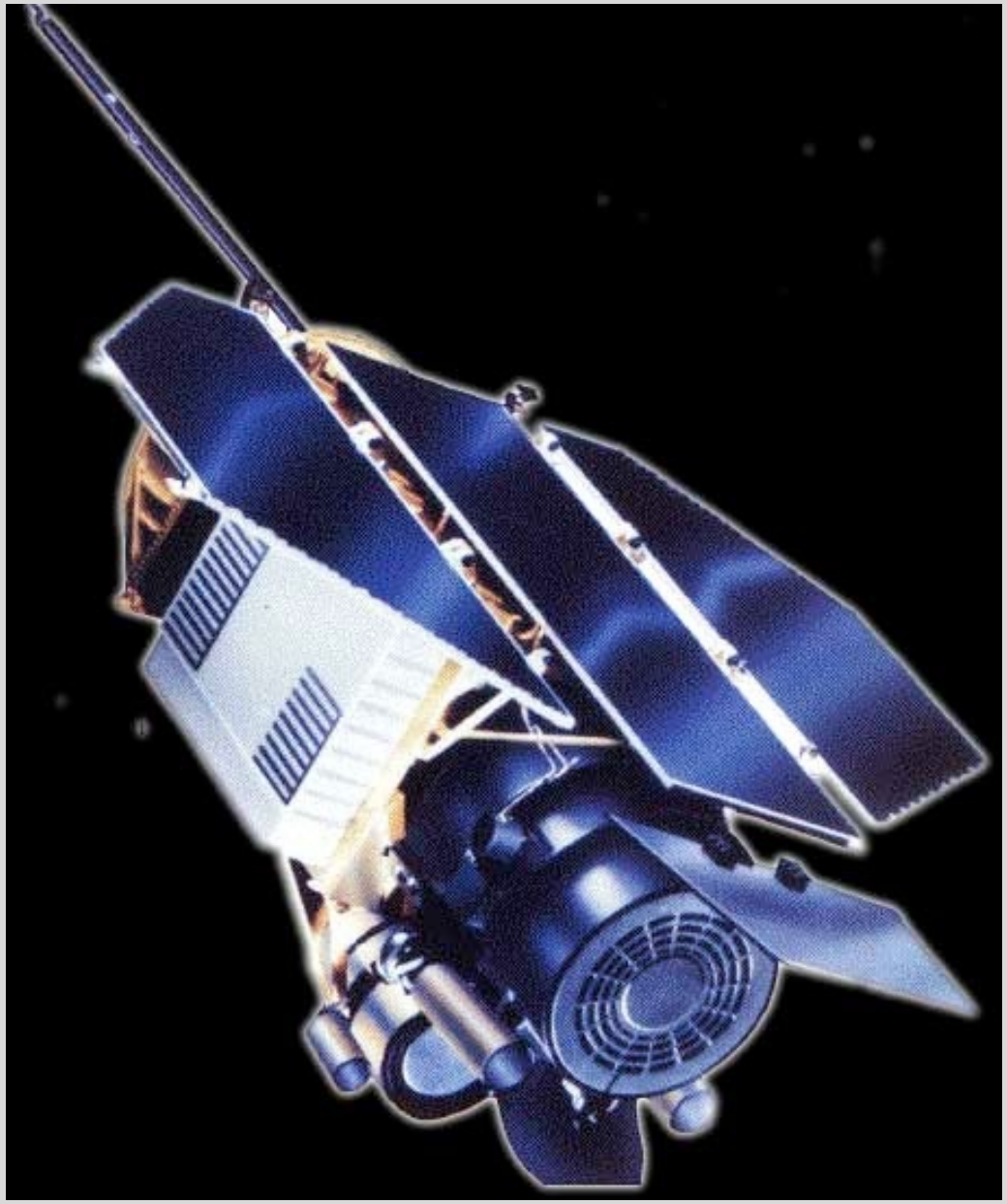
ROSAT – Instrumentation

Position Sensitive Proportional Counter (PSPC)

- 20” resolution, 2 degree FOV
- Energy range 0.1 – 2.5 keV
- Effective area ~ 240 cm^2 at 1 keV
  (measure of efficiency of collecting photons)
- Conducted all-sky survey
- Also did pointed observations

High Resolution Imager (HRI)

- 5” resolution, 38’ FOV
- Effective area ~ 80 cm^2 at 1 keV
- Pointed observations



