Current status of the LAMOST Survey Strategy System(SSS) and the 2D pipeline

Haotong Zhang
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Collaborator: Haolong Yuan,Zhongrui Bai,Yanjuan Lei,Guangwei Li, Yiqiao Dong, Huiqi Yang & Wei Zhang


NAOC
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CQISUH

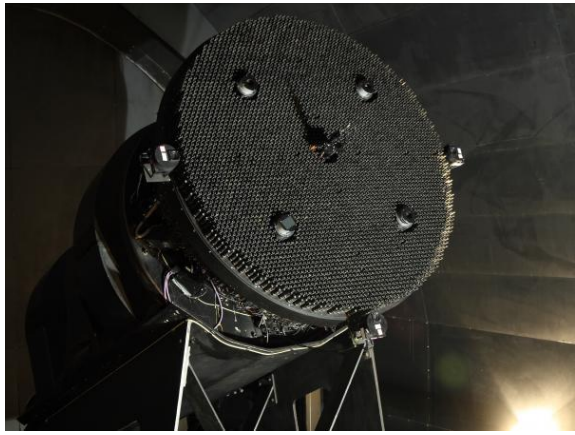
SSS (survey strategy system)

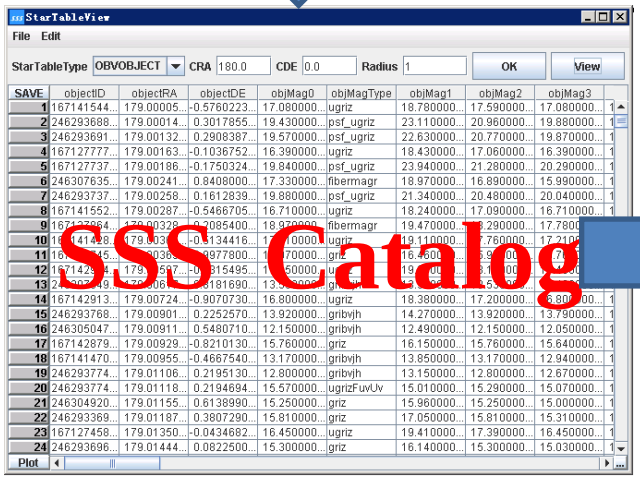
Survey Strategy System

Catalogues from individual Researchers

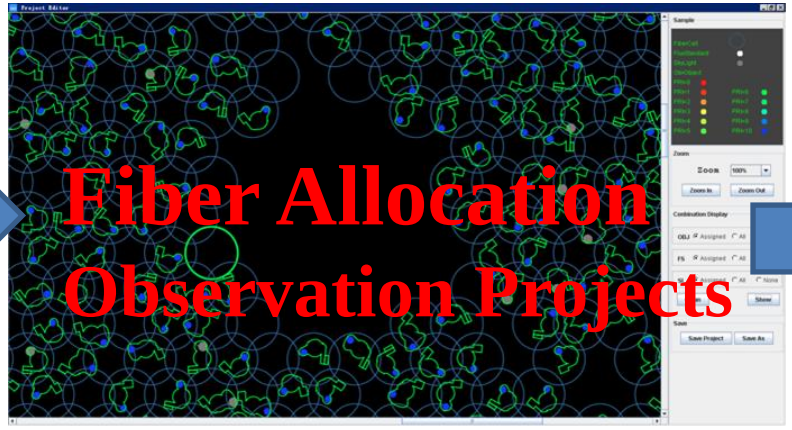
ra,dec,mag

requirements: priority, SNR, obs times

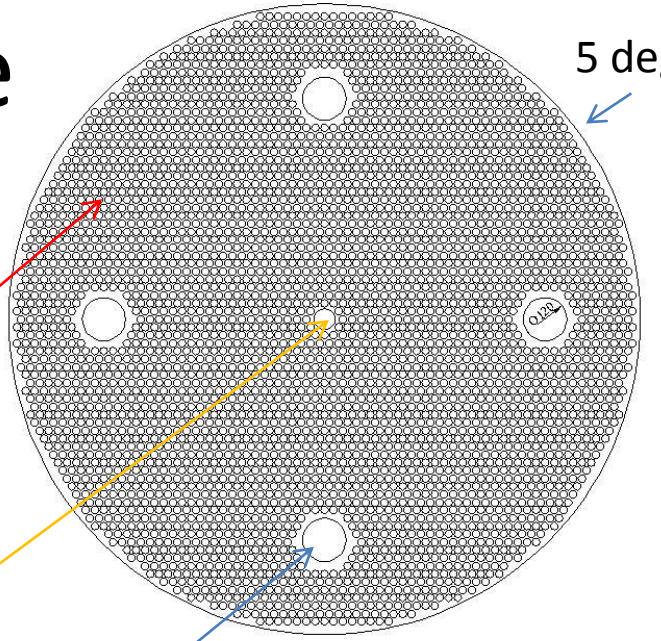




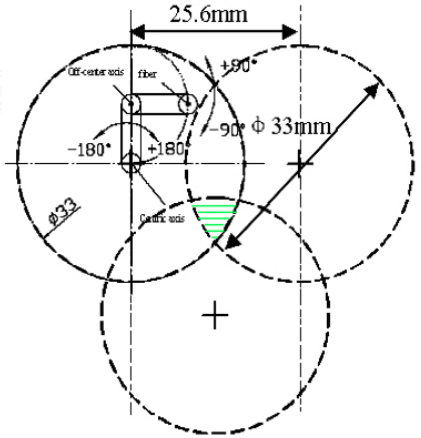
SSS Catalog



Focal Plane



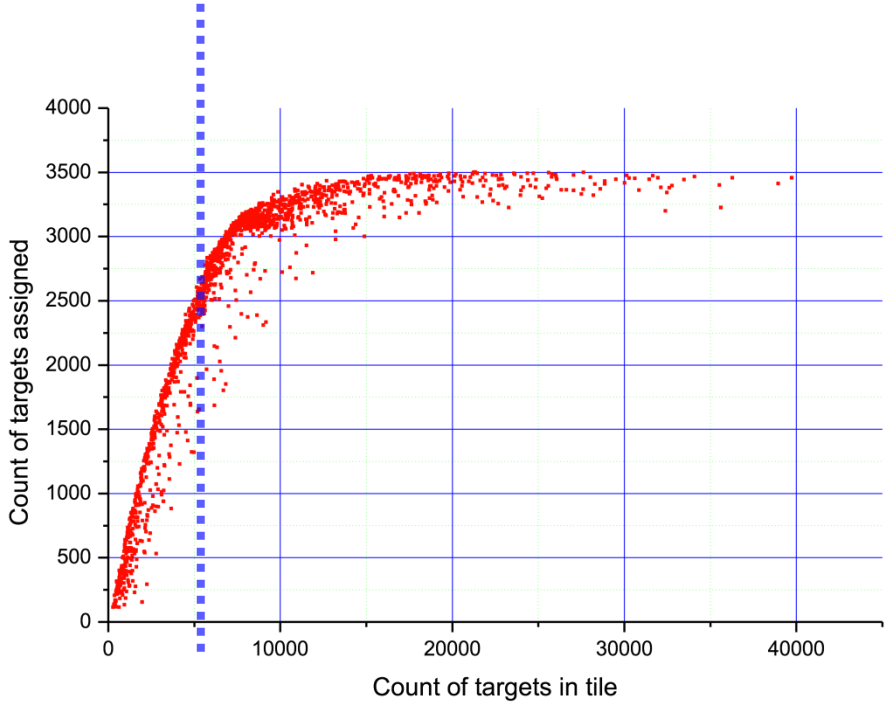
5 degree focal plane



- Homogeneously distributed fiber
- Central Bright star

(< 8 mag)for SH test

- 4 guide stars (< 16 mag, weather dependent) on guiding CCD cameras



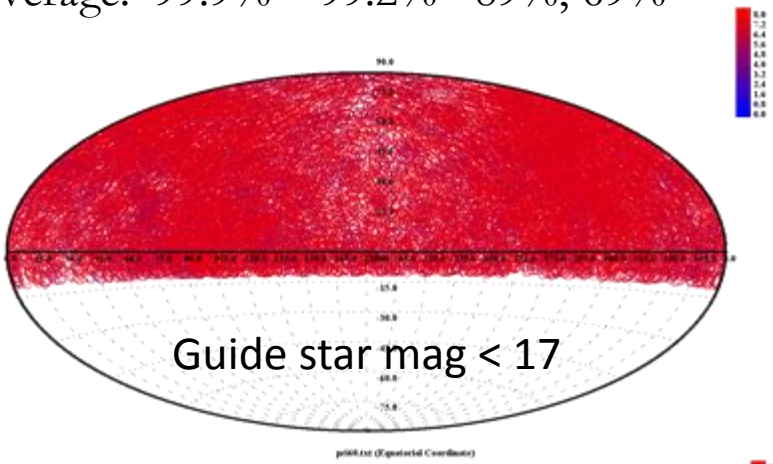
Algorithms

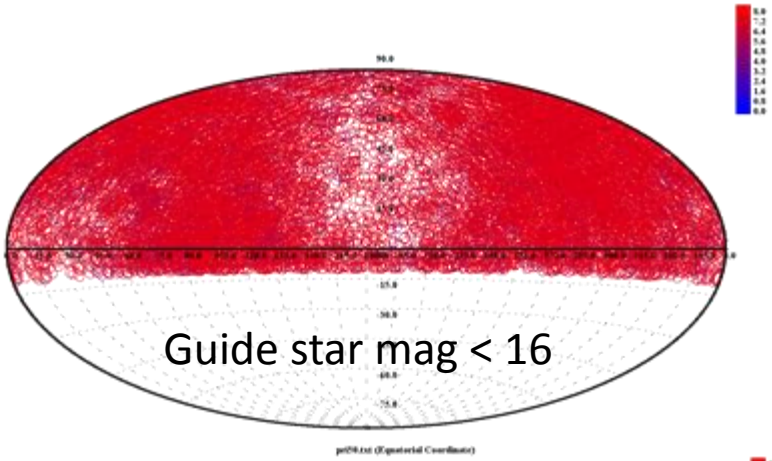
- Level 1： Telescope Tiling (5 degrees)
  - 5 degree Field of View
  - Center star mag < 8
  - 4 guide star in 4 CCDs, mag < 16 (weather dependent)
  - New CCD System: 8 CCDs; more center star can be used; multiple rotation angles

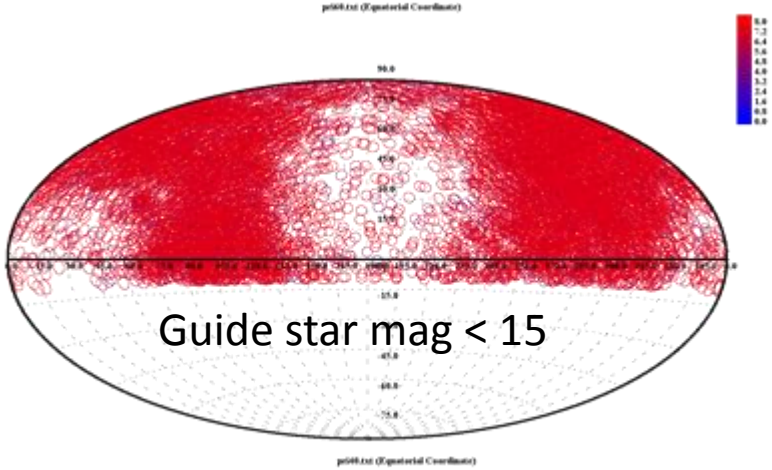
- Level2： Fiber allocation (5 arcmins)
  - ***Maximize fiber utilization ratio， --->4000***
  - Fiber collisions
  - Target Priority
  - Skylights (20*16=320), flux calibration stars(5*16=80), targets
  - Fiber performance

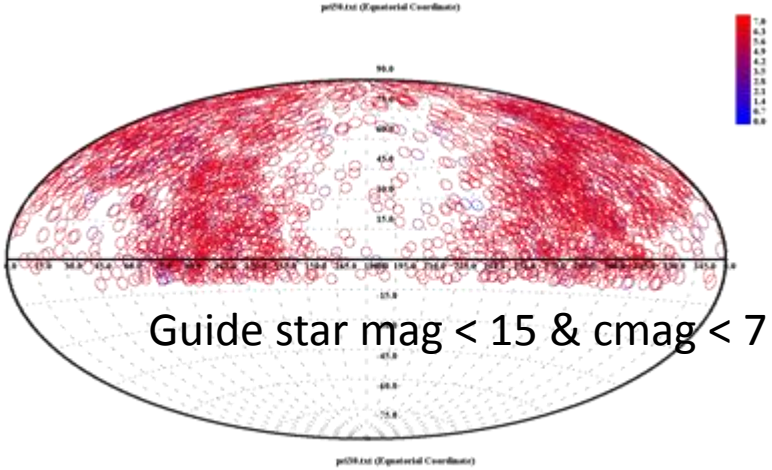
database of good SH center

Coverage: 99.9% 99.2% 89%, 69%



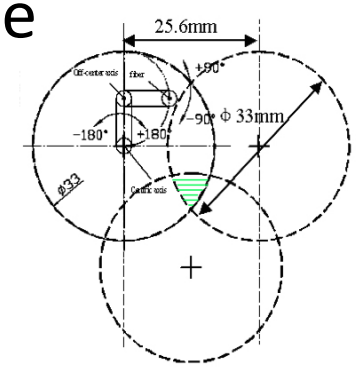






Fiber Allocation Principle

- Hi-priority objects first
- Same object priority inside one fiber, target closest to the fiber position center first
- Same object could be reached by more than one fiber, fiber with the least number of neighbour targets first
- sky fibers(20/spectrograph) considered last, rejecting target with lowest priority

