"	0.32"×1.28" - 3.2"×6.4"	3"×3"

Conceptual design of SWIMS-IFU

✓ SWIMS-IFU

- advanced image slicer IFU
- compact & lightweight
  → enable to install into MOS camera as a "mask-slit"

parameters of SWIMS-IFU

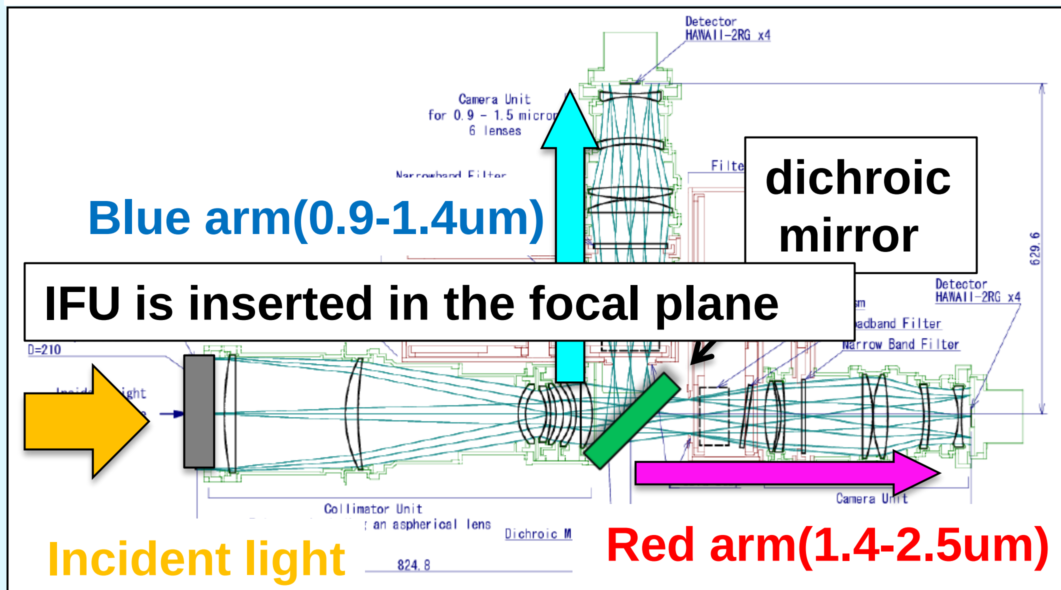
λ [um]	FoV	Slice width	No. of slice
0.9 – 2.5	14" × 10"	0.4"	26

NIR-MOS camera: SWIMS

✓ SWIMS = **S**imultaneous–color
Wide-field
Infrared
Multi-object
Spectrograph

SWIMS is capable of

- **wide-field** imaging(6.6’ x 3.3’) & spectroscopy(2.8’ x 3.3’)
- covering the entire NIR spectra (0.9- 2.5 um) in a single exposure



M. Konishi et al. Proc. SPIE, 8450-144 (2012)

Development of SWIMS-IFU

✓ What are problems ??

(1) IFU is mounted inside the SWIMS slit slide mechanism

→ **"compact & lightweight" design is required !**

But such a optical solution can be really exist…?

(2) IFU is placed under a cryogenic environment

→ **Metal processing mirrors are desirable !**

How can we achieve required surface accuracy…?

