Current Status of K-SPEC for A-SPEC

Hwang, Ho Seong[1,2], Kim, Jae-Woo[1],
Hyeonguk Bahk[2],Young-Man Choi[3], Moo Young Chun[1], Sang-Hyun Chun[2], Haeun Chung[4], Sungwook E. Hong[1], Minhee Hyun[1], Donghui Jeong[5,6], Ueejeong Jeong[2], Kang-Min Kim[2], Dongkok Kim[2], Yunjong Kim[1], Jongwan Ko[1], Chung-Uk Lee[1], Ho-Gyu Lee[1], Jong Chul Lee[1], Sungho Lee[1], Yongseok Lee[1], Hyun-Ho Lim[3], Heeyoung Oh[1], Chan Park[1], Changbom Park[6], Junsup Shim[8], Hyunmi Song[7], Mingyeong Yang[1], Yongmin Yoon[1]

[1]KASI, [2]SNU, [3]Ajou, [4]UoA, [5]PSU, [6]KIAS, [7]CNU, [8]ASIAA

Jan. 29, 2024

2024 Survey Science Group Workshop

A-SPEC All Sky Spectroscopic Survey with Korea Multi-Object Spectrograph(K SPEC)

K-SPEC Korea Multi-object Spectrograph

KASI 한국천문연구원 Korea Astronomy & Space Science Institute

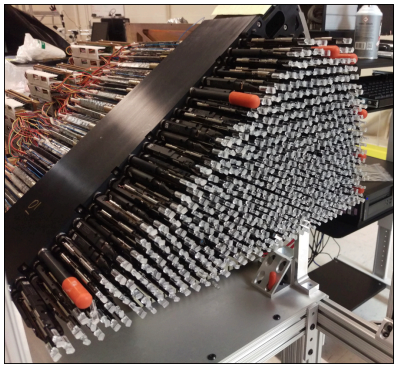
KIAS Korea Institute for Advanced Study

in S.N.U. Astronomy

Multi-Object Spectrograph System (K-SPEC) Development + Spectroscopic Survey (A-SPEC): 2 page Summary

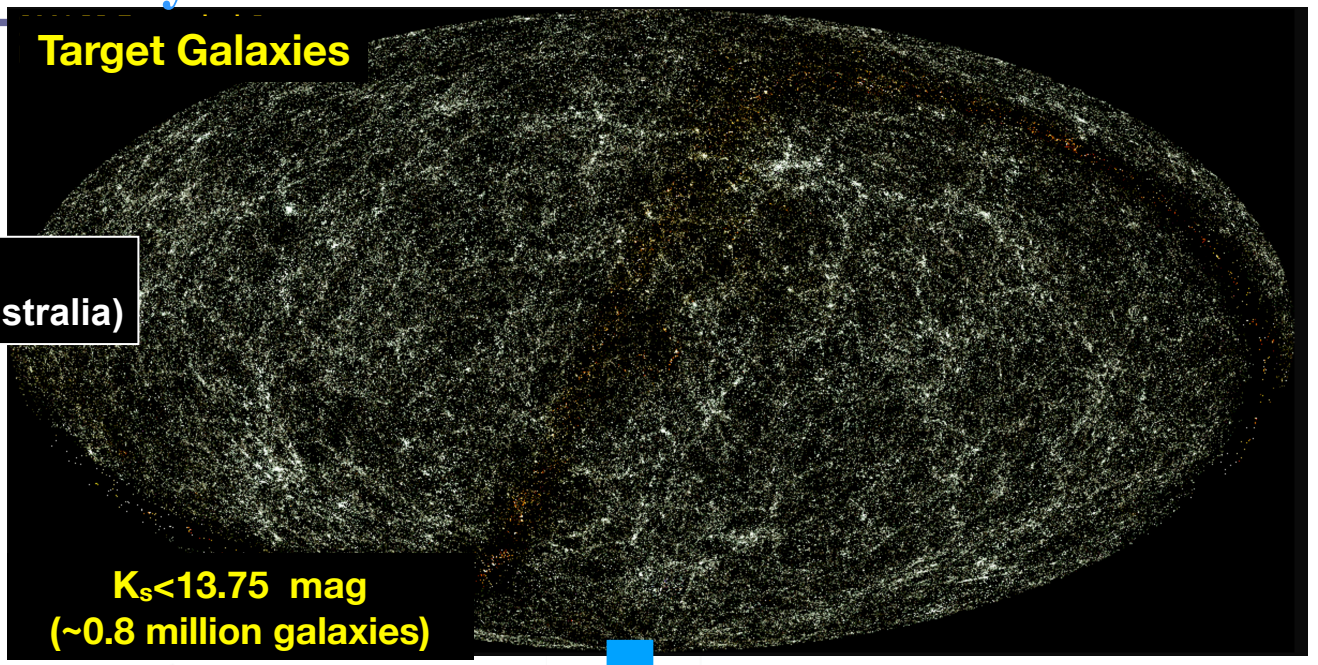
2. [2025-27]
All-sky Spectroscopic Survey

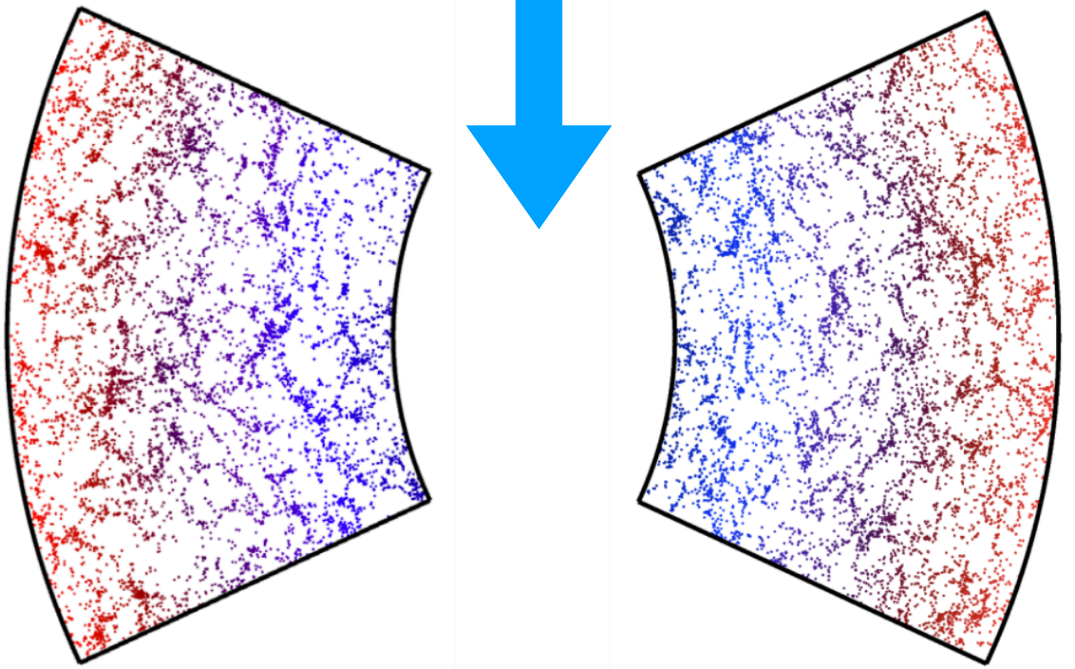
Northern Hemi.: 1-2 m class Tel.
Southern Hemi.: KMTNet 1.6 m Tel. (Australia)



1. [2021-25]
Development of MOS







3. [2027-29] Study of Cosmology and Galaxy Formation by comparing Observations (Left) and Simulations (Right)

Multi-Object Spectrograph System (K-SPEC) Development + Spectroscopic Survey (A-SPEC): 2 page Summary

Research Collaboration Agreement

MACQUARIE University

Parties	Macquarie University ABN 90 952 801 237 of North Ryde, NSW 2109 (**Macquarie**) Korea Astronomy and Space Science Institute of 776 Daedeok-daero, Yuseong-gu, Daejeon 34055, Republic of Korea (**Collaborating Organisation**) on behalf of Korea Spectroscopic Survey Consortium (KSSC) consisting of Korea Astronomy and Space Science Institute, Korea Institute for Advanced Study and Seoul National University
Agreement	The parties agree to conduct the Project on the terms set out below and in the attached document headed 'General Terms'. These General Terms and Annexures form part of this agreement.

Details	
Commencement Date	10 Dec 2021
Agreement End Date	30 Jun 2024
Project	A spectrograph for KMTNet as described in the project proposal given at Annexure 1
Chief Investigators	**Macquarie** Prof Jon Lawrence <jon.lawrence@mq.edu.au> **Collaborating Organisation** Dr. Jongwan Ko <jwko@kasi.re.kr>

한국 분광탐사사업 컨소시엄에 관한 협약서

한국천문연구원 (이하 '천문연'), 고등과학원 (이하 '고등과학원'), 서울대학교 산학협력단(이하 '서울대')은 '한국 분광탐사사업 컨소시엄' 결성 및 운영을 위하여 다음과 같이 협약한다.

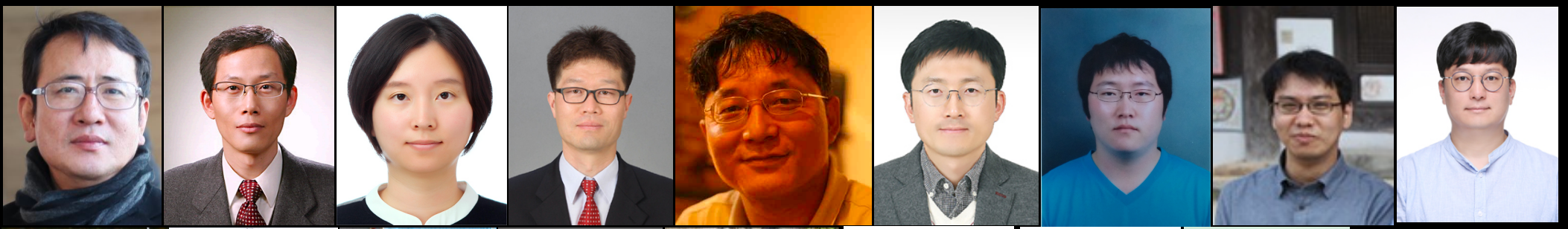
Q: Why do we want this new survey?

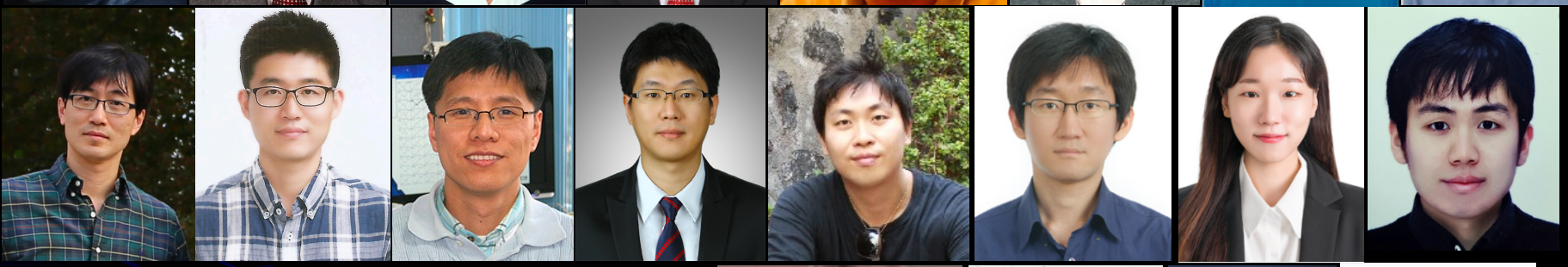
Let's
1. make MOS by ourselves, and
2. do a lot of interesting research with all-sky redshift data.