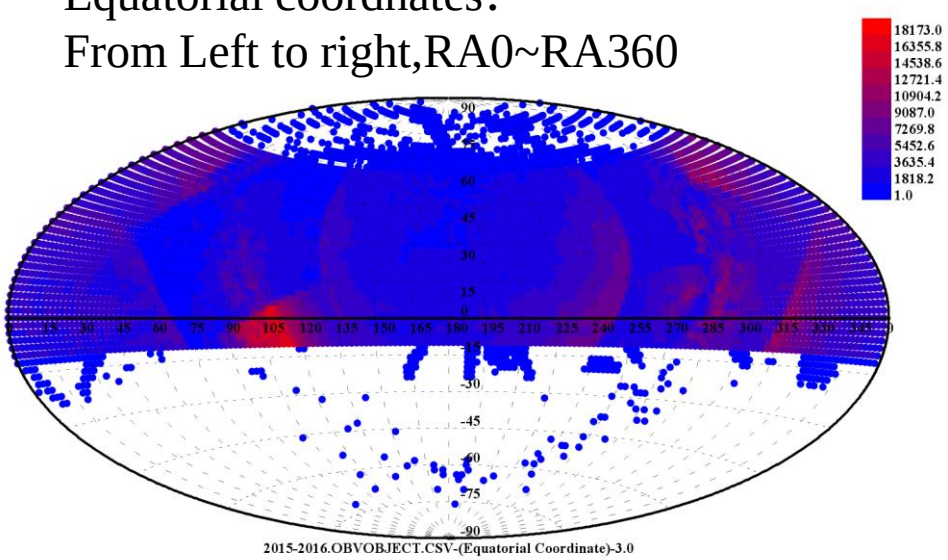


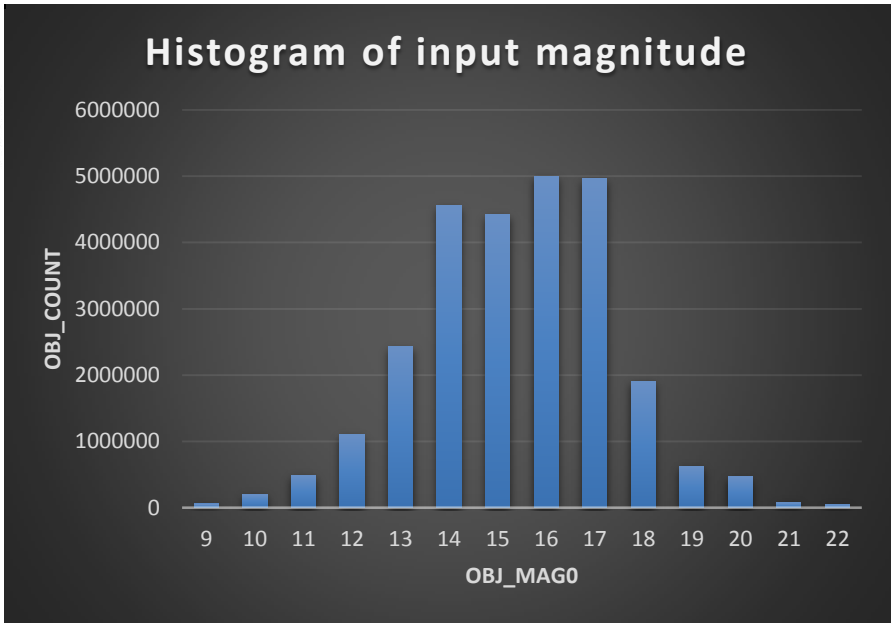
Current Input catalog

Total :29.63 million

galaxy，LEGAS_SSY，**1124655**
QSO，LEGAS_ZYX，**512548**
star，LEGUE_LCH，**24078447**
star，LEGUE_LJF，62753
star，LEGUE_ZG，11428
star，LEGUE_NAOC，585582
star，KEPLER+K2，3200000+61000
Rejected bright star，**564737**：12,10；10,20；9,40；lch, 42w, ssy 13w
http://lamostss.bao.ac.cn/projects/catalog.summary.txt

Equatorial coordnates：
From Left to right,RA0~RA360



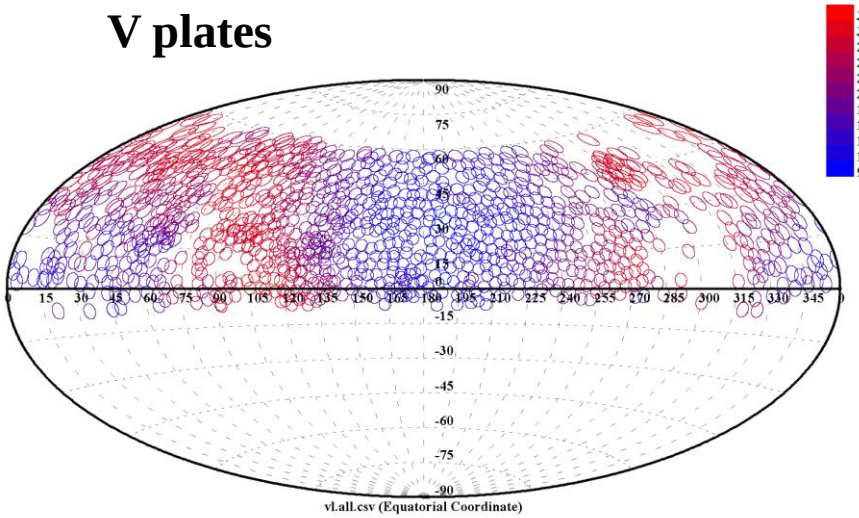


Plates

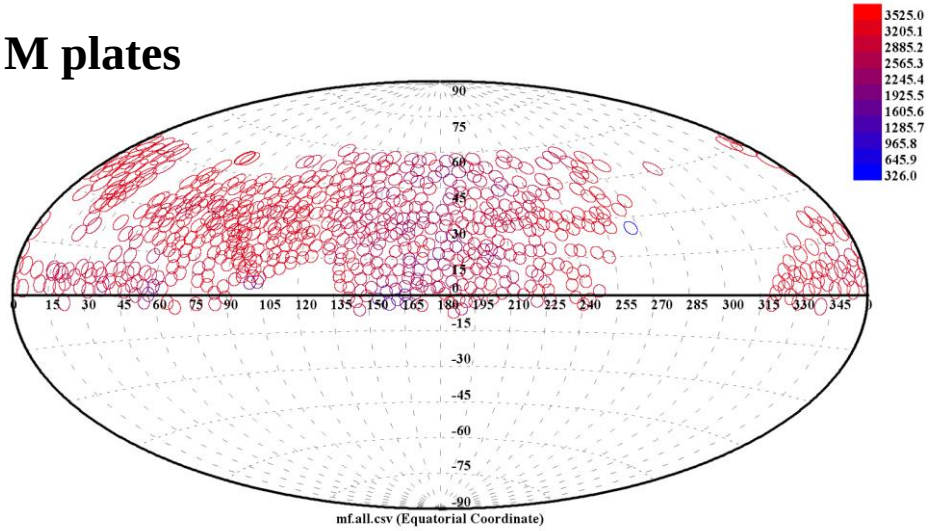
- Magnitude
  - V plate: 11 to 14mag ,9~11mag is offsetted to 13mag
  - B plate: 14 to 16.8mag
  - M plate: 16.8 to 17.8mag -- stars
- Object type
  - V、B plate: stellar object
  - M plate: galaxies from 15 to 18.6 mag and quasars from15 to 20mag
  - Adding extragalactic object to B plate from Jan,2014
- Galactic Anti-center area
  - V plate: 9 to14
  - B plate: 14 to16.3
  - M plate: 16.3 to17.8

plates distribution

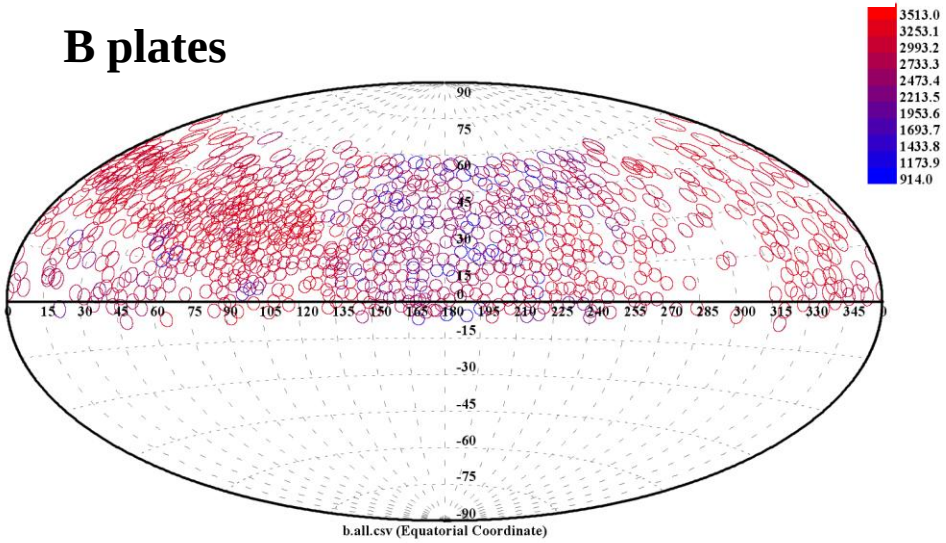
V plates



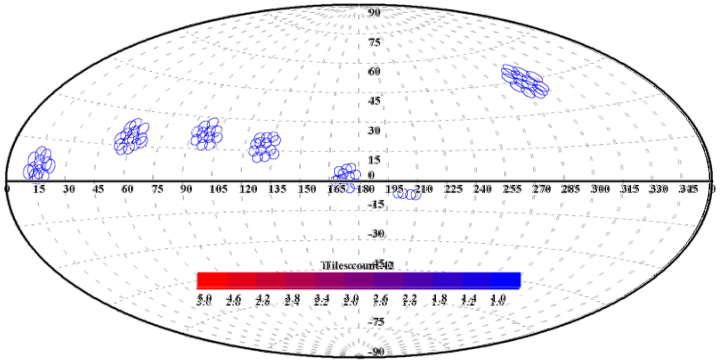
M plates



B plates



Kepler plates



Daily Observation Plan

- List of daily projects are generated 3 days before observation, and put online (http://lamostss.bao.ac.cn/projects) for the astronomers to check.
- We make 10 times more projects than could be observed. Observers could find at least one plate in every 15 degree in RA, so that they could start observation any time at night.
- Appointed area(such as Kepler field) will have higher priority.
- Make V、B& M plan for the same plate center.
- In bright night, plates within 30 degree of the Moon is rejected to avoid moon light pollution. No M plate in Bright night or when the Moon is up.
- Observers on the mountain will finally determine which plate to observe.

projects web site

http://lamostss.bao.ac.cn/projects

Directory Listing For

Filename	Size	Last Modified
20111110_SCHEME.zip	8122.1 kb	Wed, 19 Feb 2014 15:01:16 GMT
20120922_SCHEME/		Wed, 19 Feb 2014 04:11:46 GMT
20120922_SCHEME.zip	85289.8 kb	Wed, 19 Feb 2014 15:01:17 GMT
20120927_SCHEME/		Wed, 19 Feb 2014 04:11:53 GMT
20120927_SCHEME.zip	81597.8 kb	Wed, 19 Feb 2014 15:01:18 GMT
20120928_SCHEME/		Wed, 19 Feb 2014 04:12:21 GMT
20120928_SCHEME.zip	247346.4 kb	Wed, 19 Feb 2014 15:01:22 GMT
20120929_SCHEME/		Wed, 19 Feb 2014 04:12:44 GMT
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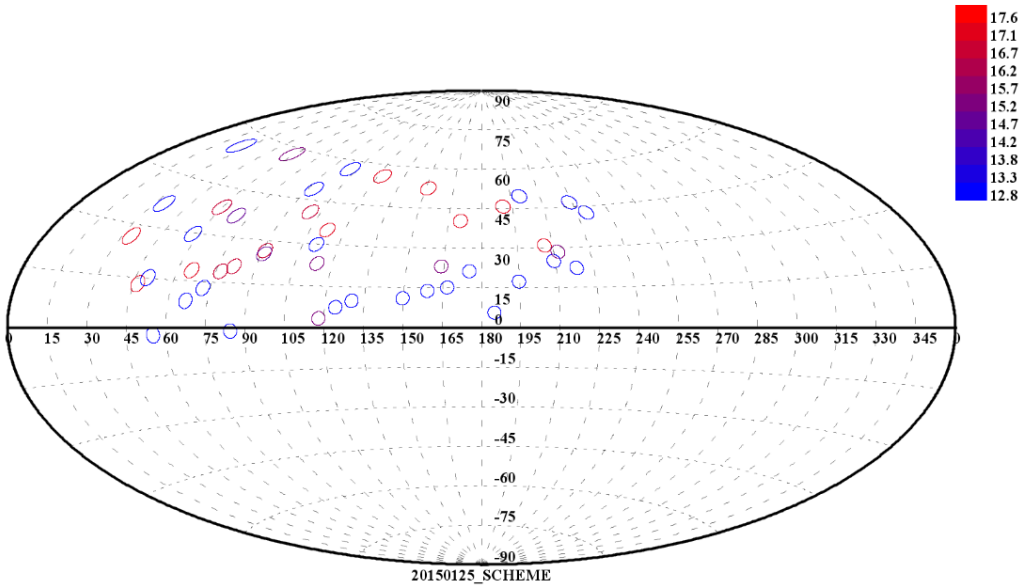
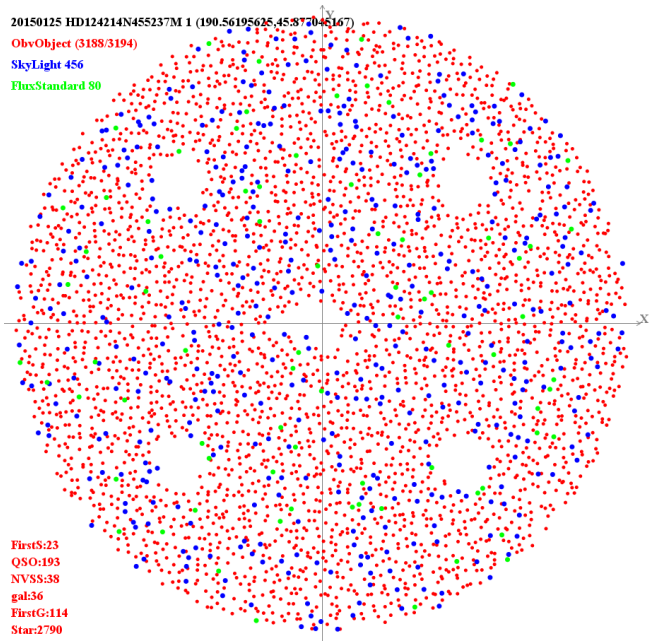
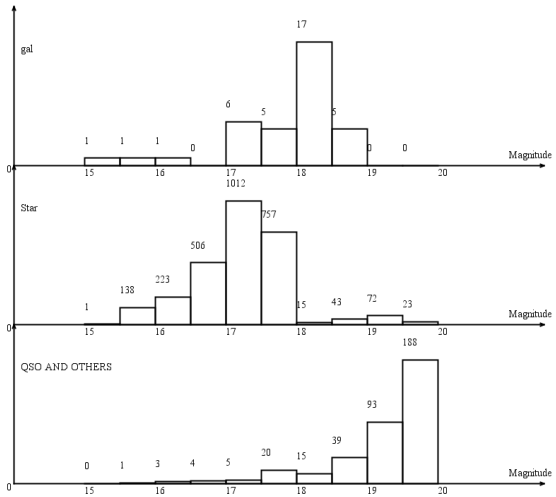
20120930_SCHEME/		Wed, 19 Feb 2014 04:12:59 GMT
20120930_SCHEME.zip	149471.2 kb	Wed, 19 Feb 2014 15:01:26 GMT
20121001_SCHEME/		Wed, 19 Feb 2014 04:13:20 GMT
20121001_SCHEME.zip	210530.4 kb	Wed, 19 Feb 2014 15:01:29 GMT
20121002_SCHEME/		Wed, 19 Feb 2014 04:13:41 GMT
20121002_SCHEME.zip	174823.8 kb	Wed, 19 Feb 2014 15:01:32 GMT
20121003_SCHEME/		Wed, 19 Feb 2014 04:14:00 GMT
20121003_SCHEME.zip	188667.8 kb	Wed, 19 Feb 2014 15:01:33 GMT
20121004_SCHEME/		Wed, 19 Feb 2014 04:14:20 GMT
20121004_SCHEME.zip	187522.8 kb	Wed, 19 Feb 2014 15:01:35 GMT

1421913610312	20150125	304540.9	HD145433N463537V01	223.640192583	46.593740083	7.34	img	12.6~15.27	122	20.50	14.0~72	1520; 13.08; Star 1520
1421911606984	20150125	310822.9	HD151718N423357B01	229.328584625	42.56587725	7.47	img	14.27~15.14	123	20.50	16.8~2188	3189; 15.53; Star 3140, gal 49
1421911738109	20150125	310822.9	HD151718N423357V01	229.328584625	42.56587725	7.47	img	14.27~15.14	123	20.50	14.0~72	1565; 13.10; Star 1565