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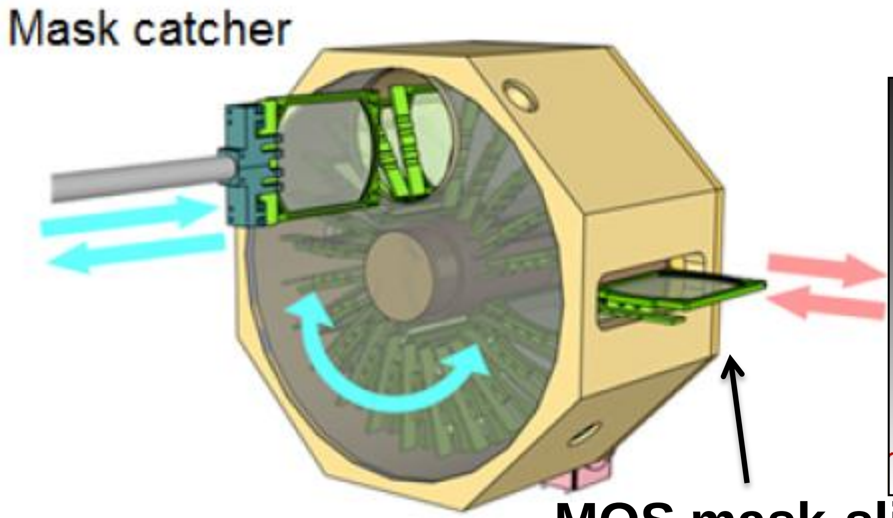
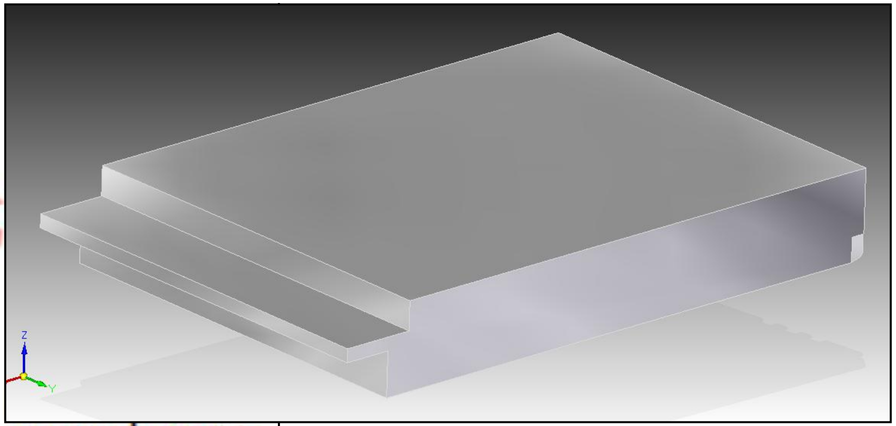
Mechanical design

