Ultra-luminous X-ray Sources in Chandra Source Catalog 2.0 and a Master Catalog of Nearby Galaxies

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Introduction

Importance of statistical study of ULXs

Why ULXs are important

- physics at extreme accretion rates ($> L_{\mathrm{Edd}}$, beaming)
  (see Kaaret at al. 2017; King 2008)
- heating of the universe during the epoch of reionization
  (e.g. Jeon et al. 2014)
- exotic objects like IMBHs
  (e.g. Earnshaw et al. 2016)
- progenitors of GW sources
  (e.g. Belczynski et al. 2016)

Difficulties...

- measuring compact objects mass
- identifying donors (e.g. M31: Yukita et al. 2017)
- various challenges (e.g. analyzing spectra, exposure times)

Statistical studies of ULXs

- indirect way to understand their nature & evolution
  (e.g. Liu 2005; Swartz 2011; Wang 2016)
- direct comparison with population synthesis codes
  (e.g. Fragos et al. 2013; Zezas et al. 2014)

Usual suspects

- # of ULXs per galaxy, luminosity functions
  (see Fabbiano 2006)
- dependence on the type of galaxy
  (Swartz et al. 2011; Plotkin et al. 2014)
- host galaxy properties (SFR, $M_\star$, metallicity)
  (e.g. Basu-Zych et al. 2016)

