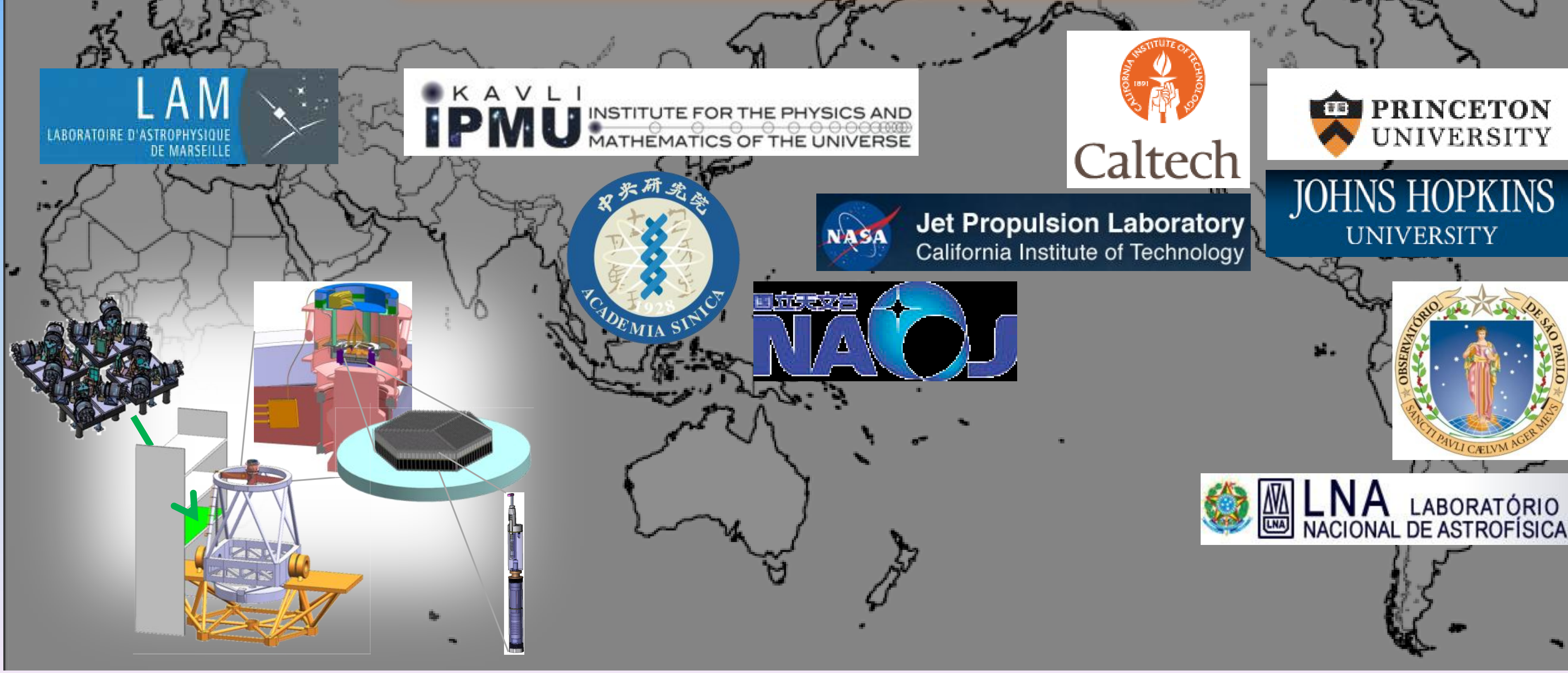
2012年8月9日 光学赤外線天文連絡会シンポジウム「2020年に向けてのロードマップ」@国立天文台三鷹

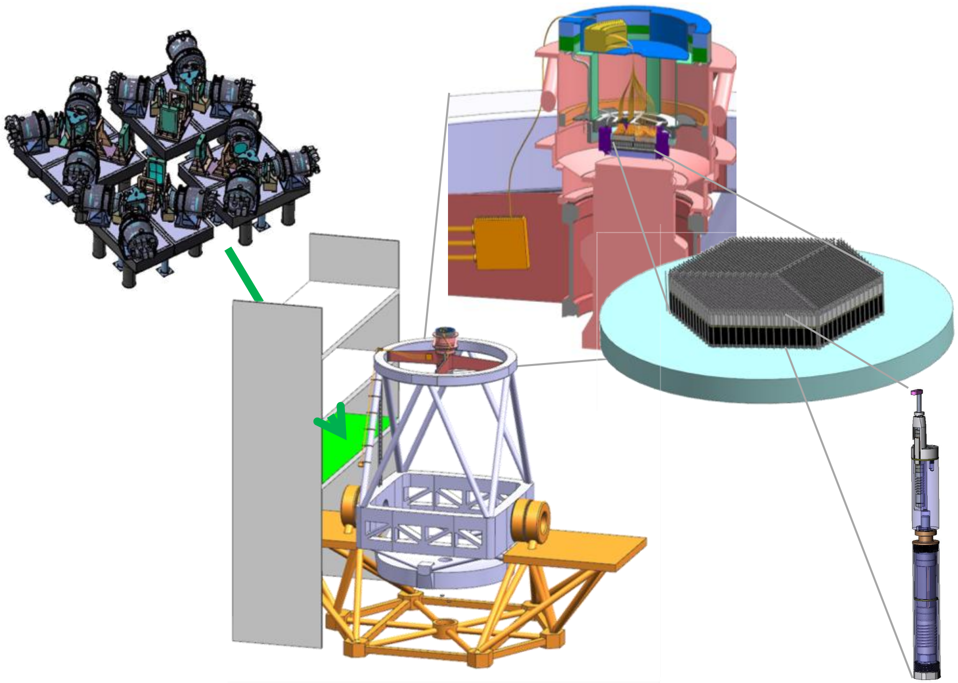
すばる Prime Focus Spectrograph (PFS)

菅井　肇 (Kavli IPMU)

実行グループ (PI 村山斉 Kavli IPMU)



Prime Focus Spectrograph (PFS)



1. What is PFS ?
2. Science targets
3. Why on Subaru ?
4. Challenges in PFS
5. Each component
6. Efficiency & sensitivity estimates
7. Major milestones
8. Summary

1. What is Prime Focus Spectrograph (PFS) ?

Optical + NIR Multi-object fiber spectrograph

概要

- Number of fibers: 2400
  600 per Spectr. X 4 Spectrographs

- Fiber core diameter 128μm
  Microlens attached to fiber input edge
  fiber input F/2.2 -> F/2.8 (1”.1 diameter per fiber)

- Field of view: 1.3 deg
- Wavelength: 0.38 - 1.3 μm

[Sugai et al. SPIE]