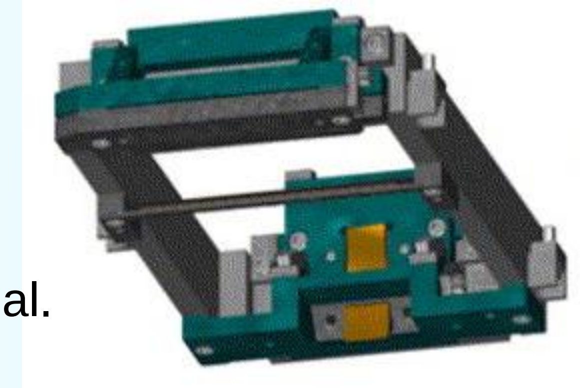
✓very compact & lightweight unit



Integral Field Unit



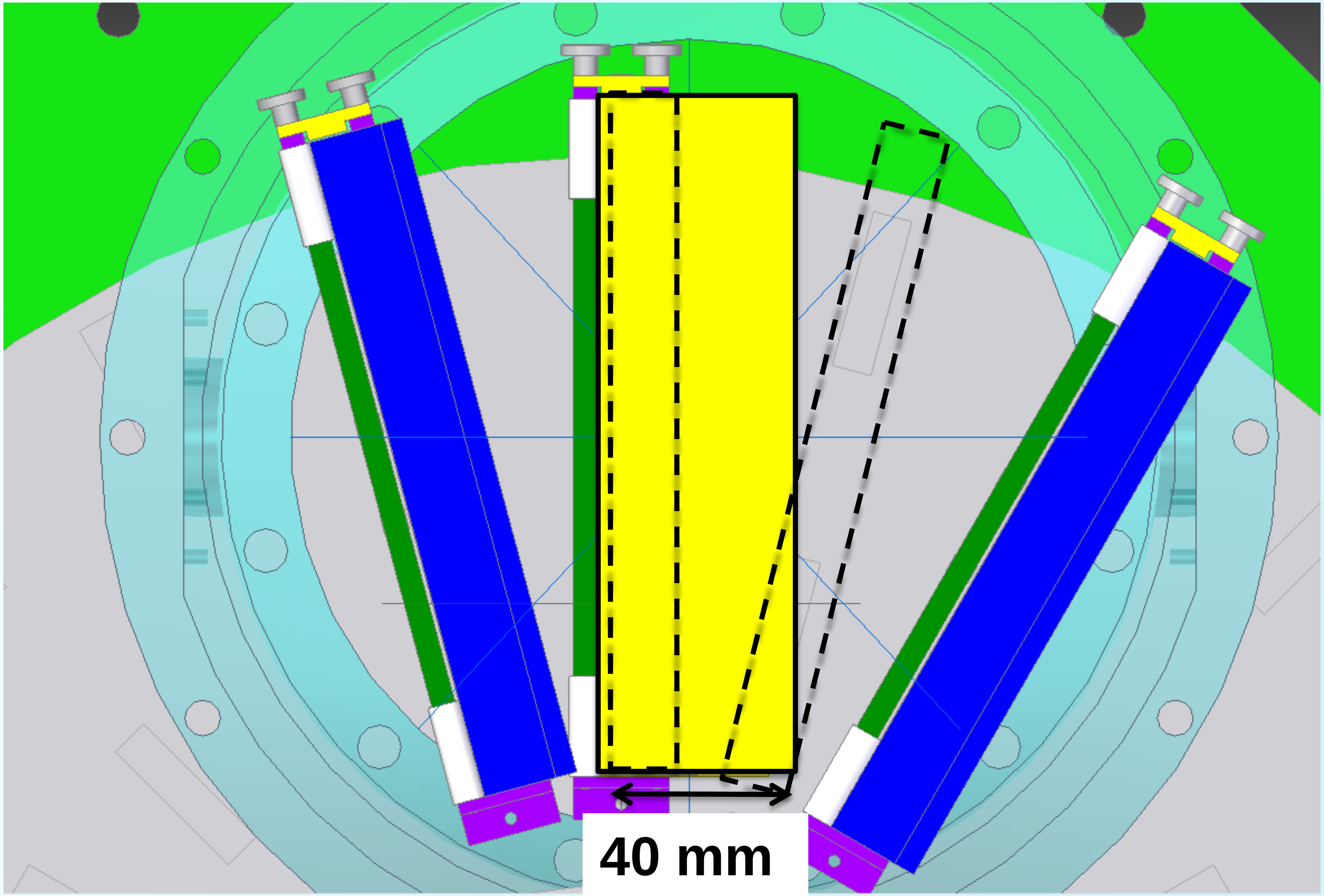
Size	170×140×40 mm³
Mass	< 700g



Cornelis et al. (2006)

