Towards an improved census of radio-loud AGNs: the FIRST Flat Spectrum Sample

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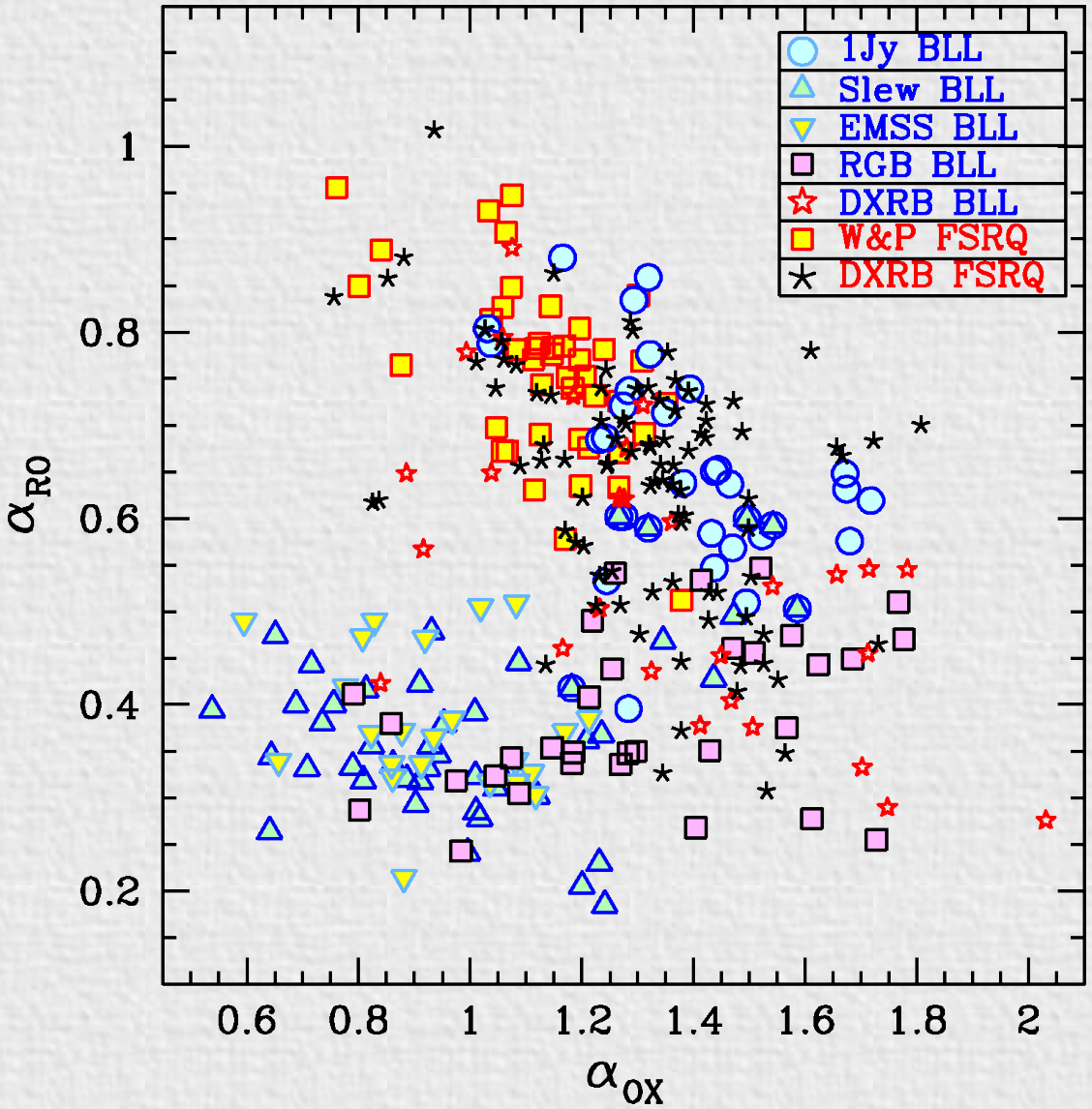
Outline

- Blazar colors, sequences and demographics.
- “Classic” surveys, and their severe limitations.
- Emerging unified (phenomenological) models.