1. What is PFS ?

Optical + NIR Multi-object fiber spectrograph

- Each spectrograph: 3-color-arm design

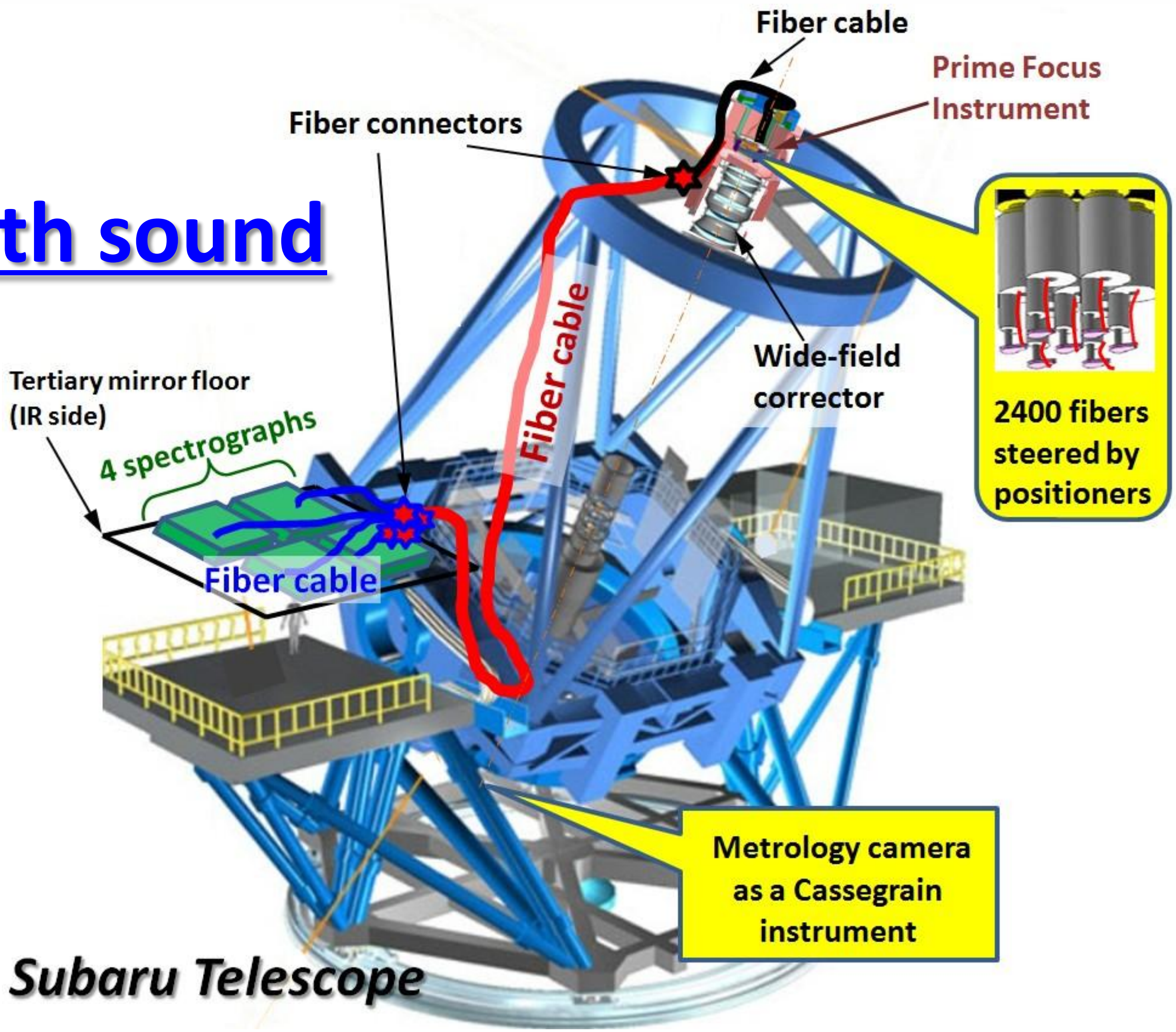
Arm	Coverage[A]	Resolution[$\lambda/\delta\lambda$]
Blue	3800-6700	2300
Red	6500-10000	3000
NIR	9700-13000	4400

Spectrograph collimator F/2.5, camera F/1.1

Detector pixel 15μm (2Kx4K x 2 FDCCDs for each Blue/Red arm,
4Kx4K HgCdTe(1.7μm cutoff) for NIR arm)

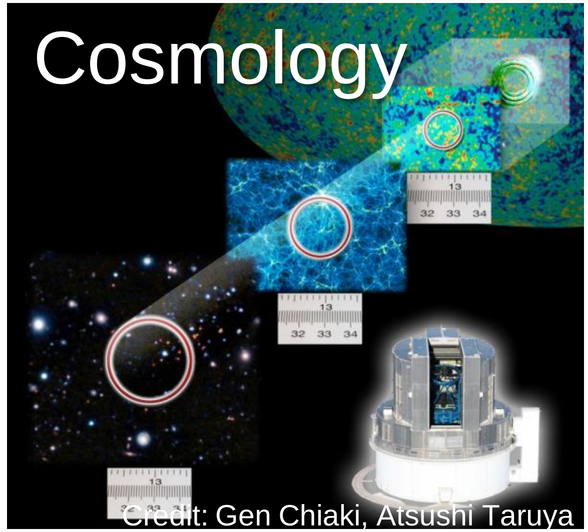
How the system works

movie
movie with sound



2. Science targets

科学的目的



Credit: Gen Chiaki, Atsushi Taruya

9.3 h^{-3} Gpc^3 in $0.8<z<2.4$
1400 deg^2

国内の他の計画との関連

Milky Way 17<V<21.5 390 deg^2
M31halo 21.5<V<22.5 65 deg^2

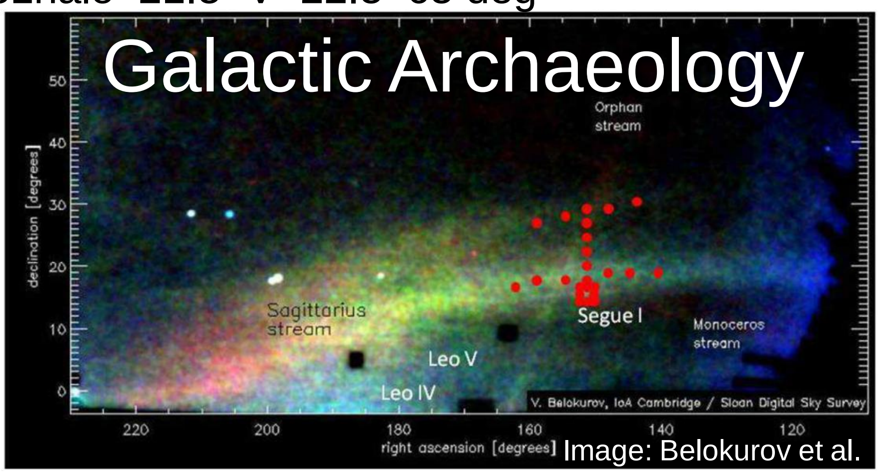
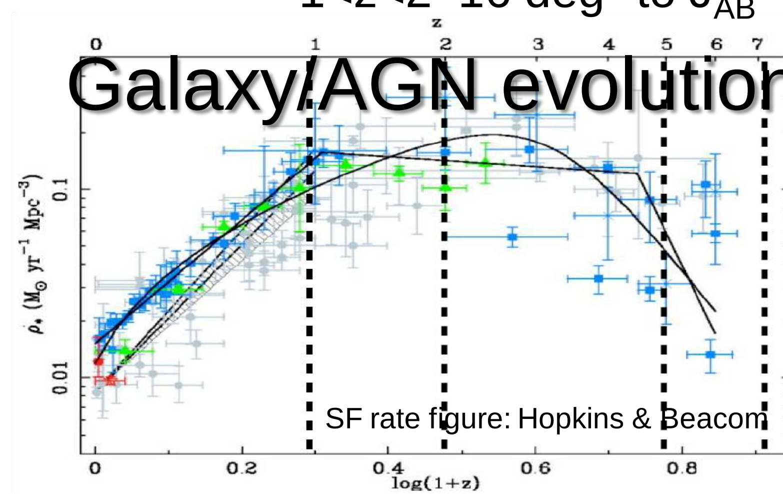


Image: Belokurov et al.

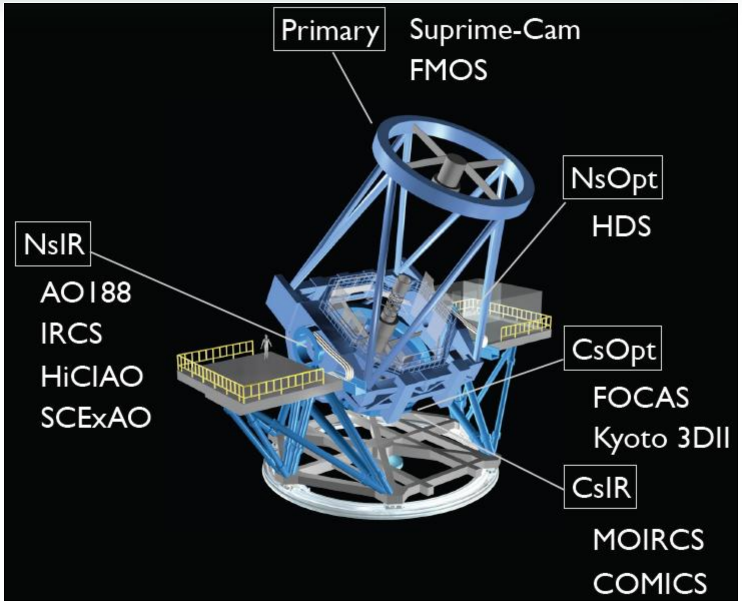
1<z<2 16 deg^2 to J_{AB}~23.4



SF rate figure: Hopkins & Beacom

See arXiv:1206.0737 “Extragalactic science and cosmology with Subaru PFS” Ellis et al. (2012)

3. Why on Subaru ?



Strengths of Subaru Telescope

Large Field of View

e.g., Suprime Cam

(Hyper Suprime Cam, Prime Focus Spectrograph)

Platescale (arcsec mm-1) ∝ 1/f → prime focus

(rigid tel. structure)