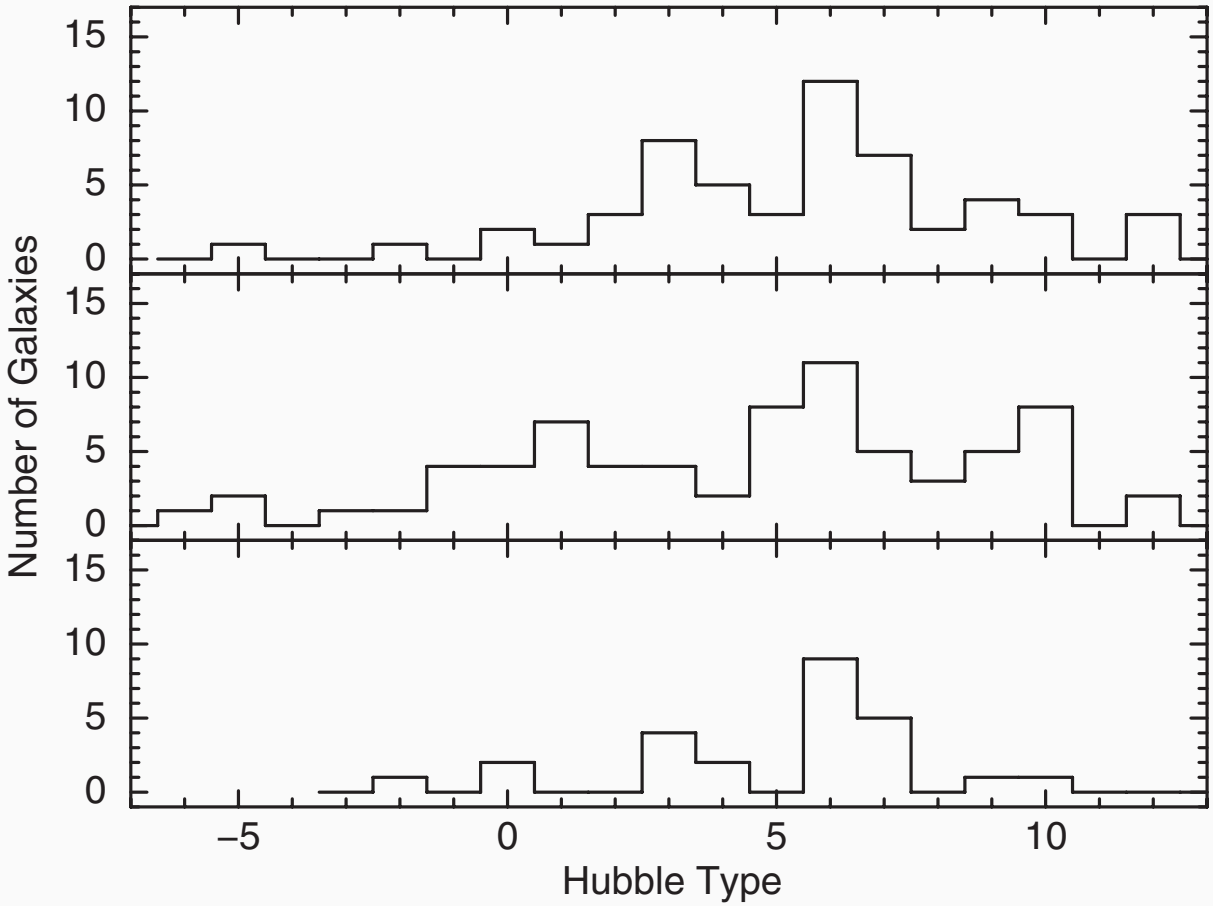
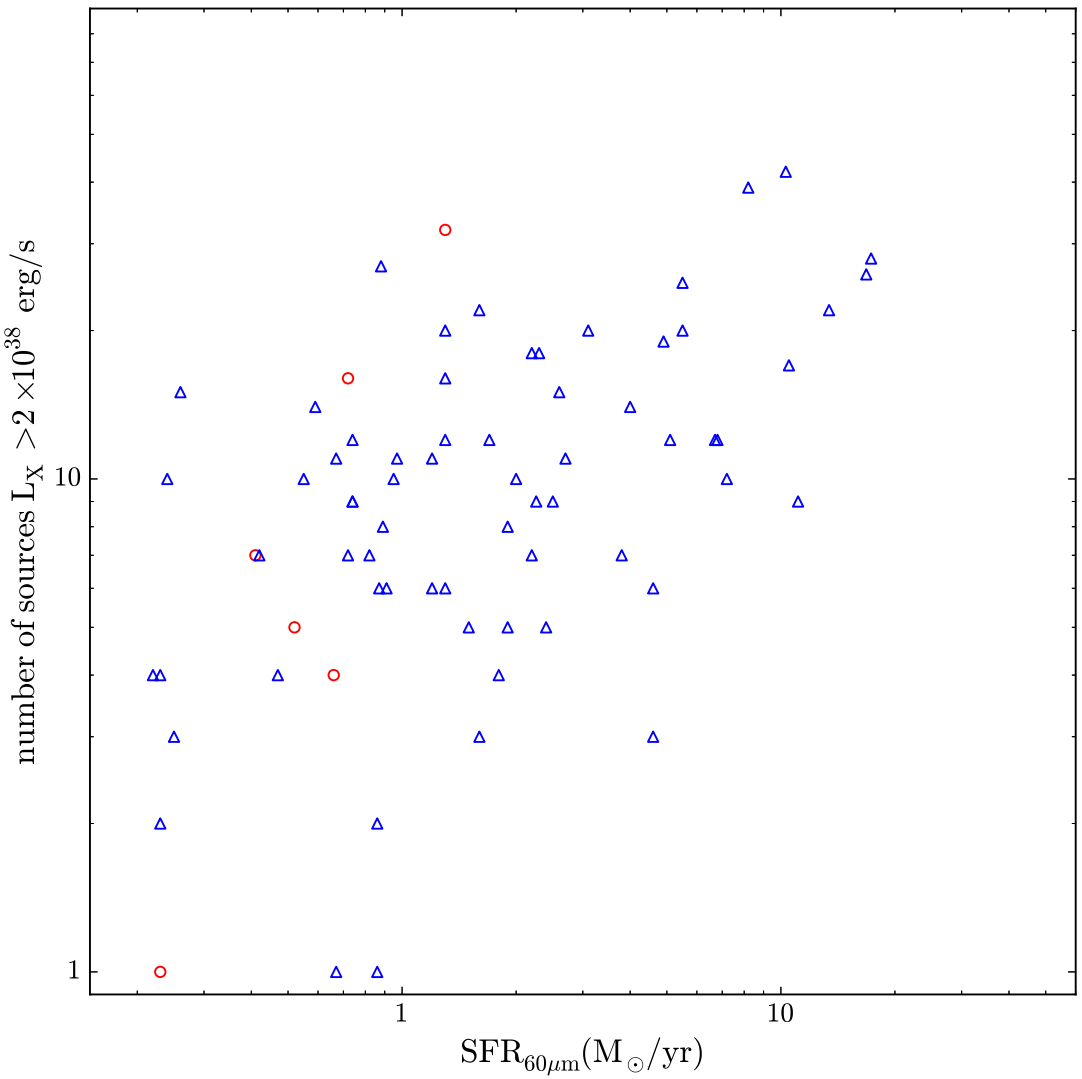


Figure 3. Distribution of revised Hubble types for (top panel) galaxies hosting ULX candidates, (middle panel) galaxies without ULX candidates, and (bottom panel) galaxies hosting ULXs with estimated luminosities in excess of 3×10^{39} erg s^{-1}.

