Primary results from ground-based lunar observations in China

Presented by Lin Chen

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NSMC

GSICS Global Space-based Inter-Calibration System

Outline

- ***Ground-based Lunar observation Implementation***
- ***Lunar observation location and Atmospheric observations***
- ***Primary Lunar Observation Results***
- ***Lessons from the experiments***

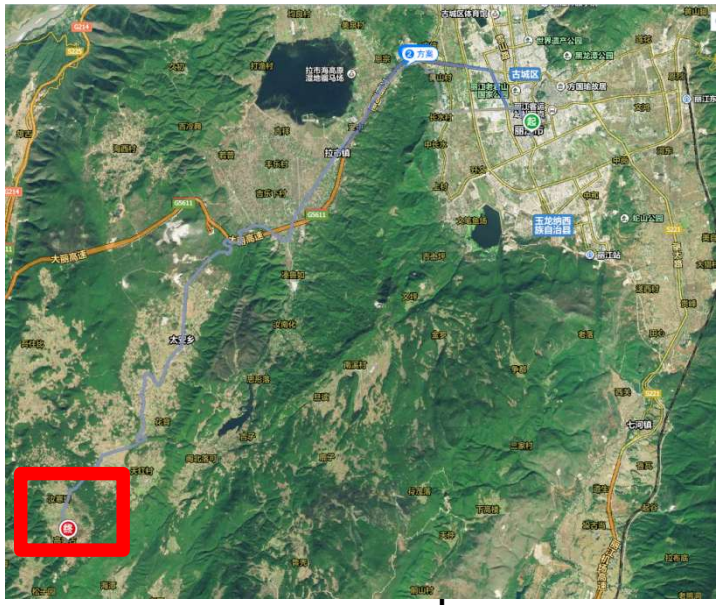
Ground-based Lunar observation Implementation

- Lunar observation concept and Instrument development
  - Lunar Imaging spectrometer
  - Hyspectral lunar-photometer
- Ancillary measurement for lunar observation data processing
  - Aerosol: Lidar or photometer
  - Atmosphere sounding profile
  - on-site Instrument checking and calibration
- Observation site selection
  - High altitude (>2km)
  - Clean and arid atmosphere
  - More clear sky
- Observation plan design
- Data processing
  - Data calibration and quality control
  - Atmosphere correction
  - Lunar phase and angle calculation
  - Model validation and improvement

Lunar observation location selection

- Lingshan
  - First instrument testing
  - Near from Beijing (122Km)
  - Latitude:2100m
  - No air pollution

- Lijiang
  - Formal experiment
  - Location:100°01′51″E，26°42′32″N
  - Latitude : 3193m
  - Near from Astronomy station



Lunar Instruments Testing experiments

- First Instrument Testing experiment in Lingshan, Beijing (June 24--July 3, 2015)
- Second Instrument Testing in Dunhuang, Gansu Province (August 20--Sep 3, 2015)
- Formal ground-based Lunar Observation for three months in Lijiang, Yunnan (Dec 17, 2015-- March 1, 2016)

Lingshang, Beijing

Ground-based Lunar instruments

	Instruments	Vendor	Spectral	Location	Remarks
Lunar instruments	Lunar imaging spectrometer	Changchun	400-1000nm Resolution: 2~10nm	Lingshan, Dunhuang, Lijiang	Lunar imaging Autom tracking
	AOTF imaging spectrometer	SITP	450nm~1000nm，2~8nm	Lingshan, Dunhuang	Manual tracking
	Shortwave Infared imaging HSFTS	Xi an	900nm~2500nm，60 bands	Lijiang	Manual tracking and imagomg
	Hyspectral lunar-photometer	Changchun	350-1100nm 1~5nm	Lingshan, Dunhuang, Lijiang	Lunar irradiance Autom tracking
	CE318U-lunar-photometer	CIMEL	10 bands	Dunhuang, Lijiang	Lunar irradiance Autom tracking
Ancillary instruments	Lidar	704 Institute	532nm; 1064nm	Lijiang	Aerosol at night
	CE318 sun-photometer	CIMEL	9 bands	Lijiang	Aerosol at daytime
	Atmosphere sounding	VISALA		Lijiang	Atmosphere profile
Reference instrument	ASD FieldSpec® 3	ASD	350-2500nm	Lingshan, Dunhuang, Lijiang	Calibration and stability monitoring

