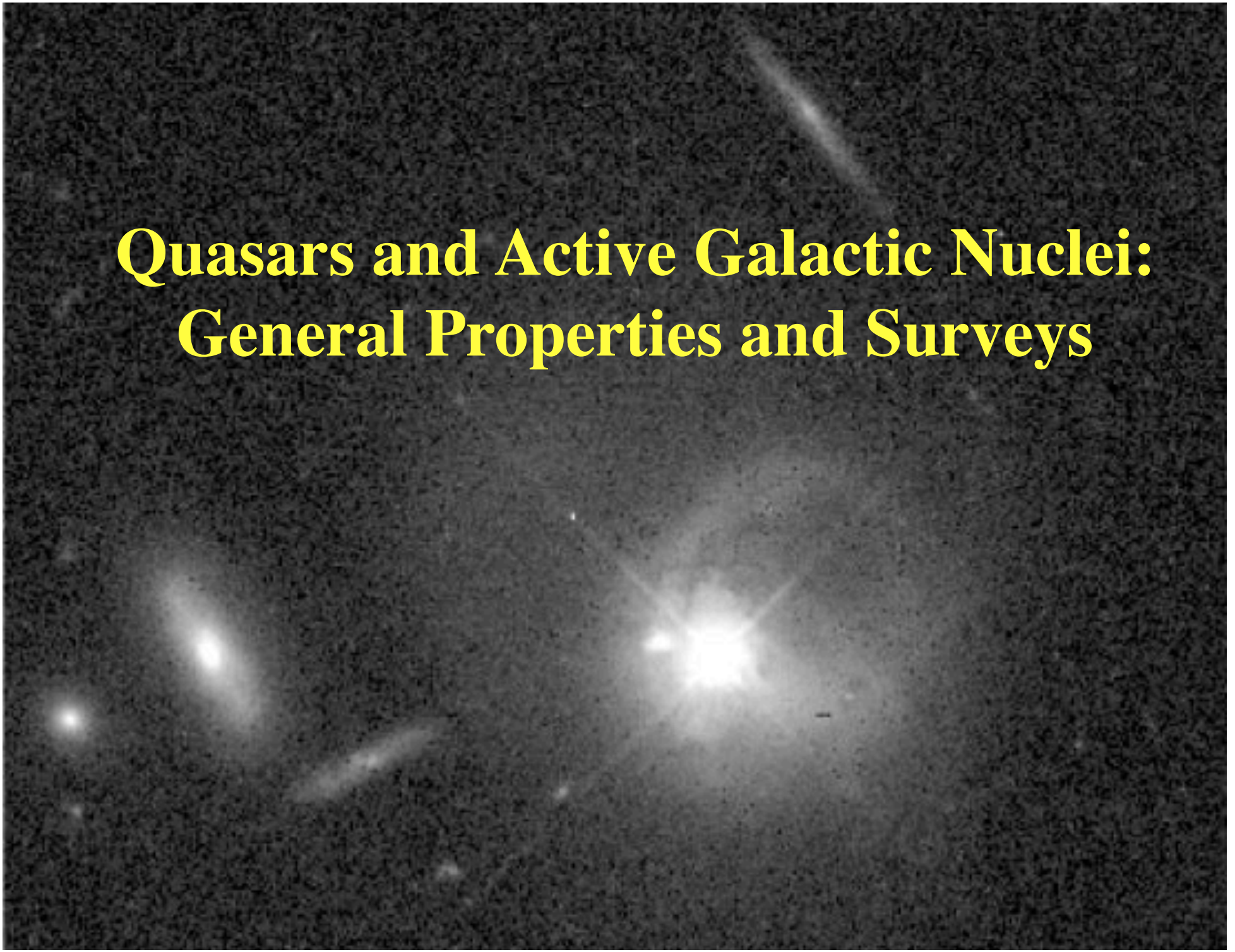
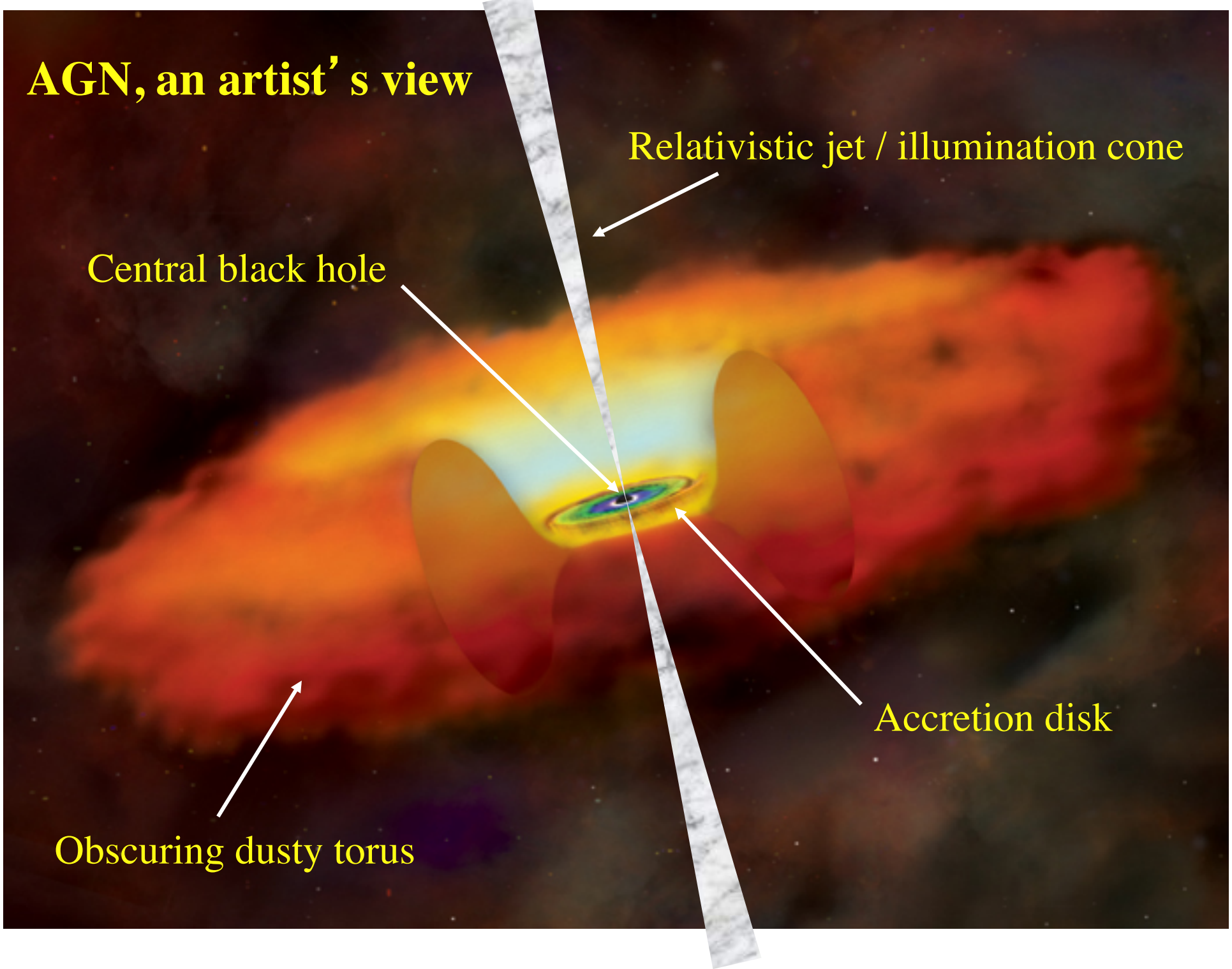