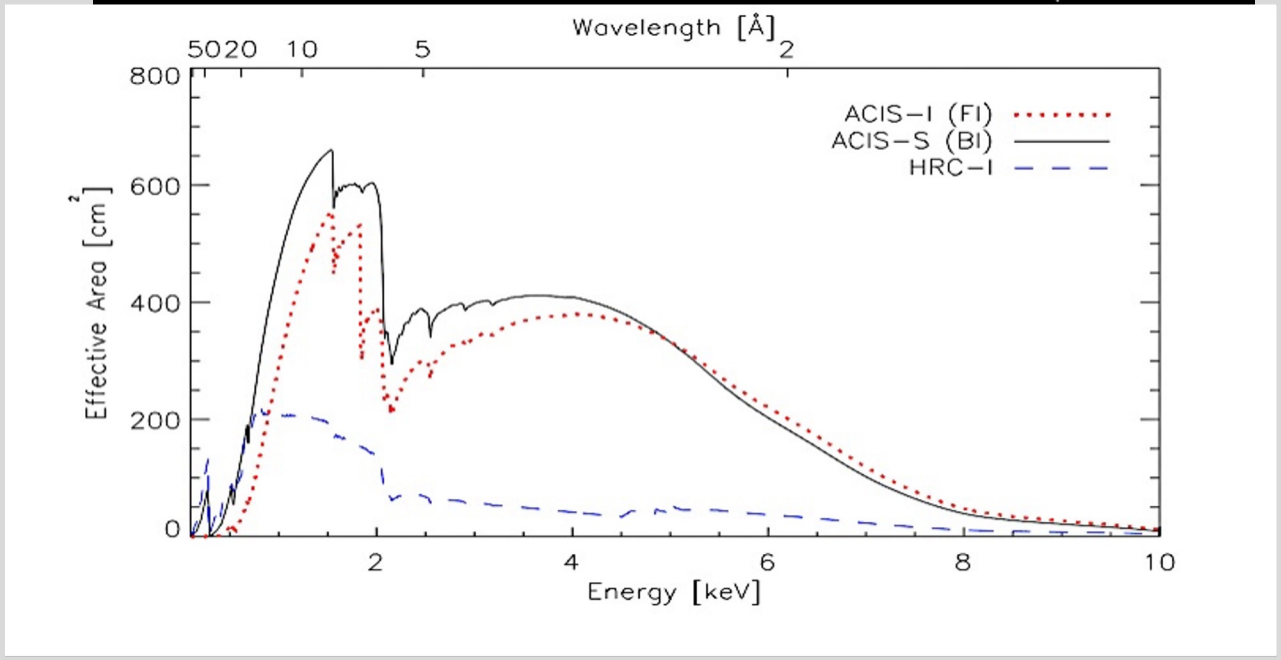
Chandra – Instrumentation

Advanced CCD Imaging Spectrometer (ACIS)
- Imaging: 2” spatial resolution, ten 8’x8’ CCDs
- Moderate resolution spectroscopy
- Energy range 0.4 – 10 keV
- Effective area ~ 600 cm^2 at 1 keV
  (measure of efficiency of collecting photons)

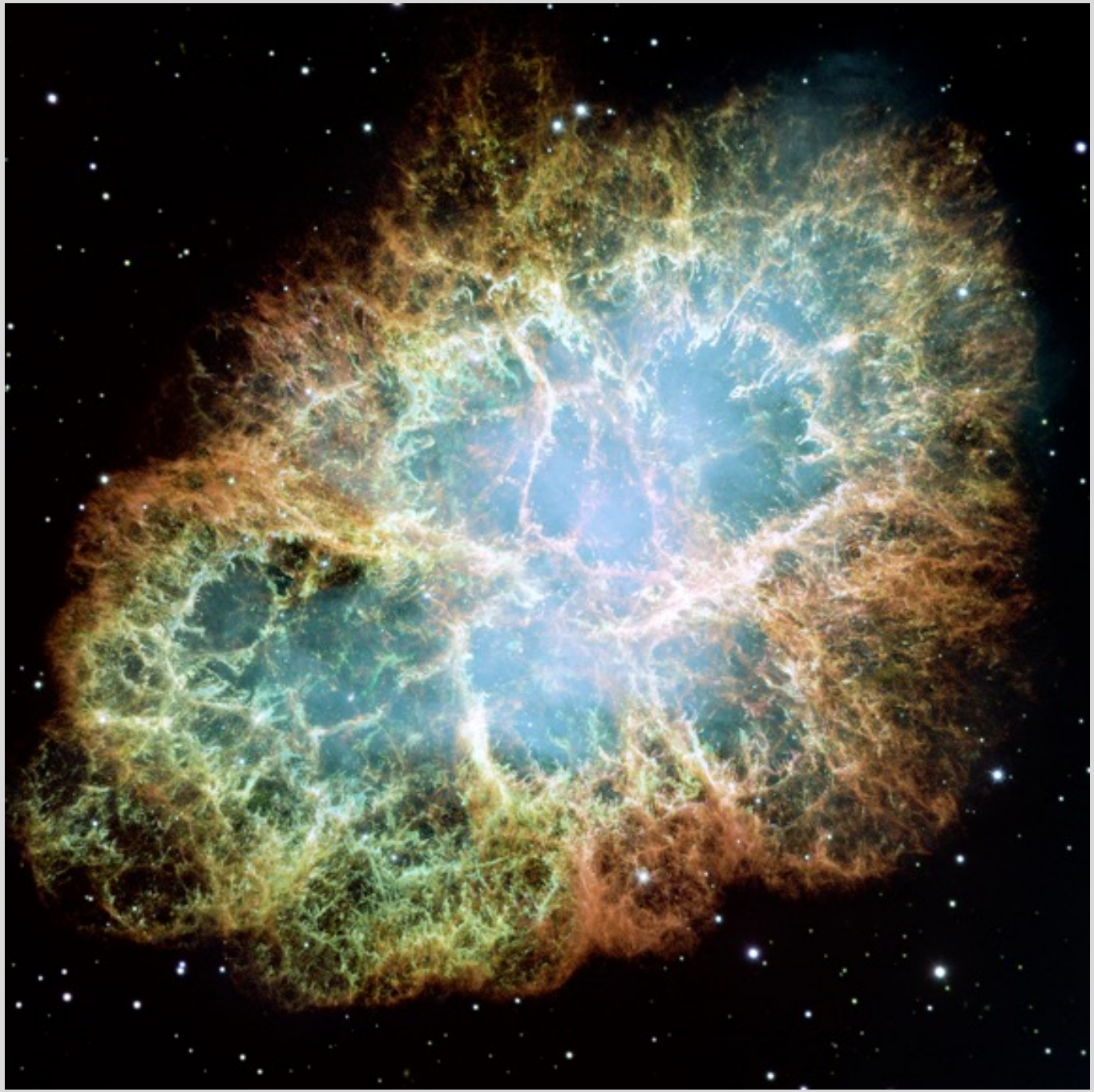
High Resolution Camera (HRC)
- 0.4” resolution, 30’ FOV
- Effective area ~ 200 cm^2 at 1 keV