＜GNIRS/GMOS＞
Size:200×100×100 mm³
Mass:<1000g

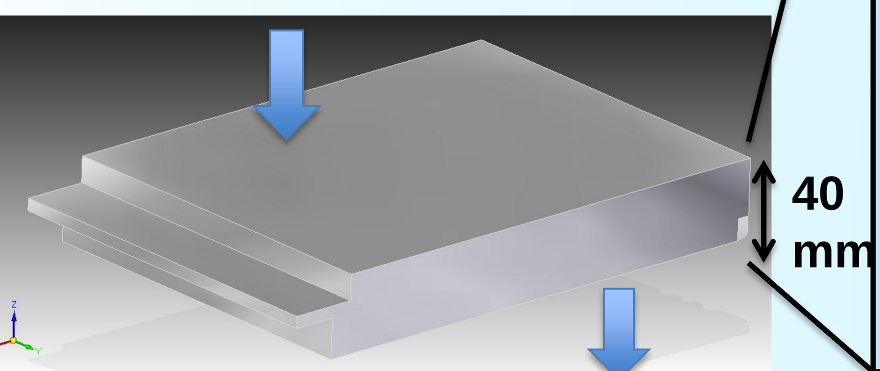
Size limit to install into MOS camera

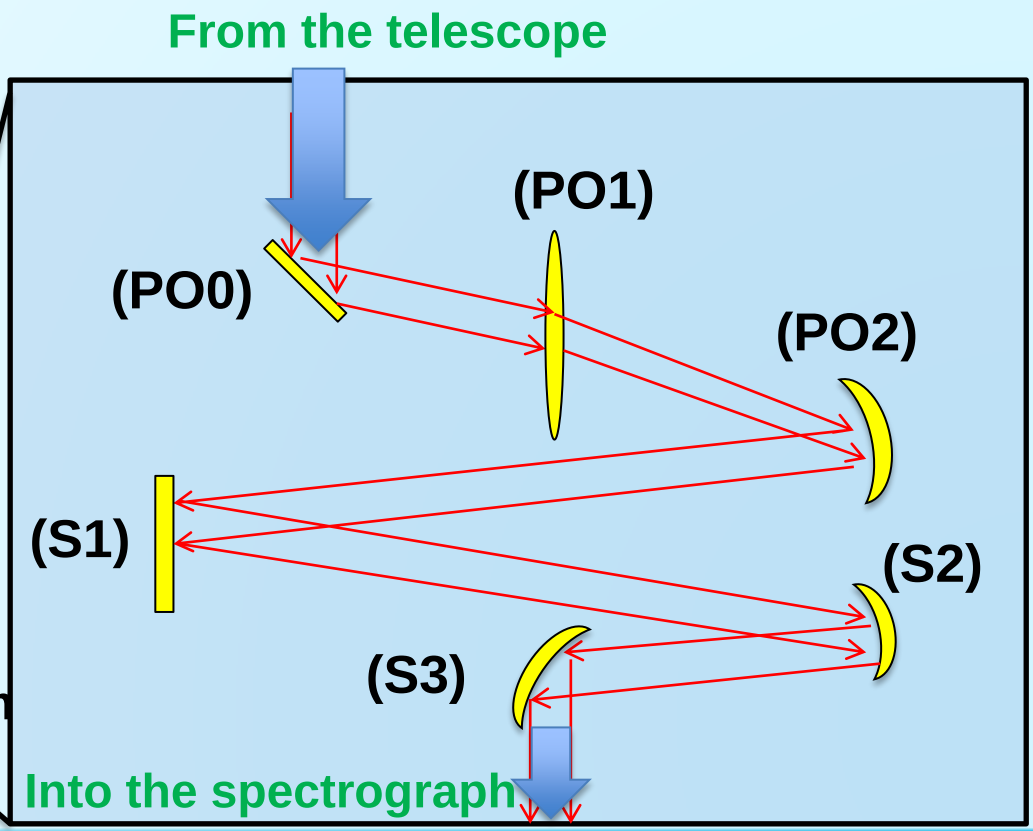


Optical design

✓ Optical components of SWIMS-IFU

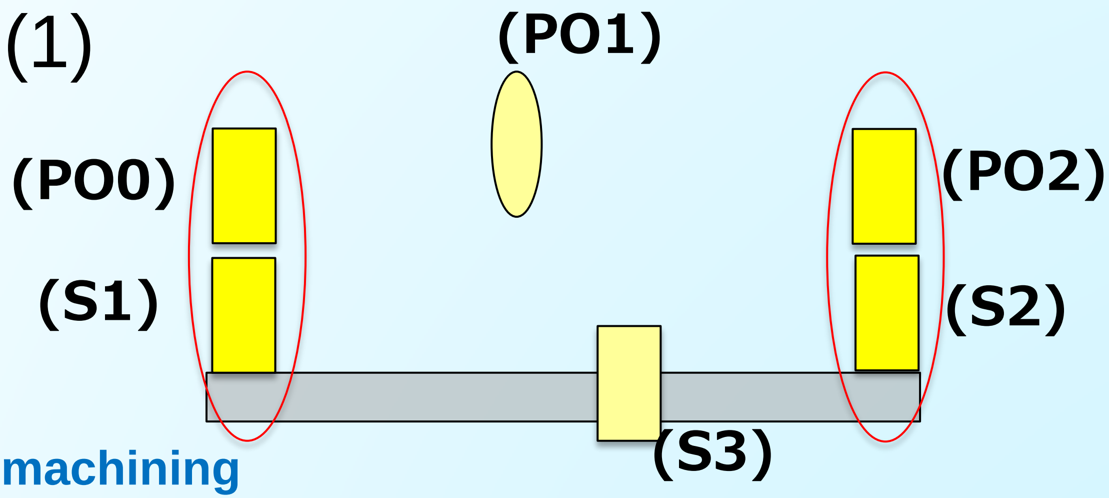
(PO0) pick-off mirror
(PO1) triplet lens
(PO2) concave mirror
(S1) Slice mirror
(S2) Pupil mirror
(S3) Pseudo-slit mirror





Optical design

✓Condition (1)



