Mapping the Nearby Universe

The Sloan Digital Sky Survey in its 4th year

Princeton University
The University of Chicago
The Johns Hopkins University
The University of Washington
The Institute for Advanced Study
The Japan SDSS Promotion Group
Fermi National Accelerator Laboratory
The US Naval Observatory
Los Alamos National Laboratory
The University of Pittsburgh
New Mexico State University
Max Planck Institute
Korean SDSS Group

THE ORIGINAL GOALS OF THE SURVEY

1. Photometry in 5 bands (3500-9500A) for all objects to ~23rd mag in the 10,000 sq. deg. North Galactic polar cap.

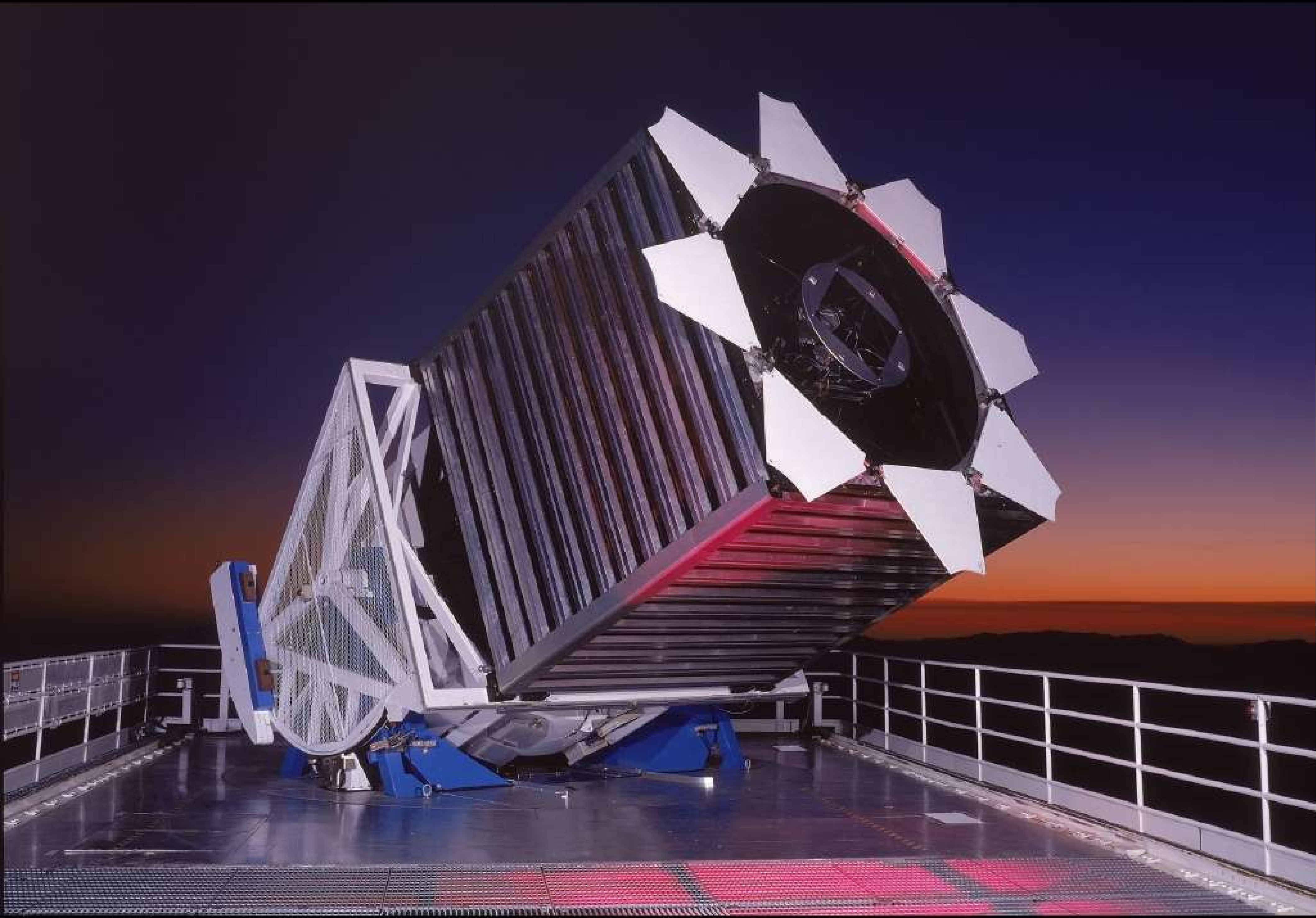
~1.5 x 10^8 stars
~7 x 10^7 galaxies
~1 x 10^6 quasars

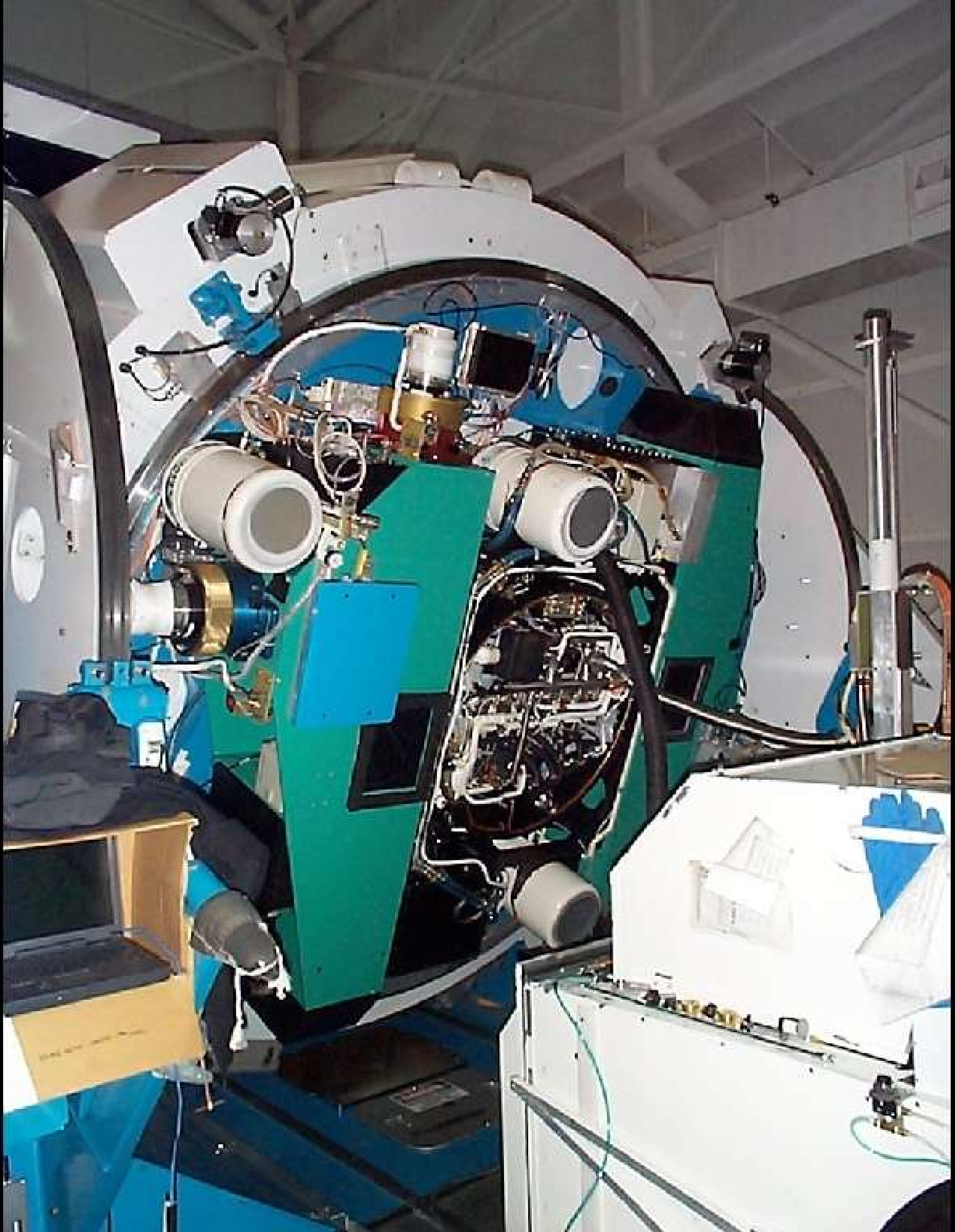
2. Redshifts for the 10^6 'brightest' galaxies and 10^5 brightest quasars in that region.

And to create as homogeneous a sample of the above objects as is humanly possible to do.

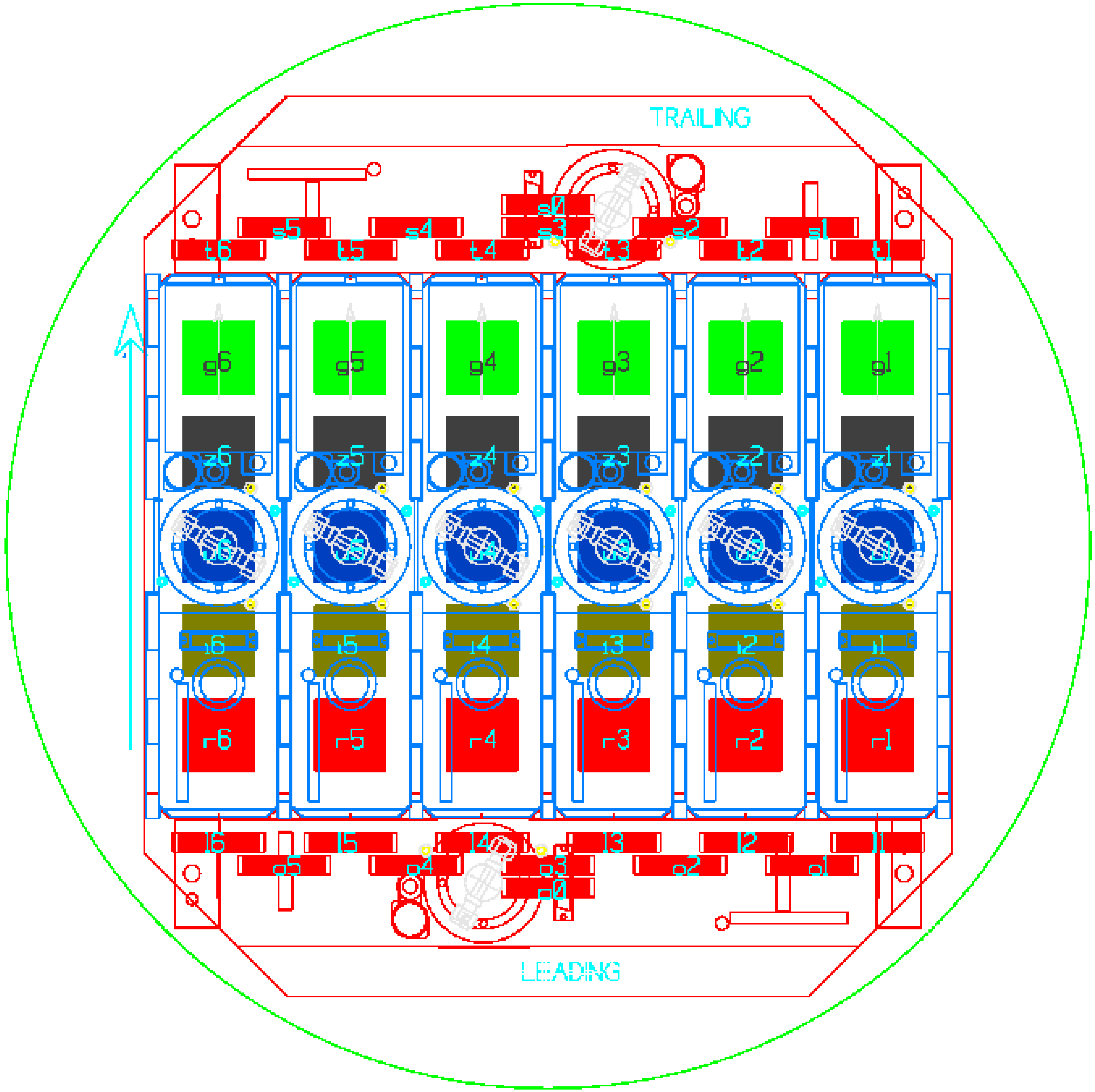
SCIENTIFIC PRODUCTS of the SDSS

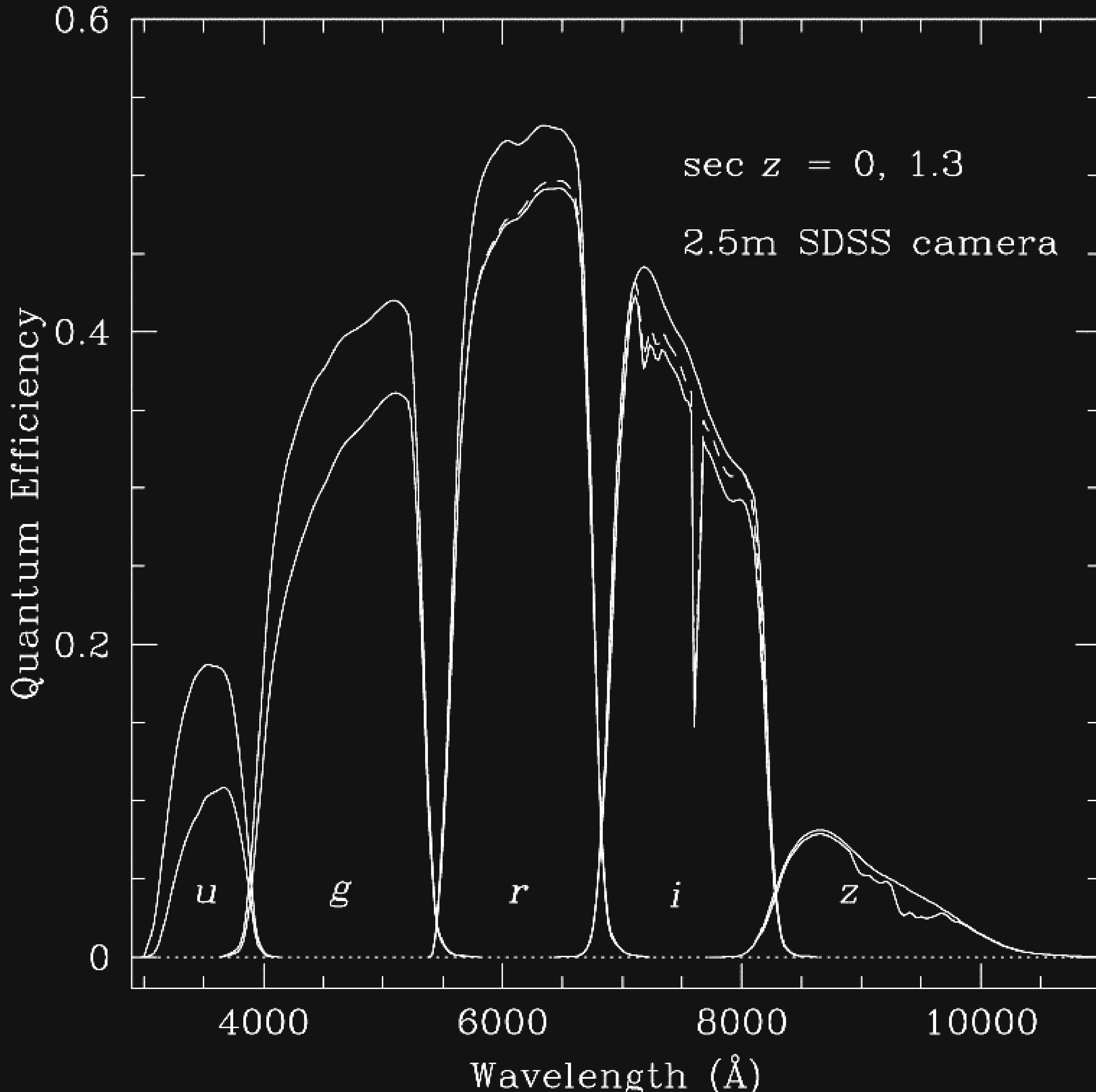
1. The large-scale distribution of galaxies and their properties to z~0.2 and more sparsely to z~0.5
   10^6 galaxies
2. 5-band photometry and photometric redshifts which facilitate population studies of galaxies and LSS to z~0.8
   10^8 galaxies
3. The space distribution of quasars, their spectroscopic properties, and evolution to z~6
   10^5 spectroscopic quasars, 10^6 photometric quasar candidates
4. Quasar absorption lines and the intergalactic medium to z~6
   100,000 lines of sight.
5. Brown dwarfs and other faint and/or rare denizens of the Galaxy
   200 L, 45 T, cool/magnetic/cyclotron WD, very metal-poor stars
6. Faint solar system objects
   135,000 asteroids
7. Detailed comparison of the "present" universe with its distant counterpart as revealed by HST, COBE, DEIMOS, WMAP. We had very little quantitative knowledge about the galactic content of the nearby universe or its distribution when we began. It is our goal to know a great deal more when the SDSS data have all been digested.



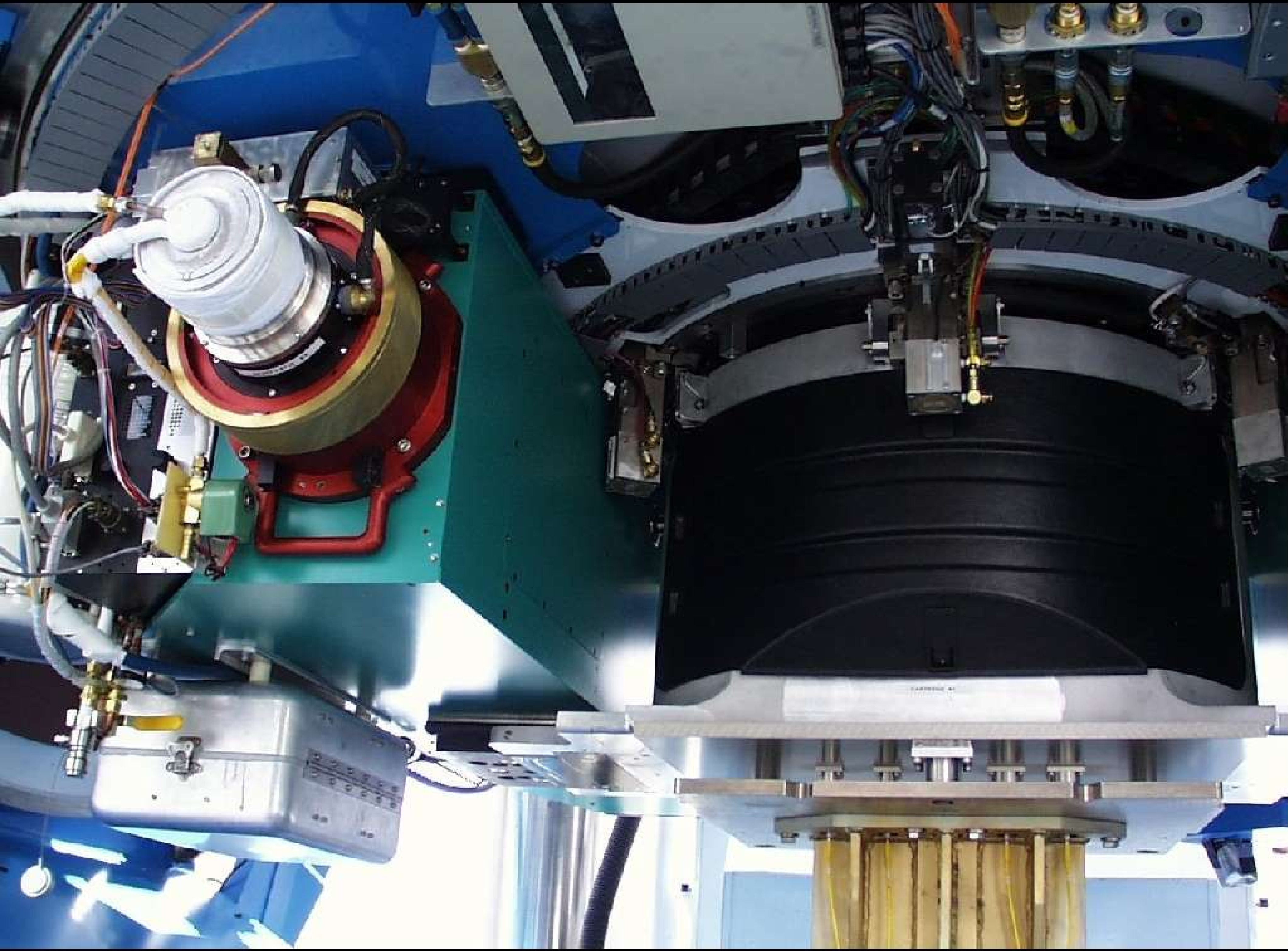


SDSS CAMERA

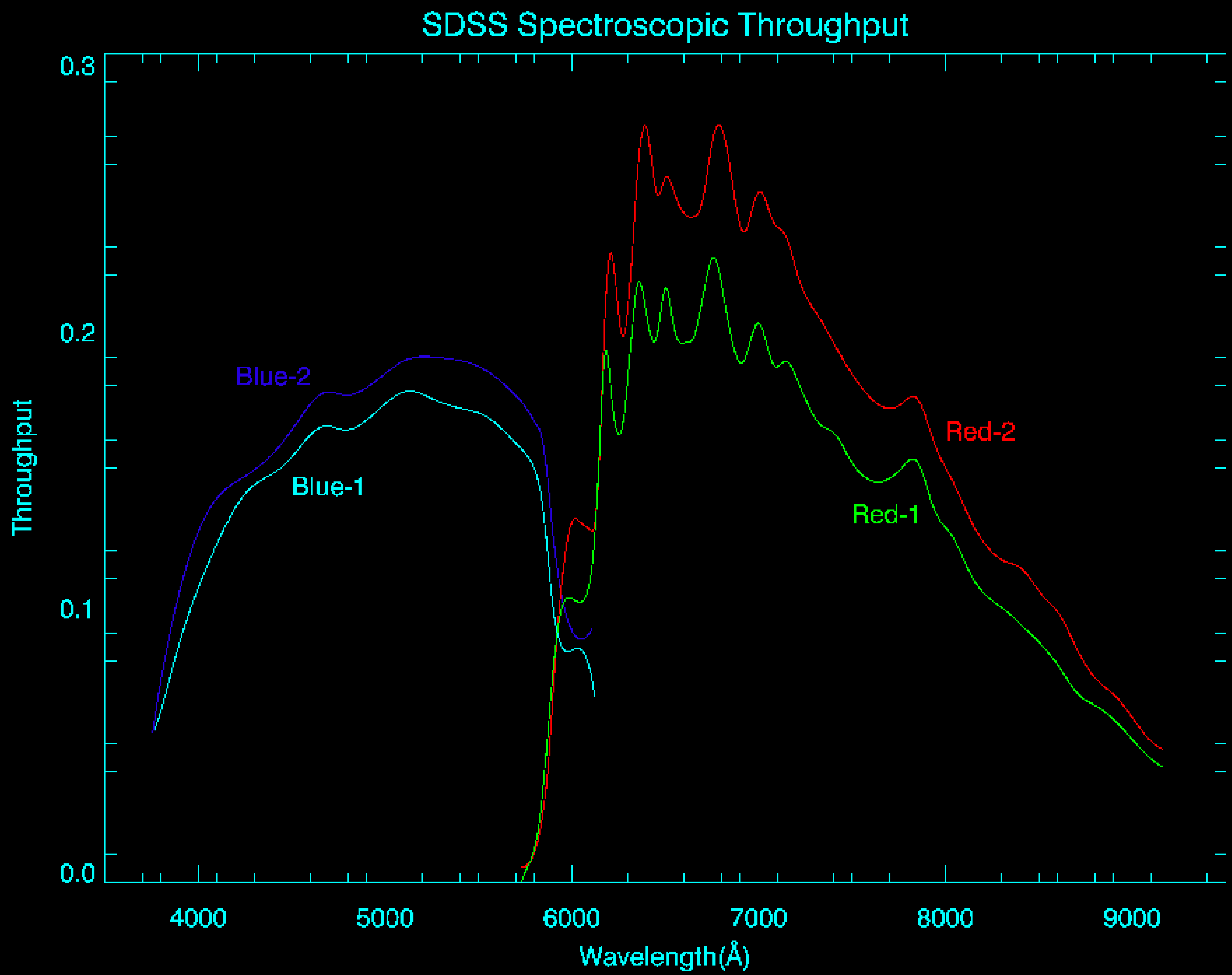

TRAILING
s0
s5
s4
s3
s2
s1
t6
t5
t4
t3
t2
t1
g6
g5
g4
g3
g2
g1
z6
z5
z4
z3
z2
z1
i6
i5
i4
i3
i2
i1
r6
r5
r4
r3
r2
r1
LEADING