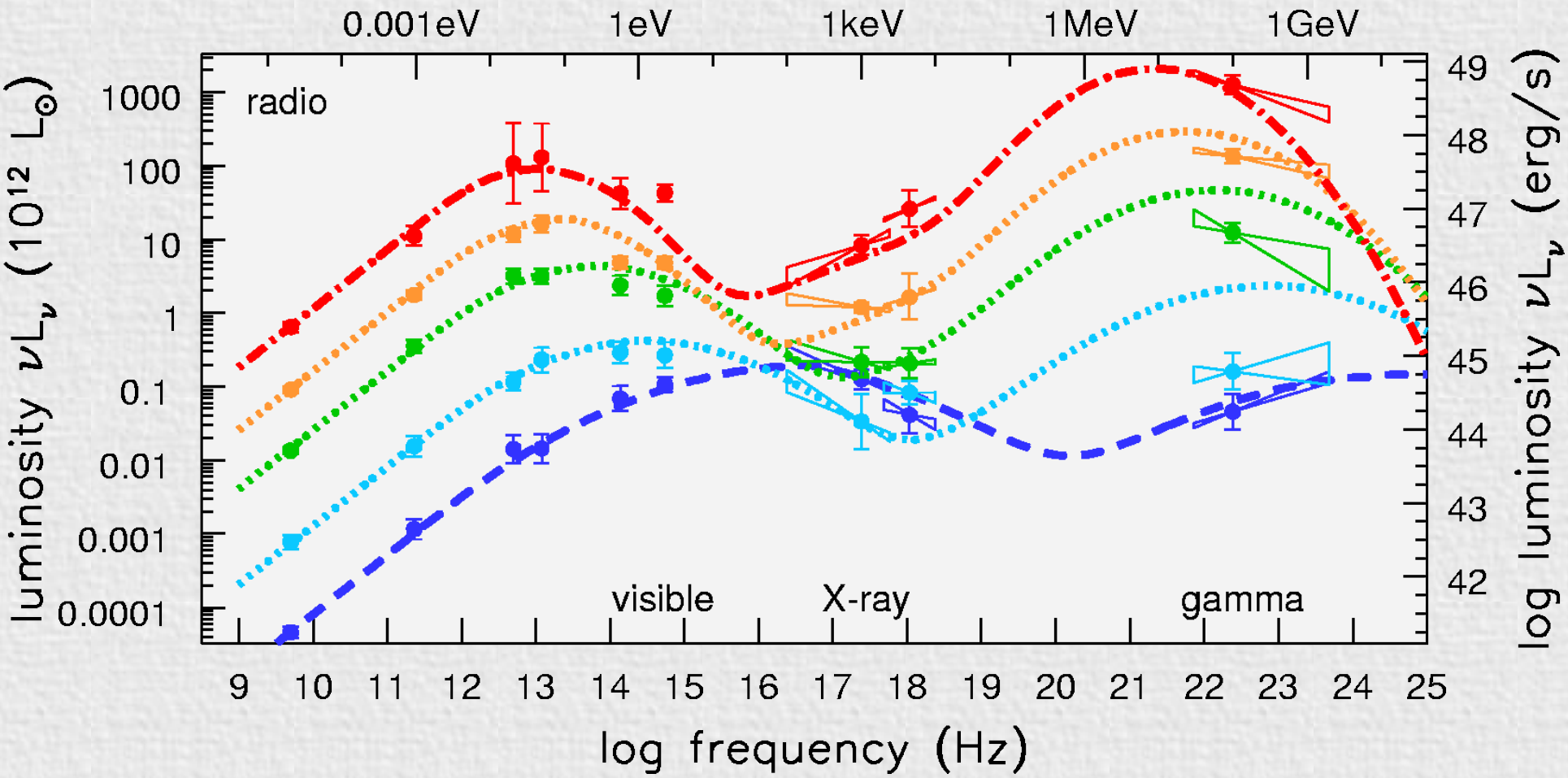
- **Checklist for improved samples.**
- **The FIRST Flat Spectrum Sample.**
- **Comparison of the FFSS with “competing” projects.**

Color-Color plane and SED "coherence"



- Blazars seem to occupy a "precise" locus in the radio/optical vs. optical/x-ray colors plane, reflecting their SED shape.
- The optical emission line properties, and luminosity seem to correlate with the SED color.