Wang et al. 2016



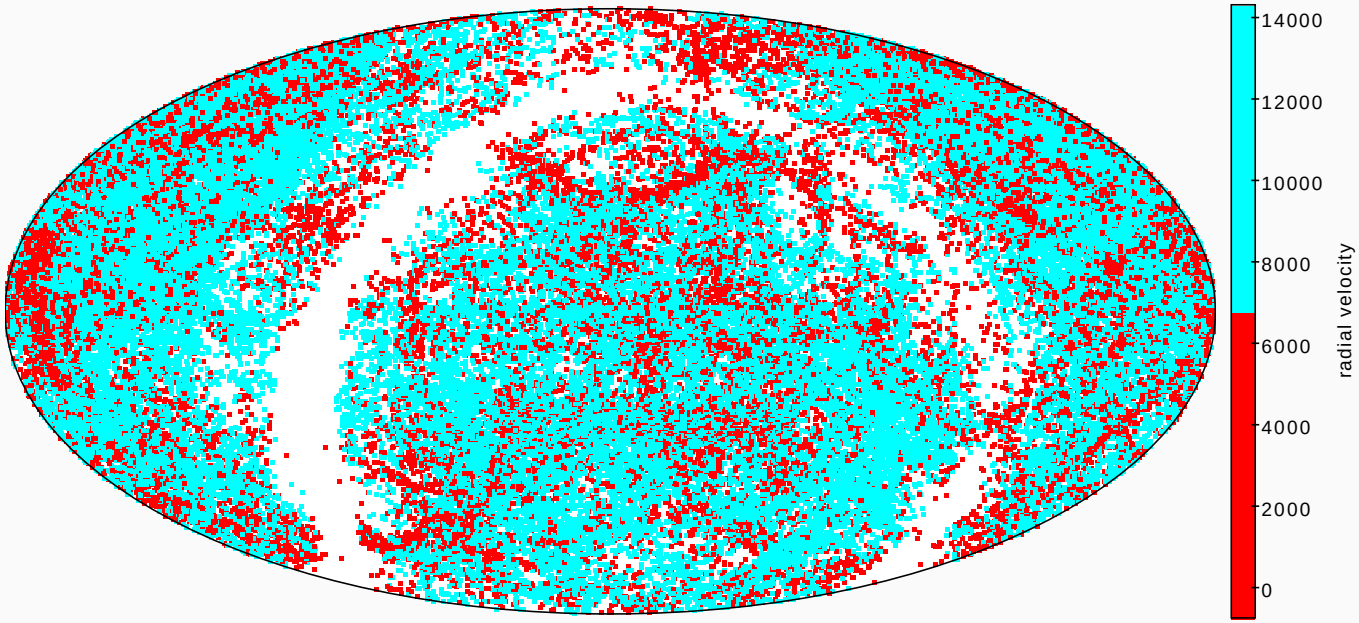
Our approach: first steps

- Master catalog of nearby galaxies with accurate positions, distances, · · ·
- Cross-matching with multi-wavelength surveys:
  multiple star-formation indicators, estimates on stellar mass and metallicity
- Cross-matching with Chandra Source Catalog 2.0:
  data release in the end of the summer
- Description of ULX hosts / correlations

Master catalog

Master catalog: HyperLEDA subsample

- HyperLEDA catalog of $5.1M$ extragalactic objects (Makarov et al. 2014)
- homogeneous parameters and multiple designations
- volume-limited subsample: heliocentric velocity $<$ 14000 km/s (169K)
- astrometric uncertainty $<$ 10 arcsec



Master catalog: NED-D redshift-independent distances

$\sim 126K$ distance measurements for $\sim 31K$ objects (Steer et al. 2017)