Excellent Image Quality

e.g., Kyoto 3DII (PI instr.: IFS,FP,etc.) + AO188 in optical wavelength

mirror surface, dome shape, rigid structure, tel. tracking

4. Challenges in PFS

- Bright telescope F-ratio of 2.2

- Bright camera F-ratio of 1.1

- Quick & accurate reconfiguration of fiber positioners

Comparison with other optical multi-fiber spectrographs

Telescope	Instr.	Prime Focus?	F-ratios/ Pixel size	Number of fibers	Fiber diameter/ Positioner
Subaru 8.2m	PFS	YES	2.2 → 2.8 with microlens (collimator 2.5; camera 1.1)/ 15 μm	2400 (1.3 deg FOV)	128 μm: 1".1/ Two rotary motors
VLT 8.2m	FLAMES/ GIRAfEE	no	15 →5 with microlens (camera 1.2)/ 15 μm	600	230 μm: 1".2/ Magnetic button
MMT 6.5m	Hectospec	no	5 (camera 1.5)/ 13.5 μm	300	250 μm: 1".5/ 5-axis robot
WHT 4.2m	AF2	YES	2.5 13.5 μm	150	90 μm: 1".6/ Robot Autofib2
Guoshoujing 4m	LAMOST	YES	5 (collimator 4; camera 1.2)/	4000 (5 deg FOV)	320 μm: 3".3/ Two rotary motors
AAT 3.9m	2dF	YES	3.5 (collimator 3.15; camera1.2)/ 24 μm	400	140 μm: 2".1
WYIN 3.5m	Hydra	no	6.3 (collimator 5; camera 1.8) 12 μm	100 (288 slots)	200 μm: 2"/ Magnetic button
SDSS III 2.5m	APOGEE	no	5 (collimator 3.5; camera 1.4)	300	120 μm: 2"
SDSS III 2.5m	BOSS	no	5	1000 (3 deg FOV)	120 μm: 2"
AAO UKST 1.2m	6dF	YES	2.5	150	100 μm: 6".7/ Off-telescope robot
(Mayall 3.8m	bigBOSS	YES	4.5 (input to spectrograph 4)	5000 (3 deg FOV)	120 μm: 1".45 (heritage: LAMOST))

4. Challenges in PFS

- Bright telescope F-ratio of 2.2

  Use of microlens

    Transformation of F-ratio from 2.2 → 2.8

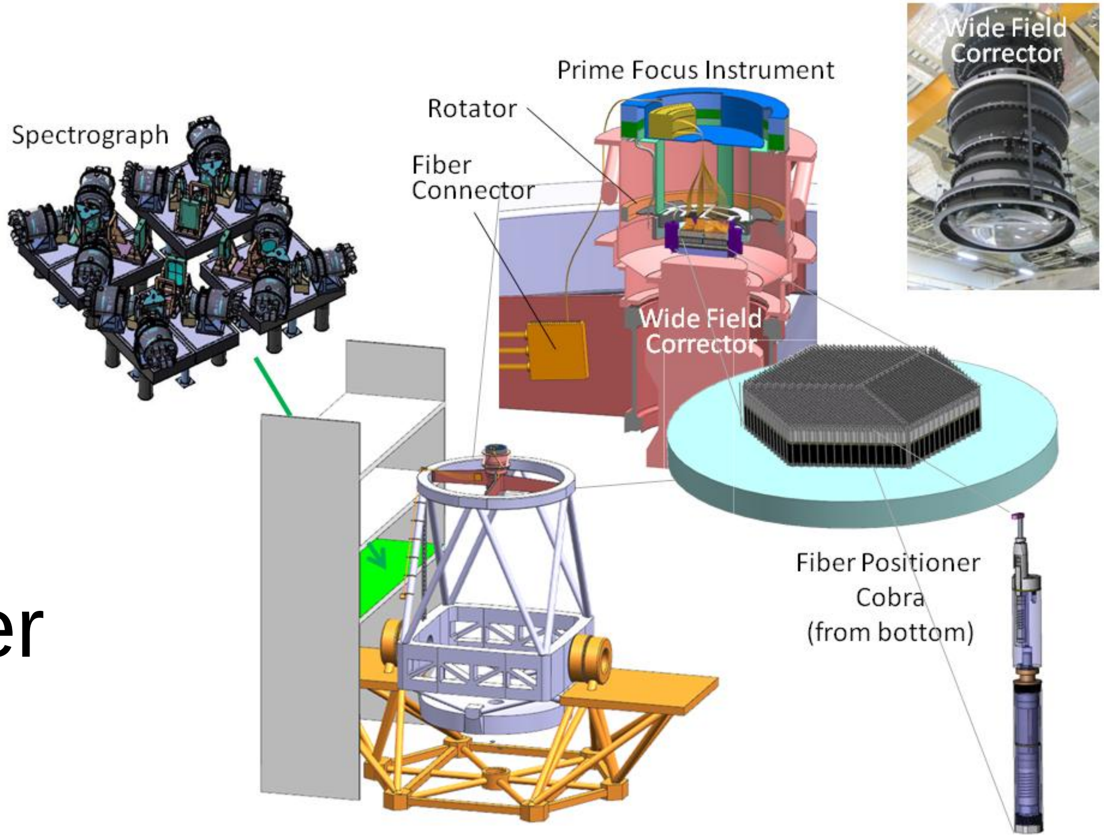
- Bright camera F-ratio of 1.1

  Use of double Schmidt corrector

- Quick & accurate reconfiguration of fiber positioners

  Uses of new-type high-precision positioner and wide-field metrology camera

5. Each component

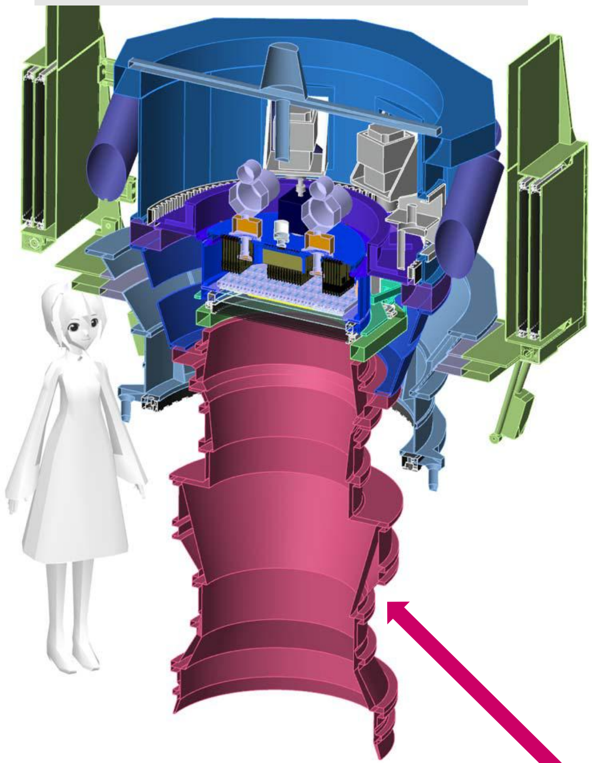


- Microlens + Fiber
- Fiber positioner
- Spectrograph
- Metrology camera

Sharing Wide Field Corrector with HSC

国内の他の計画との関連

Hyper Suprime-Cam
(HSC)



PFS case:

Optical interface with Wide Field Corrector

Field element

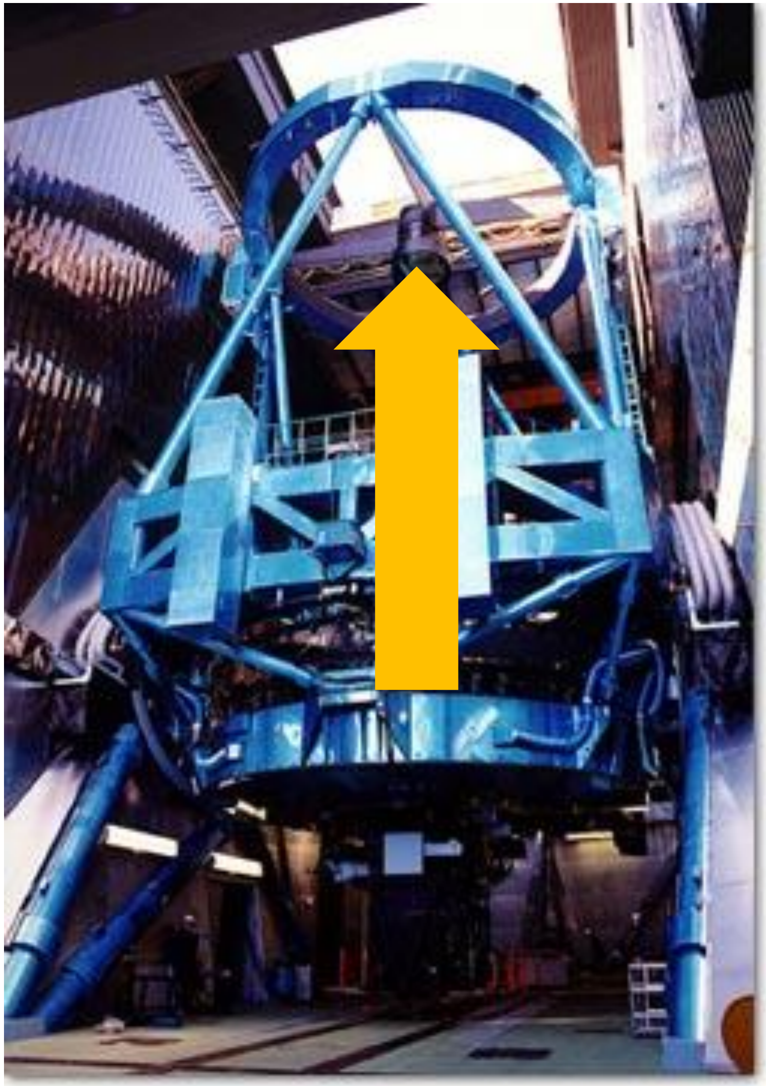
= 52-mm thickness flat plate

substitutes for filter + dewar window

http://www.eso.org/sci/facilities/eelt/fp7-elt-pub/wfi_workshop/pdffile/SMiyazaki.pdf