Quasars and Active Galactic Nuclei: General Properties and Surveys

Quasars and AGN

- They are highly energetic manifestations in the nuclei of galaxies, believed to be powered by accretion onto massive black holes
- Empirical classification schemes and various types have been developed, on the basis of the spectra; but recently, various unification schemes have been developed to explain AGN as different appearances of the same underlying phenomenon
- Quasars/AGN are observed to evolve strongly in time, with the comoving densities of luminous ones increasing by $\sim 10^3$ from $z \sim 0$ to $z \sim 2$
- At $z \sim 0$, at least 30% of all galaxies show some sign of a nuclear activity (mostly low level); ~ 1% can be classified as Seyferts (moderately luminous), and $\sim 10^{-6}$ contain luminous quasars
- However, we think that most or all non-dwarf galaxies contain SMBHs, and thus probably underwent at least one AGN phase

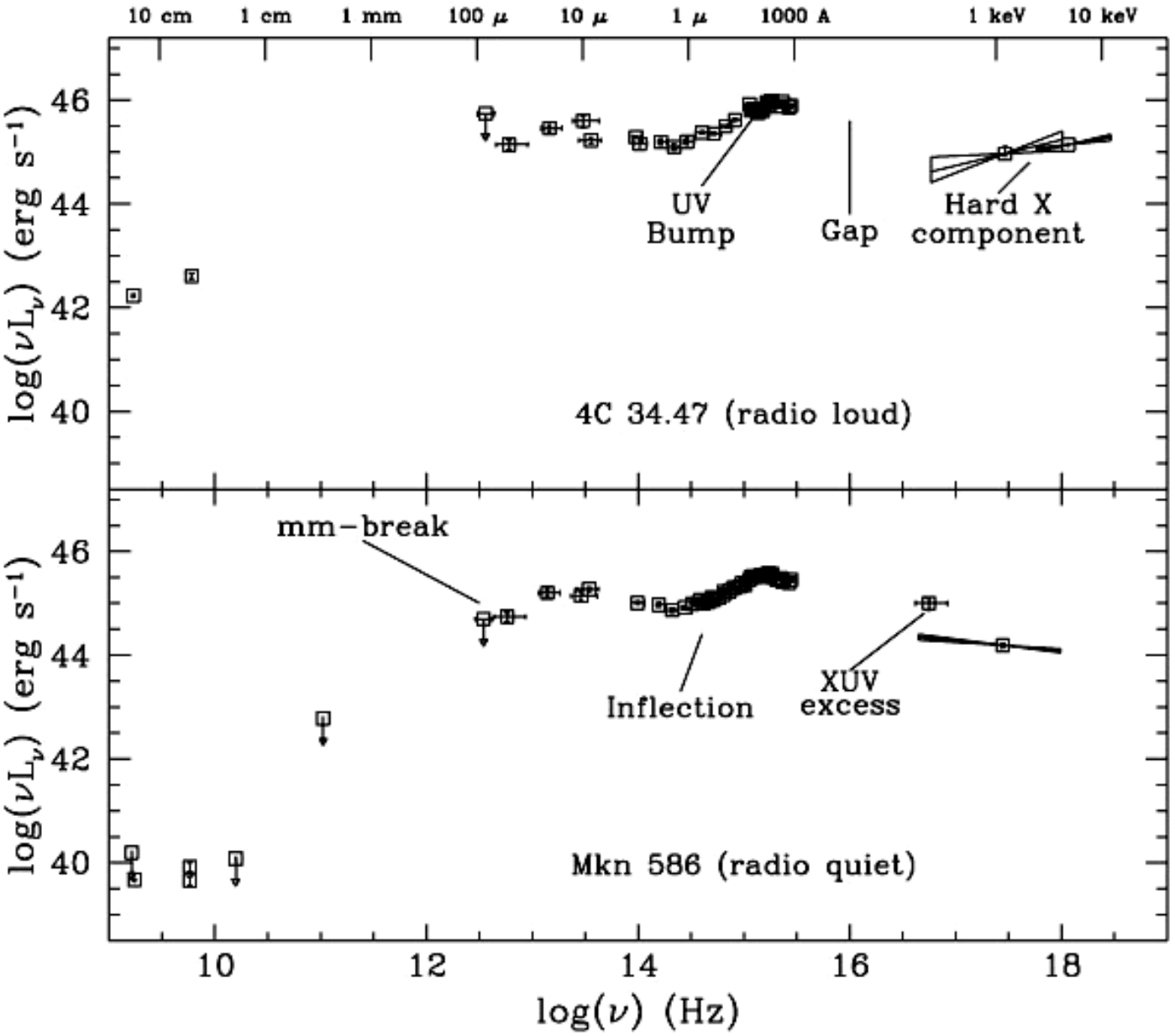

AGN, an artist's view
Relativistic jet / illumination cone
Central black hole
Accretion disk
Obscuring dusty torus

Observable Properties of AGN

- Energy emission over a broad range of frequencies, from radio to gamma rays
  - Nonthermal radio or X-ray emission is a good way to find AGN
  - Generally bluer spectra than stars: "UV excess"
  - Colors unlike those of stars, especially when modified by the intergalactic absorption
- Presence of strong, usually broad emission lines in their spectra
- Can reach large luminosities, up to $\sim 10^{15}\ L_{\odot}$
- Strong variability at all time scales
  - Implies small physical size of the emission region
- Central engines unresolved
- Zero proper motions due to a large distances