Targets summary:
CSS_var 301, Dual_AGN 160, EMOs 6, FirstG 547, FirstS 135, NVSS 219, QSO 1607, RRlyare 8, Star 115679, gal 1844, star 53930, stars 2796, wds 16, wise_vari 1005
CountAll=178253







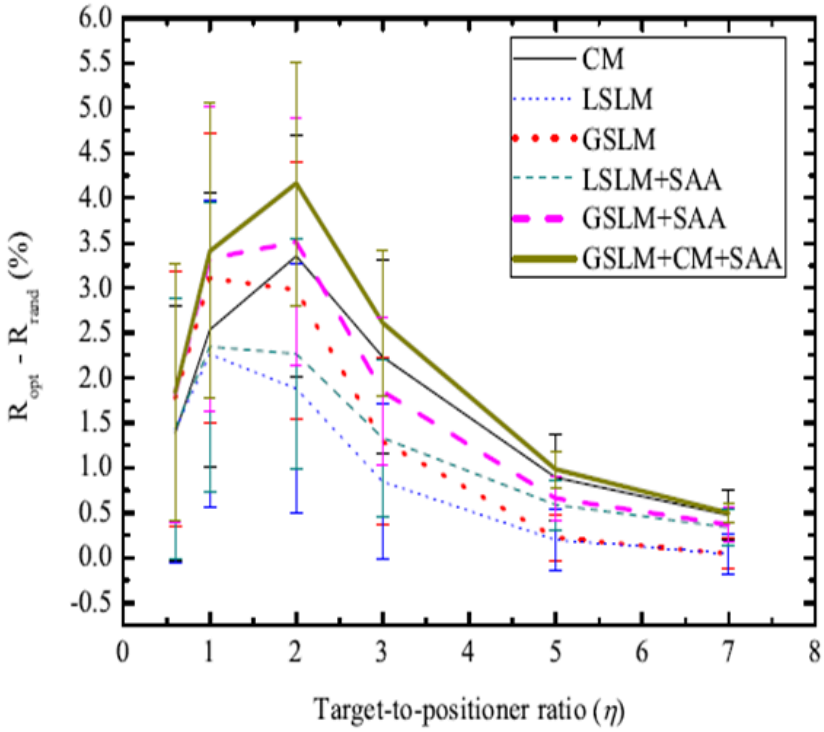
Simulated annealing algorithm

- Local Short List Method(LSLM), Global Short List Method(GSLM)

  centralization Method(CM)

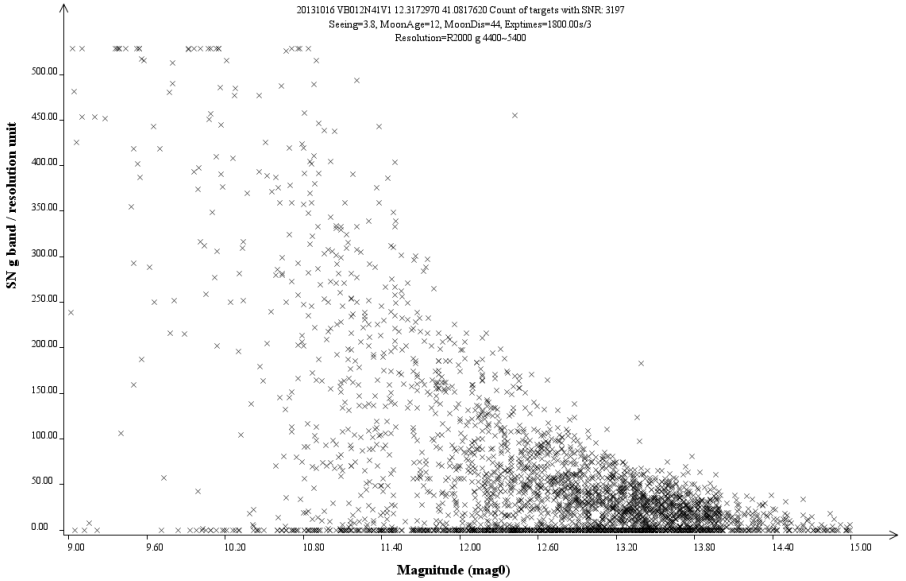
  Simulated annealing algorithm (SAA)

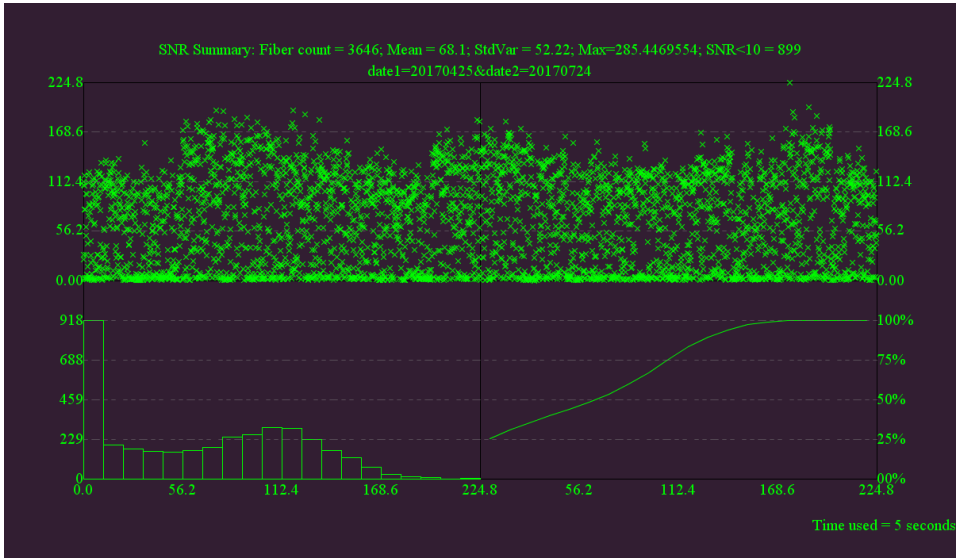
- GSLM+CM+SAA allocate 2%~4% more fibers than random allocation. For a survey with 5M targets, we will have 0.1-0.2M more targets.



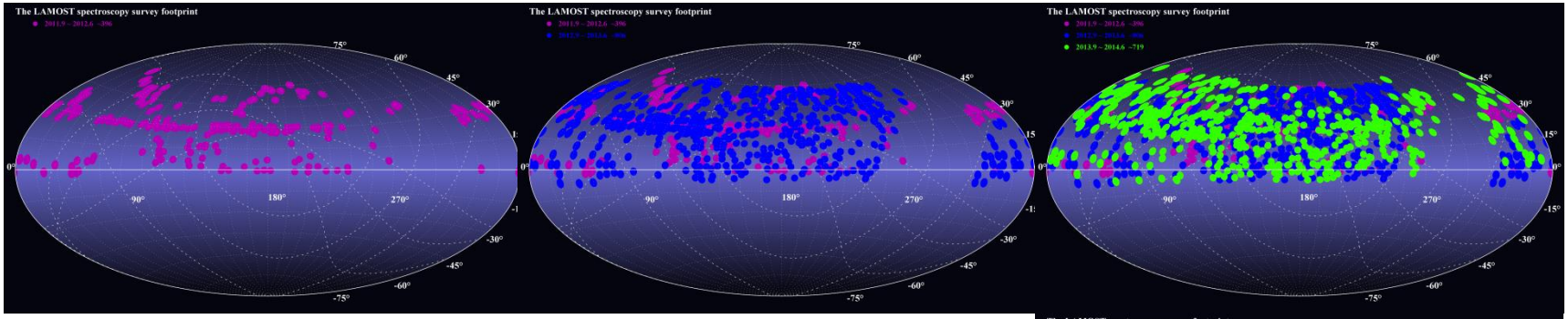
S/N feed back and fiber status monitor

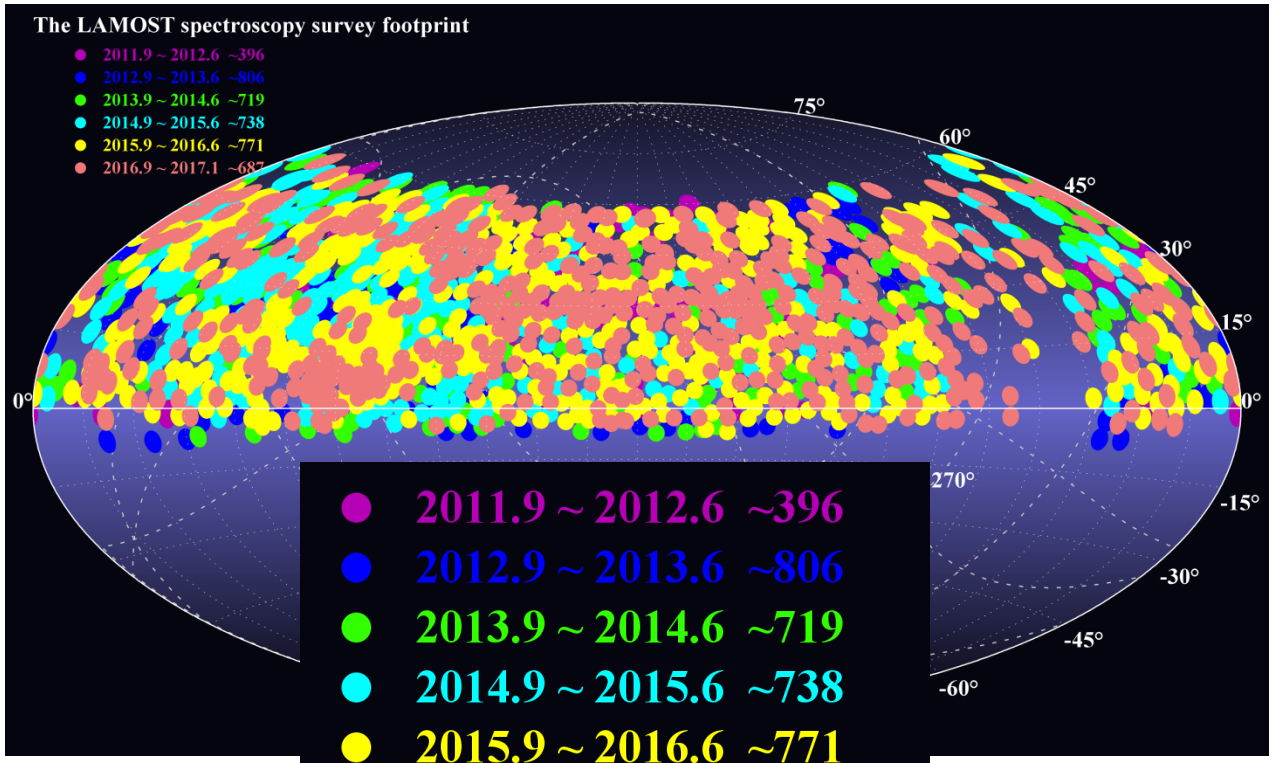
- SSS share the same output S/N database with 2D pipeline, the objects with satisfied S/N will have lower priority in next observation.
- SSS monitors the S/N of each fiber and find the bad fiber / fiber positioner