Wide Field Corrector (WFC)

Light from telescope through WFC & Field element to **microlens + fiber**



Microlens at fiber entrance

Transforms input f-ratio (F/2.2 → F/2.8)

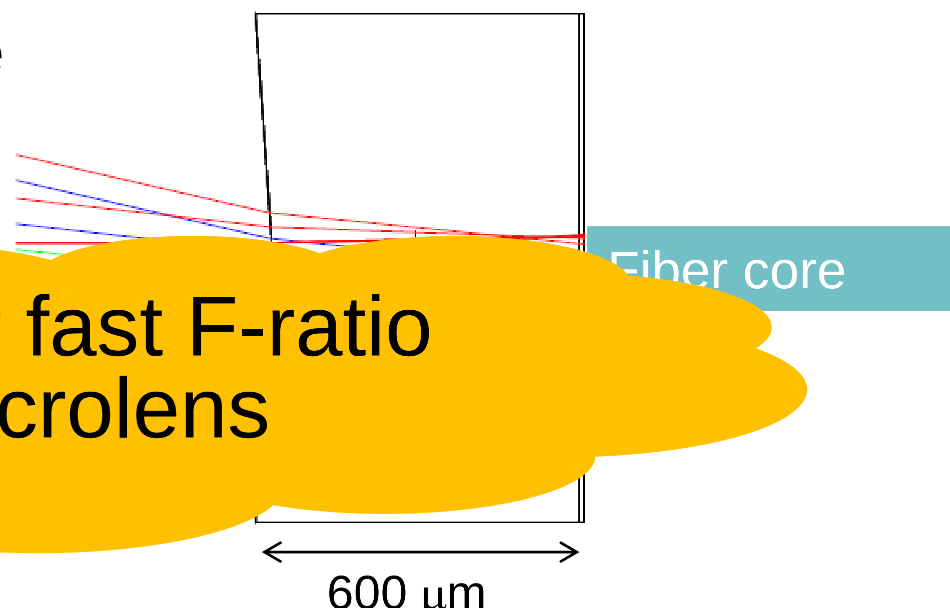
(1) to reduce light loss caused by over-filling acceptance angle of fiber

(2) to ease difficulties of spectrograph design

Molding a suitable microlens out of glass

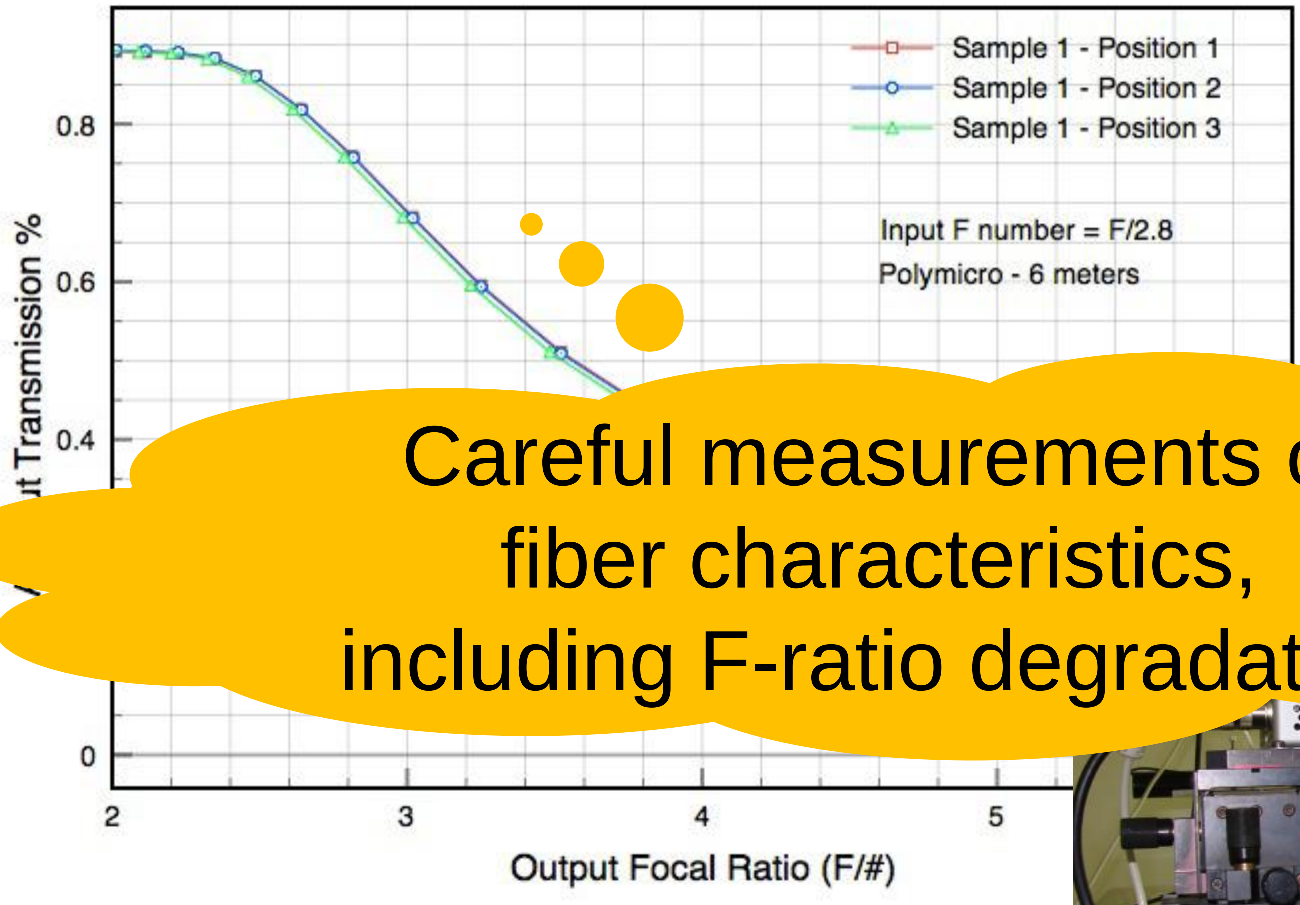
glass - variety of refractive-index selection