High Energy Transmission Grating (HETG)
- $E/\Delta E = 1000$
- 0.4 – 10 keV

Low Energy Transmission Grating (LETG)
- Optimized for low energy (0.08-0.2 keV) spectroscopy

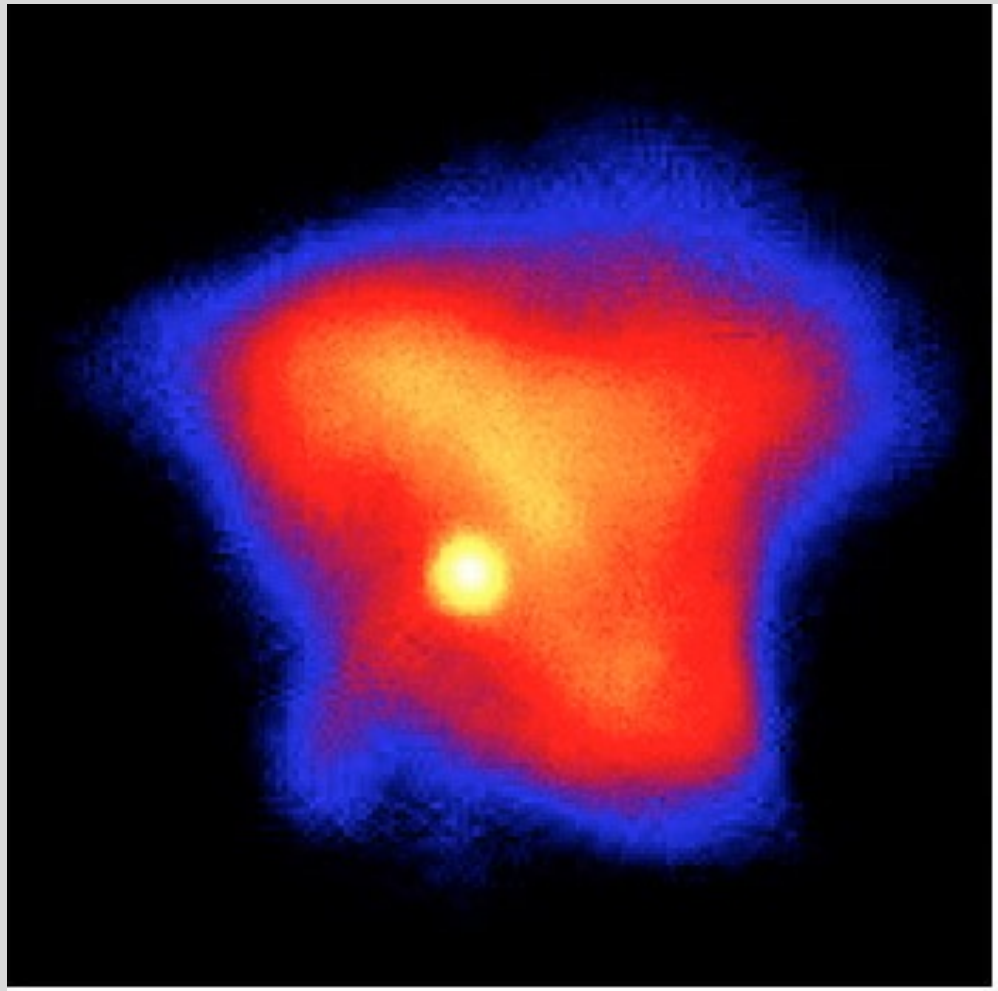


ROSAT vs Chandra: The Crab Nebula



Optical image

ROSAT vs Chandra:
The Crab Nebula



Crab Nebula, Rosat

Crab Nebula, Chandra

The Sloan Digital Sky Survey (skyserver.sdss.org)

Dedicated 2.5m telescope at Apache Point, NM
Main Survey ("Legacy") operated 2000 – 2008, through Data Release 7 (DR7)
Additional projects since then: SEGUE, BOSS, APOGEE, MARVELS, MANGA (now in DR18)

Imaging:

- Multiband *ugriz*, median seeing ~ 1.3"
- 54s exposure time by scanning gives g_{lim} = 22.2