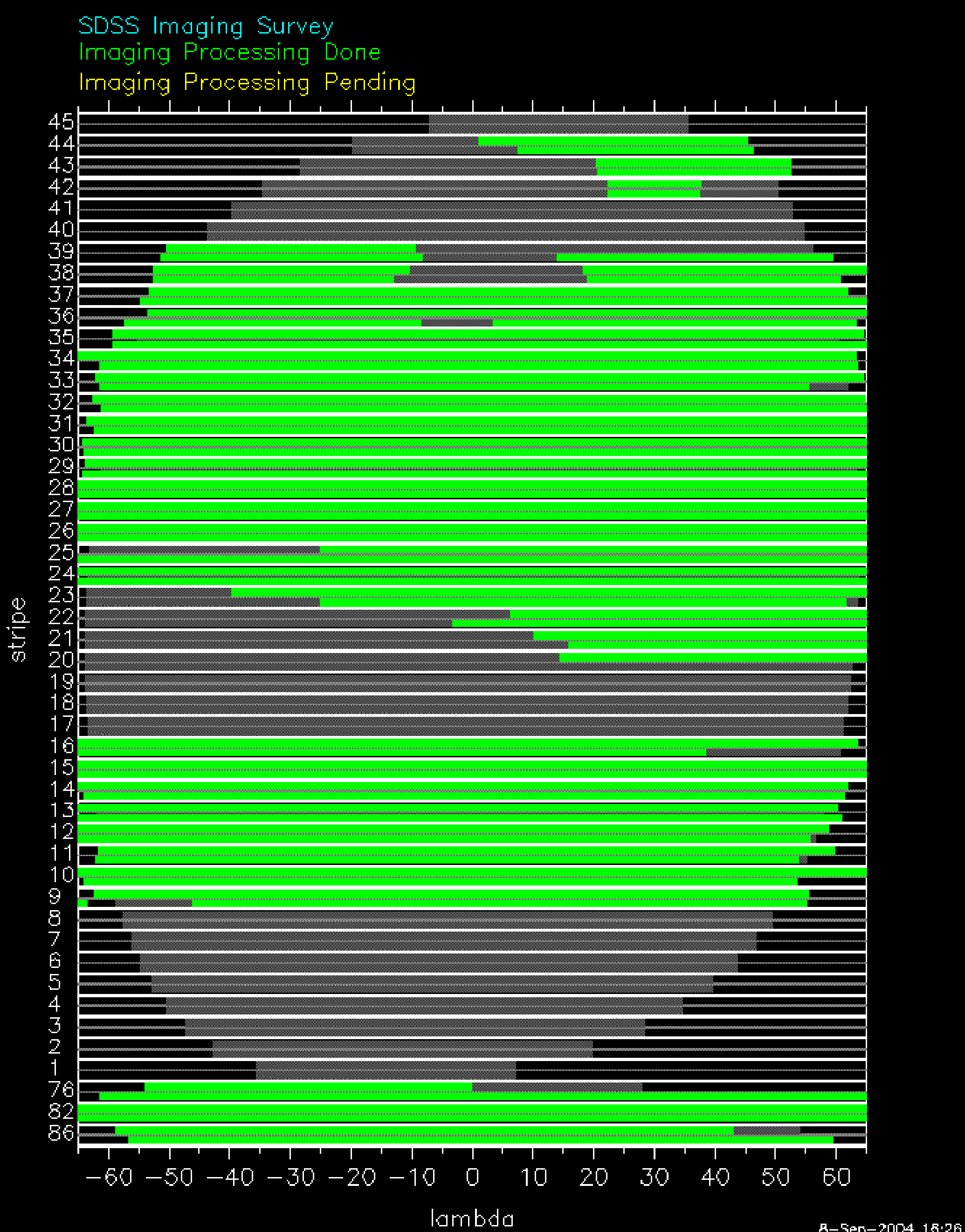


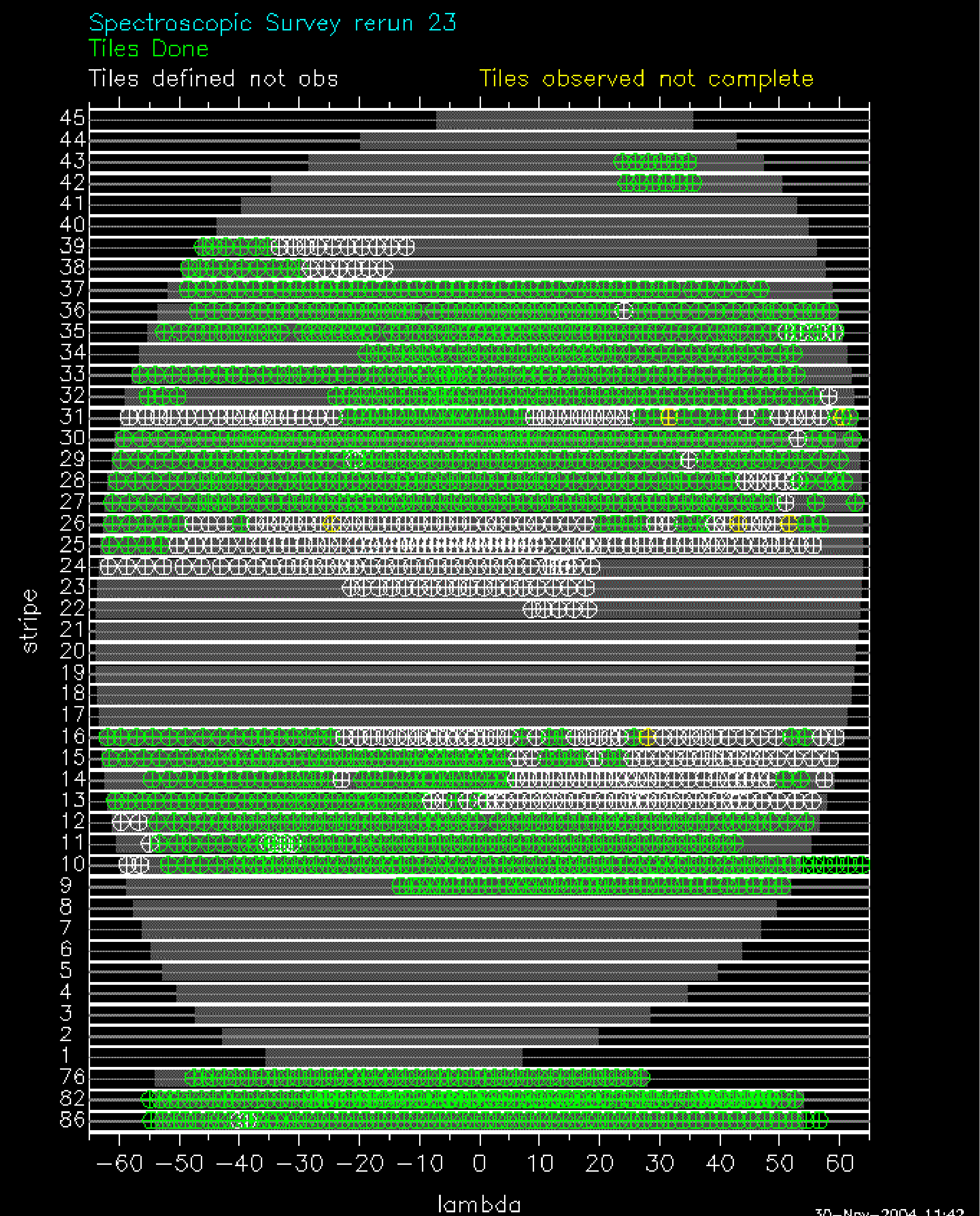
sec z = 0, 1.3
2.5m SDSS camera
u
g
r
i
z
Quantum Efficiency
0
0.2
0.4
0.6
4000
6000
8000
10000
Wavelength (Å)



SDSS Spectra


SDSS Spectroscopic Throughput
Throughput
Wavelength(Å)
0.0
0.1
0.2
0.3
4000
5000
6000
7000
8000
9000
Blue-2
Blue-1
Red-2
Red-1


SDSS Imaging Survey
Imaging Processing Done
Imaging Processing Pending
stripe
lambda
8-Sep-2004 18:26

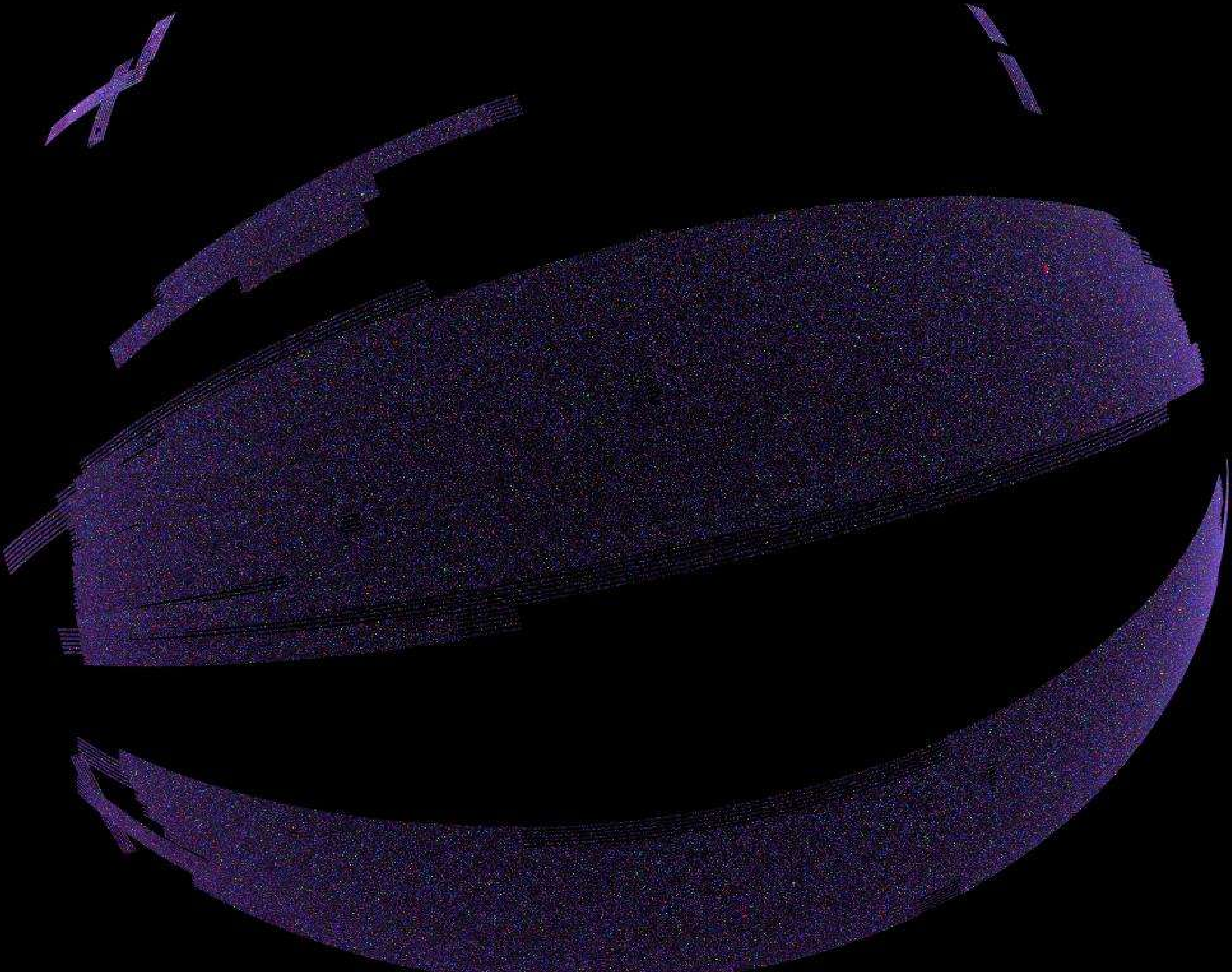

Spectroscopic Survey rerun 23
Tiles Done
Tiles defined not obs
Tiles observed not complete
stripe
lambda
30-Nov-2004 11:42

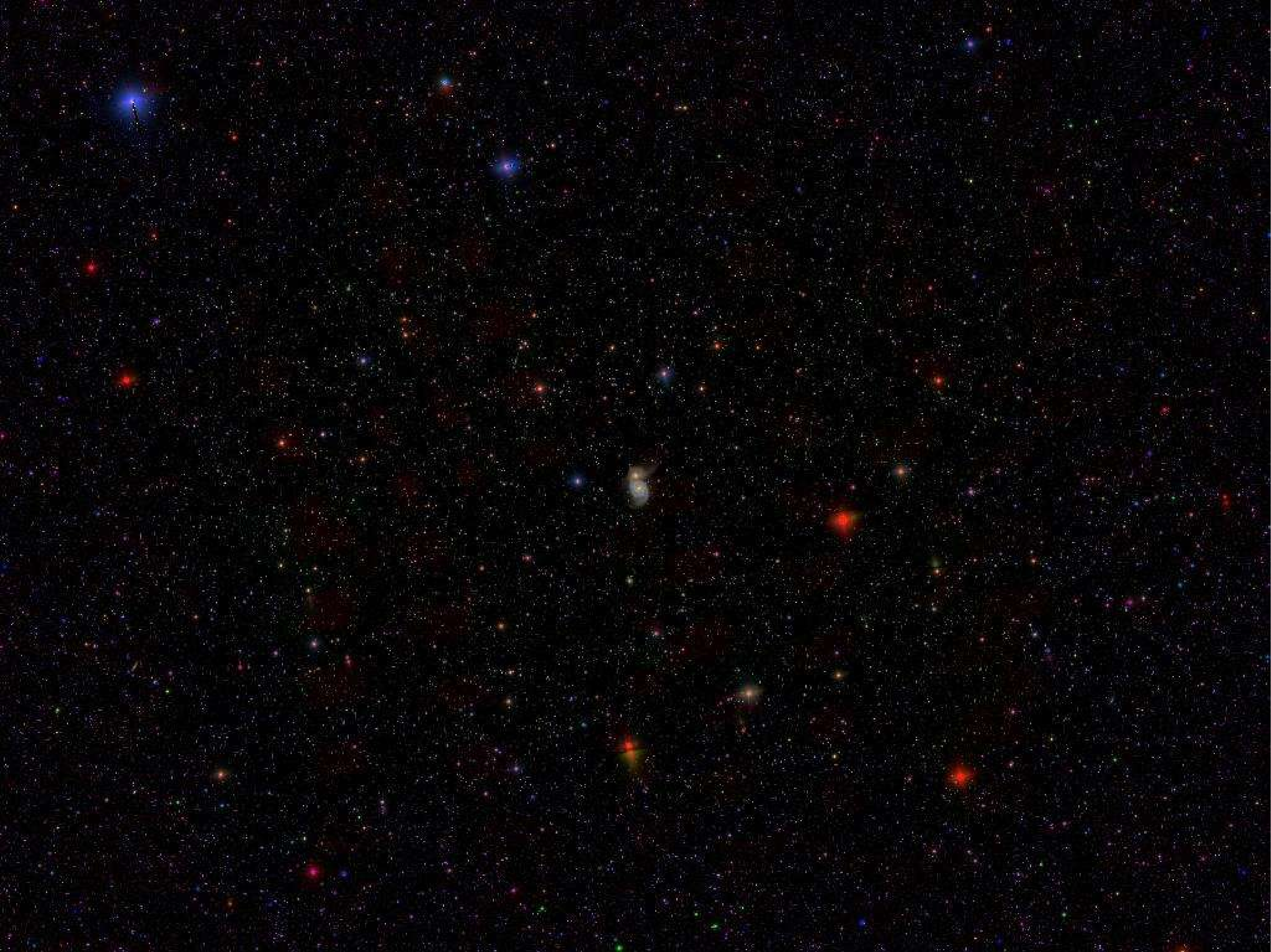
THE SDSS DATA RELEASES

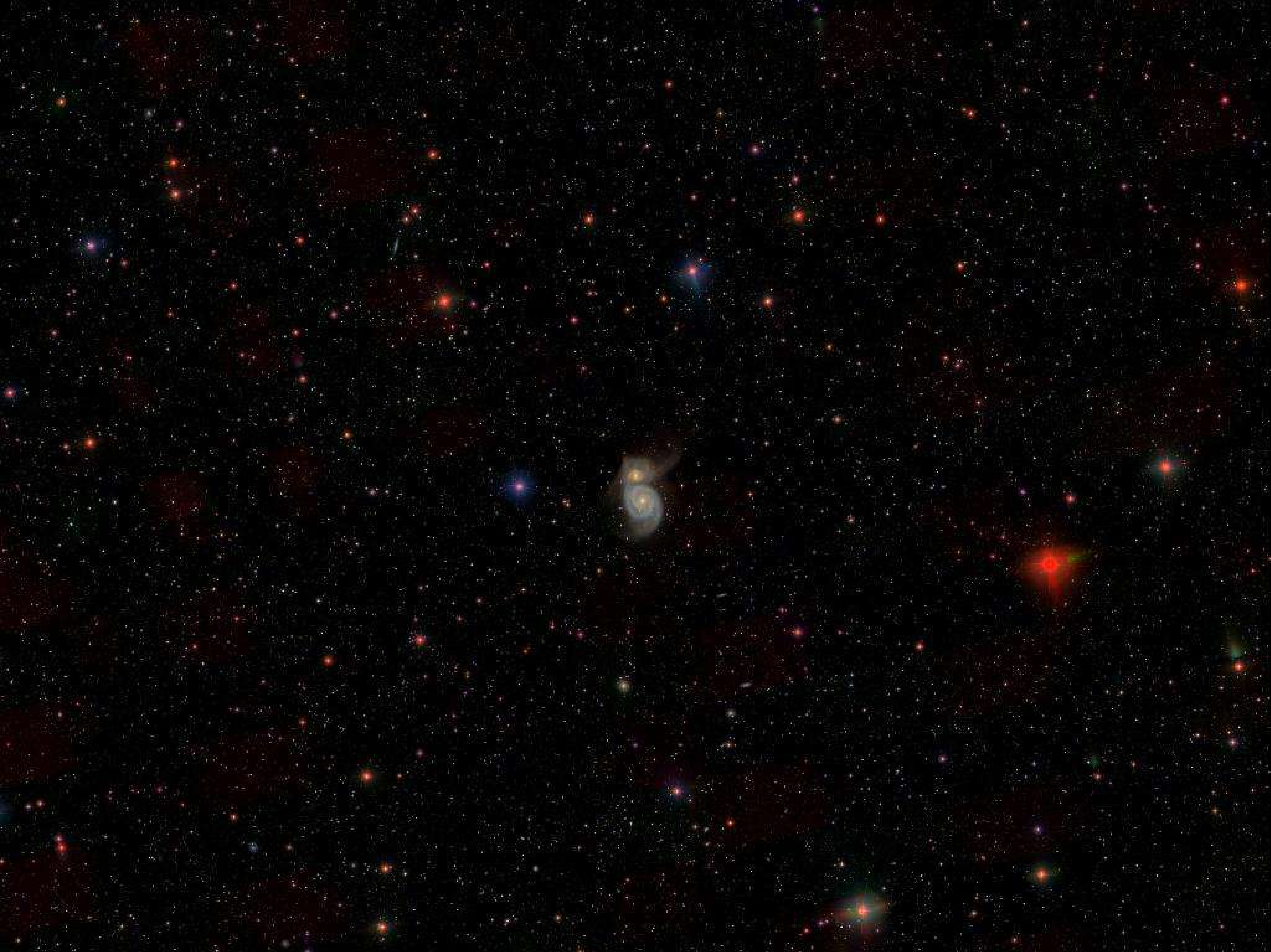
release	area sq deg	spectra	when
EDR:	462	54,000	6/2001
DR1:	2099	186,000	4/2003
DR2:	3324	367,000	3/2004
DR3:	5382	529,000	10/2004 (on time!)
DR4:	~6500	~700,000	7/2005
DR5:(final ?)	~7700	~800,000	7/2006

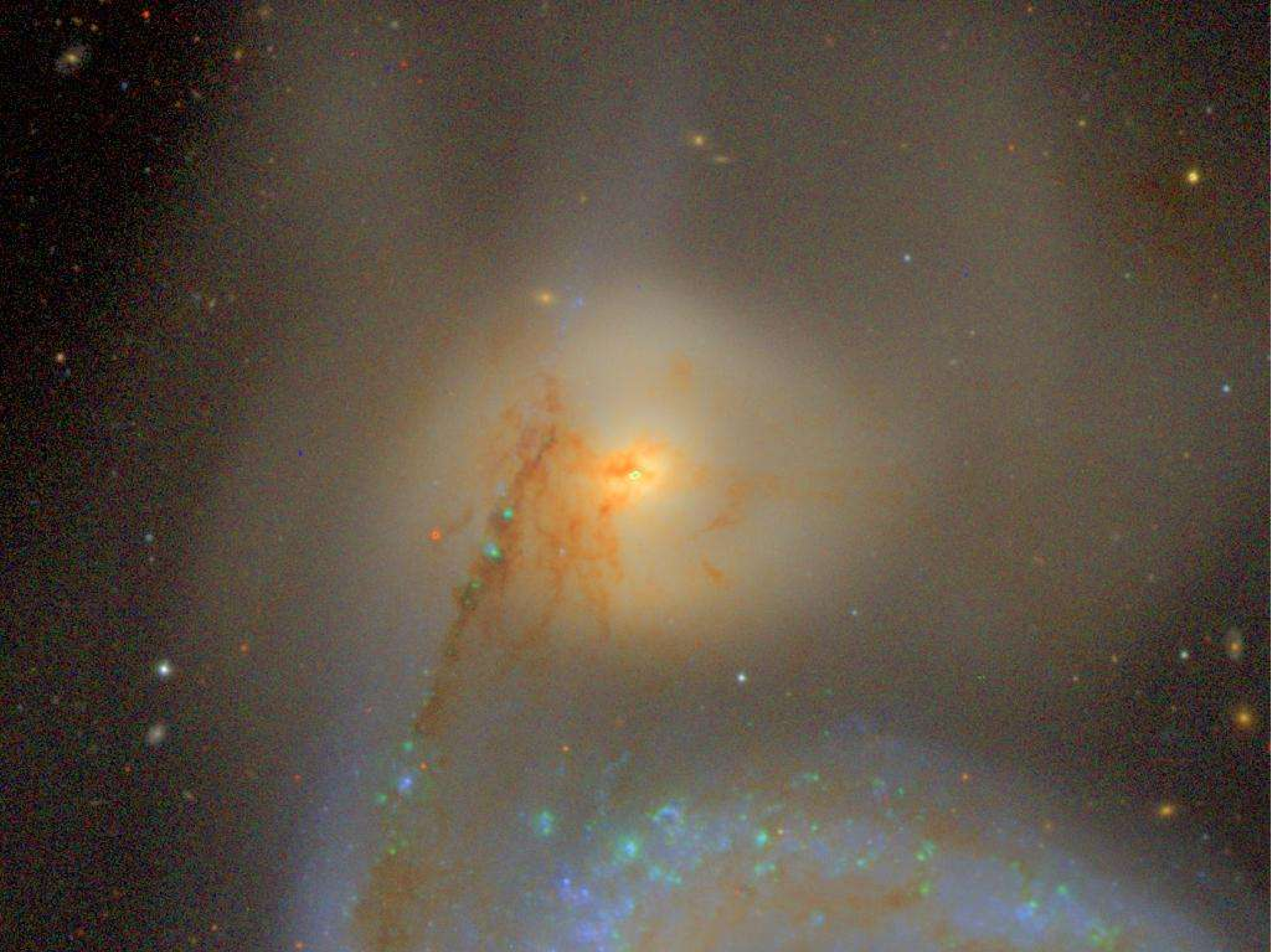
The Third Data Release of the Sloan Digital Sky Survey

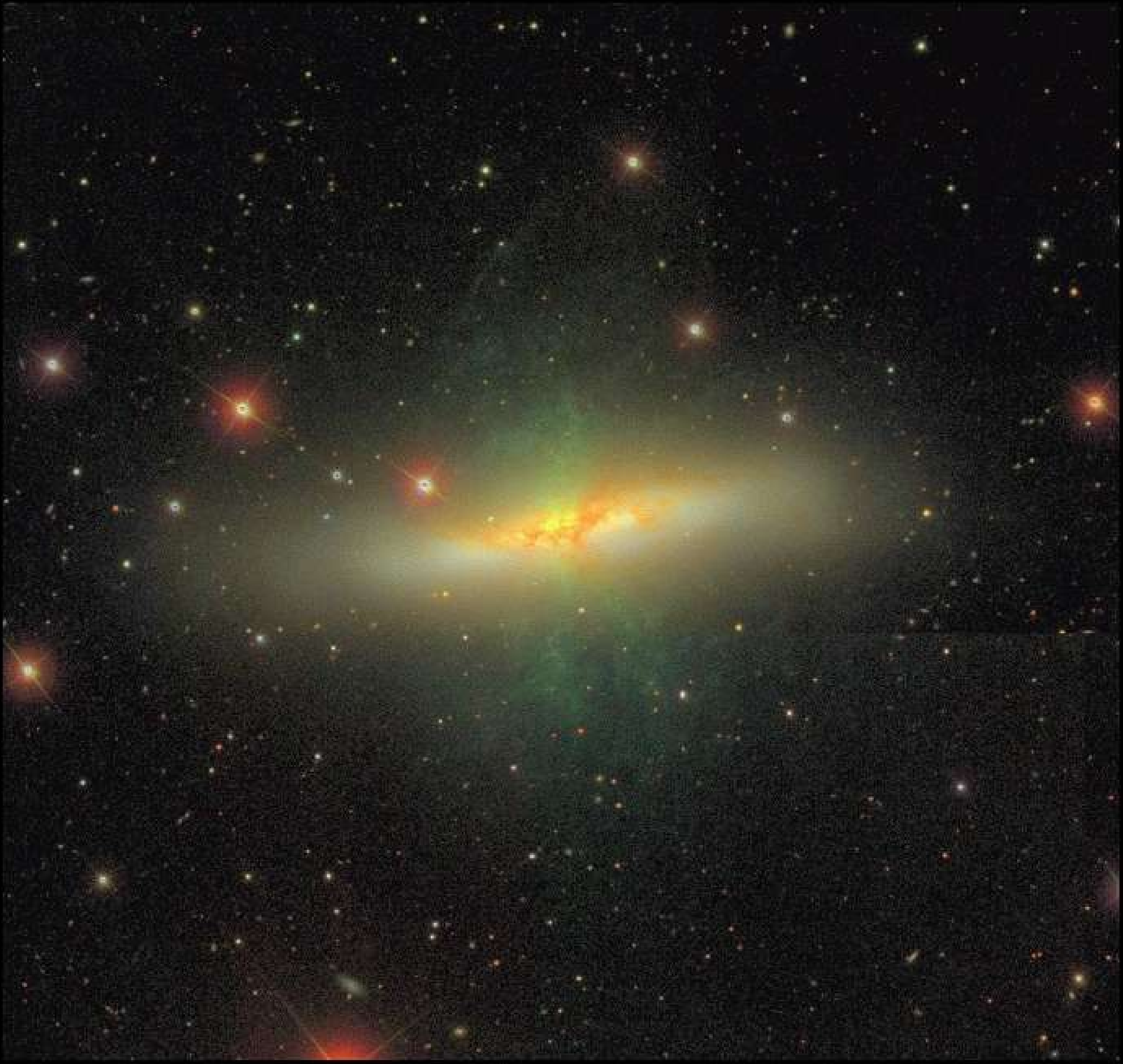
Kevork Abazajian[1], Jennifer K. Adelman-McCarthy[2], Marcel A. Agüeros[3], Sahar S. Allam[2], Kurt S. J. Anderson[4,5], Scott F. Anderson[3], James Annis[2], Neta A. Bahcall[6], Ivan K. Baldry[7], Steven Bastian[2], Andreas Berlind[8,9,10], Michael R. Blanton[10], William N. Boroski[2], Howard J. Brewington[4], John W. Briggs[49], J. Brinkmann[4], Robert J. Brunner[11], Tamás Budavári[7], Larry N. Carey[3], Francisco J. Castander[12], A. J. Connolly[51], Kevin R. Covey[3], István Csabai[13,7], Julianne J. Dalcanton[3], Daniel J. Eisenstein[14], Michael L. Evans[3], Xiaohui Fan[14], Douglas P. Finkbeiner[6,15], Scott D. Friedman[16], Joshua A. Frieman[2,8,9], Bruce Gillespie[4], Karl Glazebrook[7], Jim Gray[17], James E. Gunn[6], Vijay K. Gurbani[2,18], Patrick B. Hall[6,19], Frederick H. Harris[20], Hugh C. Harris[20], Michael Harvanek[4], Suzanne L. Hawley[3], Jeffrey Hayes[21], Timothy M. Heckman[7], John S. Hendry[2], Gregory S. Hennessy[22], Robert B. Hindsley[23], Craig J. Hogan[3], David W. Hogg[10], Donald J. Holmgren[2], Shin-ichi Ichikawa[24], Takashi Ichikawa[25], Željko Ivezić[6], Sebastian Jester[2], David E. Johnston[6], Anders M. Jorgensen[26], Mario Jurić[6], Stephen M. Kent[2], S. J. Kleinman[4], G. R. Knapp[6], Alexei Yu. Kniazev[27], Richard G. Kron[8,2], Jurek Krzesinski[4,28], Donald Q. Lamb[8,29], Hubert Lampeitl[2], Brian C. Lee[33], Huan Lin[2], Daniel C. Long[4], Jon Loveday[30], Robert H. Lupton[6], Ed Mannery[3], Bruce Margon[16], David Martínez-Delgado[27], Takahiko Matsubara[31], Peregrine M. McGehee[5,32], Timothy A. McKay[33], Avery Meiksin[34], Jeffrey A. Munn[20], Thomas Nash[2], Eric H. Neilsen, Jr.[2], Heidi Jo Newberg[35], Peter R. Newman[4], Robert C. Nichol[36], Tom Nicinski[2,37], Maria Nieto-Santisteban[16], Atsuko Nitta[4], Sadanori Okamura[38], Russell Owen[3], Nikhil Padmanabhan[39], George Pauls[6], John Peoples[2], Jeffrey R. Pier[20], Adrian C. Pope[7], Dimitri Pourbaix[6,40], Thomas R. Quinn[3], Gordon T. Richards[6], Michael W. Richmond[41], Hans-Walter Rix[27], Constance M. Rockosi[32], David J. Schlegel[6], Donald P. Schneider[42], Joshua Schroeder[6,43], Erin Sheldon[8,9], Kazu Shimasaku[38], J. Allyn Smith[44,26], Vernesa Smolčić[45], Stephanie A. Snedden[4], Chris Stoughton[2], Michael A. Strauss[6], Alexander S. Szalay[7], István Szapudi[49], Paula Szkody[3], Gyula P. Szokoly[46], Max Tegmark[40], Luis Teodoro[1], Aniruddha R. Thakar[7], Douglas L. Tucker[2], Alan Uomoto[7,47], Daniel E. Vanden Berk[42], Michael S. Vogeley[48], Wolfgang Voges[46], Nicole P. Vogt[5], Lucianne M. Walkowicz[3], David H. Weinberg[19], Andrew A. West[3], Simon D.M. White[50], Brian C. Wilhite[8], Yongzhong Xu[1], Brian Yanny[2], Ching-Wa Yip[51], D. R. Yocum[2], Donald G. York[8,29], Idit Zehavi[11], Stefano Zibetti[50], Daniel B. Zucker[27]

