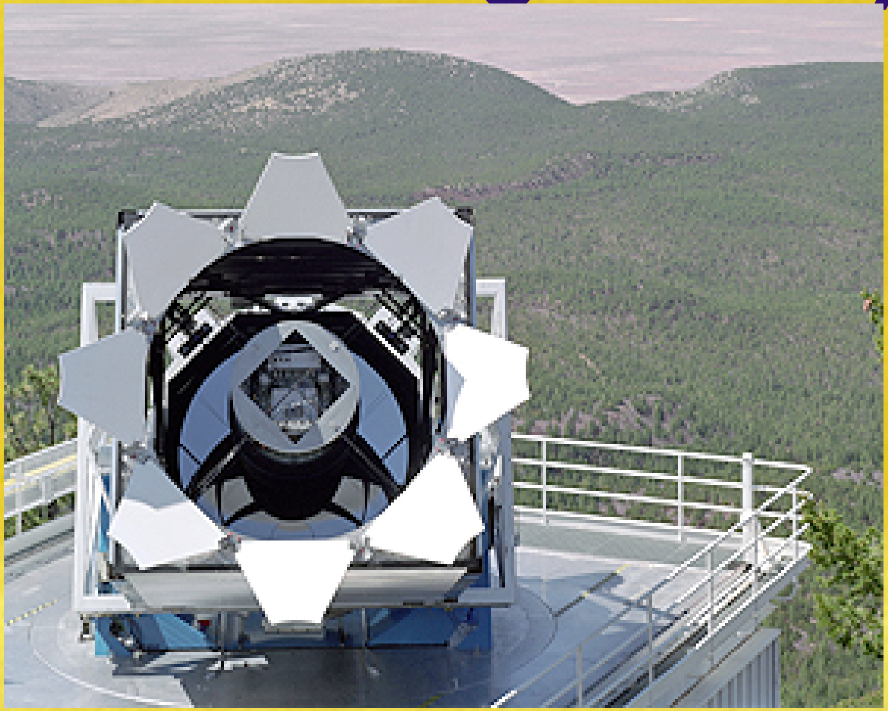
SDSS III

Sloan Digital Sky Survey



Kaike Pan

July, 2010, Guiyang

Outline

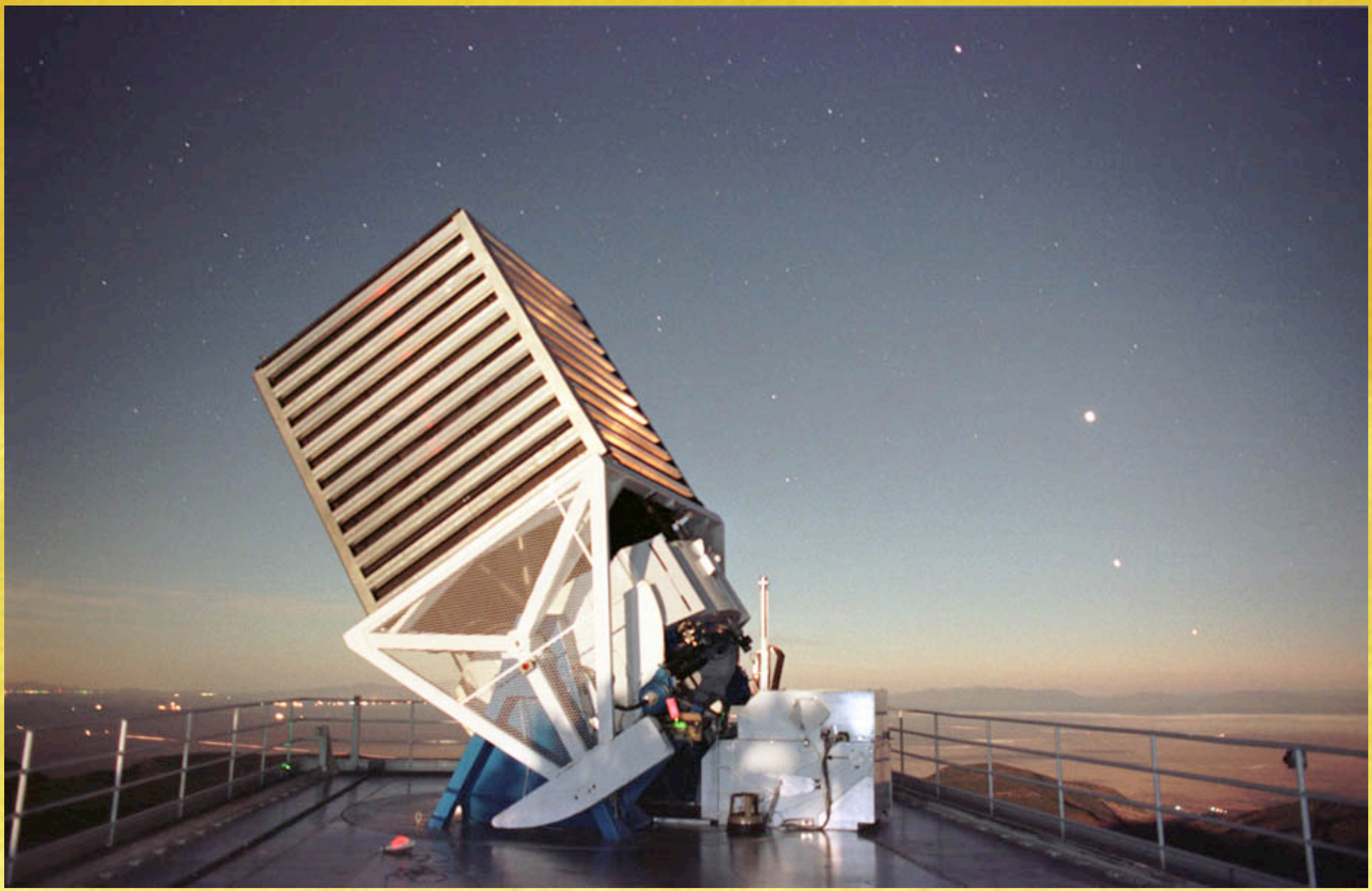
- Instruments and Instruments and Site
- What projects have been finished
- examples of SDSS contributions
- Site Operation efficiency
- Current projects
- BOSS: from design, implement, commission, to operation

The Instruments

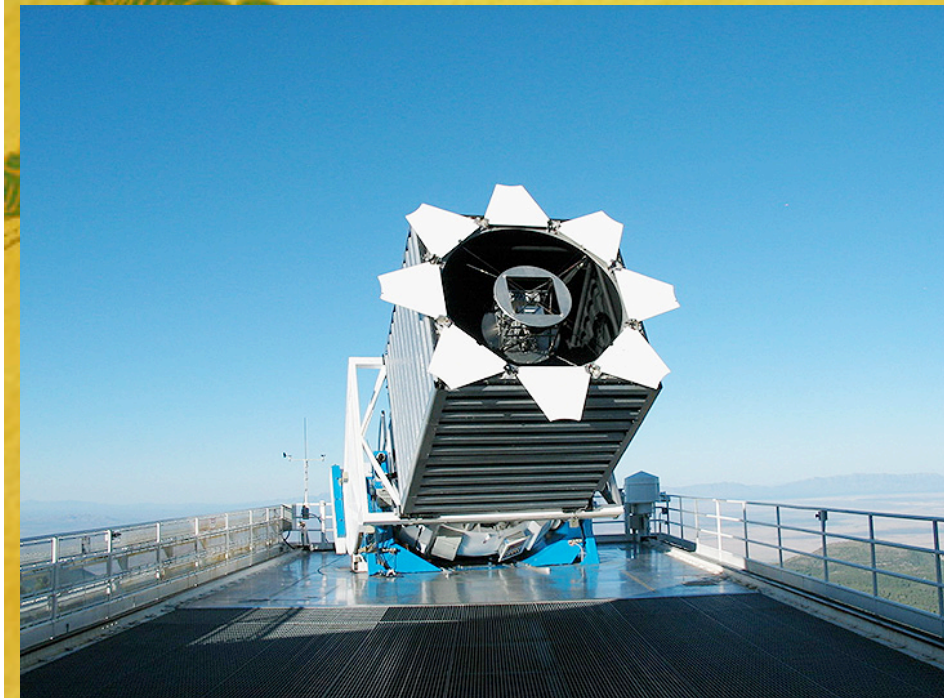
- Dedicated 2.5-m Telescope at Apache Point Observatory
  - Imager
  - Spectrographs - SEGUE2 and BOSS
  - MARVELS: interferometer + Spectrograph
  - APOGEE spectrograph (2011)
  - Engineering Camera
- Photometric Telescope (brightness calibration)
- DIMM-monitoring seeing
- Weather station: Wind, temperature, humidity, condensation temp, dust counter etc
- IR All-Sky Camera - monitoring sky condition