- ~ 1% photometric uncertainty
- 14,500 square degrees
- 208M galaxies, 260M stars

Fiber spectroscopy:

- R ~ 2000 spectra from 3800 – 9200 Å
- Redshift accuracy ~ 30 km/s
- Galaxies (r<17.8) and Quasars (i<19.1 or 20.2)
- ~ 2.4M galaxy spectra, 0.5M quasar spectra, 0.85M stellar spectra

SDSS Main Survey Data Products: skyserver.sdss.org

Calibrated Images and Spectra:

- Quick look format
- Reduced fits files

Data Products (Imaging):

- Magnitudes, colors
- For galaxies: size, structural information, “photometric redshifts”

Data Products (Spectra):

- Redshift/velocity
- Emission/Absorption Line measurements
- Spectral classification

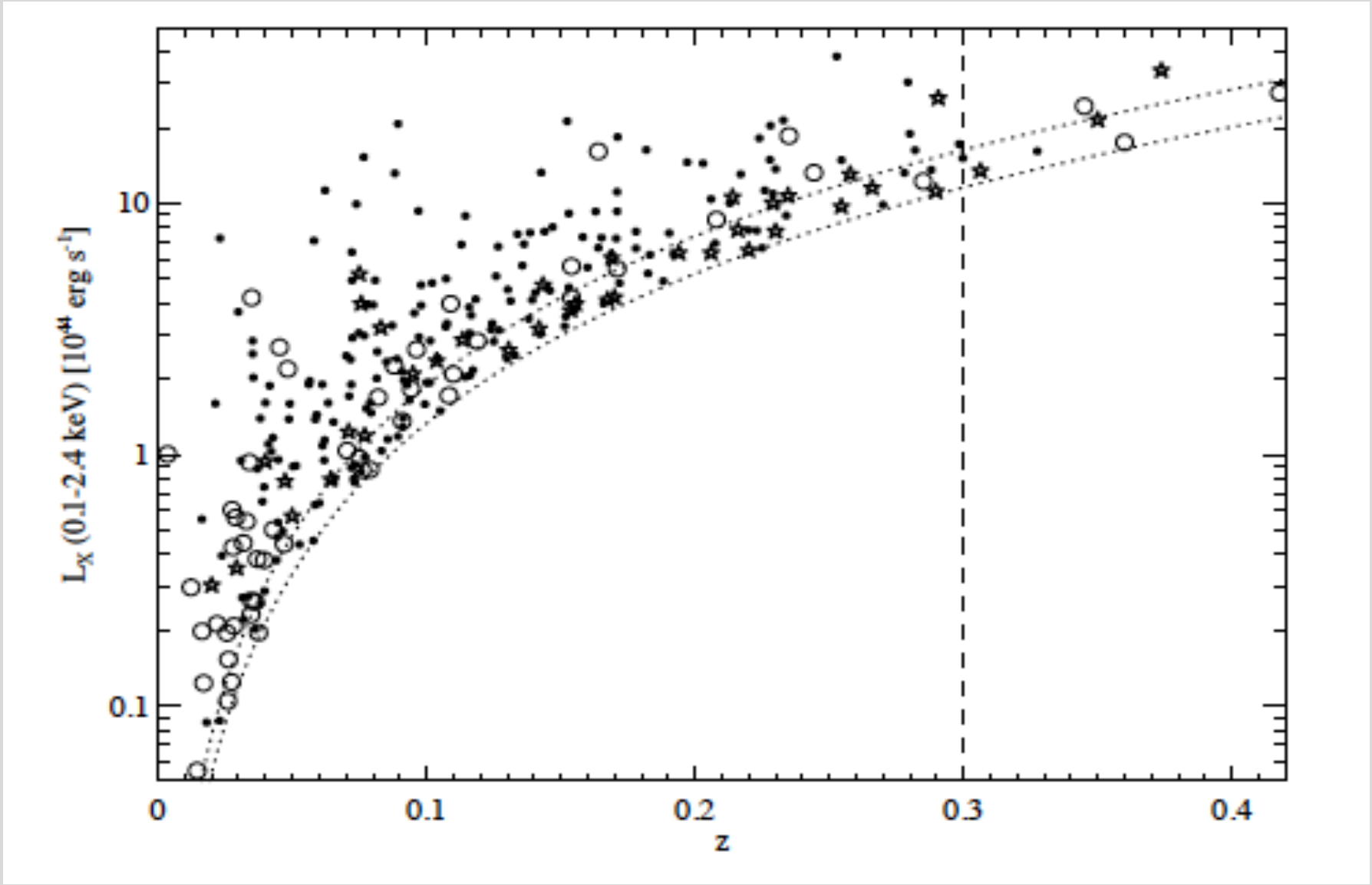
Catalogs, for example:

