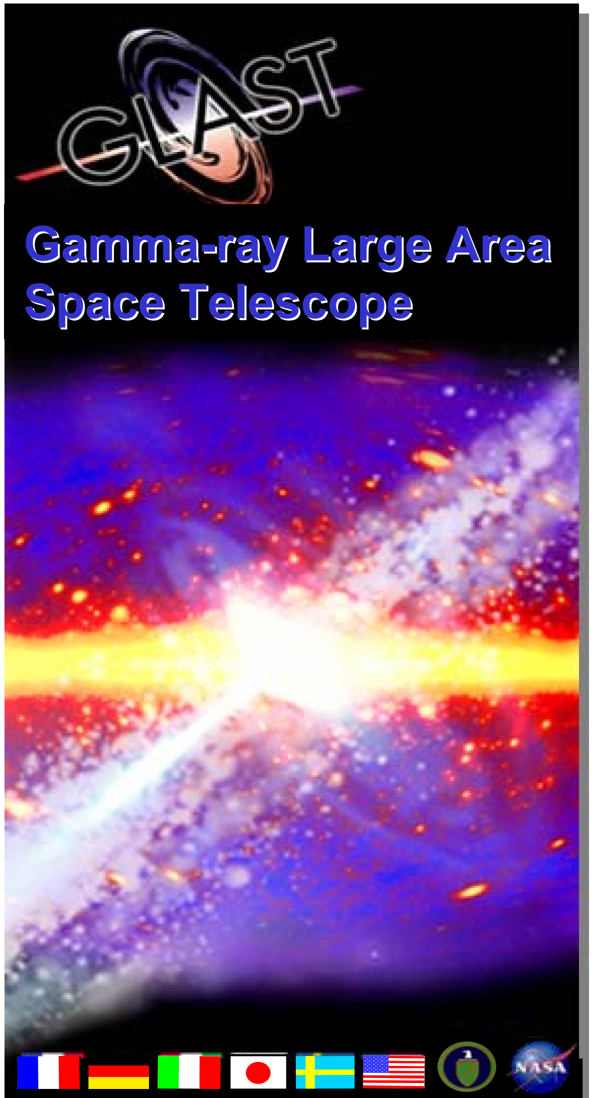

GLAST Large Area Telescope

GLAST Lunch: Some Results from X-ray and Optical AGN Surveys

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Introduction

- Objective
  - Review some AGN surveys at other wavelengths
    - optical
    - X-ray
  - Focus on observed redshift distributions
- Motivation
  - Understand the evolution of AGN at other energies, as basis for comparison with GLAST AGN data
  - Does AGN evolution differ at different energies? Distinct AGN populations at different energies?
  - How many high redshift AGNs will GLAST see, for EBL studies?
  - Prospects for x-identification of GLAST sources with other wavelength sources

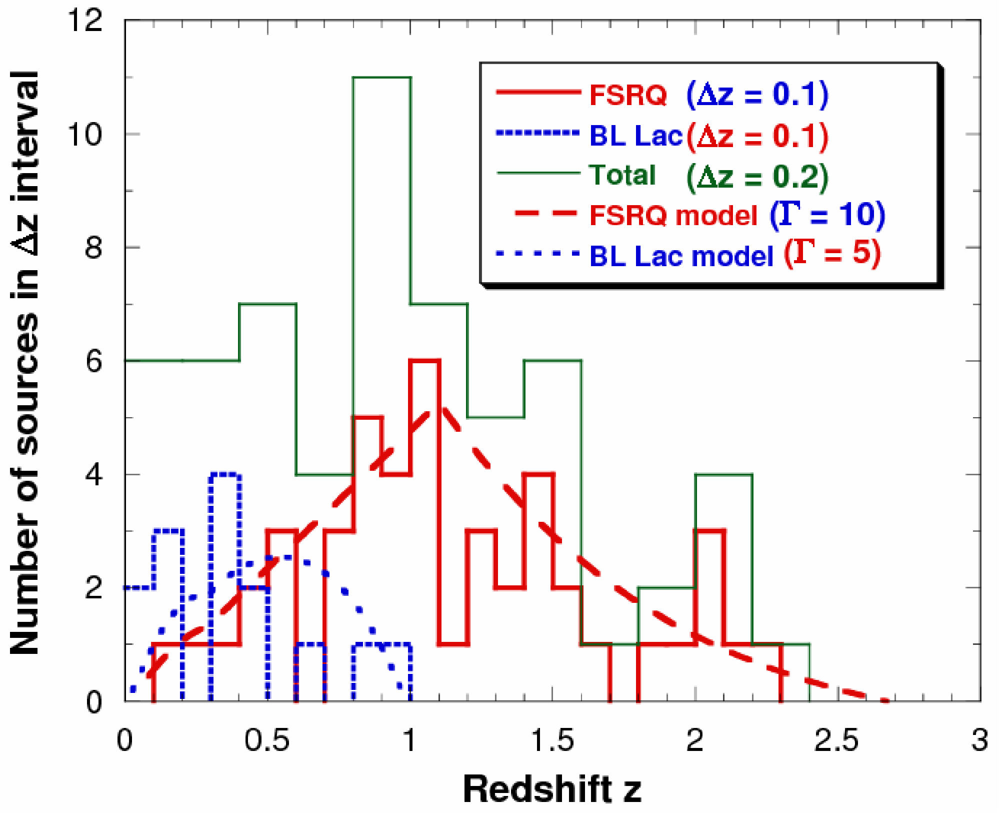
Overview

- EGRET AGNs and some predictions for GLAST
- Optical QSO survey results – SDSS, 2dF
- X-ray surveys of AGNs
  - Chandra Multi-wavelength Project
  - Hasinger et al. : ROSAT + XMM + Chandra
- Conclusions

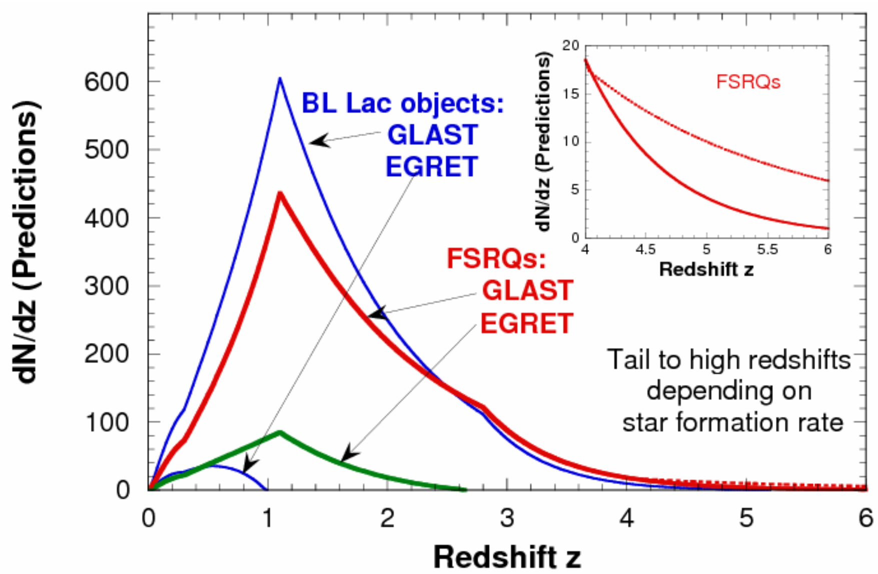
EGRET AGNs

Dermer and Davis (2000):

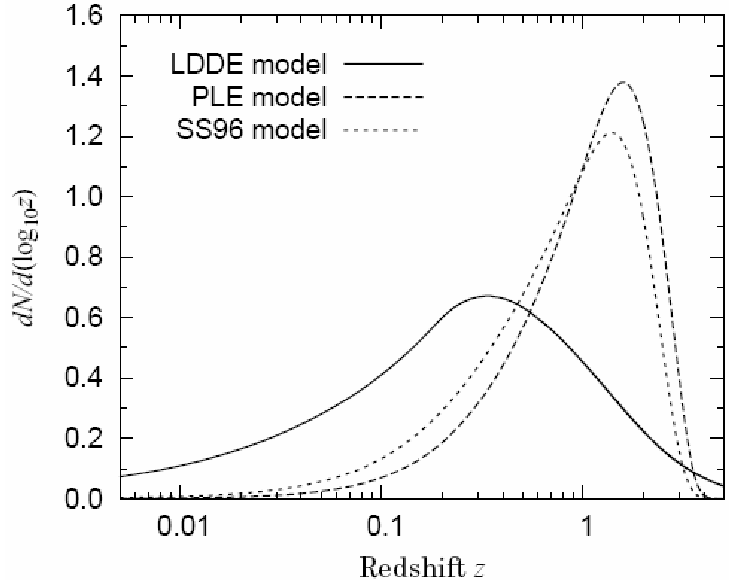
- ❑ **60 identified gamma-ray blazars from 3EG catalog**
  - – ***|b|* > 10°**
  - – **14 BLs**
  - – **46 FSRQs**