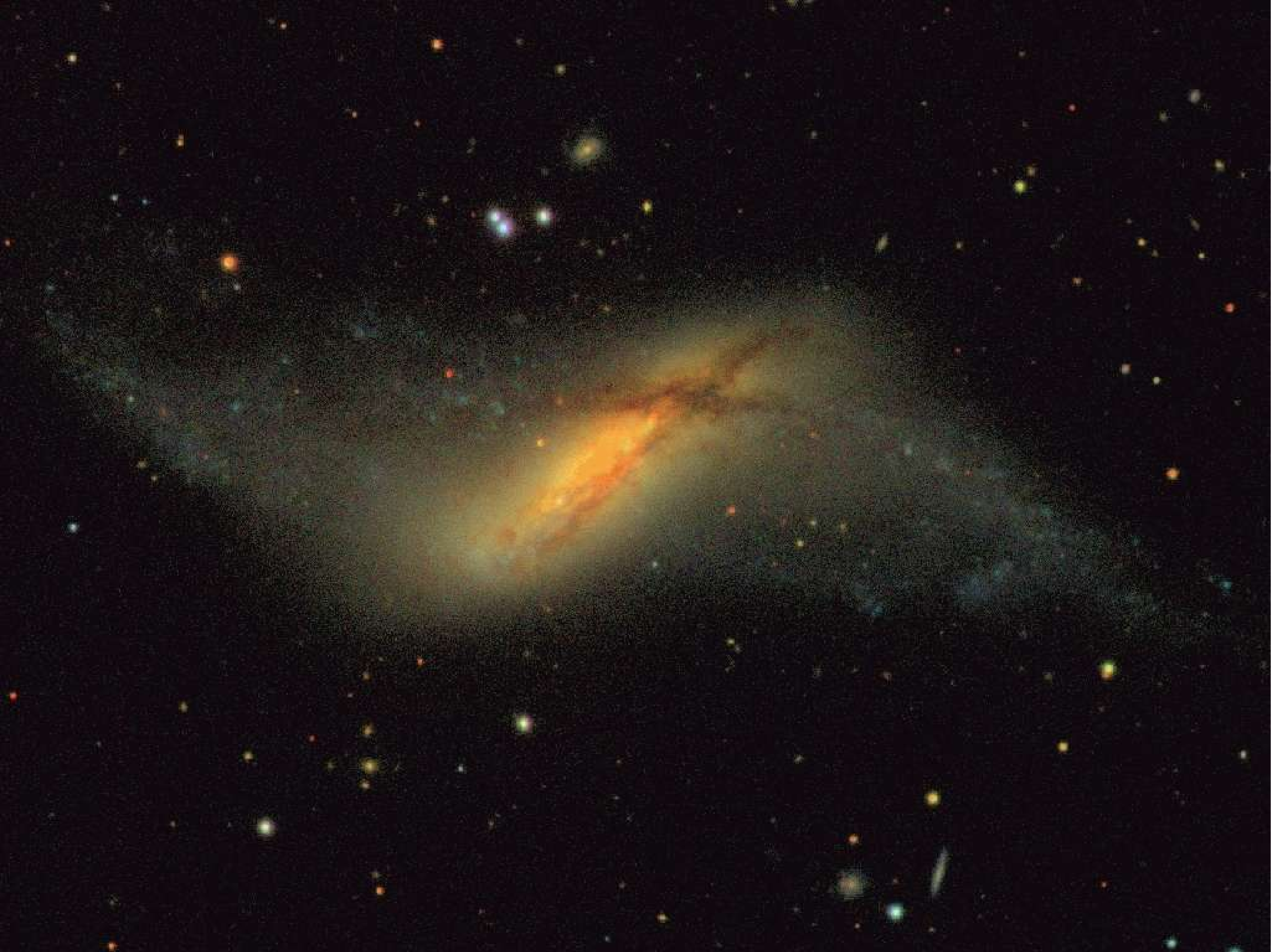


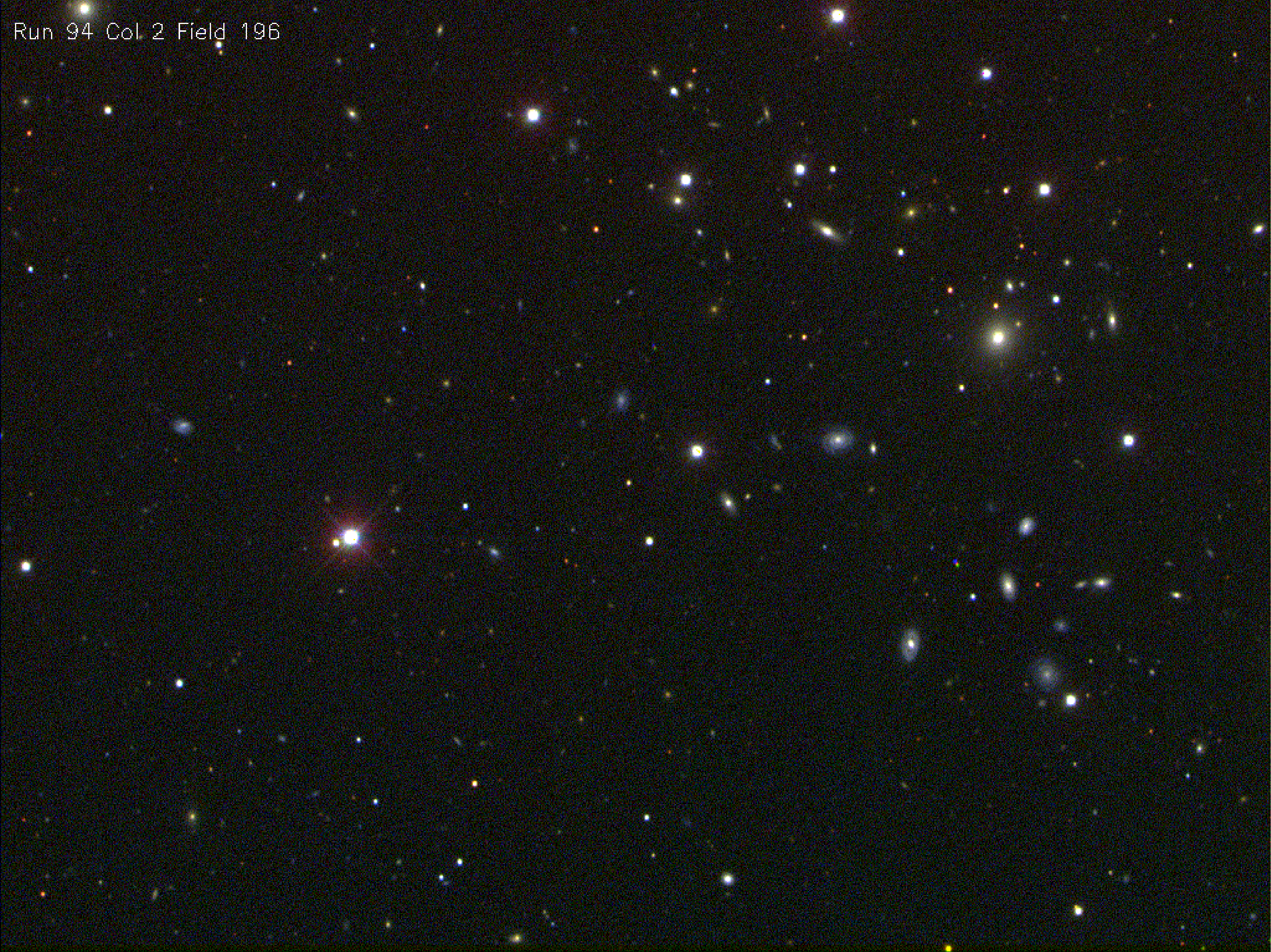


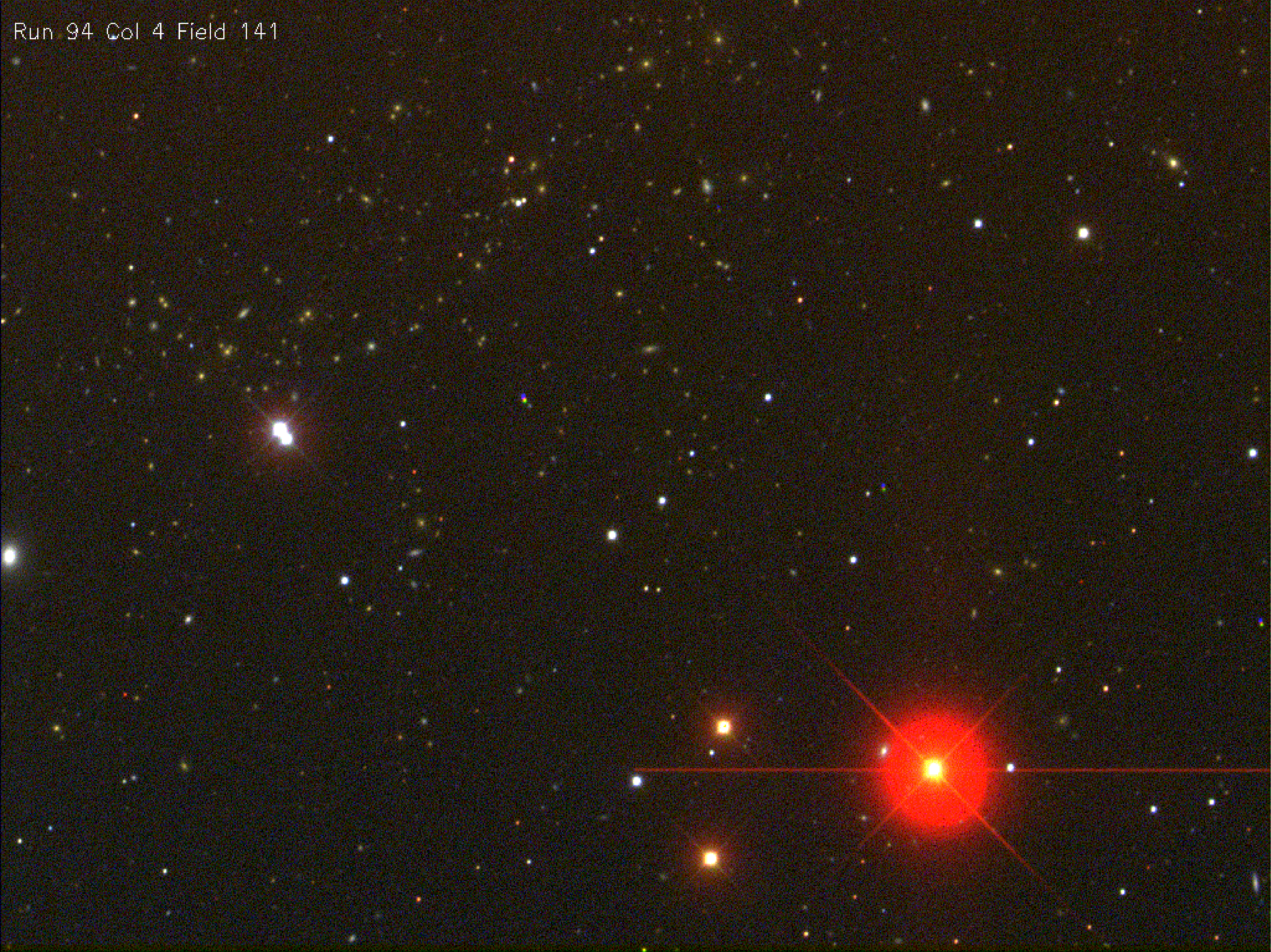









Run 94 Col 2 Field 196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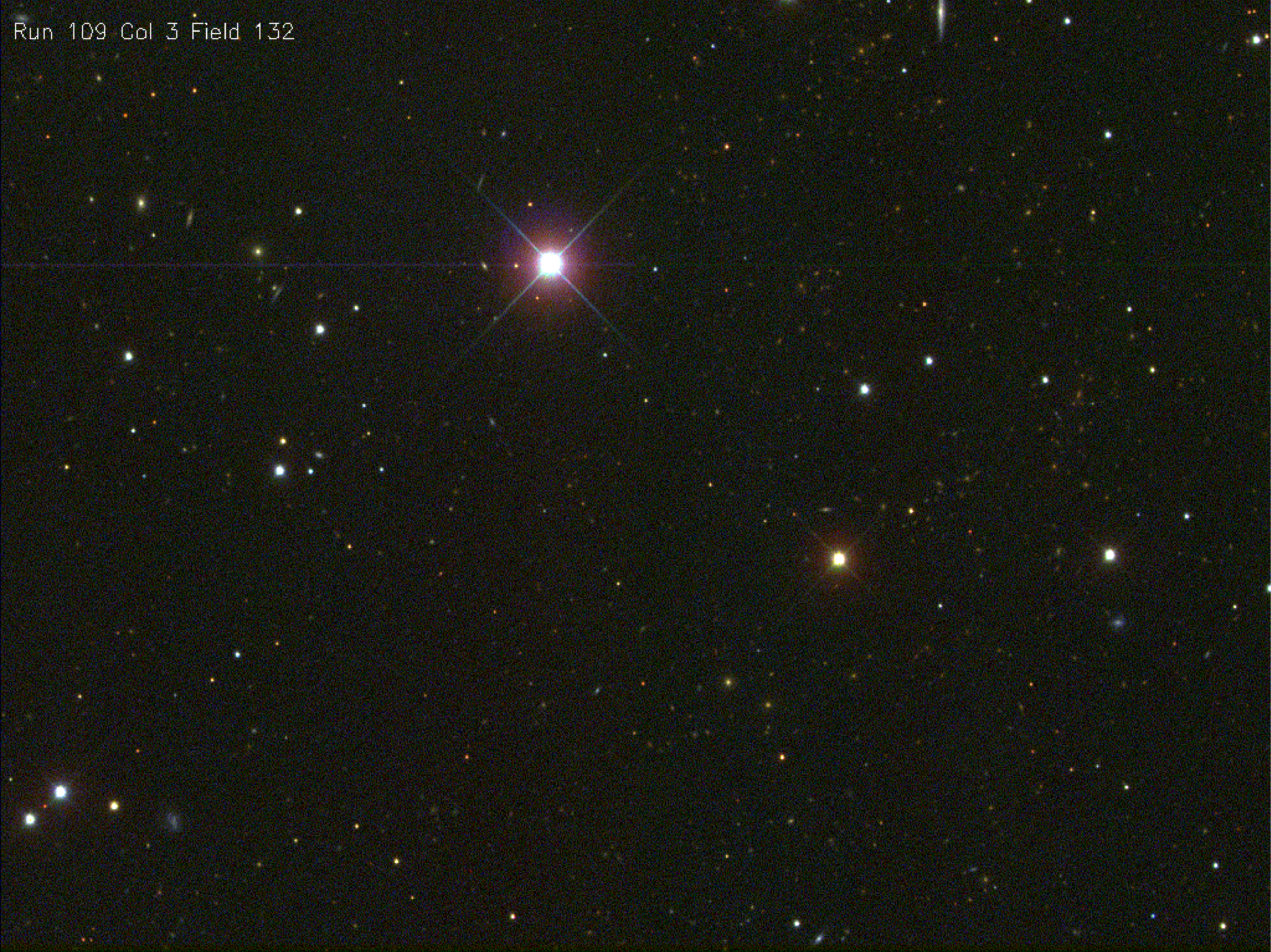
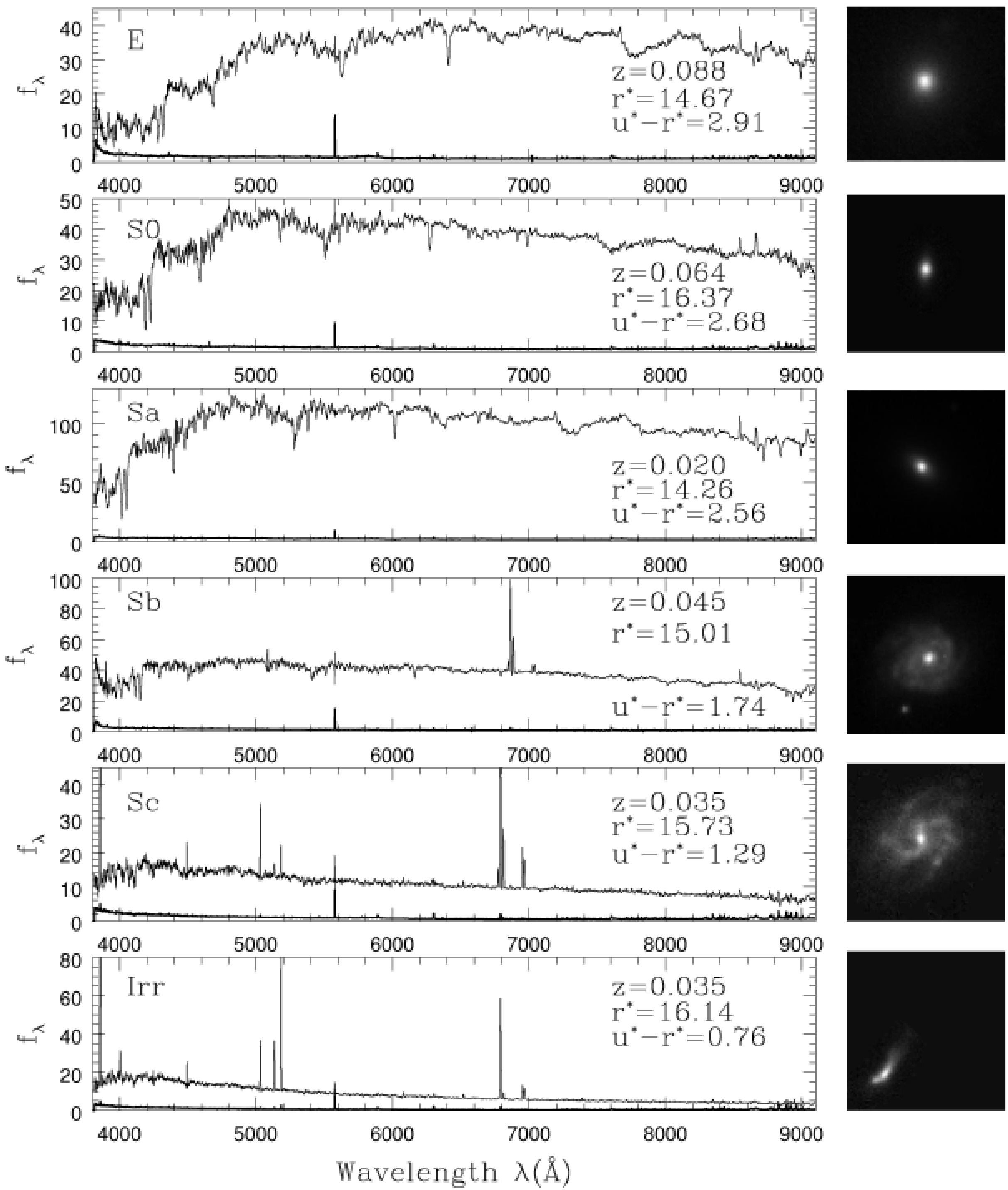
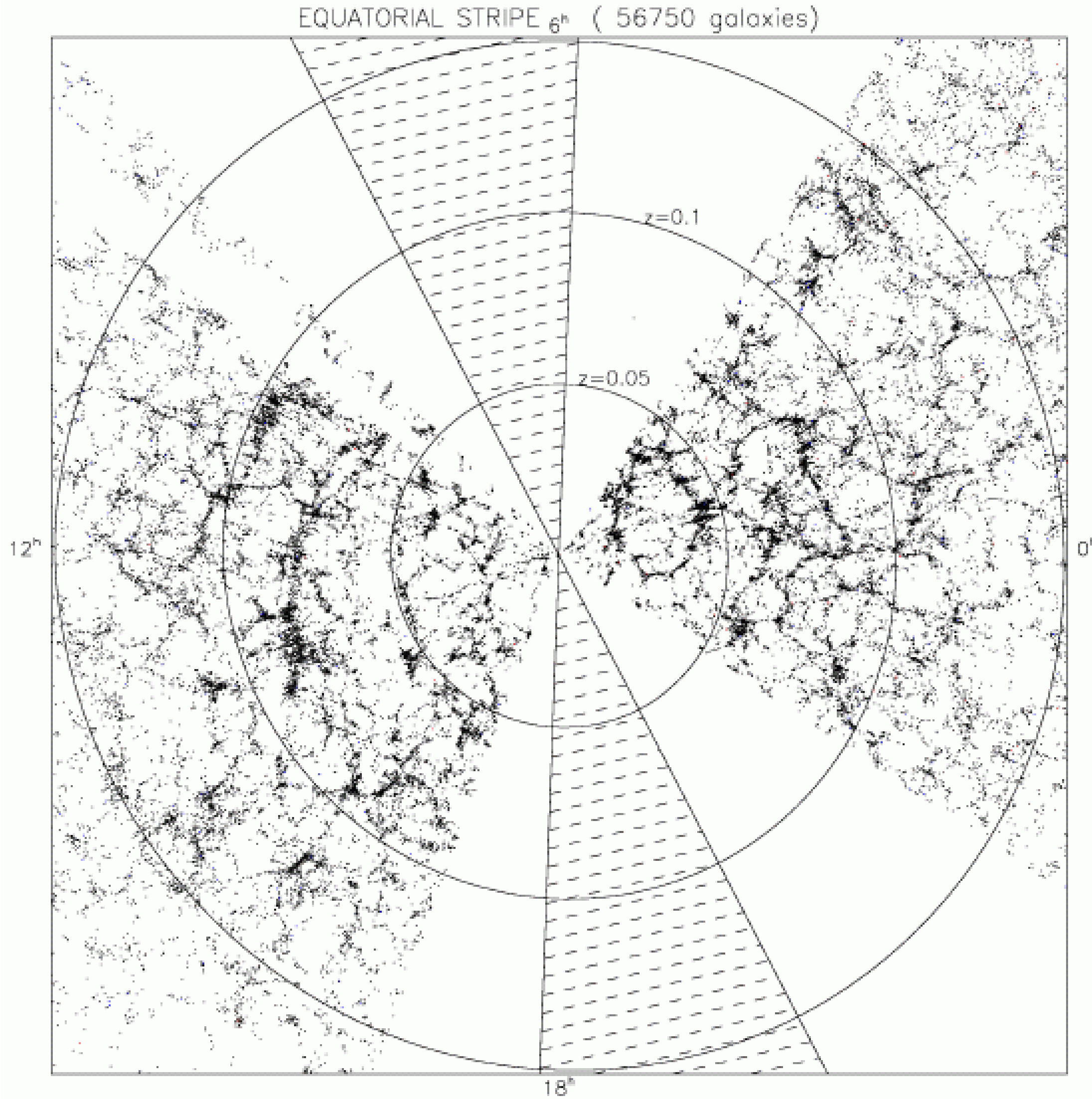
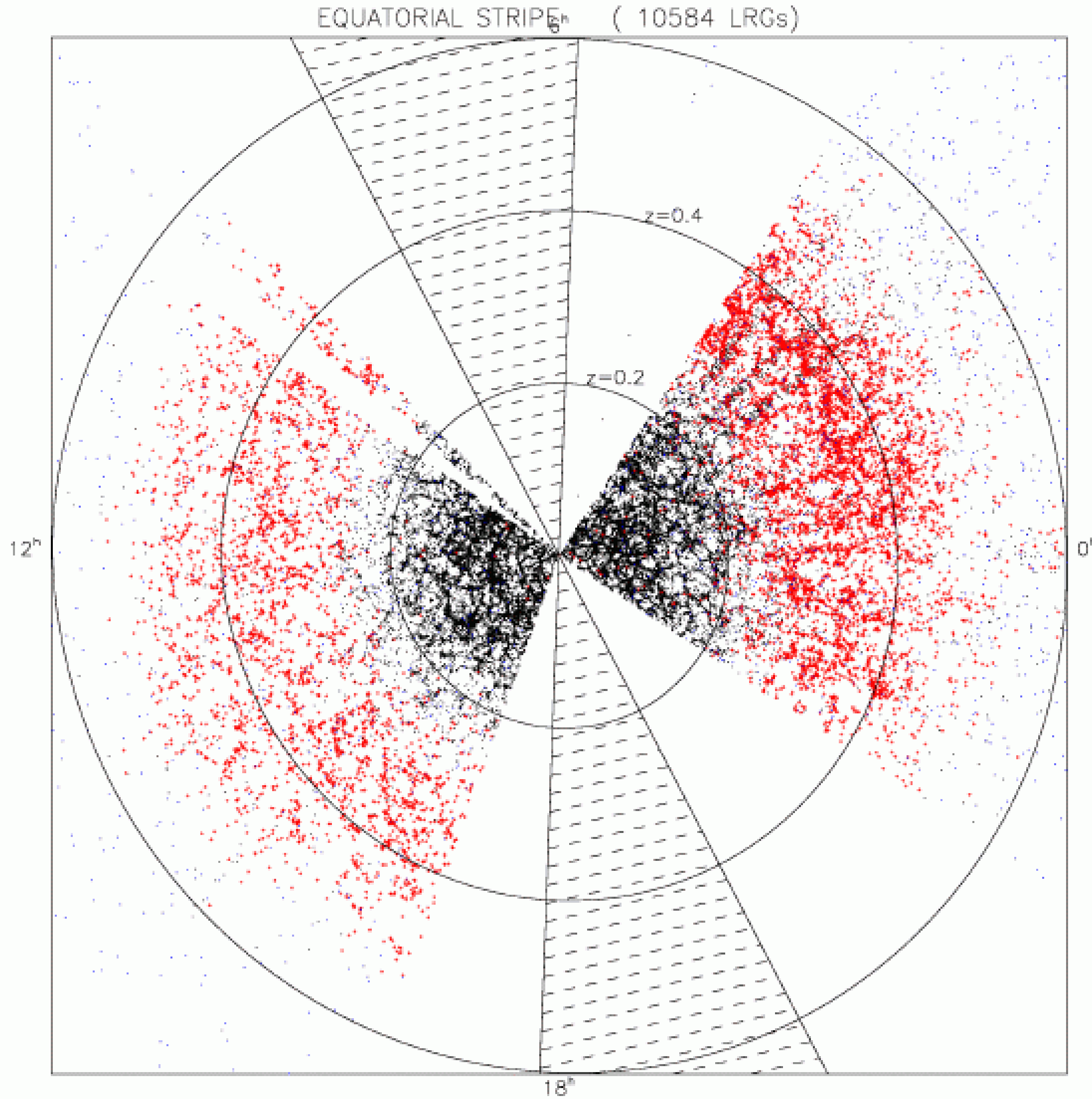