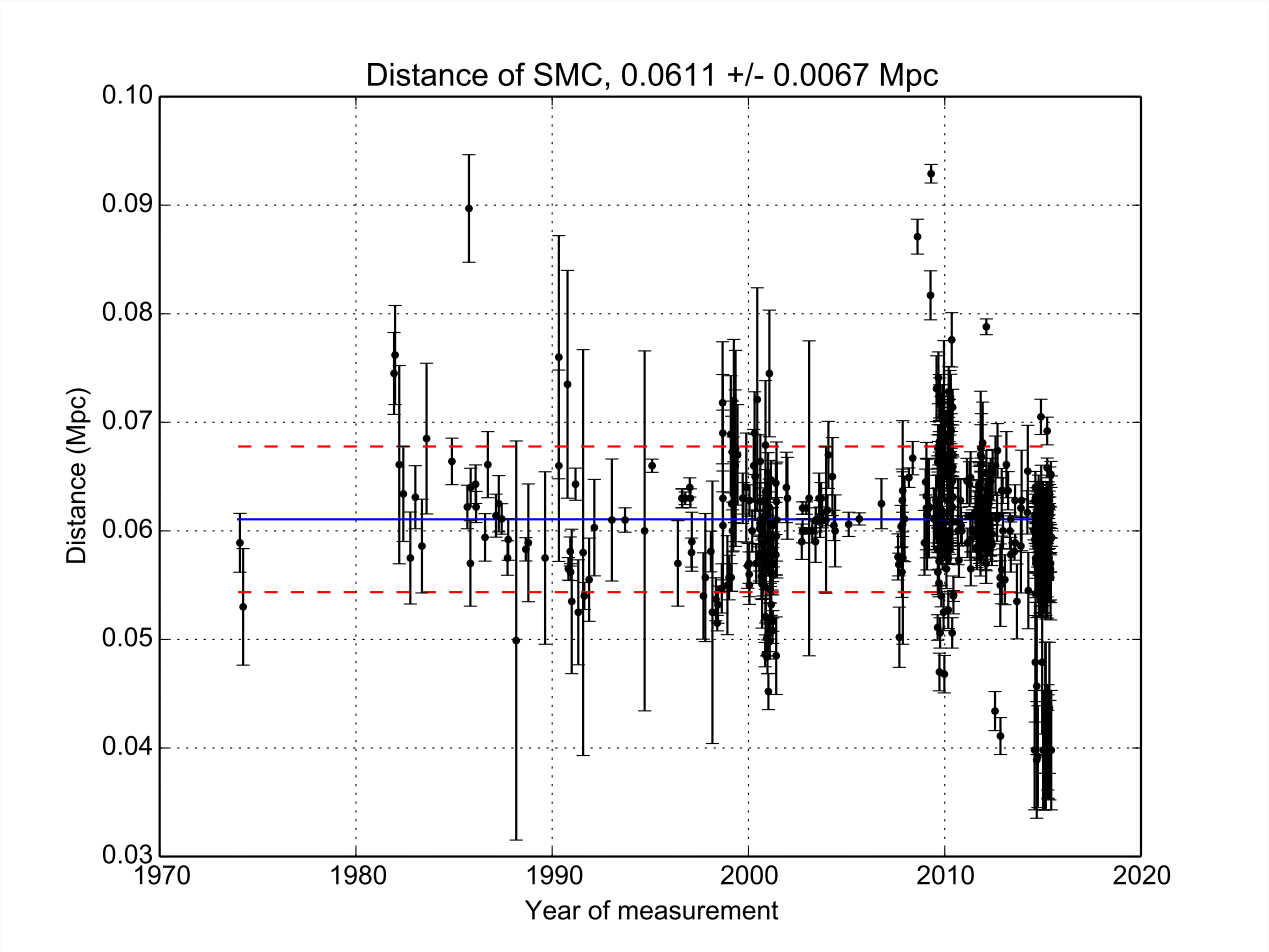


Figure 1: NED-D measurements for Small Magellanic Cloud

Master catalog: combining distances

Subsample: only 18 out of 77 methods — ignore non-galaxies

Resolver: manual check of > 500 references

Monte Carlo: sample N points from M distributions (mean, std.err of measurement) with weight defined by uncertainty and year of measurement.