molding - aspheric surface



Challenge for fast F-ratio with Microlens

Fiber experiment/development

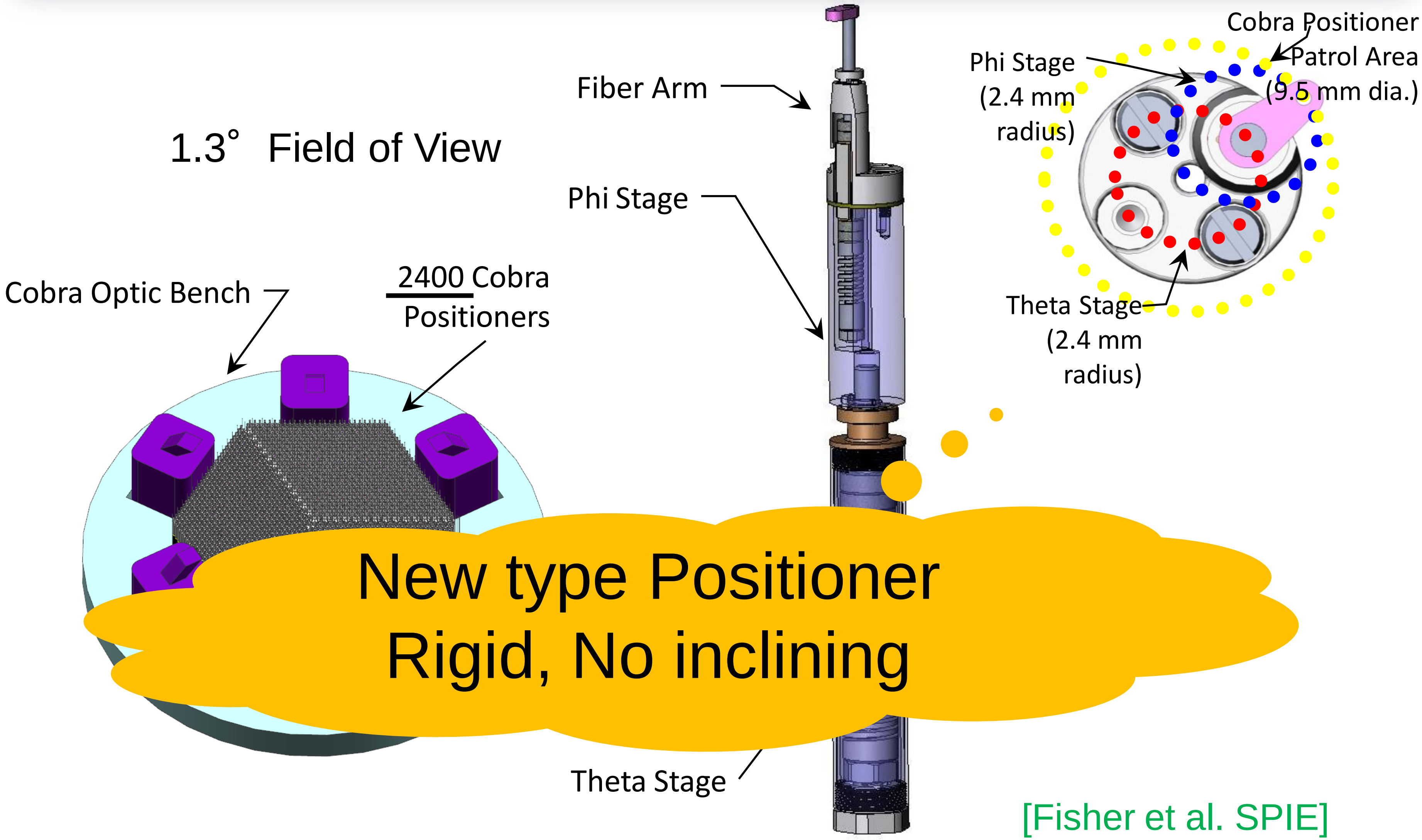


Careful measurements of
fiber characteristics,
including F-ratio degradation

[de Oliveira et al. SPIE]

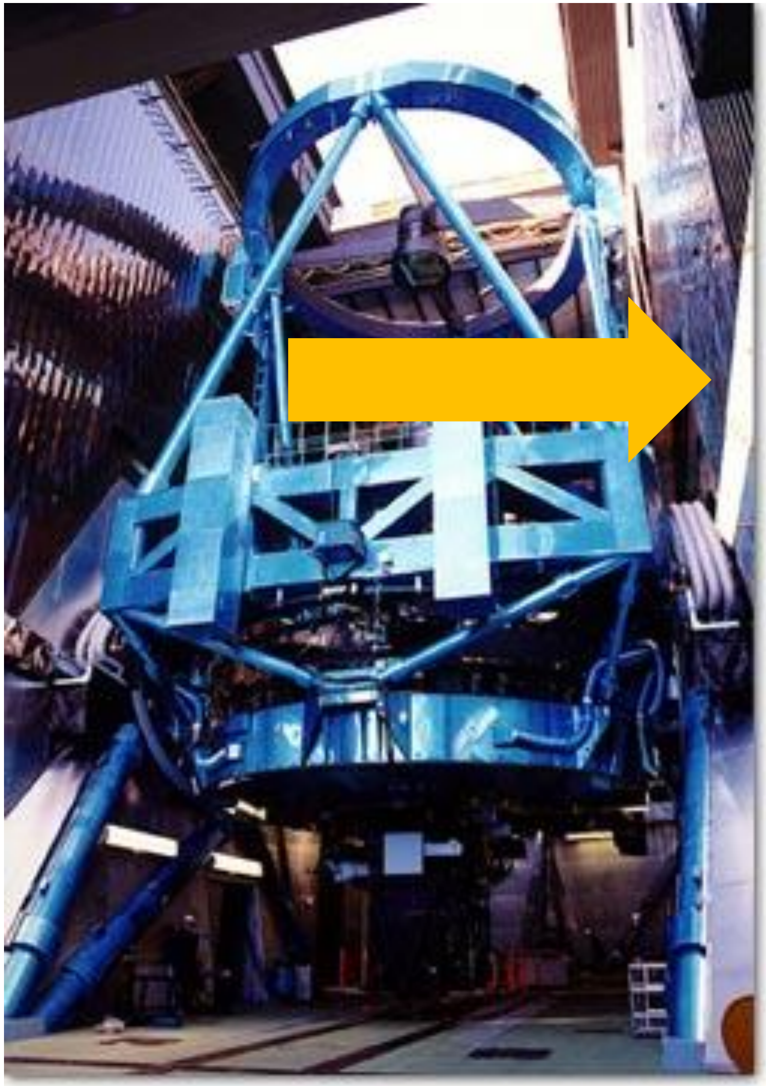
Fiber Positioner

1.3° Field of View



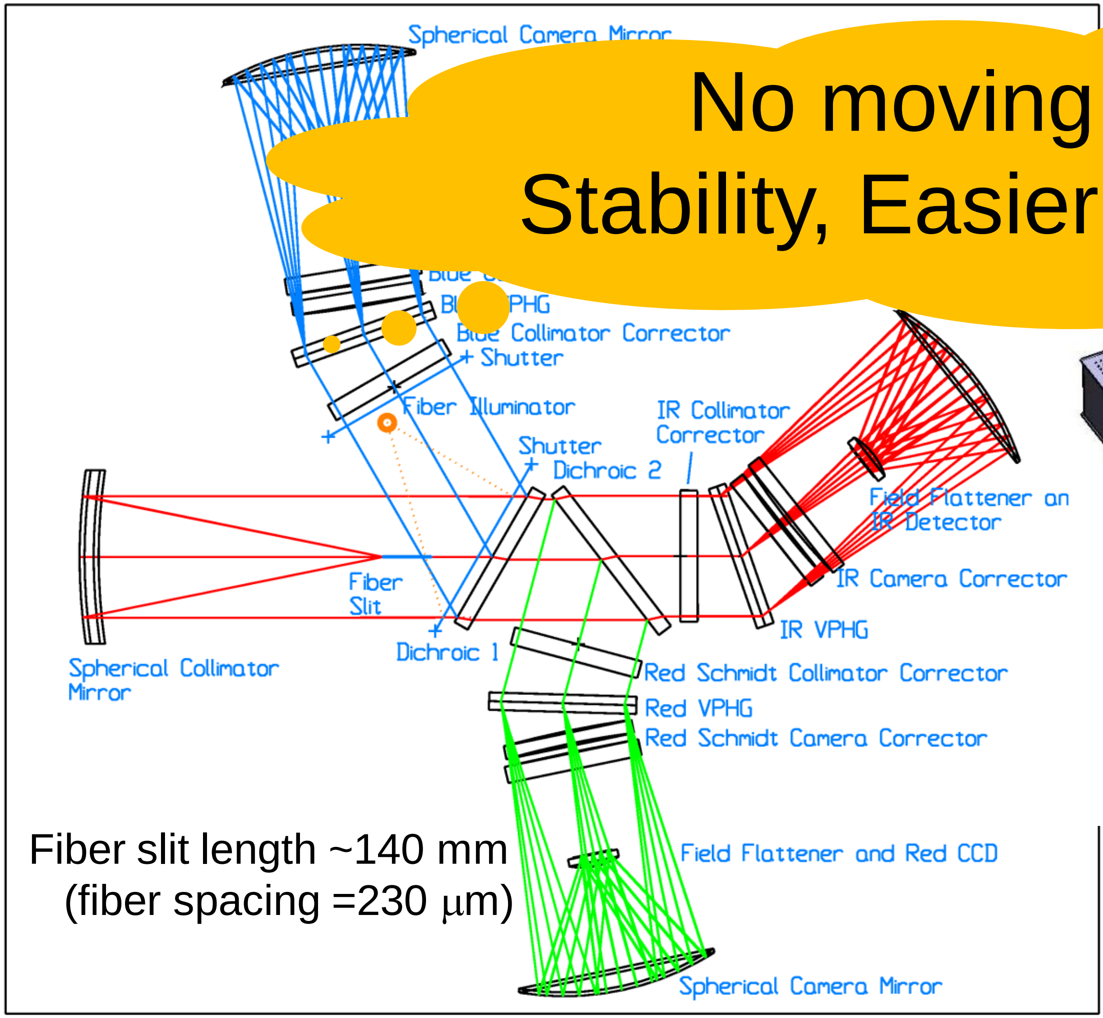
[Fisher et al. SPIE]