- Luminous Red Galaxies
- Quasar catalog
- White dwarf catalog
- Moving objects

The ROSAT Brightest Cluster Sample (Ebeling et al 1998)

Flux limited catalog of bright X-ray clusters (**N=206**)

("Flux limited" means that to be included in the catalog, the cluster must have an X-ray flux that is above some detection minimum.)



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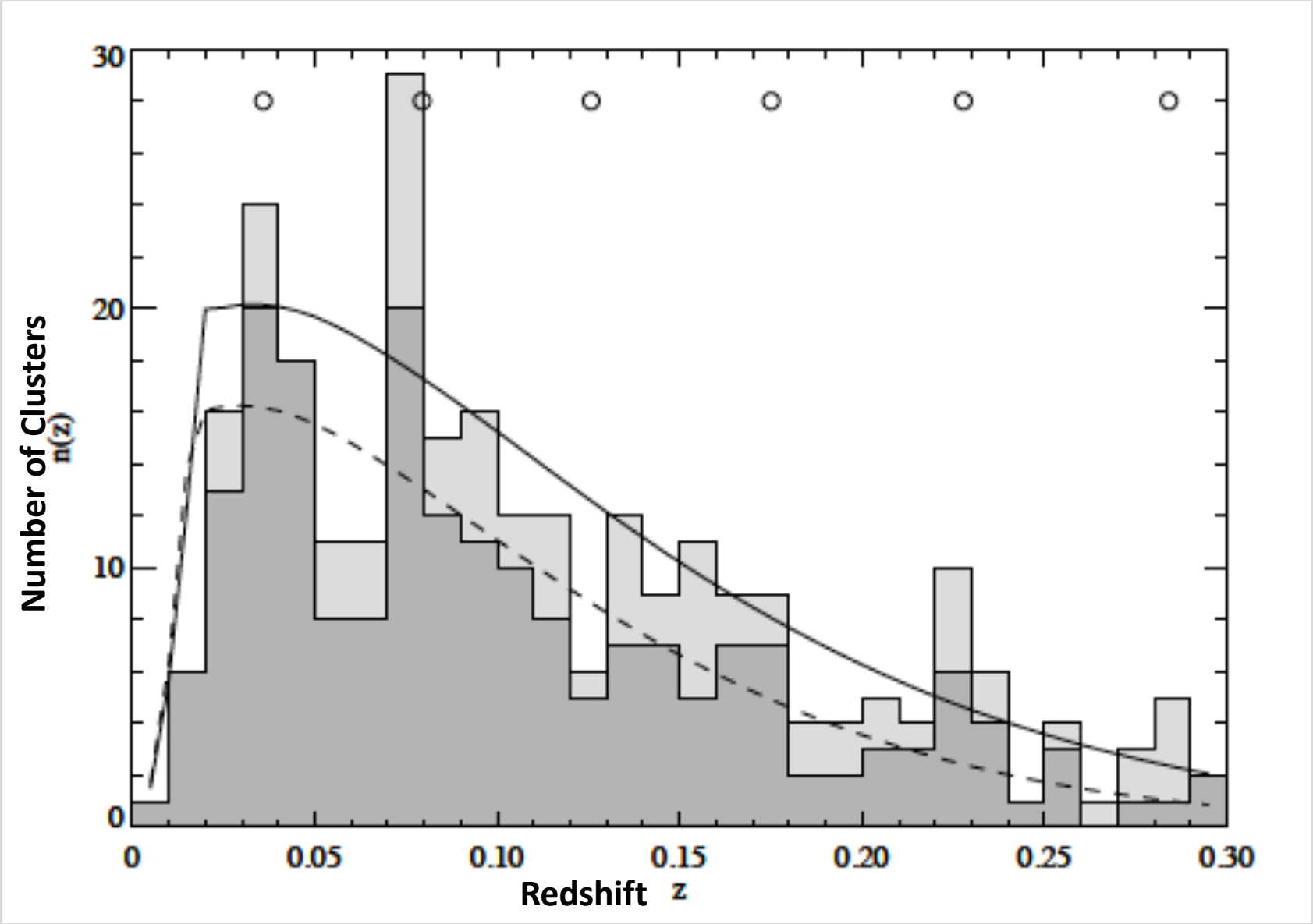
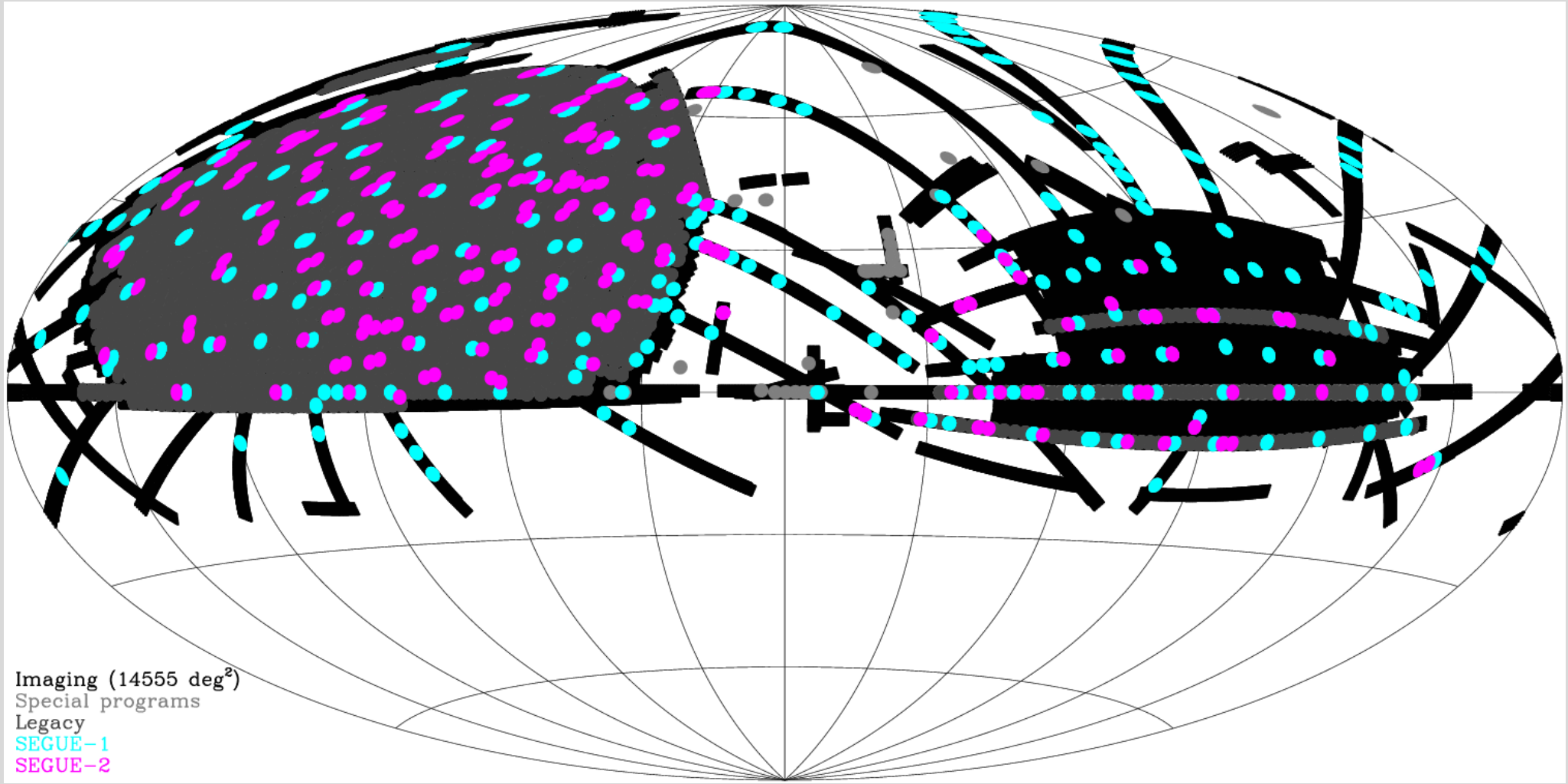


Picking Clusters from the Rosat catalog

1: Sky position: must be in the SDSS survey area (“footprint”)
(**N=206 → N=159**)

All sky RA/dec map of SDSS coverage



Picking Clusters from the Rosat catalog

2: Cluster properties: we want **massive clusters**.