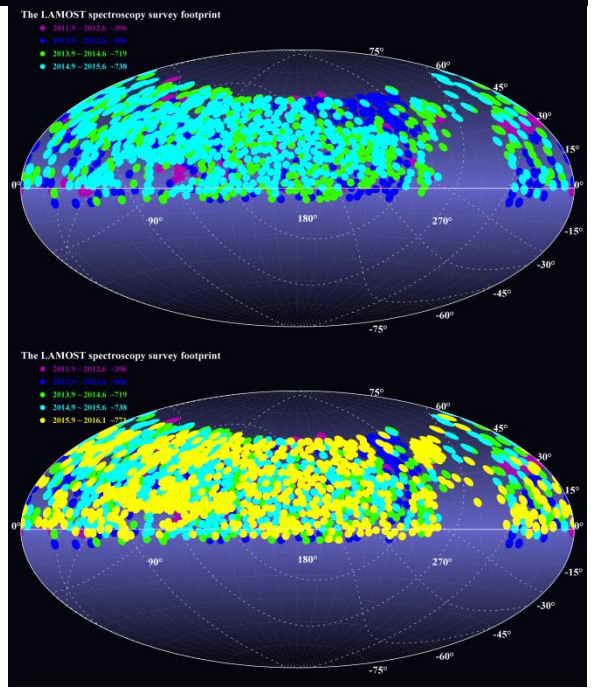




Observed sky 2011-2017



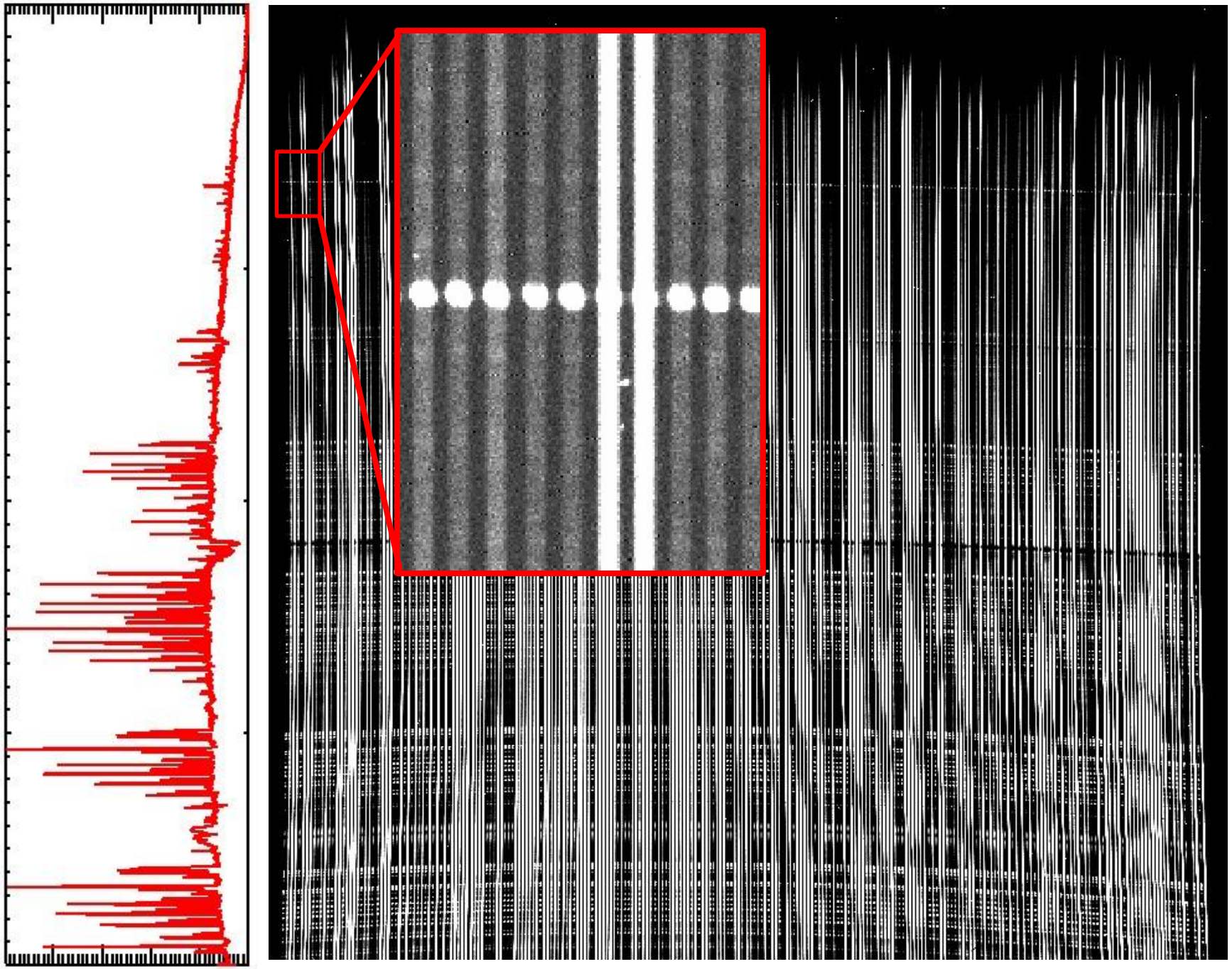




summary

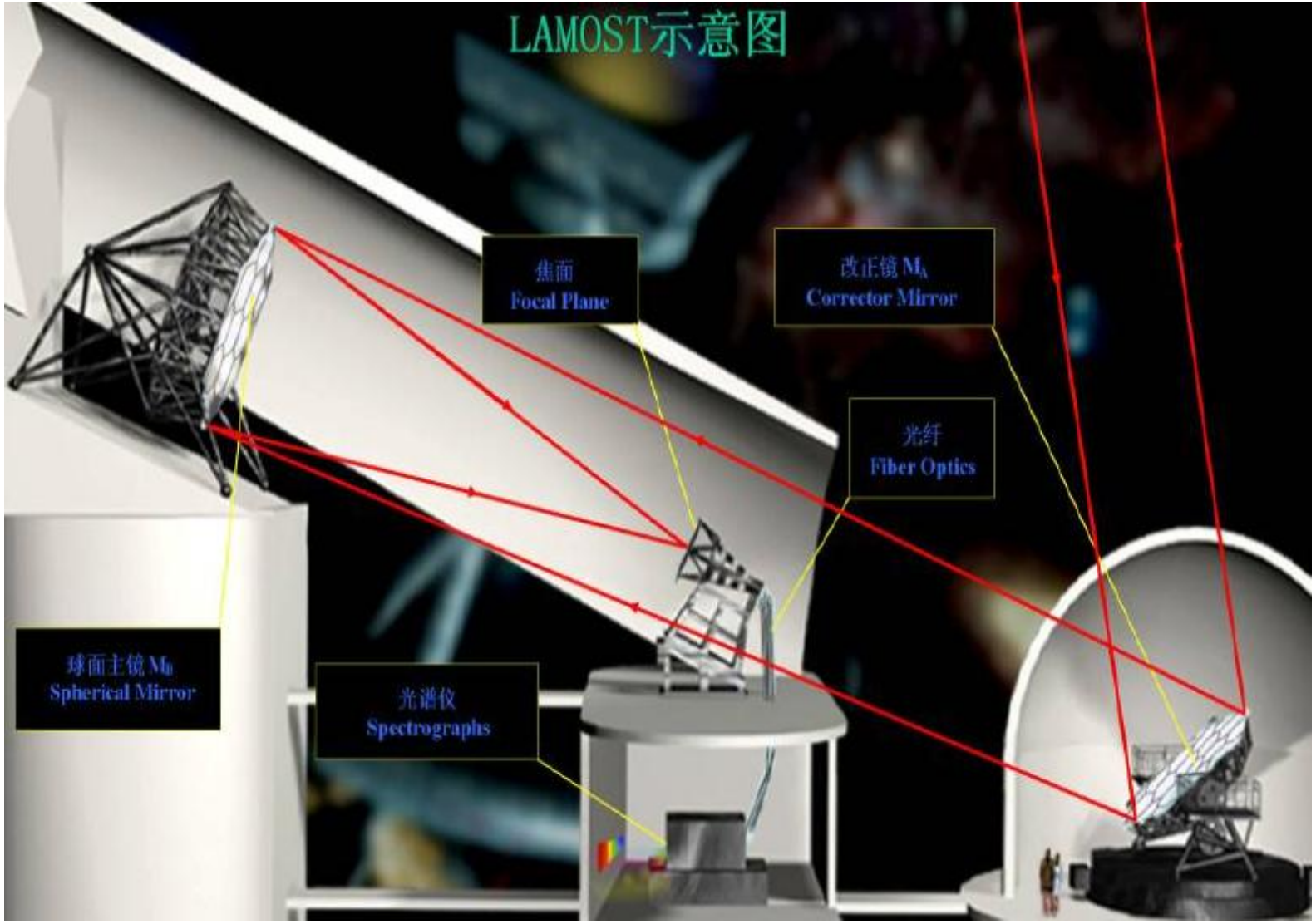
- I review the principle and working process of SSS
- SAA improve the fiber allocation rate ~2-4%
- We use S/N feedback from 2D pipeline to reallocate those failed object and analysis the fiber performance.

2D pipeline

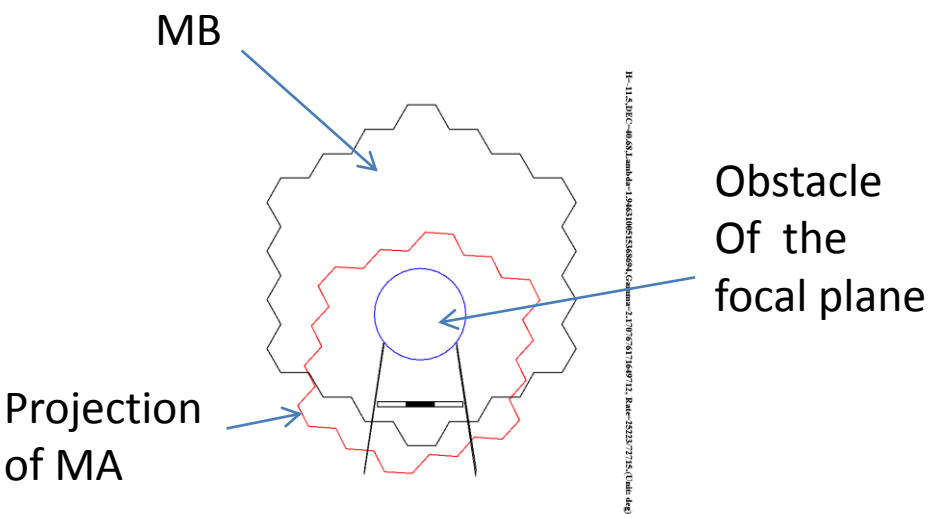


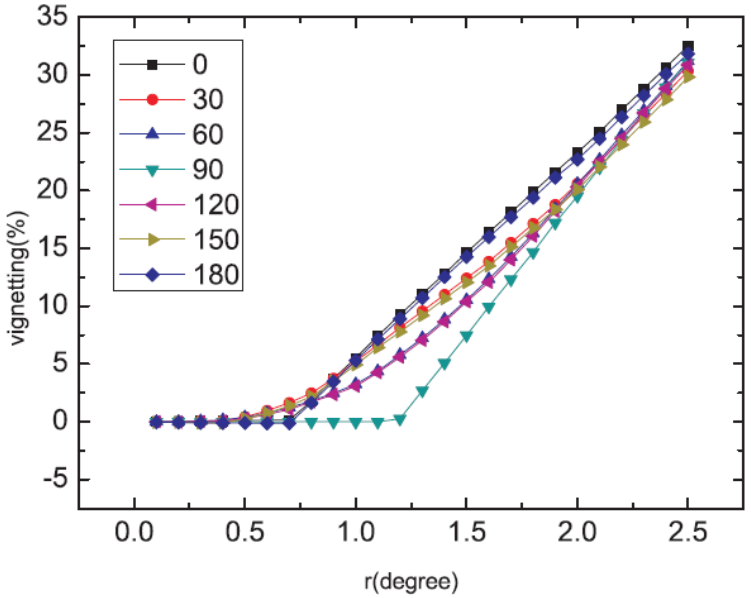
Troubles with 2D pipeline

- Fiber efficiency difference
  - Vignetting effect – variable with telescope pointing
  - Variation with fiber position – light loss due the fiber bending or twisting
  - No valid flat field
- Profile difference
  - Slit induced distortion
- Wavelength unstablity
  - Spectrograph shift

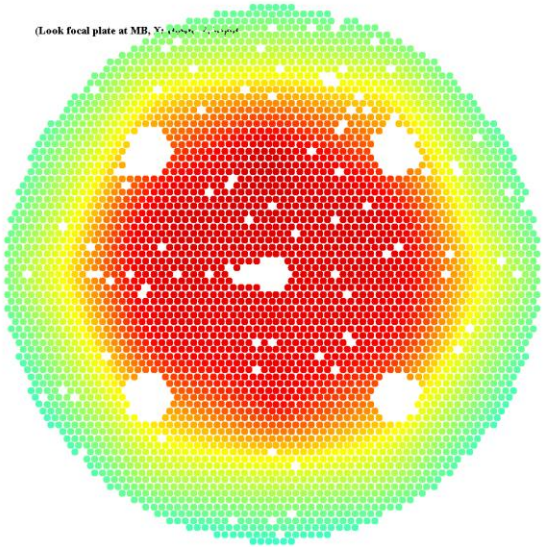

LAMOST示意图
焦面
Focal Plane
改正镜 M_A
Corrector Mirror
光纤
Fiber Optics
球面主镜 M_B
Spherical Mirror
光谱仪
Spectrographs

Vignetting effect

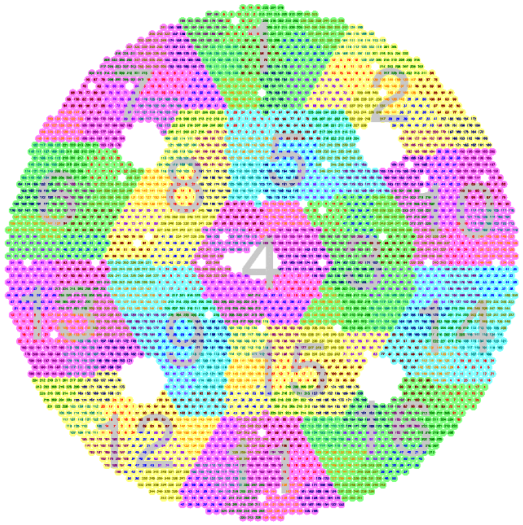




Can not be ignored within one spectrograph



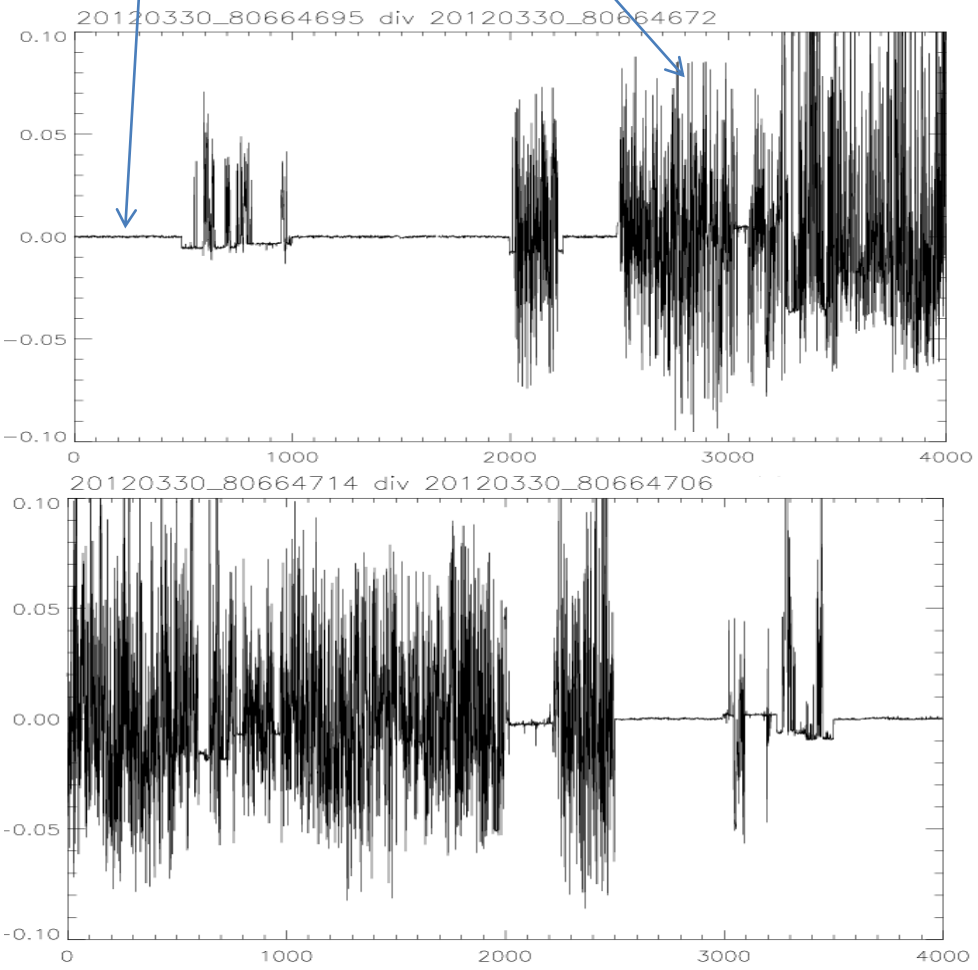
Distribution of Vignetting effect on the focal plane



Efficiency variation with fiber position

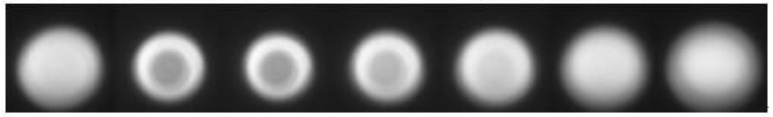
Fibers keep the same position in the 2 exposure

Fibers move to appointed position

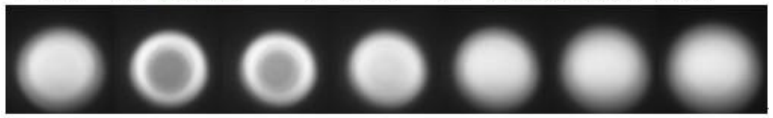


（二） H0405 随光纤头入射端旋转出射端光斑变化情况

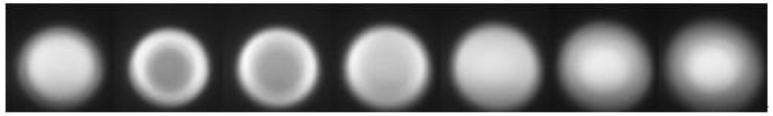
中心轴 0 度，偏心轴 0-180 度（间隔 30 度）出射端光斑如下图所示：



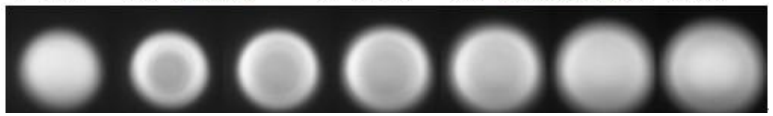
中心轴 60 度，偏心轴 0-180 度（间隔 30 度）出射端光斑如下图所示：