All of these have been used to devise methods to discover AGN, and each method has its own limitations and selection effects

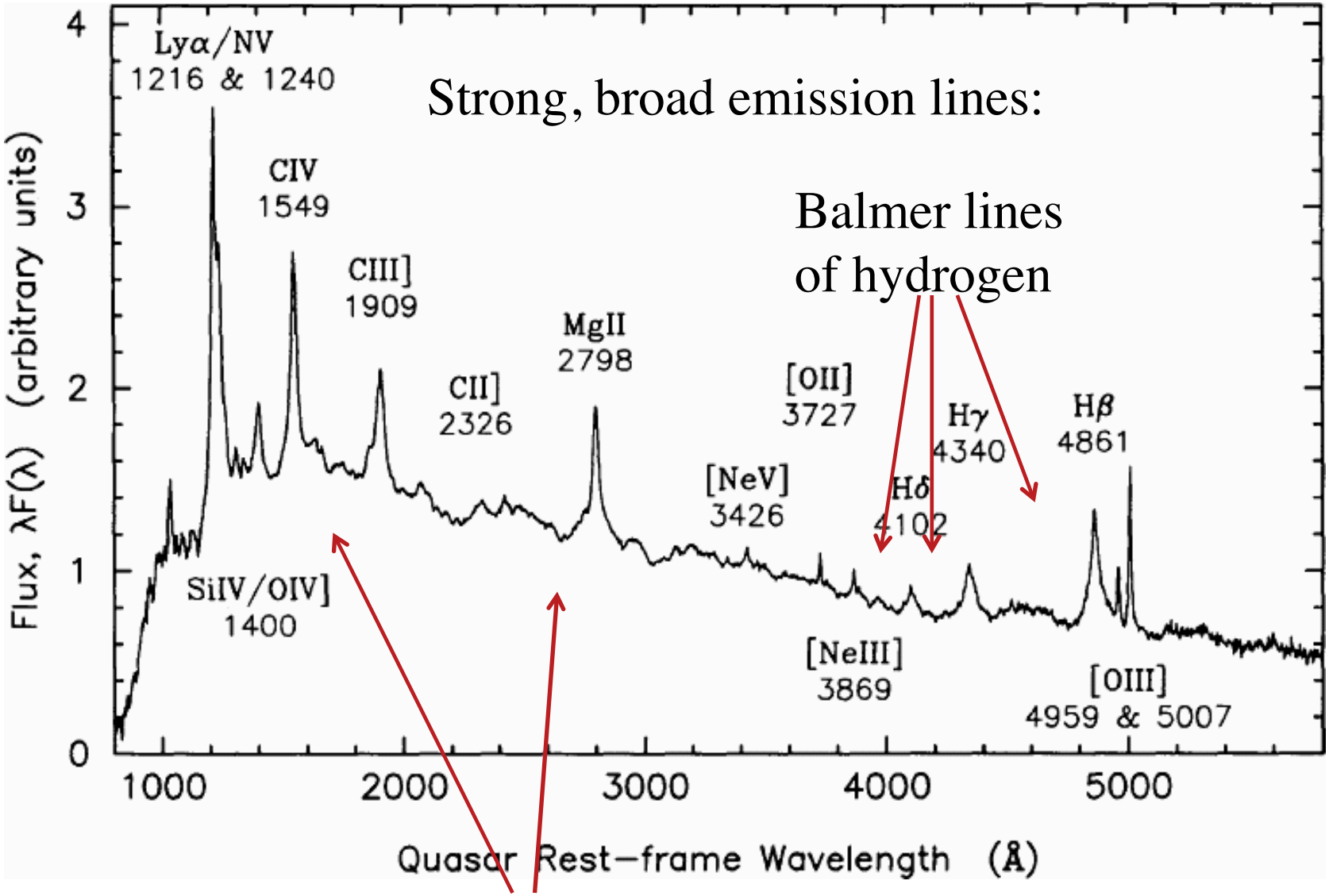
Broad-Band Spectra of Quasars



Radio Loud

Radio Quiet

UV-Optical Spectra of Quasars



Prominent lines of abundant ions

Quasar Surveys

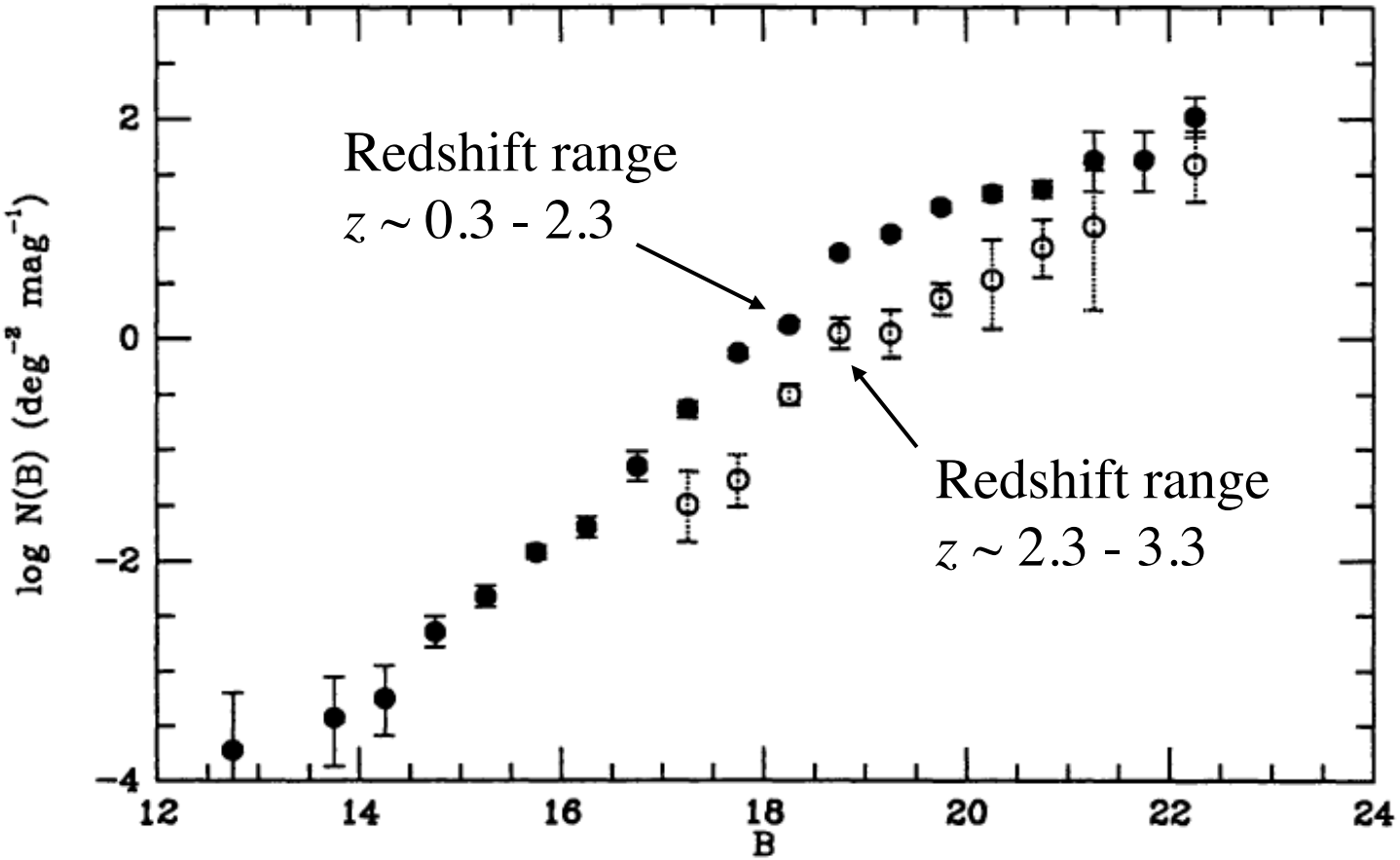
- In order to study QSOs (and other AGN), we first have to find them, in large numbers, and hopefully in a systematic fashion
  - This is especially important for studies of their evolution
- Recall that ***each discovery method has its own biases***
- Nowadays the most popular technique is to use colors to separate QSOs from normal stars
  - In optical, one can also use slitless spectroscopy, variability, and zero proper motions
- Soft X-ray (up to a few keV) and optical selection find the same types of relatively unobscured objects; hard X-ray selection and FIR/sub-mm detect more obscured populations; radio finds both
- Next: multi-wavelength, survey cross-matching in the Virtual Observatory framework - will help with the selection effects

Quasar Surveys and Catalogs

- To date, there are > 100,000 spectroscopically confirmed QSOs