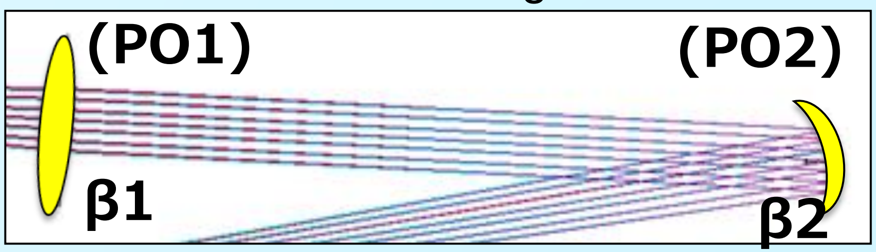
integrally machining

→ can be achieved alignment accuracy in processing precision

✓Condition (2)

collimated light between (PO1) and (PO2)

PO1 & PO2 work as magnifier

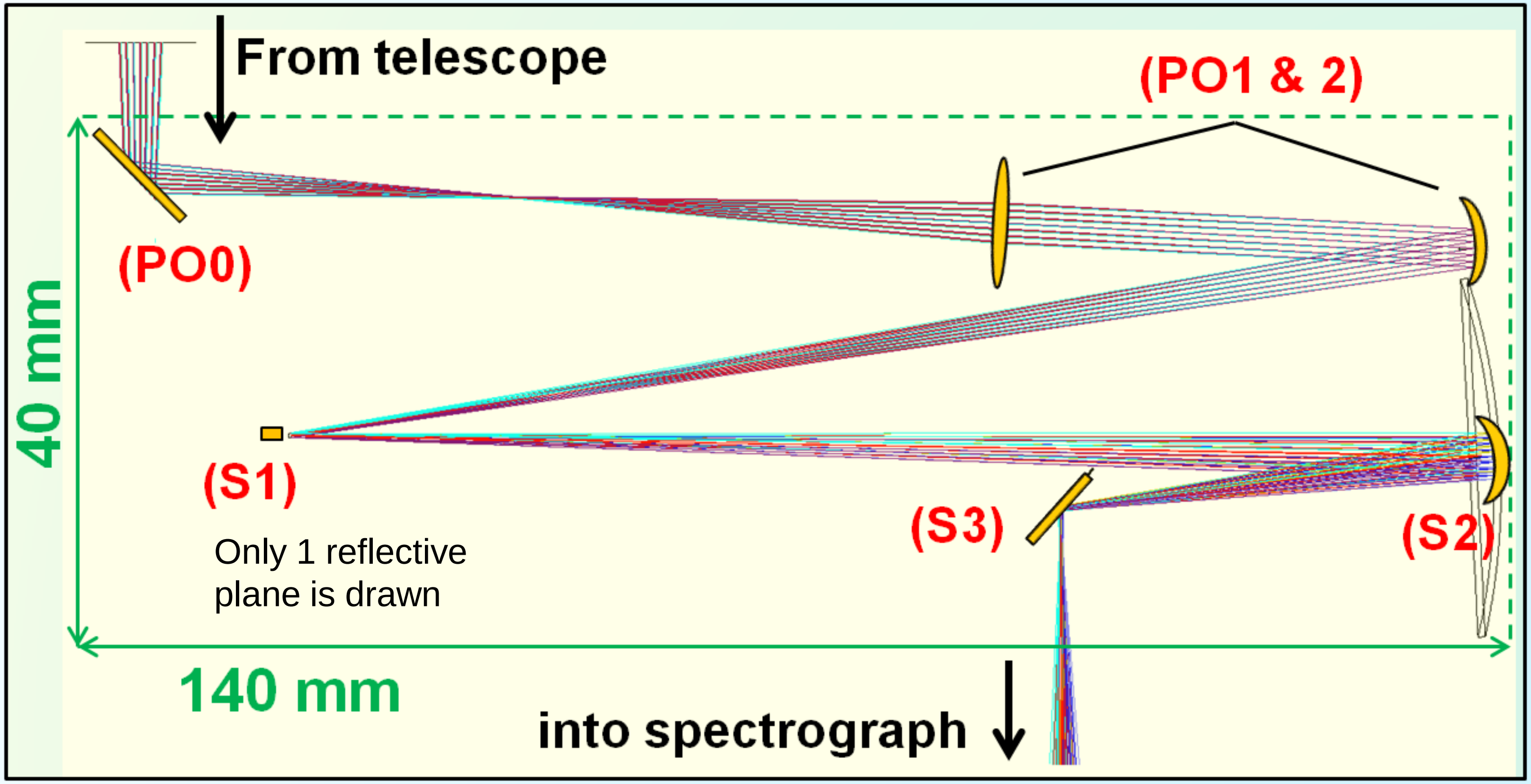


✓Condition (3)

β(magnification)= β1 x β2 = 2.5

Optical design

✓ constructing the solution which satisfies the size limit



But in this case, each reflective surface of slice mirror has curvature…

Development of SWIMS-IFU

✓ What are problems ??