Run 109 Col 3 Field 132

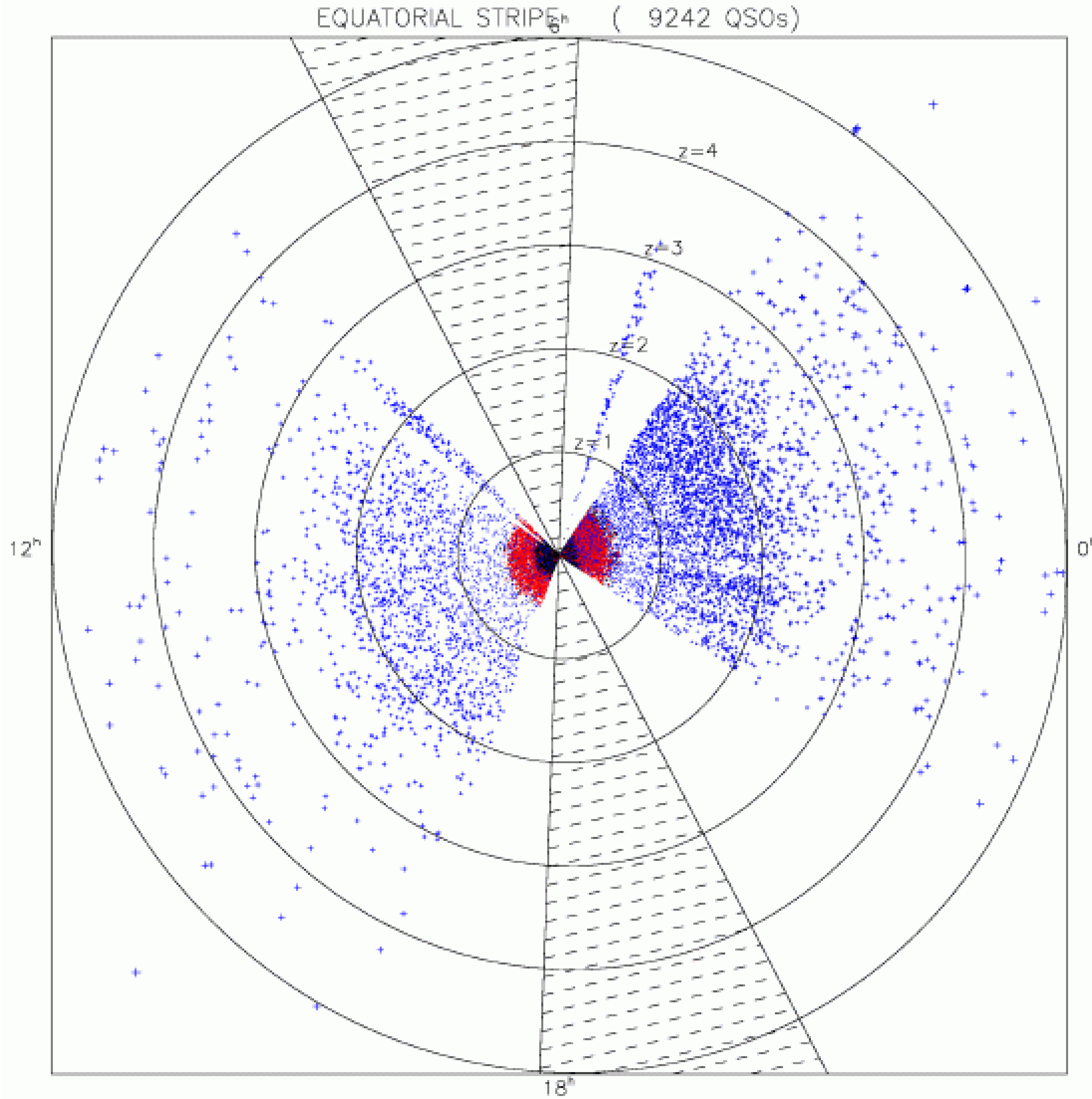


E
z=0.088
r*=14.67
u*−r*=2.91
S0
z=0.064
r*=16.37
u*−r*=2.68
Sa
z=0.020
r*=14.26
u*−r*=2.56
Sb
z=0.045
r*=15.01
u*−r*=1.74
Sc
z=0.035
r*=15.73
u*−r*=1.29
Irr
z=0.035
r*=16.14
u*−r*=0.76
f_λ
Wavelength λ(Å)

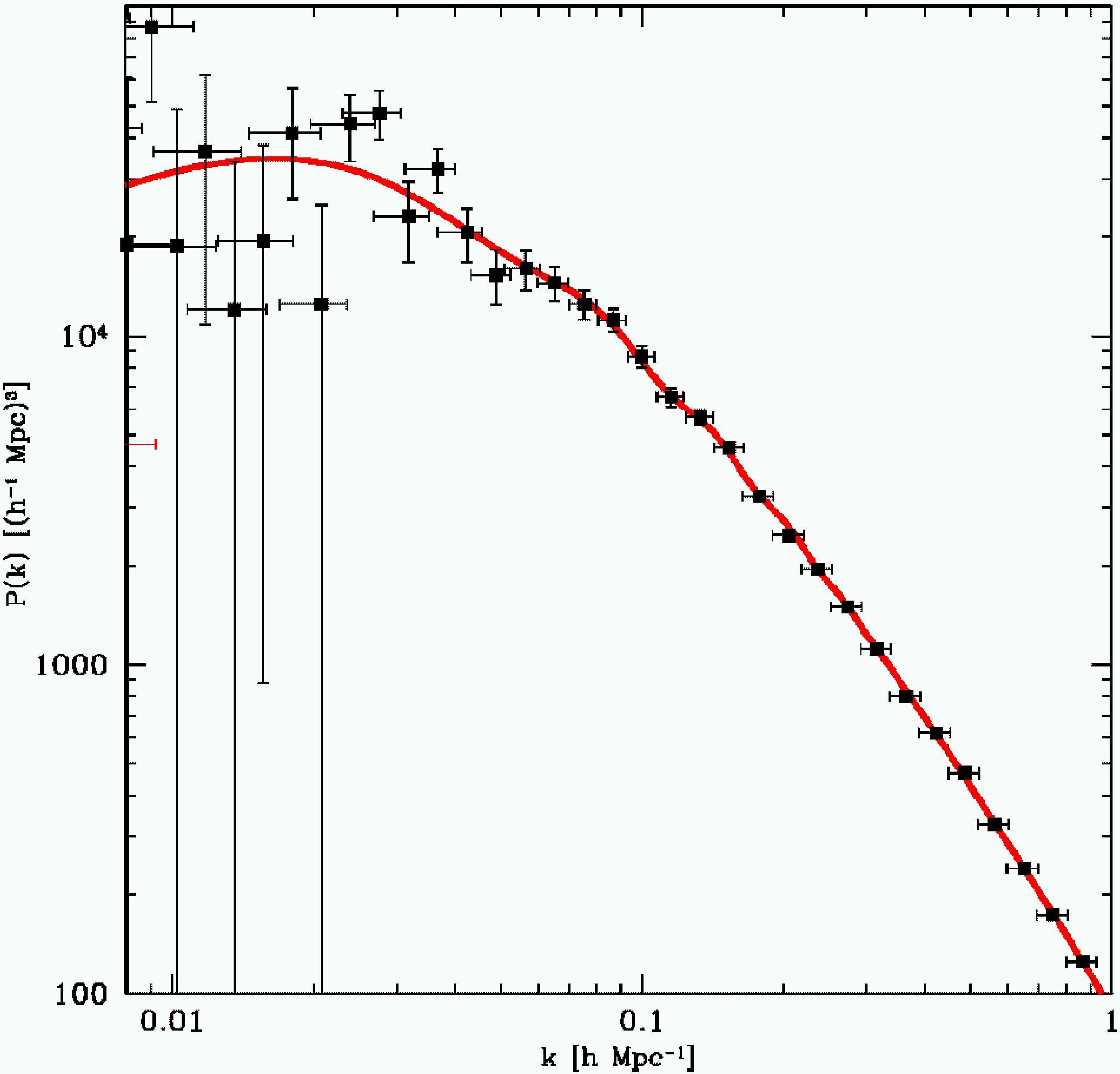

EQUATORIAL STRIPE
(56750 galaxies)
6ʰ
12ʰ
0ʰ
18ʰ
z=0.1
z=0.05



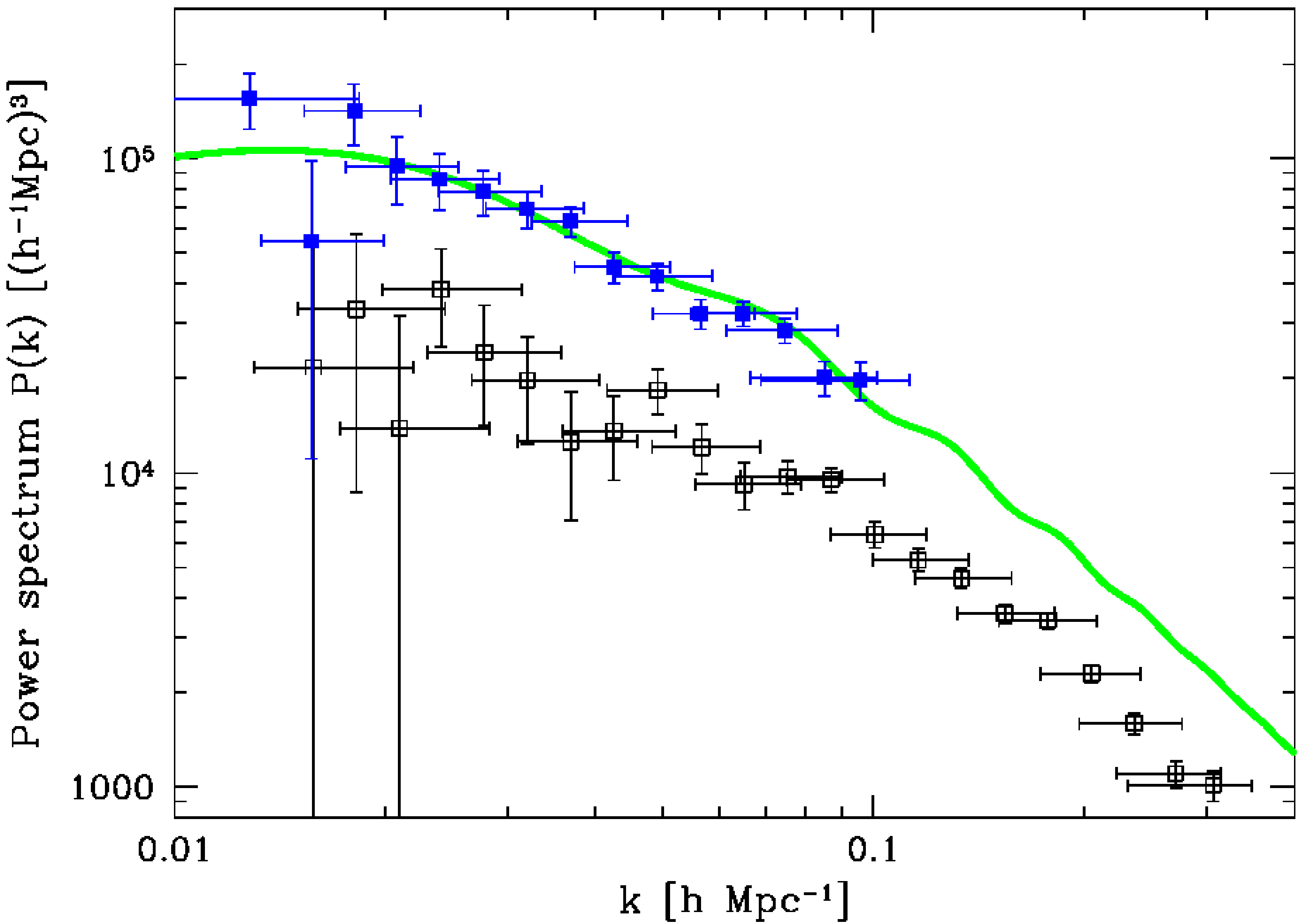
EQUATORIAL STRIPE (10584 LRGs)
6h
z=0.4
z=0.2
12h
0h
18h



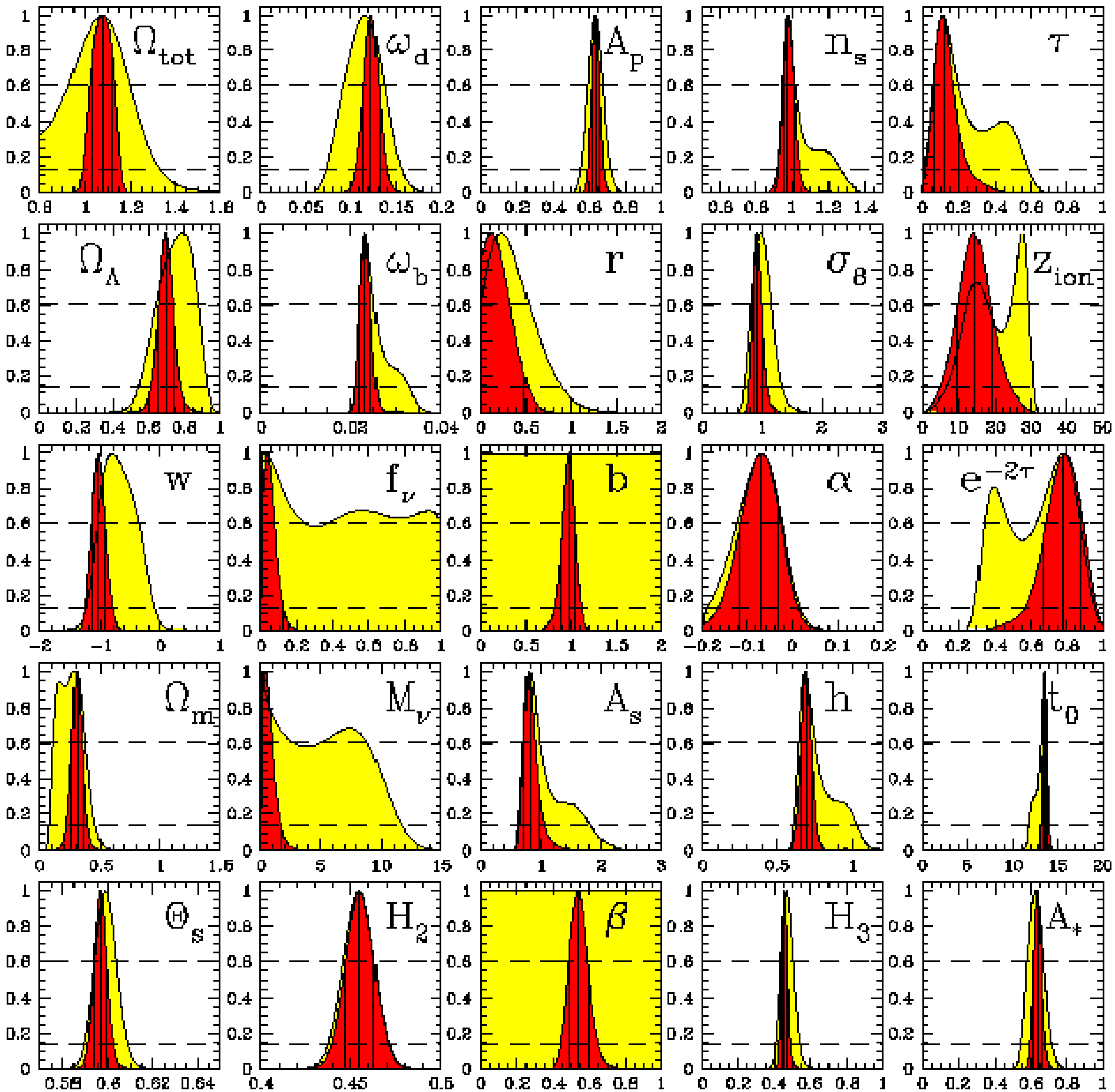
EQUATORIAL STRIPE (9242 QSOs)
6h
z=4
z=3
z=2
z=1
12h
0h
18h

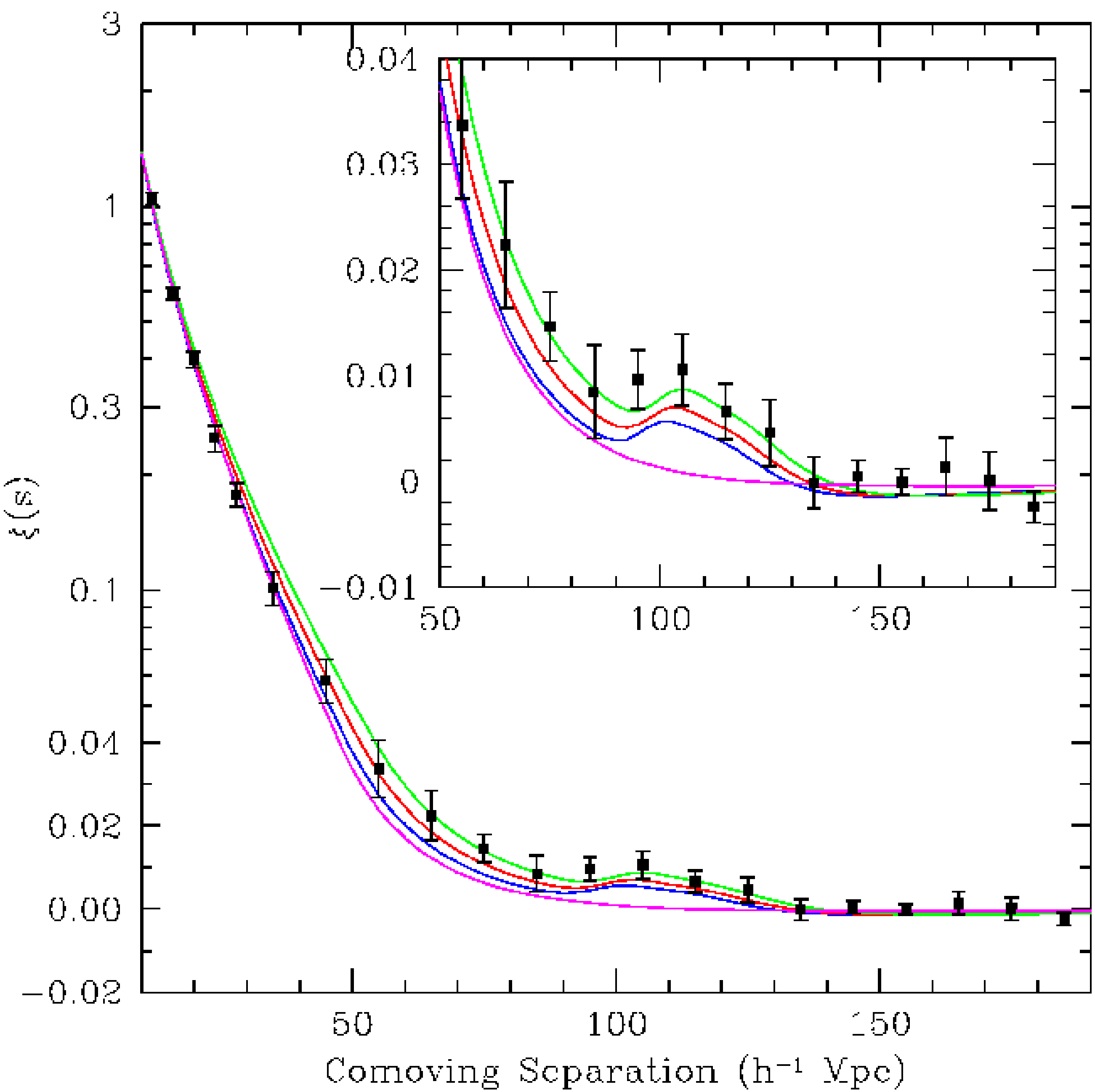


P(k) [(h⁻¹ Mpc)³]
10⁴
1000
100
0.01
0.1
1
k [h Mpc⁻¹]

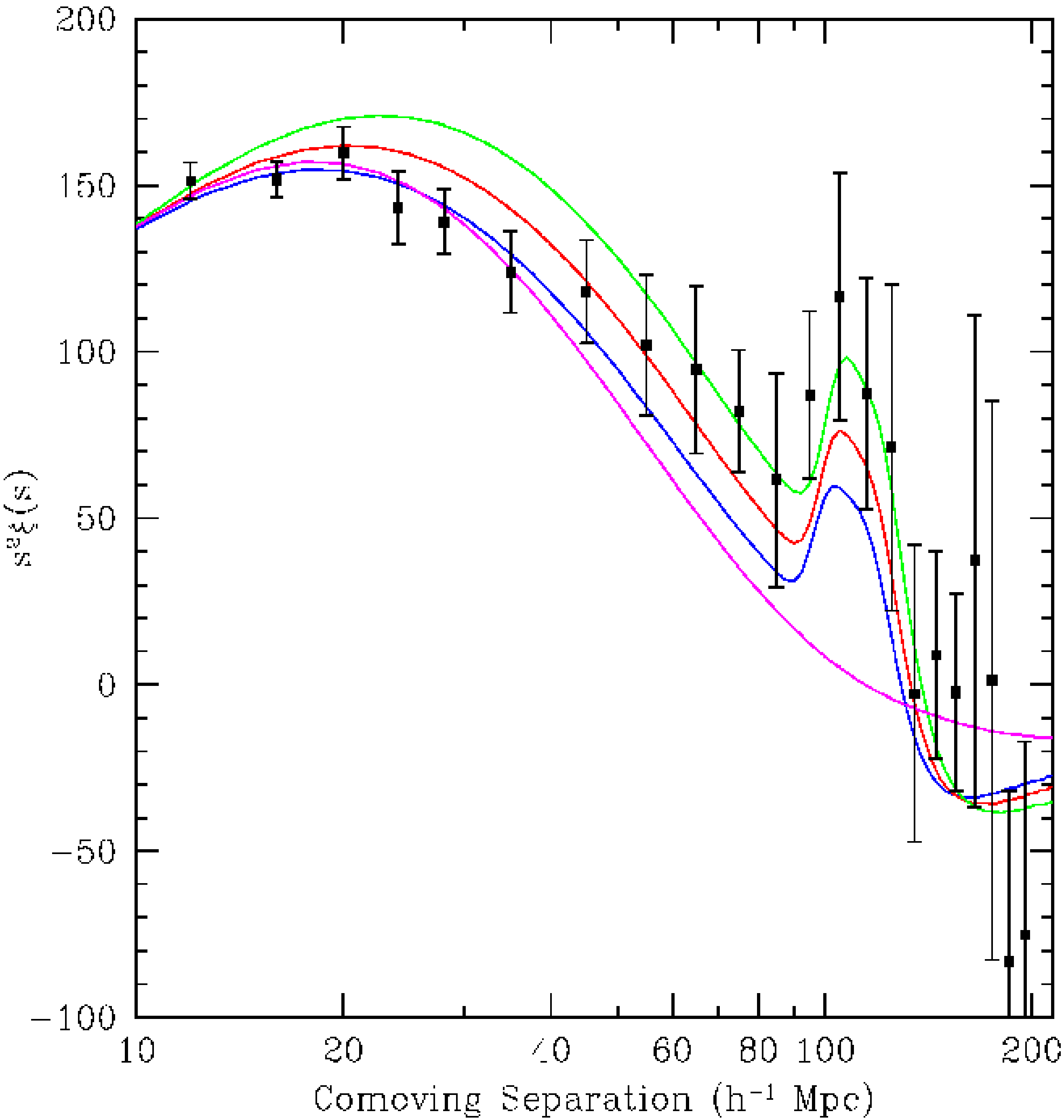


Power spectrum P(k) [(h⁻¹Mpc)³]
10⁵
10⁴
1000
0.01
0.1
k [h Mpc⁻¹]