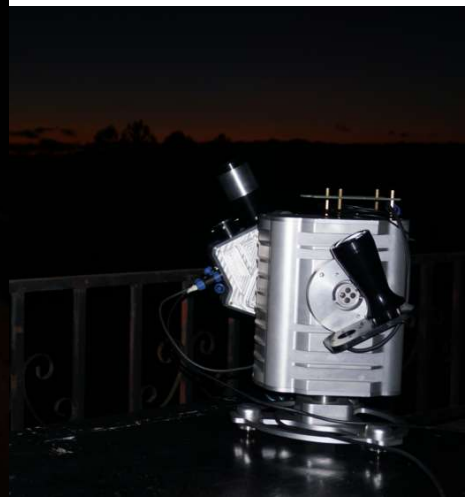
Lunar Observation in Lijiang, Yunnan

Lunar Imaging Spectrometer

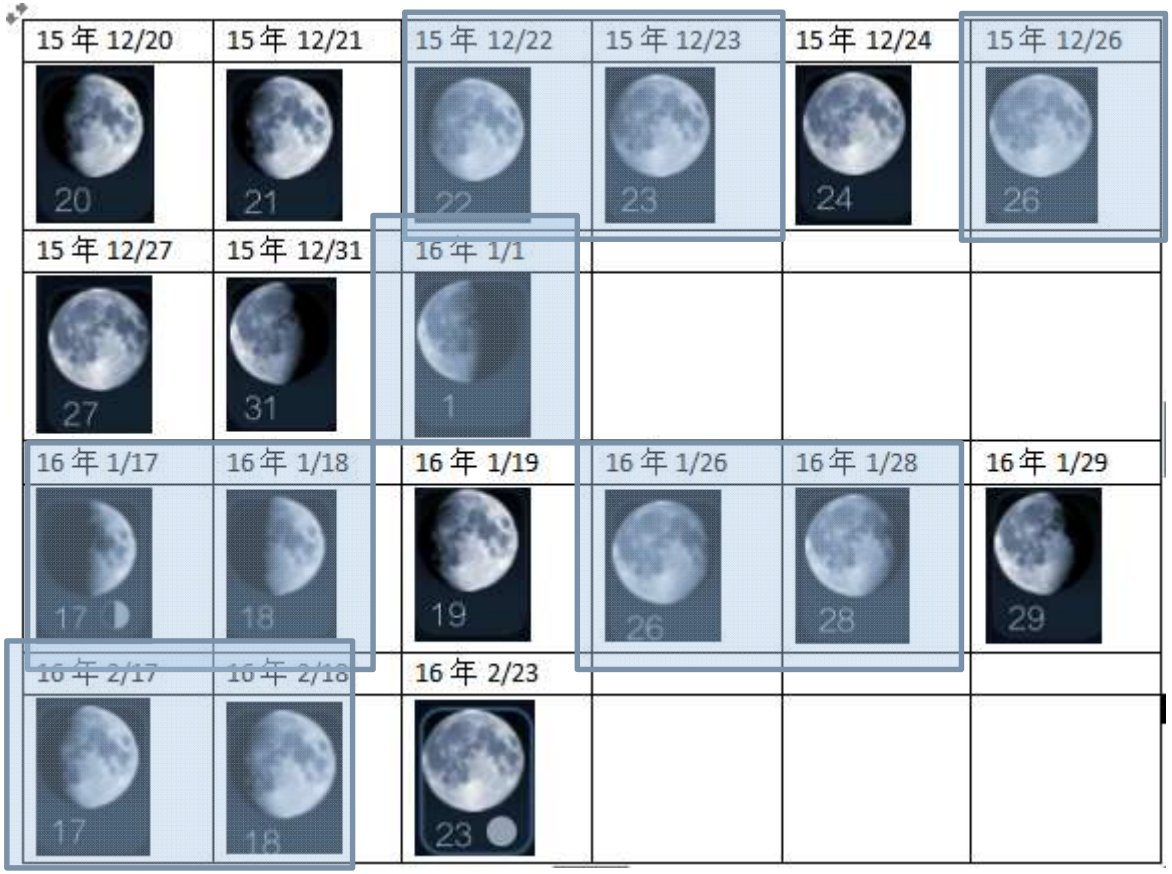
Hyperspectral Lunar-photometer

AOTF Imaging Spectrometer

CE318U Lunar-photometer



Valid Experiments Data



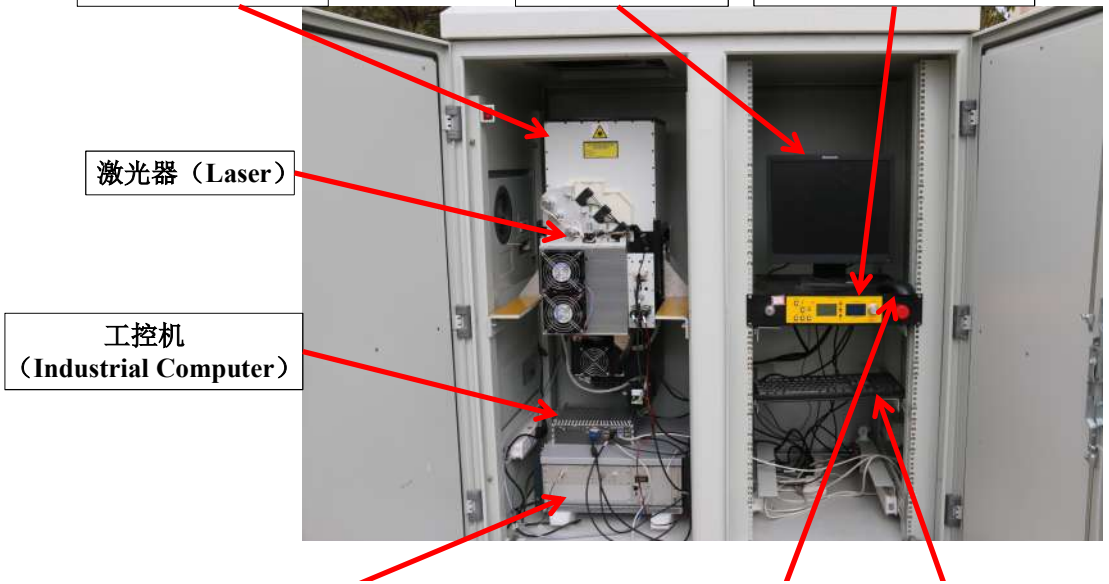
Weather Records

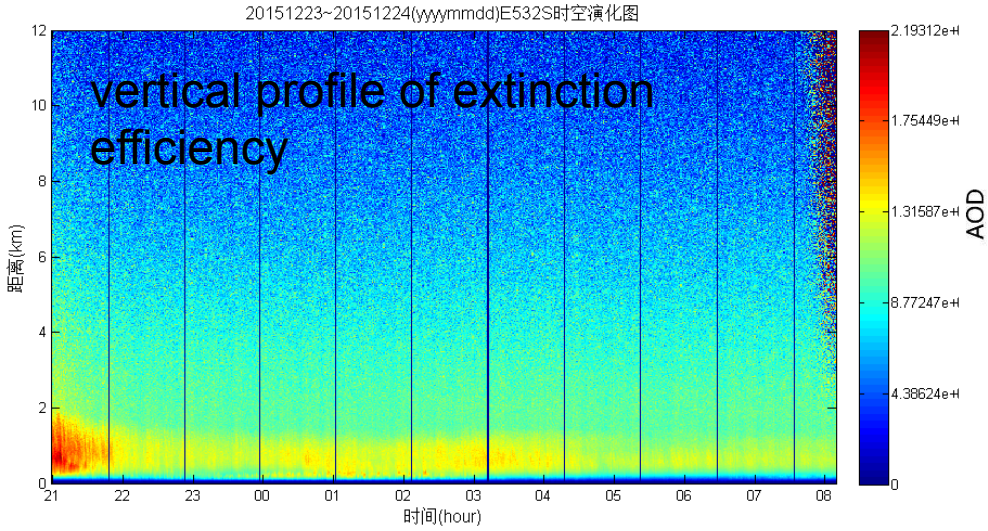
2015/12/27	27日夜间21:44至28号06：59	少量云
2015/12/31	1月1日00：58至1日07：07	少量云
2016/1/1	02日00:02至02日07:51	晴
2016/1/2	----------	多云
第二周期		
2016/1/16	16日19:55至17日01:00	晴
2016/1/17	17日19:58至18日02:08	晴
2016/1/18	18日20:12至19日03:08	晴
2016/1/19	19日19:29至18日04:13	夜间有薄云
2016/120-25	----------	天气过程，降雪
2016/1/26	26日21:36至27日06:31	晴
2016/1/28	28日23:34至18日07:08	晴
2016/1/27	----------	降雪
2016/1/29	30日00:38至18日07:04	夜间薄云
2016/1/30	----------	降雪
第三周期		
2016/2/17	17日19:50至18日03:54	夜间气溶胶较大
2016/2/18	18日20:17至19日04:52	薄云
2016/2/19-22	----------	降雪
2016/2/23	23日20:49至18日07:44	有云
2016/2/24-28	----------	降水