中心轴 120 度，偏心轴 0-180 度（间隔 30 度）出射端光斑如下图所示：



中心轴 180 度，偏心轴 0-180 度（间隔 30 度）出射端光斑如下图所示：



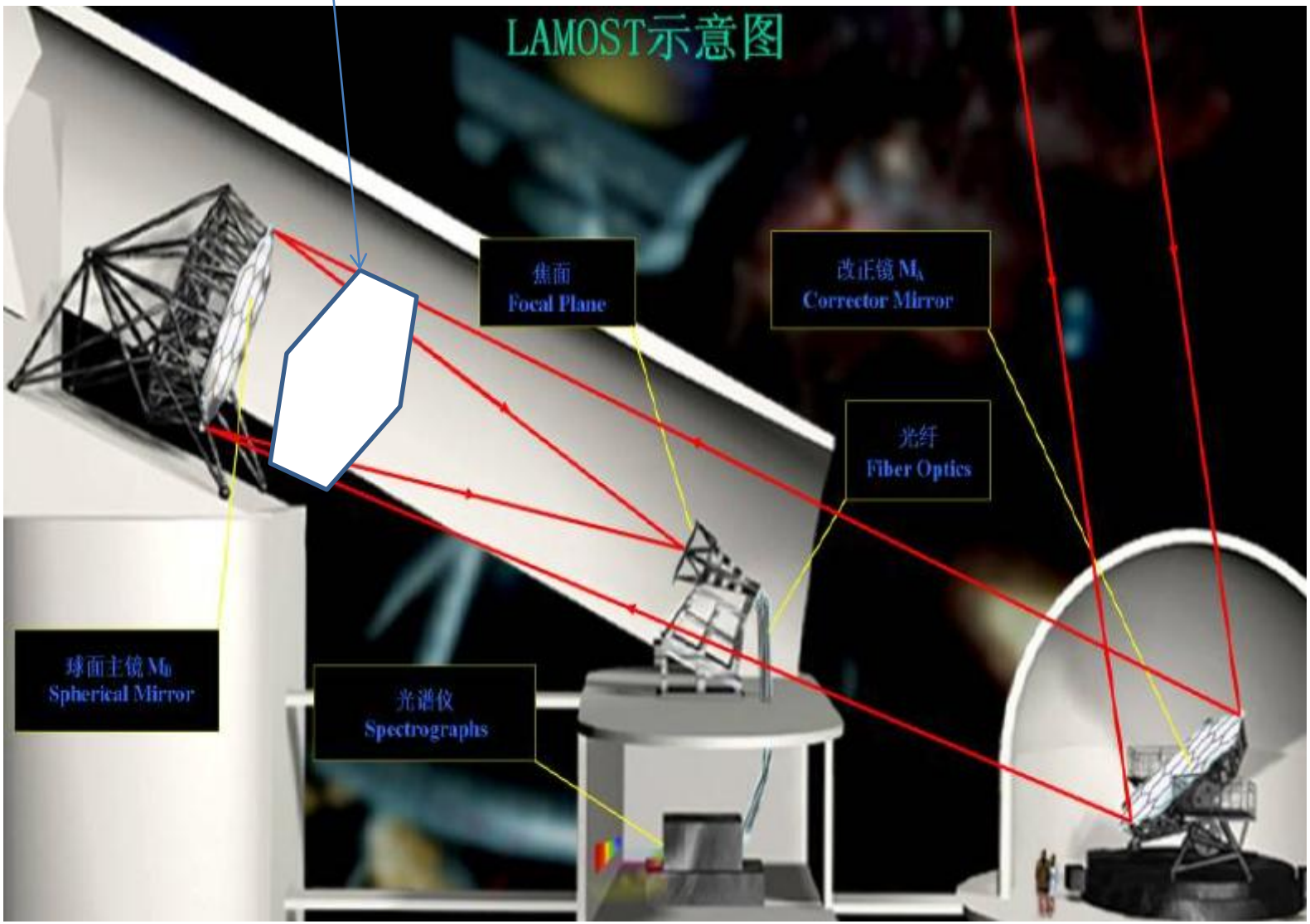
Images measured at output end of the fiber with different fiber position

Dome flat field screen:

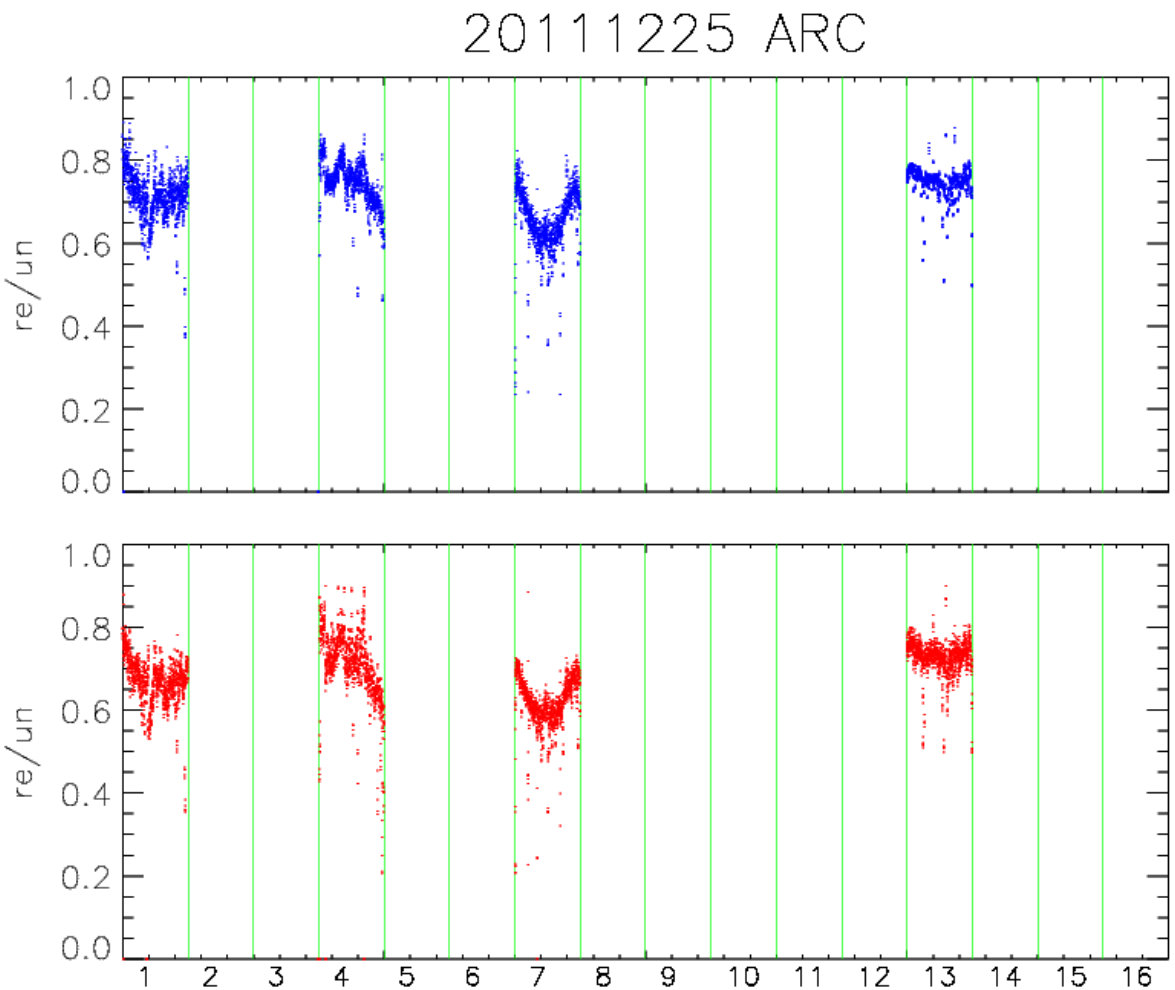
1. Not installed at the telescope pupil
2. No homogenous illumination

Twilight flat

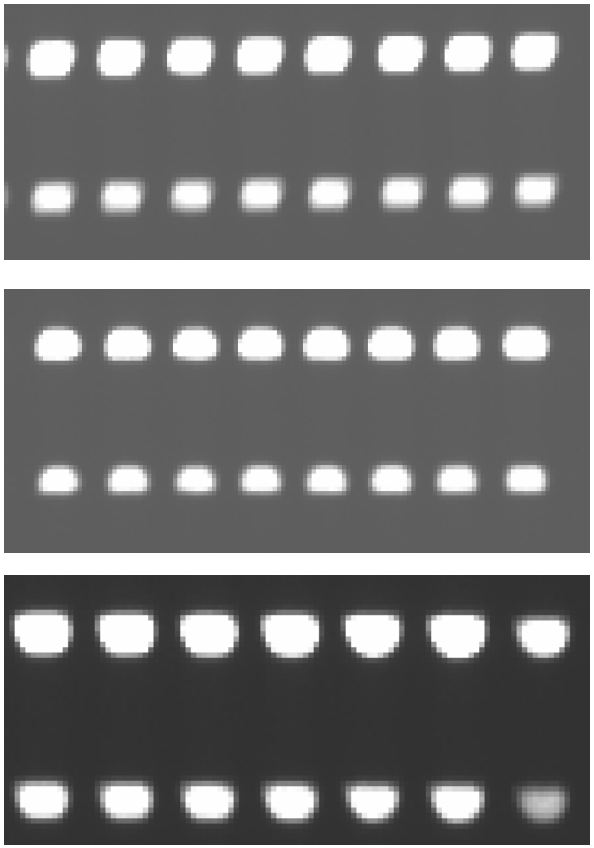
1. Taken at zenith, don't change with position
2. Valid time is very limited
3. Only homogenous around zenith, not for LAMOST