➢ Team Members (29 in total: 22 professors/staffs, 3 postdocs, 4 grad students)

➢ KASI (Project management: Planning, Manufacture, Science)

- ➢ Galaxy Evolution/Cosmology Group
  (Sang-Hyun Chun, Sungwook Hong, Minhee Hyun, Jongwan Ko, Jong Chul Lee, Jae-Woo Kim, Yongmin Yoon, Mingyung Lee)
- ➢ GMT Science/Instrumentation Group
  (Kang-Min Kim, Moo Young Chun, Chan Park, Heeyoung Oh, Ho-Gyu Lee, UeeJeong Jeong)
- ➢ Technology Center for Astronomy and Space Science (Sungho Lee, Yunjong Kim)
- ➢ KMTNet Operation Group (Chung-Uk Lee, Yongseok Lee)





Kim, Dongkok

Lim, Hyun-Ho

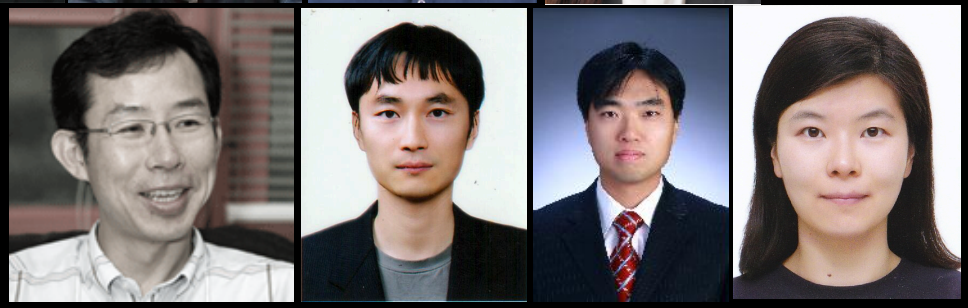
Kwon, Minseong

Bahk, Hyeonguk

Kim, Dachan

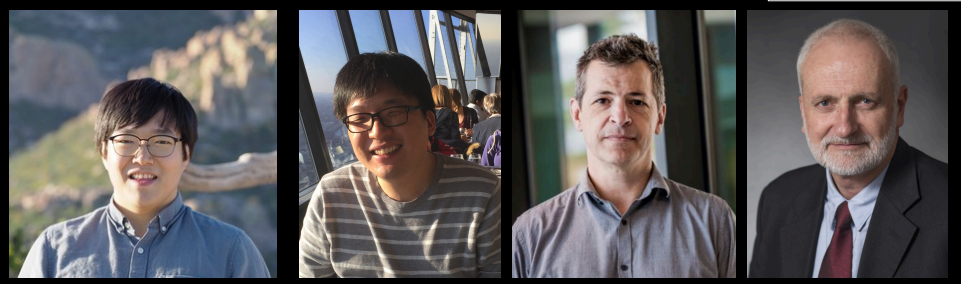
➢ Domestic Collaboration

- ➢ KIAS (Planning, Science: Changbom Park)
- ➢ SNU (Management, Manufacture: Ho Seong Hwang, Dongkok Kim, Hyeonguk Bahk, Minseong Kwon)
- ➢ CNU (Science: Hyunmi Song, Dachan Kim)
- ➢ Ajou (Fiber Positioner: Young-Man Choi, Hyun-Ho Lim)



➢ International Collaboration

- ➢ University of Arizona (MOS design: Haeun Chung)
- ➢ Penn State University (Science: Donghui Jeong)
- ➢ Macquarie University (Spectrograph: Jon Lawrence)
- ➢ Australian National University (Science: Matthew Colless)



Q: Why do we want this new survey?

➢ Immediate Goal: Construction of a complete sample of galaxies at z<0.05

- ➢ Galaxy Formation/Evolution Related…
  - ➢ Construction of complete sample of nearby galaxy clusters/groups (Song, H.)
  - ➢ Study of Galaxies with Bars (Yoon, Y.)
  - ➢ Study of Brightest Cluster Galaxies (Lee, J. C.)
  - ➢ Combination with the data including SDSS:
    - ➢ Make a complete sample of galaxies at r<17.77
      by including bright galaxies not observed in previous surveys
    - ➢ Very useful for studying the galaxies in high-density regions
      (e.g. galaxy clusters) that were incomplete in previous surveys
- ➢ Cosmology related…
  - ➢ Test of the cosmological models
    through statistical comparisons with cosmological simulations
  - ➢ Study of galaxy clustering by combining the data at z>0.05 (e.g. 2pCF, AP test):
    Trace the evolution of dark energy effects on galaxy clustering (Park, C.)
  - ➢ Measurement of density contrast of nearby universe:
    Contribute to resolve the Hubble parameter discrepancy (Hwang, H. S.)
  - ➢ Study of growth rate of the universe
    using density/momentum field of early-type galaxies (Shim, J.)
  - ➢ Study of isotropy of the universe (Shim, J.)



Speaking of Cosmology…

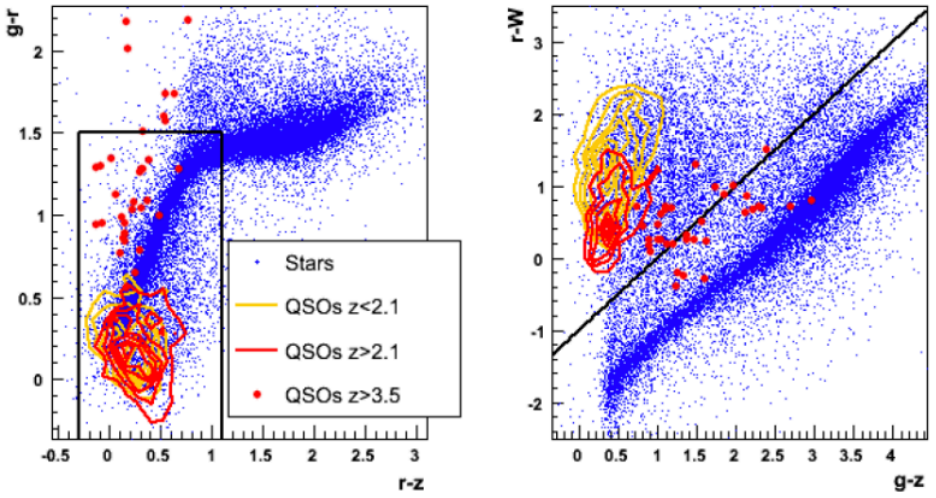
With Alexander Friedman (great-grandson of THE Alexander Friedman!) @ 2024 Korean-American Kavli Frontiers of Science Symposium, Jan. 10, 2024

Main Galaxy Target + Additional Targets

All-sky bright quasar survey

Abundance of quasars
Large-scale structure
Co-evolution of SMBH & galaxies
Line-of-sight gaseous medium
Bright-end of quasars

Quasars from limited survey area
(mainly SDSS)
Missed from deep surveys
(r>17.5 for DESI)



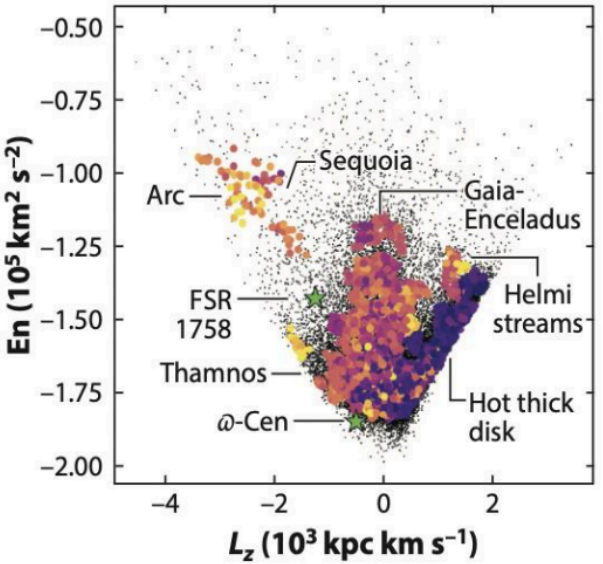
Spec. survey for stars

Complete survey of nearby stars
Unbiased survey for halo stars

Metallicity distribution
Metal poor stars

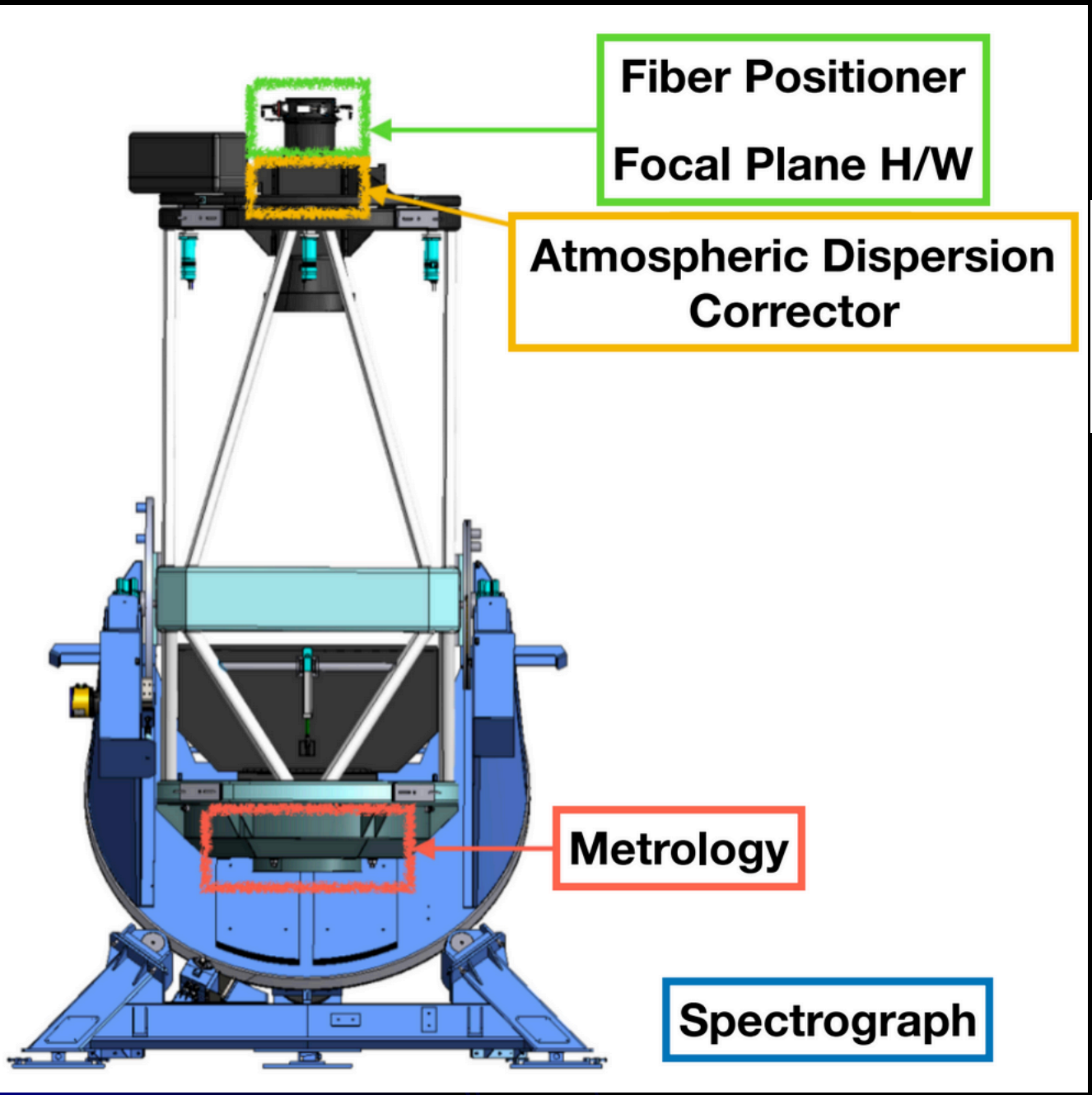
Chemical linking of substructures & streams in MW