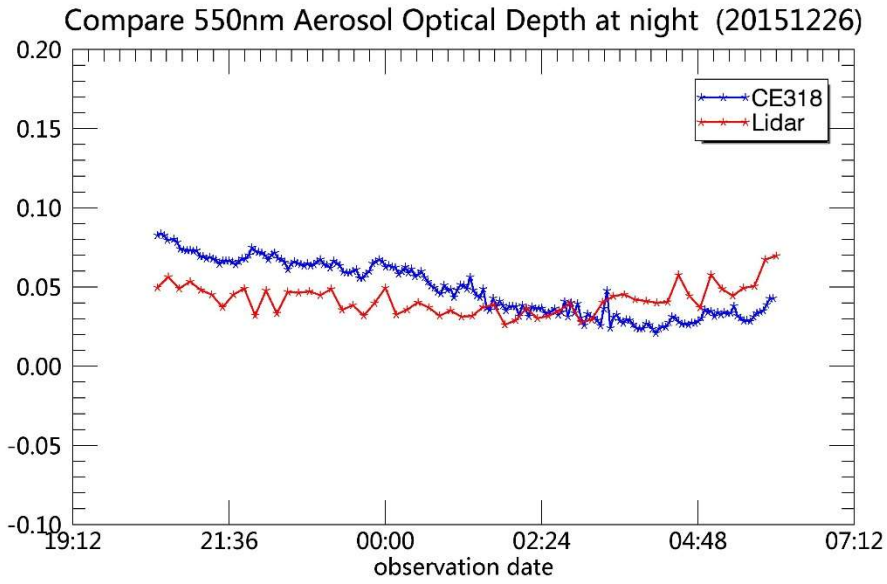
This figure shows the experiments days in Lijiang. According to the weather records, we selected 10d valid experiment data for analysis.

Atmospheric observation

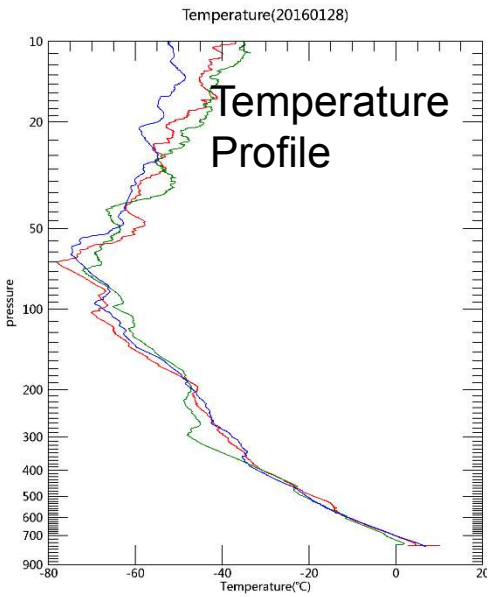
Lidar and CE-318-Lunar for day-night aerosols optical depth