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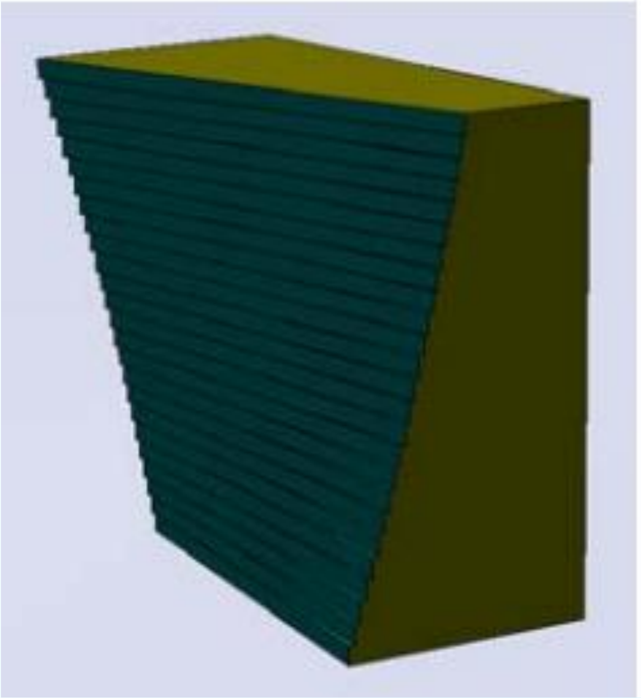
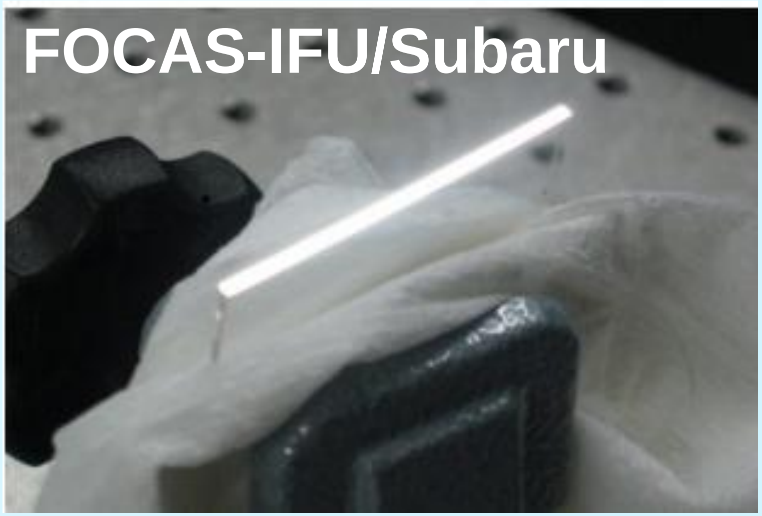
How can we achieve required surface accuracy…?

Fabrication of a slice mirror

Slice mirror (flat)





Processing method using glass can achieve high accuracy.