Chemical property of streams
Formation & evolution history
Assembly history



Slide from Jae-Woo Kim

KMTNet for Spectroscopy



Commissioning with KMTNet
Dec., 2023 - Feb., 2024 +1 year

Full operation with KMTNet
Nov., 2024 +1 year

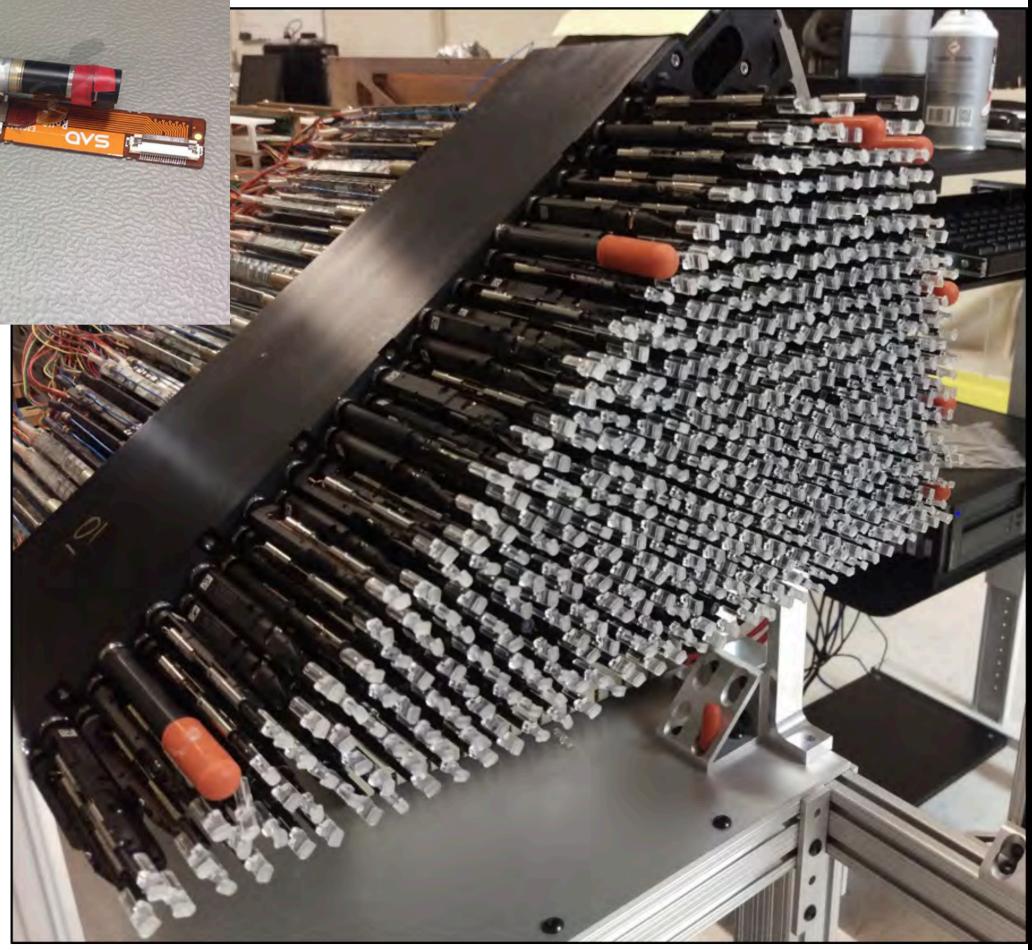
Work for KMTNet

1. Fiber Positioner
2. Fiber Cable Management
3. Wide Field Corrector
4. Spectrograph
5. Focal Plane H/W
6. Plate & Cage for Focal Plane H/W
7. Electronics, Power & Thermal
8. Metrology system
9. Interface Control System
10. Data Management
11. Instrument Storage
12. Delivery & Installation
13. Survey Plan
14. Science Cases

Slide from Jae-Woo Kim

1. Fiber Positioners

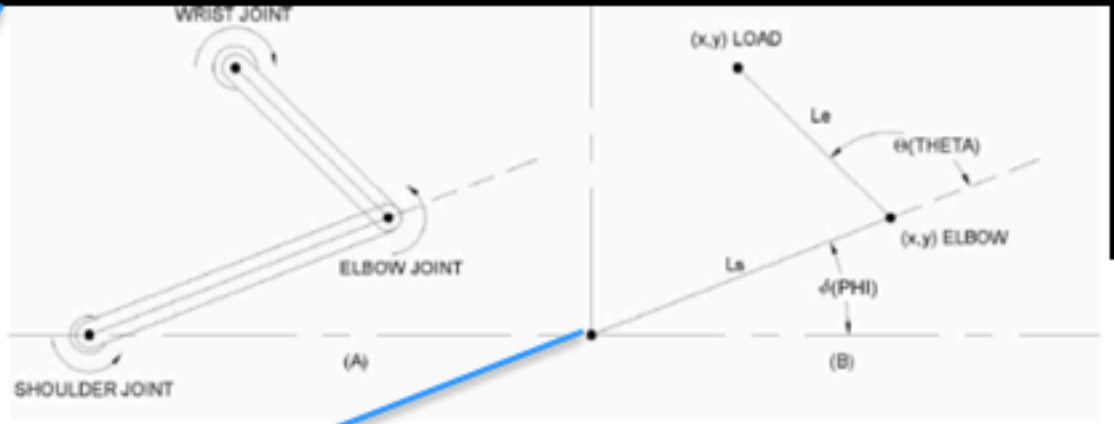


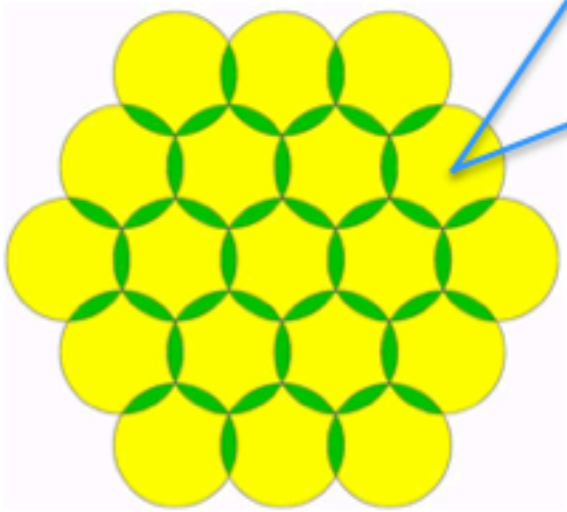


DESI

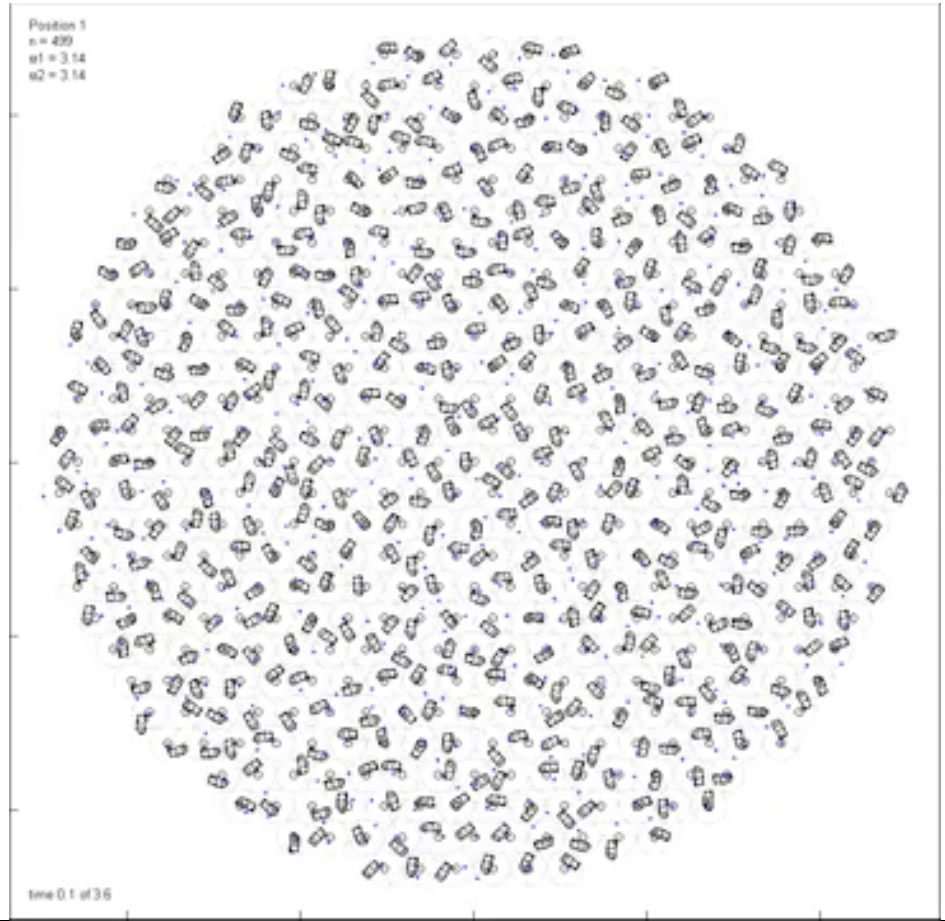
1. Fiber Positioners

Focal plane integration



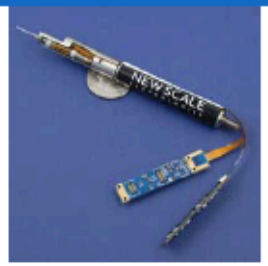
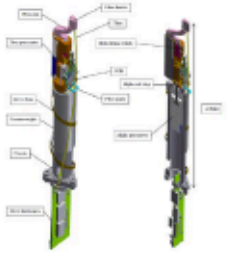