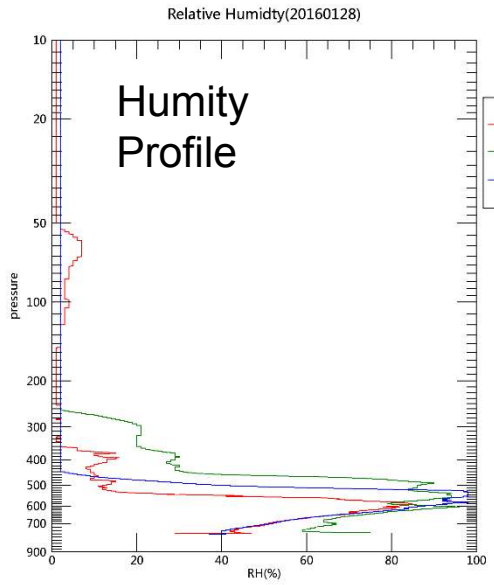


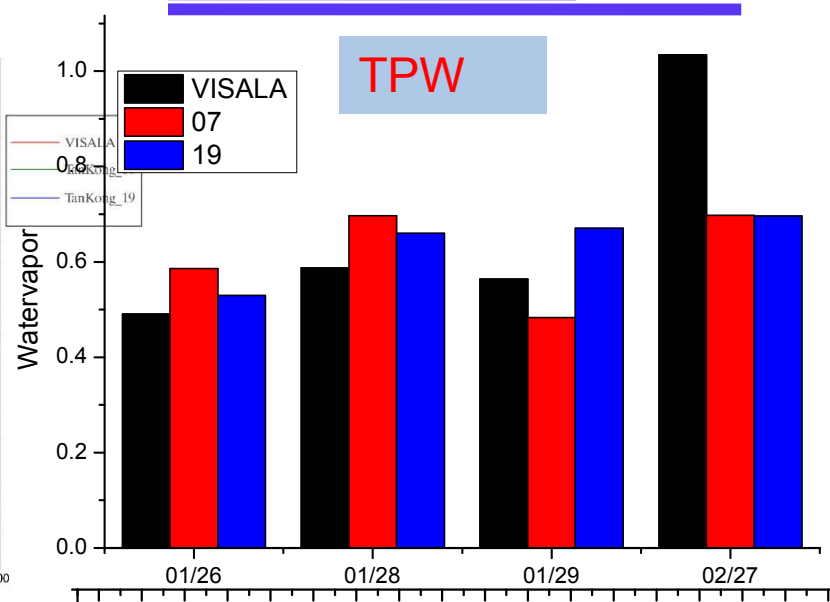


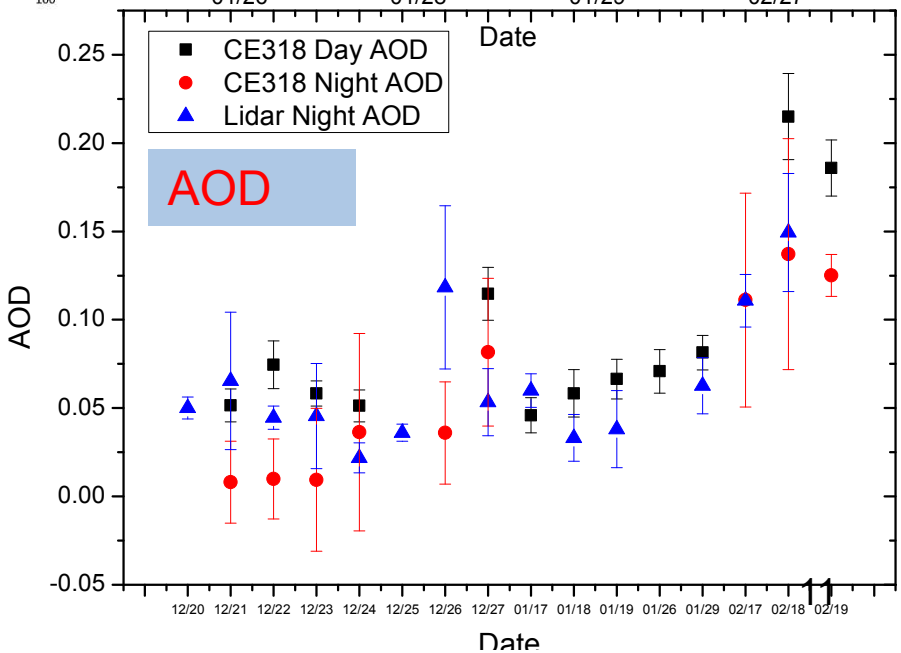


Atmospheric Profiles

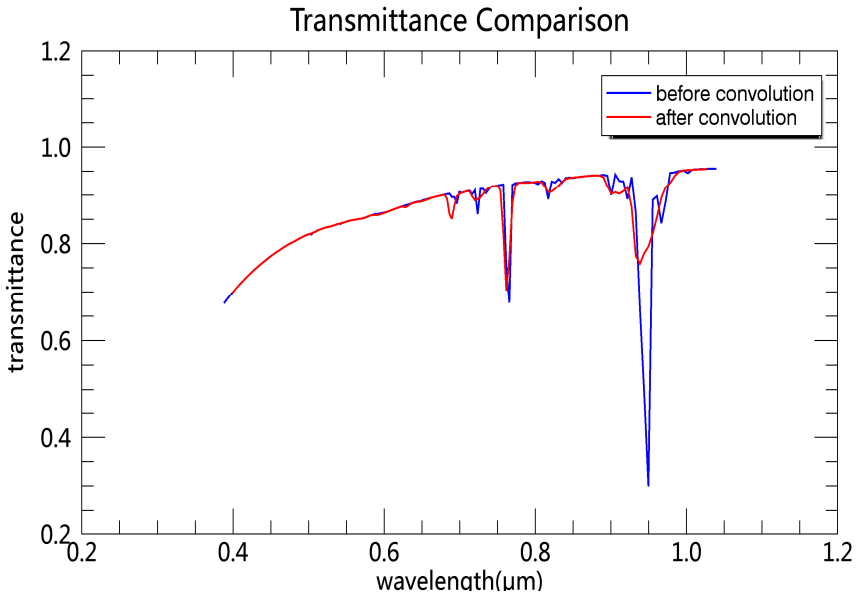


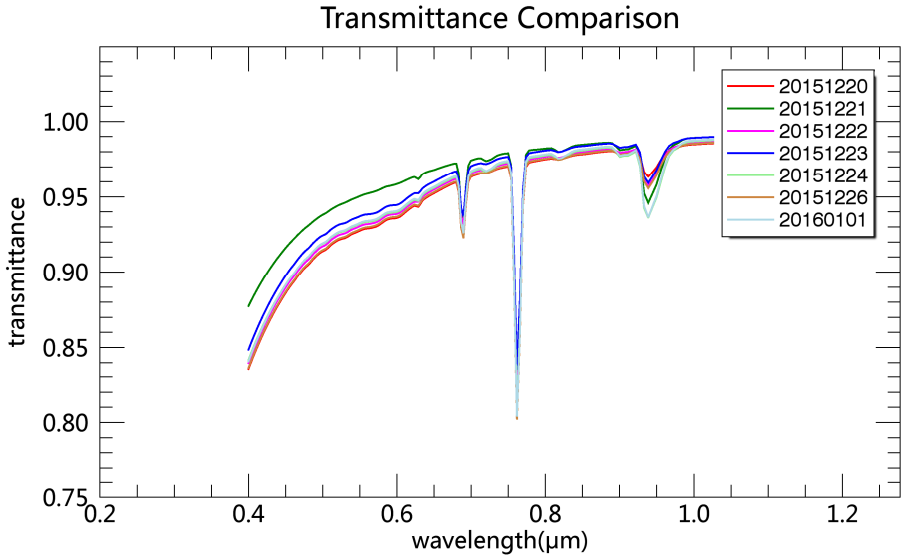


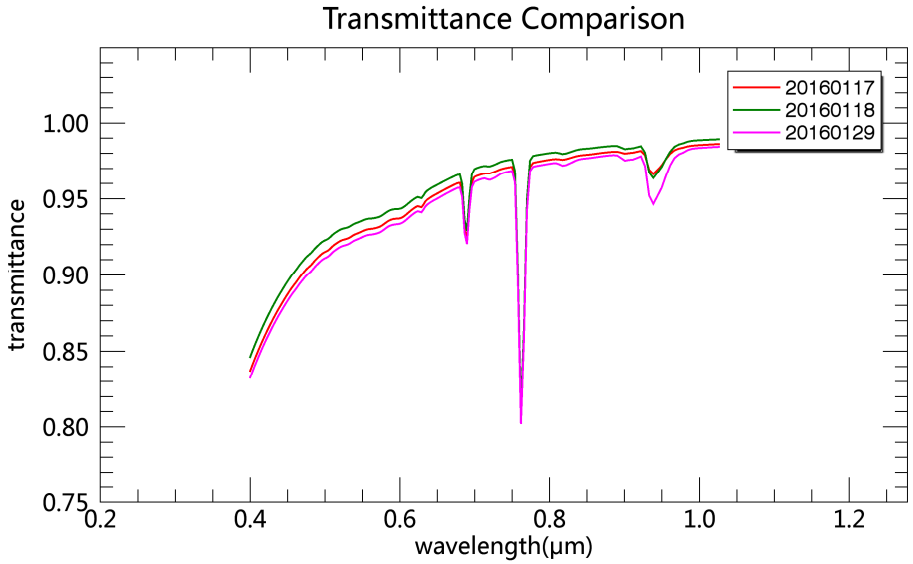


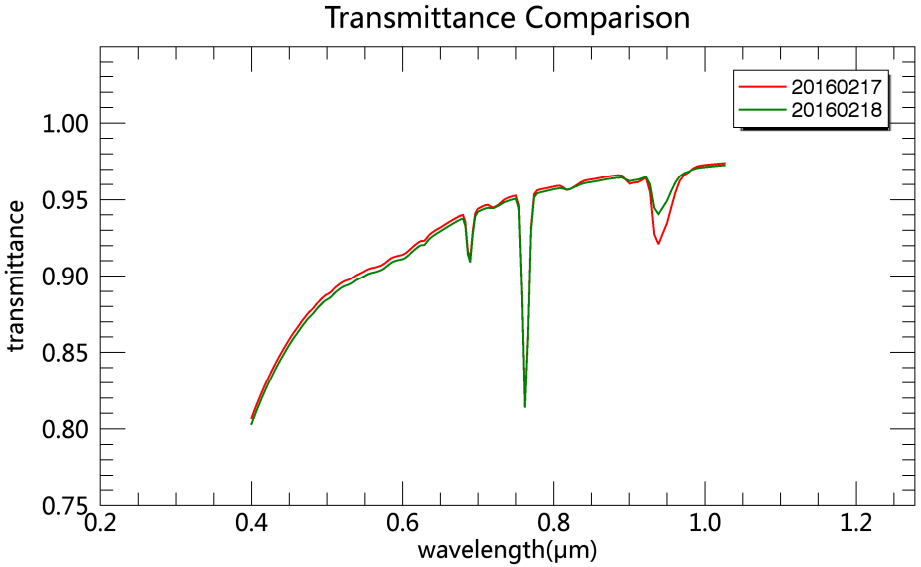


Atmospheric Correction







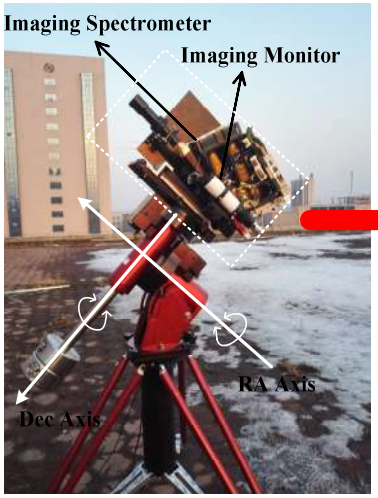


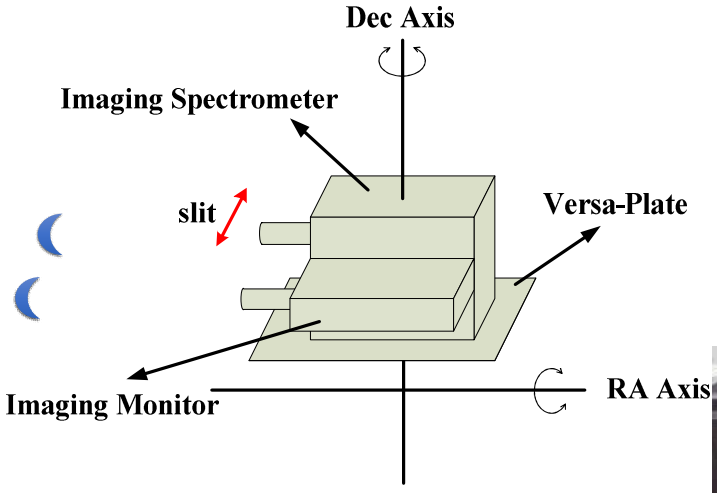
Ground-based Lunar Imaging Spectrometer

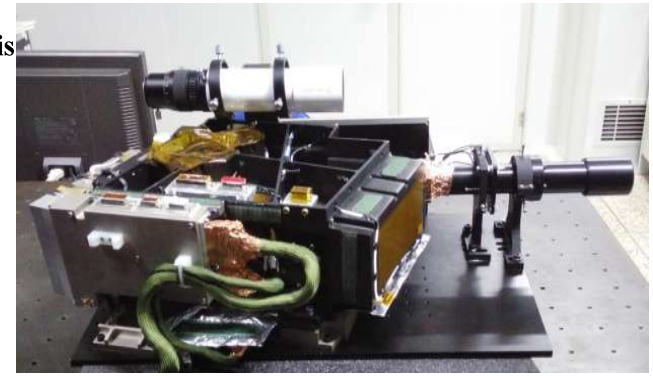
Imaging Spectrometer	Specification
Spectral range	400-1000nm
Spectral channels	>260
Spectral sampling width	2-10nm
Field of view	0.7 degree
Instantaneous Field of view	0.0056 degree
Pixels across track	253

Imaging Monitor	Specification
CCD	1280×1024 pixel
Field of view	1.84°×1.47°

Equatorial Mount	Specification
Tracking accuracy	±7"







Equatorial Mount

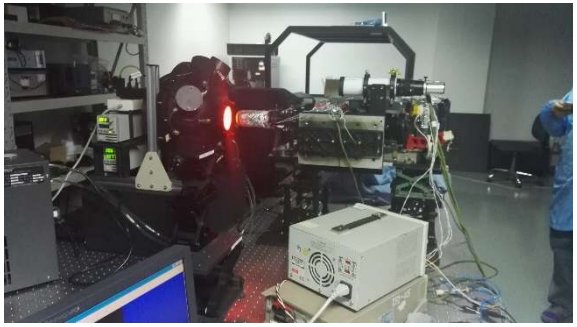
2016-8-31

Instrument calibration activity

(1) **Spectral calibration**：

laser+

Integrating sphere(SIRCUS)