A Sunny Day at APO

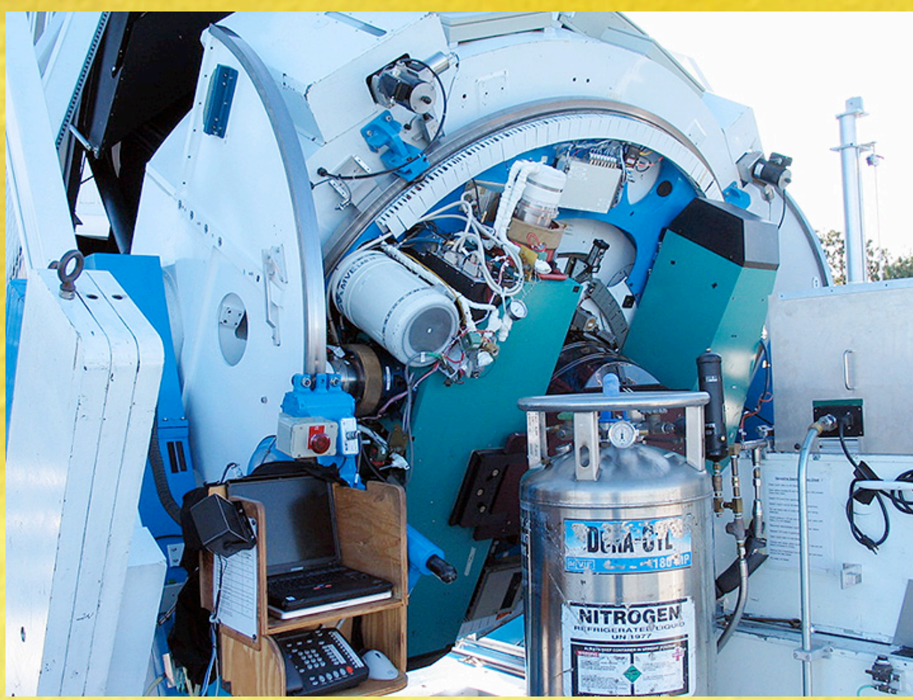
It will be a clear night



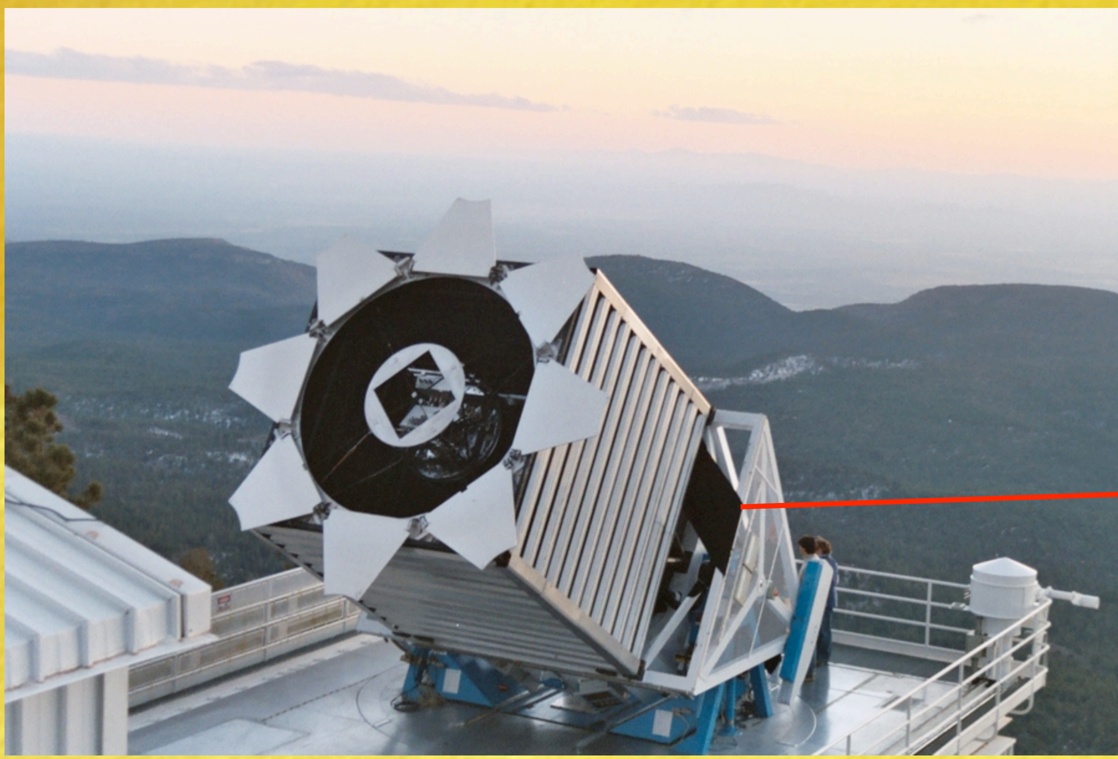
A Snowy Day at APO

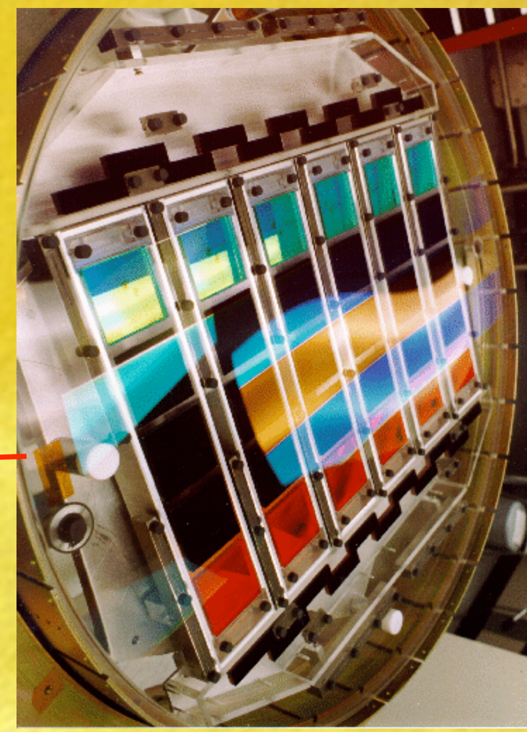


Telescope: Single object. vs Multiple objects (FOV) Pencil beam vs. large-scale structures.