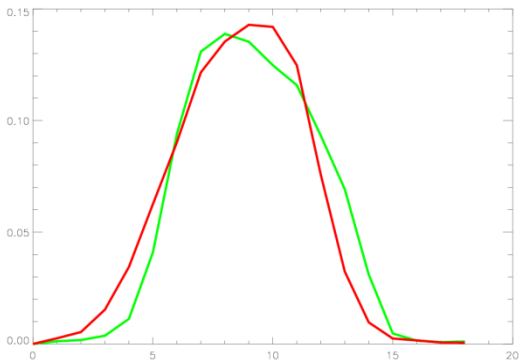


Slit induced distortion

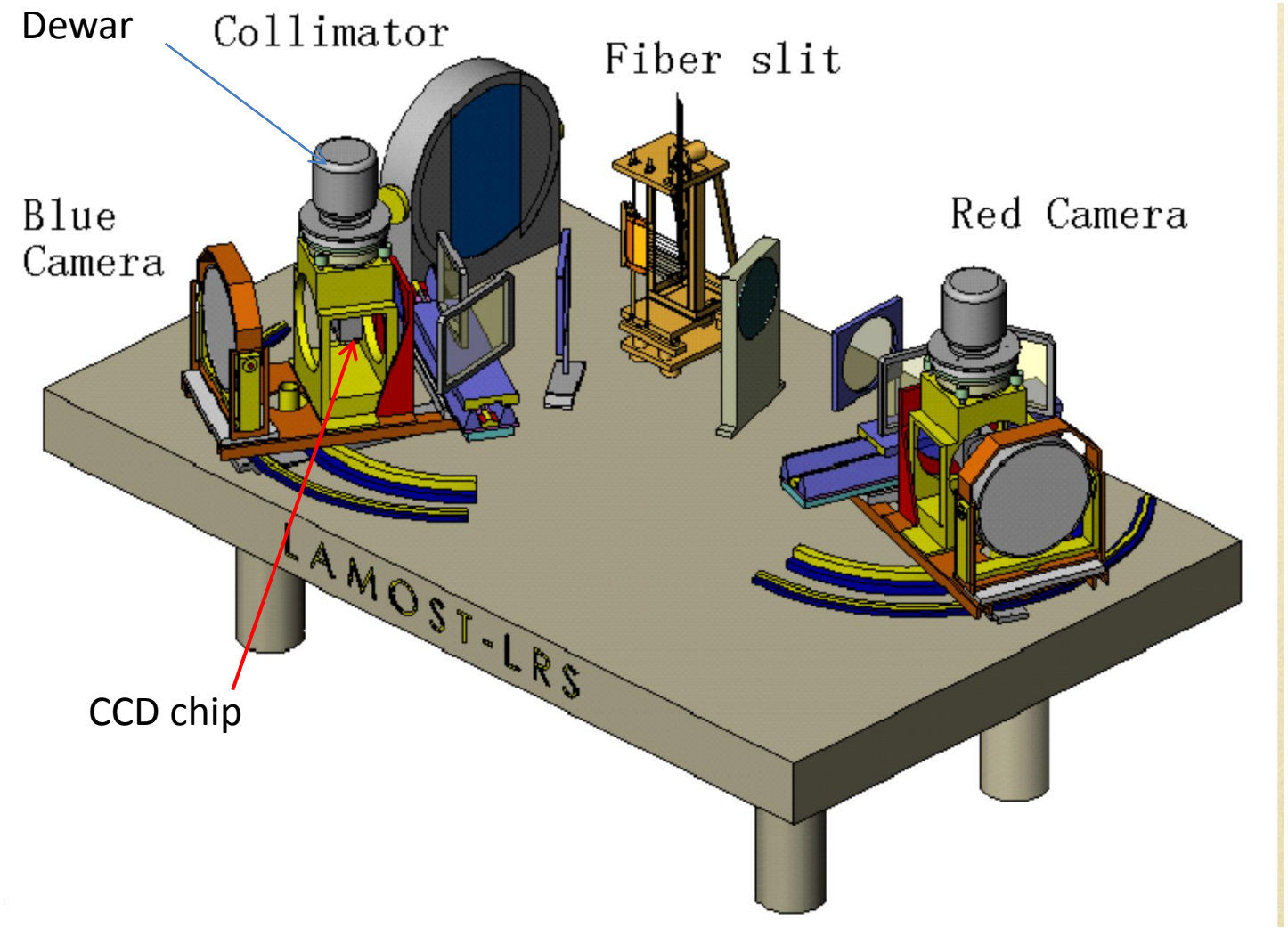


PSF of arc lamp





Spectrograph shift



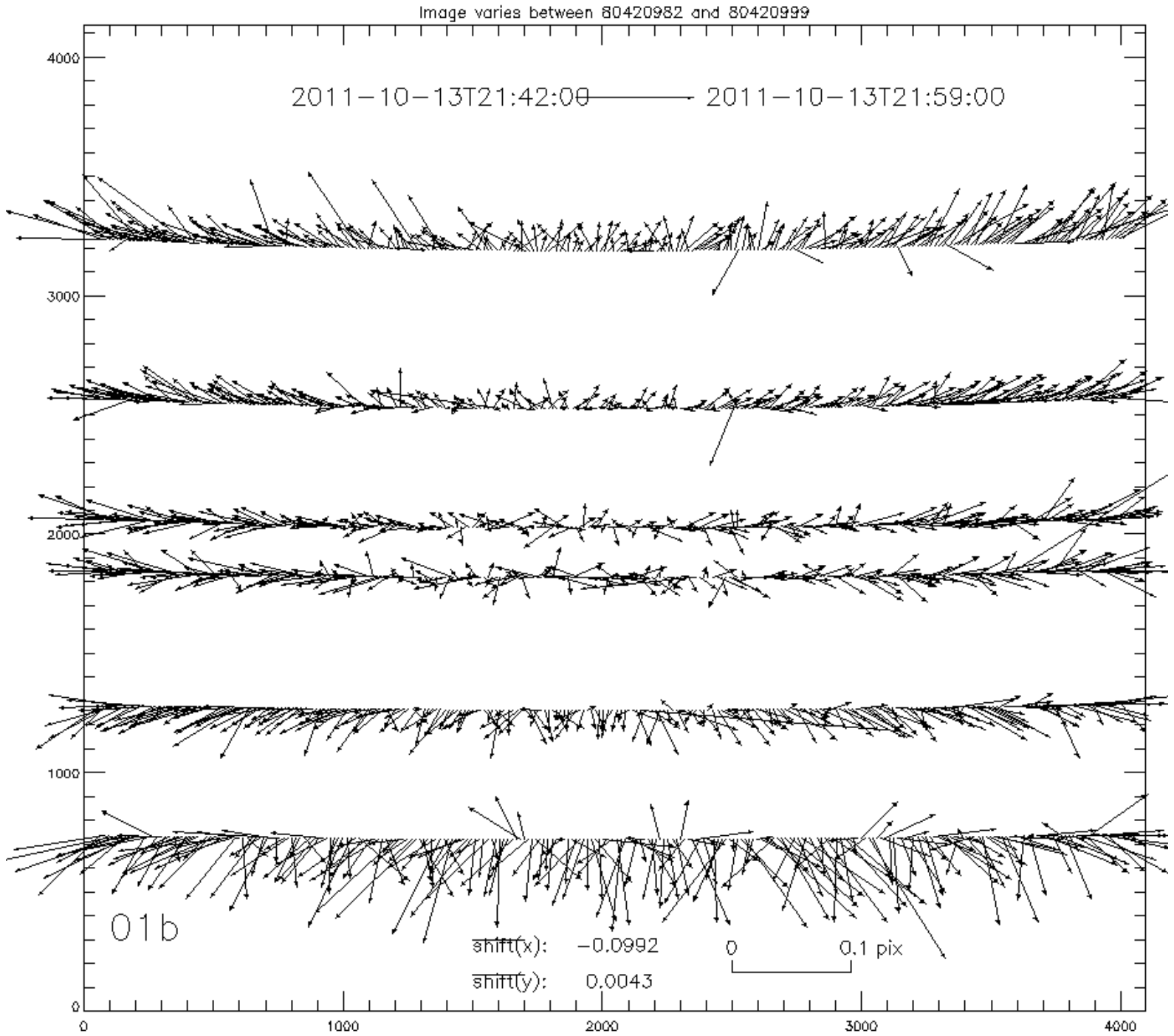
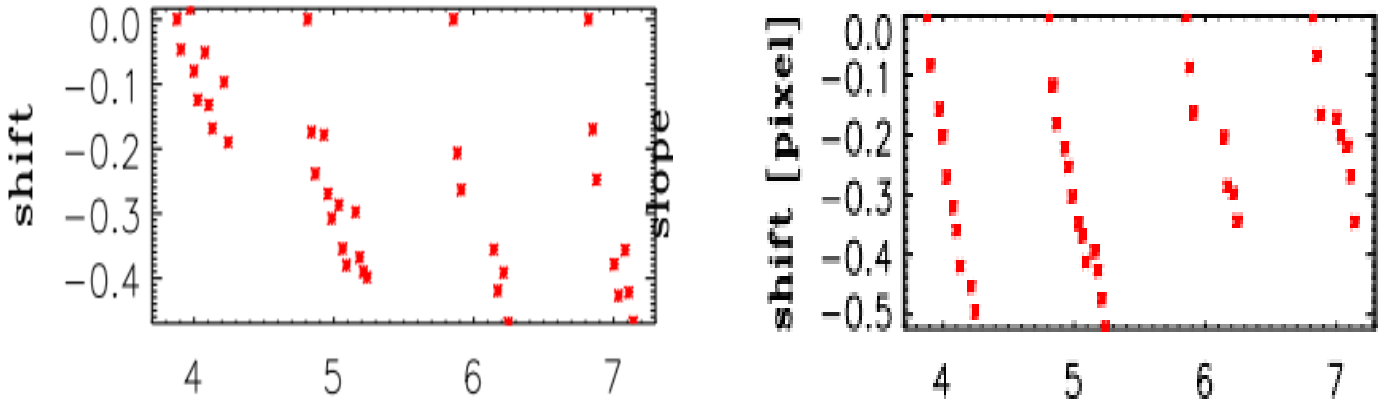
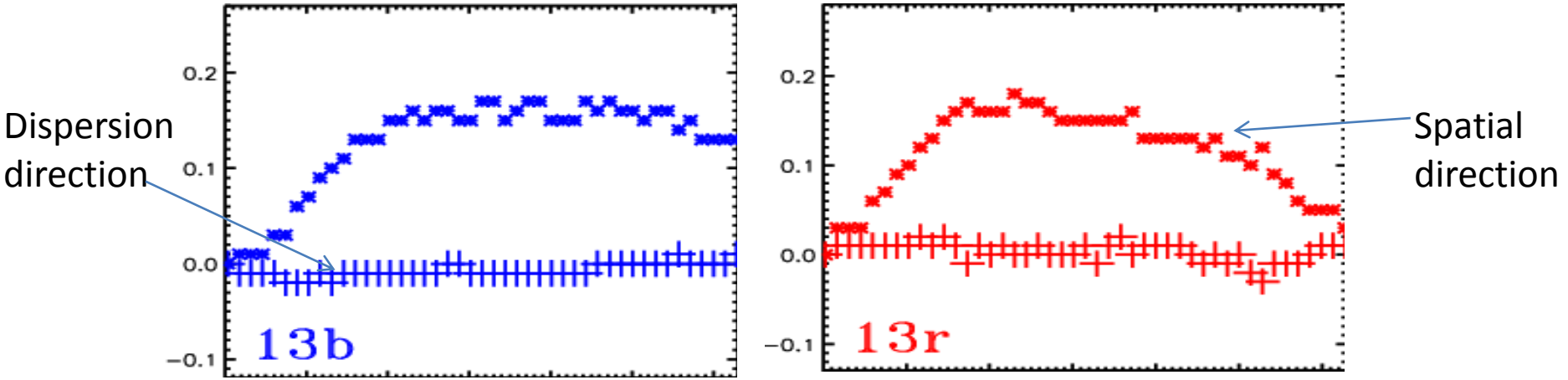


Image varies between 80420982 and 80420999
2011-10-13T21:42:00
2011-10-13T21:59:00
01b
shift(x): -0.0992
shift(y): 0.0043
0
0.1 pix
0
1000
2000
3000
4000



2011 03 before spectrograph remodeling



2011 10 after remodeling

Solutions

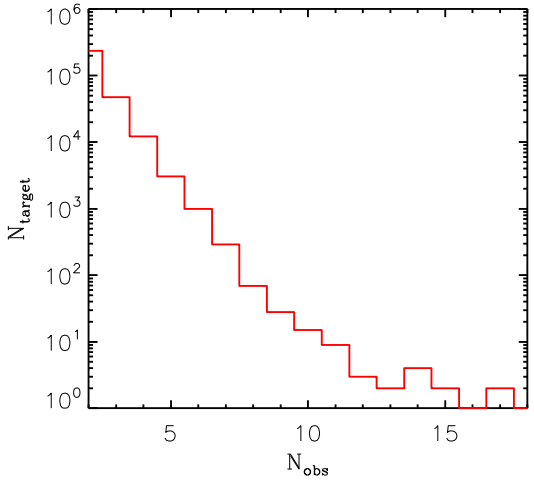
- Sky emission lines calibrate the fiber to fiber throughput difference
- Flat field calibration the color term
- Add more arc exposures. Sky emission line wavelength offset calibration
- Induce fiber dependent coefficient when interpolating super sky to each fiber ; 2D deconvolution to eliminate the profile difference(Li,2015)
- PCA sky subtraction

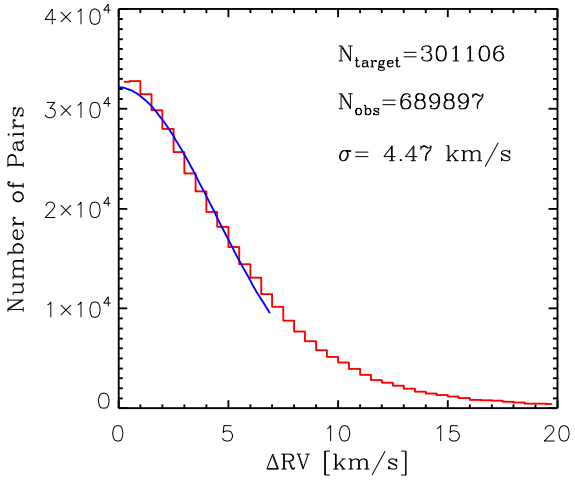
Wavelength Accuracy

- Sky emission line accuracy < 0.1Å
- LAMOST DR4 Repeat observation(>1 days)