Predicted redshift distributions for GLAST



(Dermer & Davis 2000)



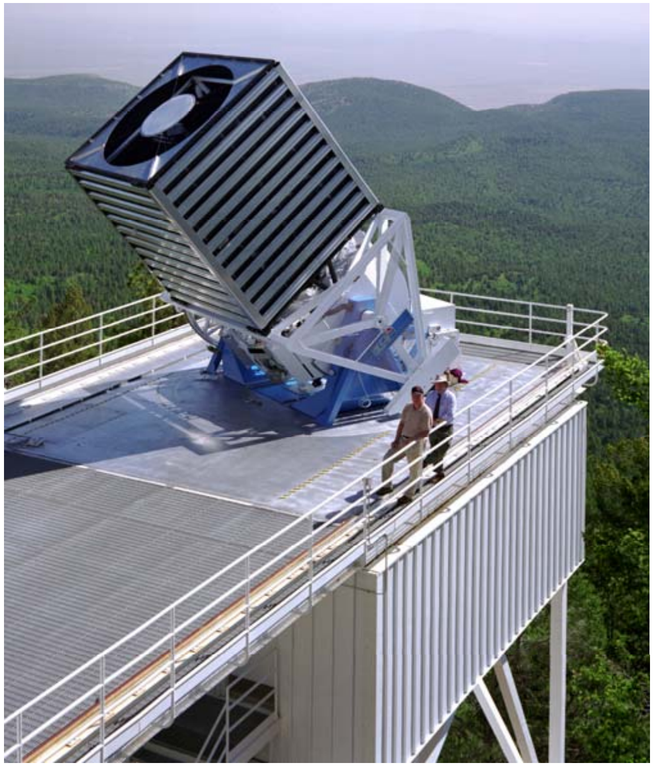
(Narumoto & Totani 2006)

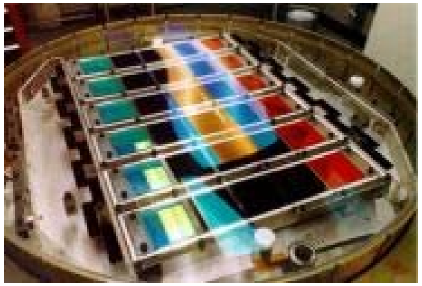
- Range of model predictions for AGN population detected by GLAST
- Predictions for GLAST depend on underlying AGN density evolution with redshift
- Candidate counterpart identifications and redshifts are key to checking predictions

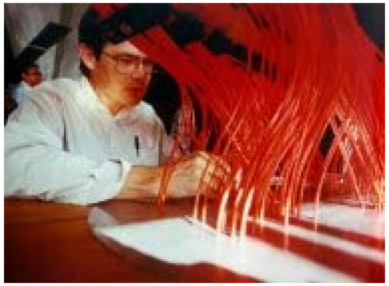
Optical: Sloan Digital Sky Survey

2.5m telescope at Apache Point, NM

- Imaging
  - 5 filter photometry
- Spectroscopy
  - 380 nm – 920 nm
  - Resolution: 1800
- SDSS-I observing completed in June 2005
  - Operated for 5 years
- SDSS-II continues to June 2008
  - Includes Sloan Legacy Survey which will fill in gaps in the survey regions from SDSS-I
    - Imaging of 7500 sq.deg.
    - Spectra of 860,000 galaxies
    - Spectra of 105,000 QSOs



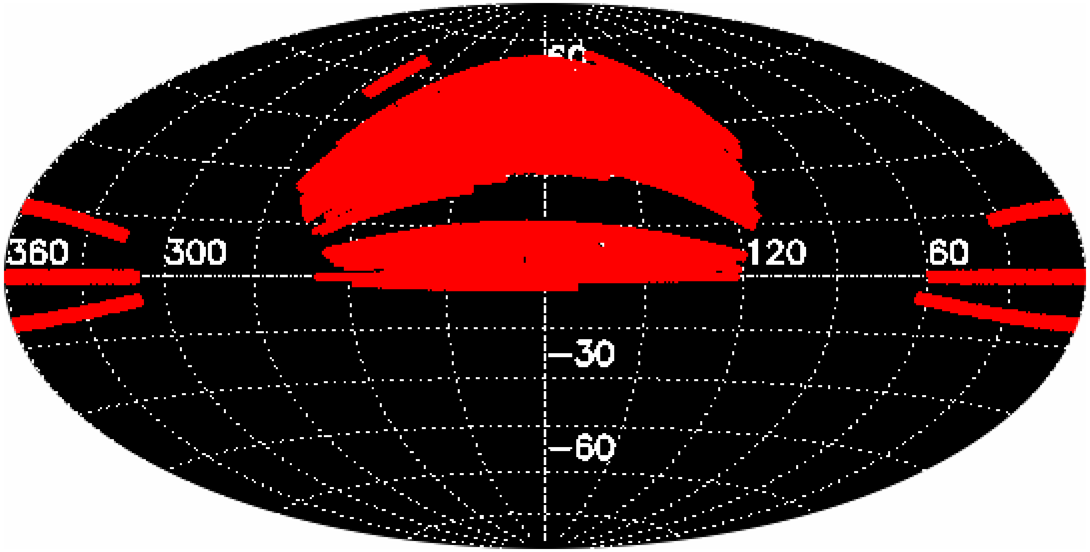




SDSS Data Release 4

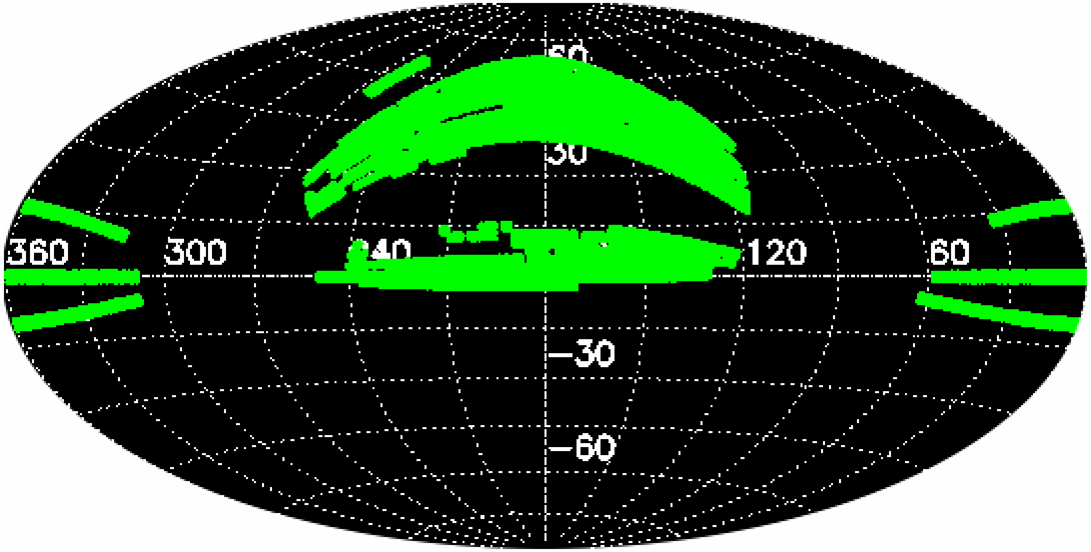
IMAGING

- Area Covered: 6670 sq. deg.
- Catalog: 180 million objects
- Magnitude limits (95% point source detection repeatability)
  - *u* 22.0
  - *g* 22.2
  - *r* 22.2
  - *i* 21.3
  - *z* 20.5
- Photometric calibration
  - *r* 2%
  - *u-g* 3%
  - *g-r* 2%
  - *r-i* 2%
  - *i-z* 3%



SPECTROSCOPY

- Area Covered: 4783 sq. deg.
- 849,920 spectra
  - 565,715 galaxies
  - 67,382 QSOs, $z < 2.3$
  - 9,101 QSOs, $z > 2.3$
  - QSO limit $i = 19.1$