But it is

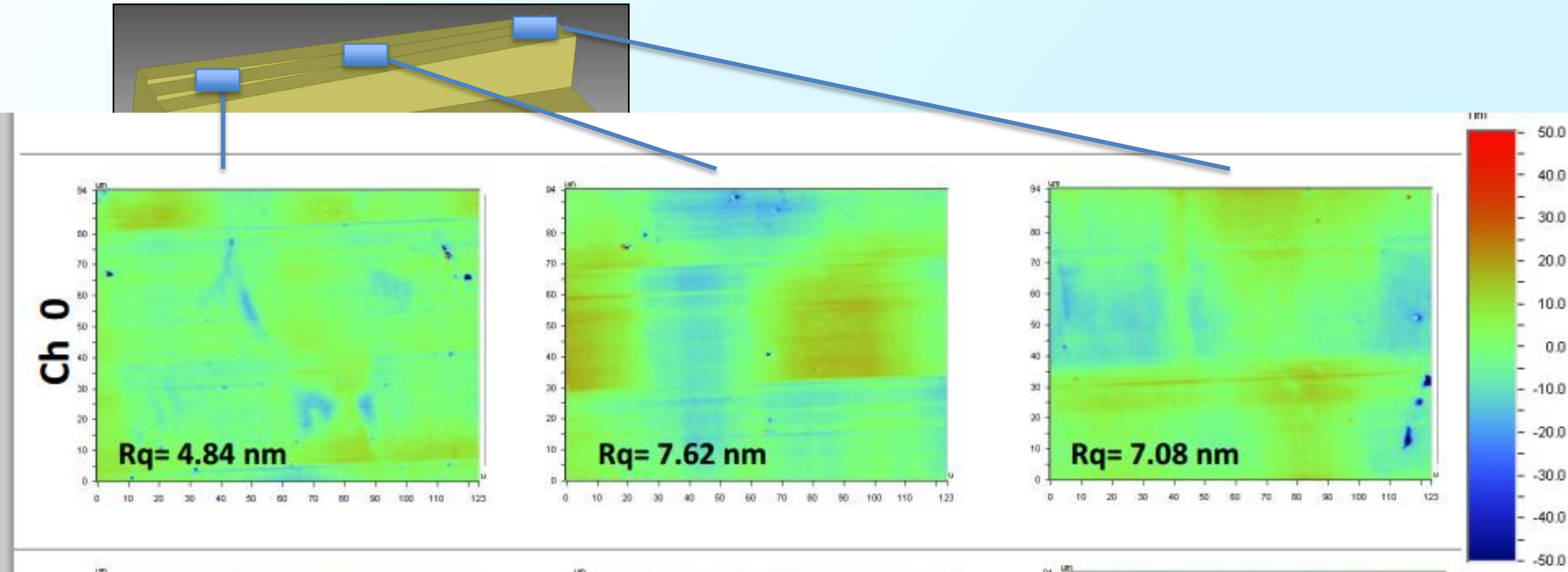
- difficult to make a non-spherical surface
- cause the optical axis deviation under low-T

S.Ozaki S et al. (2012)

Test fabrication

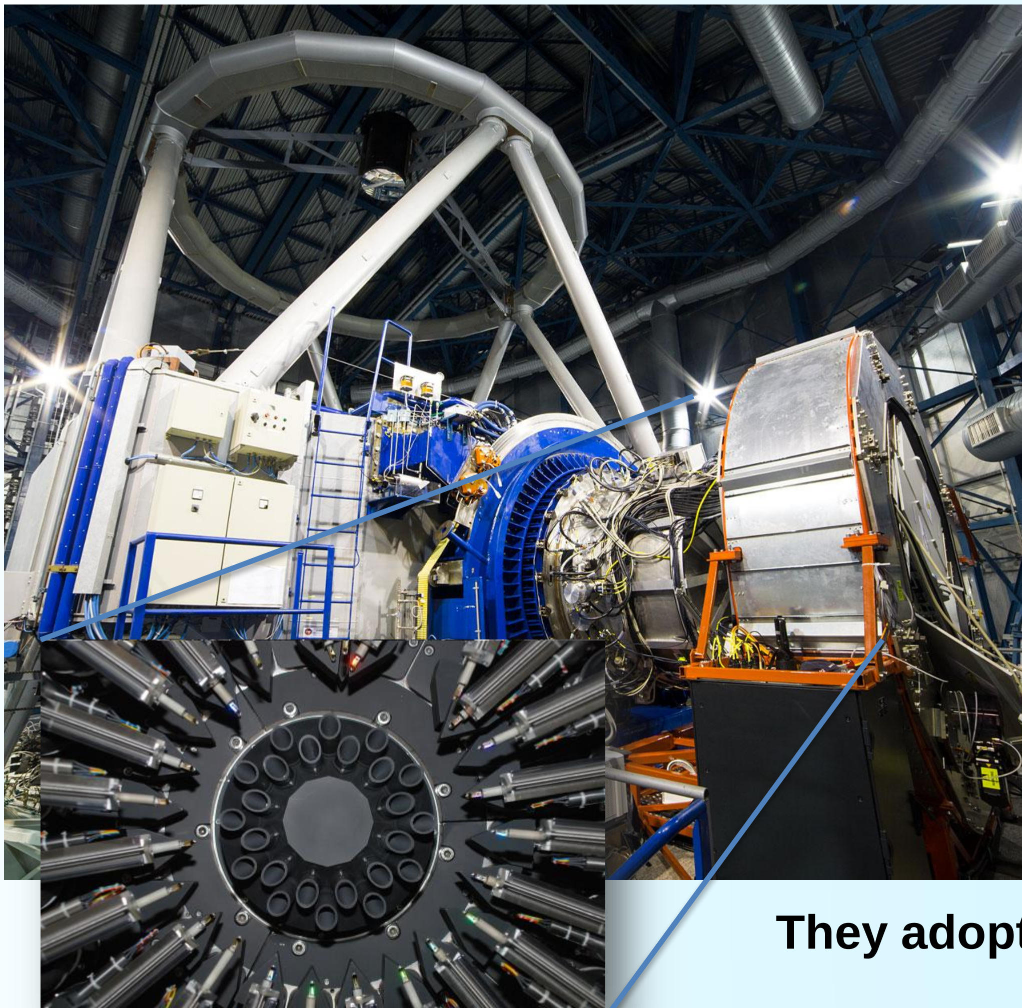
✓ All mirror in SWIMS-IFU will be made of aluminum alloy with high precision machining technique