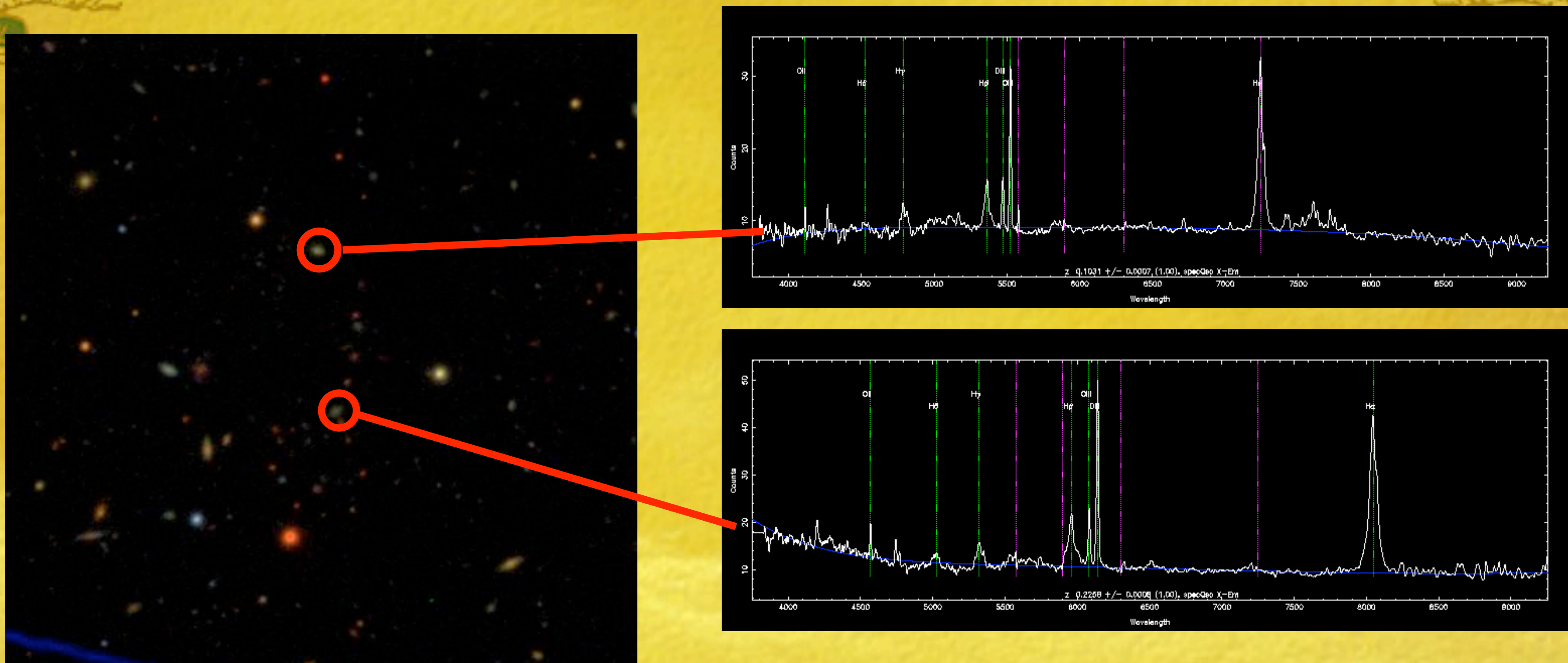


SDSS Imager (54 chips, 5 filters)

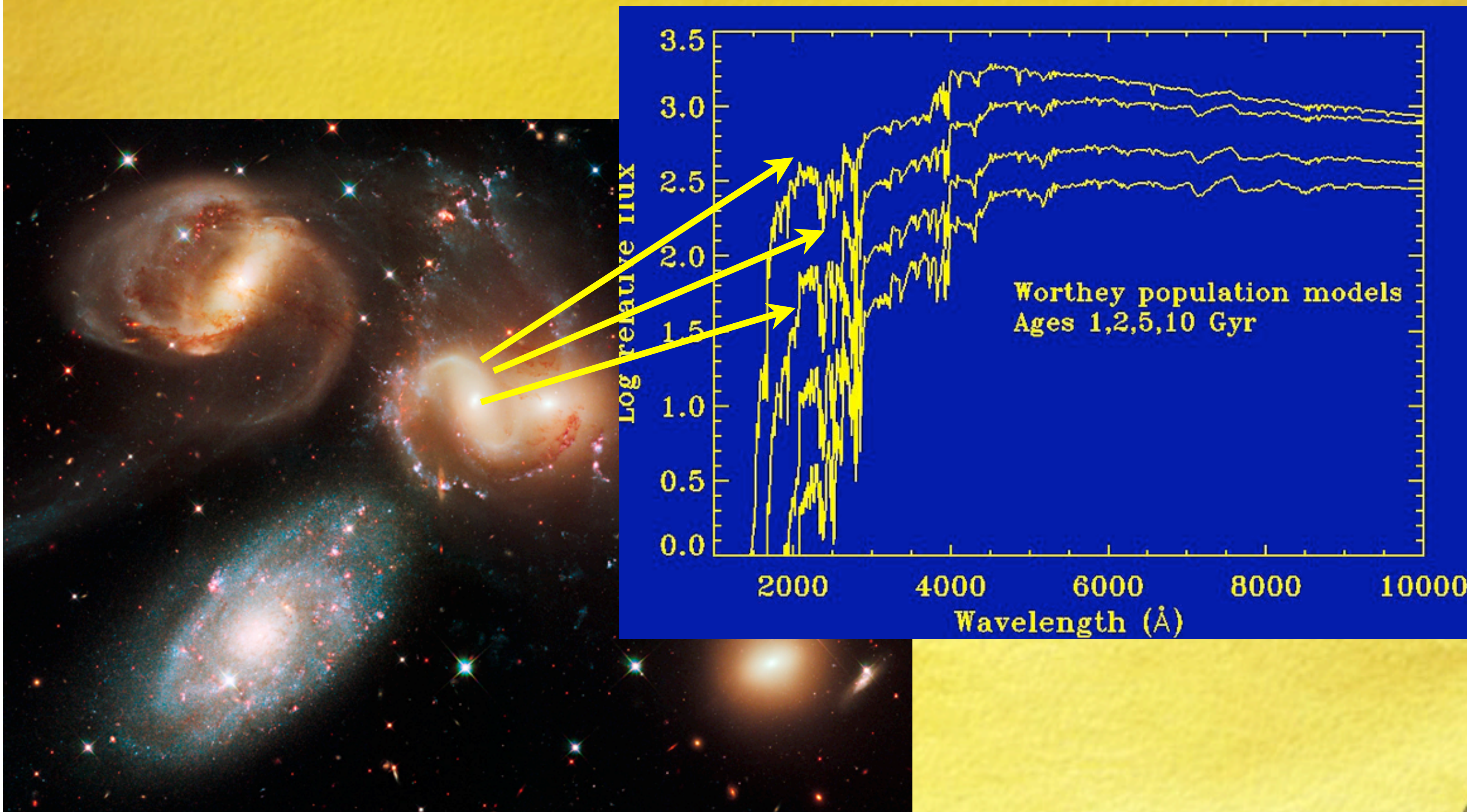




SDSS: imaging + Spectroscopy



Measure spectrum in different parts of each galaxy
→ Stellar populations (star formation)



What have been done

- Legacy Survey: Mapping the universe, provided detailed optical images(multi-color) covering more than a quarter of the sky, and a 3-dimensional map of about a million galaxies and quasars.
  - 230 M objects detected from images in 8.4 K square degree;
  - Spectra for ~1M galaxies, 120 K quasars, 120 M stars (wavelength coverage)
- SEGUE: Probed the structure and history of the Milky Way galaxy.
  - 3.5 K square degree sky images + 500 K stars

What have been done (cont.)

- The Sloan Supernova Survey: Repeat imaging 320 square degree southern equatorial strip to discover and measure supernovae (and other variable objects).

Examples of science contributions

- The discovery of the most distant quasars, powered by supermassive black holes in the early Universe.
- Mapping extended mass distributions around galaxies with weak gravitational lensing.
- Systematic characterization of galaxy population
- Precision measurements of large scale clustering and cosmological constraints.
- Discovery of acoustic oscillation signatures in the clustering of galaxies
- The demonstration of ubiquitous substructure in the outer Milky Way
- Discovery of many new companions of the Milky Way and M31
- ……..

Science contributions (cont.)

- SDSS papers received ~35 citations, more than any other facility (ground + space).
- Many astronomers outside of the collaboration use SDSS data.
- High-impact observatories (Madrid et al 2009)

Rank	Facility	Citation
1	SDSS	1892 (14.3%)
2	Swift	1523 (11.5%)
3	HST	1078 (8.2%)
4	ESO	813 (6.1%)
5	Keck	572 (4.3%)
6	CFHT	521 (3.9%)
7	Spitzer	469 (3.5%)
8	Chandra	381 (2.9%)
9	Boomerang	376 (2.8)
10	HESS	297 (2.2%)

Site Operation Efficiency

- Efficiency

	scheduled hours	useful on-sky hours	Lost to Weather	Lost to Technical
2001/02	1907	921(48.3%)	46%	5.7%
2006/07	2035	950(46.7%)	52%	1.3%
2008/09	2791	1733(62%)	36.5%	1.5%

Weather (08/09): CITO best 35%. APO a typical site.

Technical down time: Comparing with other 3-4m telescopes, 1.4 vs. ~3.1%(2.2-4.0%), plus less engineering time (cloudy nights).

Typical overhead: 30-40%

Site Operation Efficiency (cont.)

- improving efficiency: Why? $10K/h (SDSS), 25K (Y)/h for LAMOST, FAST? More if constructions
- Increasing on-sky hours, reducing overheads, decrease eng. time and tech down time.
- Change closing criteria: SDSS dust criteria
- Extra time during twilight
- Integrated multiple steps into one, save 2+ min
- Short read-out time by ~20 sec (85 to 65)
- No CCD flushing, Read-out only part of chips for hartmann tests,   ~ 130 sec
- Flex eng. nights: engineering work will not prevent night operation unless absolutely necessary.
- Preventive routine check + Cloudy night tasks

Site Operation (cont.)

- Operation is a not a easy work.
- Sparse Modules save on-sky time
- Maintenance (Designers, implementers should be available)
- Procedure page and trouble-shooting page
- Simply engineering skill: Night staff performs some simple engineering tasks with engineering staff on phones. Involving in some engineering tasks.
- Managements: in general, no cross-level.