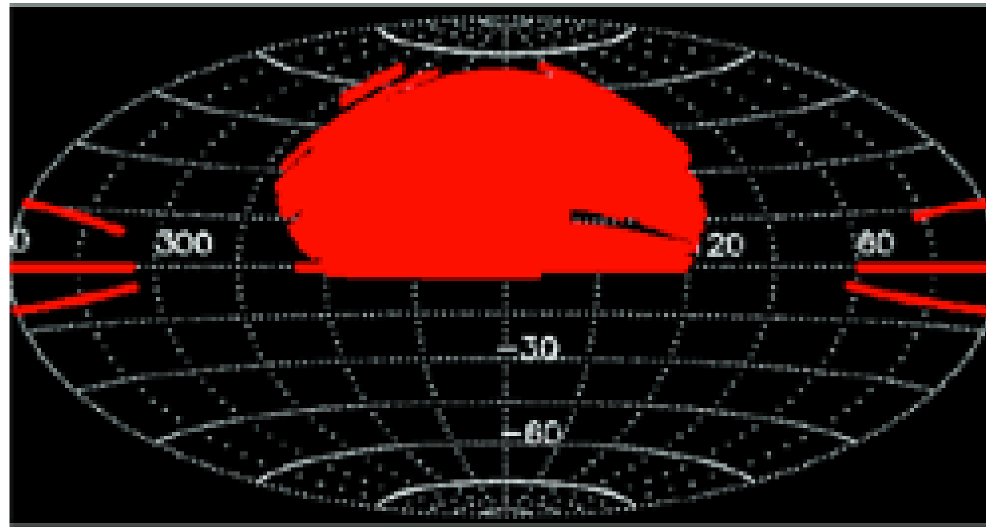


June 2006: SDSS Data Release 5

Final data release for SSDS-I

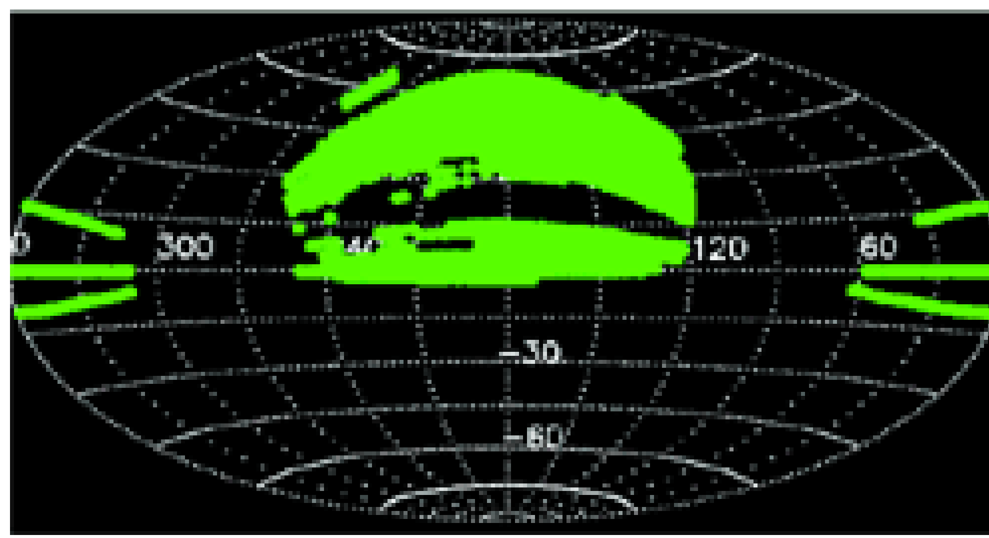
IMAGING

- **Area Covered: ~7000 sq. deg.**
- **Catalog: ~200 million objects**



SPECTROSCOPY

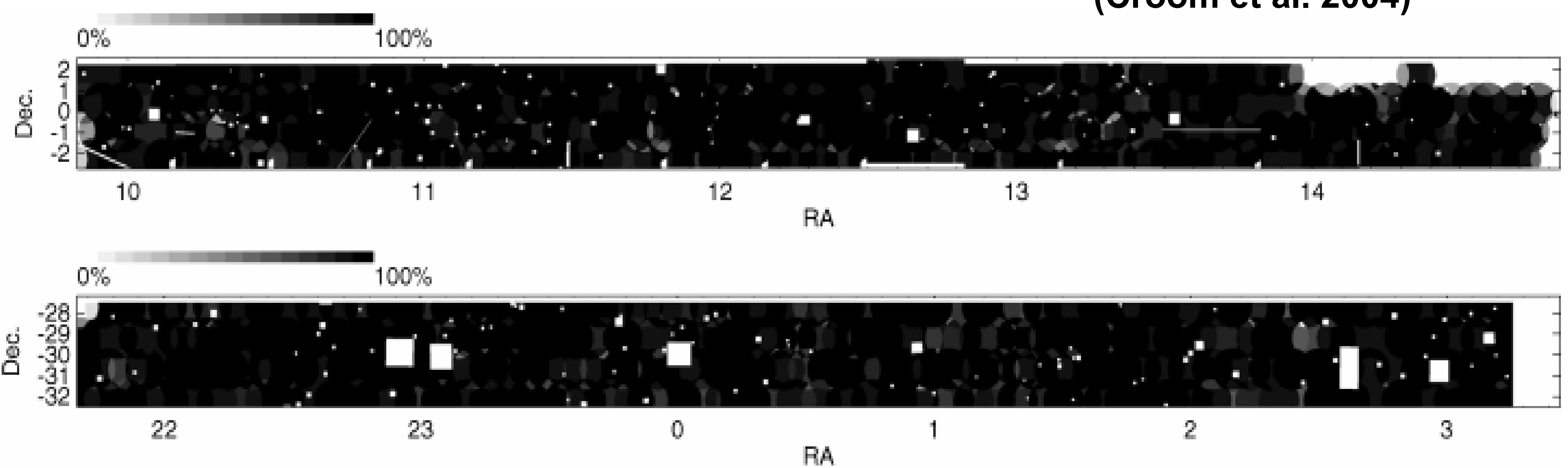
- **> 800,000 spectra**



Optical: 2dF Survey

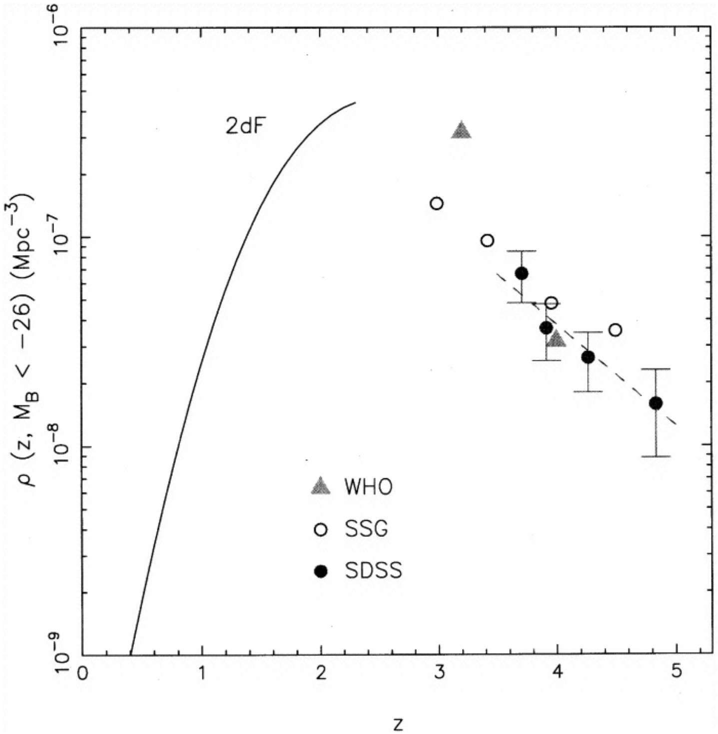
- QSO redshift survey using AAT with 2dF fibre spectrograph
  - 2 sky coverage strips: equatorial and south galactic pole
- Optical spectroscopy of 44576 objects
  - Optically selected
  - Magnitude range: $18.25 < b_J < 20.85$
  - 23338 QSOs (35 QSOs / sq. deg.)
  - 4558 compact NELGs
  - 12292 stars

(Croom et al. 2004)