The universal shape of Blazars SEDs



Blazar SEDs averaged in bins of source power (Fossati et al. 1998).

From the phenomenological point of view blazars are coarsely classified on the basis of their synchrotron peak position, into **red** and **blue** SED blazars, or low-peaked (LBL) and high-peaked (HBL).

Blazar “sequences” (?)

- There are several observational properties which seem to be all tightly connected to each other, possibly through a common correlation with the SED color:
  - Source power.
  - Optical emission line properties.
  - Cosmological evolution.
- Blazar phenomenology as we see it seems to be governed by a high degree of coherence.
- There is a strong suggestion that the true dimensionality of the blazars parameter space is reduced to a few (2 ?) key physical properties.

Outstanding Issues

- True census of SED colors.
  If the current paradigm is correct, this would yield a census of jet powers too.
- Relationship between BL Lacs and FSRQs.
  Do the optical emission line properties really correlate with the jet power?
- Cosmological evolution.
  There is marginal evidence that RED and BLUE BL Lac evolve differently, and BL Lac and *Quasar-like* blazars too. New ideas have been put forward recently by Cavaliere et al. and others linking evolution and fueling and jet power.
- Verify/falsify the "blazar sequence".
  There are some killer observations, with *"HFSRQ"* topping the list.

Checklist for improved samples

- Improvement are necessary along these directions:
  - Include in an unprejudiced way RED and BLUE blazars.
  - Must not distinguish a priori between BL Lacs and FSRQs.
  - Be "*weak blazar"-aware*.
  - Go deeper in flux limit.
  - Large area coverage is also necessary because blazars are rare objects.
  - *Homogeneity* of the datasets might also be an issue (especially for what concerns those adopted to define the sample).

- In the last few years several different groups have worked towards these goals, *e.g.*:
  - DXRBS, Padovani, Giommi et al.
  - REX, Wolter, Caccianiga, et al.
  - CLASS, Caccianiga, Marcha et al.
  - *Sedentary Survey*, Giommi et al.

FIRST Flat Spectrum Sample

- The FIRST Flat Spectrum Sample (FFSS) is a deep radio selected sample based on the FIRST radio survey, covering 10,000 deg. with VLA (1.4GHz).
- 580 candidates with $F_{[1.4GHz]} > 35$ mJy and $B < 19$.
- Candidates are selected based on the radio flatness.
- No morphological, or color criteria were applied.
- No x-ray detection is required a priori.