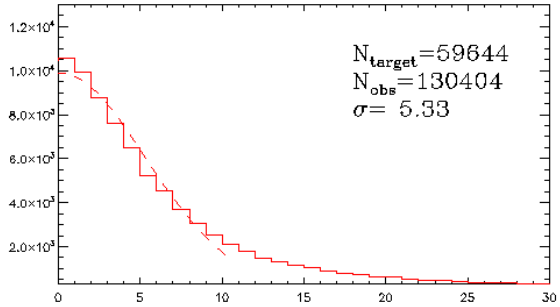
  F、G、K，SNR>20

  301106 stars，689897spectra



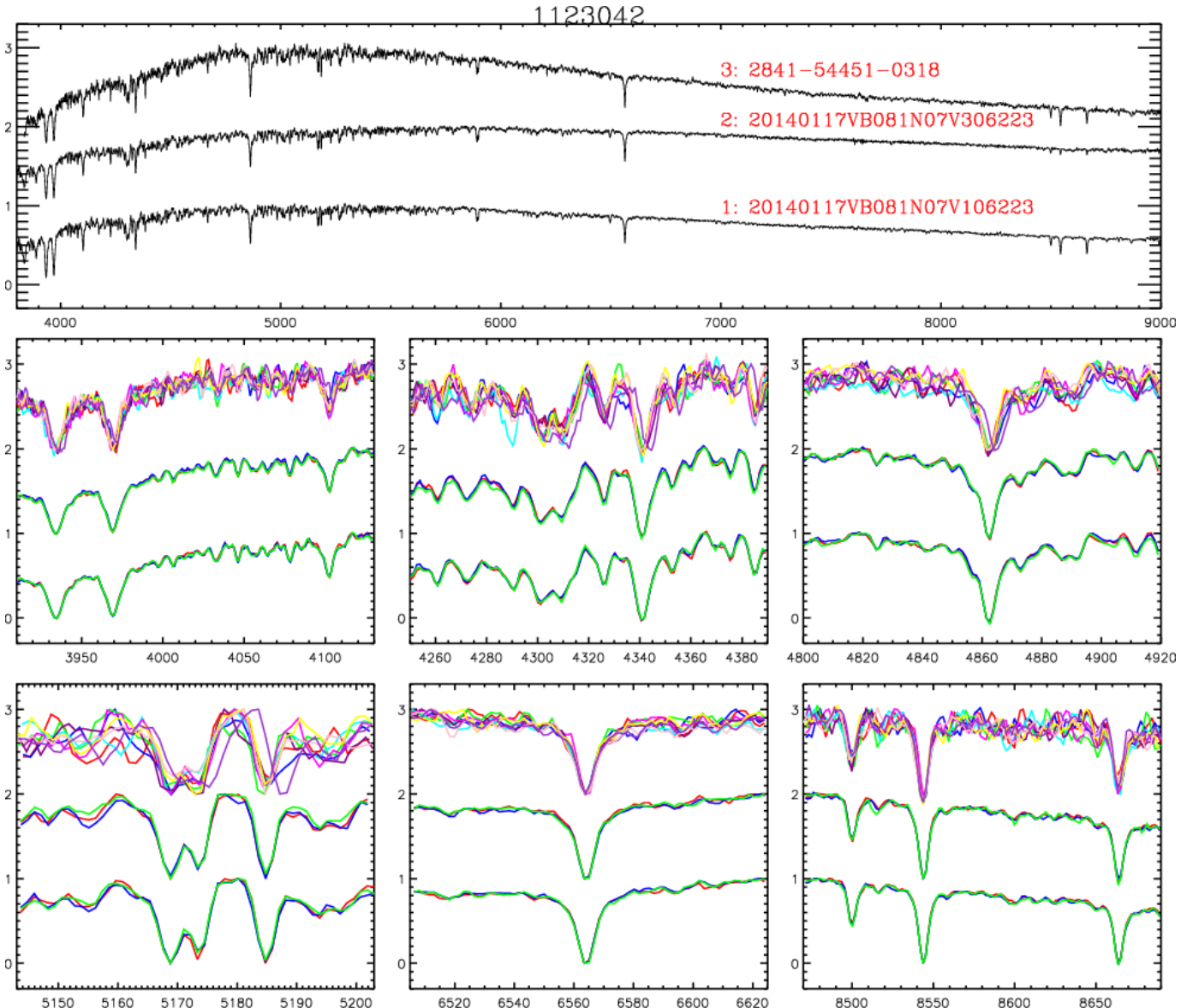


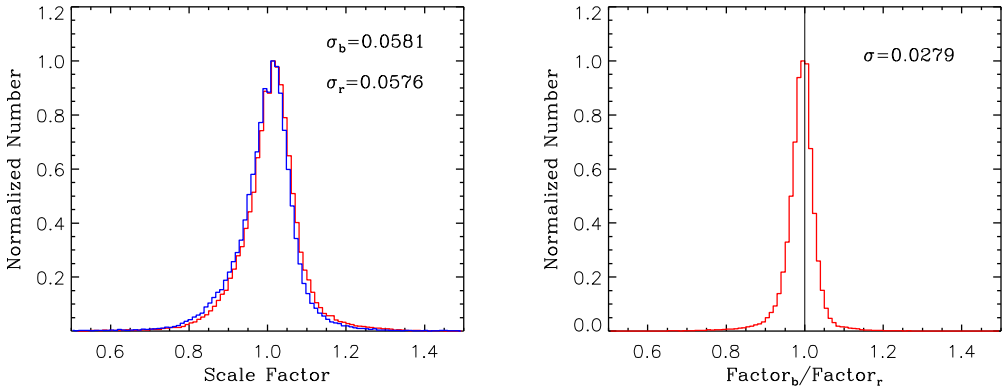
LAMOST



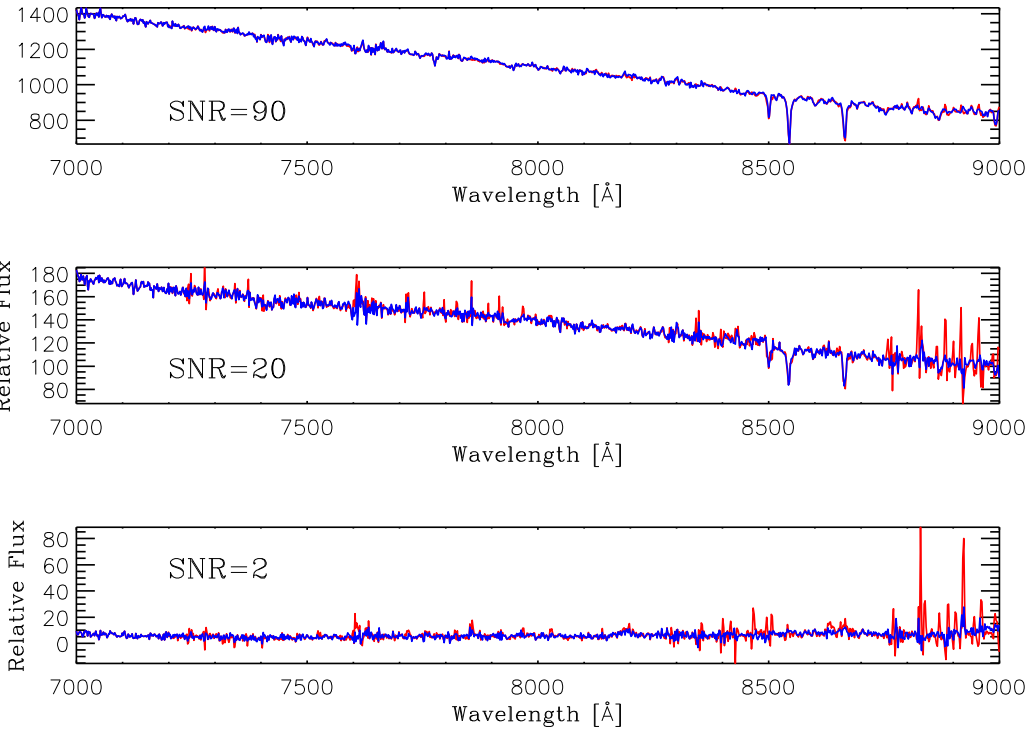
SDSS Dr8

example

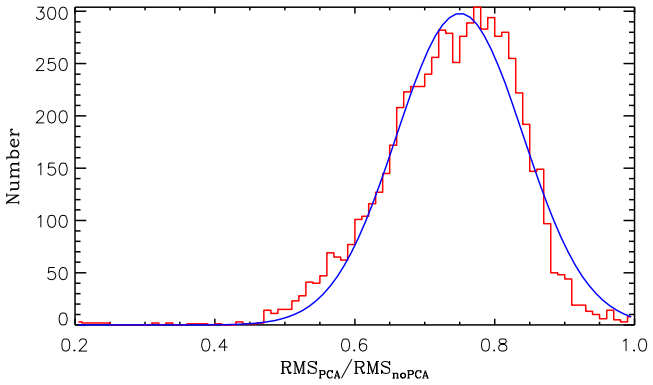

1123042
3: 2841−54451−0318
2: 20140117VB081N07V306223
1: 20140117VB081N07V106223



Sky emission line throughput calibration

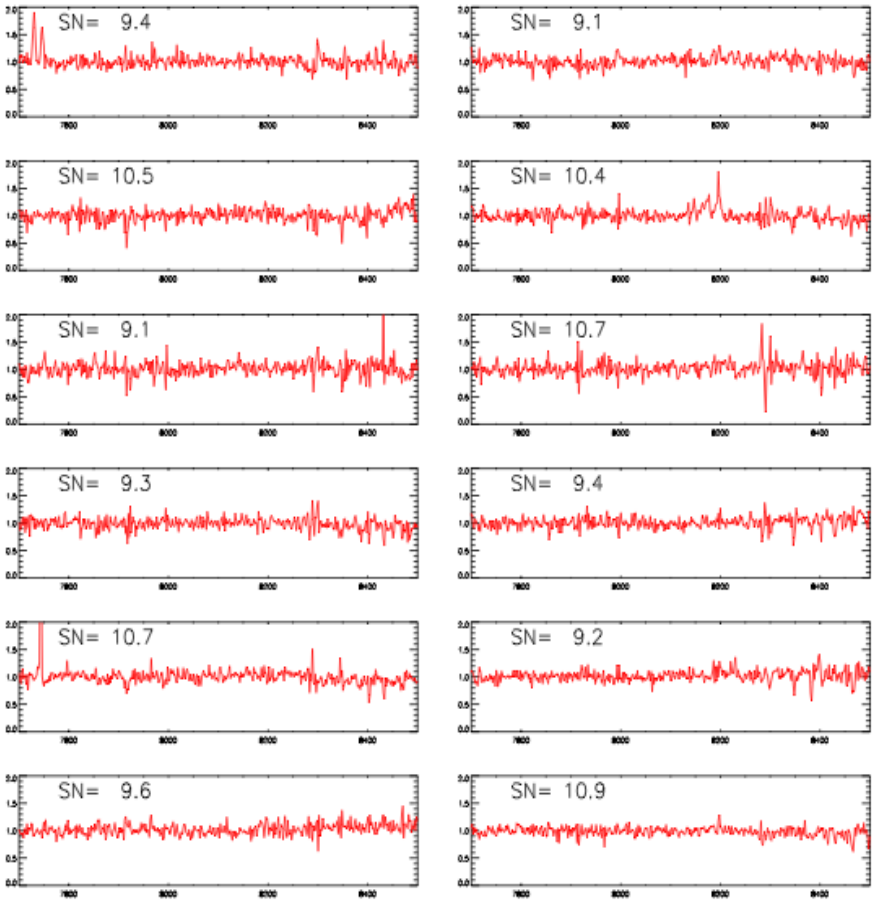


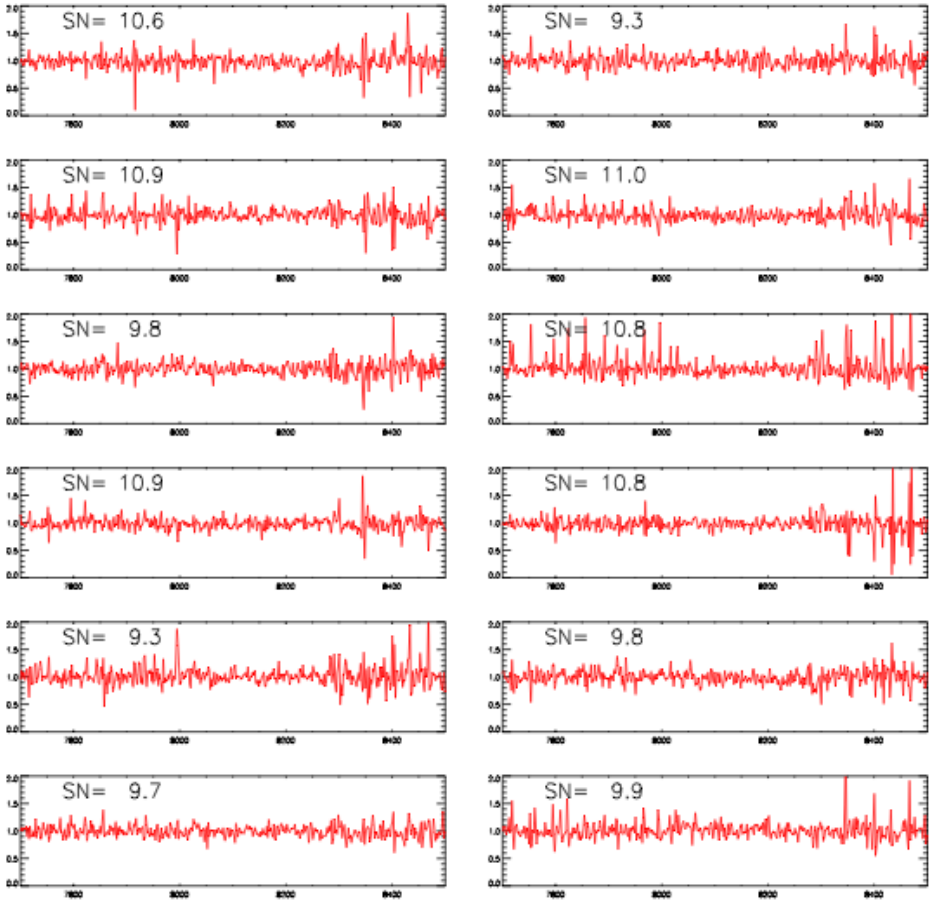
PCA sky subtraction



PCA improvement

Comparing with SDSS

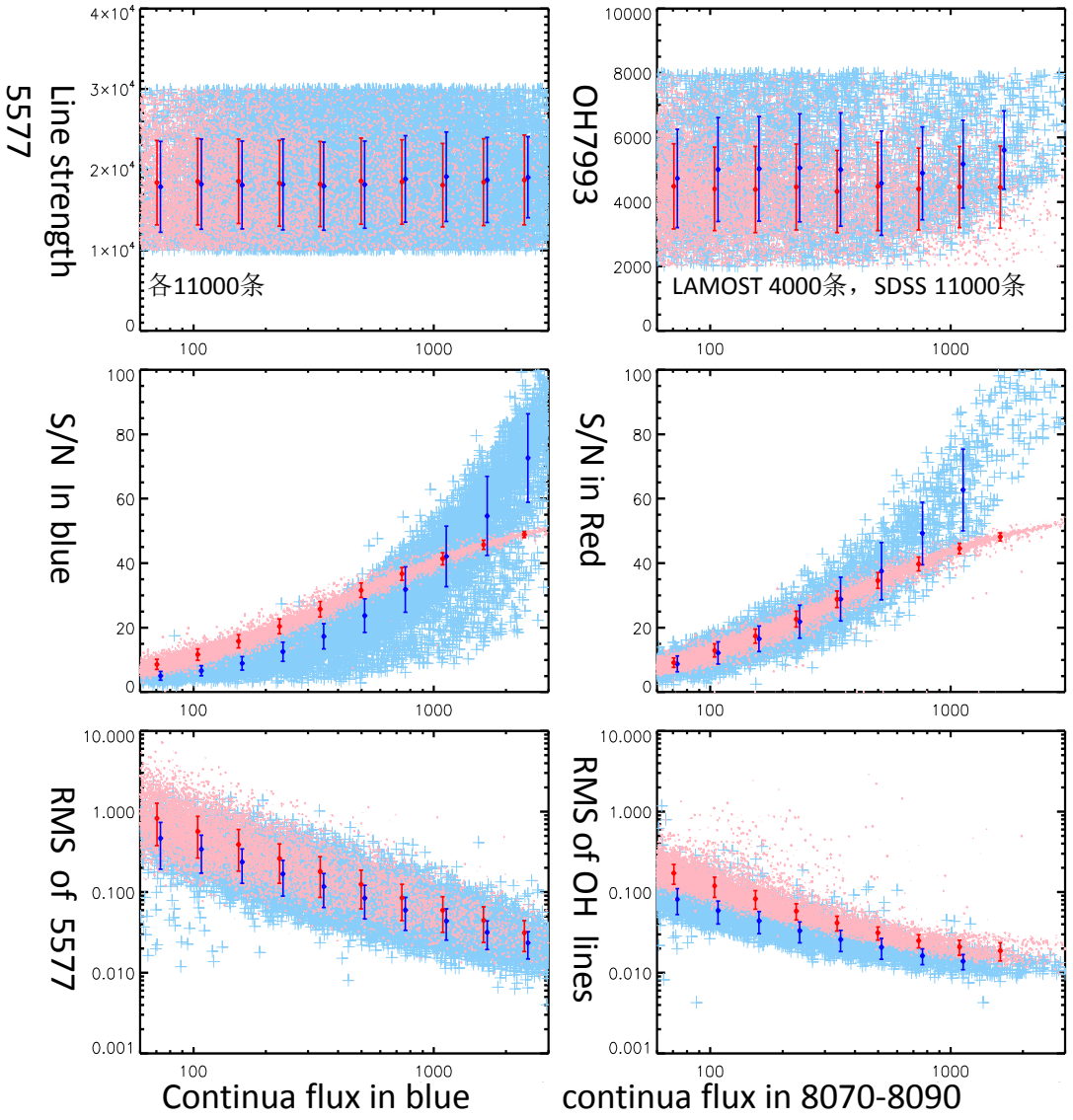




LAMOST

SDSS

Comparing with SDSS(Bai,et al.,2017)



F star from LAMOST DR3 & SDSS DR10
With similar sky emission line flux；

$$a_t = RMS\left(\frac{f_r - c}{c}\right),$$

a_t Including :
sky emission line residual
fluxtuation of different S/N
fluxtuation from the stellar feature

Red : SDSS
Blue: LAMOST

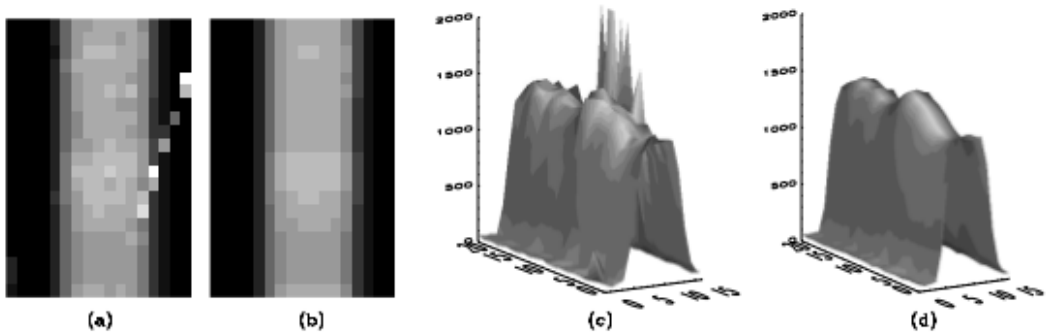
$$e_S = \sqrt{f + (g * n_{rd})^2 + 10^{-4} f^2}$$

$$e_L = \sqrt{f + (g * n_{rd})^2}$$

Cosmic Rays rejection in single exposure LAMOST Image(Bai,et al., 2017)

- Cosmic Rays(CR) are rejected by combing images of ≥ 3 consecutive exposures in regular survey.
- It's necessary to do CRs rejection in single exposure images for time domain studies.
- Pervious CRs rejection method are designed for Photometry or long-slit spectra(Farage,2005, etc), no available method for multi-fiber spectra.

Cosmic Rays Rejection



$$I_{xy} = \mathcal{F}_{xy} + \varepsilon_{xy}$$
$$= S(x)P(y) + \varepsilon_{xy},$$

- Fibers Profiles on 2D images are smooth and changing slowly.
- 2D profile on CCD image can be fit in 2 directions $F_{xy} = S(x) \cdot P(y)$
- CRs could be found by comparing the observed Image I_{xy} with F_{xy}, and the CR polluted pixels could be replaced by F_{xy} .