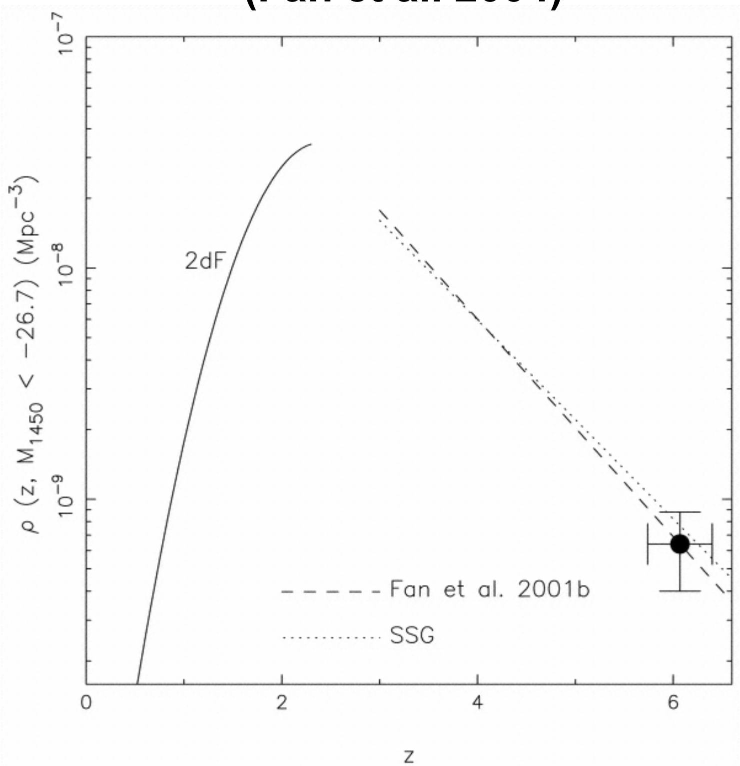


Optical QSO density evolution

(Fan et al. 2001)



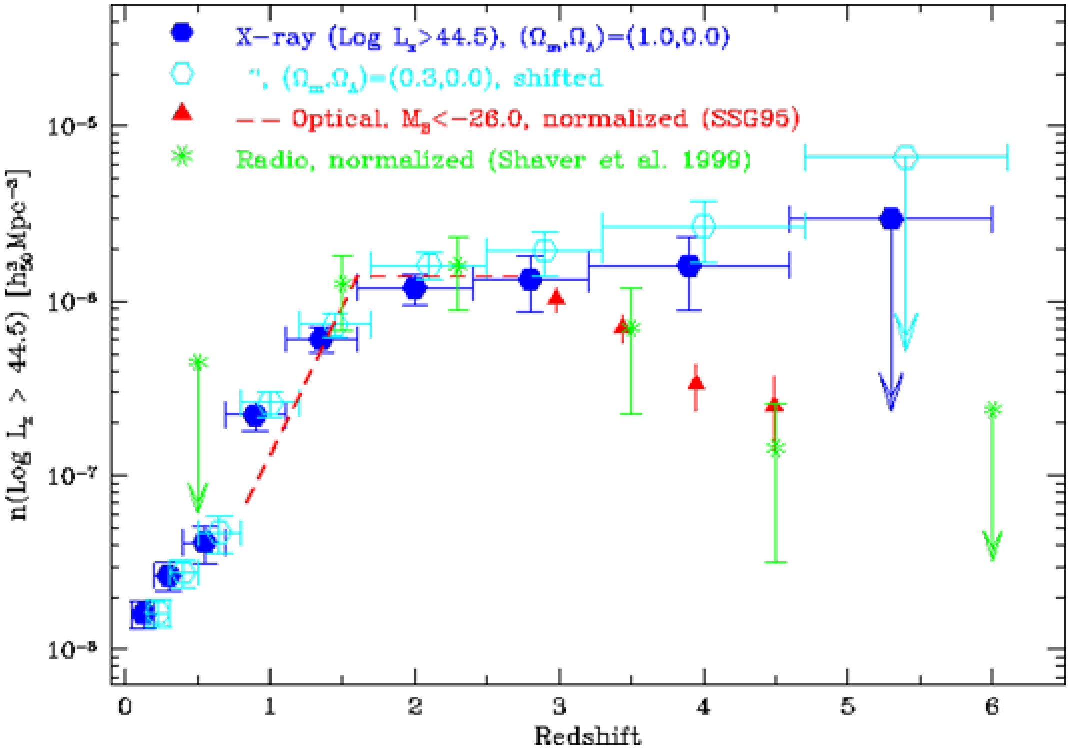
(Fan et al. 2004)



- Optically selected QSO density peaks at $z \sim 2 - 3$
- Fan et al. 2004 uses 12 QSOs at $5.7 < z < 6.4$

Early X-ray results from ROSAT

(Miyaji et al. 2000)



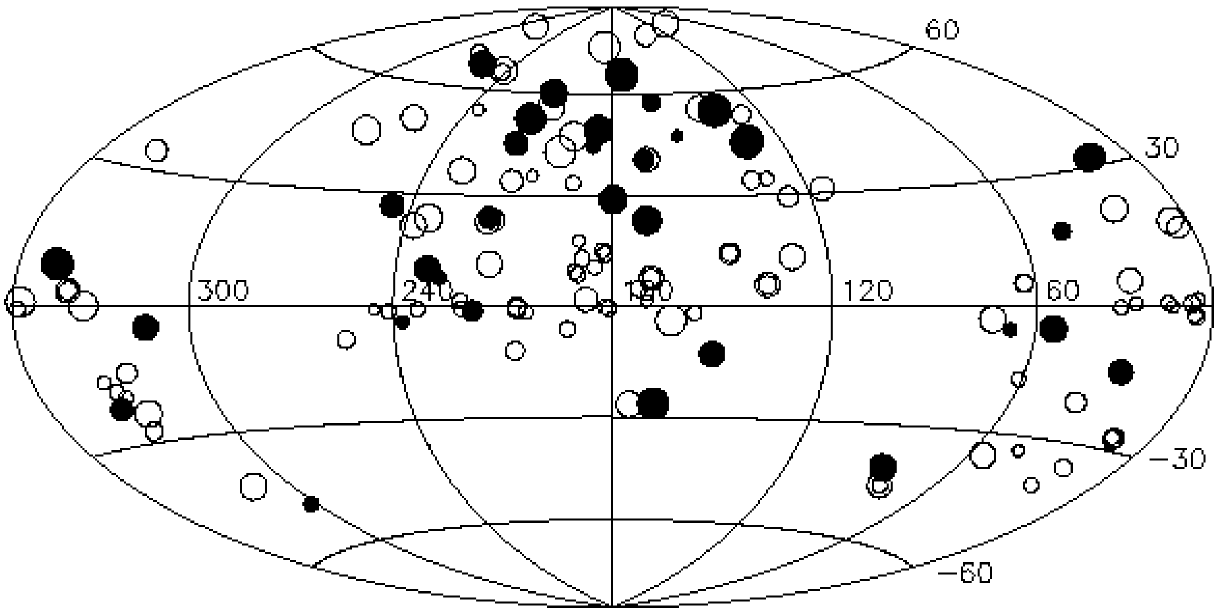
Survey[a]	S_{x14}^{lim} [erg s^{-1} cm^{-2}]	Area [deg^2]	No. of[b] AGNs
RBS	≈ 250	2.0×10^4	216
SA-N	≈ 13	685.	130
RIXOS	3.0	15.	205
NEP	1.0	0.21	13
UKD	0.5	0.16	29
RDS-Marano	0.5	0.20	30
RDS-LH	0.17–0.9	0.30	68

[a] Abbreviations – RBS: The *ROSAT* Bright Survey, SA-N: The Selected Area-North, RIXOS: The *ROSAT* International X-ray Optical Survey, NEP: The North Ecliptic Pole UKD: The UK Deep Survey, RDS-Marano: The *ROSAT* Deep Survey – Marano field, RDS-LH: The *ROSAT* Deep Survey – Lockman Hole. See text for references.
[b] Excluding AGNs with $z < 0.015$.