JPL --- started prototype 7-element Cobra development through fiber to **spectrograph**

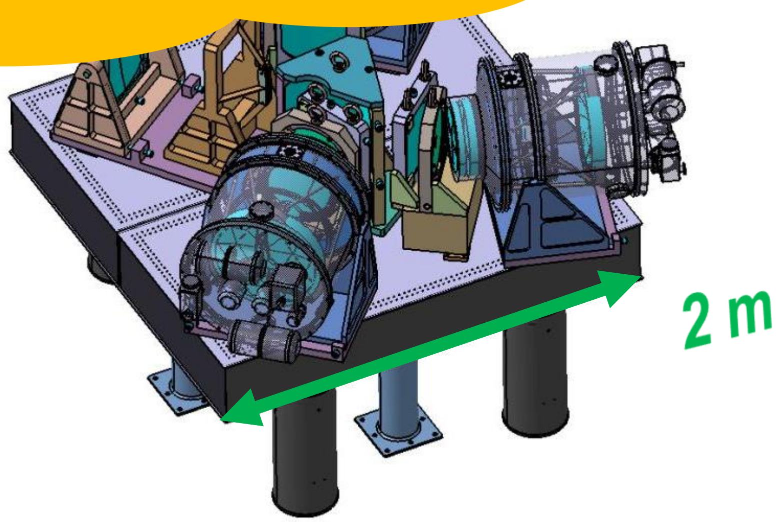


Spectrograph

No moving parts
Stability, Easier operation



Fiber slit length ~140 mm
(fiber spacing =230 μm)



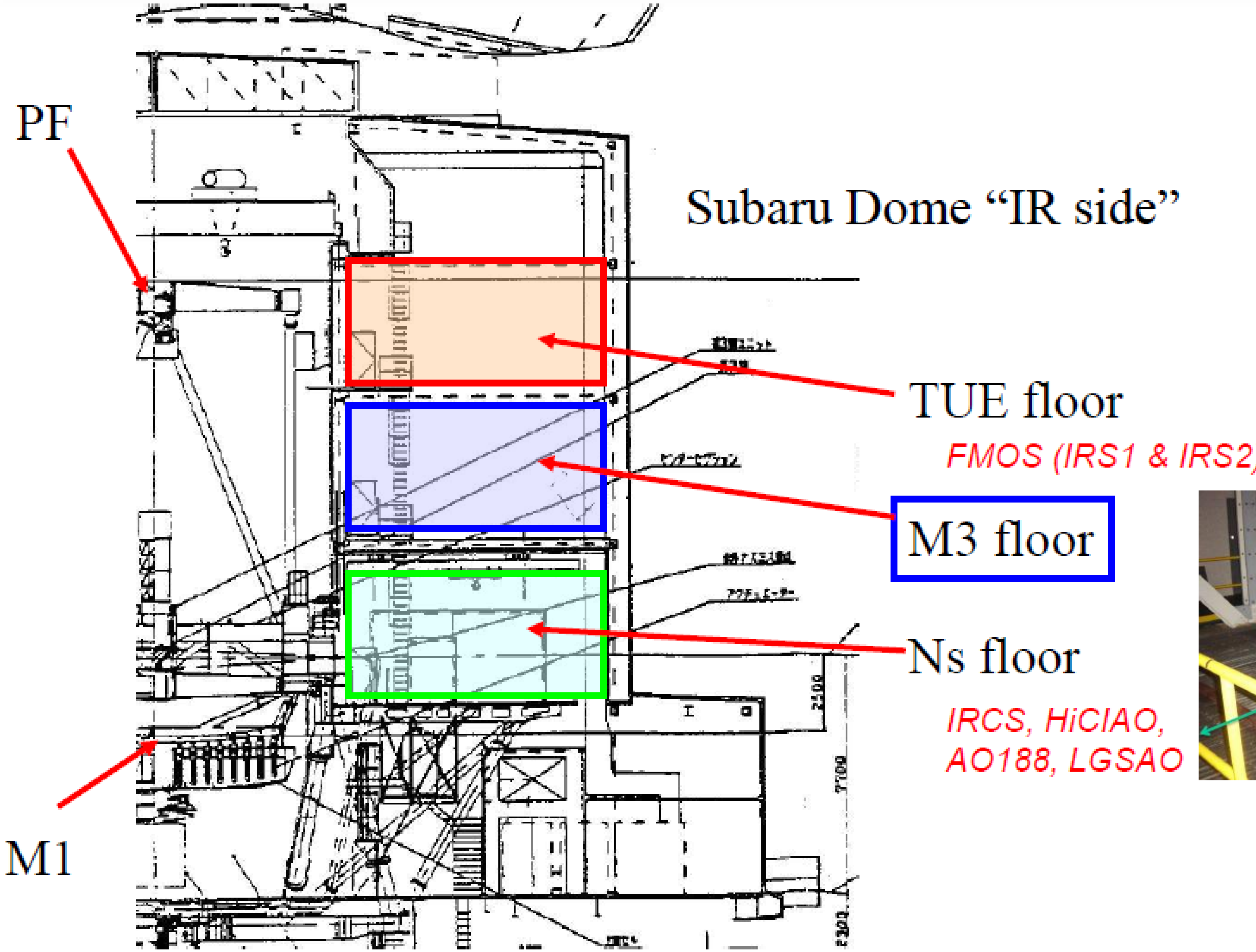
We build four of these

[Vivès et al. SPIE]

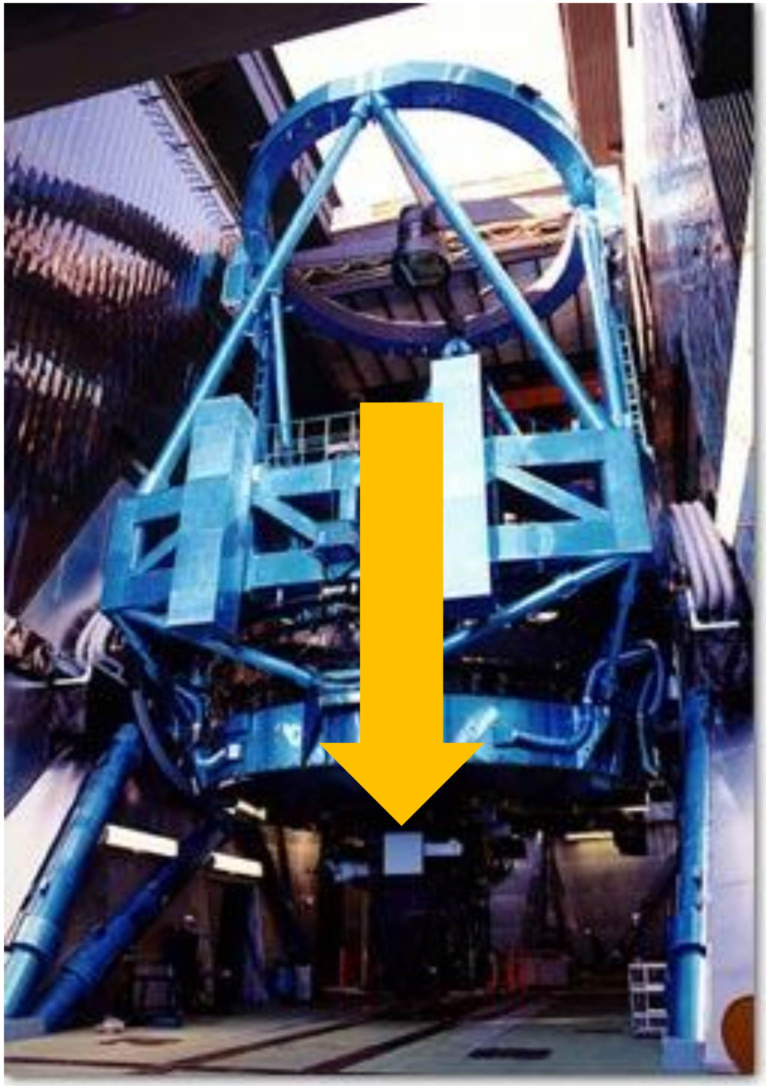
[Gunn et al. SPIE]

0.38-1.3μm: VPH gratings 280 mm diam. each
Resolving power = $\lambda/\delta\lambda$ ~ 3000