Comparing with L.A.Cosmic

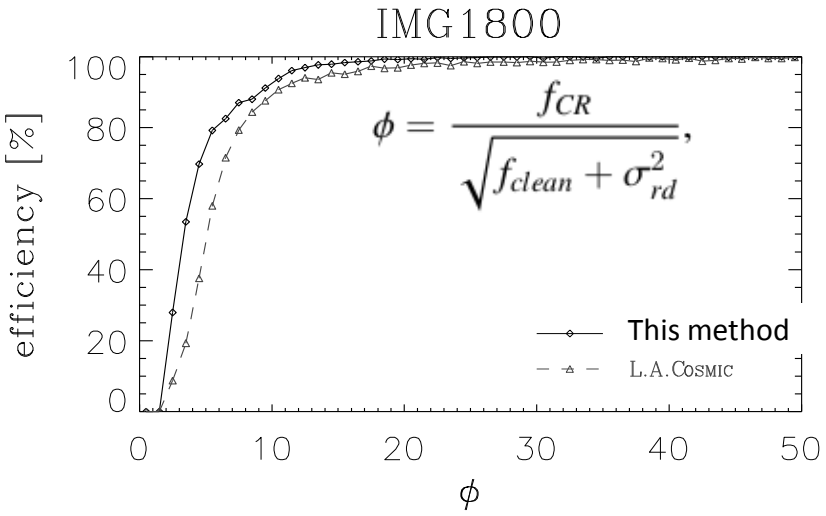
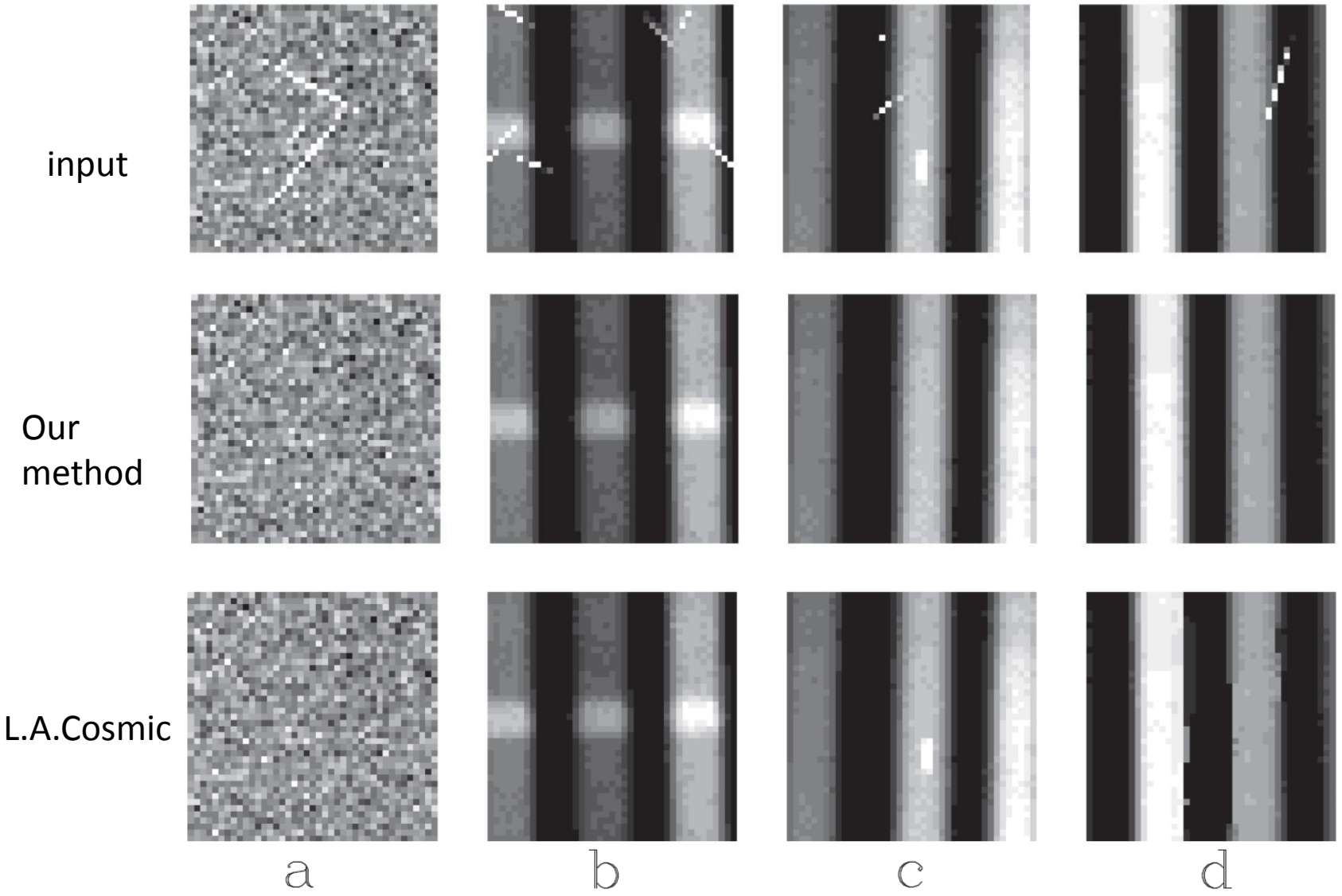


Table 1
Results of CR Detection on Simulated Images

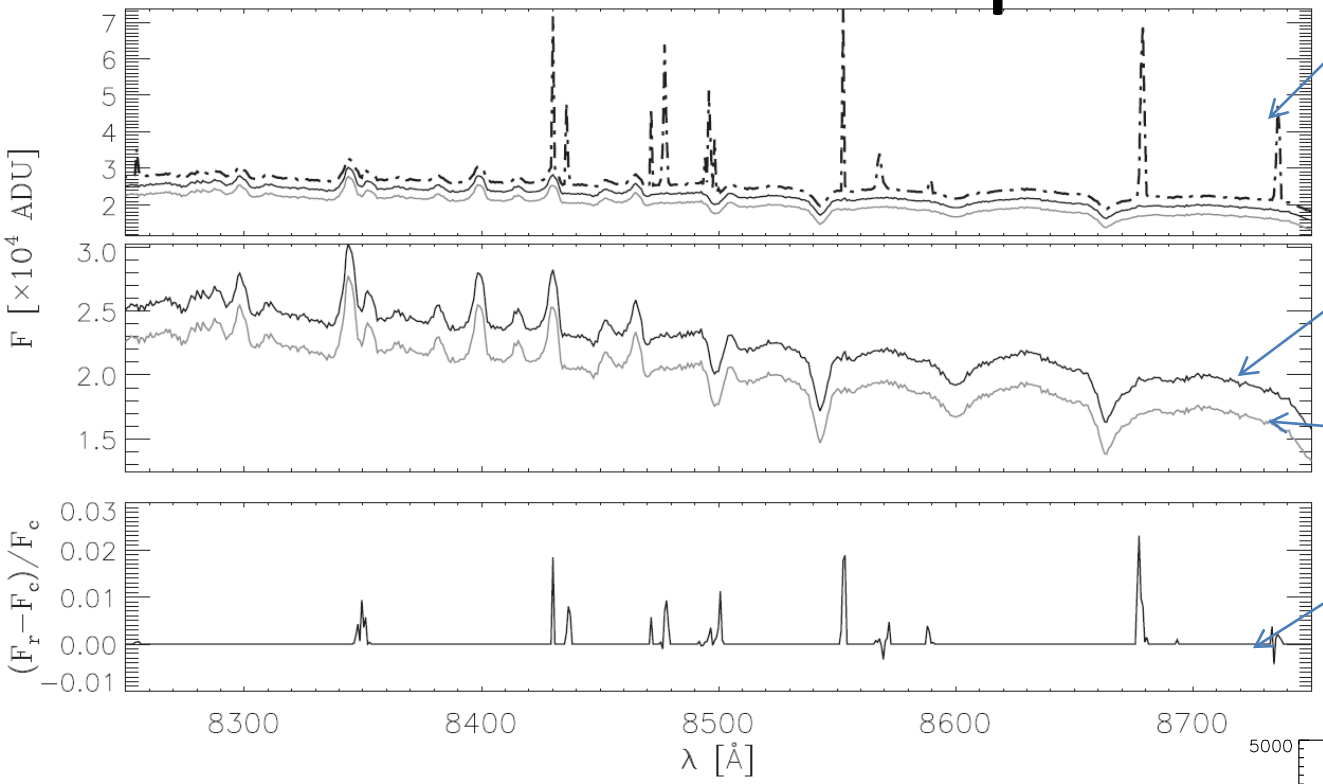
Items	IMG600	IMG1800
CR added	227451	227451
CRs detected by this paper	167844	184019
CRs detected by L.A.COSMIC	163434	173963
efficiency of this paper	73.8%	80.9%
efficiency of L.A.COSMIC	71.9%	76.4%
False detections of this paper	5820	16626
False detections of L.A.COSMIC	559414	38912

- L.A.Cosmic(van Dokkum 2001) is the best method for rejecting CRs in photometric image(Farage2005).
- For Multi-fiber spectral image, our method precede L.A.Cosmic in efficiency and number of false detection

Examples



Extracted spectra

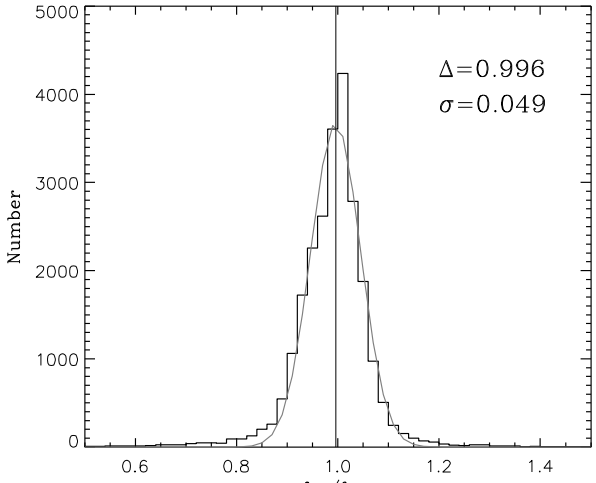


Spectra with CRs

CR free spectra

CR corrected spectra

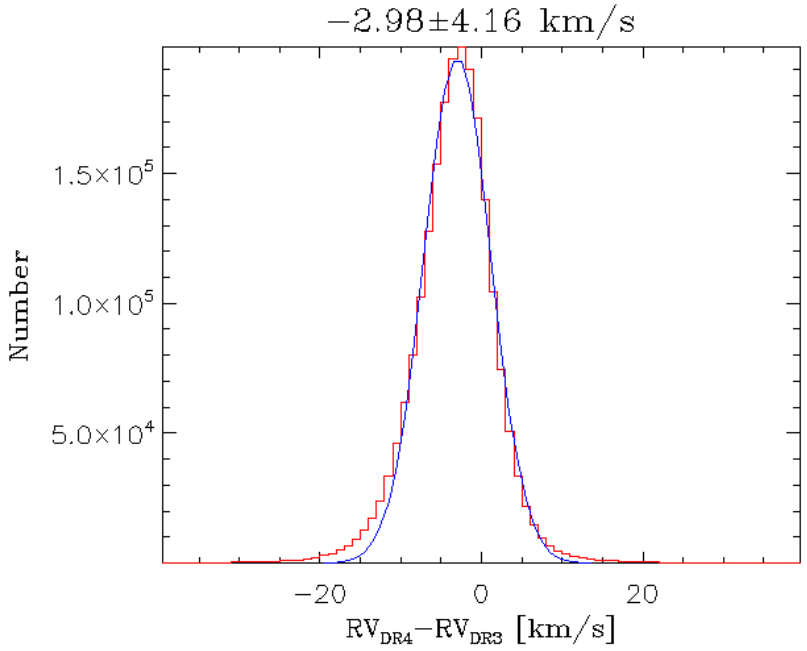
difference

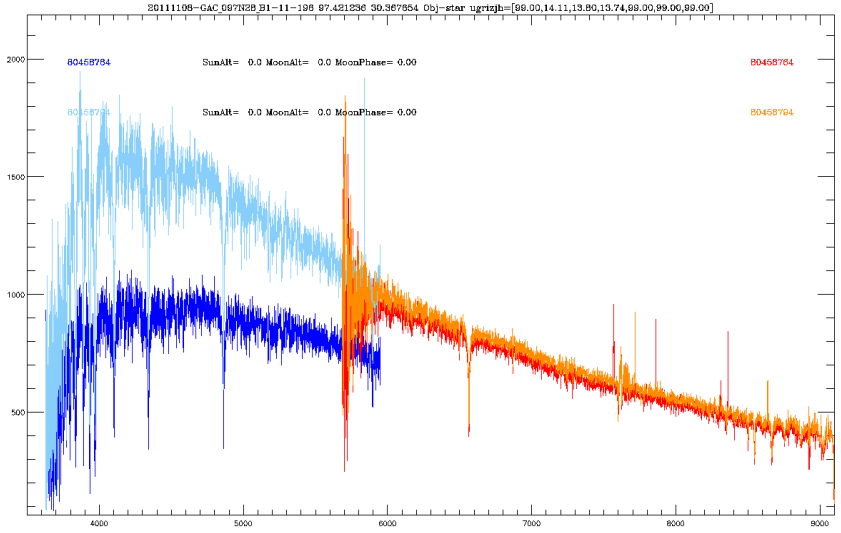


- We use the observed LAMOST data to test the algorithm.
- Statistics of difference between the CR free spectra (derived from combined image) and CR rejected spectra show the difference is about 5%.

Known bugs in V2.8

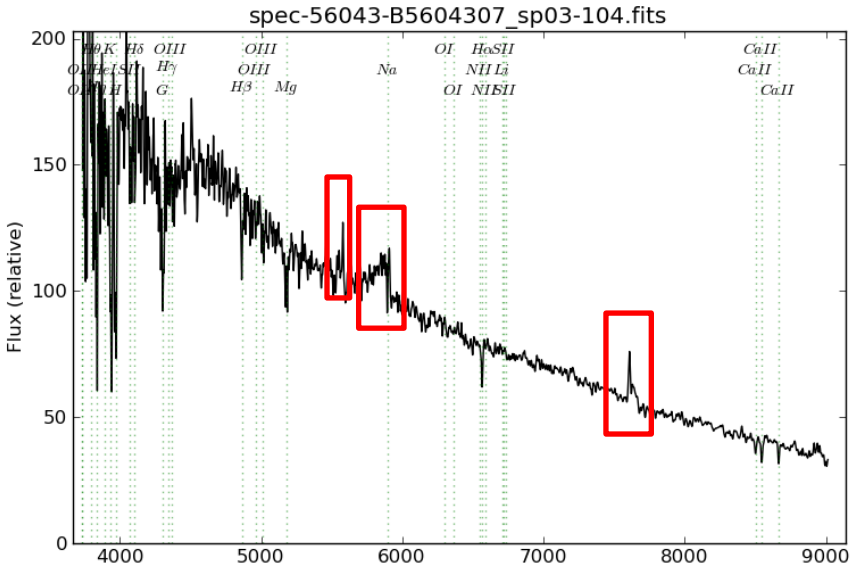
- ~ -3km/s wavelength calibration offset with V2.7
- Flux differences between difference exposures are not corrected(a few hundreds spectra)
- S/Ns are underestimated

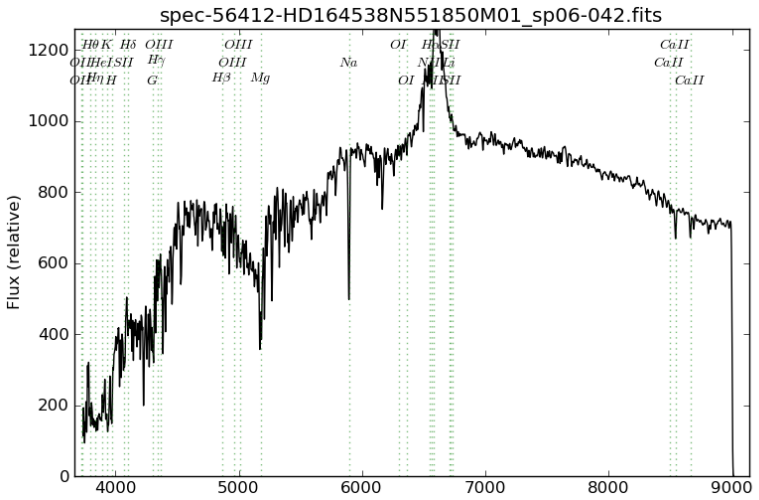




precautions for using the Data

- Mask Bit
- Low galactic latitude flux calibraiton
- Sky emission lines: 4358,5460,5577,6300,6363,…
- Telluric band: 6850-6960, 7150-7350, 7560-7720, 8105-8240
- Connection part (5700-6000)
- Stray light(solved): infrared





summary

- I review the problem we met when developing 2D pipeline and our solution to the problem.
- The wavelength calibration is about 4.5km/s as derived from RV difference of repeated FGK spectra.
- Our sky subtraction is better than SDSS when the conditions are similar.
- We developed a method to remove cosmic rays from single exposure image.

Thanks!