- Combination of several ROSAT surveys, 0.5 – 2 keV
- X-ray AGN did not show decline in density at z > 3
- Marginal statistics: 17 AGN at z > 2.2, log Lx > 44.5

X-ray AGN: Chandra Multi-wavelength Project

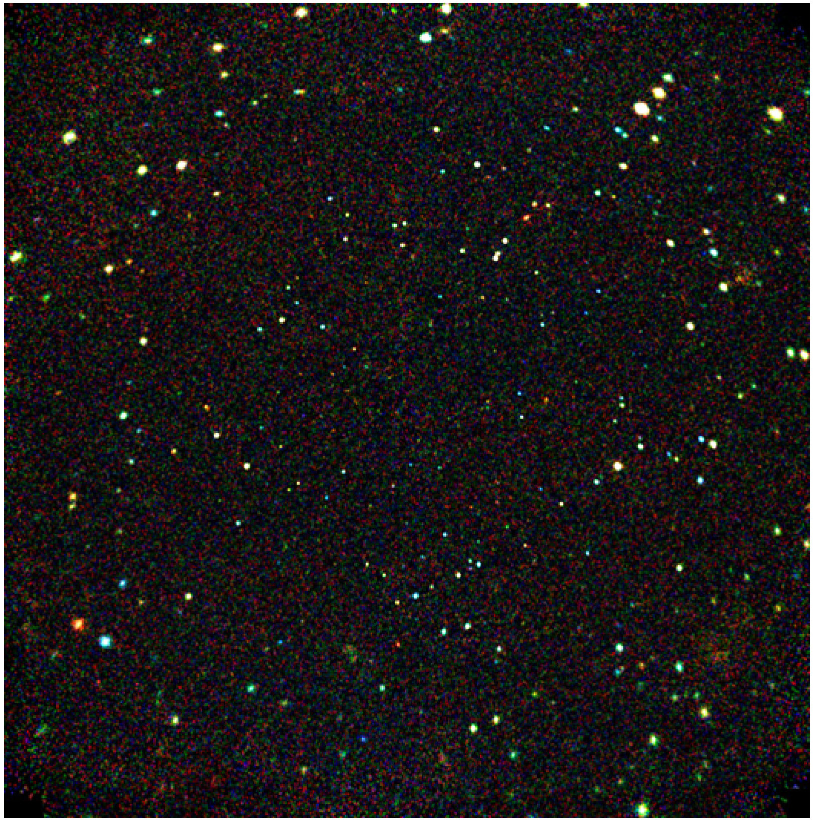
- Serendipitous source survey in Chandra observations
- 145 ACIS fields, 14 sq. deg.
- $|b| > 20°$
- X-ray exposures: 2 – 200 ksec
- Source ID via optical imaging
  - SDSS *g’ r’ i’* filters, on 1m - 4m telescopes
- optical spectroscopy of bright sub-sample
- 65% BLAGN
- 14% NELG
- 8% Stars
- 1% Clusters



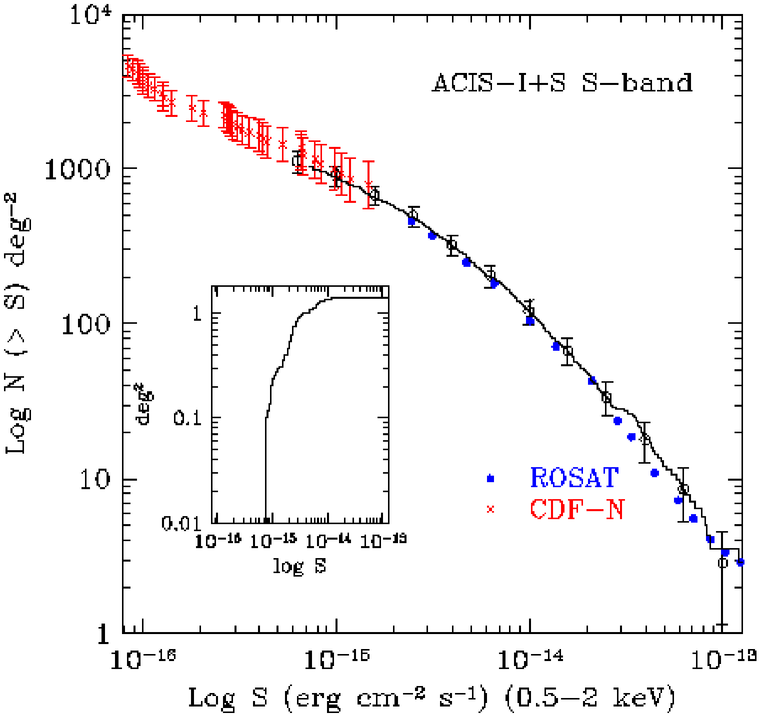
Chandra Deep Fields

- North and South fields, matching Hubble DFs

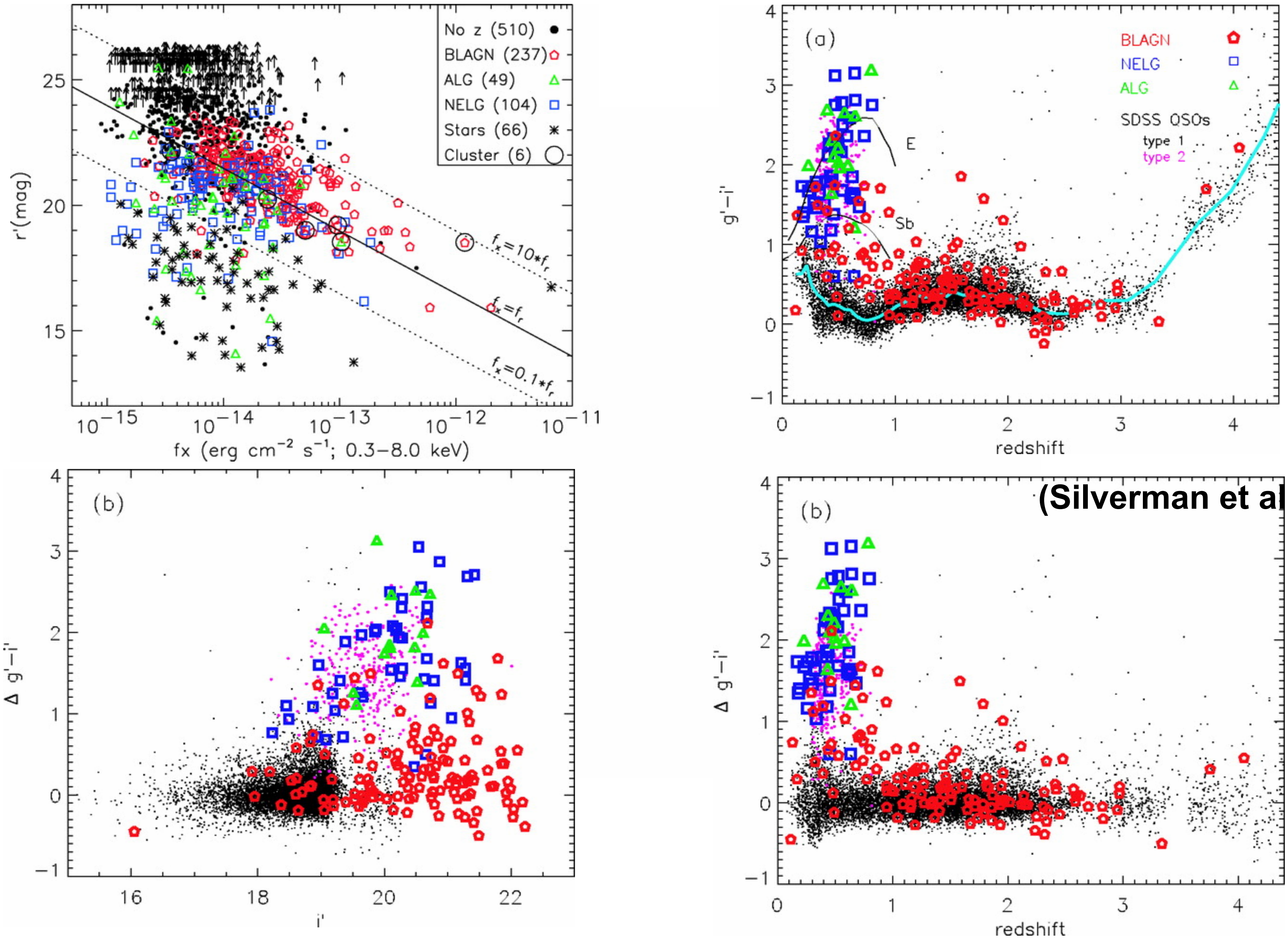
(Giacconi et al. 2001) CDF-S, 1MS



(Kim et al. 2004)