Advantage: accounts for spread & individual uncertainties

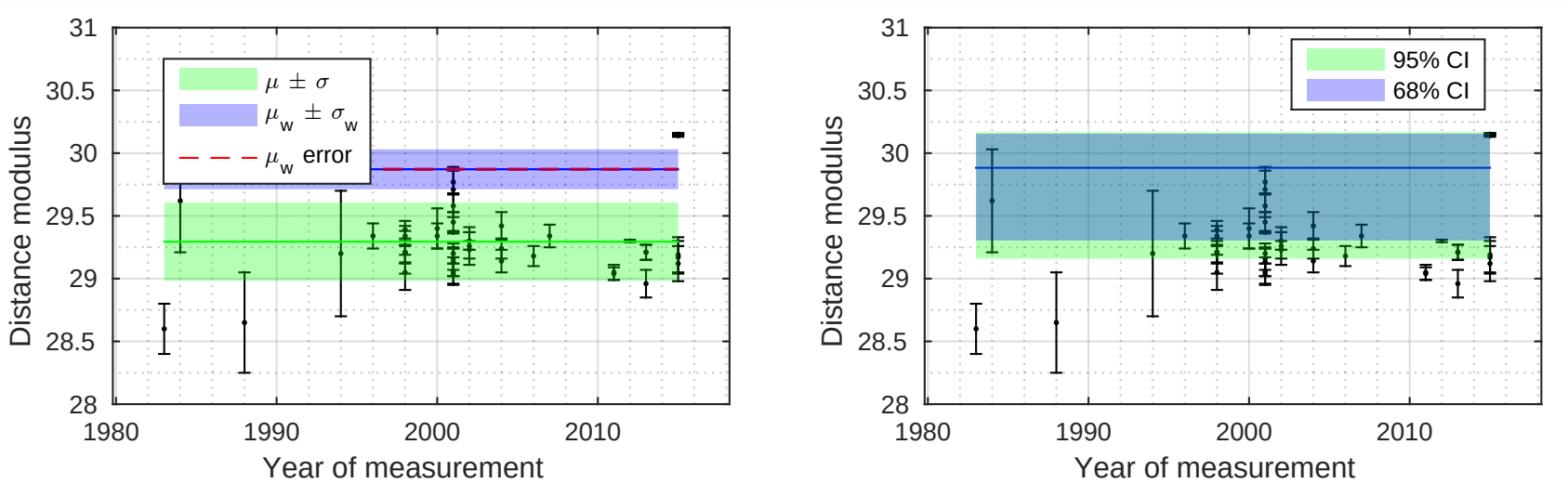


Figure 2: M101 distance measurements

Master catalog: accounting for peculiar velocities

For some galaxies no uncertainties are reported or no measurements in NED-D.
Hubble law does not consider peculiar velocities: use NED-D galaxies of same D