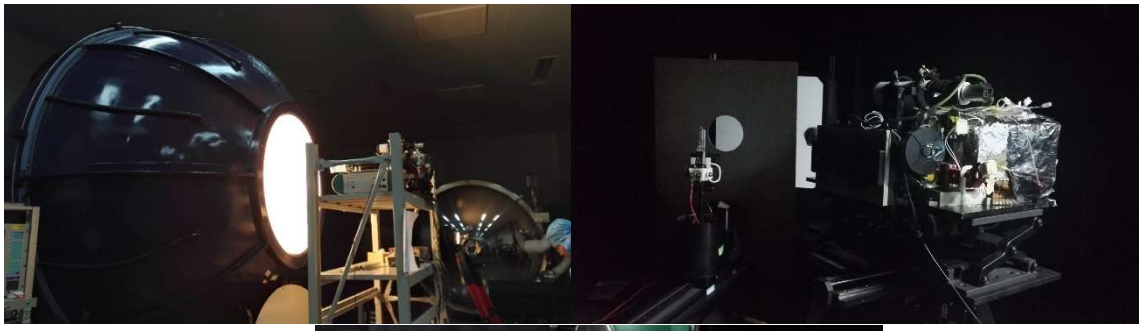


(2) **radiometric calibration**：

Lamp + Reference plate

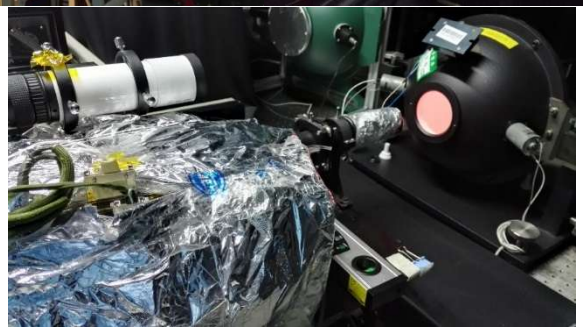
Reference detector+

Integrating sphere（lamp/leds）

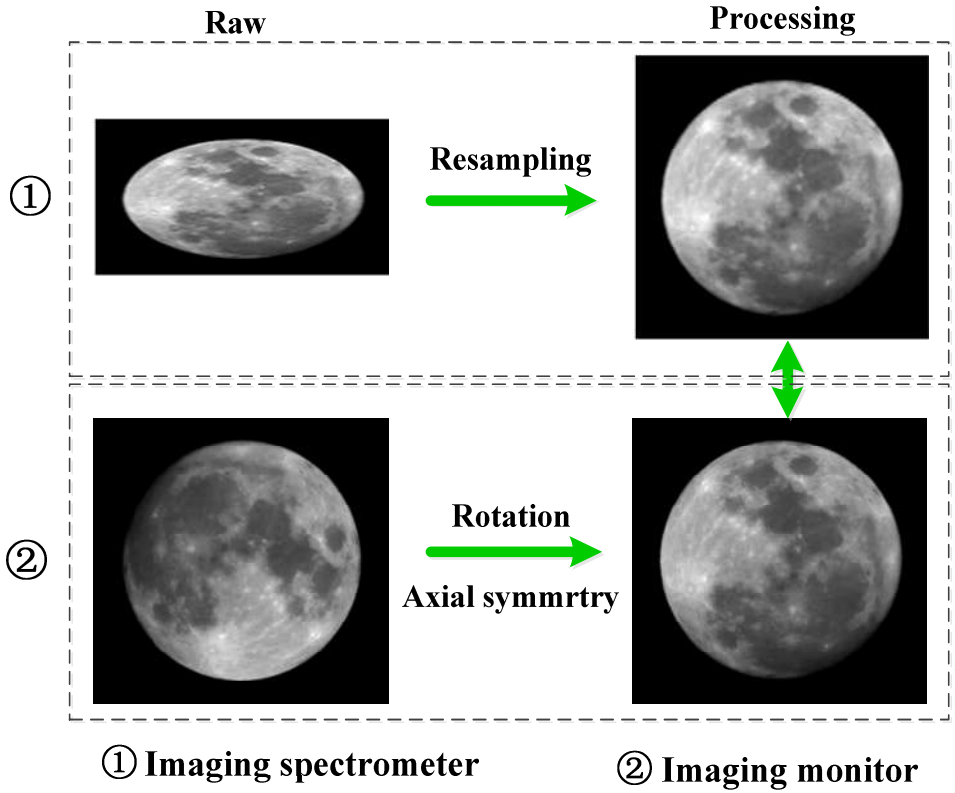


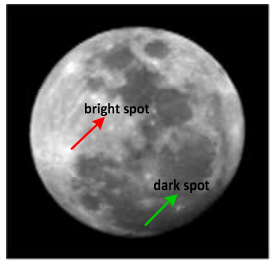
(3) **stray light measurement**

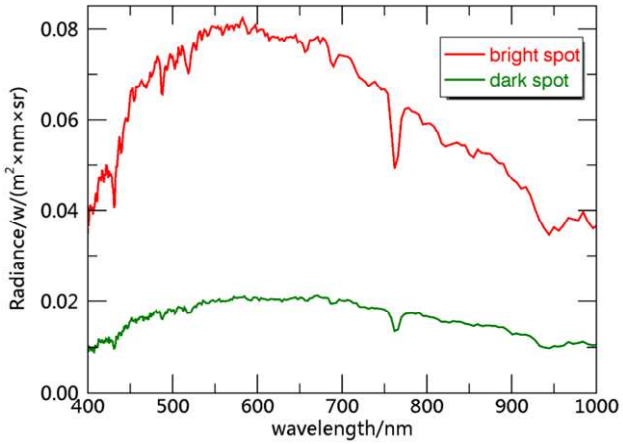
LEDs integrating sphere（tunable）

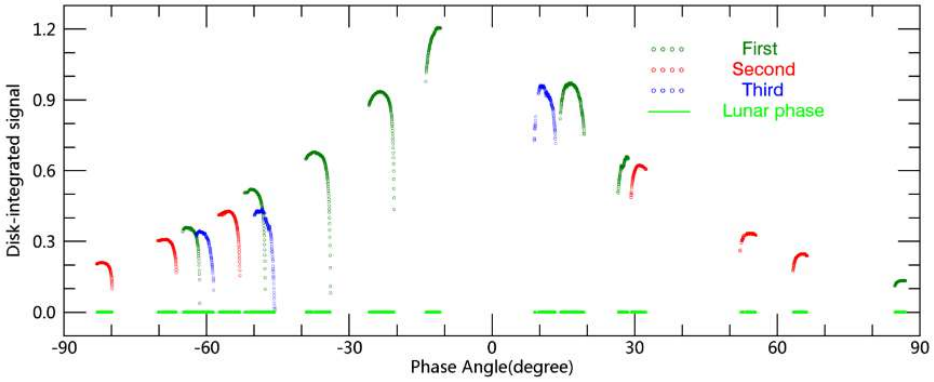


Primary Observation Results

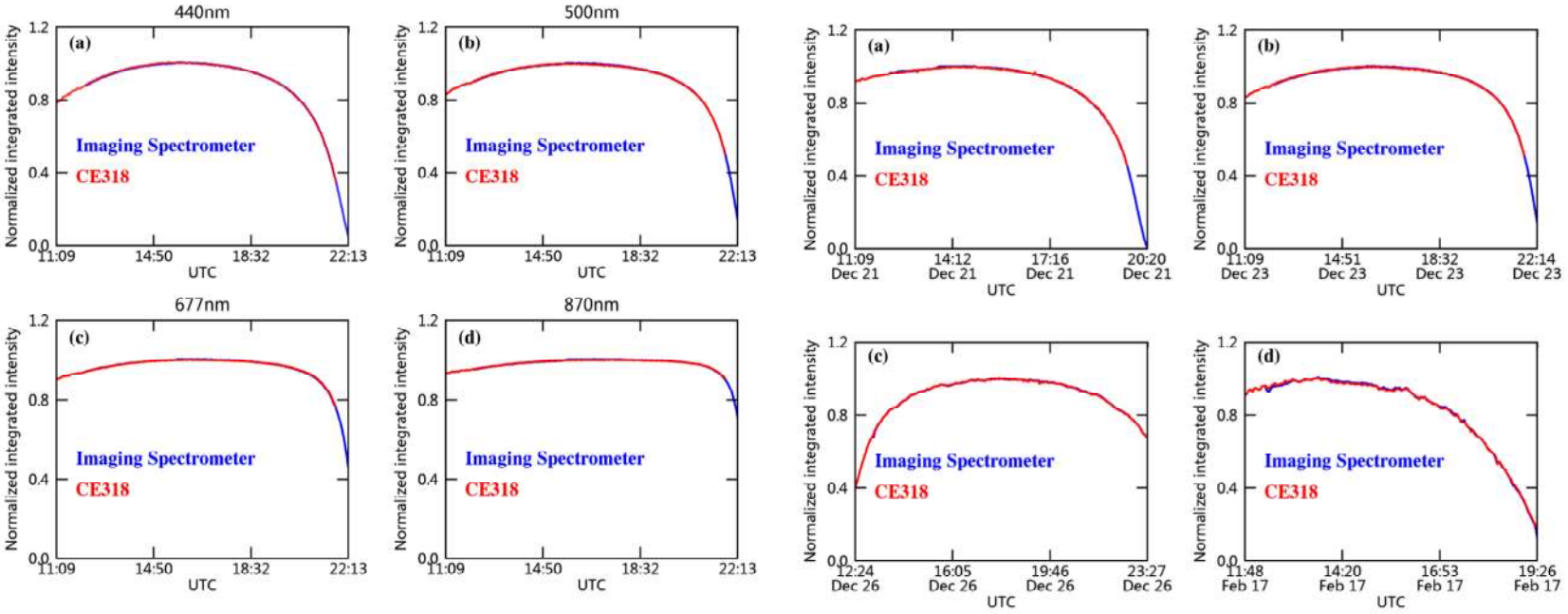








Comparison between Lunar Imaging Spectrometer and CE318-lunar



(1) wavelength **(2) time**

Normalization Imager data and CE318 Lunar data