CHAMP Object Classification

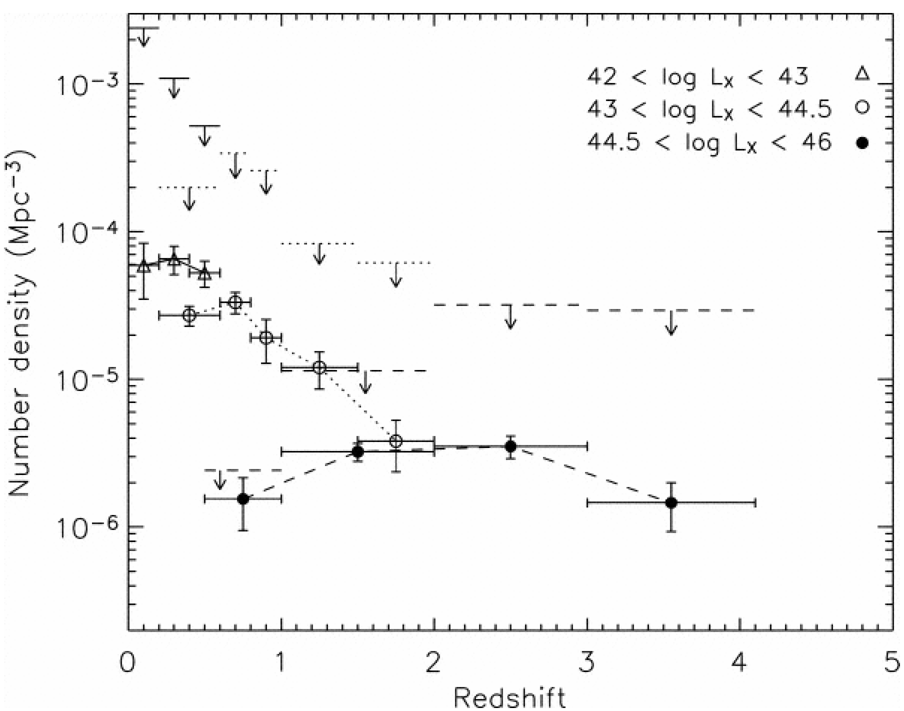


(Silverman et al. 2005a)

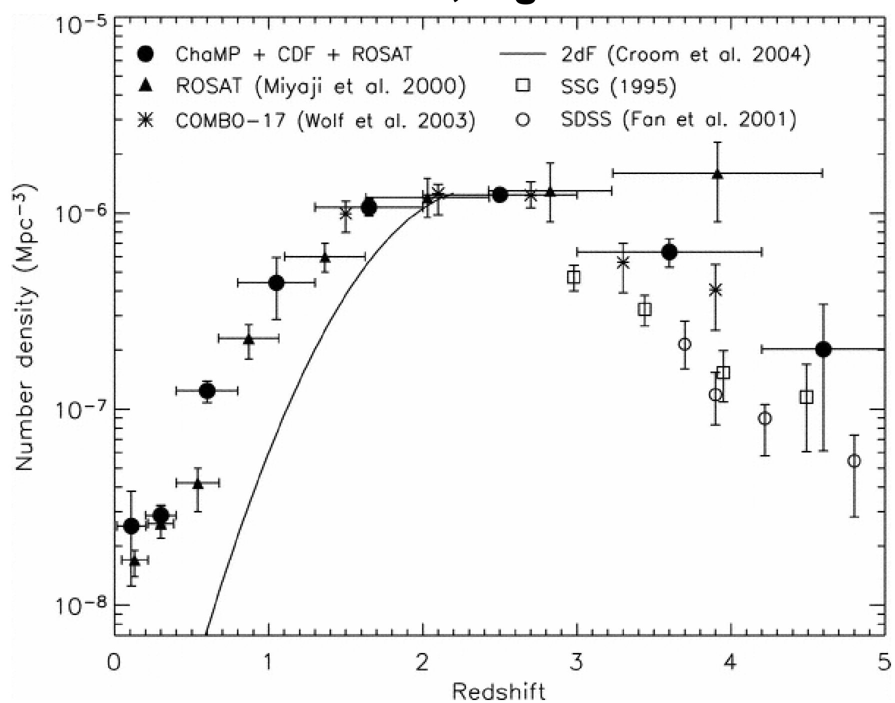
CHAMP: X-ray AGN density evolution

- Two passbands
  - 0.3 – 8.0 keV: data from CHAMP (23 fields), CDF-N and CDF-S fields
  - 0.5 – 2 keV: data from CHAMP + ROSAT
- 217 AGN in 0.5 – 2 keV sample with log Lx > 44.5
- 368 AGN in 0.3 – 8 keV sample, incl. 14 BLAGN at *z* > 3
- Peak in X-ray volume density for luminous AGNs at *z* ~ 2 – 3
  - Similar to behaviour of optically selected QSO surveys

0.3 – 8 keV



0.5 - 2 keV, log Lx > 44.5

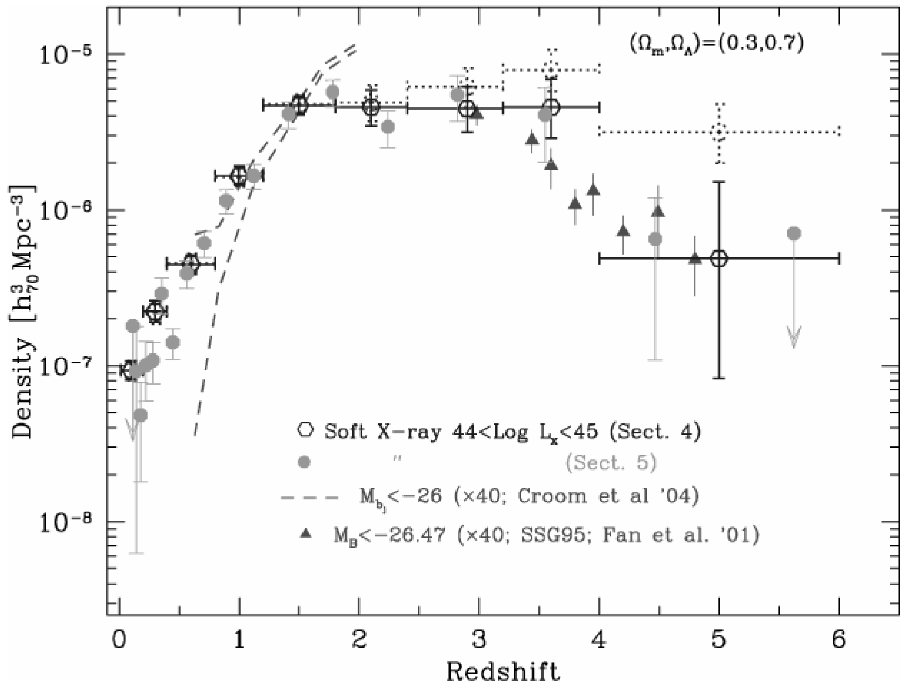


(Silverman et al. 2005)

ROSAT + XMM + Chandra

(Hasinger et al. 2005)

Survey[a]	Solid Angle [deg^2]	$S_{X14,lim}$ [cgs]	N_{tot}	N_{AGN-1}[b]	N^{c}_{unid}
RBS	20391	$\approx$ 250	901	203	0
SA–N	684.0–36.0	47.4–13.0	380	134	5
NEPS	80.8–70.5	12.4–10.1	252	101	1
RIXOS	19.5–15.0	10.2–3.0	340	194	14
RMS	0.74–0.32	1.0–0.5	124	84	7
RDS/XMM	0.126–0.087	0.38–0.13	81	48	8
CDF–S	0.087–0.023	0.022–0.0053	293	113	1
CDF–N	0.048–0.0064	0.030–0.0046	195	67	21
Total			2566	944	57



- Unabsorbed X-ray selected AGN
- Combined survey, 0.5 – 2 keV
  - ROSAT surveys
  - XMM observations of Lockman Hole
  - Chandra Deep Fields
- Shows (log Lx < 45) AGN density decrease at z > 3

ROSAT + XMM + Chandra (cont.)