FFSS Multiwavelength data status

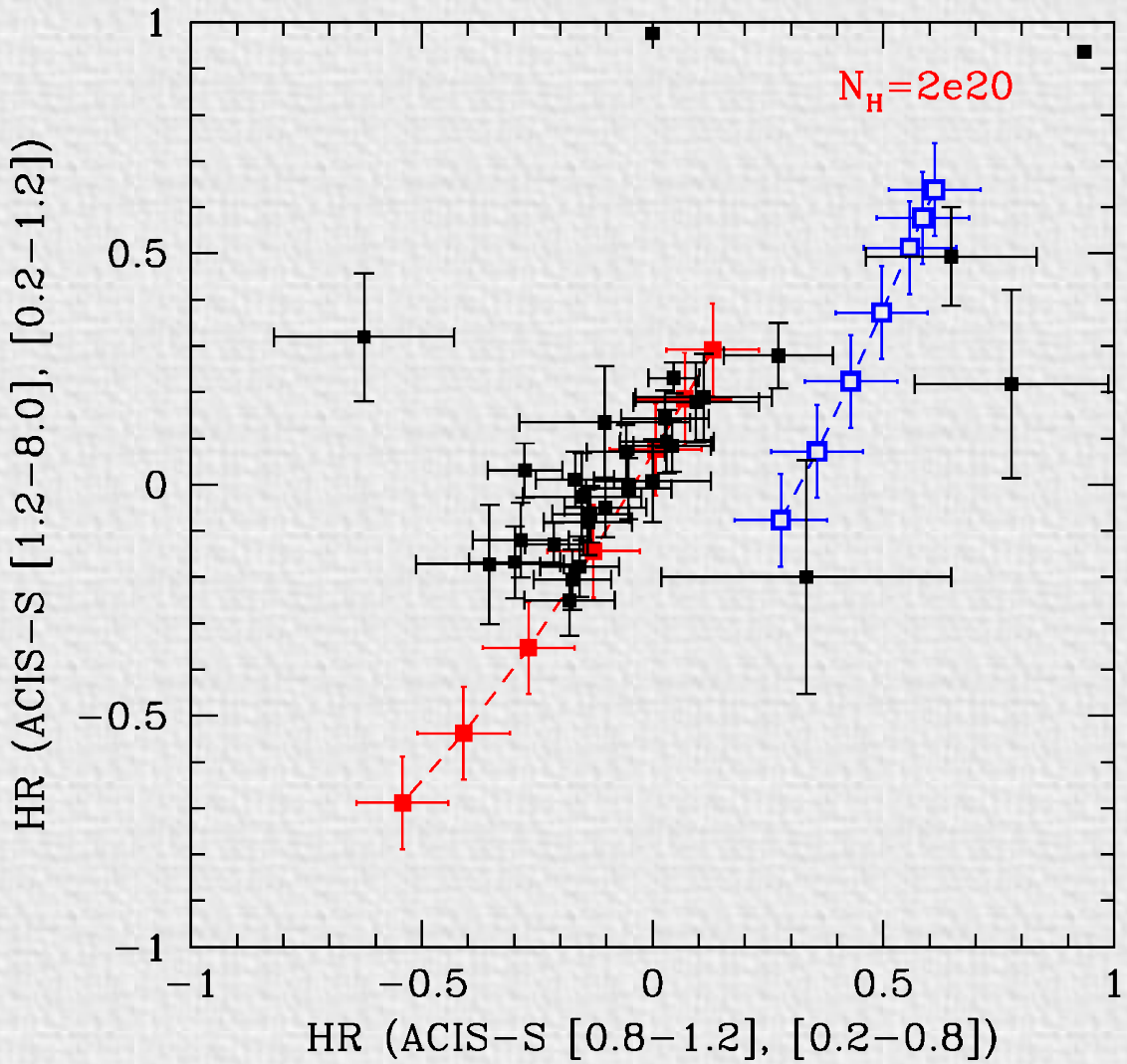
- **OPTICAL**: ≈95% identified (>200 Lick spectra + SDSS + literature)
  - Most objects are blazars, about 15% are “galaxies”.
  - Full information on emission lines and Ca Break properties.
  - ≈530 redshifts.
  - SDSS-DR5 provides multiband photometric data for about 540 FFSS objects..
  - ...and spectra for 350 of them (83 *free* new redshifts!).

- **INFRARED**: 2MASS All-Sky PSC comprises 328 matches with FFSS (305 with data in three bands).

- **X-RAY**: RASS (BSC+FSC) and WGACAT yield 279 reliable Ids (50% of the sample)
  - Observed 13 targets in CXO Cycle 4 and 18 targets in CXO Cycle 6.
  - Eighteen more targets observed/approved in XMM Cycle 3+4+5.
  - Archival Chandra data for about 40 more targets.

Chandra (Cycle 4+6) Observations

Short observations targeted at about 150 counts, enough to tell whether the source is hard or soft, and if it is heavily absorbed.



Striking agreement between the observed rate and that guessed on the basis of the object α_{RO}.

We have 30 firm detections out of 31 observed targets. The HR analysis allows us to infer the spectral slope to ±0.3.
Most objects seems to be consistent with no extra absorption.

No evidence of extended emission.

Further observations have been performed during XMM cycles 4 and 5.