Positioners reaching their center



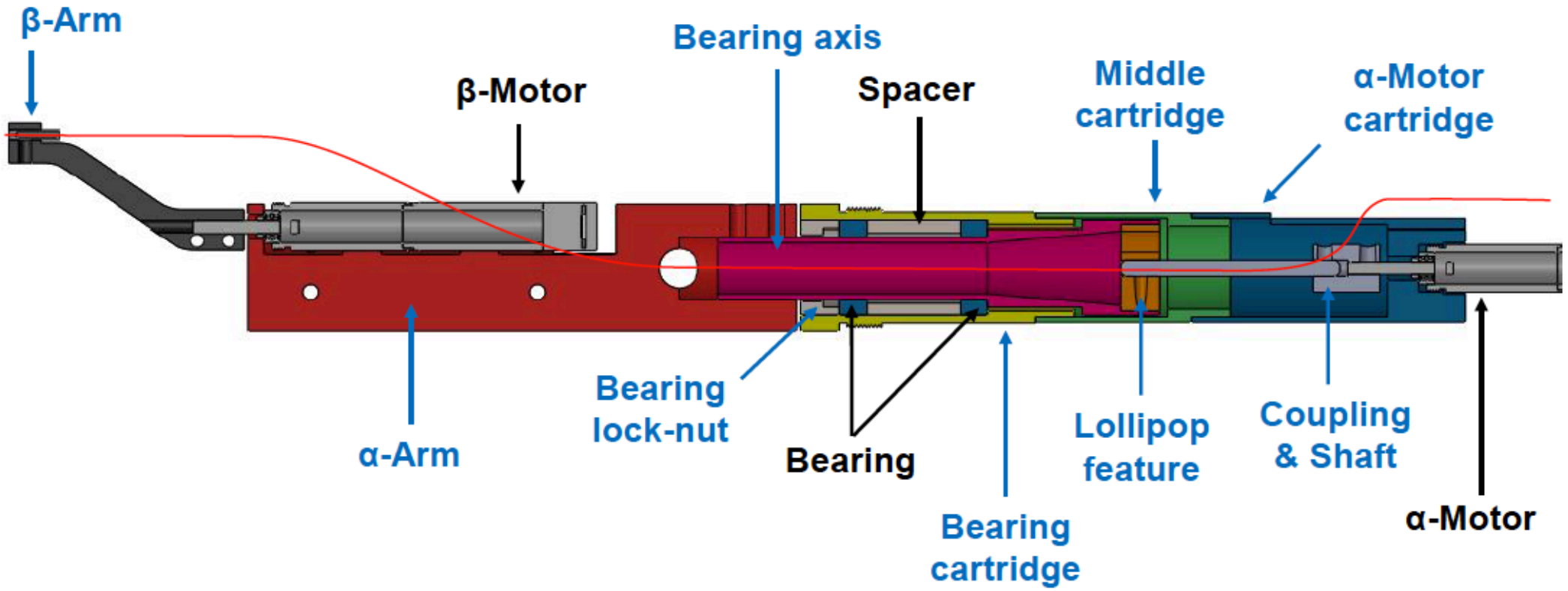
DESI

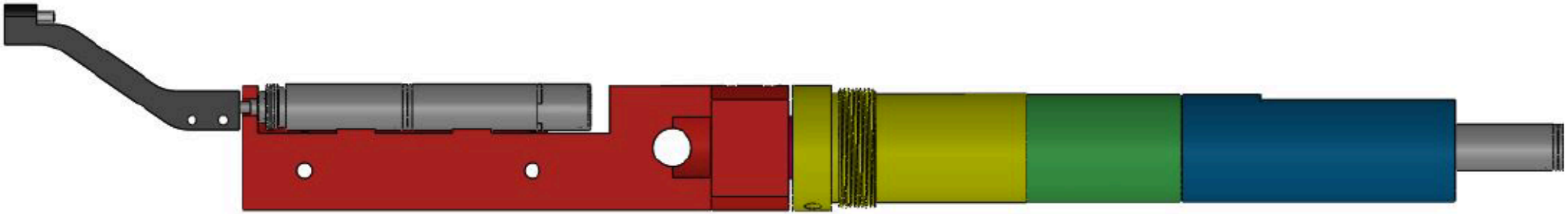
Fiber Positioners

	Cobra[1,2]	MOONS[3]	SDSS-V[4-6]	DESI[7,8]	K-SPEC
Figure					
Range	Φ 9.5 mm	Φ 50 mm	Φ 30 mm	Φ 10.4 mm	**Φ 33.2 mm**
XY Error	≤ 5 μm	≤ 20 μm	10.36 μm (bef. correc.) 1.12 μm (after correc.)	10-13 μm (bef. correc.) 1-2 μm (after correc.)	**≤ 5 μm**
Housing Dimensions	Φ 7.7 mm	-	<Φ 25 mm	Φ 8 mm	**Φ 16 mm**
Actuation Principle	Piezo motor	Stepper motor (MPS Faulhaber)	BLDC motor (MPS Faulhaber)	BLDC motor (Namiki Precision Jewel Co.)	**BLDC motor (Maxon, Swiss)**
Feedback	NO	YES(IEM3-1024)	Hall sensor	Digital hall sensor	**Magnetic encoder (256 pulse/rev)**
Telescope / Instrument	Subaru / PFS	VLT / MOONS	Apache Point / SDSS-V	Mayall 4m / DESI	**KMTNet /K-SPEC**
Research group	Caltech/ New Scale Technologies	United Kingdom Astronom y Technology Center	École Polytechnique Fédérale de Lausanne	LBNL	**Ajou Univ,/KASI**

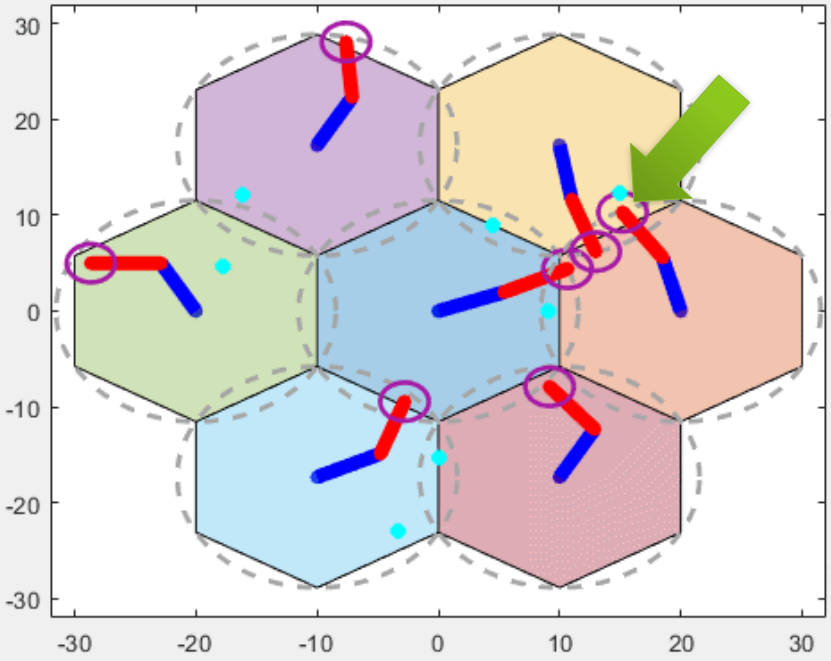
1. Fisher C., Braun D., Kaluzny J., Haran T., 2009, IEEE Aerospace Conference
2. Status Report, New Scale Technologies, 2016
3. Proc.SPIE 9908, Ground-based and Airborne Instrumentation for Astronomy VI, 990895 (9 August 2016)
4. High density fiber positioner system for massive spectroscopic surveys, MNRAS 481, 3070–3082 (2018)
5. INTERNATIONAL JOURNAL OF OPTOMECHATRONICS, 2020, VOL. 14, NO. 1, 53–77
6. An 8-mm diameter Fiber Robot Positioner for Massive Spectroscopy Surveys, MNRAS 450, 794–806 (2015)
7. The DESI experiment part II: Instrument design (2016)