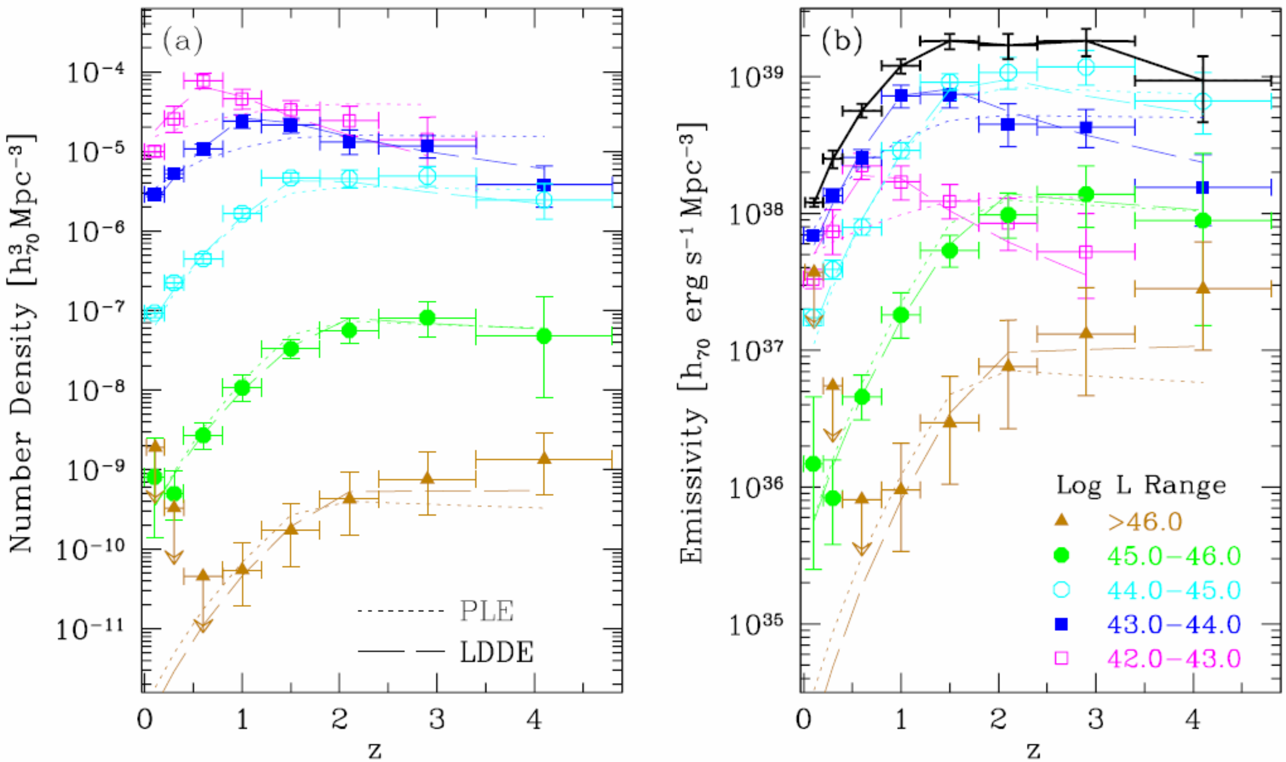


Fig. 5. (a) The space density of AGNs as a function of redshift in different luminosity classes and the sum over all luminosities with log $L_x \geq 42$. Densities from the PLE and LDDE models (Sect. 4.4) are overplotted with solid lines. (b) The same as (a), except that the soft X-ray emissivities are plotted instead of number densities. The uppermost curve (black) shows the sum of emissivities in all luminosity classes plotted.

- **Luminosity-dependent density evolution is preferred over pure density evolution**
- **Low luminosity AGNs have peak density at *z* < 1**

Conclusion

- Recent X-ray AGN surveys show general agreement with optical survey results on density evolution of AGNs with redshift
  - Evidence for luminosity-dependent density evolution in X-ray AGN: less luminous AGN density peaks at lower z
- Prospects for comparison study with GLAST all-sky AGN survey
  - Need observationally cheap methods for counterpart identification & classification
    - Imaging is easier than spectroscopy
    - Prospects for optical imaging-based candidate selection
      - SDSS better than USNO-B
    - Sloan-filter photo-redshifts?

SDSS Photometric Redshifts

- observationally “cheap” method of searching for high redshift QSOs
  - Imaging with SDSS filters available even on small telescopes, e.g. FLWO 1.2m

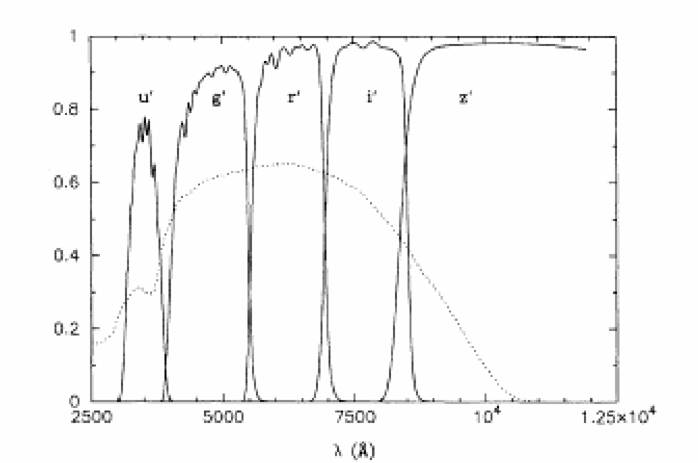
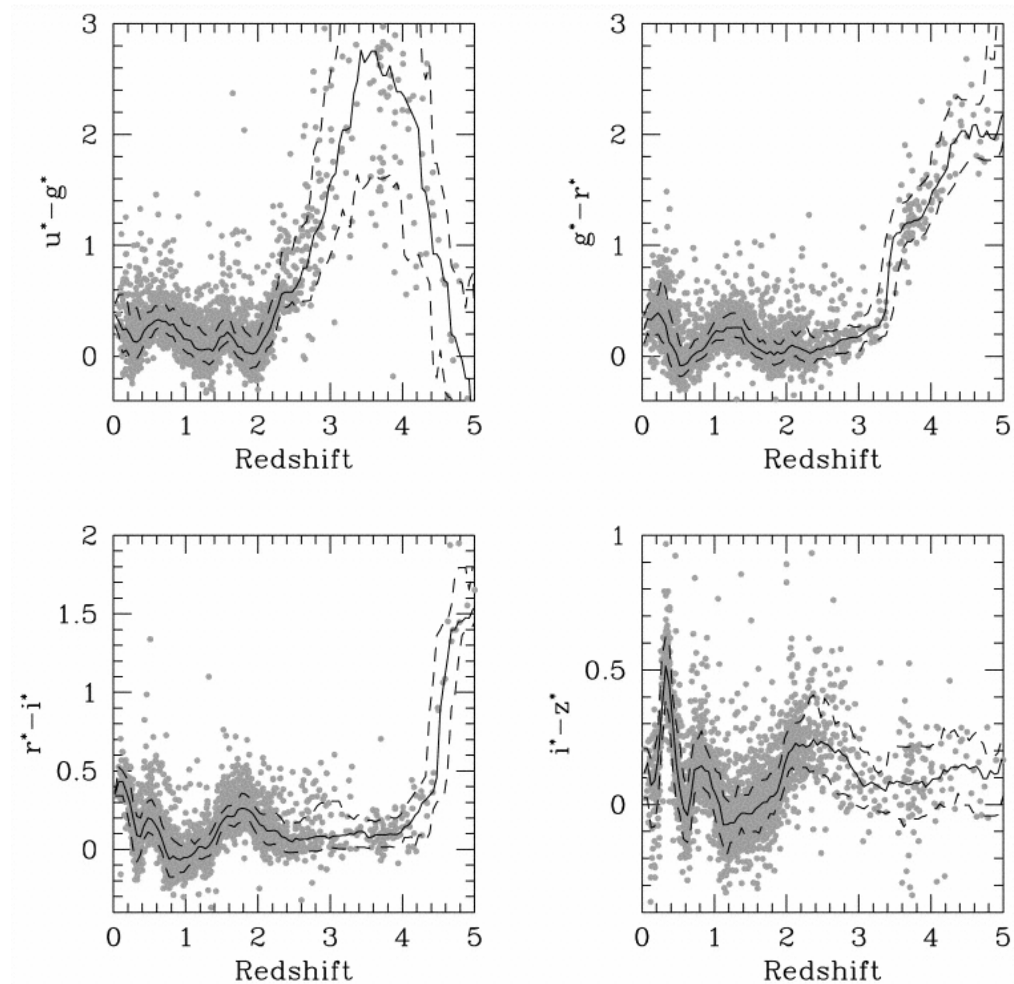


FIG. 1. Transmission of the $u'g'r'i'z'$ filters. Redleaks shortward of 11 000 Å are not shown. The dotted curve is the quantum efficiency of a thinned, UV-coated SITe CCD; this is the detector that is used in the definition of the SDSS system.