Current projects

- BOSS: Measures the cosmic distance scale via clustering in the large-scale galaxy distribution and the Lyman-α forest.

Goal: Dark energy and cosmological parameters

- APOGEE: will use high-resolution infrared spectroscopy to see through the dust to the inner Galaxy (SEGUE, Supernova, APOGEE are not only stellar or galaxy astrophysics, near field cosmology).

Goal: The structure, dynamics, and chemical evolution of the Milky Way

- MARVELS: will probe the population of giant planets via radial velocity monitoring of 11,000 stars.

Goal: The architecture of planetary systems

BOSS: High-level Science requirement

- Requirements and Goals

LRGs:

d_A to 1.2% (1%) at z= 0.35 and 0.6

H(z) to 2.2% (1.8%) and 2.0% (1.7%) at z = 0.35 and 0.6

QSOs:

d_A to 2.3% (1.5%) at z= 2.5

H(z) to 1.8% (1.2%) at z = 2.5

Technical Reqs (Survey Size)

- Galaxy Survey: volume and density

10K (2.2 K in S, 7.8 K in N) sq deg (~2000 plates) with target density 3×10^{-4} (h/Mpc)-->Redshift accuracy at 300 km/s > 94% success rate

- QSO survey: volume and density

8K sq deg at 15 QSOs/40 targets

Survey size ==> More Imaging

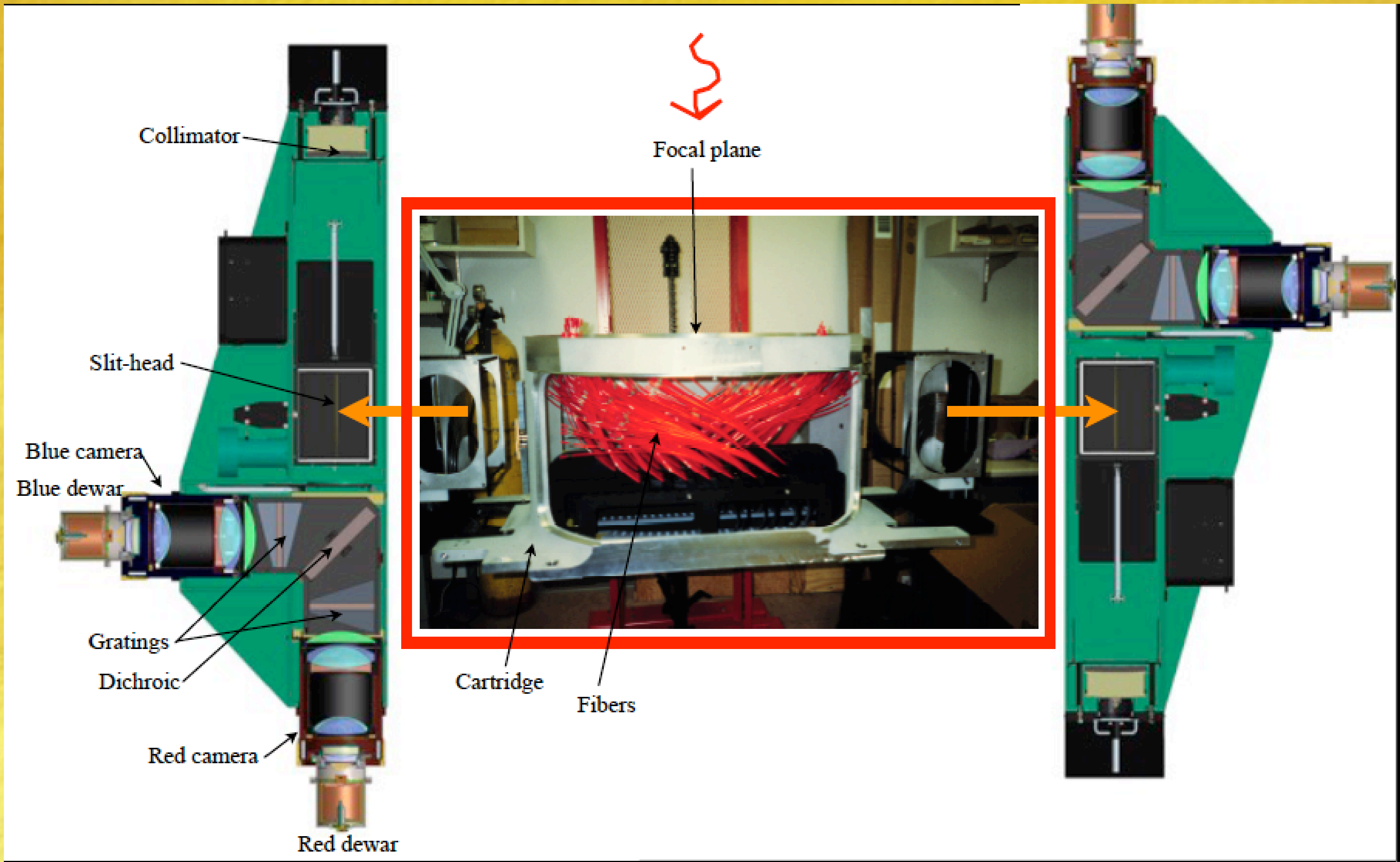
2900 sq deg contiguous footprint in Southern Galactic sky --> 15,100 sq deg

Instrument Requirements

How errors on d_A and H degrade as λ coverage, resolution, and S/N

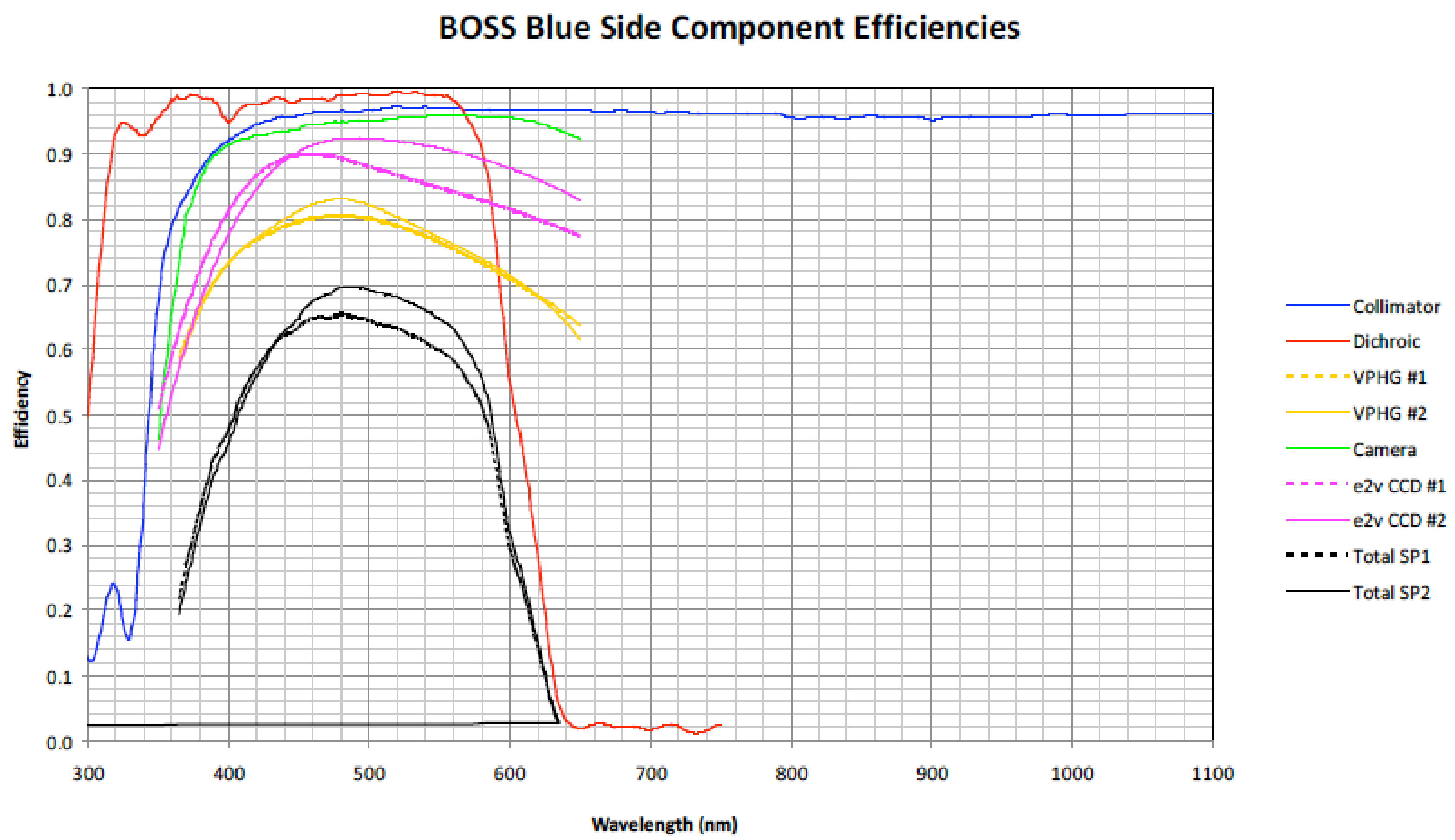
- λ coverage: 3,600 - 10,500 A
- Resolution: > 14000
- Throughput: Throughput and noise requirements on the spectrograph are determined by the faintest objects (targets: g > 23, I > 23, using g=22, I=21 as reference, survey base line I > 20)