Design of Fiber Positioner

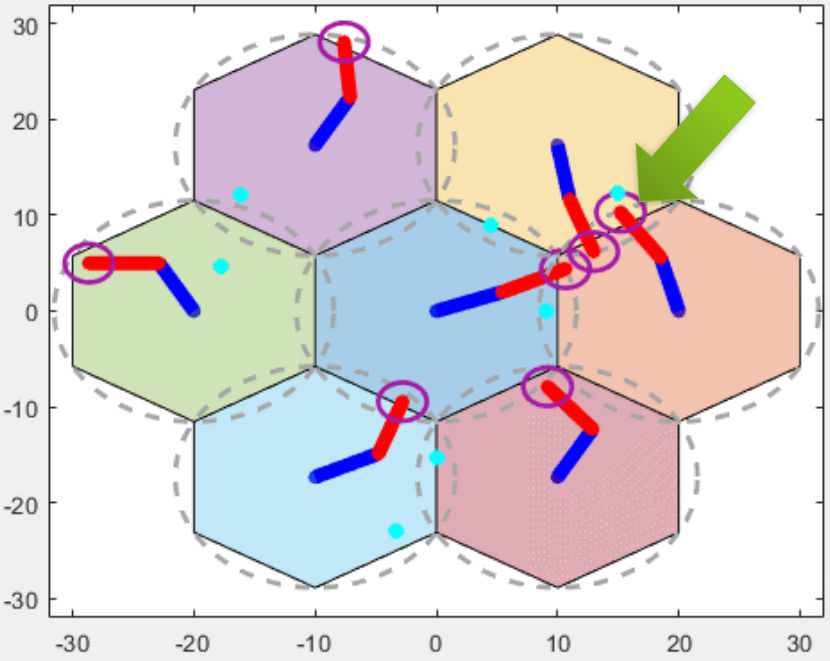




Motion Plan : Collision Avoidance Simulation

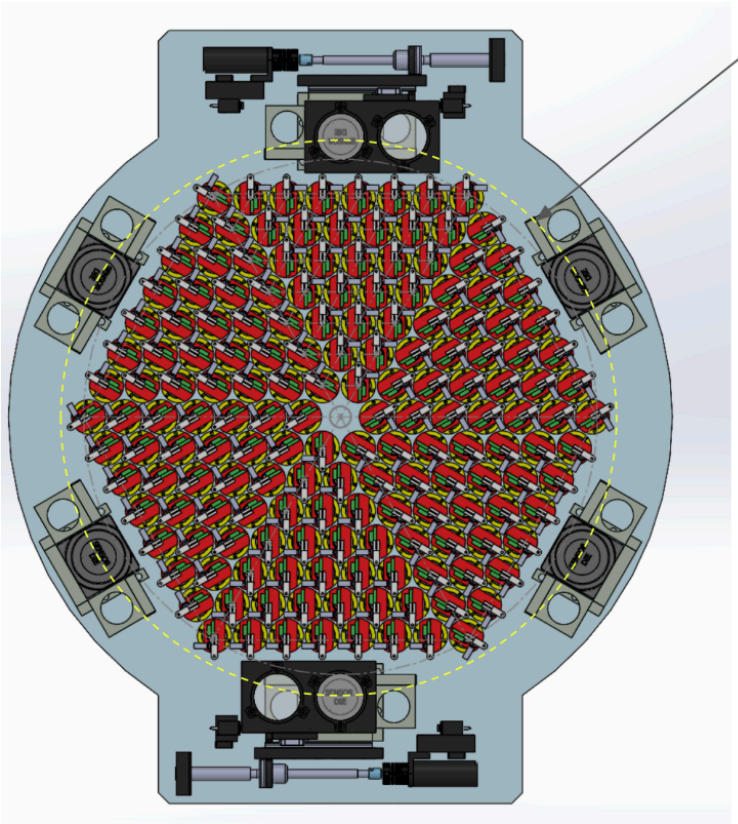


Collision avoidance 미적용

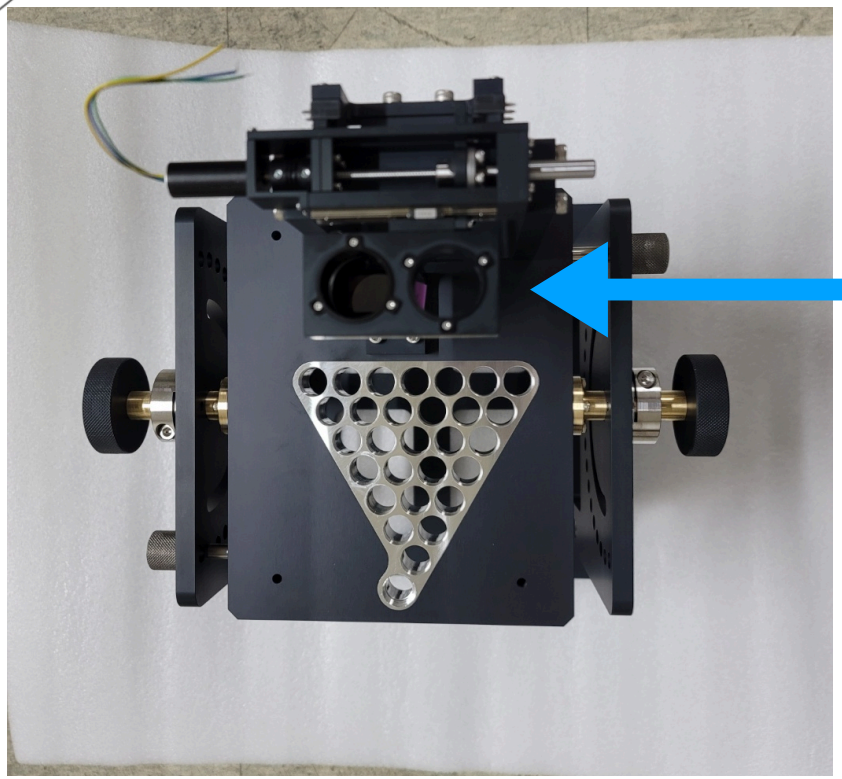


Collision avoidance 적용

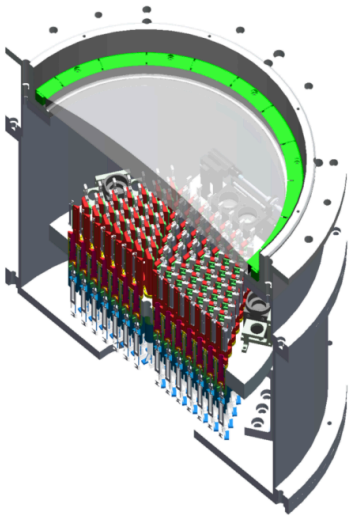
Focal Plane



Φ 260 -- diameter of guide camera center







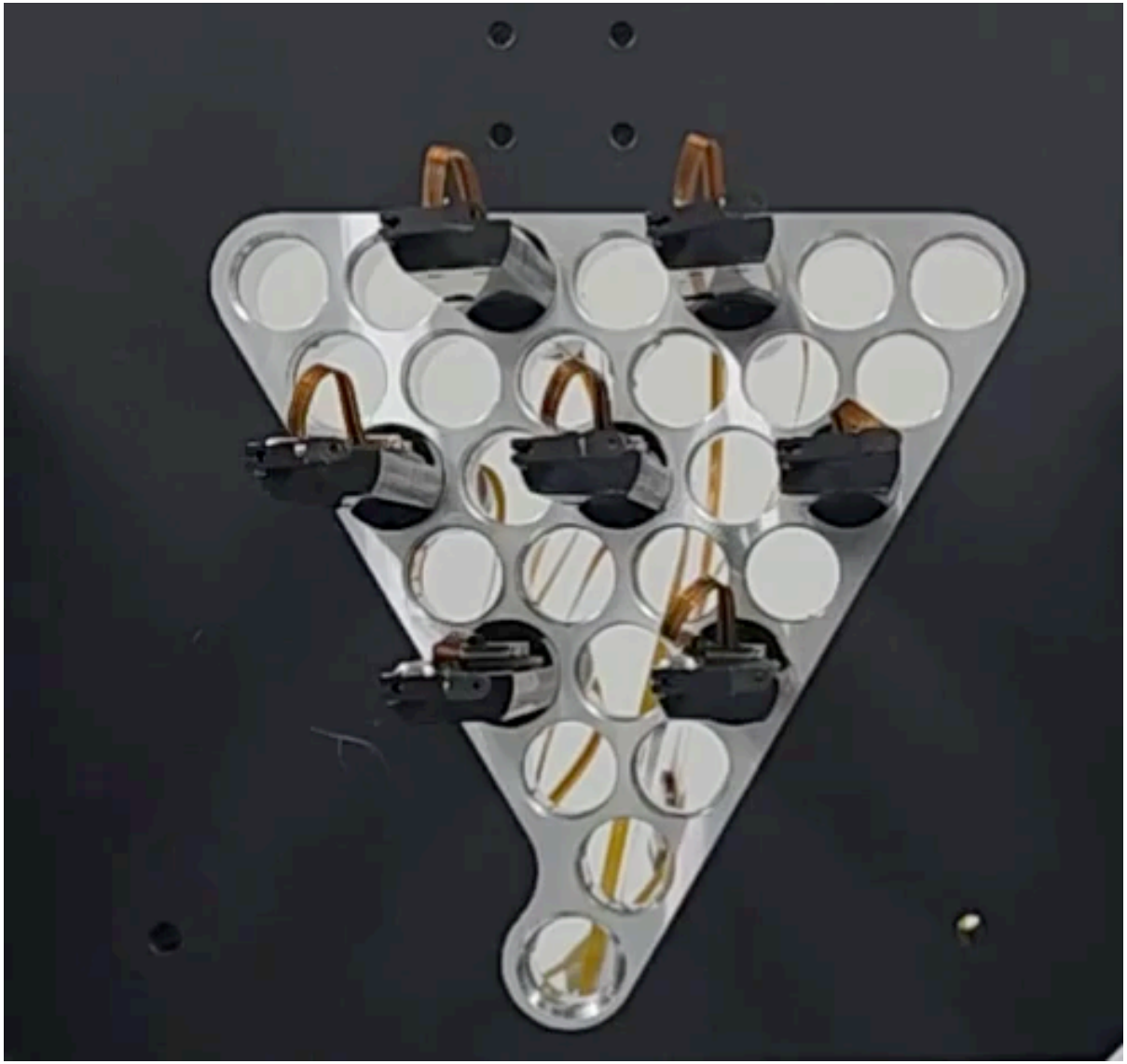
Replacing the current imaging camera

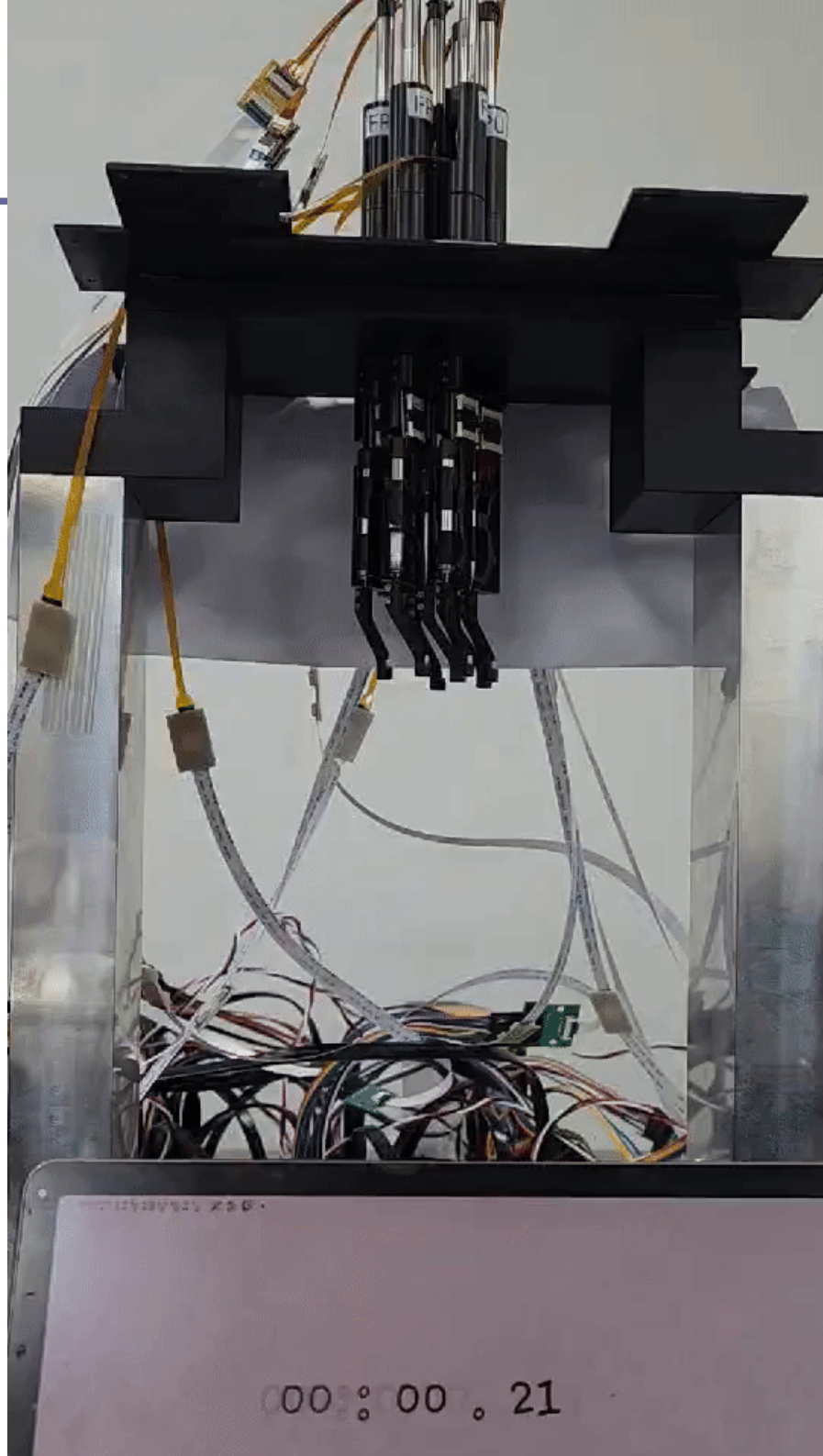
Focal Plane hosts

- **150 fiber positioners** in 256mm (= 2.8 degree) diameter
- **7 CMOS cameras** with SDSS r filters for guiding, focusing & Alignment
- **26 fiducials** as a reference for the metrology

The final one will be manufactured in the late this year.

Fiber Positioner + Focal Plane





8. Fiber View Camera (Metrology System)

Metrology system?