- Strong colour evolution for z > 3 QSOs as Lyα break moves through filter passbands



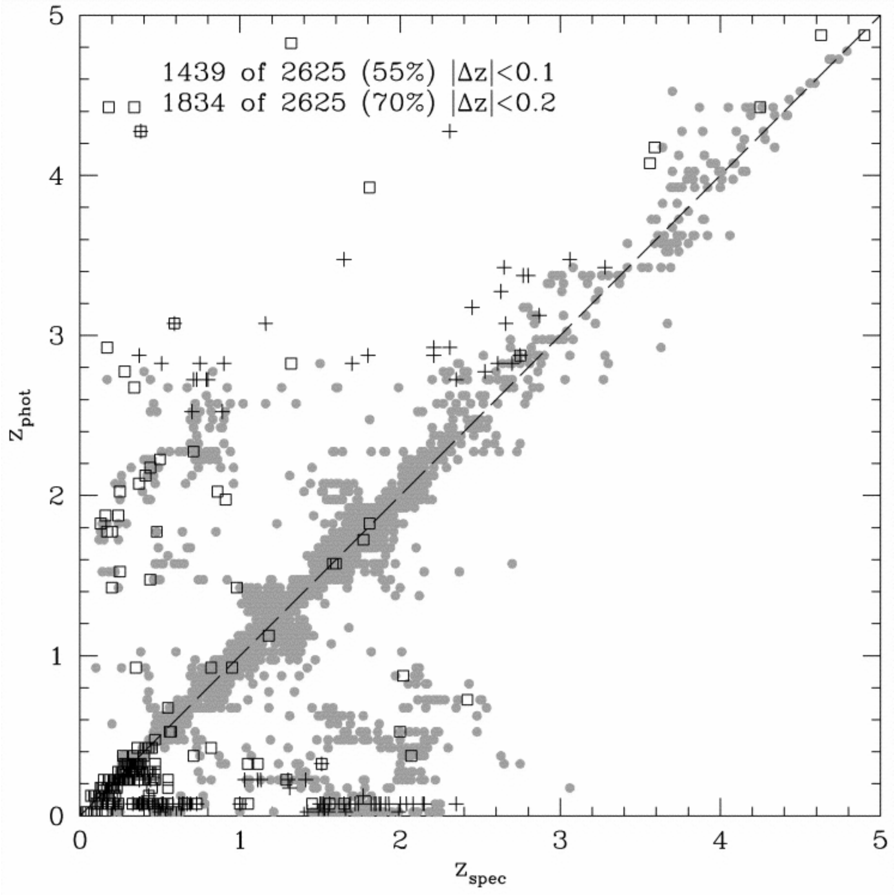
(Richards et al. 2001)

SDSS photometric redshifts (cont.)

$$\chi^2_z = \frac{[(u'-g') - (u'-g')_z]^2}{\sigma^2_{u'-g'} + \sigma^2_{(u'-g')_z}} + C_{gr} + C_{ri} + C_{iz}$$

- **Photo-z estimated by simultaneous 4 colour fit**
- **Final photo-z catalog not yet released for SDSS**
- **What is feasibility for FSRQ blazars?**

(Richards et al. 2001)



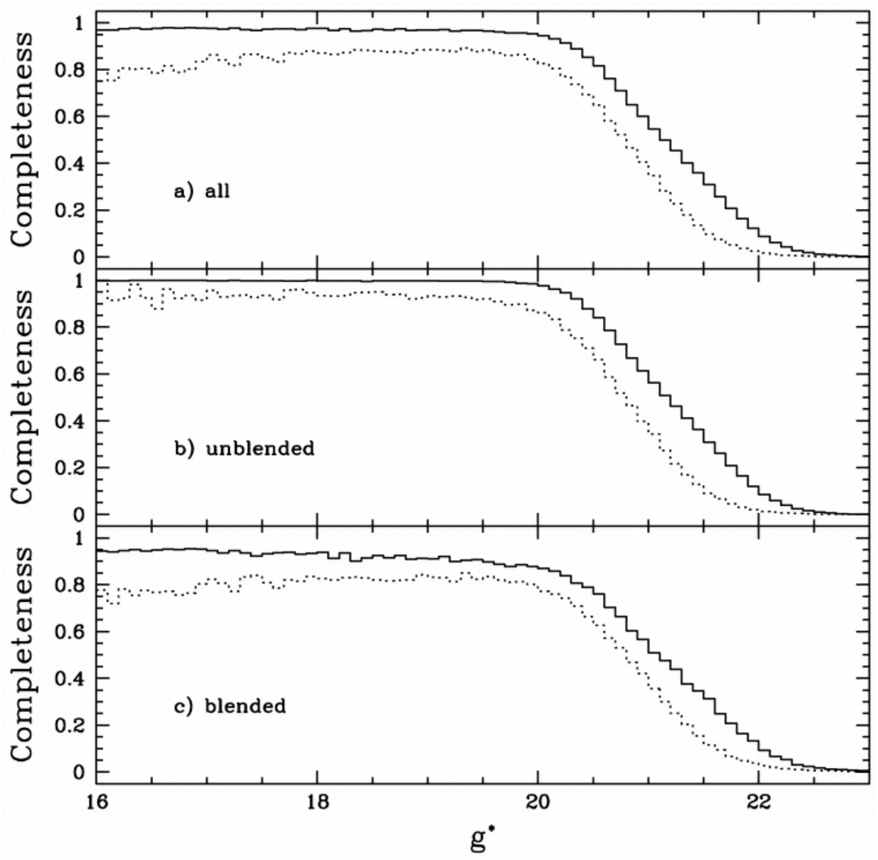
Backup Slides

USNO-B Catalog

- All sky catalog
- 1,042,618,261 objects
- From 7435 Schmidt plates
  (1949 to 2002)
- ~ 0.3 mag photometric accuracy

$$O = g^* + 0.08 + 0.452(g^* - r^*), \quad \sigma = 0.34$$
$$E = r^* - 0.20 - 0.086(g^* - r^*), \quad \sigma = 0.30$$
$$J = g^* + 0.06 + 0.079(g^* - r^*), \quad \sigma = 0.33$$
$$F = r^* - 0.09 - 0.109(g^* - r^*), \quad \sigma = 0.26$$
$$N = i^* - 0.44 - 0.164(r^* - i^*), \quad \sigma = 0.31$$

(Monet et al. 2003)



USNO-B Catalog Source Data

PHOTOGRAPHIC DATA

Survey	Emulsion	Wavelength (nm)	Declination[a]	Fields	Epoch[b]	Archive[c]
POSS-I..................	103a-O	350–500	−30 to +90	936	1949–1965 (first)	O
	103a-E	620–670	−30 to +90	936	1949–1965 (first)	O
POSS-II	IIIa-J	385–540	0 to +87.5	897	1985–2000 (second)	O
	IIIa-F	610–690	0 to +87.5	897	1985–1999 (second)	O
	IV-N	730–900	+5 to +87.5	800	1989–2000	O
SERC-J..................	IIIa-J	395–540	−90 to −20	606	1978–1990 (second)	G
SERC-EJ	IIIa-J	395–540	−15 to −5	216	1984–1998 (second)	G
ESO-R	IIIa-F	630–690	−90 to −35	408	1974–1987 (first)	G
AAO-R..................	IIIa-F	590–690	−90 to −20	606	1985–1998 (second)	O
SERC-ER	IIIa-F	590–690	−15 to −5	216	1979–1994 (second)	G
SERC-I..................	IV-N	715–900	−90 to 0	892	1978–2002	O
SERC-I[d]	IV-N	715–900	+5 to +20	25	1981–2002	O

NOTE.—References for the individual surveys can be found in Morgan et al. 1992, and the wavelength data presented above were copied from this source.

[a] Range of field centers in nominal B1950 used in the compilation of USNO-B. In many cases, the survey covers a larger area.

[b] The assignment of first or second epoch is used in the compilation of the catalog. In this notation, there is no first-epoch blue survey south of $\delta = -33°$.

[c] " O " is the original plate, " G " is the glass copy. In isolated cases, a glass copy was scanned when the original plate was found to be broken, missing, or otherwise unacceptable. For surveys marked with G, the glass copies were borrowed from the National Optical Astronomy Observatory.

[d] Extension of SERC-I survey to fill holes in POSS-II IV-N survey.