Ω_{tot}
ω_d
A_p
n_s
τ
Ω_Λ
ω_b
r
σ_8
z_{ion}
w
f_ν
b
α
$e^{-2\tau}$
Ω_m
M_ν
A_s
h
t_0
Θ_s
H_2
β
H_3
A_*



3
1
0.3
0.1
0.04
0.02
0.00
−0.02
ξ(s)
50
100
150
Comoving Separation (h⁻¹ Mpc)
0.04
0.03
0.02
0.01
0
−0.01
50
100
150



200
150
100
50
0
−50
−100
$s^2\xi(s)$
10
20
40
60
80
100
200
Comoving Separation (h^{-1} Mpc)

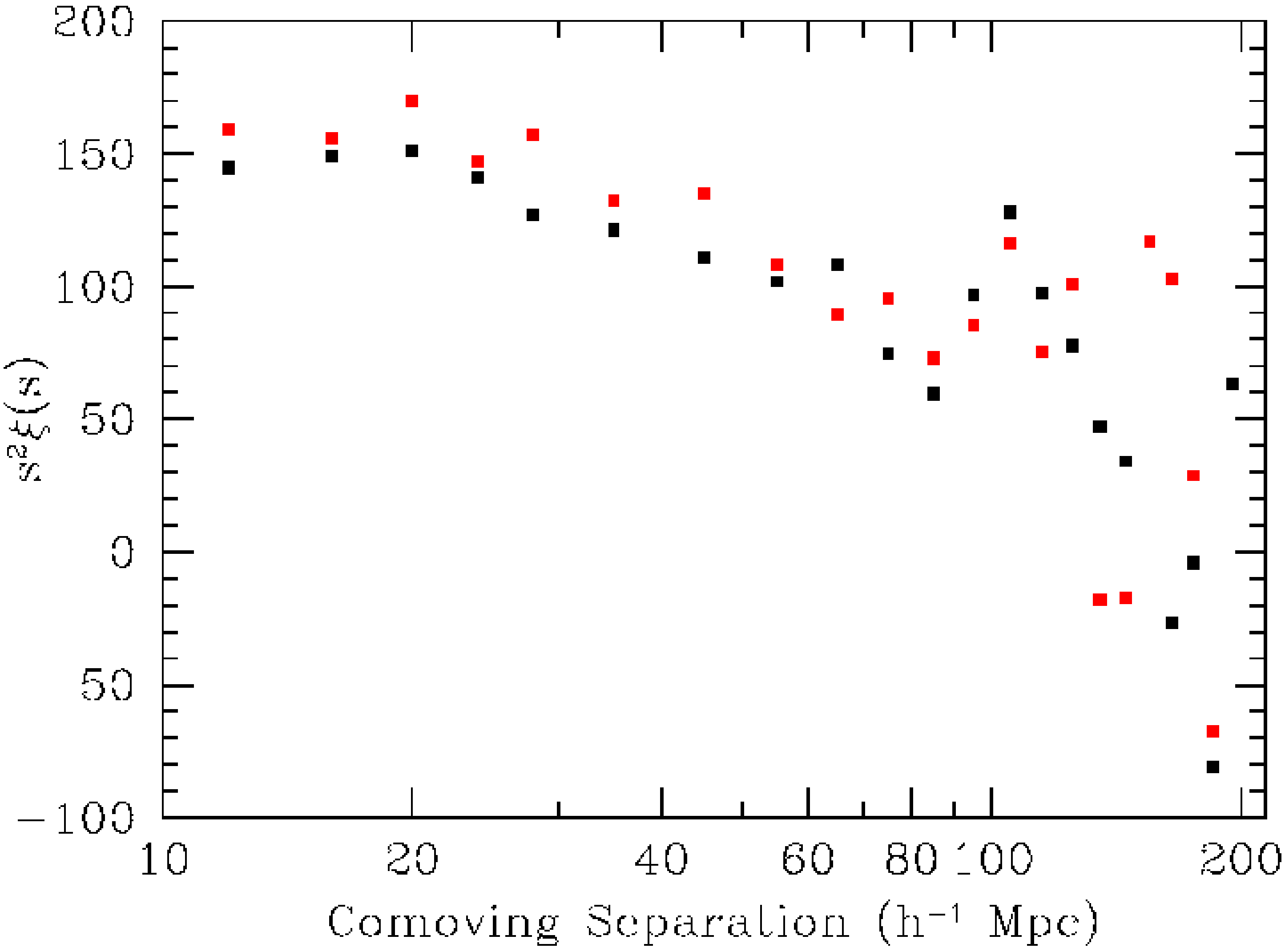


FIG. 3.— The correlation function times r^2 for two different redshift slices, $0.16 < z < 0.36$ (black) and $0.36 < z < 0.47$ (red). The latter is somewhat noisier, but both show evidence for the acoustic peak.

TABLE 1

SUMMARY OF PARAMETER CONSTRAINTS FROM LRGS

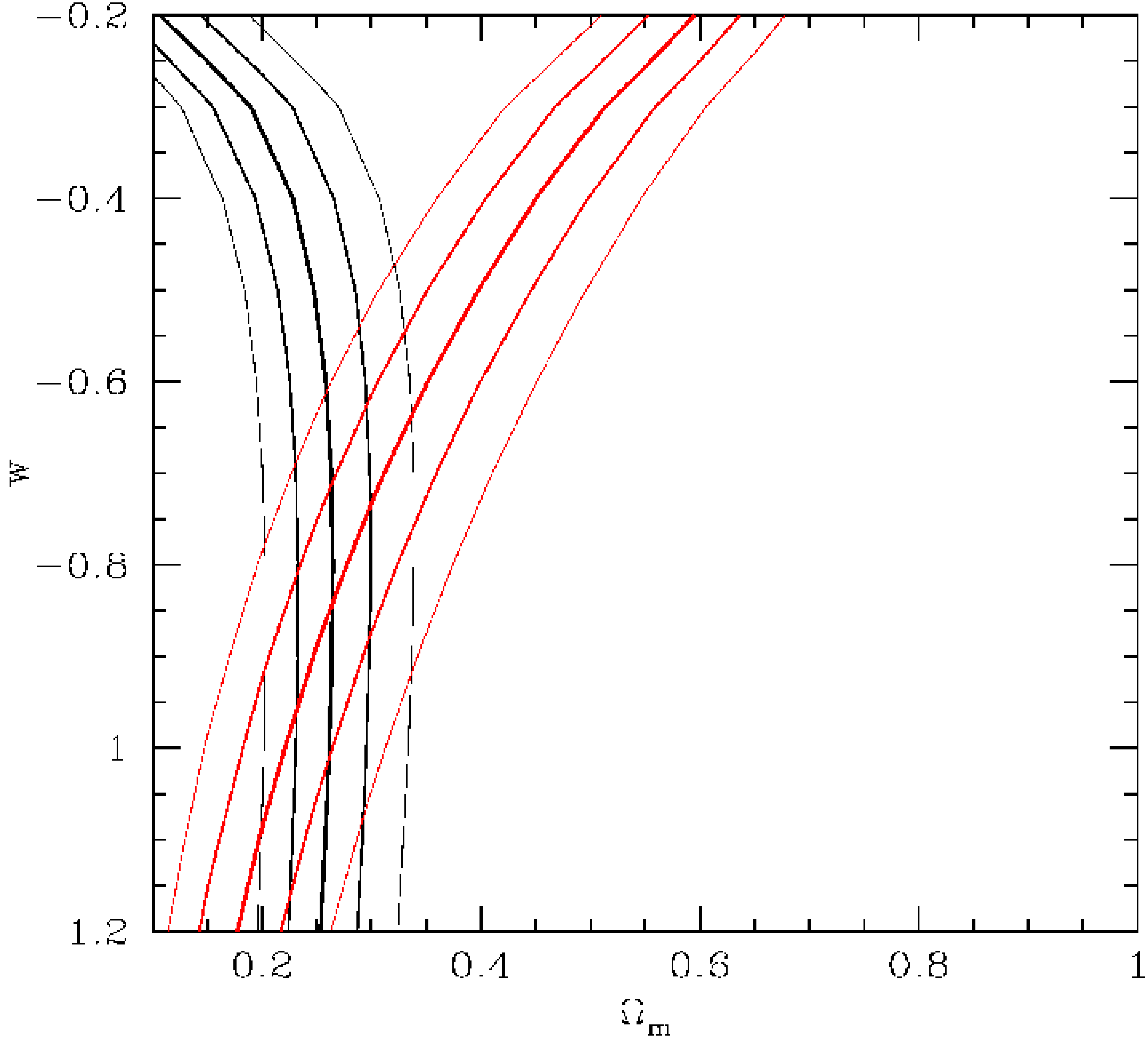
$\Omega_m h^2$	$0.130(n/0.98)^{1.2} \pm 0.011$
$D(0.35)$	1370 ± 64 Mpc (4.7%)
$R_{0.35} \equiv D(0.35)/D_M(1089)$	0.0965 ± 0.036 (3.7%)
$A \equiv D(0.35)\sqrt{\Omega_m H_0^2}/0.35c$	$0.469(n/0.98)^{-0.35} \pm 0.017$ (3.6%)

NOTES. We assume $\Omega_b h^2 = 0.024$ throughout, but variations permitted by WMAP create negligible changes here. We use $n = 0.98$, but where variations by 0.1 would create 1-σ changes, we include an approximate dependence. All constraints are 1-σ.

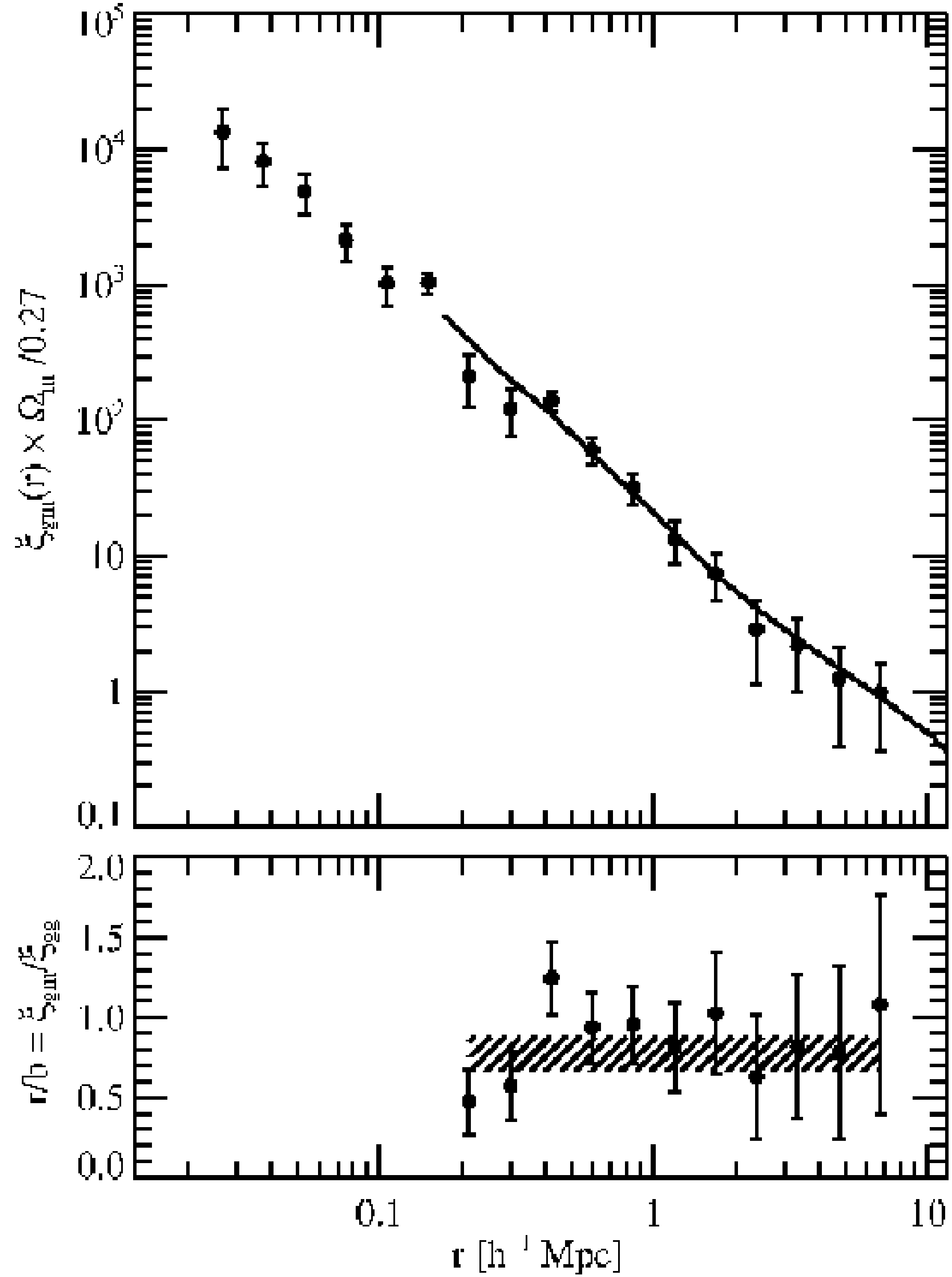
TABLE 2

JOINT CONSTRAINTS ON COSMOLOGICAL PARAMETERS INCLUDING CMB DATA

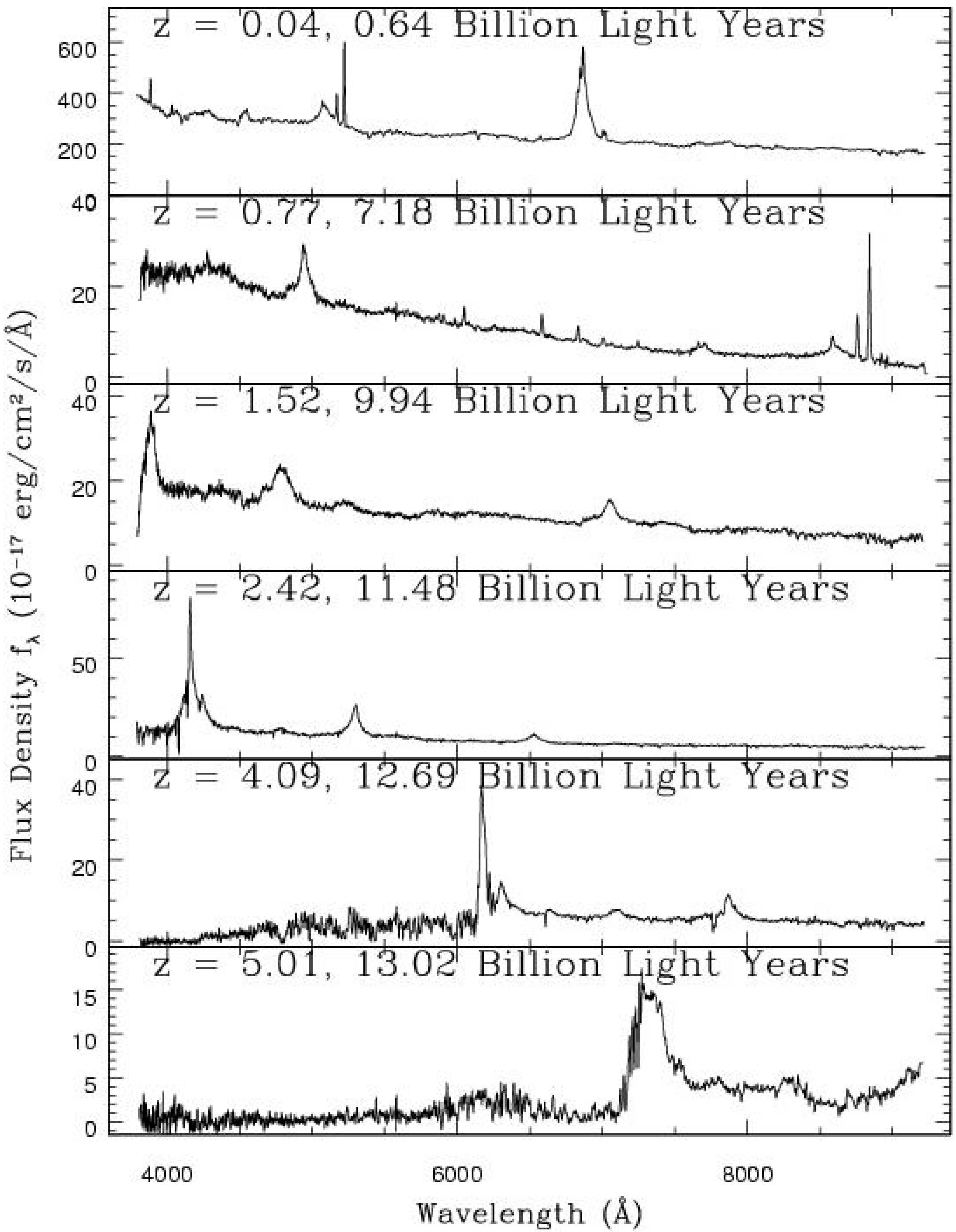
Parameter	Constant w flat WMAP+MAIN	+LRG	$w=-1$ curved WMAP+MAIN	+LRG	$w=-1$ flat all
w	0.92(30)	0.83(19)	...	...	...
Ω_K	...	...	–0.045(32)	–0.008(09)	...
$\Omega_m h^2$	0.145(14)	0.135(09)	0.134(12)	0.136(08)	...
Ω_m	0.329(74)	0.314(36)	0.431(96)	0.298(25)	0.271(23)
h	0.679(100)	0.659(47)	0.569(82)	0.677(28)	0.721(18)



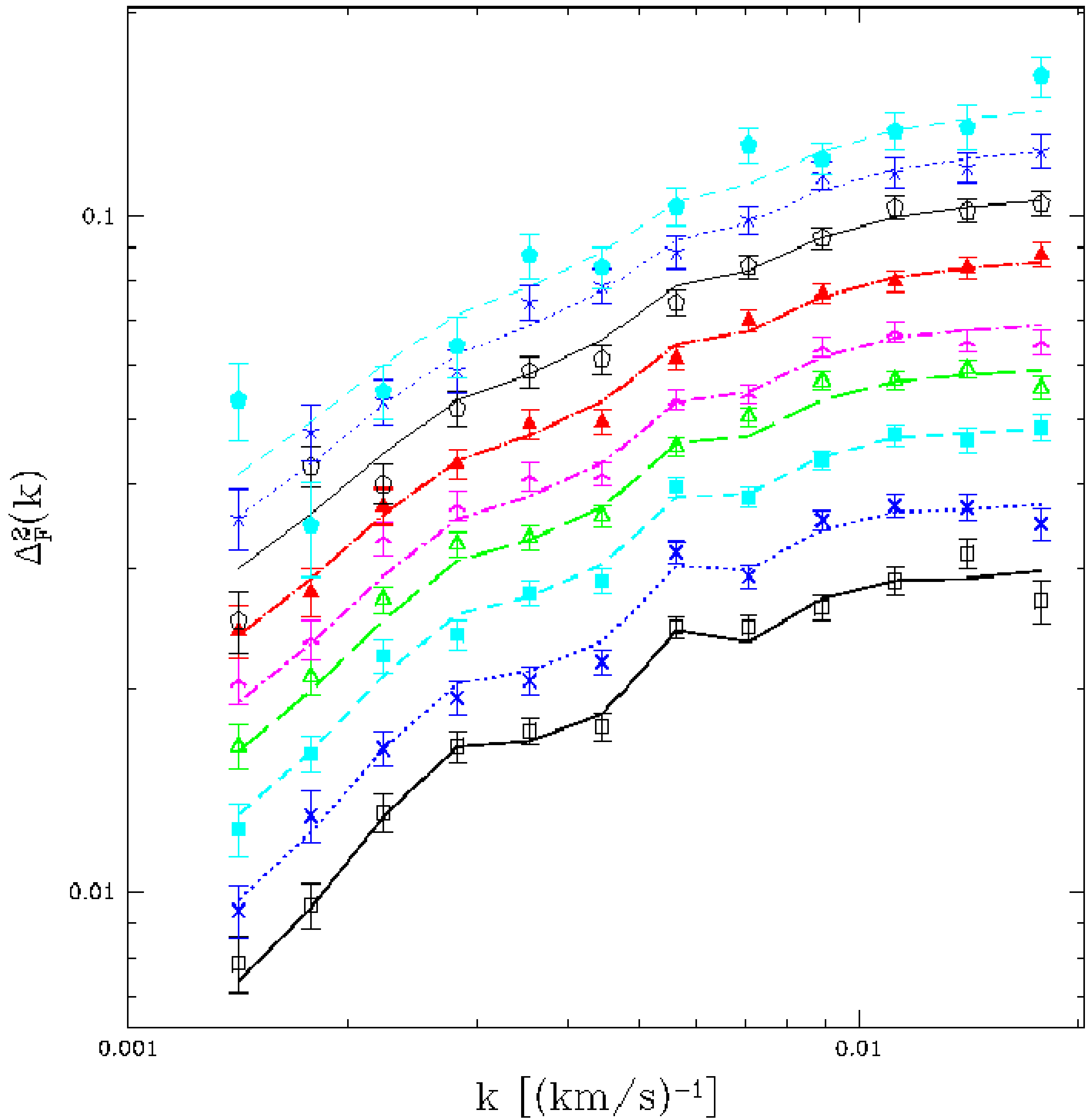
−0.2
−0.4
−0.6
−0.8
1
1.2
w
0.2
0.4
0.6
0.8
1
Ωm



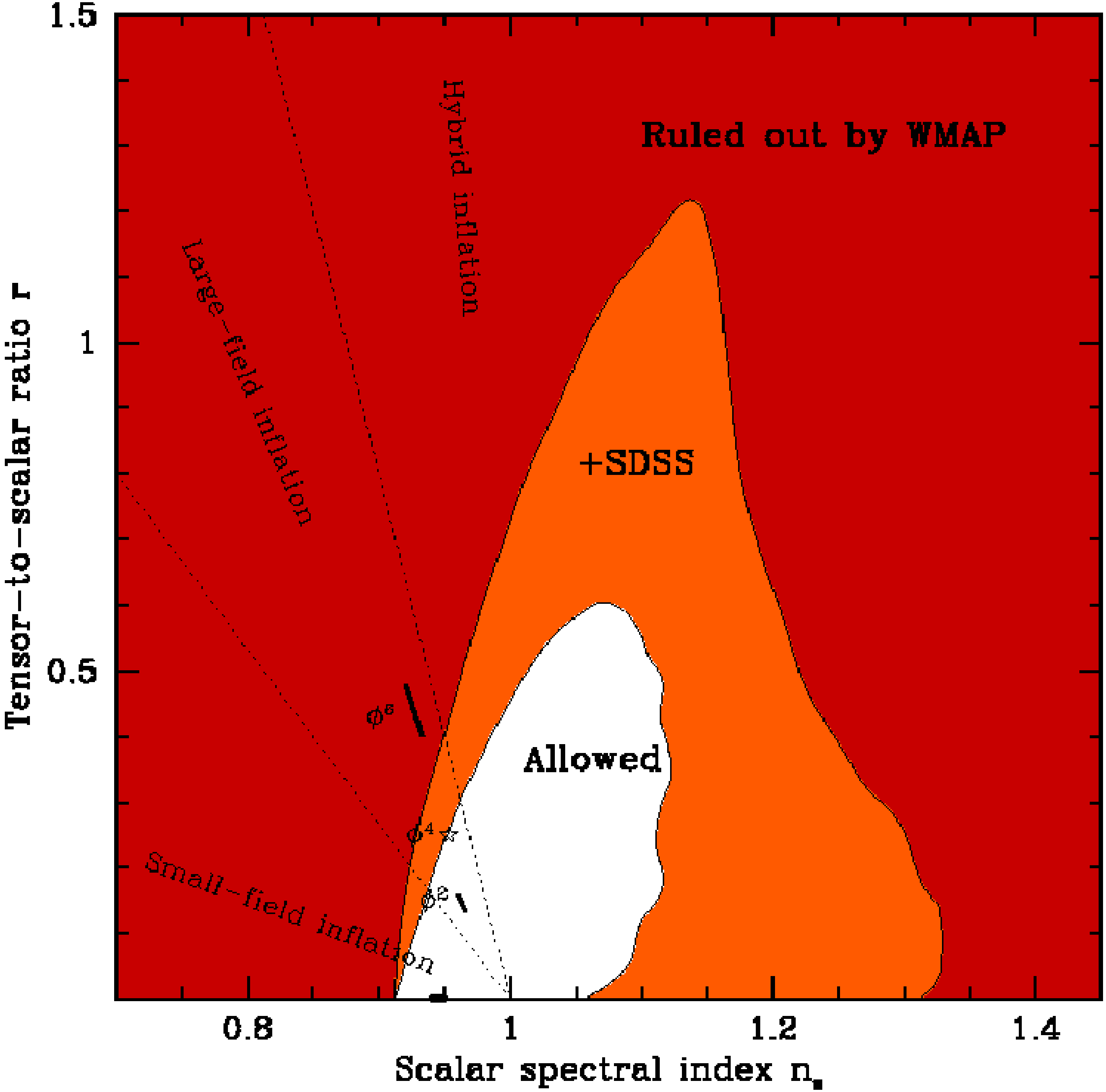
$\xi_{gm}(r) \times \Omega_m / 0.27$
10^5
10^4
10^3
10^2
10
1
0.1
$r/b = \xi_{gm}/\xi_{gg}$
2.0
1.5
1.0
0.5
0.0
0.1
1
10
r [h^{-1} Mpc]