  - And about 1,000,000 additional QSO candidates selected from colors, still awaiting spectroscopy
  - Most come from large systematic surveys, e.g., SDSS and 2QZ
  - Many smaller surveys in the past were done at Palomar, e.g., Palomar Green (PG), Palomar CCD (PC), Palomar Sky Survey (PSS), etc.
  - There were also many searches for emission line objects (some are AGN, some starformers), e.g., Mrk, UM, CSO, KISS, etc.
  - Older heterogeneous catalogs include Hewitt & Burbidge, and Veron & Veron-Cetty compilations
- There are now also > 10^5 X-ray sources catalogued (most are probably powered by AGN)
- There is also probably close to ~ 10^6 radio sources in various catalogs, and many (most?) of them are powered by AGN
  - Major radio surveys include: Parkes (PKS), Green Bank (GB), NRAO VLA Sky Survey (NVSS), Faint Images of Radio Sky at Twenty cm (FIRST), etc. etc.

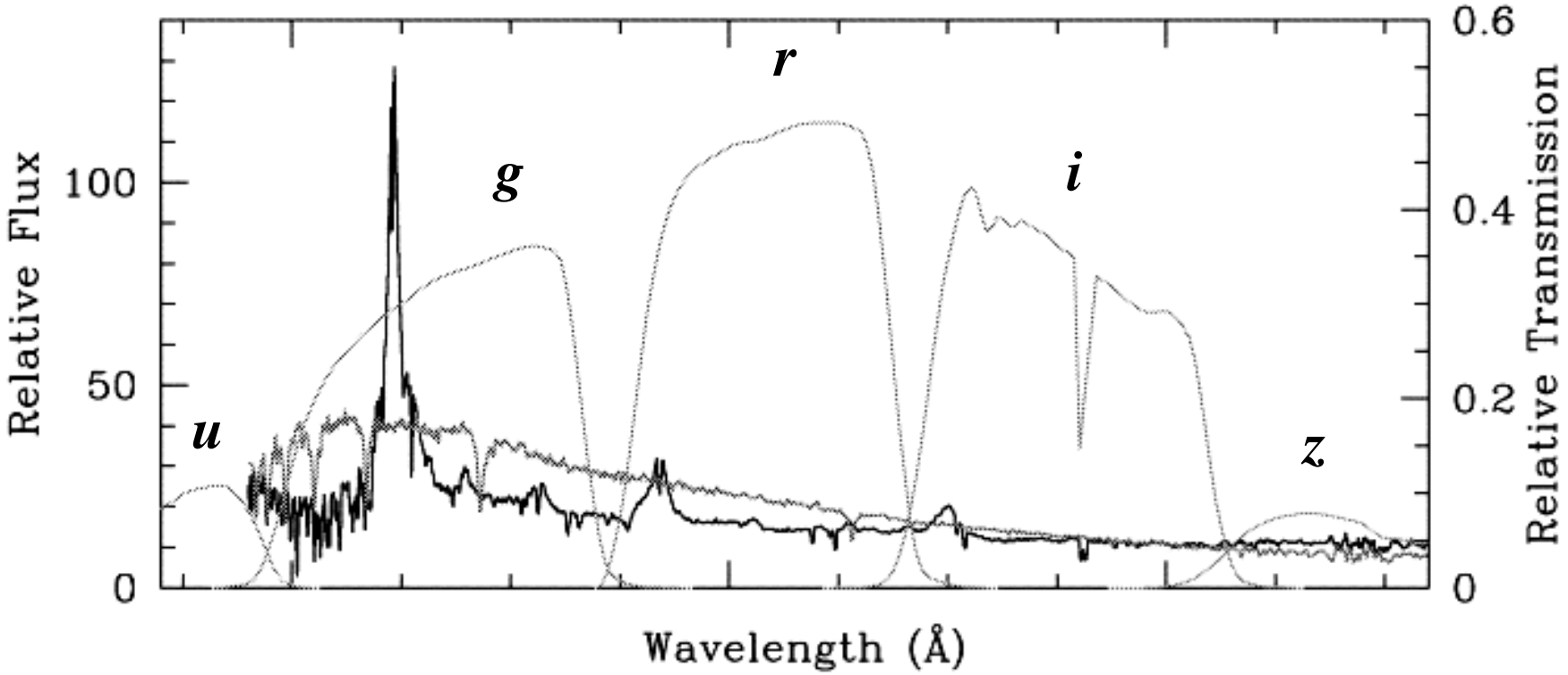
Quasar Counts

For the unobscured, Type 1 QSOs; they may be outnumbered by the obscured ones. Down to ~ 22th mag, there are ~ 100 deg^{-2}; down to ~ 29th mag, probably a few hundred more ➔ a total of a few × 10^{7} over the entire sky, or ~ 1 per 1000 faint galaxies