Spectrograph



Back-illuminated fiber observed by **metrology camera**



Metrology camera

Planned to be located in Cassegrain container

“Directly” seen and taken with one shot

Magnification	~0.0415
Camera aperture size	~130 mm
Detector	120M 2.2μm-pixel CMOS (diffraction-limited image quality)

[Wang et al. SPIE]

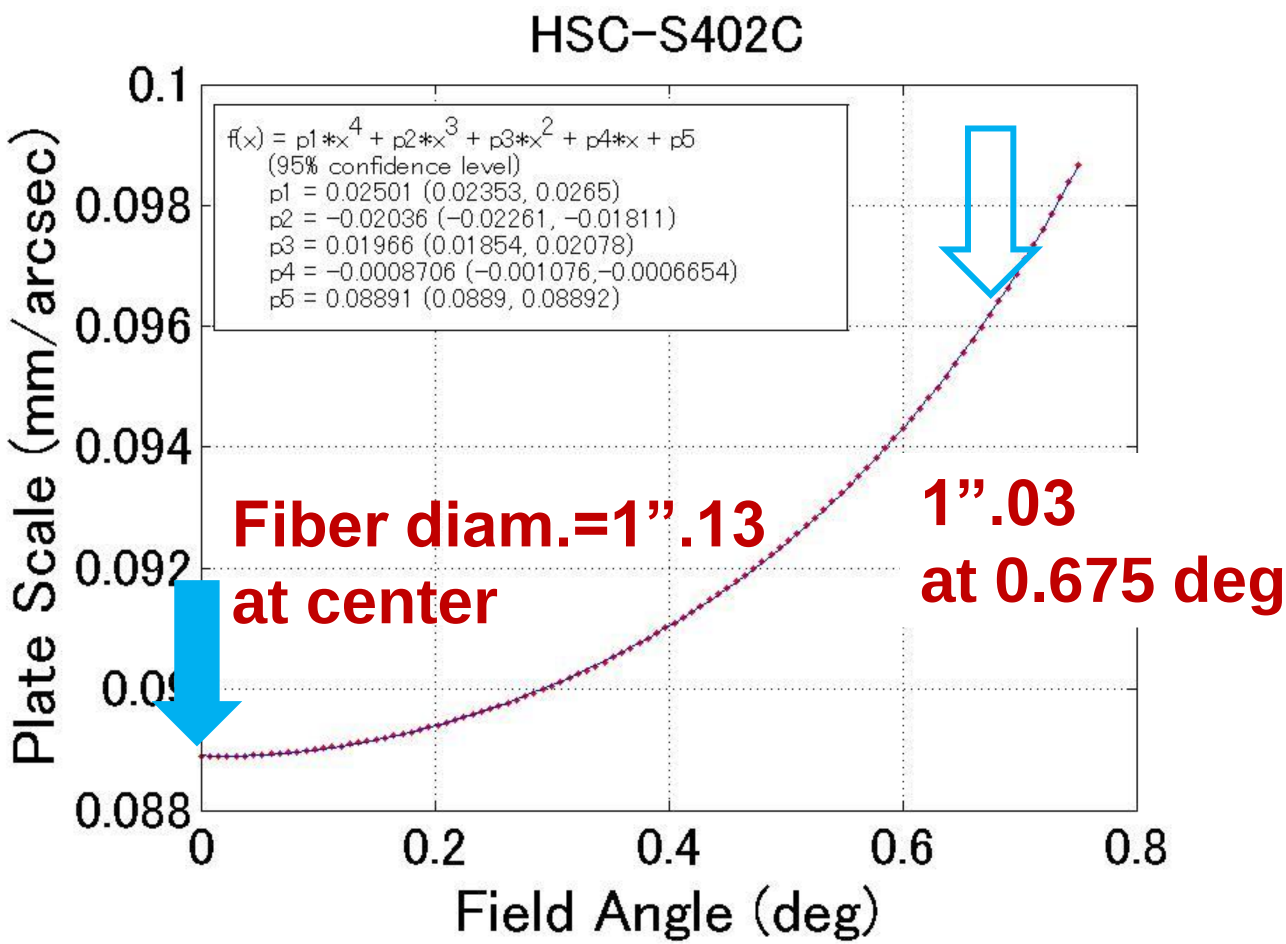
6. Efficiency & sensitivity estimates

6.1 Total efficiency estimates

6.2 Signal-to-noise ratio estimates

Efficiency & S/N estimates

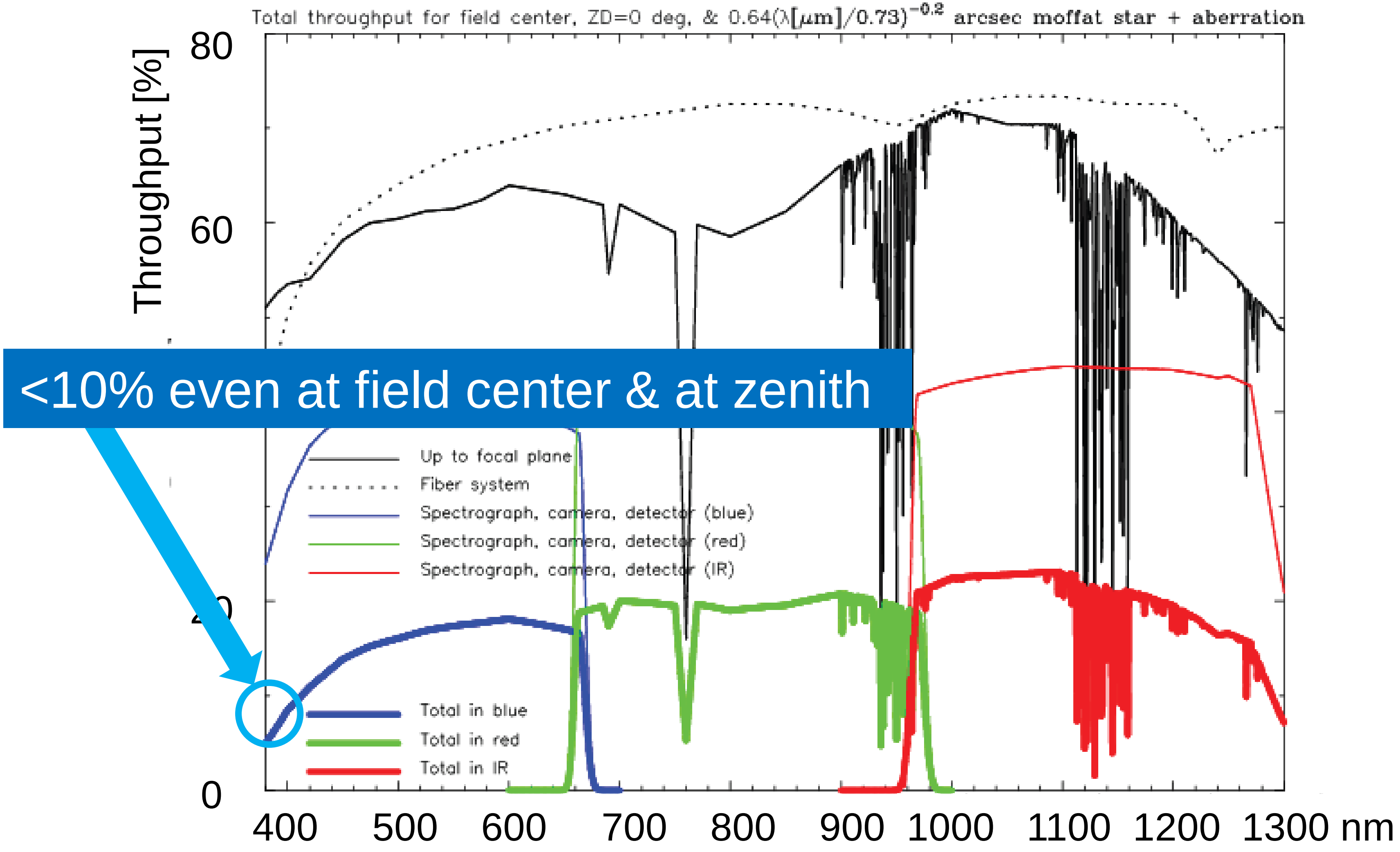
Taking Wide Field Corrector (WFC) distortion into consideration