SDSS spectrohraphs

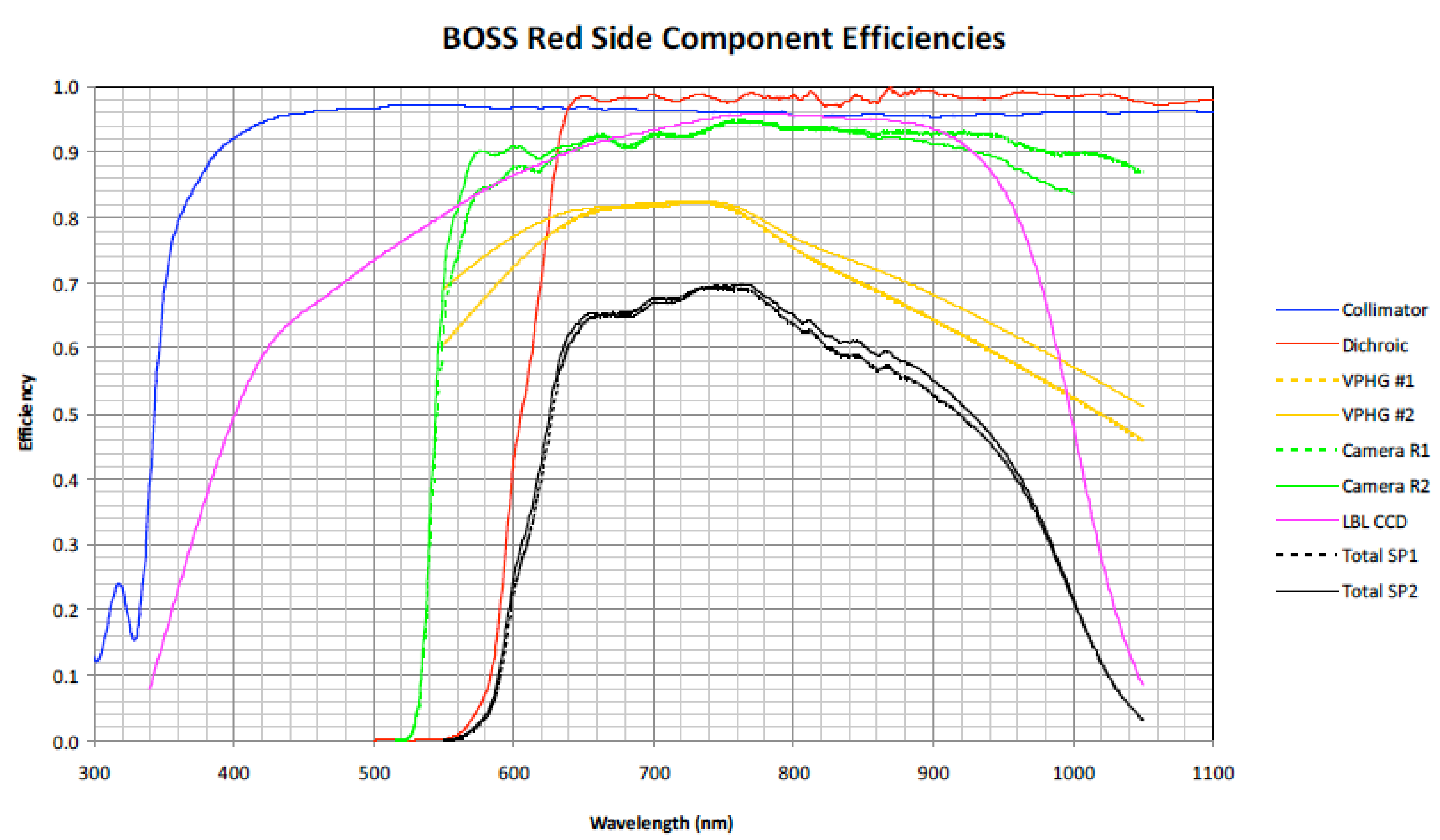


$\lambda/\text{Å}$	VPH(b)	VPH(r)	CCD(b)	CCD(r)	Throughput
3700	0.52	–	0.68	–	0.034
3800	0.59	–	0.74	–	0.060
3900	0.64	–	0.78	–	0.084
4000	0.69	–	0.80	–	0.104
4100	0.72	–	0.81	–	0.117
4200	0.74	–	0.82	–	0.125
4400	0.78	–	0.83	–	0.141
4600	0.82	–	0.82	–	0.161
4800	0.86	–	0.82	–	0.181
5000	0.88	–	0.81	–	0.195
5500	0.84	0.57	0.78	0.80	0.178
6000	0.75	0.71	0.77	0.82	0.170
6500	0.63	0.82	0.76	0.86	0.166
7000	–	0.87	–	0.88	0.189
7500	–	0.90	–	0.91	0.212
8000	–	0.87	–	0.93	0.190
8500	–	0.85	–	0.94	0.200
9200	–	0.80	–	0.92	0.158
9500	–	0.78	–	0.84	0.120
9800	–	0.73	–	0.66	0.102
10000	–	0.70	–	0.48	0.071

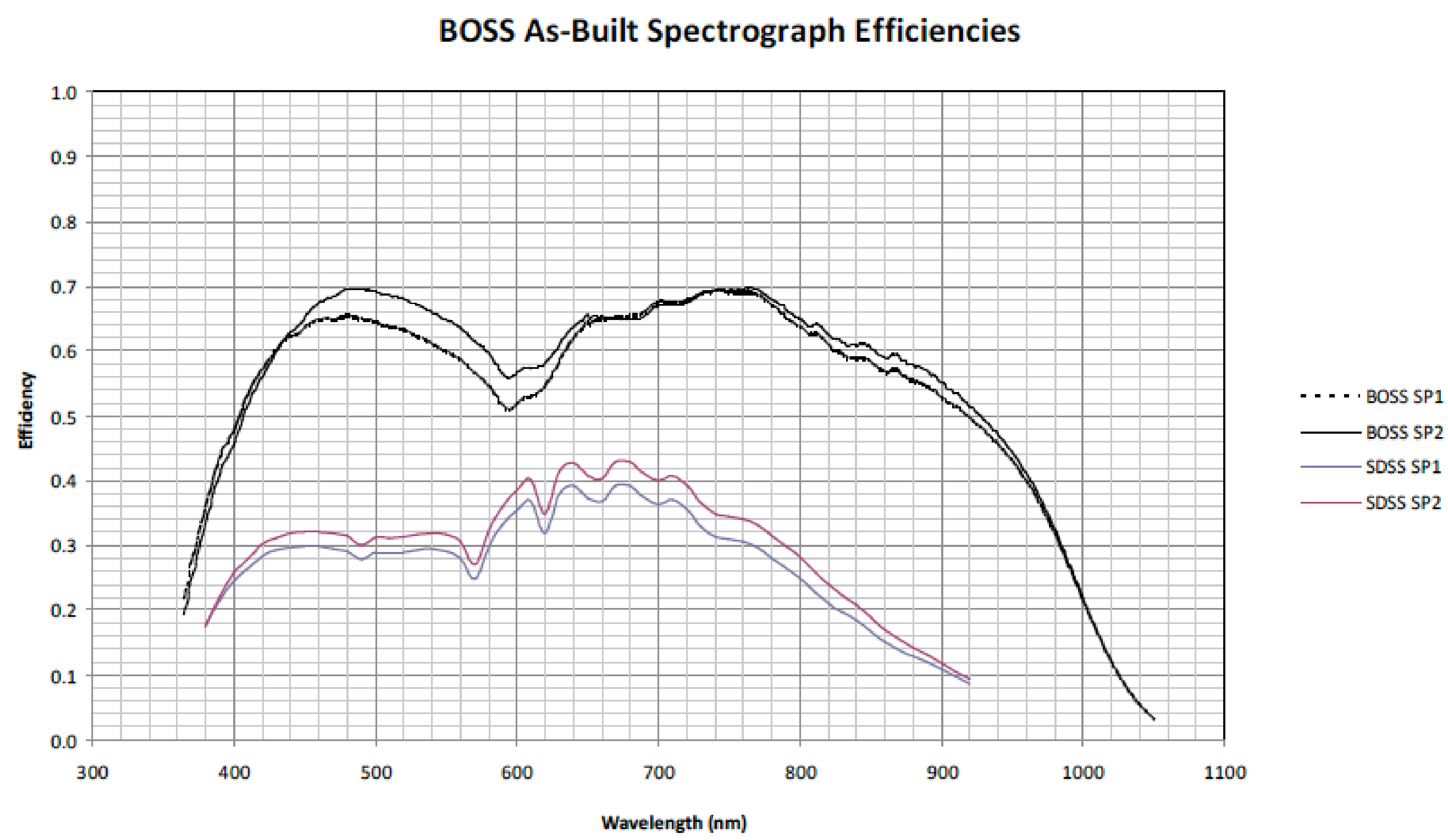
Breakdown of Individual Components - Blue