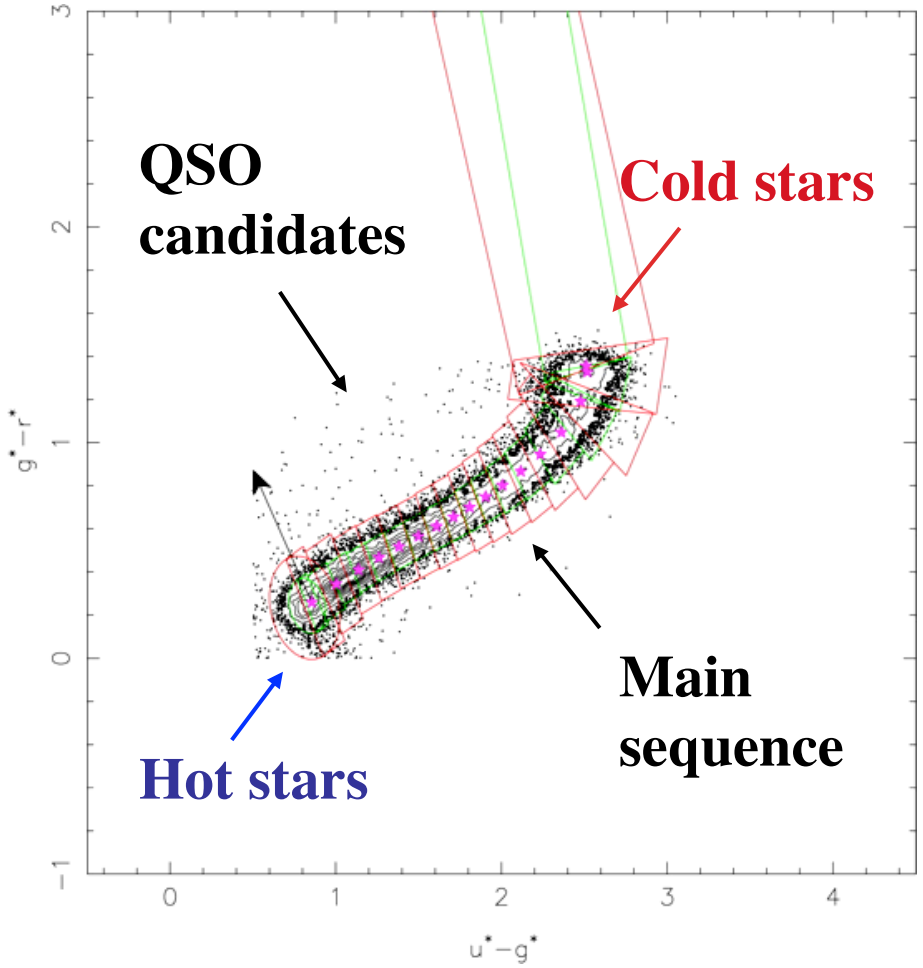
SDSS Quasar Survey

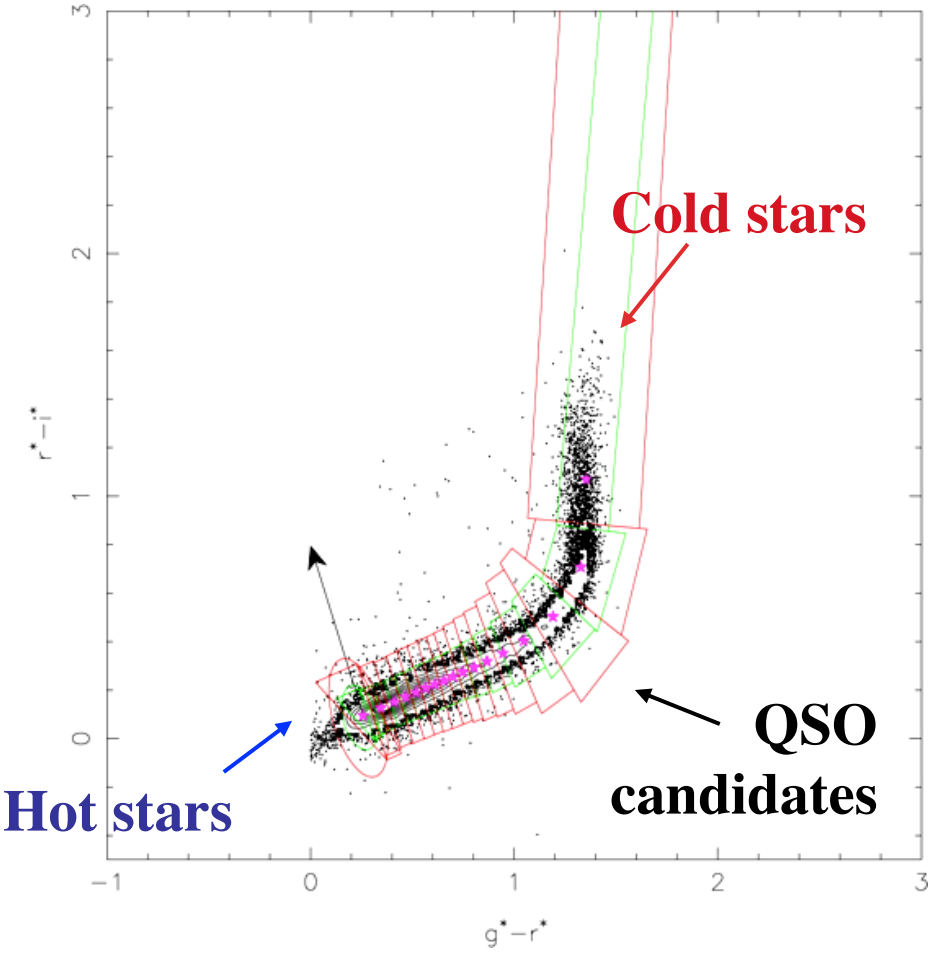
Ratios of fluxes in different survey filters (=colors) are in general different for QSOs and for stars - even though both look "stellar" on the images. The colors will change with redshift as different features (emission lines, continuum breaks) shift from one filter to another. For each redshift range, a different filter combination would be the optimal one for QSO selection