Non-telecentricity, vignetting, residual chromatic aberration also considered

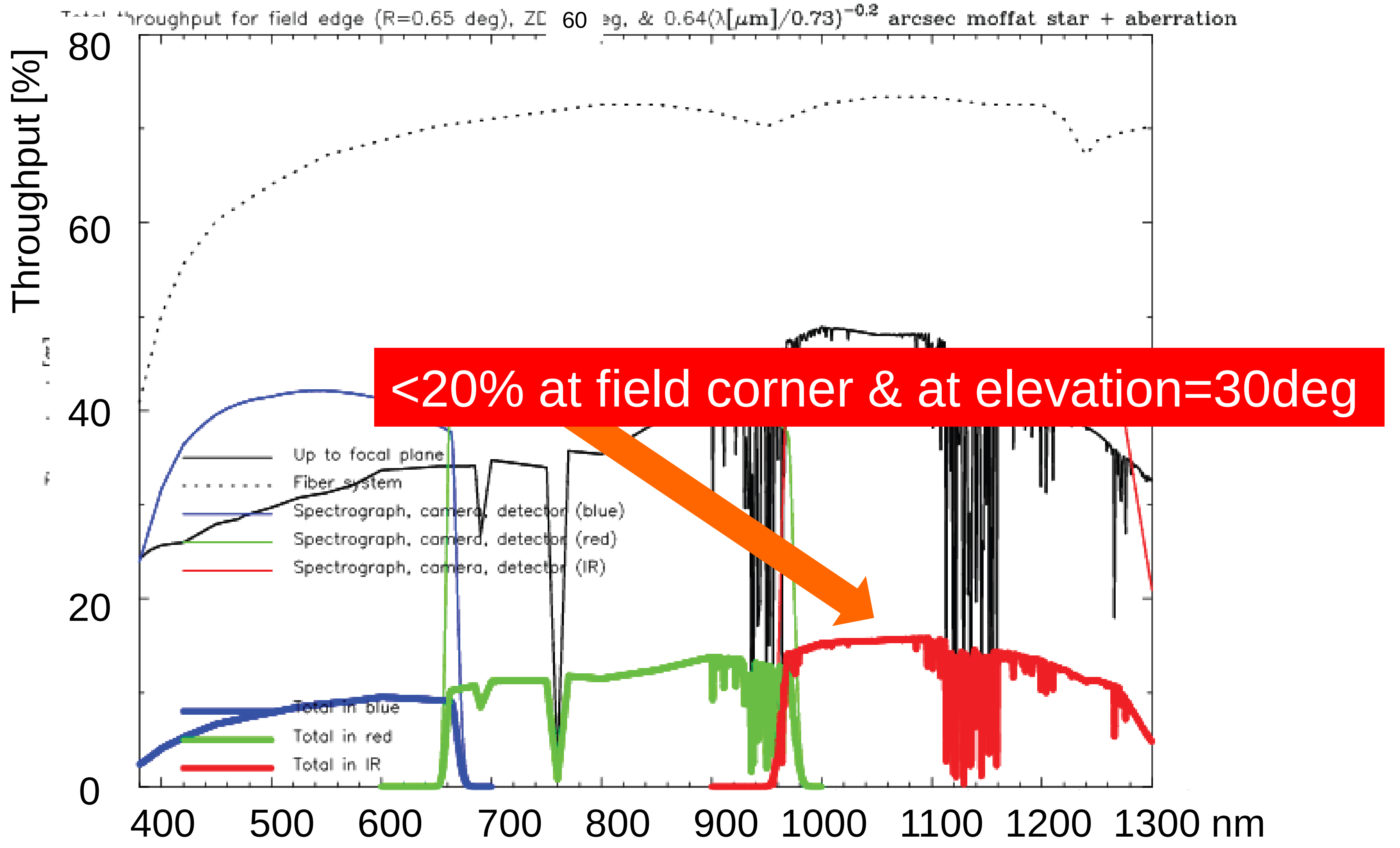
Total efficiency for field center at zenith

Includes everything from sky to detector (0”.64 seeing at 730nm) & aperture effect

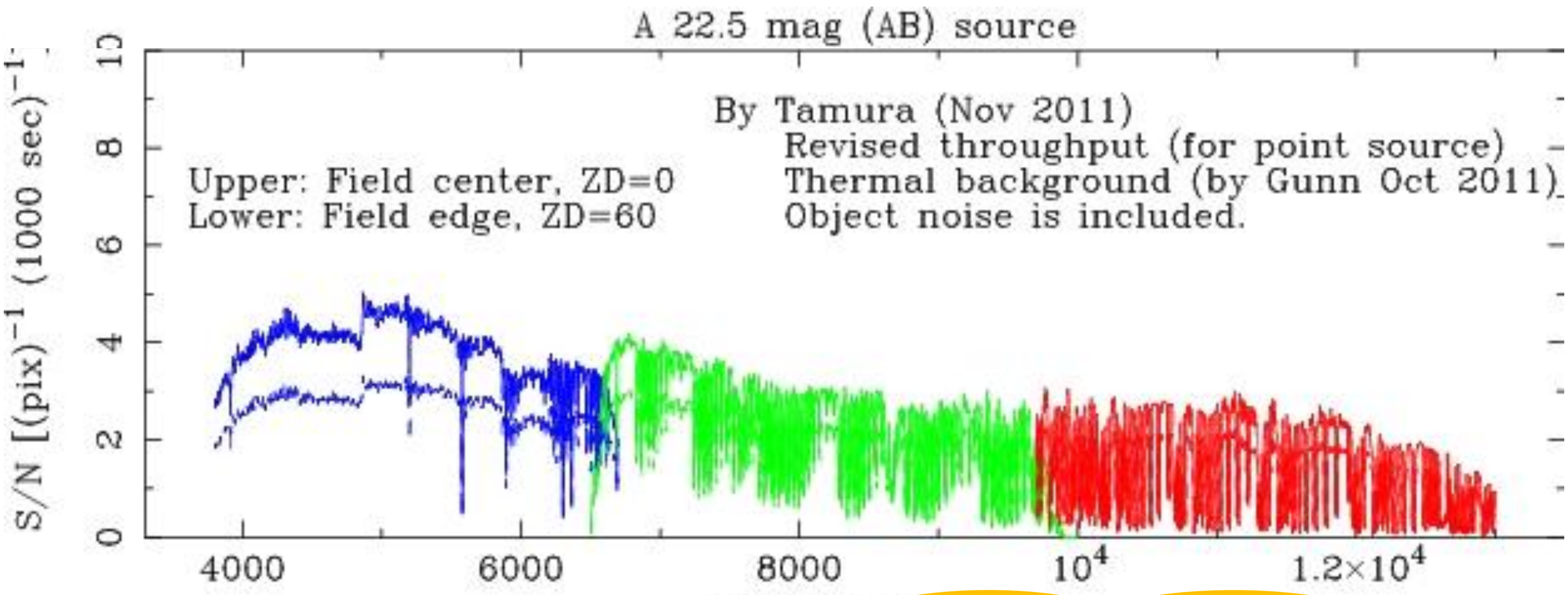


Total efficiency for field corner at el=30deg

Includes everything from sky to detector (0".64 seeing at 730nm) & aperture effect



Signal-to-noise ratio estimates



Balanced S/N ratio over
wide wavelength range

7. Major milestones (events)

Endorsement by Japanese community	2011 Jan
MOU between NAOJ and Kavli IPMU	2011 Dec
Project CoDR (Conceptual Design)	2012 Mar

現在想定しているスケジュール

Project PDR (Preliminary Design)	2013 Jan
Project CDR (Critical Design)	2013 Dec
SIR/TRR (System Integration /Test Readiness)	2016 Feb
ORR (Operational Readiness)	2016 Nov
First Light (Engineering)	2017 Jan

海外の類似計画との差別化

暗黒エネルギーの性質をLSST、Euclidなどの**巨大計画に迫る精度で、彼ら以前に**測定する。z~1–2の今までにない大規模な銀河データ、超遠方の銀河の分光データ、銀河系内星の6次元位相空間分布を得る。

なお、地上望遠鏡による多天体ファイバ分光器はBigBOSSや4MOSTをはじめ口径4メートルクラス望遠鏡で計画されているが、PFSでは**8メートルの口径を活かし高品質のより遠方**の銀河までを含むデータで対抗する。(なお、4メートルクラスでは**可視光のみ**)

またTMT時代には**target selectionにHSC+PFSが不可欠**となる。

8. PFS Summary

Optical + NIR Multi-object fiber spectrograph

- On Subaru prime focus (8.2m; F/2.2)
- Target sciences:
  - cosmology, Galactic Archaeology, galaxy/AGN evolution
- Basic parameters
  - Number of fibers 2400 (600 x 4)
  - Field of view: 1.3 deg
  - Wavelength: 0.38 - 1.3 μm
  - Spectral resolution: $\lambda/\delta\lambda \sim 3000$
- Now in Preliminary Design phase (PDR ~2013 Jan)
  - Conceptual Design Reveiw succeeded 2012 March

関連ホームページ

PFSポータルサイト

http://sumire.ipmu.jp/en/2652

(より一般向けのwwwも近日公開)

技術的なより詳細

http://pfs.ipmu.jp/factsheet/