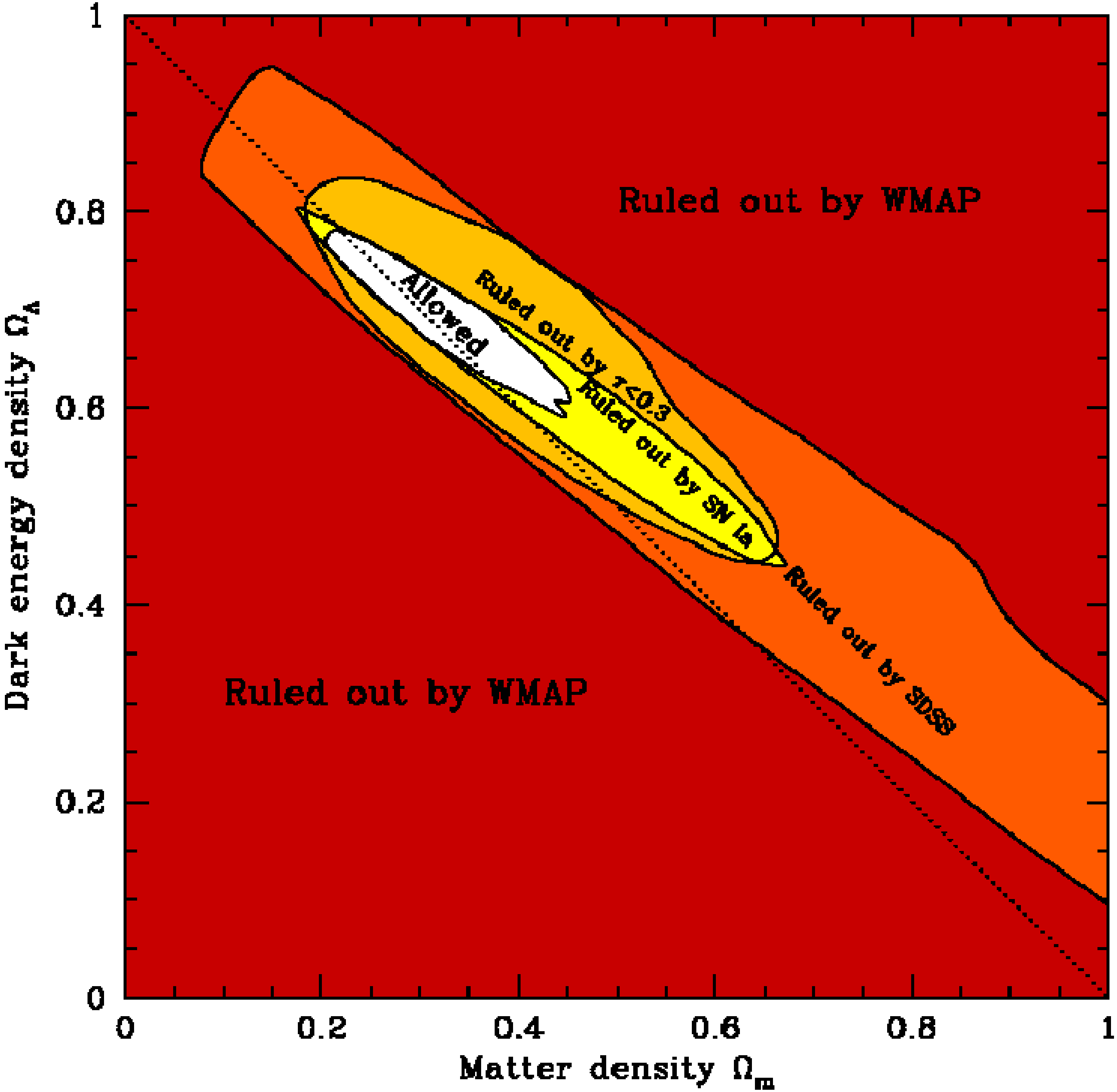
z = 0.04, 0.64 Billion Light Years
z = 0.77, 7.18 Billion Light Years
z = 1.52, 9.94 Billion Light Years
z = 2.42, 11.48 Billion Light Years
z = 4.09, 12.69 Billion Light Years
z = 5.01, 13.02 Billion Light Years
Flux Density f_λ (10^{-17} erg/cm²/s/Å)
Wavelength (Å)
4000
6000
8000



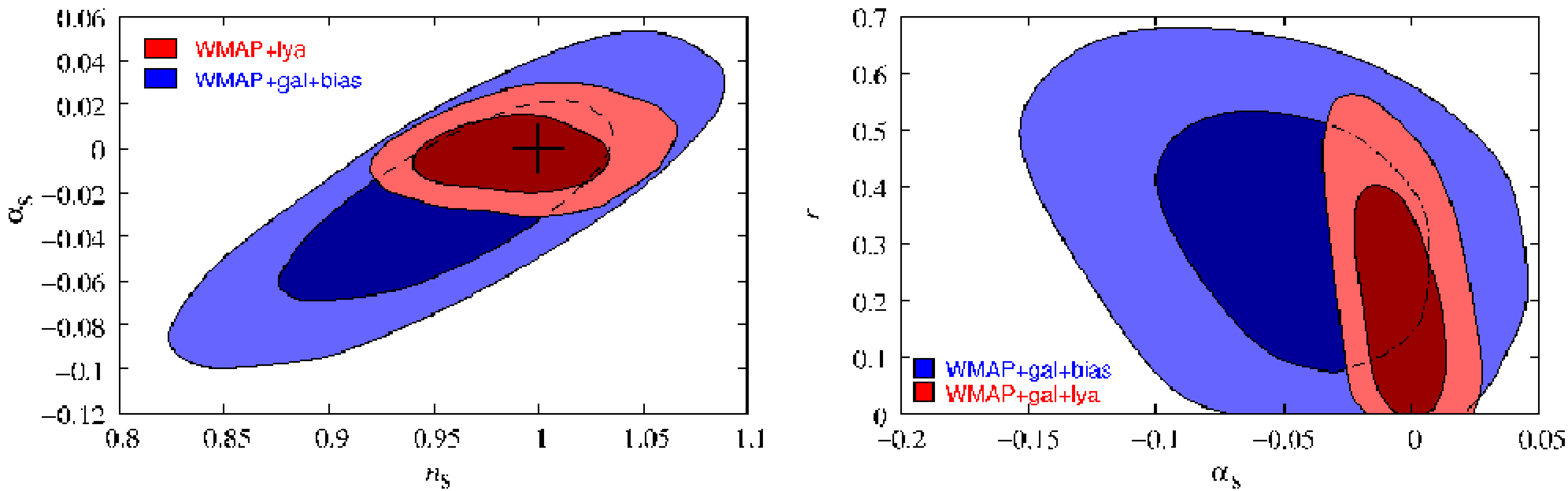
0.1
0.01
0.001
0.01
$\Delta_F^2(k)$
k [(km/s)$^{-1}$]



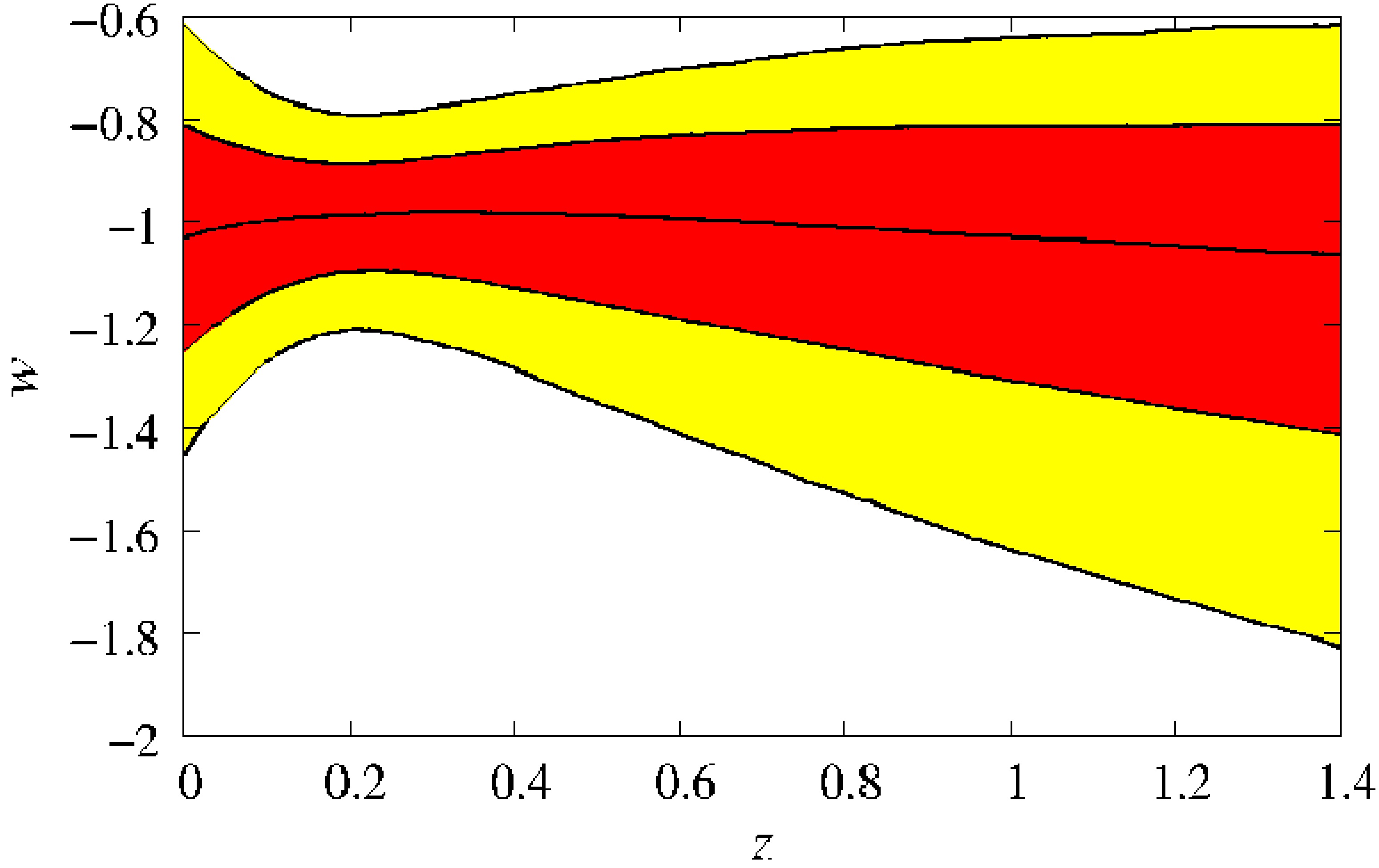
Ruled out by WMAP
+SDSS
Allowed
Hybrid inflation
Large-field inflation
Small-field inflation
ϕ^6
ϕ^4
ϕ^2
1.5
1
0.5
0.8
1
1.2
1.4
Tensor-to-scalar ratio r
Scalar spectral index n_s



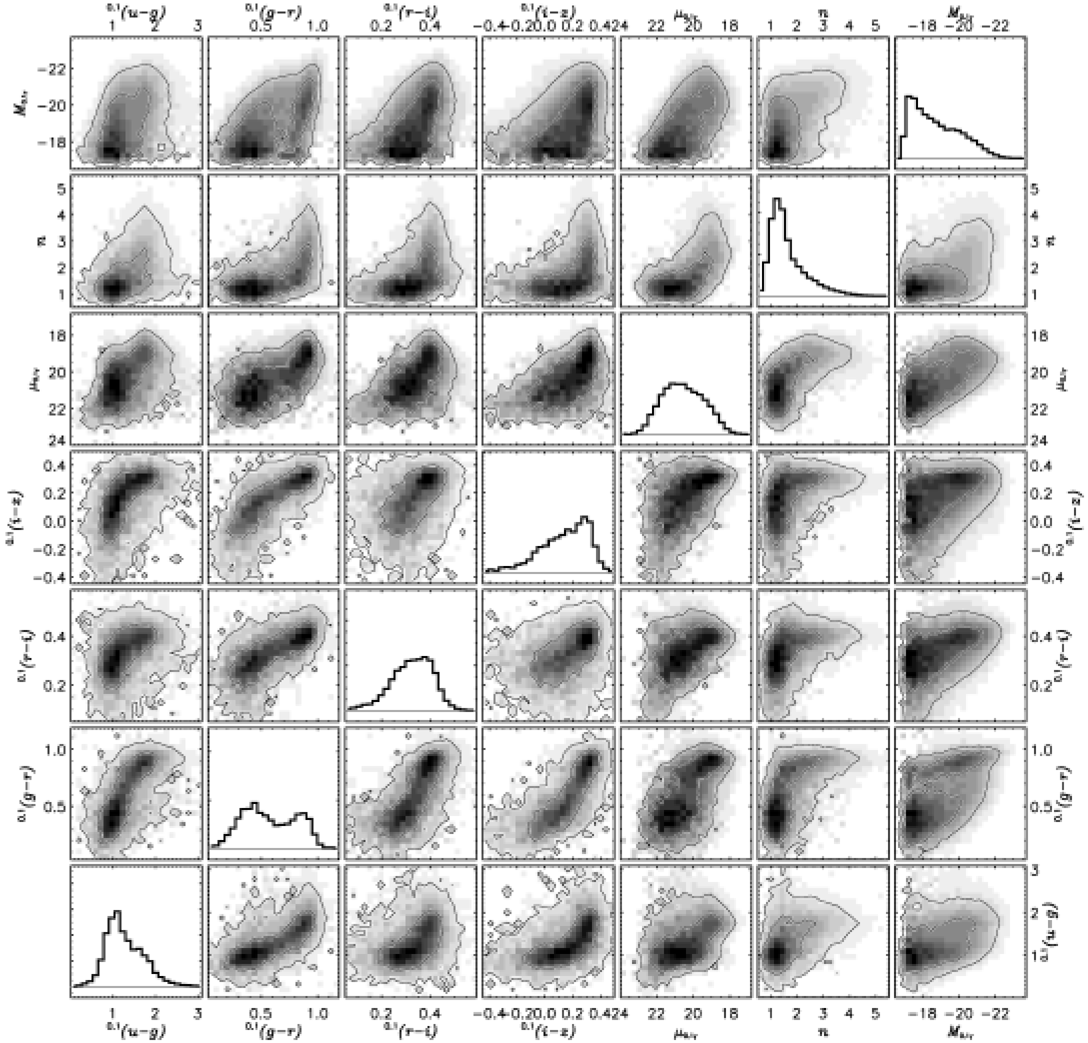
Ruled out by WMAP
Allowed
Ruled out by τ<0.3
Ruled out by SN Ia
Ruled out by SDSS
Ruled out by WMAP
Dark energy density Ω_Λ
Matter density Ω_m
0
0.2
0.4
0.6
0.8
1



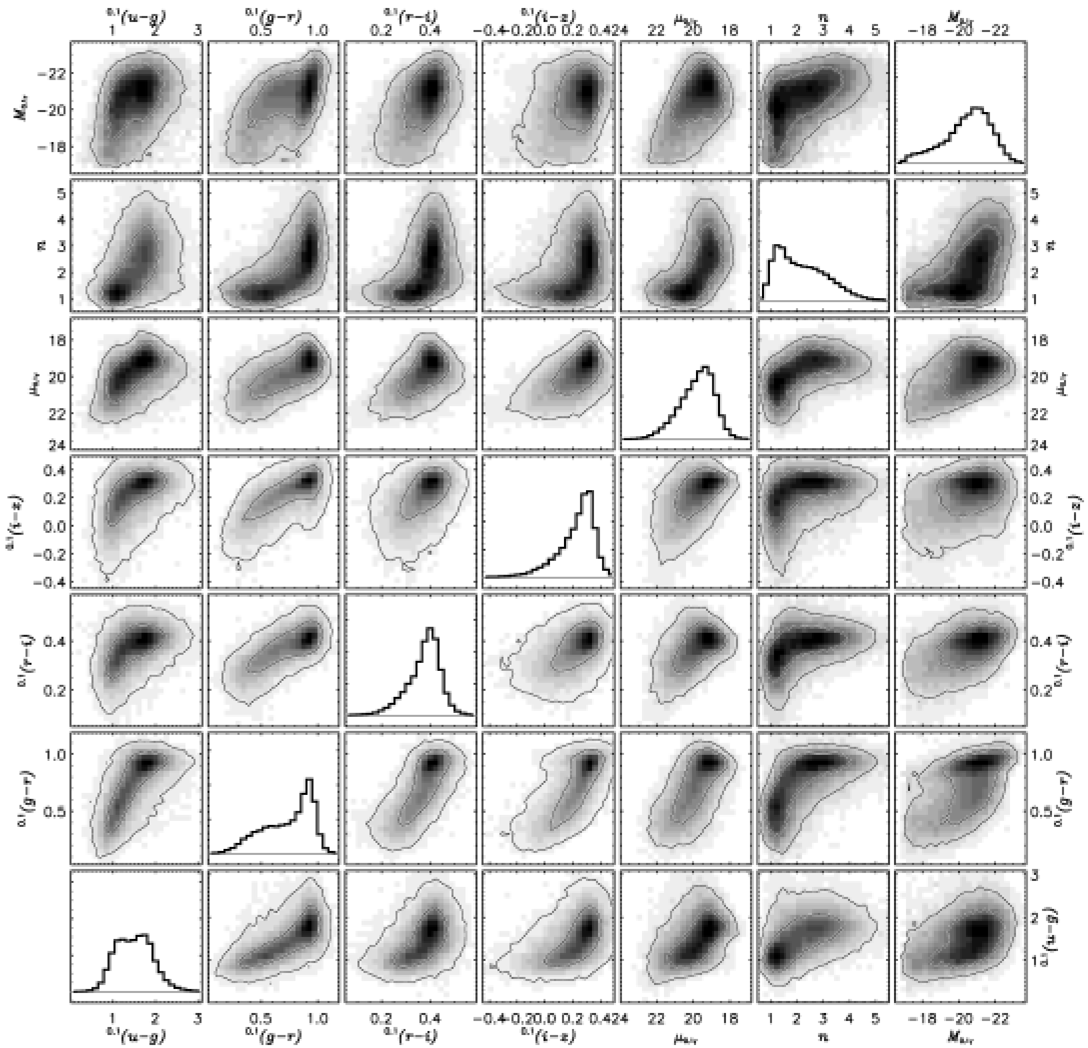
WMAP+lya
WMAP+gal+bias
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
−0.08
−0.1
−0.12
α_s
0.8
0.85
0.9
0.95
1
1.05
1.1
n_s
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
r
−0.2
−0.15
−0.1
−0.05
0
0.05
α_s
WMAP+gal+bias
WMAP+gal+lya



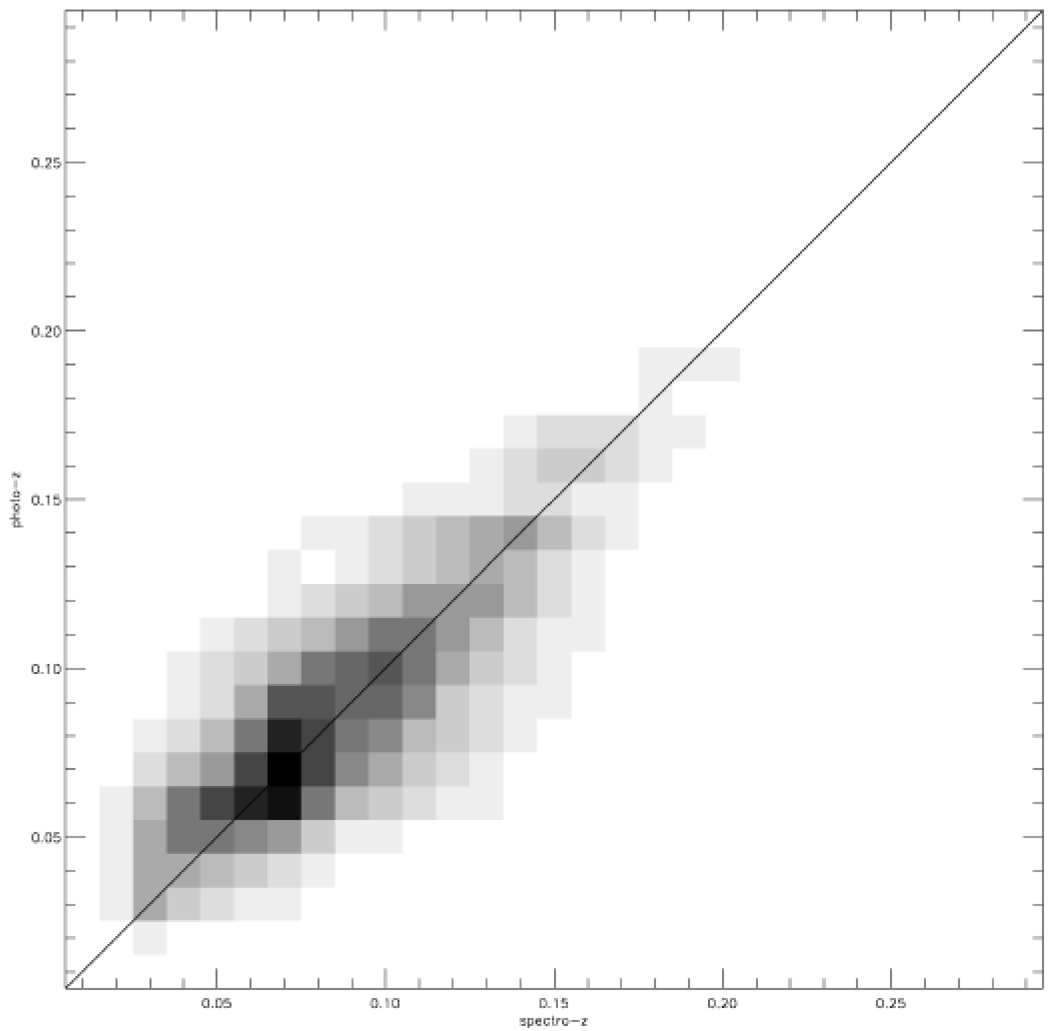
−0.6
−0.8
−1
−1.2
−1.4
−1.6
−1.8
−2
w
0
0.2
0.4
0.6
0.8
1
1.2
1.4
z

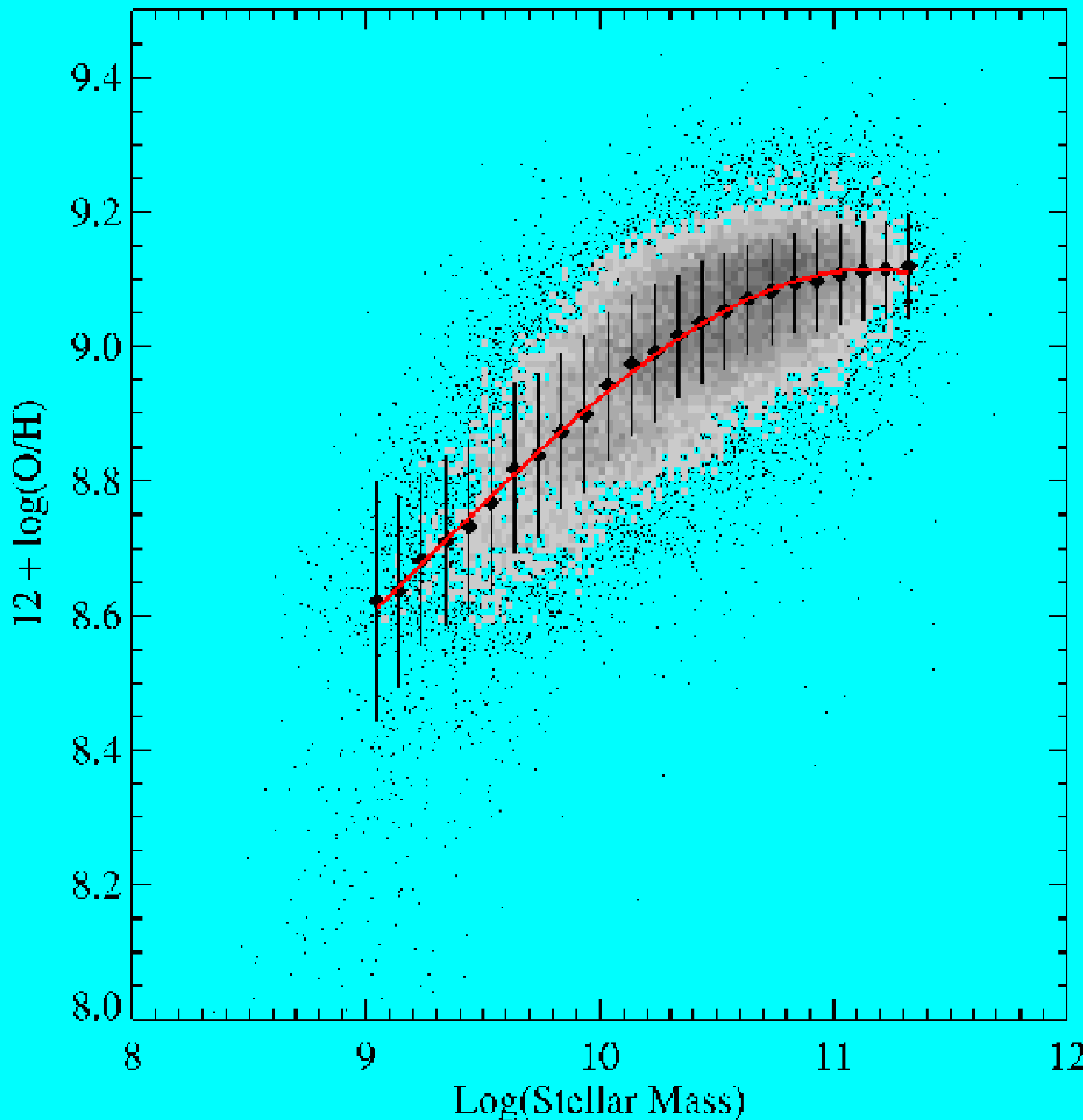


$^{0.1}(u-g)$
$^{0.1}(g-r)$
$^{0.1}(r-i)$
$^{0.1}(i-z)$
$\mu_{50,r}$
n
$M_{50,r}$