Breakdown of Individual Components - Red



Improved Spectrograph Throughput



CCD and Electronics Specifications

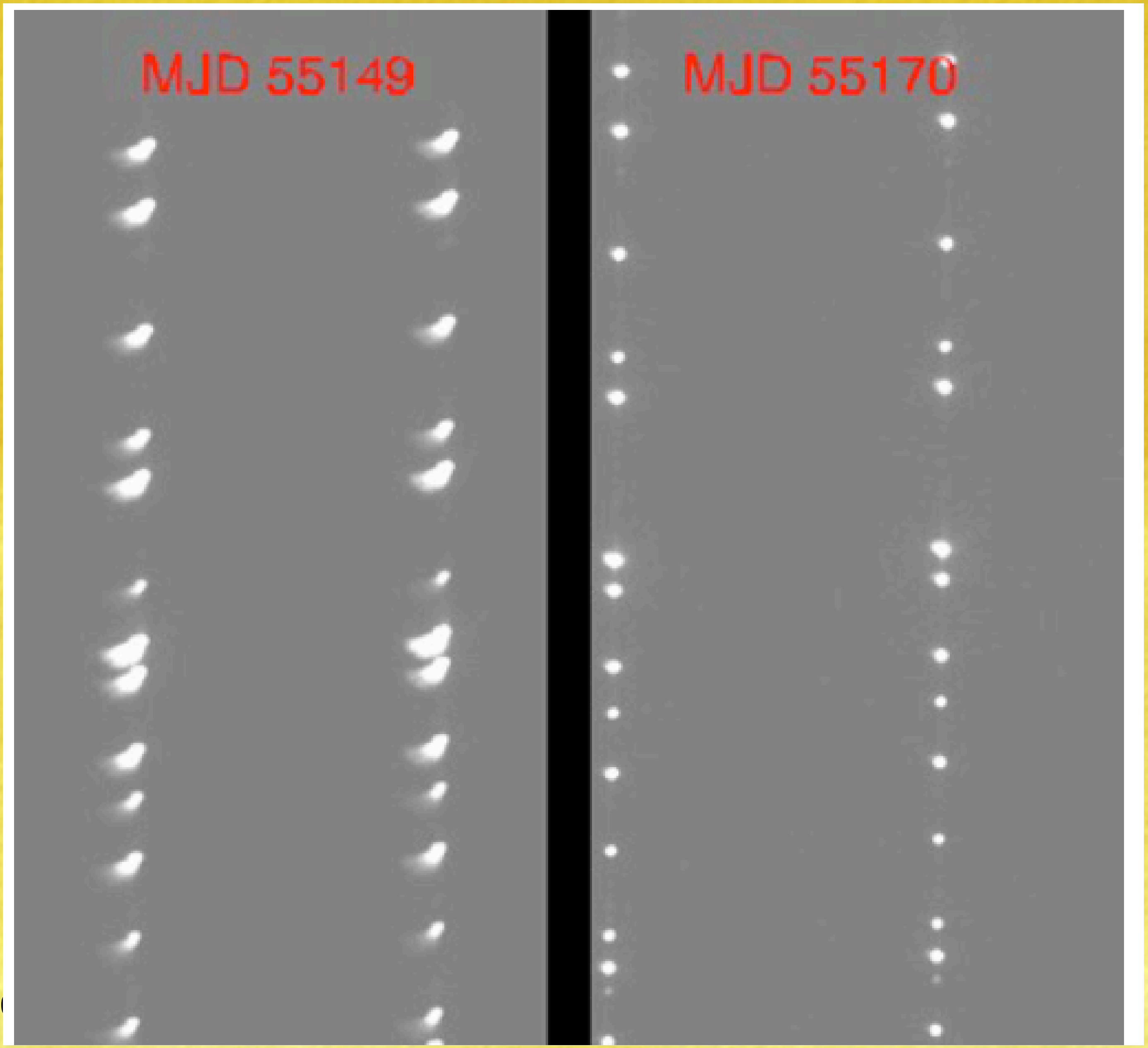
- CCD Noise Reqs: read noise 3.0 or 5.0 e^{-1}, dark < 1 or 2 e^{-1} /pixel in 15 min.
- CCD flat: peak-to-valley < 20 um
- Read time < 70 sec
- Bad column, pixels <
- Non-linearity < 0.5%
- Charge transfer efficiency > 99.999%
- Full well > 65 K e^{-1}

…

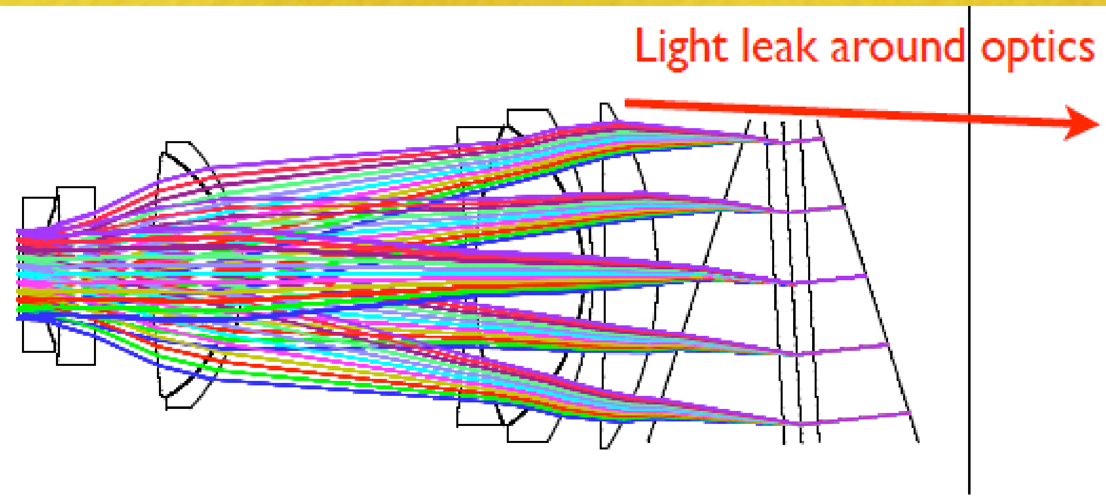
Other technical reqs

- Fiber replacement better than 15 um (0.25 arcsec), throughput: 91%, no one < 87%. Angle tol: 1°
- Astrometric uncertainty < 150 mas
- guider: < 0.1 arcsec
- total offset: better than 0.4 arcsec for seeing better than 2.2 arcsec.