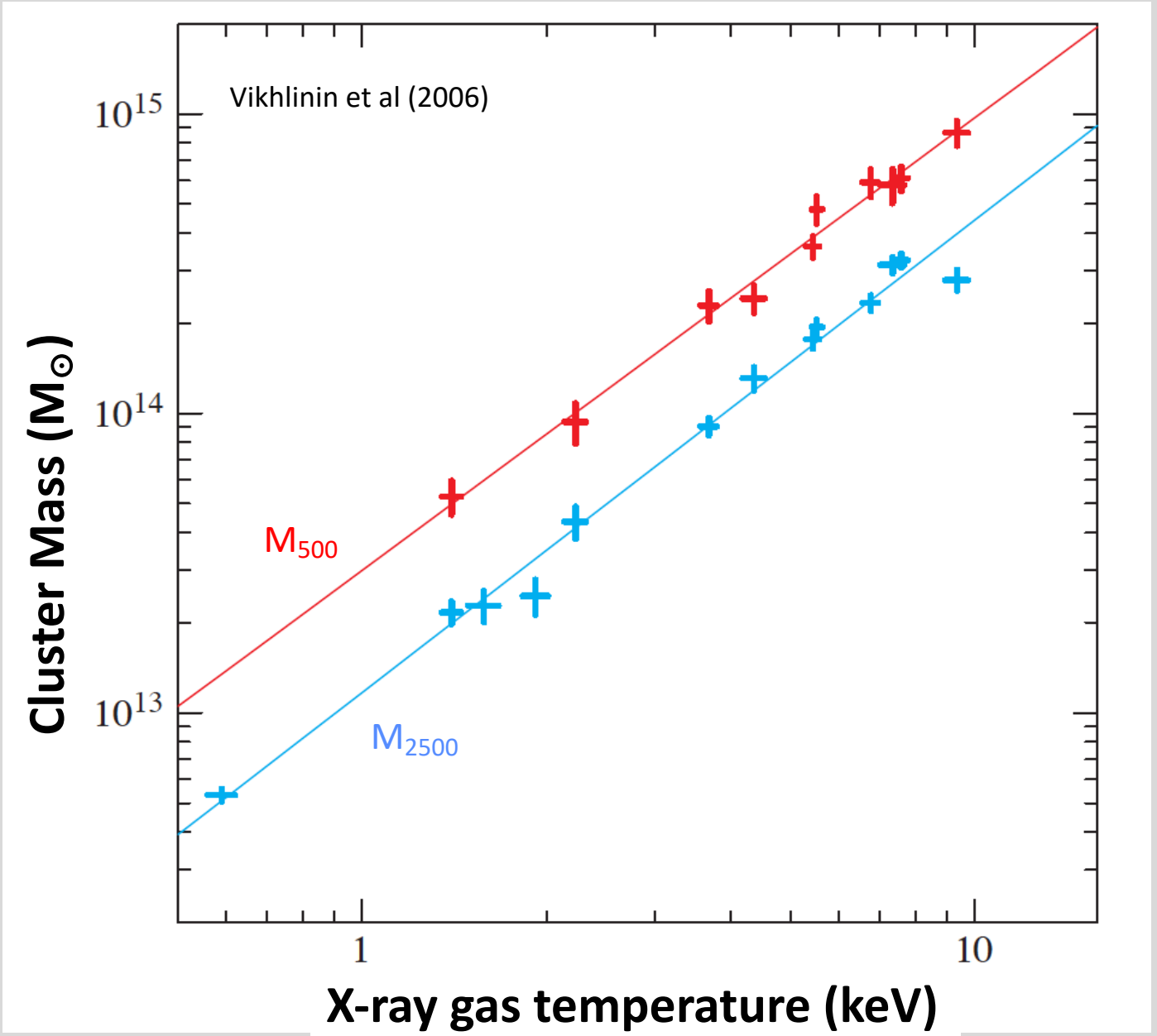
Look at relationship between cluster mass and cluster X-ray temperature. Massive clusters have hotter gas.

M_N = cluster total mass contained within a radius with an density of N times the average density of the universe.

Let's select clusters with mass > 10^{14} M_{sun}

kT > 4 keV

(N=159 → N=111)



Picking Clusters from the Rosat catalog

3. Distance:

- We want them to fit on Chandra X-ray imager's field of view (array of four 8'x8' CCDs).

z>0.035

- We want to understand their optical morphology and nuclear spectra.