Fiber가 원하는 위치(타겟)에 잘 도달했는지 측정, 보정

① back illuminated fiber/fiducial 카메라로 촬영

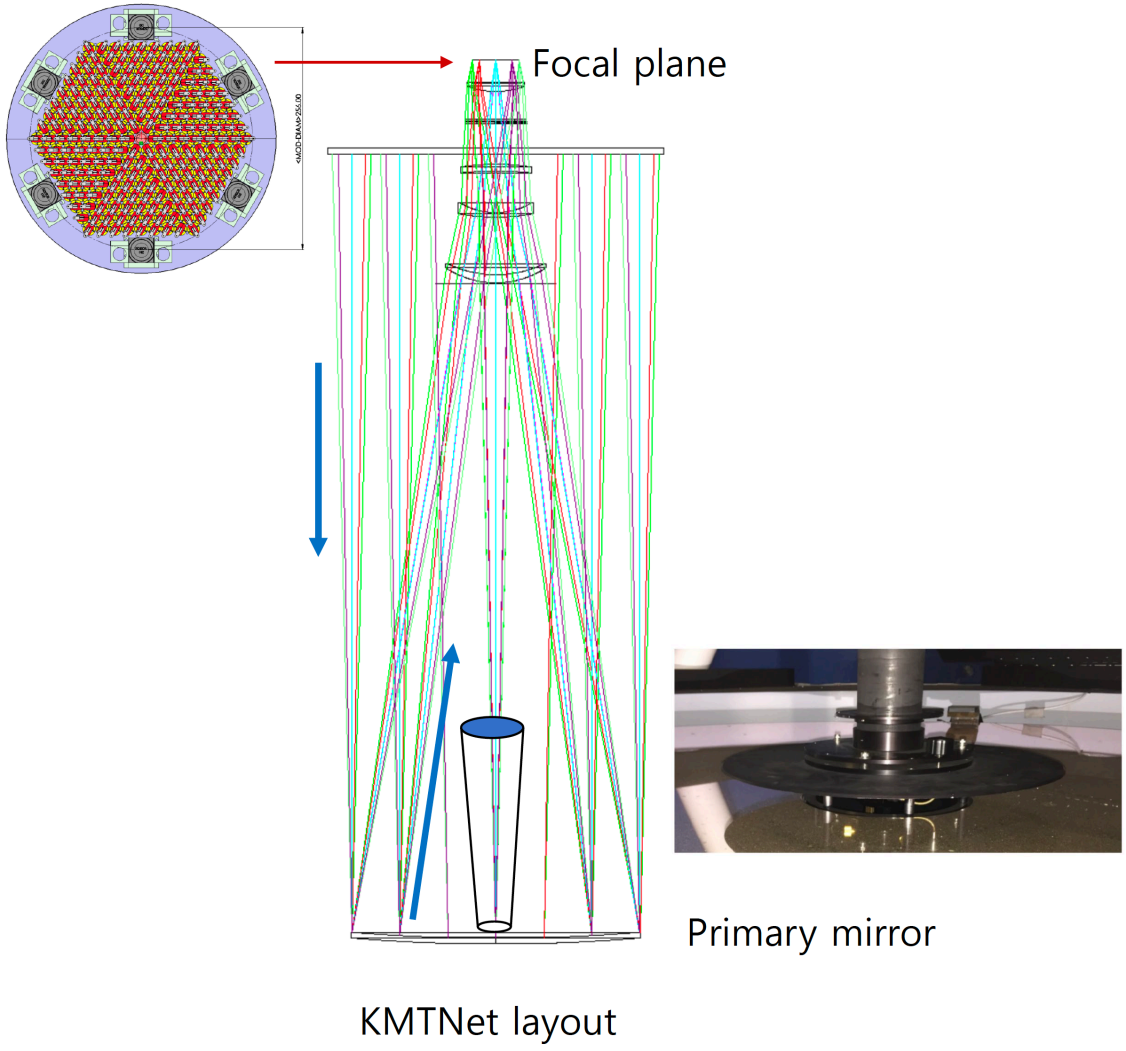
② (카메라 좌표 → focal plane 좌표) 변환

③ 위치 보정

- Requirements

1. (< ~5 μm) 위치 정밀도
2. 촬영 후 위치 보정까지의 시간

8. Fiber View Camera (Metrology System)



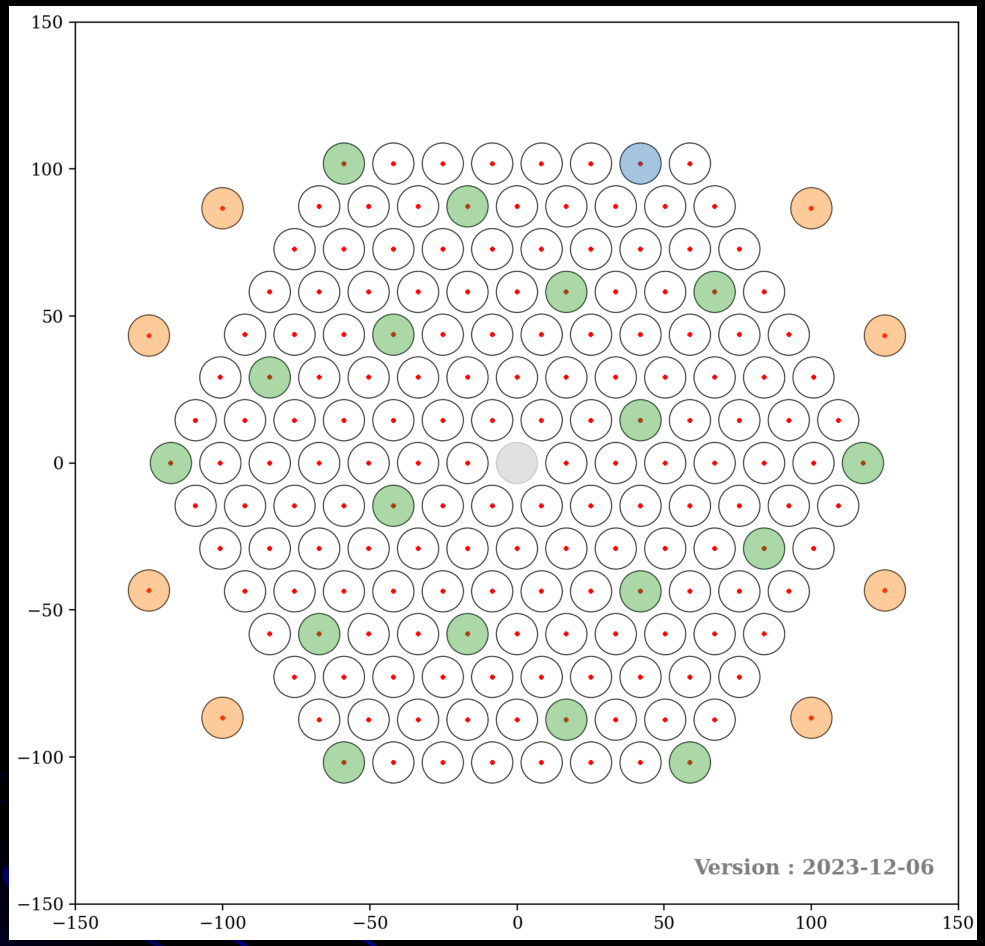
KMTNet layout

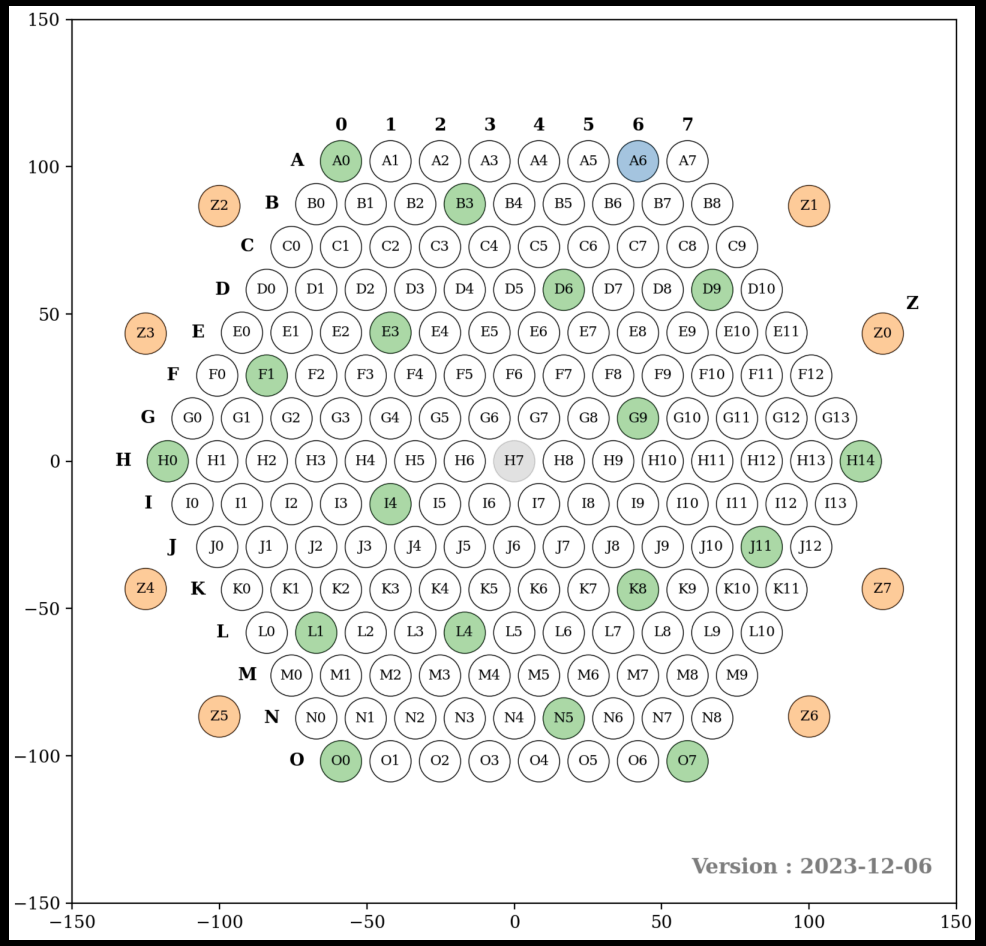


Metrology system layout

Prepared by Dongkok Kim (SNU)

8. Fiber View Camera (Metrology System)

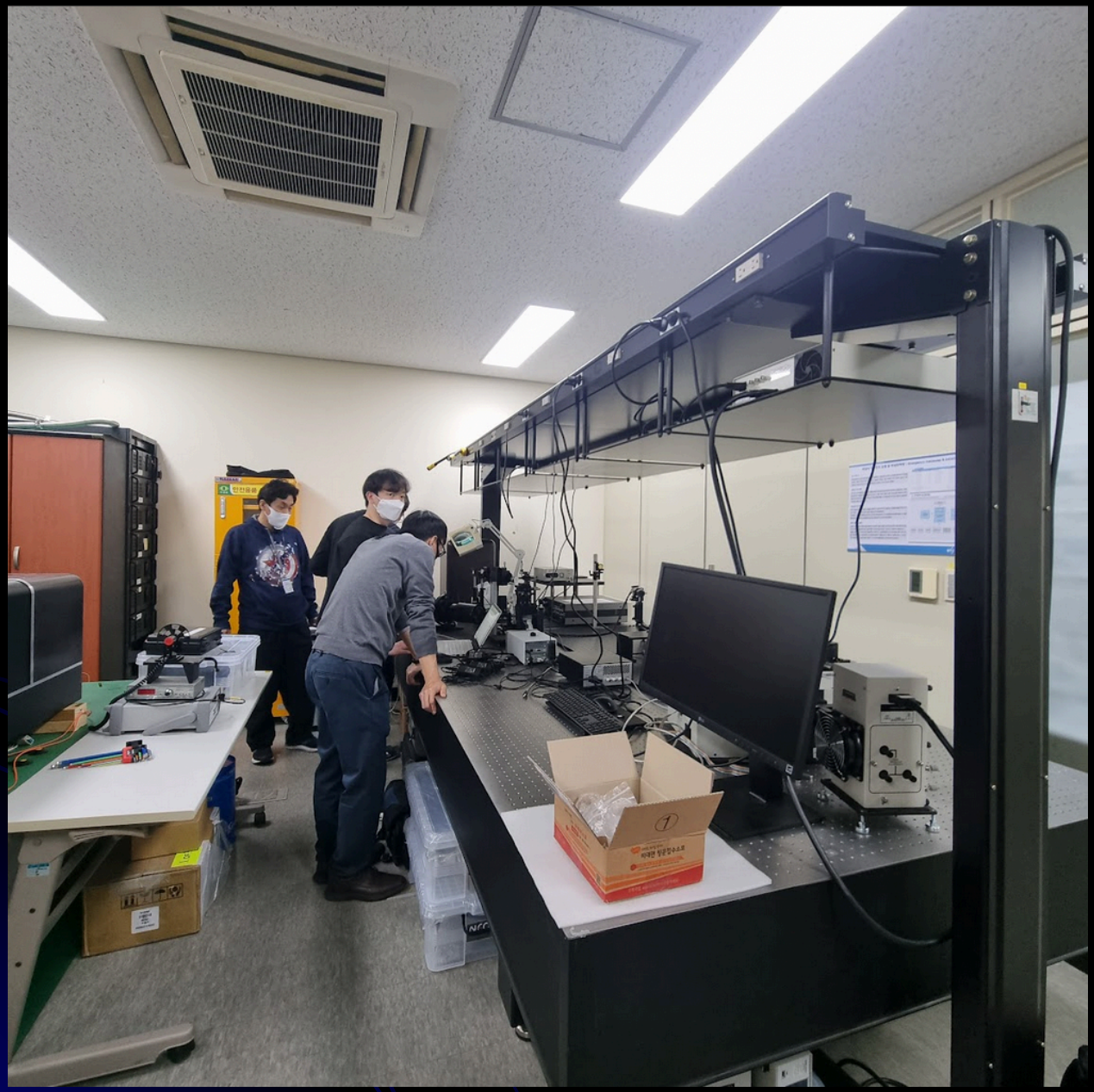




* Total number of holes: 177 (= 169 + 8)
  * Number of Fiducials: 26 (= 8 orange + 18 green/blue)
  * Number of hole used for guiding camera: 1 (gray)
  * Number of fibers for scientific observation: 150
    * For Targets: ~130
    * For Skys: ~20

Prepared by Dongkok Kim (SNU)

8. Fibers in Real World

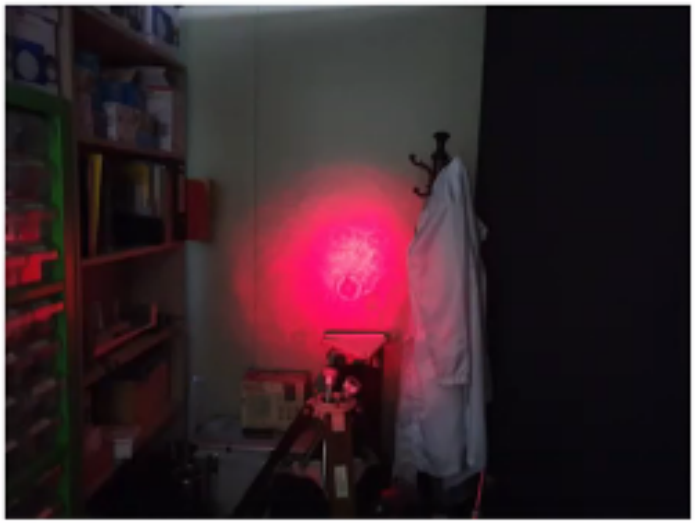




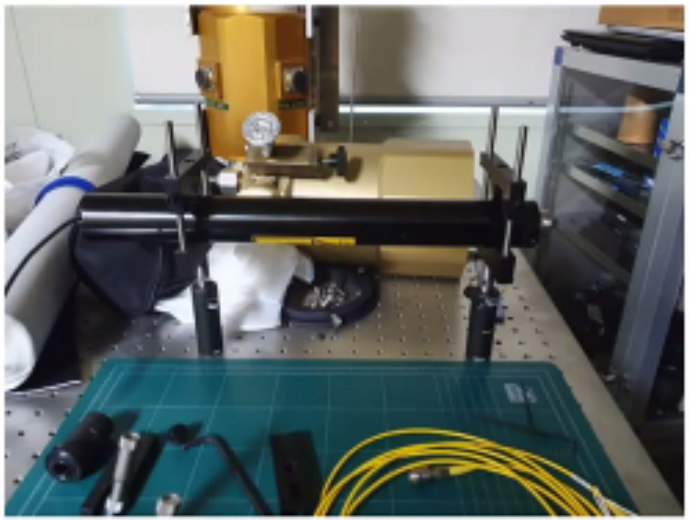
Mar. 9, 2023 [Credit: Dongkok Kim (SNU)]