→ match the thermal expansion with support structures under a cryogenic environment.



Present condition of multi-object IFU

✓KMOS-VLT (first light occurred on 21 November 2012)



- λ=0.8 – 2.5 um (R=3000-4000)
- patrol field: Φ7.2’
- 24 IFUs (each FOV is 2.4” × 2.4”)
- spatial sampling: 0.2” × 0.2”

They adopted the advanced image slicer IFUs.

Future instruments using IFS

＜Ground-based observation＞

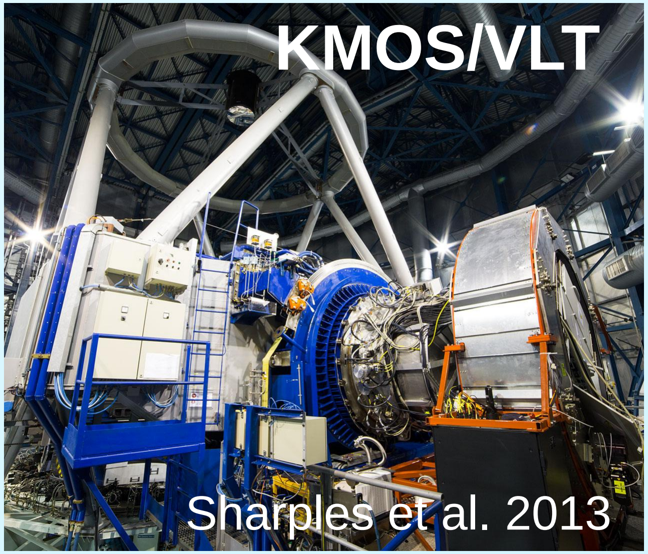
✓ VLT

・KMOS(near-IR), MUSE(optical)

✓ TMT

・IRIS(near-IR),

They have also lenslets mode.



＜Space observation＞

✓ JWST

・NIRSpec(near-IR)

The advanced image slicer IFUs is the key technique for future instruments

Future instruments using IFS

Questions to Speakers

To all workshop speakers: please include your responses to the q

Questions on instrument specifications

Primary questions

- (Q.1) In the baseline specifications of NIR instruments, w
  1. Wide-Field Near-IR Imager
  2. Wide-Field NIR Imager and Multi-Object Spe[…]graph
  3. Multi-Object Integral Field Spectrograph

  Which instrument is *essentially* important for your science cases?
- (Q.2) What is the optimal plate scale / FoV for your science cases? (see GLAO specifications for expecte

I'd like to propose the 4th option !
"MOS camera + IFU"

Wide-field NIR imager & MOS with GLAO + IFS mode

✓ **This type of IFU (e.g. SWIMS-IFU, GNIRS, ν-MOIRCS?) is a fully independent , self-contained module**

There are no IFUs with GLAO for now, but above will give the way to achieve it.

Summary

✓ Integral Field Spectroscopy have an increasing impact on our understanding of galaxy evolution mechanisms.

✓ The advanced image slicer IFUs is the key technique for future instruments such as TMT, JWST (Of course for Subaru !!)

✓ SWIMS-IFU is now under developing

- constructing the solution which satisfies the size limit
  In this case, slice mirror has curvature

- verifying the high precision machining technique
  by fabricating the test pieces