FFSS as a "*blazar sample*": comparison with other blazar samples

COMPARISON OF THE COMPOSITION OF THE FFSS WITH OTHER "MAJOR" SAMPLES

Sample	#	ID %	$F_{R,lim}$ mJy	Opt.[a]	$F^{b}_{X,lim}$	Red[c] %	*Int.*[c] %	Blue[c] %	FSRQ #	BL Lac #	Gal. #
FFSS	580	95	35	19.0	n/a	30	36	34	380	92	79
CLASS	302	70	30	17.5	n/a	18	21	61	114	42	63
XB-REX	239	95	5	20.5	$4 \cdot 10^{-13}$	6[d]	16[d]	78[d]	95	55	66
DXRBS	165	95	50/100	24.0	$5 \cdot 10^{-14}$	76	15	9	134	31	8

[a]Magnitude limits are for different bands: O for FFSS, B for REX, R for CLASS. – [b]*ROSAT* flux in the 0.5–2 keV band. – [c]Red are objects with $\alpha_{RO} \geq 0.55$; Blue are those with $\alpha_{RO} \leq 0.45$. For sources for which we have the x-ray information, that enables a more precise determination of the SED color (e.g. Fossati 1998), the distribution of colors and of α_{RO} are consistent, and so the fractions reported here are probably reliable. – [d]Multiwavelength data published only for the 55 BL Lac subsample.

- **FFSS**: provides a unique mix of optical and SED types.
  - 380 *quasars*, 90 BL Lacs, 80 *galaxies*.
  - SED color coverage quite good (as measured using α_{RO} as proxy)
  - Redshifts: 189 @z<0.5, 96, 95, 82 in next Δz=0.5; 72 @z>2
  - Good mix of "optical types".

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- **CLASS**: from cosmic lenses radio survey.
  - Similar radio flux limit.
  - Good mix of "optical types".
  - Brighter magnitude cut.
  - Biased towards BLUE SEDs.

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- **XB-REX**: NVSS cross ROSAT-PSPC.
  - Very faint radio cut, BUT...
  - ...relatively high x-ray flux limit —> biased towards BLUE.