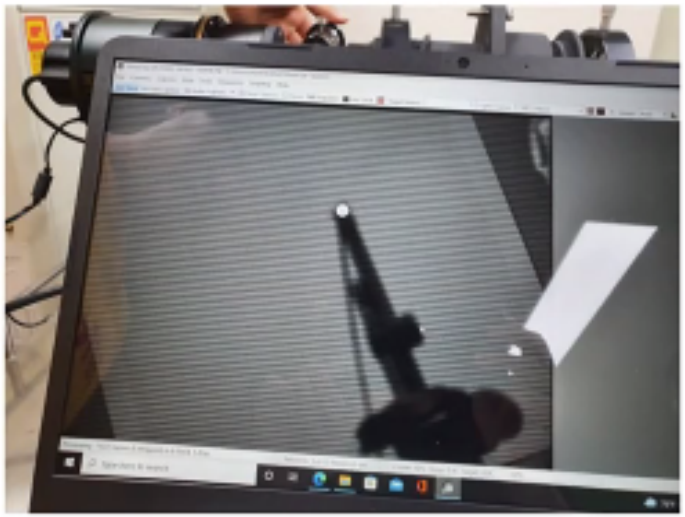
8. Fibers in Real World





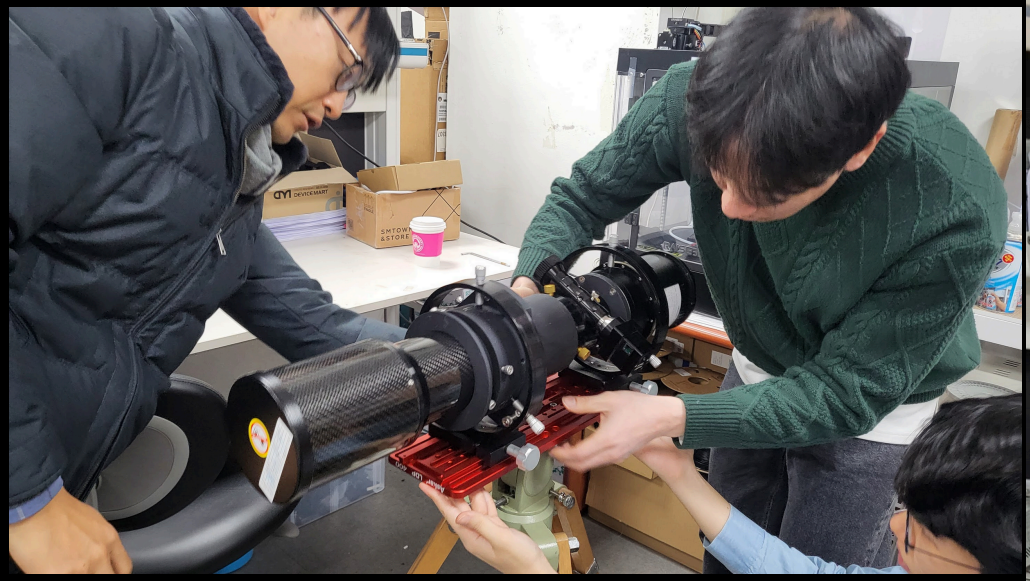


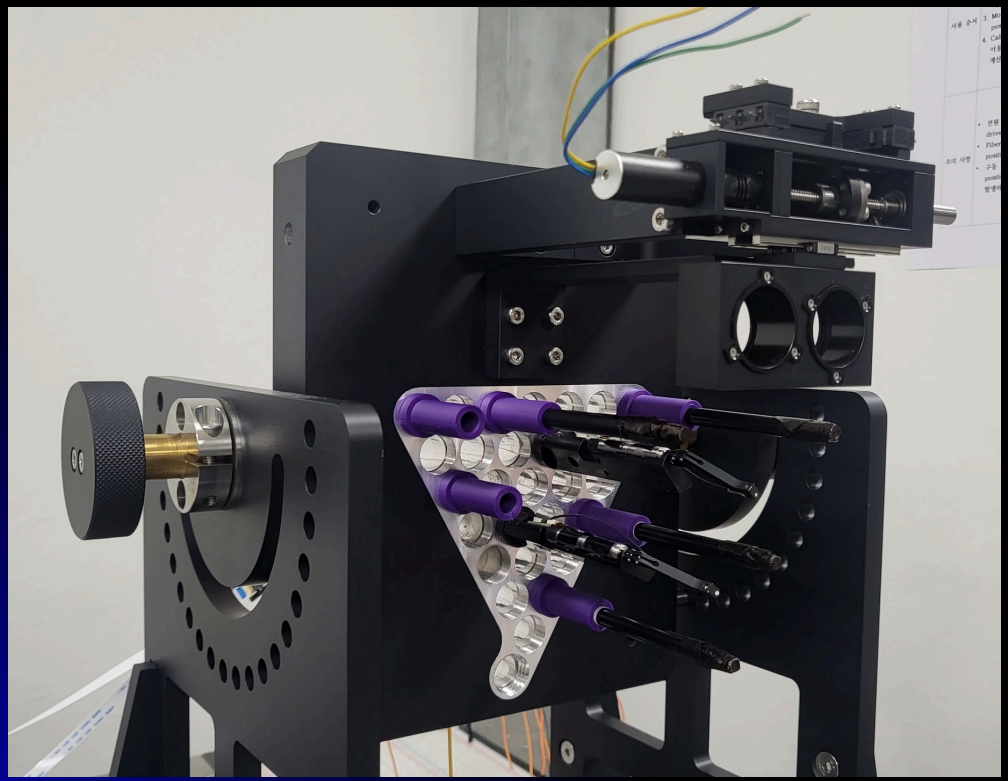




June, 2023 [Credit: Dongkok Kim (SNU)]

8. Fibers in Real World

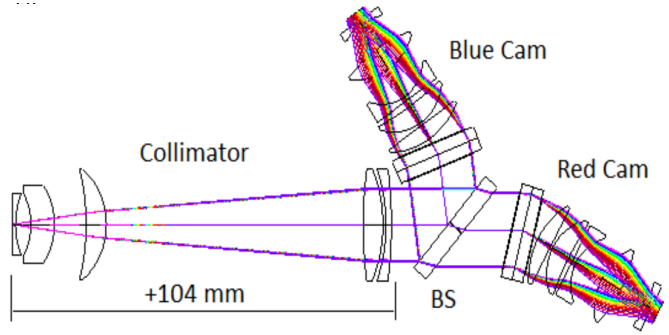


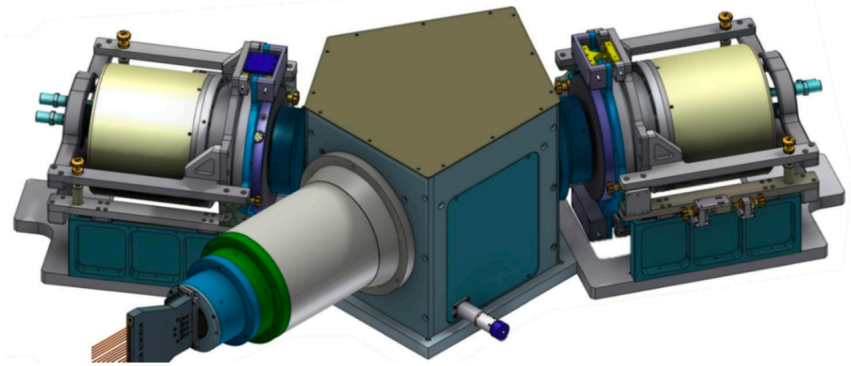


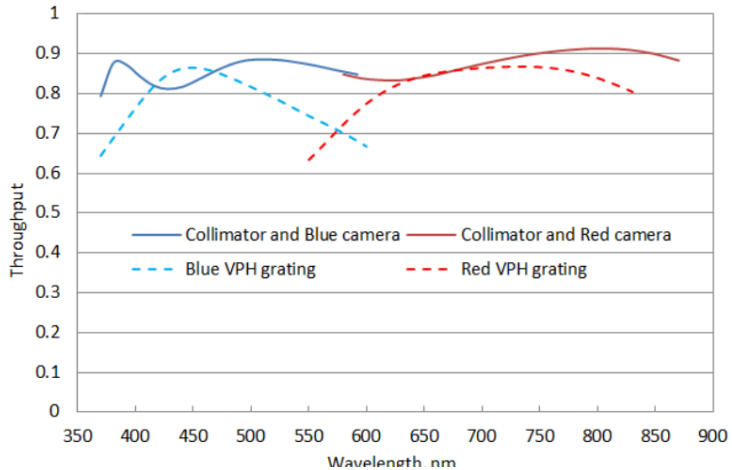


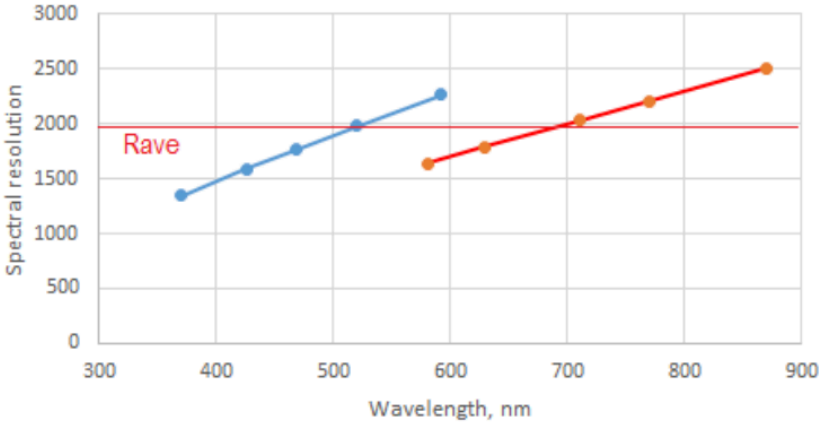
Dec. 20, 2023 [Credit: Dongkok Kim (SNU)]

Spectrograph









Collaboration with AAO in Macquarie University, Australia

Supported by the Korean Spectroscopic Survey Consortium (KASI, KIAS and SNU)

Nearly identical to the TAIPAN spectrograph

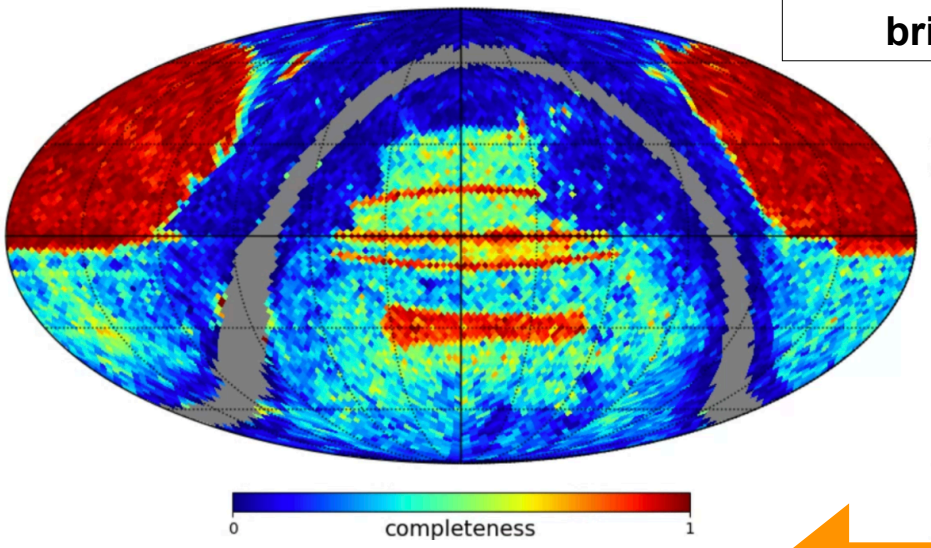
Optimized spectrograph for KMTNet

- Optics for KMTNet f/3.2
- Wavelength coverage of **370-870nm**
- Mean Spectral Resolution of **R>1600 for blue & R>1800 for red**
- **150 fibers** with a back-illumination system

Planned to be delivered by the early Feb. 2025

Survey Plan

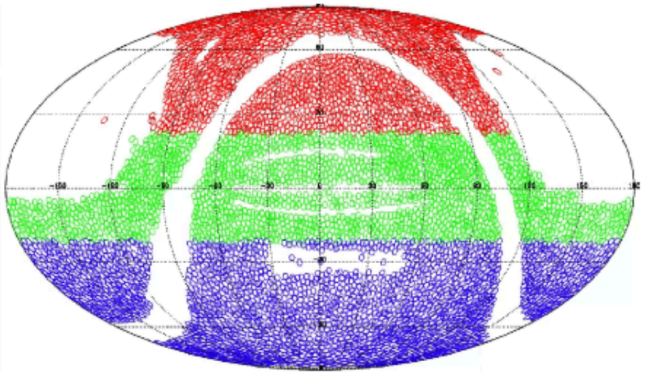
- Targets
  - Primary: ~165,000 nearby galaxies with K_S < 13.75 (Vega) & −84º.8 < Declination < −21º.4
  - Secondary (filler, bright time): metal-poor star candidates, bright quasar candidates, mid-infrared excess galaxies, etc.