Lunar Imaging Spectrometer and CE318 lunar Cross-Comparison :

(1) 2015.12.23： 440，500，677，870nm

(2) 500nm: 2015.12.21，201512.23，2015.12.26, 2016.2.17

Consistent trendency → stability of the imaging spectrometer

Comparison between ground-based lunar observation and Lunar Models(ROLO & MT2009)

During the experiment period, 2098 hyper-spectral of lunar irradiance samples had been obtained. But only 145 irradiance meet the requirements of Quality Control(including Lunar zenith angle, Solar zenith angle, atmospheric fluctuation)

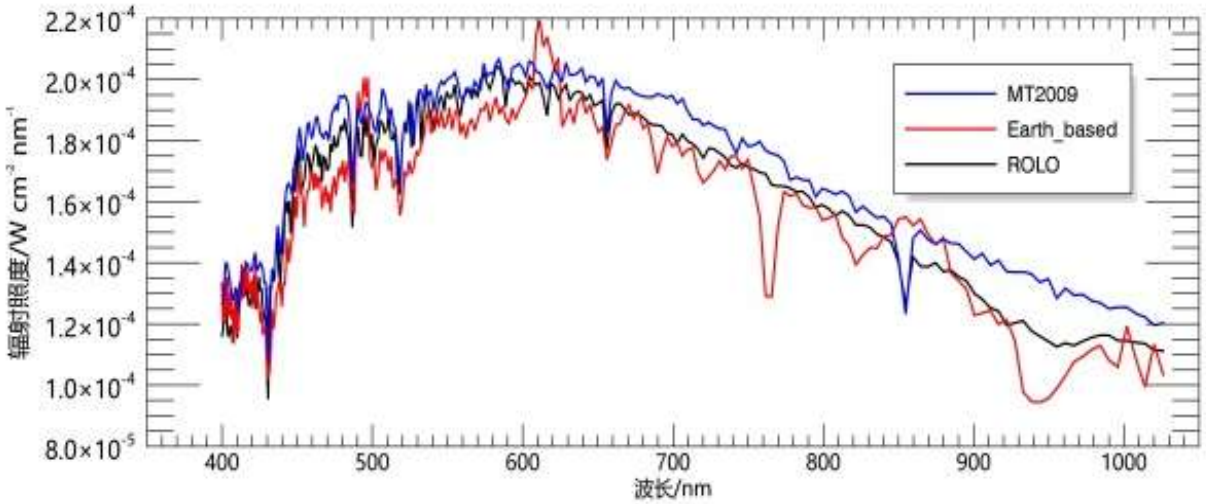
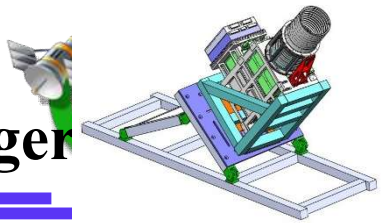