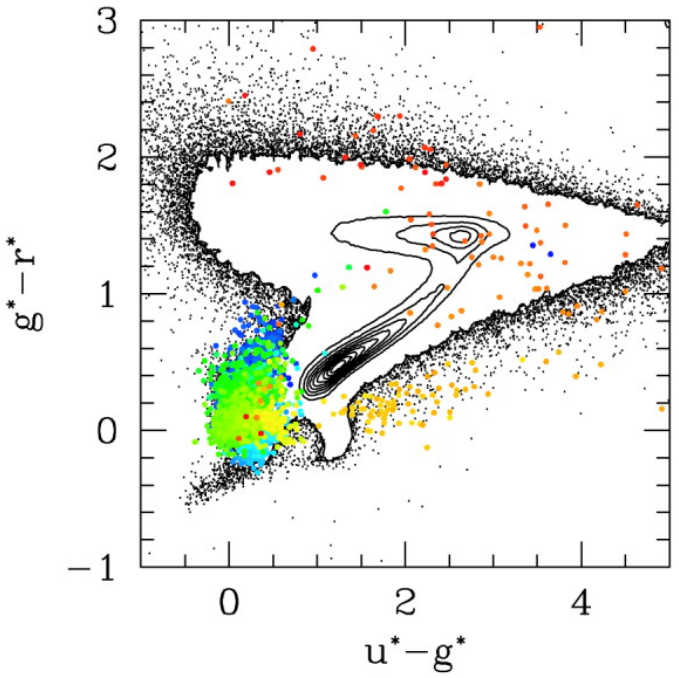


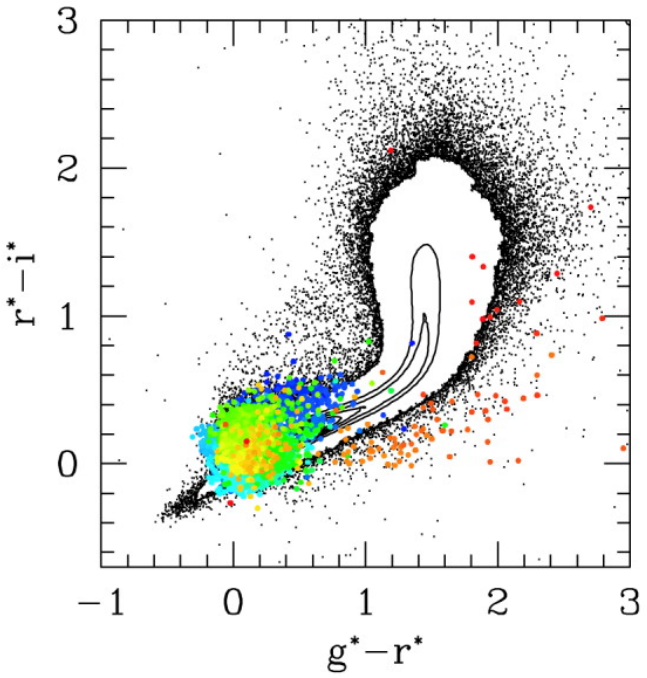
SDSS Quasar Survey

Examples of color selection of QSOs, as outliers away from the stellar locus

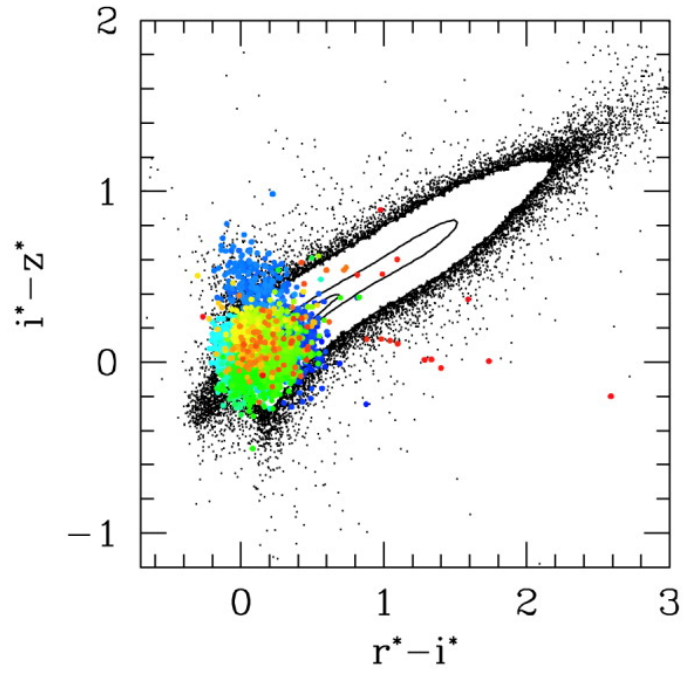


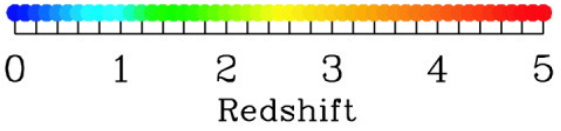