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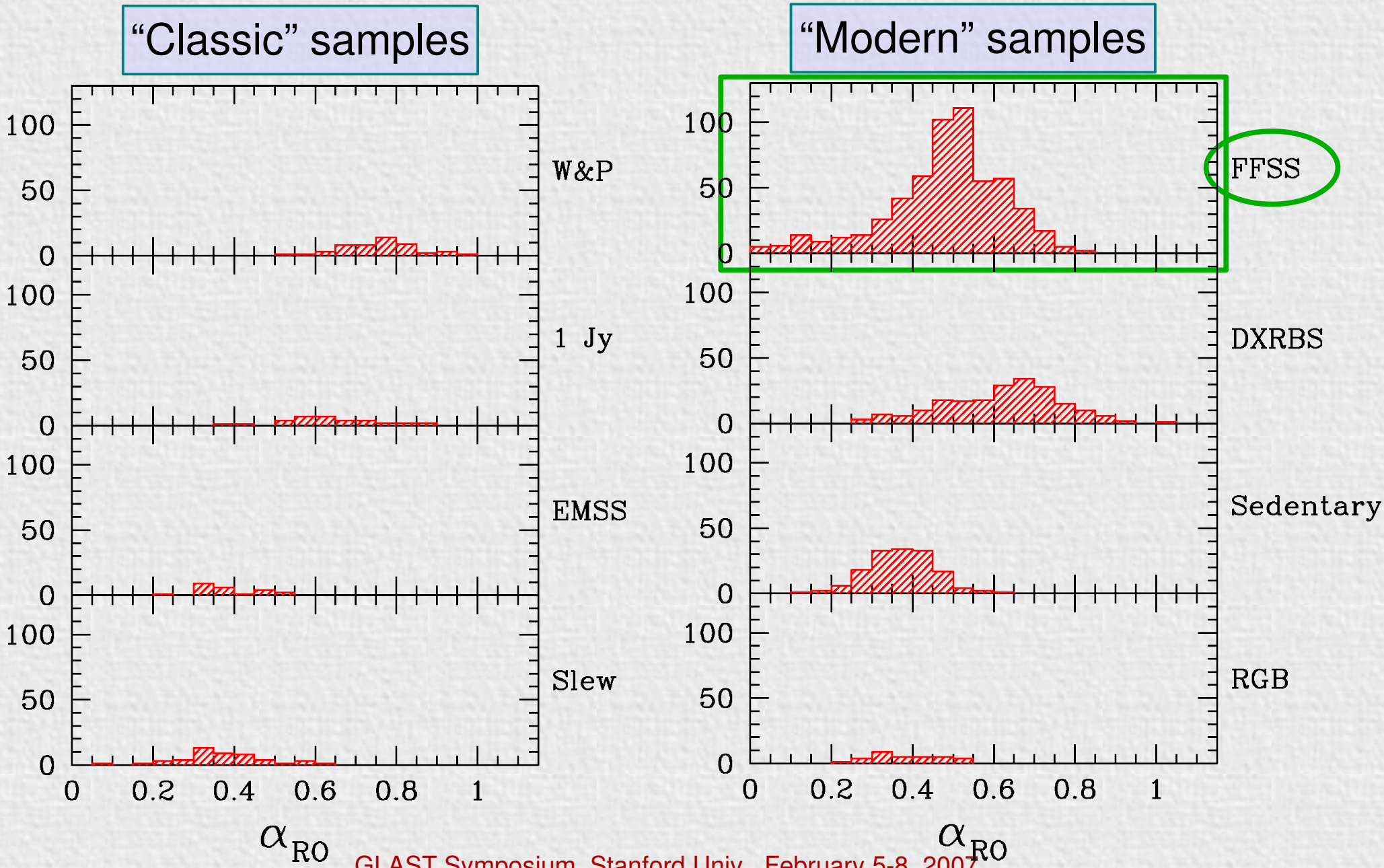
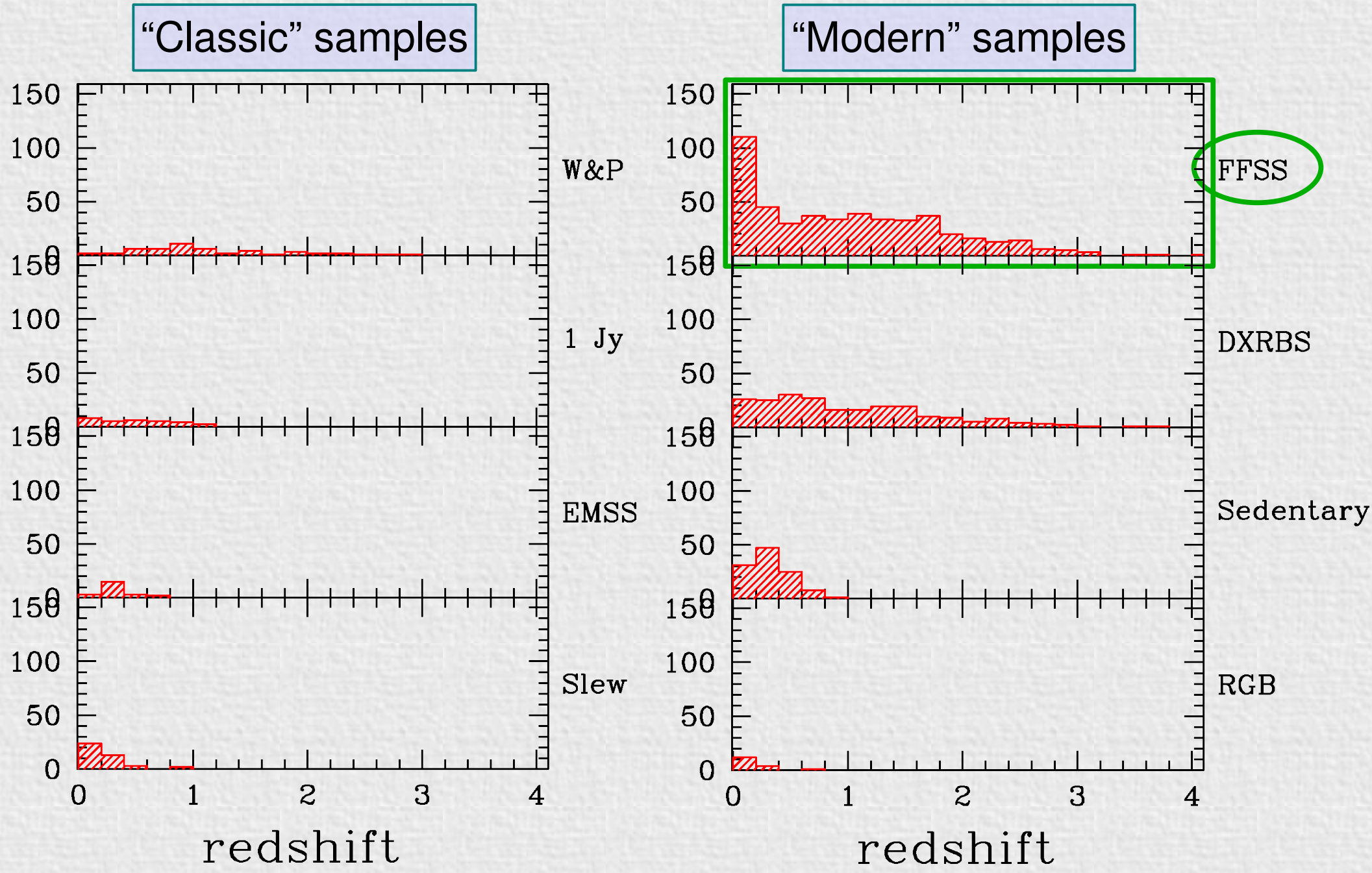
- **DXRBS**: radio cross WGACAT.
  - The x-ray detection imposes a very severe cut.
    The statistics on the x-ray matches for the FFSS (279/580) show that the DXRBS might be missing 50% of good candidates.
  - Not very uniform selection across the sky and bands.
  - Breakdowns by SED color and "optical type" show that it might not provide a well sampled picture of the blazar variety.