Checking images: Optical Coma

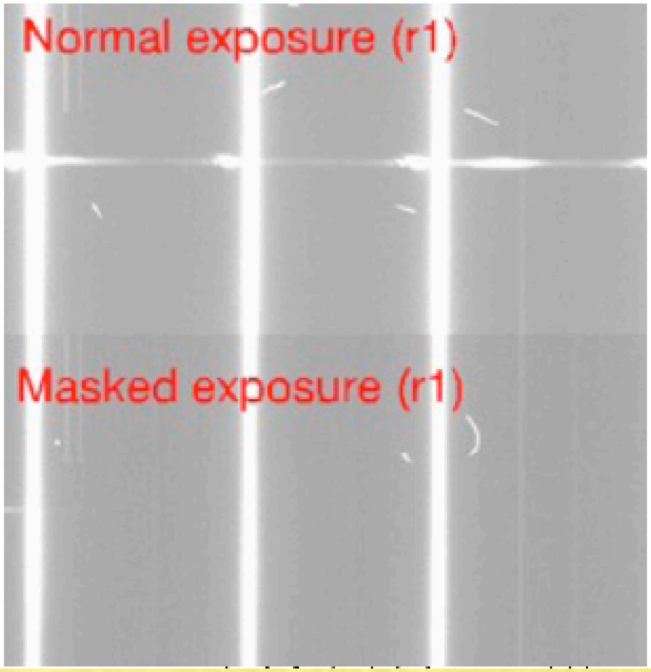


Checking images: light leak



Photons at ~4900, 8000 Ang
for all spectra

We should mask in the data!!

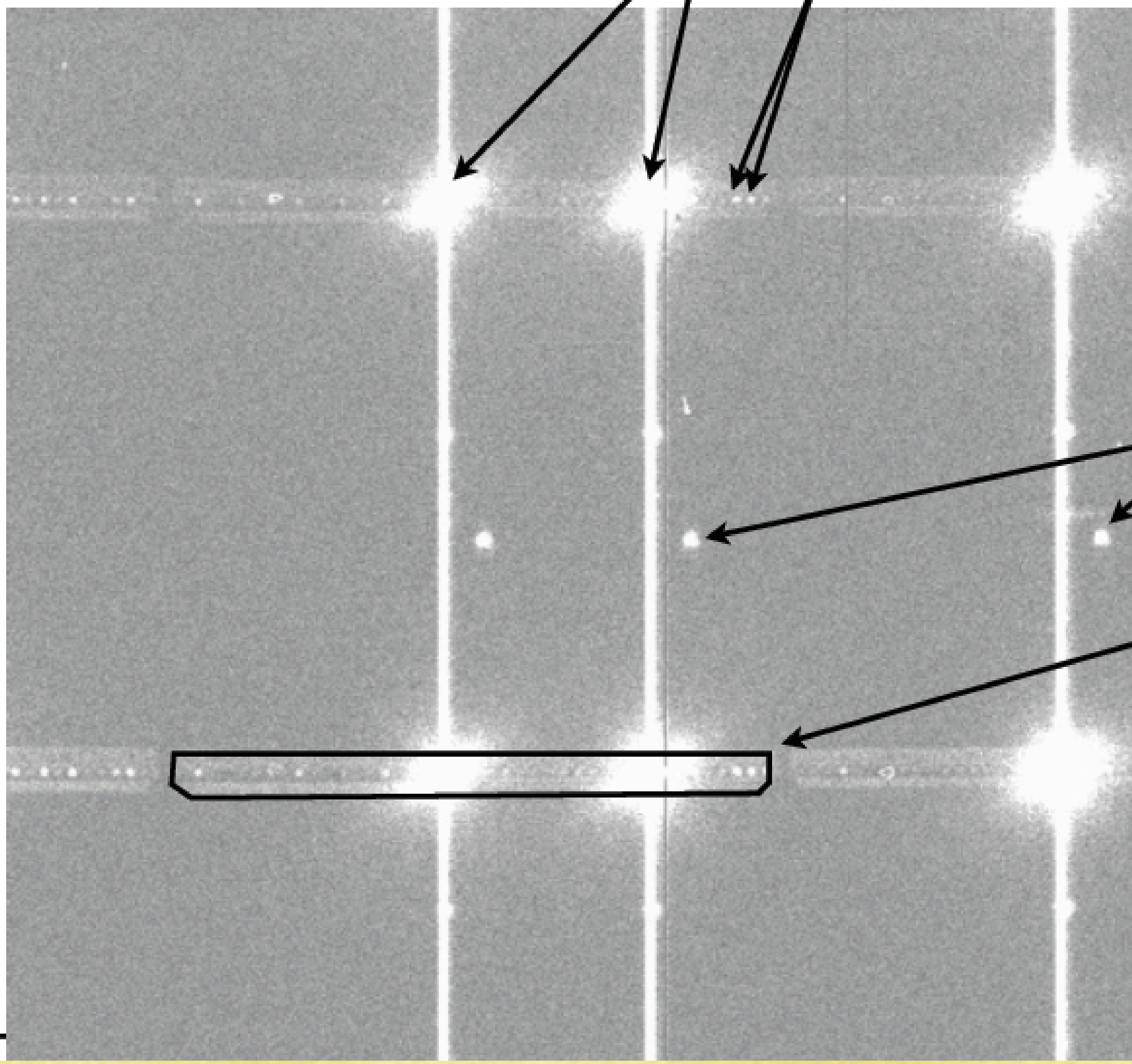


Reflection off Slit-head

Overexposed arc (64 sec)
55068/sdR-b2-00100514.fit

Plugged fibers

Unplugged fibers seeing some light



VPH ghost

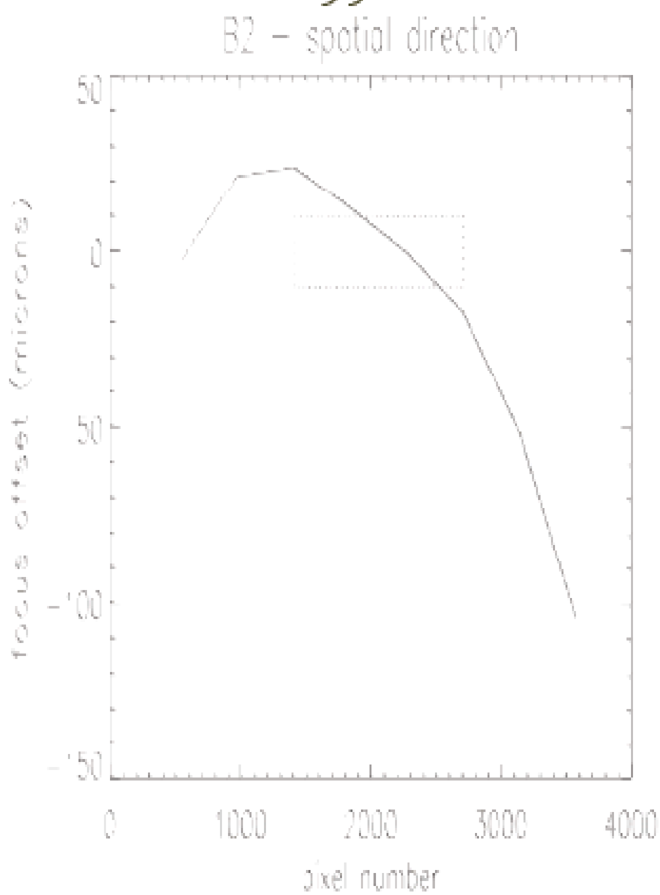
Reflection off slit-head
5.4 mm x 0.354 mm
→ 280 x 18 pix
0.35% of light

Check System Specifications

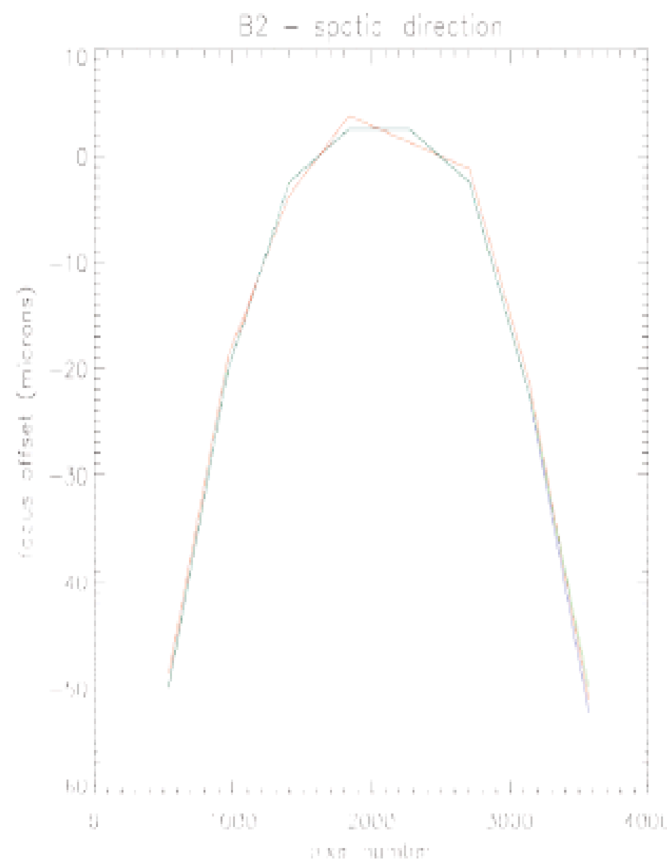
- CCD readout noises, read-out time, linearity etc
- Verifying operational efficiency, including weather etc factors: finish the plan, at least the base line?