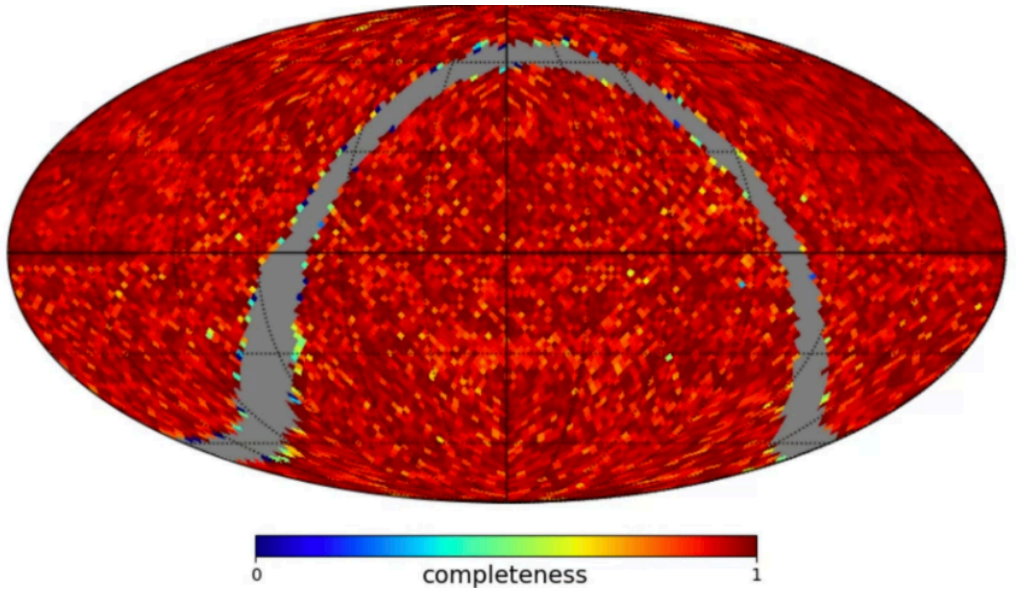
Currently, for Ks<13.75 galaxies

- 41.9% completeness for decl.<22.3
- 33.6% completeness for decl.<0

Tiling

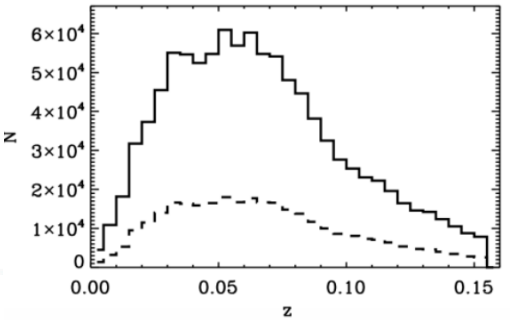


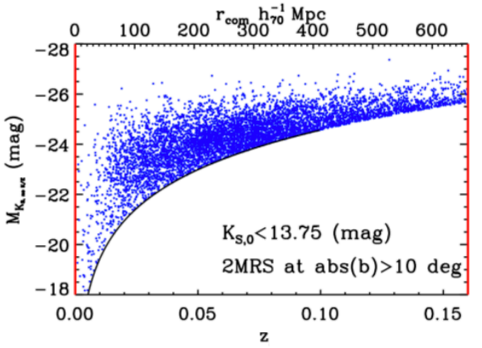
Blue is for this PHASE 3



Aiming >90% completeness

- For Ks<13.75 galaxies (~782,000 sources)
- On the nearly entire sky





Survey Plan

KMTNet Phase 3 Observation Proposal

1. Research Title: A Spectroscopic Survey for the Nearby Universe with KMTNet

2. Organization of Research Team

PIs: Jae-Woo Kim (KASI, kjw0704@kasi.re.kr) & Ho Seong Hwang (SNU, galaxy79@snu.ac.kr)
Co-Is:
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University of Arizona: Haeun Chung (haeunchung@arizona.edu)
Australian National University: Matthew Colless (matthew.colless@anu.edu.au)
Macquarie University: Jon Lawrence (jon.lawrence@mq.edu.au)

- **Goal: S/N=5 for a galaxy with r_{fiber}=19.1 => required exposure time: 13.8 mins**
- **So, nominal exposure time = 3x5 min (will be adjusted according to the Moon phase)**

- **Bright time (5 days per month): other programs (e.g.: stars, quasars) will be conducted.**

- **Observing Time**
  - **~6000 tiles to complete the survey with 90% completeness (red + green + blue)**
  - **4286 tiles are accessible at the KMTNet SSO (-84°.8<Decl.<22°.3)**
  - **2198 tiles with Decl.<-21°.4 for this Phase 3**
  - **2198 tiles × [15 min per tile × 1.6 airmass & moon factor (from scheduling sim.) + 3 min ohd]**
    × 1.5 weather factor (by considering 65% observation rate at the KMTNet SSO)
    / 7.1 hours per night (average for the non-bulge season)
    / 60 minutes per hour
    = 209 nights
  - **209 nights with three blocks of non-bulge season from February 2025**
    - **19 nights from February 1st to 19th 2025**
    - **120 nights from October 23rd 2025 to February 19th 2026**
    - **70 nights from October 23rd to December 31st 2026)**

시민과함께과학

Science with Citizens

고등과학원 Open KIAS 센터에서 주관하는 "시민과 함께 과학"은 과학자들이 실제로 활용하는
방대한 양의 자료를 대중에게 공개함으로써 시민들이 직접 연구 자료를 가공하여 연구에 참여할 수 있도록 합니다.
과학자들은 시민들의 결과를 이용하여 더 유의미한 분석을 수행함으로써 과학 연구의 선순환을 기대할 수 있습니다.

프로젝트

모두의은하연구소

별과 은하들은 어떻게 태어났을까요?





우주선뮤온입자찾기

Comming soon

A-SPEC 은하분류 프로젝트

밤하늘에는 수많은 별이 있습니다. 또 수많은 은하들이 있습니다.
이런 별과 은하들은 어떻게 태어났을까요?
시민 여러분들과 함께 이 질문에 대한 답을 찾고 싶습니다.

연구의 목표

은하는 태양과 비슷한 별이 수천억 개 정도 모여 있는 집단입니다. 특히 블록 놀이의 조각처럼, 거대한 우주를 연구하는 데 있어서 기본 단위가 되는 아주 중요한 천체입니다. 실제로 우주가 빅뱅 이후 138억 년 동안 어떤 역사를 거쳐서 진화하고 성장했는지를 이해하기 위해서는, 바로 이 은하들의 다양한 특성을 이해하는 것이 매우 중요합니다. 이번 과제는 시민과 함께 은하들의 형태를 시각적으로 분류함으로써 우주를 이해하는 연구에 유용한 자료를 만드는 데 그 목표가 있습니다.

우주의 역사를 연구하기 위해서 고등과학원, 한국천문연구원, 서울대학교가 힘을 합쳐 A-SPEC (에이스펙, The All-sky SPECtroscopic survey of nearby galaxies)이라는 은하 분광 탐사를 준비하고 있습니다 (이 탐사를 위해 제작 중인 기기는 K-SPEC(케이스펙)이라고 합니다). 이 탐사를 통해 정교한 우주 지도를 만들 계획입니다. 우주 지도의 자세한 분석을 위해서 은하의 다양한 정보가 필요한데, 한 가지 부족한 것이 바로 형태 정보입니다. 이 형태 정보는 은하가 타원 모양인지, 나선 모양인지, 불규칙 모양인지 등을 의미합니다. 이 정보를 얻기 위해서는 은하의 다양한 특징을 종합적으로, 정확하게 판단하는 것이 필요한데, 최고의 도구는 바로 사람의 눈입니다. 그동안 컴퓨터를 이용한 분석을 통해서 많은 자동 분류 작업이 진행되었지만, 은하 형태의 복잡성 때문에 그 결과가 여전히 만족스럽지 못한 상황입니다. 따라서 이번 과제를 통해 A-SPEC 분광 탐사에서 분석하게 될 약 80만 개 은하의 형태 분류를 진행하고자 합니다. 이 분류 결과는 천문학자들이 우주 역사를 연구하는 데 아주 중요한 자료로 활용될 예정입니다.

시민과 함께 과학 Mission Galaxy
과제지도단장 황호성 / 과제지도단원 박보미

85 Hoegiro Dongdaemun-gu,
Seoul 02455,
Republic of Korea.

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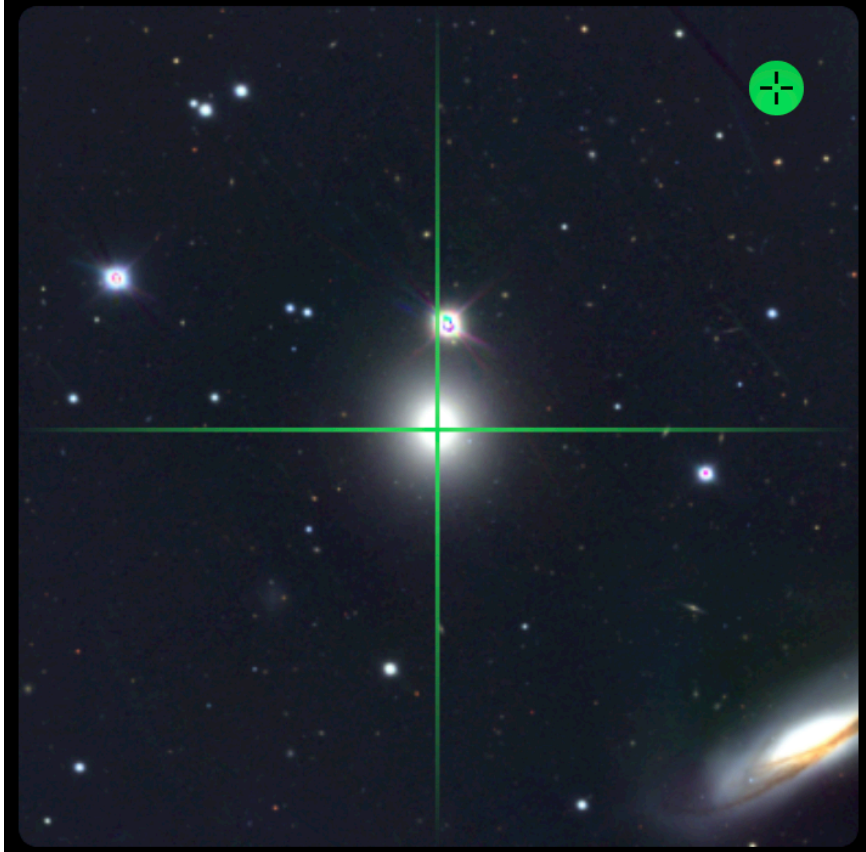
개인정보 처리방침



Mission STEP 01

튜토리얼 은하 분류중..
각 항목의 의미를 모르겠다면, 질문 오른쪽의 아이콘을 눌러보세요

힌트

빛이 매끄럽게 퍼지는 원형의 은하입니다.그 외에 특별한 모습은 보이지 않는군요.

가지고 있나요?

3. 나선팔이 있나요?

4. 고리 모양의 특징이 보이나요?

5. 위에 언급된 일정한 형태를 가지고 있지 않은 모습인가요?

6. 은하 중심에 막대가 보이나요?

7. 다른 은하와 상호작용 또는 합병하는 은하인가요?

8. 조석력에 의한 꼬리 모양의 특징이 보이나요?

9. 위의 질문에 없는 다른 특징이 있나요?
(은하를 에워싼 아크, 은하 중심에 여러 밝은 점, 매우 빛나는 은하 중심핵 등)

튜토리얼 종료하기 가이드북 채점하기 >

참가증명서

황 호 성 시민연구원

시민과함께과학은 모두의 은하 연구소에서

2023.12.20.-2024.01.22 동안

0개 의 은하 이미지를 식별하는데

참여한 공로를 인정하여 이 증서를 드립니다.

2024.01.22

OPEN KIAS 센터장 박창범

시민과 함께 과학 Mission Galaxy 과제지도단장 황호성

Summary

1st Korean MOS instrument (K-SPEC)
for all-sky spectroscopic survey (A-SPEC)

KMTNet SSO for the southern hemisphere survey
- Assembly of main components at KASI (Mar-May 2024)
- Commissioning observation at Feb. 2025

1st MOS instrument & large spectroscopic survey by Korean researchers
Currently, most components are under test!!!

Hope to present nice results in a few years!!!

Thank you!