Black dots: stars and galaxies



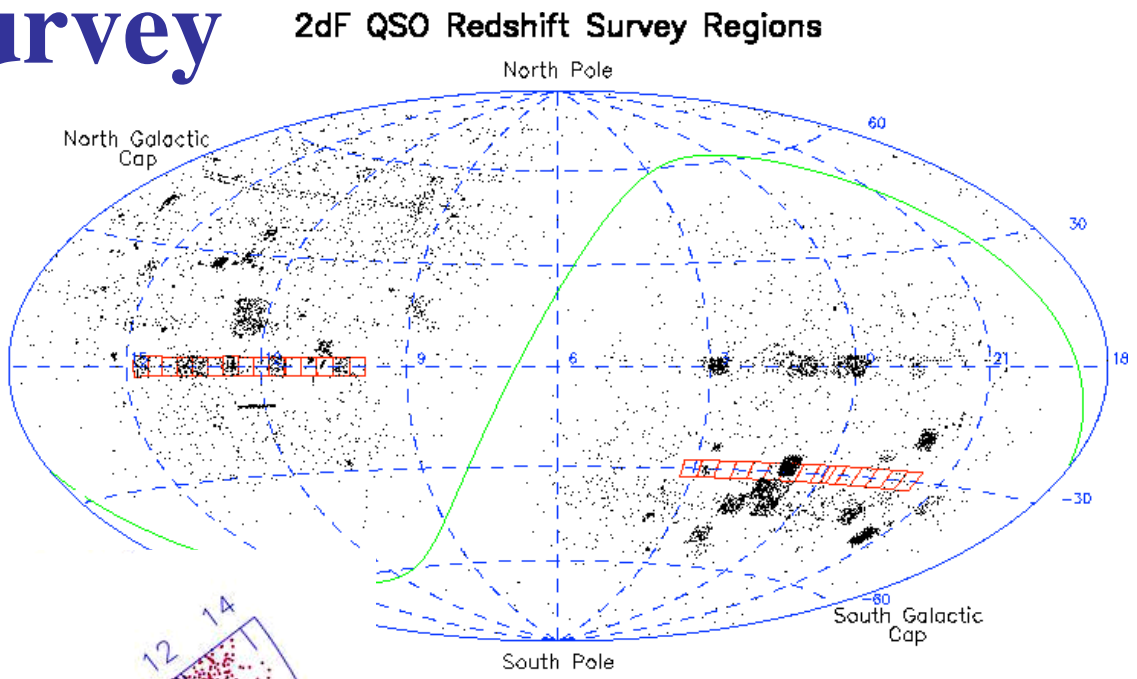


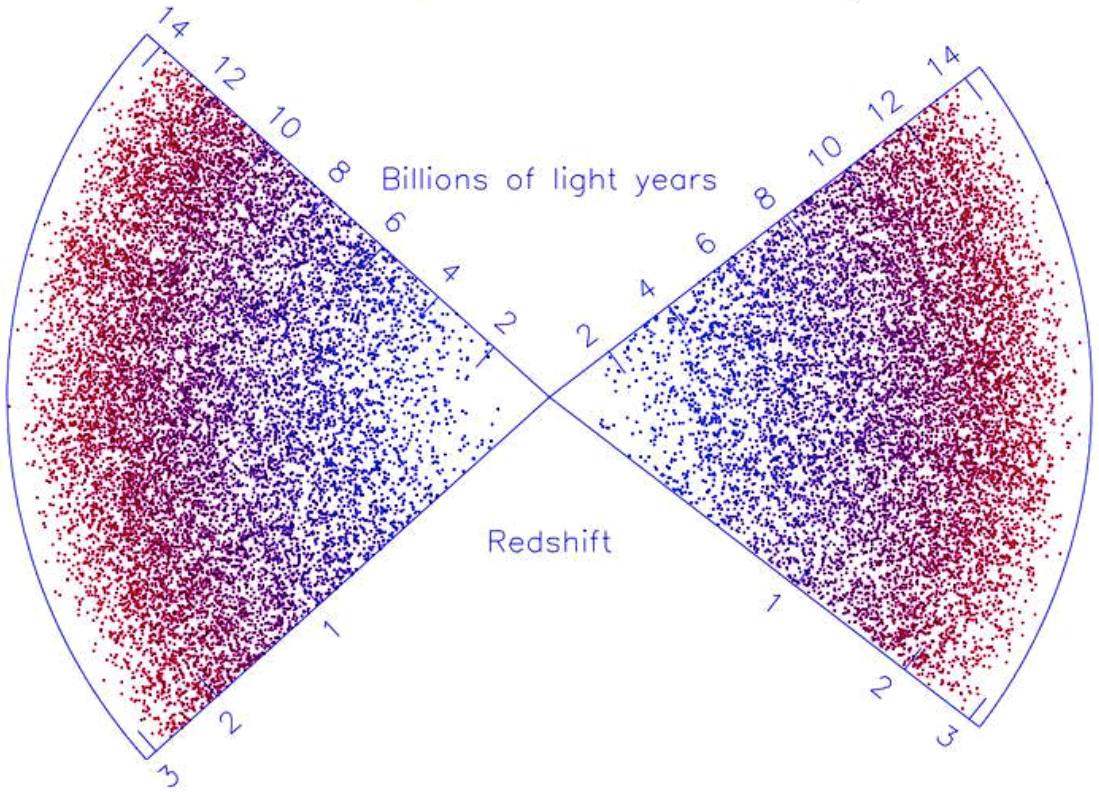
Where the QSOs (colored dots) are as a function of redshift in each color space

2QZ Quasar Survey

Uses 2dF spectrograph
at the AAT

UV color selection
(limits redshifts to $z < 2.3$)