CCD tilt

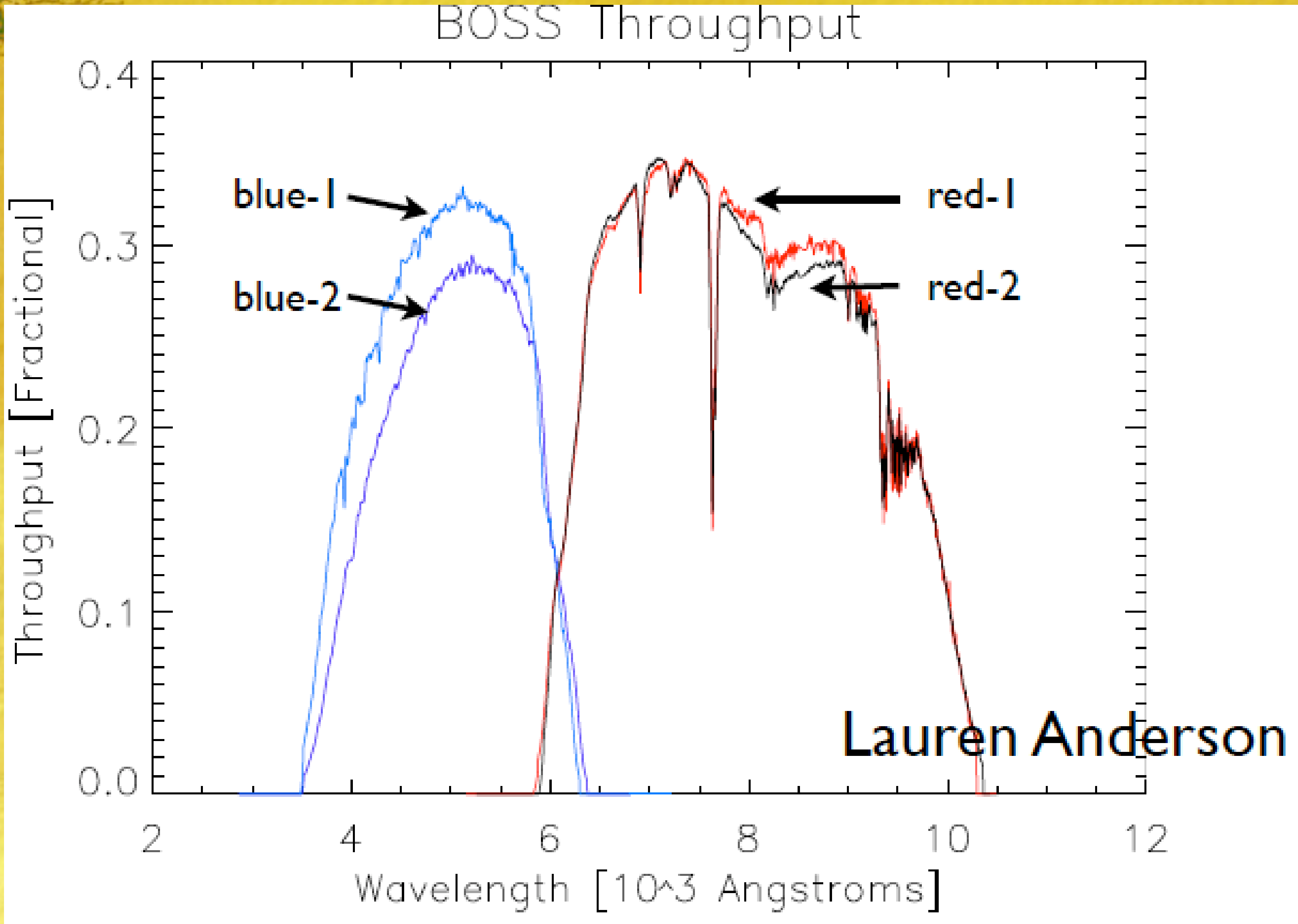
Before (55218)



After (55253)



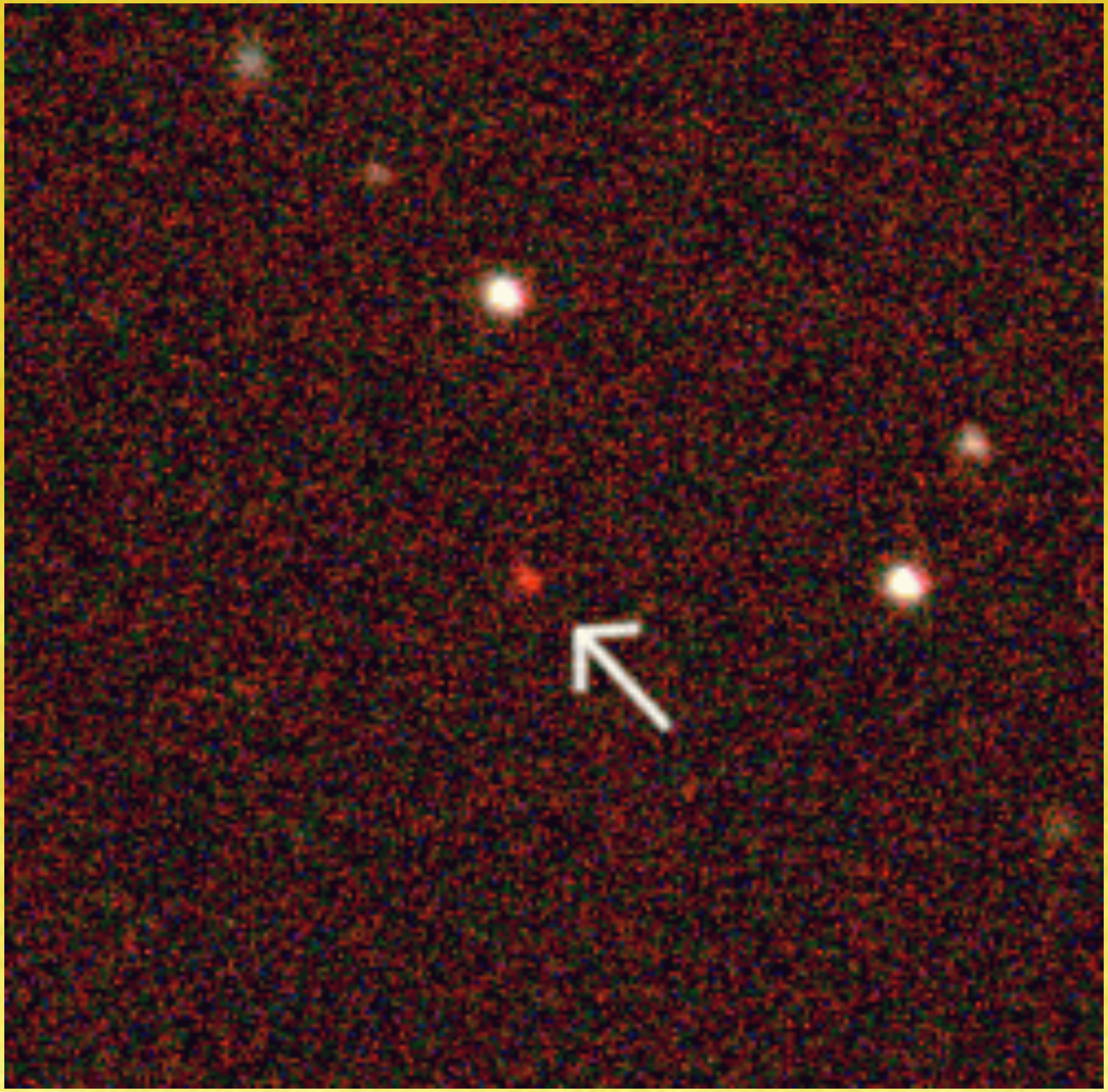
Measured throughputs



Key points

- What are research goals: big pictures
- Operation of a big project is not a easy job; on-sky time is priceless, make every effort to improve operation efficiency.
- Big project stream: high level science goals (simple) --> Technical req. (samples and parameter accuracy, work plan) --> System req (data quality, S/N) --> Tech specifications of system components (leave margins) --> components meets requirements? --> System meet req? --> Plan is feasible? --> operation --> Data reduction --> science results

SDSS images （quasar z=5.74)



Merging galaxies