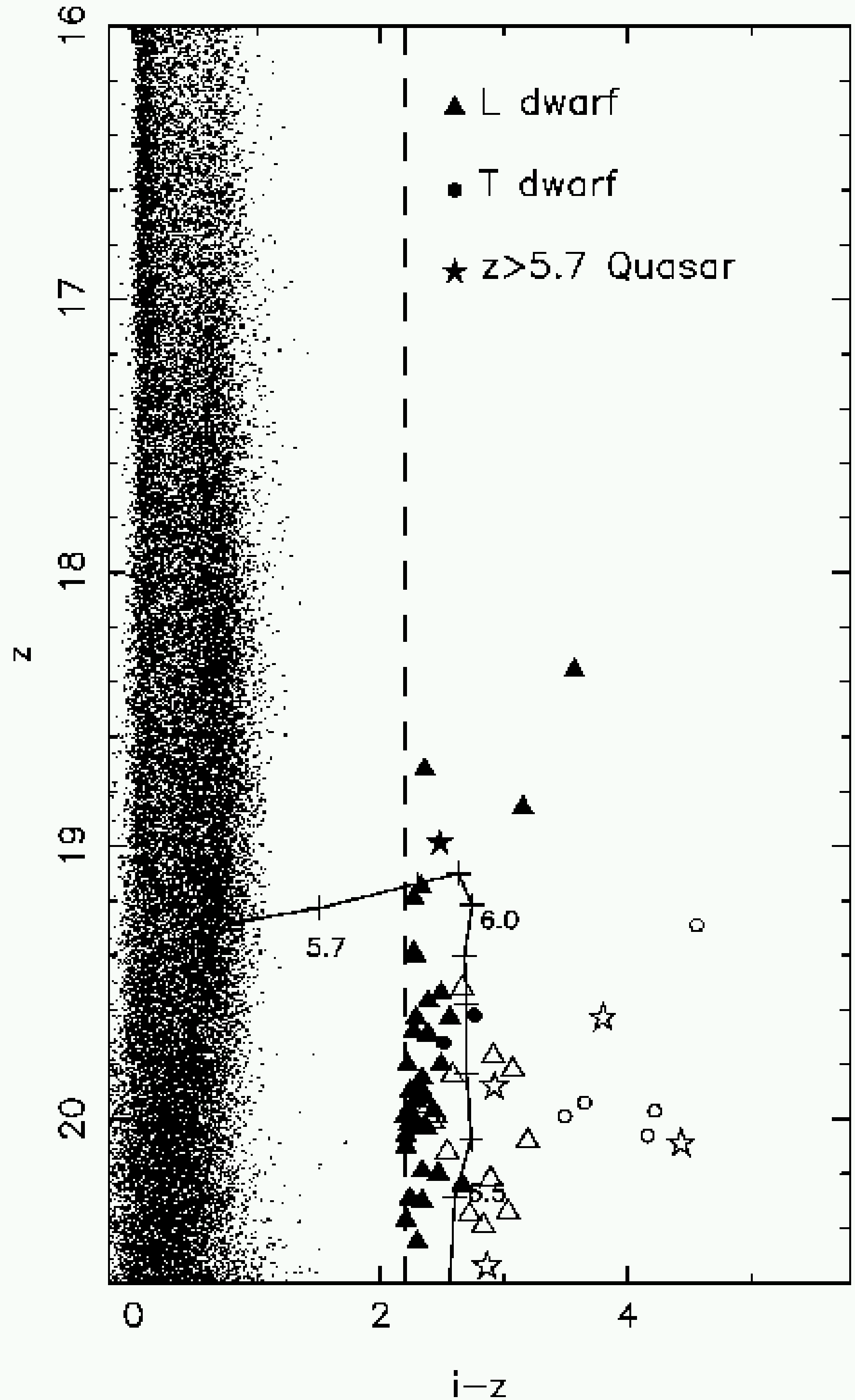


0.1(u-g)
0.1(g-r)
0.1(r-i)
0.1(i-z)
n

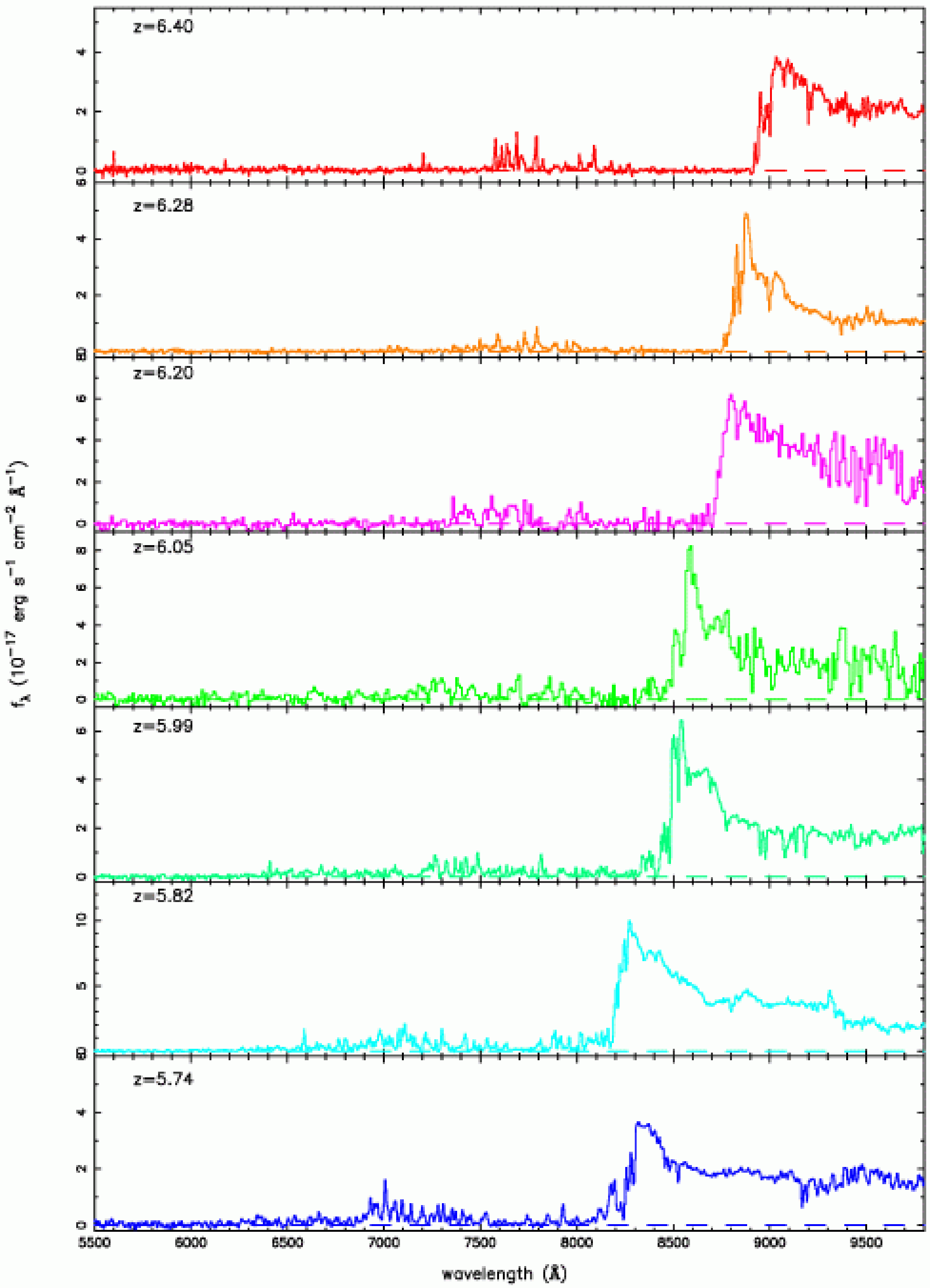

0.25
0.20
0.15
0.10
0.05
photo-z
0.05
0.10
0.15
0.20
0.25
spectro-z



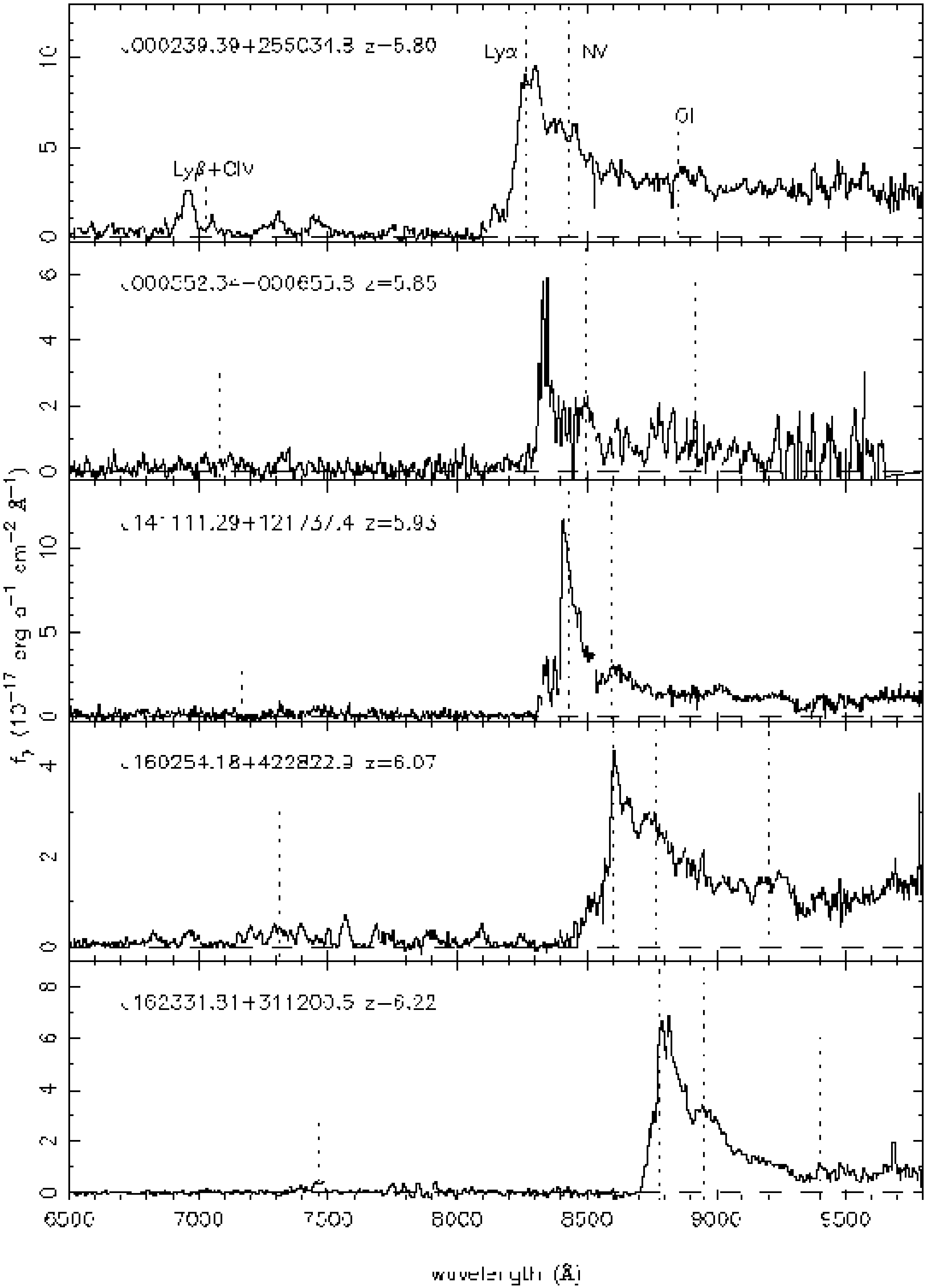
9.4
9.2
9.0
8.8
8.6
8.4
8.2
8.0
12 + log(O/H)
8
9
10
11
12
Log(Stellar Mass)



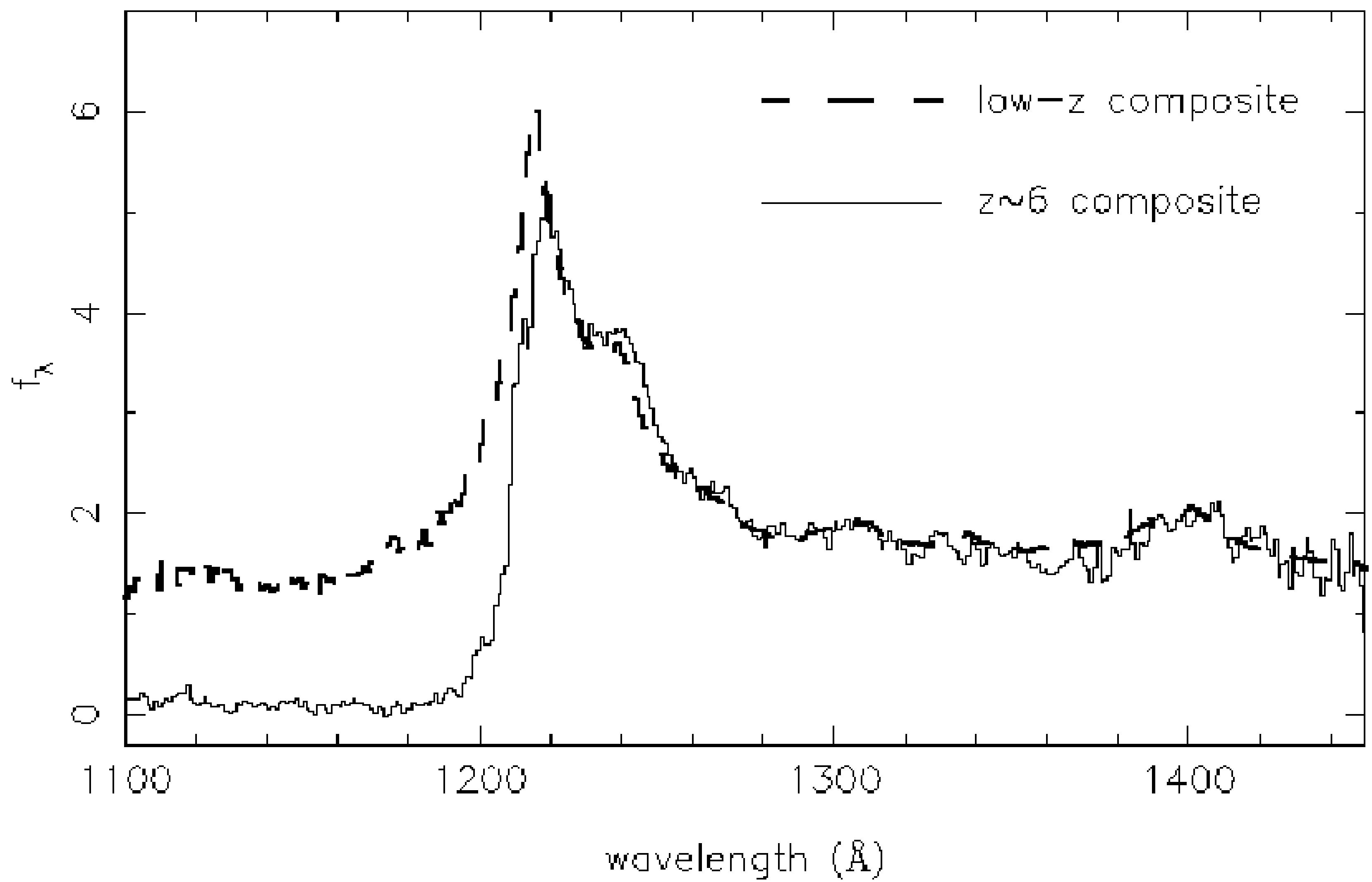
L dwarf
T dwarf
z>5.7 Quasar
5.7
6.0
5.5
16
17
18
19
20
z
0
2
4
i−z



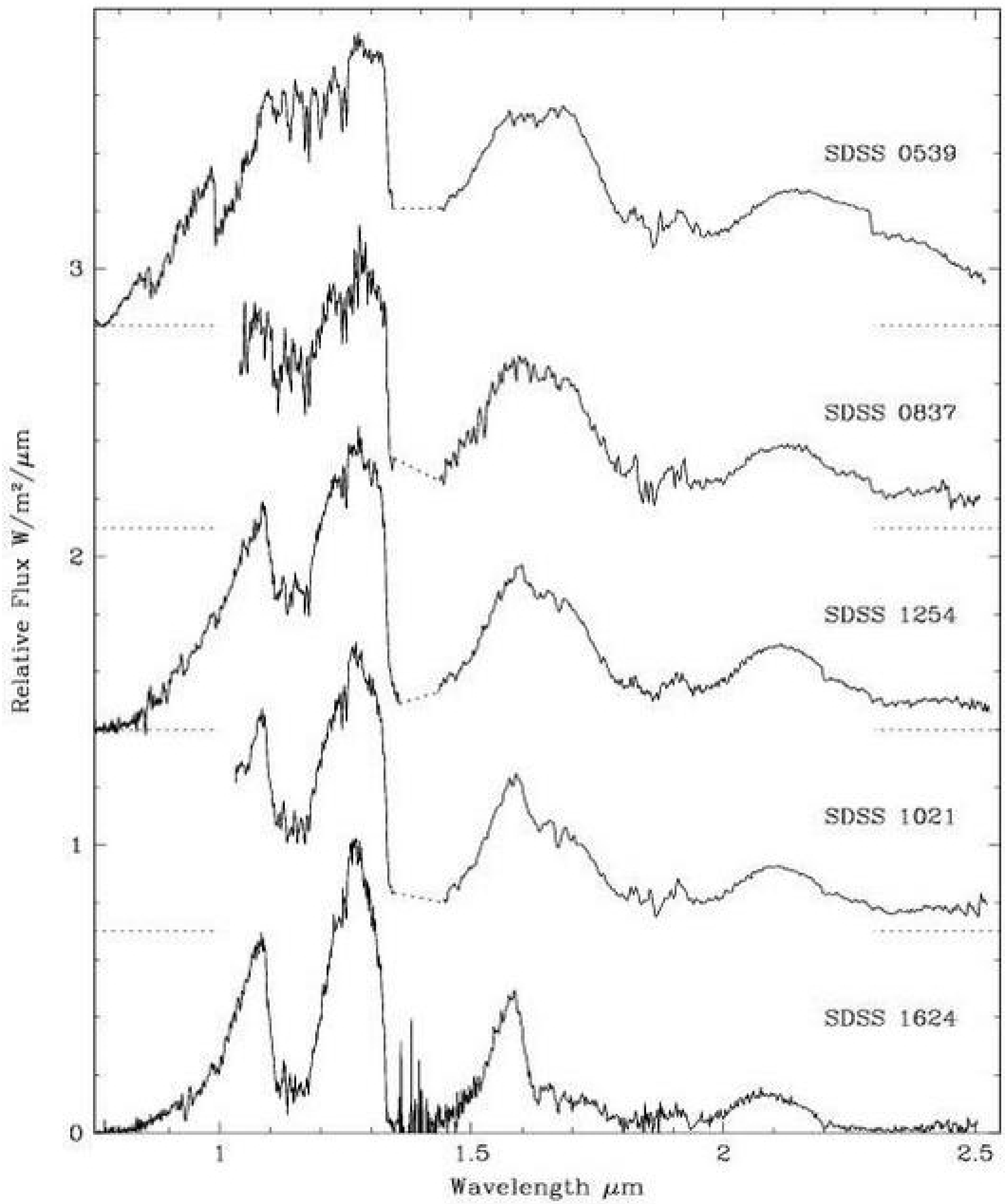
z=6.40
z=6.28
z=6.20
z=6.05
z=5.99
z=5.82
z=5.74
f_λ (10^{-17} erg s^{-1} cm^{-2} Å^{-1})
wavelength (Å)
5500
6000
6500
7000
7500
8000
8500
9000
9500



000239.39+255031.8 z=5.80
Lyα
NV
OI
Lyβ+OIV
000552.34−000655.8 z=5.85
z=5.93
160254.18+422822.9 z=6.07
162331.81+311200.5 z=6.22
6500
7000
7500
8000
8500
9000
9500
wavelength (Å)



low−z composite
z~6 composite
0
2
4
6
f$_\lambda$
1100
1200
1300
1400
wavelength (Å)



SDSS 0539
SDSS 0837
SDSS 1254
SDSS 1021
SDSS 1624
Relative Flux W/m²/μm
Wavelength μm
0
1
2
3
1
1.5
2
2.5

SDSS POST-2005 POSSIBILITIES

Desideratum: Find a way to finish the northern survey. If possible, connect this with new science or new areas of the sky concentrating in the fall.

2005-2008:

1. LEGACY: (filling the gap)

- ***We should be finished or nearly finished with the imaging in the gap by 2005.***
- ***It will take about two years to finish the spectroscopy after 2005.***

Justification:

- ***Image the NGP region: Legacy and mission support***
- ***Create a sample area with much improved window function for P(k), contiguous area for other statistics***
- ***Calibration improvements to yield ~1% photometry locally and globally***

ACCURACY OF UEBERCALIBRATION AS MEASURED FROM BLUE TIP

before ubercalib, g-r bluetip color is:

Mean: 0.221442 +/-0.0367982 5-sig clipped stdev: 0.0289913

after:

Mean: 0.237774 +/-0.0259161 5-sig clipped stdev: 0.0190995

These include real variation from stellar population variation. DF estimates .01-.015 after correction.

r-i

before uebercalibration:

Mean: 0.0654849 +/- 0.0204347 5-sig clipped stdev: 0.0199372

After:

Mean: 0.0733310 +/- 0.0109497 5-sig clipped stdev: 0.0106448

RMS of r-i measurements on few degree scales is .007 mag, so .005 mag per band.

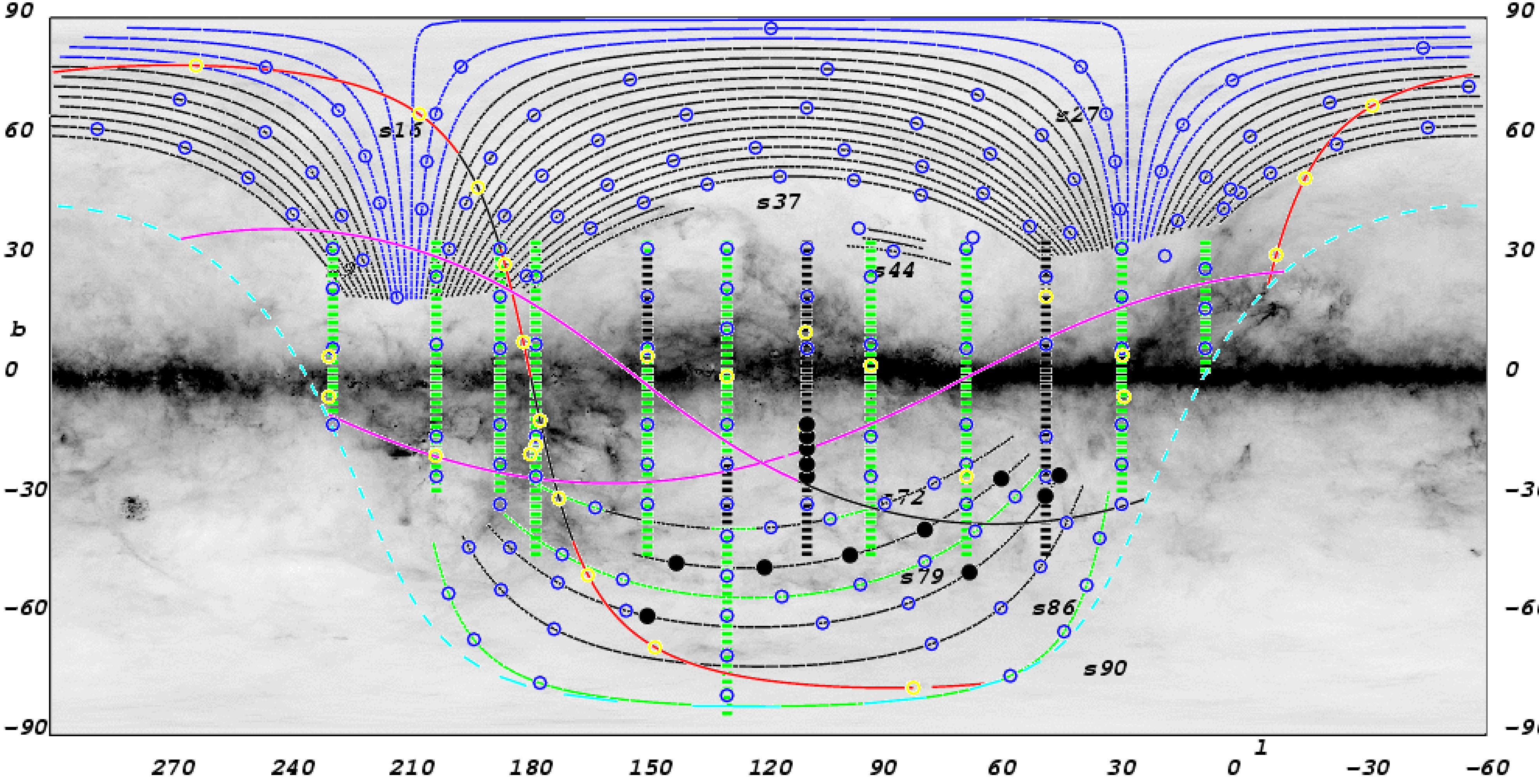
2. SEGUE: New Science

Aim to understand the structure, history, and composition of the old disk, thick disk, and halo of the galaxy, and incidentally to enable a large amount of low-latitude science.