Fig 1 The lunar irradiance of 2016/01/26T18:45（Blue line is MT2009 model，Red line is Earth based observation，Black line is ROLO model）

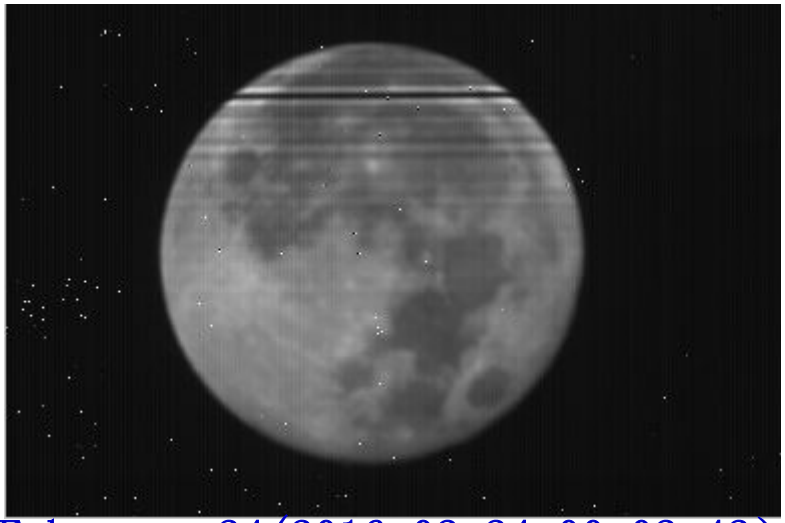
The lunar irradiance obtained by Li Jiang observation is less than the ROLO and MT2009 Models. The difference between Li Jiang observational lunar irradiance and ROLO is 5.86% in this case(except some strong absorption bands).

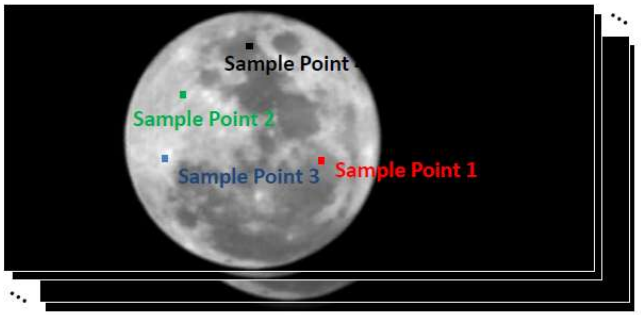
High étendue static Fourier transform spectral imager



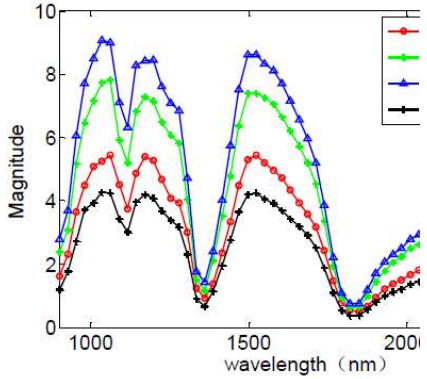
Sensor: HSFTS

Imaging	Pushbroom
Spctral range	0.9μm~2.5μm
Spectral resolution	118 cm^{-1}
IFOV	41.7μrad
FOV	1.2degree
Frame rate	Up to 180fps
Detector	HgCdTe, 500×256pixels
Digtization	14bit
Mass	36kg





(a)



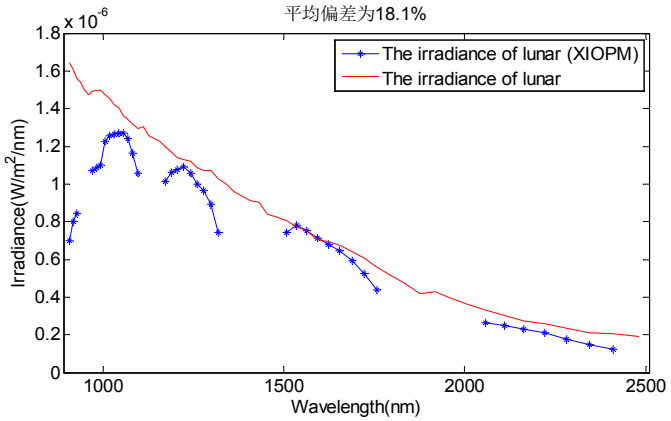
(b)

Fig. 10. Spectral data reconstruction results. (a) Reconst datacube and the positions of the sample points. (b) The

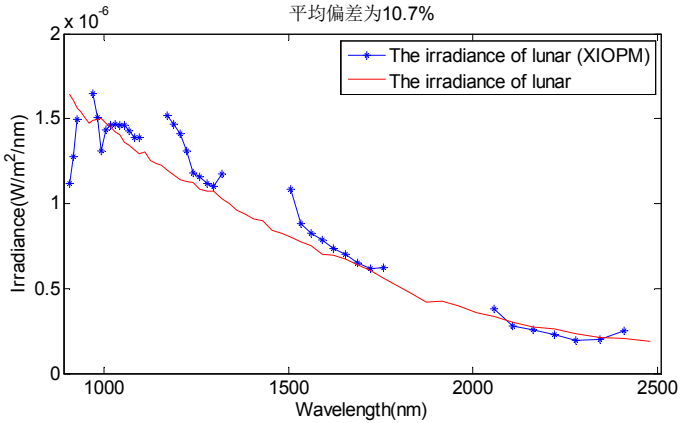
- February 24(2016-02-24-00-02-42)

Comparison with Lunar model ROLO

◆ Disk Irradiance



Before atmosphere correction
Irradiance Mean Bias=18.1%
2月24日（2016-02-24-00-02-42）



After atmosphere correction Using MODTRAN
Irradiance Mean Bias=10.7%
2月24日（2016-02-24-00-02-42）

Summary

- Experiences and Lessons:
  - Lijiang is a good location for Lunar observation
  - Instrument improvement and accuracy calibration
  - More validation between observations and model
  - Finding on the difference form ROLO and MT2009 model

- Next steps:
  - Instrument improvement based on previous experience.
  - Long term observation need automatic control by remote
  - Accurate calibration and Data quality control
  - Data processing for model validation and improvement
  - International cooperation is welcome

Thanks