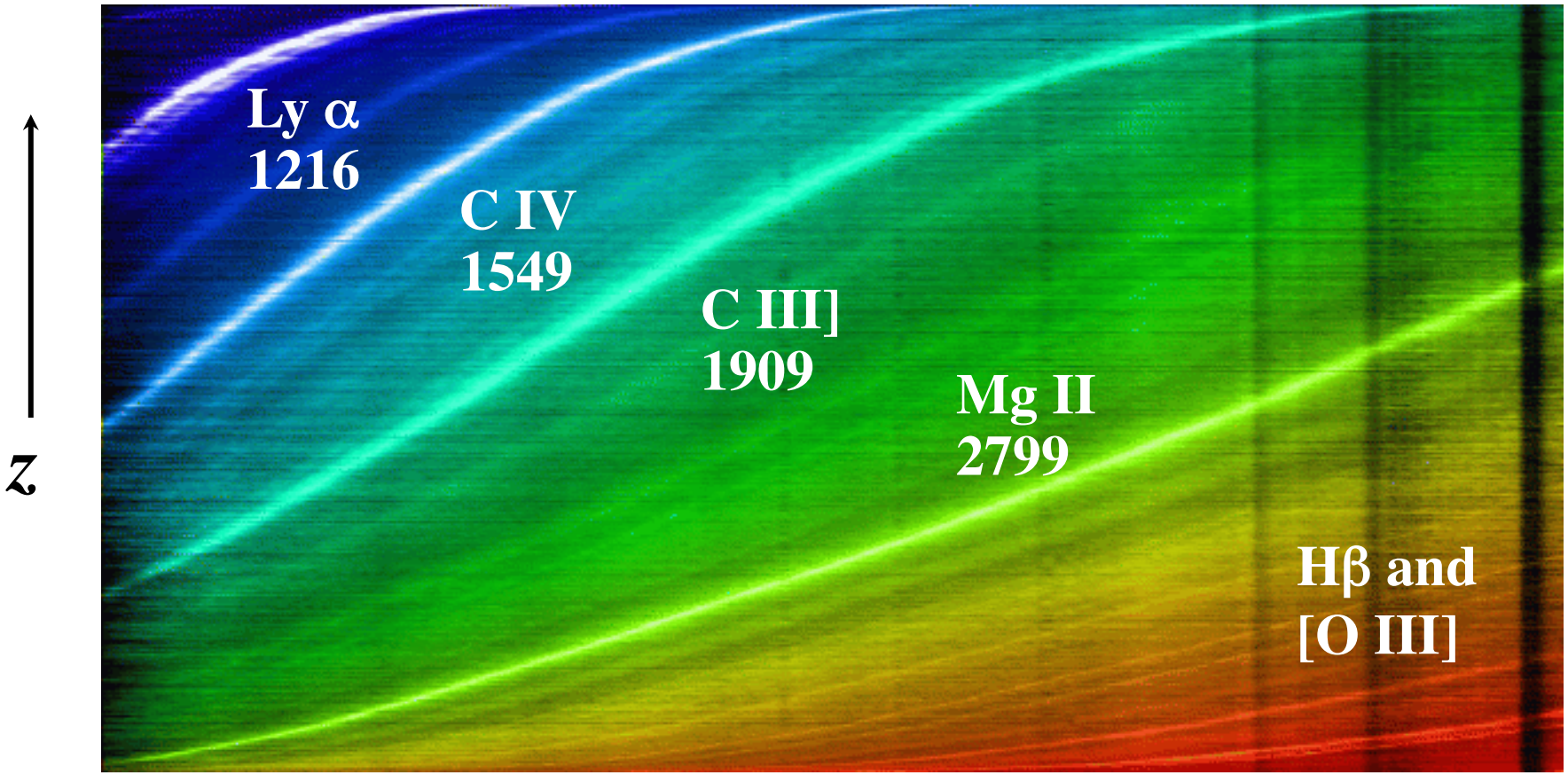


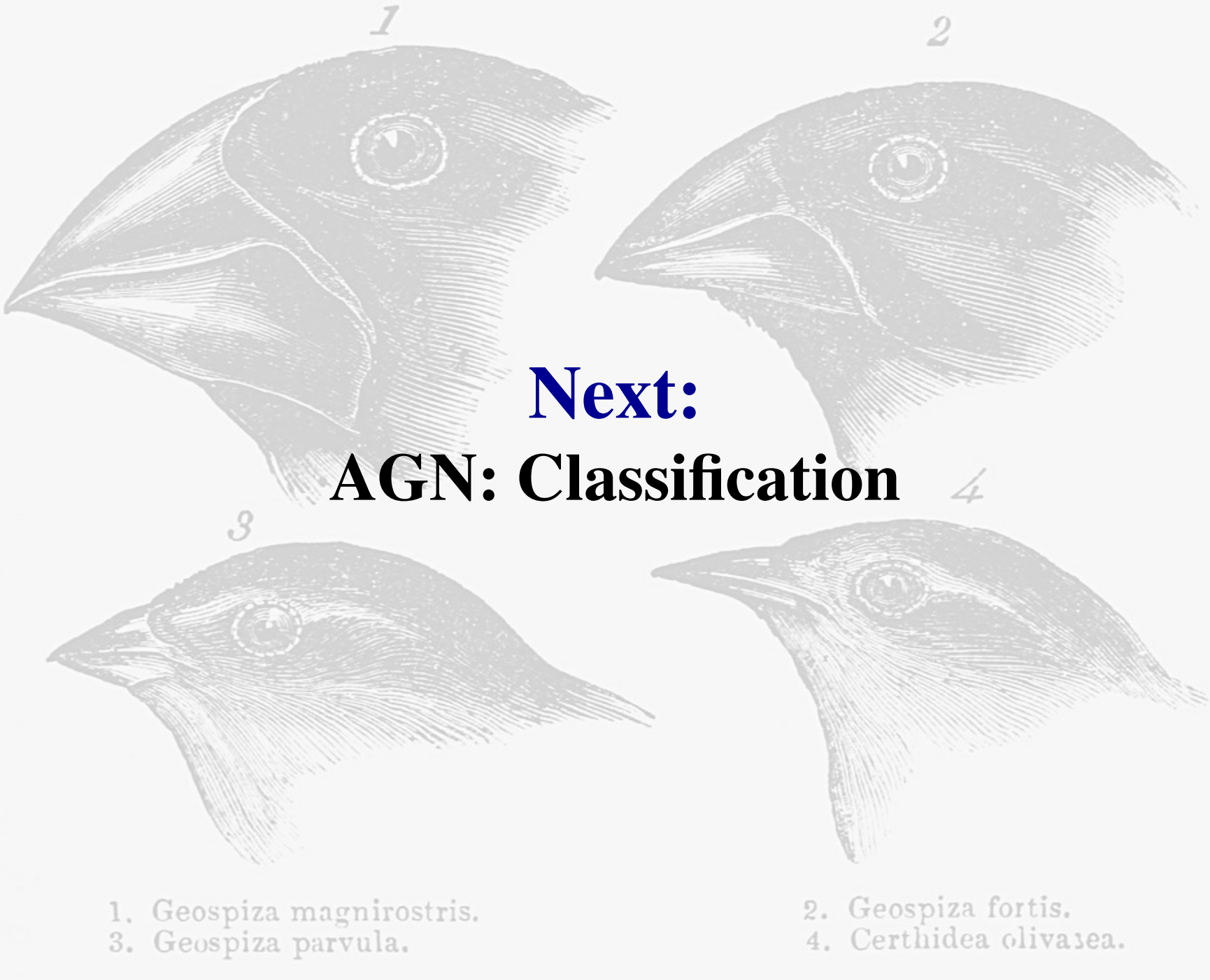
23,424 QSOs

http://www.2dfquasar.org/

2QZ Quasar Survey

Redshift-sorted spectra. Strong emission lines (bright ridges) shift to the red as the redshift increases





Next:

AGN: Classification