New imaging beginning in the fall of 2004 at lower latitudes. Stripes at essentially constant longitude overlapping northern and southern SDSS regions

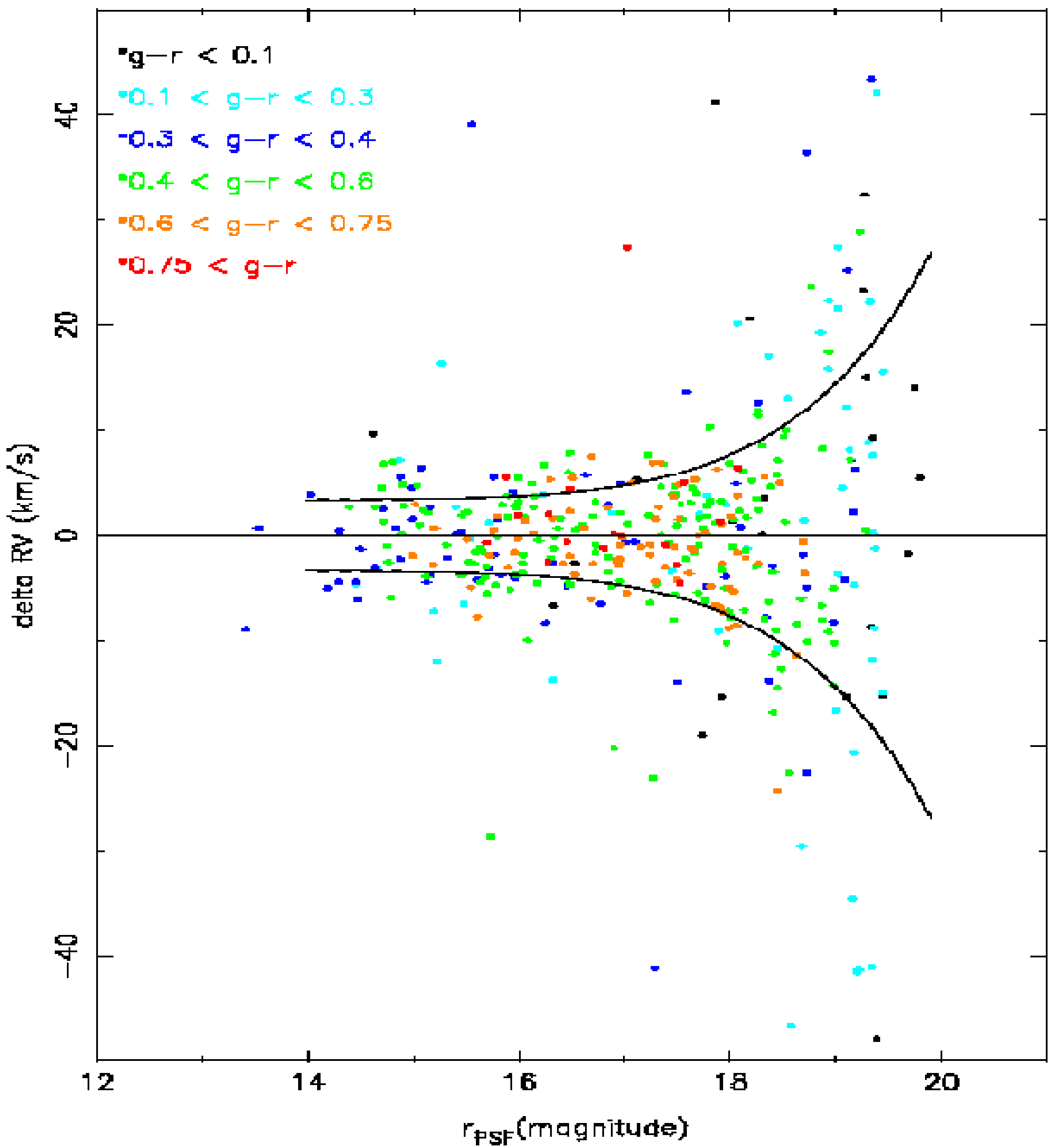
New spectroscopy of stellar targets for radial velocities, chemistry, and other stellar parameters in selected fields sparsely sampling the whole sky available from APO

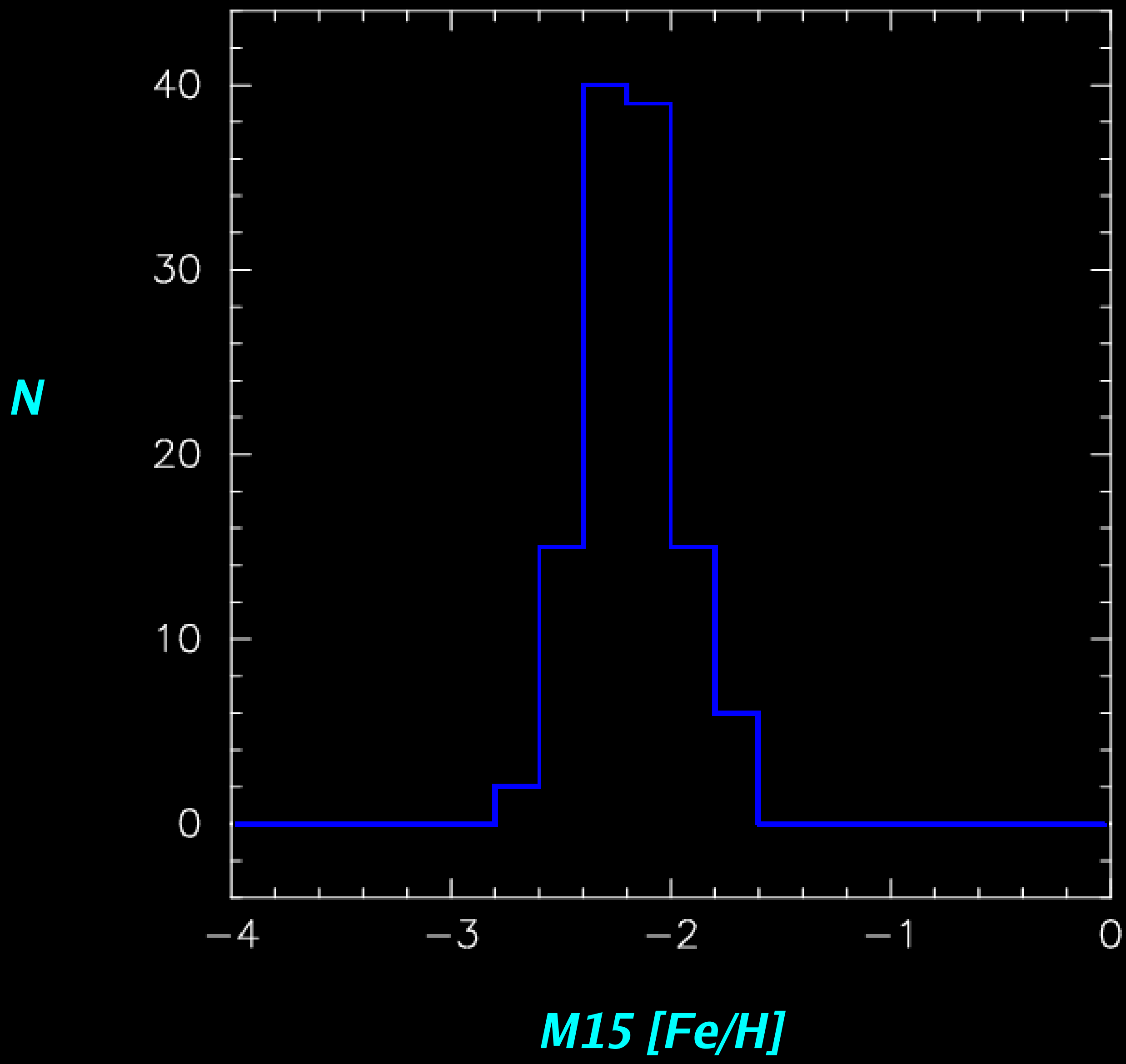
Calibration spectroscopy in galactic clusters



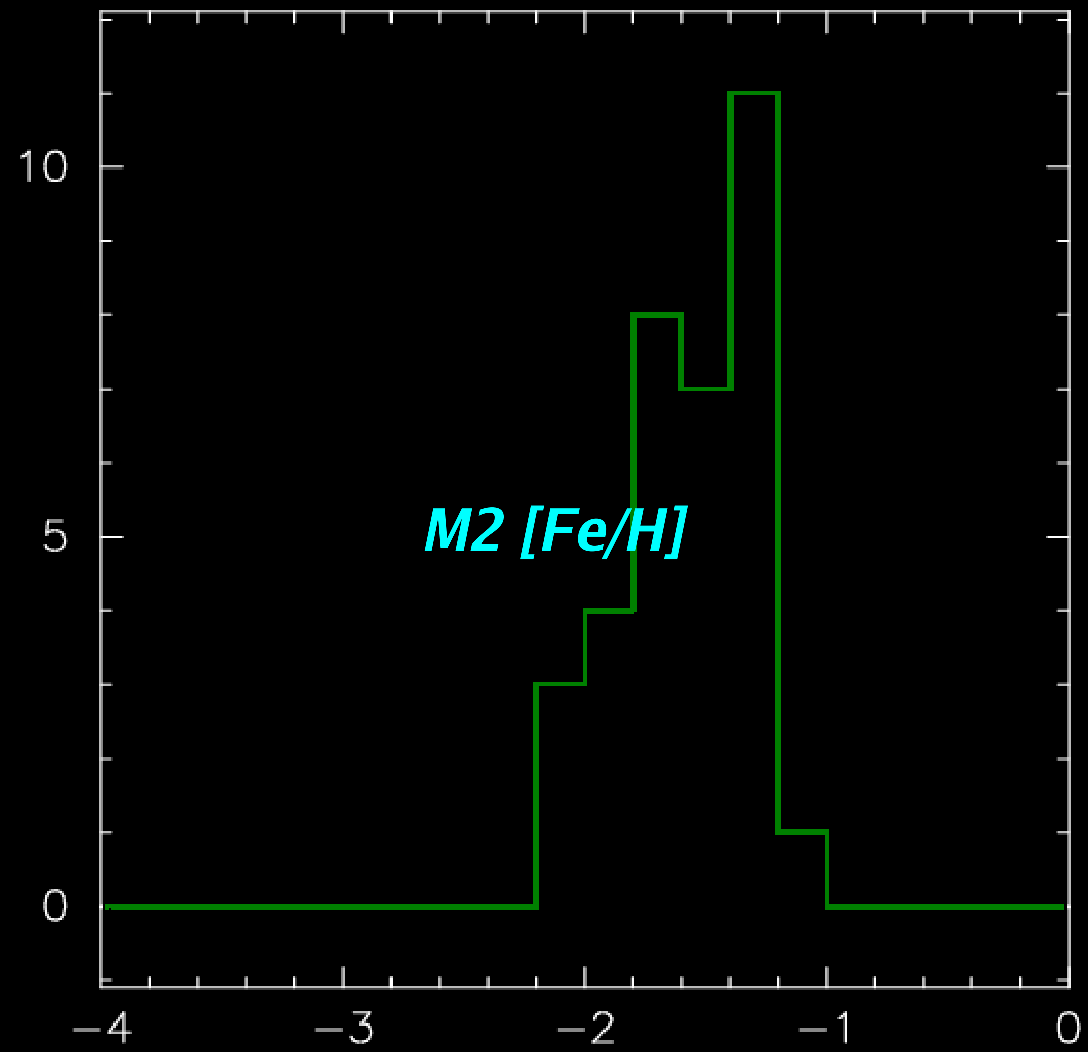
90
60
30
0
−30
−60
−90
b
s16
s27
s37
s44
s72
s79
s86
s90
270
240
210
180
150
120
90
60
30
0
−30
−60
l

Plate 1664 independent plugging RV test

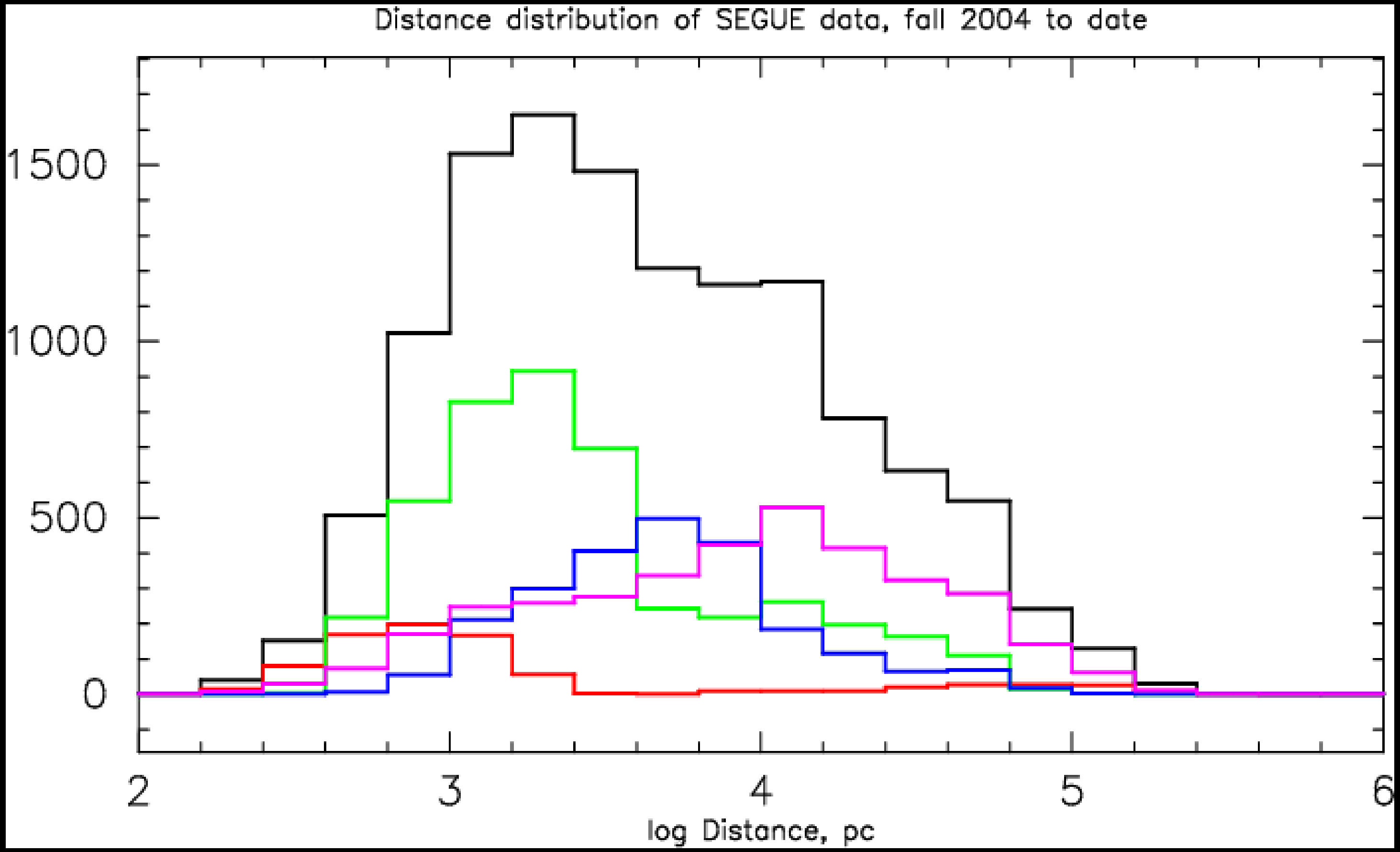


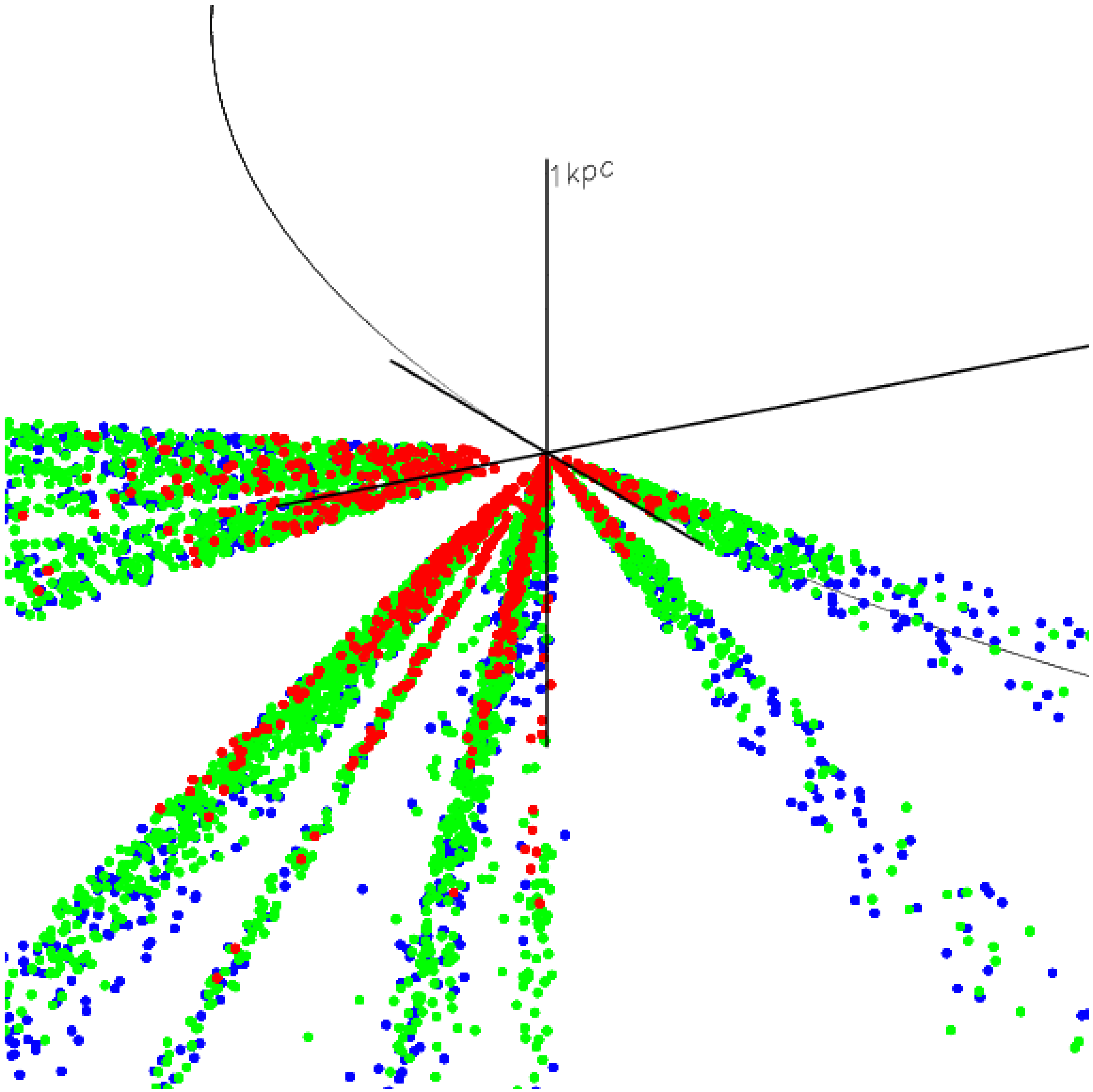


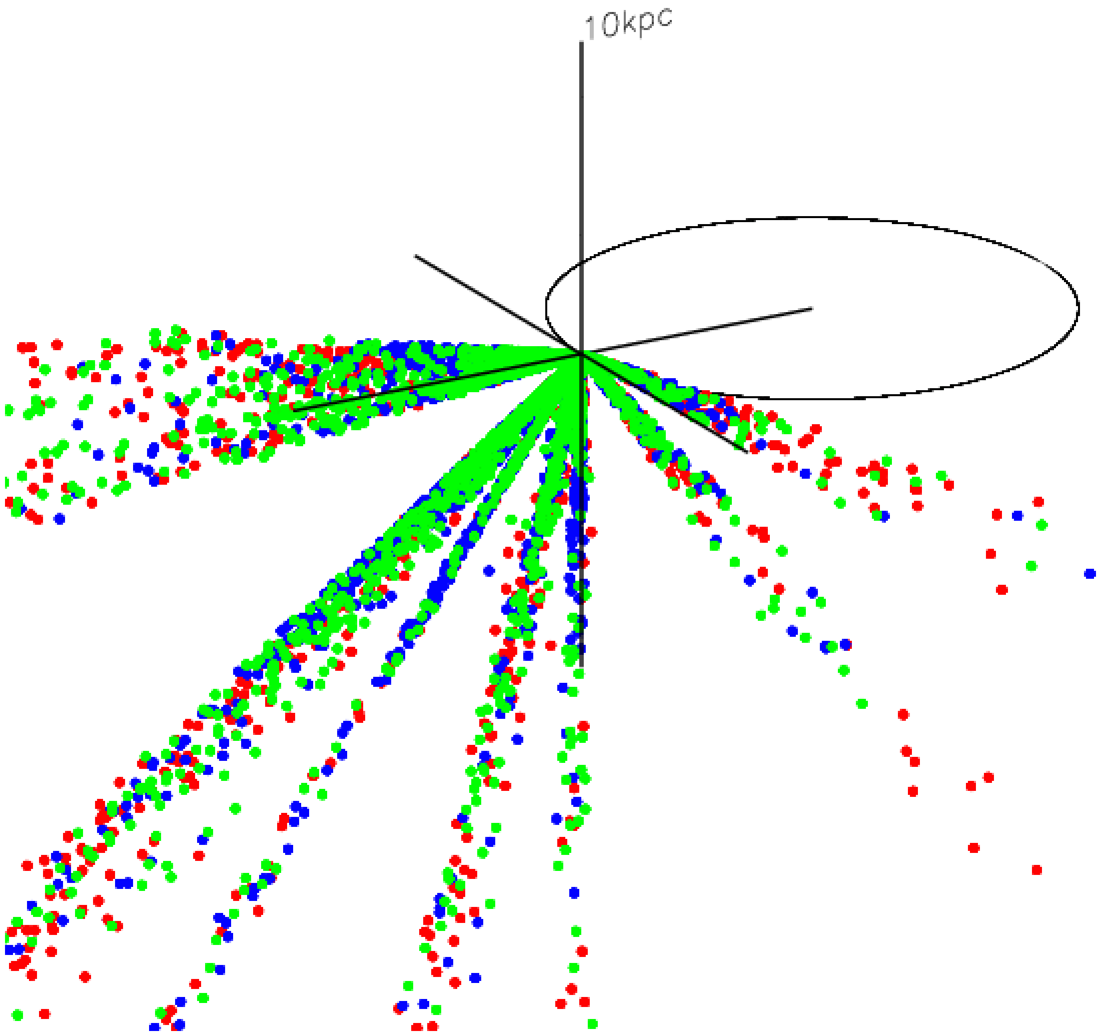
N
40
30
20
10
0
−4
−3
−2
−1
0
M15 [Fe/H]

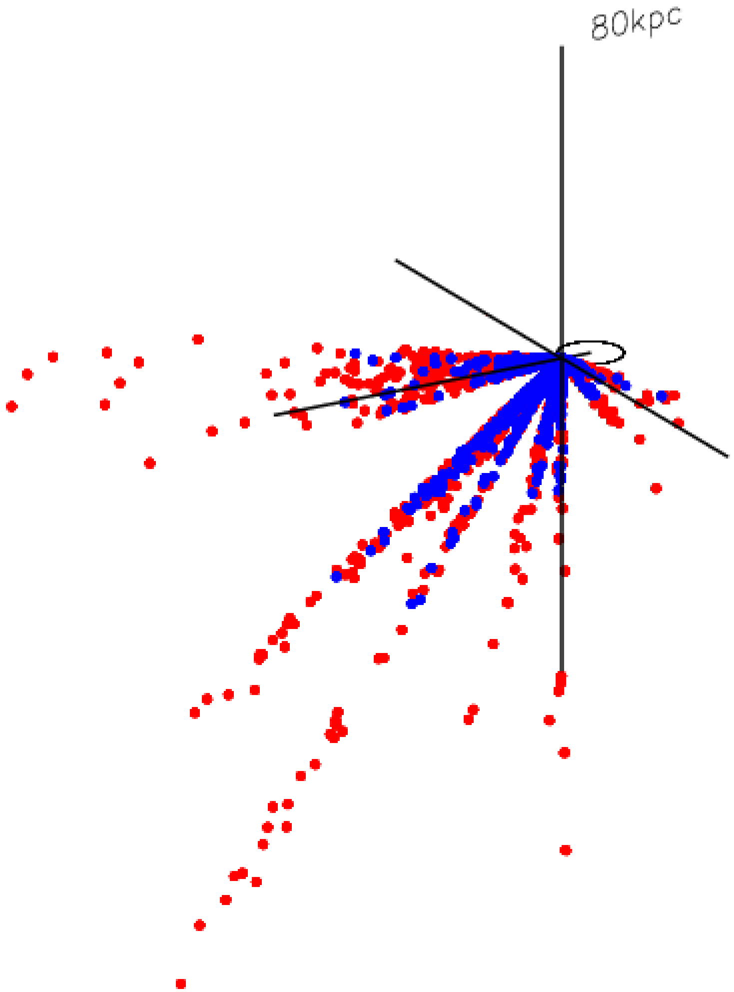


10
5
0
−4
−3
−2
−1
0
M2 [Fe/H]


Distance distribution of SEGUE data, fall 2004 to date
1500
1000
500
0
2
3
4
5
6
log Distance, pc


1 kpc


10kpc


80kpc

3. Type I Supernovae

Two fall seasons, imaging under essentially all conditions on the equatorial stripe

AIM: Obtain 150-200 high-quality SN Ia light curves for $0.05<z<0.4$, in the epoch in which dark energy actually dominates the expansion

Enables very large amount of non-SN time domain science

We have successfully approached the Sloan Foundation and a number of new (and old) partners and have submitted a proposal to the NSF for funding from the fall of 2005 through the spring of 2008 for these three programs. With weather which is the average of the period we have been working we can finish all three, and they fit together well with the necessary sky coverage.