SED color distributions

Using radio/optical index as a proxy for the SED color.



Redshift Distributions



FFSS Summary

- The FFSS sources span across the range of blazar phenomenology in a remarkable and unique way.
- All SED colors are well sampled by the FFSS.
- It is well positioned for studying the transition between FSRQ and BL Lac.
- The sizeable “galaxy” sub-sample will allow objective investigation of the existence and properties of weak blazar nuclei.
- We currently have completed x-ray characterization of a first *milestone*, a 160-objects sub-sample (z<1.0, Fr>100 mJy), and are working on a 254-strong one.

FFSS, next

- RADIO: combination of FIRST and NVSS complementary strengths in terms of sensitivity to compact *vs.* diffuse emission (e.g. Best et al. '05)
- OPTICAL/IR: follow up spectroscopy for improved determination of "thermal properties". *Spitzer* observations for a subset of objects for which it is going to be important to constrain the SED peak.
- Millimeter: crucial wavelength for getting at the synchrotron peak position. Hoping on Astro-F/AKARI all sky survey for picking up a few dozen FFSS objects. New, large, facilities are going to be available (e.g. LMT/GMT) which could allow sample-wide coverage.
- X-ray/Gamma-ray: besides dedicated proposal, and archive mining, with Chandra/XMM, *Swift* will probably contribute data for some FFSS objects, interestingly either the most extreme blue (with synchrotron extending into its bandpass) and red, MeV, blazars (with the rapidly rising IC component.)

GLAST

- A few items relevant for our understanding of blazar phenomenology (with possibly a bias towards assessing the validity of a blazar sequence scenario):
  - Full picture of the source energetics.
  - (more) Accurate estimate of the SED peak(s) positions.
- Preliminary simulations on a *pilot sample* comprising several 100s known blazars suggest that all objects in surveys like FFSS, DXRBS may be detected over a two-year all sky survey.
- BIG caveat: EGRET *captured* most of the objects during their most active phases, almost certainly offering us a skewed picture. We do not know their quiescent properties (if any, but see HESS on PKS2155; Impey 1990), e.g. the "real" IC/synchro ratio. This unfortunately will largely still be the case for GLAST.