(SDSS imaging resolution ~ 1" and fiber diameter ~ 3")

z<0.075

(N=111 → N=14)

D_A: angular size distance

z	D_A (Mpc)	1 Mpc (arcmin)	1 arcsec (kpc)
0.025	102	34	0.5
0.035	142	24	0.7
0.05	199	17	1.0
0.075	290	12	1.4
0.1	376	8	1.8

The angular size of a 1 Mpc object

The physical size of a 1 arcsec pc object

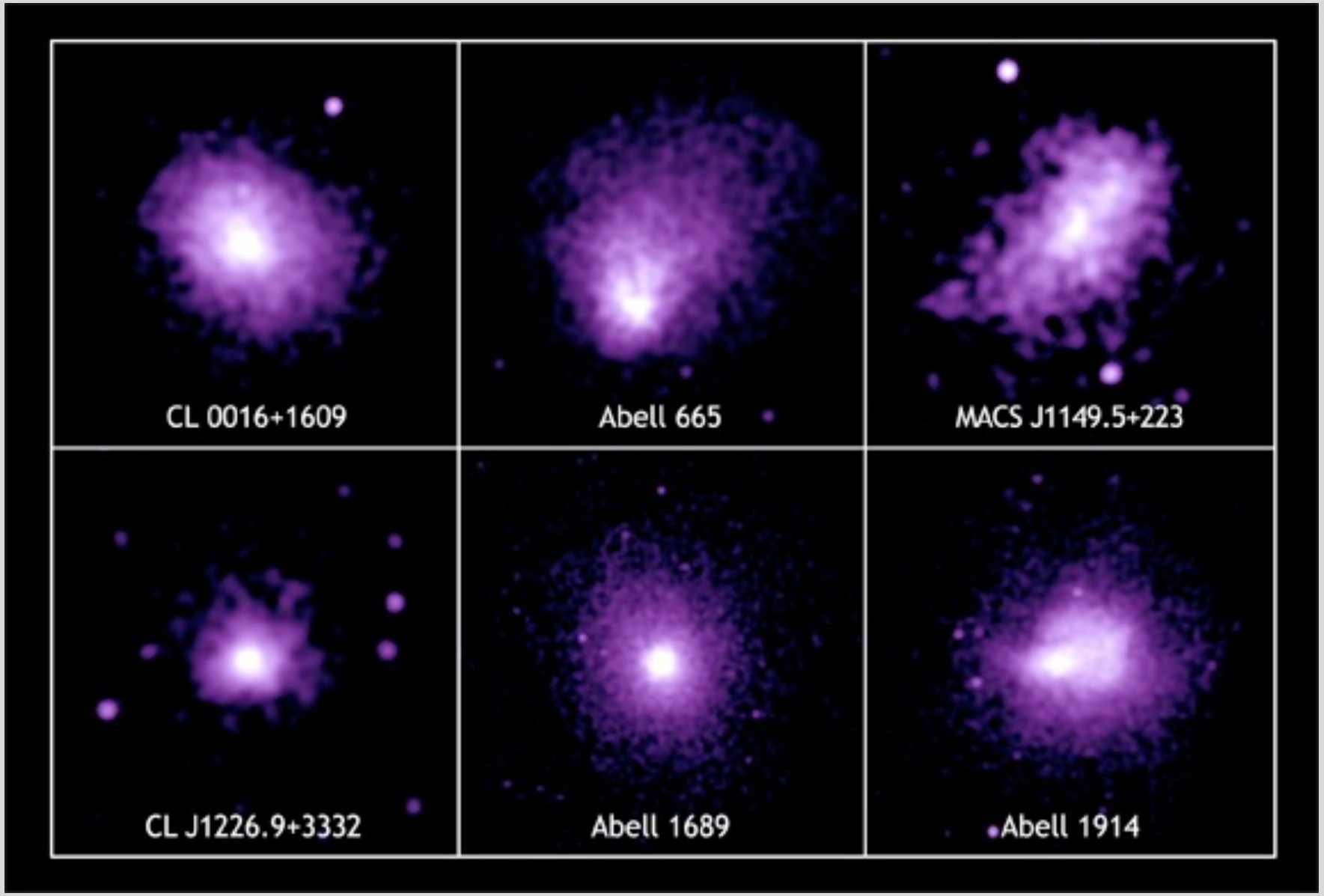
Picking Clusters from the Rosat catalog

so far….

- SDSS footprint
- kT > 4 keV
- 0.035 < z < 0.075

4. There must be X-ray imaging data in the Chandra data archive!

Chandra ACIS pointings



Final Cluster Targets

Cluster	RA (deg)	Dec (deg)
Abell 2065	230.62156	+27.70763
Abell 2063	230.77116	+08.60859
Abell 1795	207.21886	+26.59160

You will estimate the cluster redshift using data from the SDSS archive.

When calculating intrinsic properties of the cluster or the galaxies (physical sizes, luminosities, etc) remember that at these distances you must use the cosmologically correct luminosity distance (D_L) and angular size distance (D_A) to do the calculations.

```
from astropy.cosmology import Planck18 as cosmo
redshift = 0.05 # or whatever
DL = cosmo.luminosity_distance(redshift)        # in Mpc
DA = cosmo.angular_diameter_distance(redshift) # in Mpc
absmag = appmag – 5*np.log10(DL.value*1E6) + 5 # remember magnitude equation needs distance in parsecs!
r_phys = r_arcsec * DA.value / 206265.          # physical size will be in whatever units DA is in
```