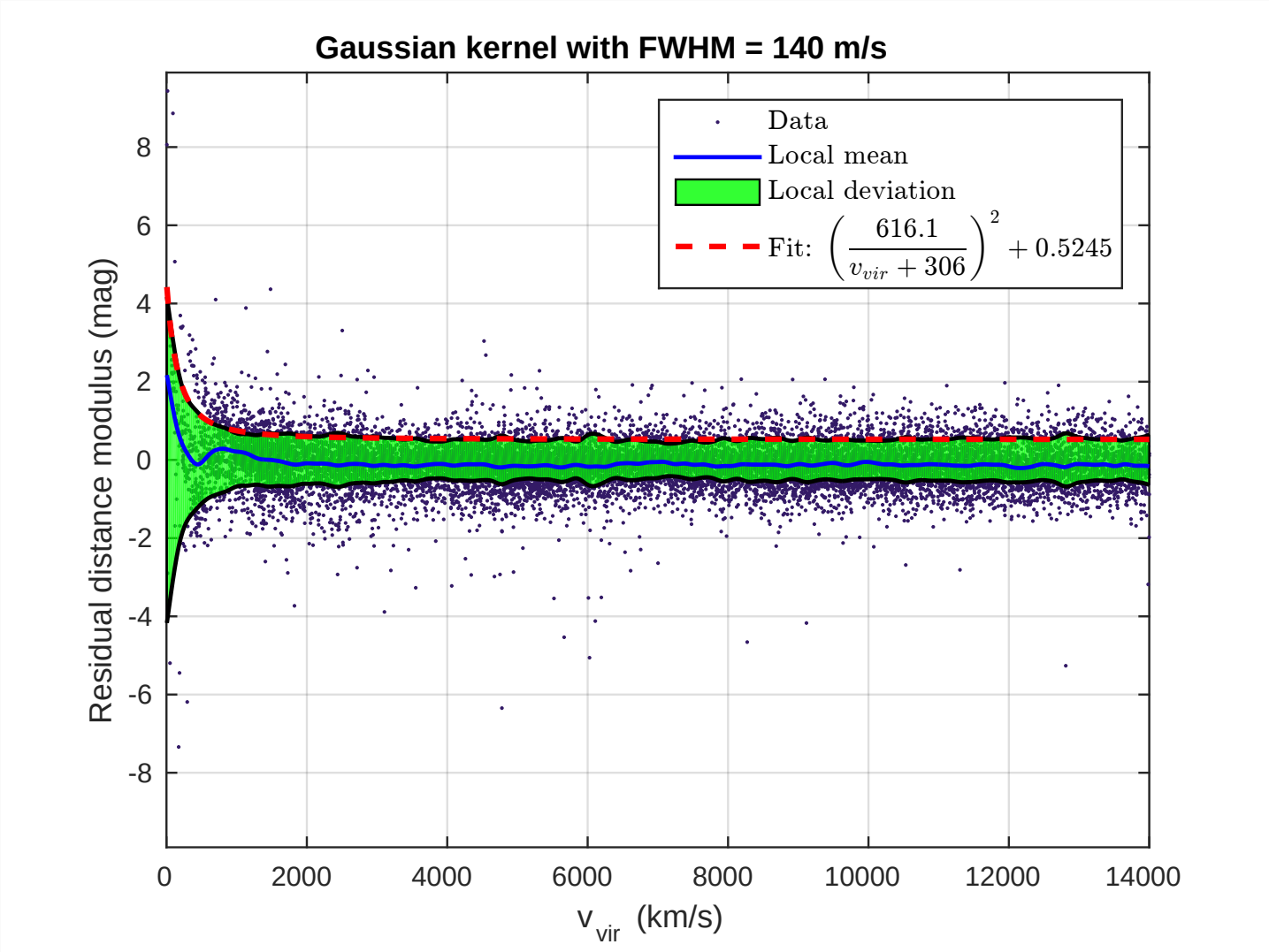


Figure 3: Velocity dispersion

Master catalog: cross-matching with other catalogs

SFR, $M_\star$, metallicity:

- GALEX
- SDSS
- WISE
- AKARI
- IRAS
- 2MASS

More to be included

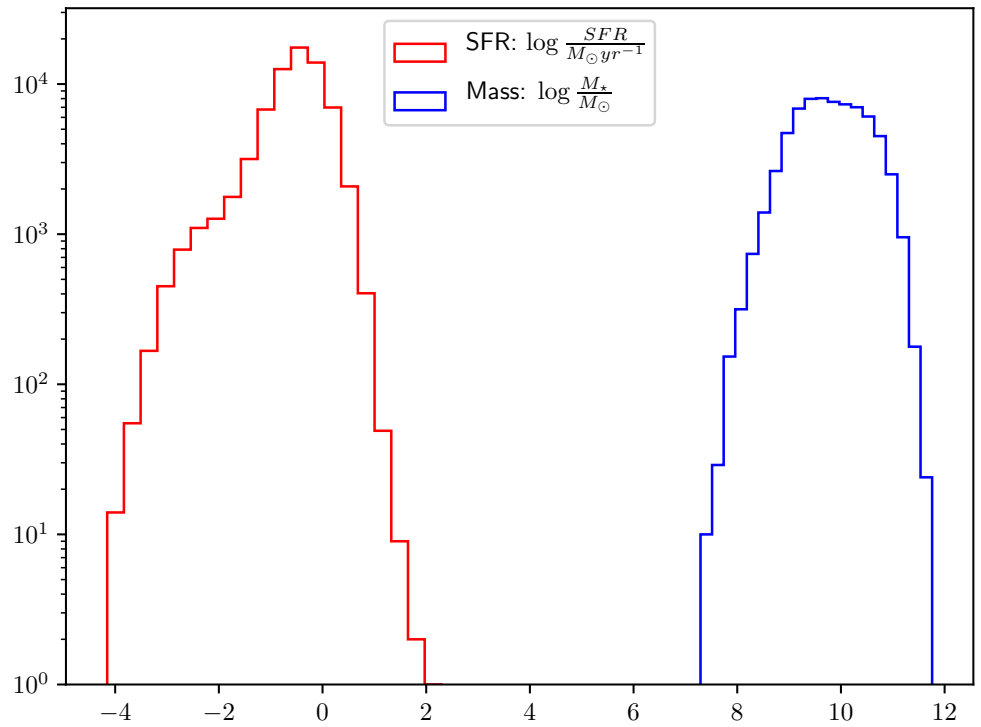


Figure 4: Range of star-formation rates & stellar masses

Preliminary results

Cross-matching with Chandra Source Catalog

Preliminary results (waiting for August!)

- 24300 point sources in 1514 galaxies ($D \lesssim 200$Mpc)
- 2289 ULX candidates in 1279 galaxies ($\times 3$ improvement)

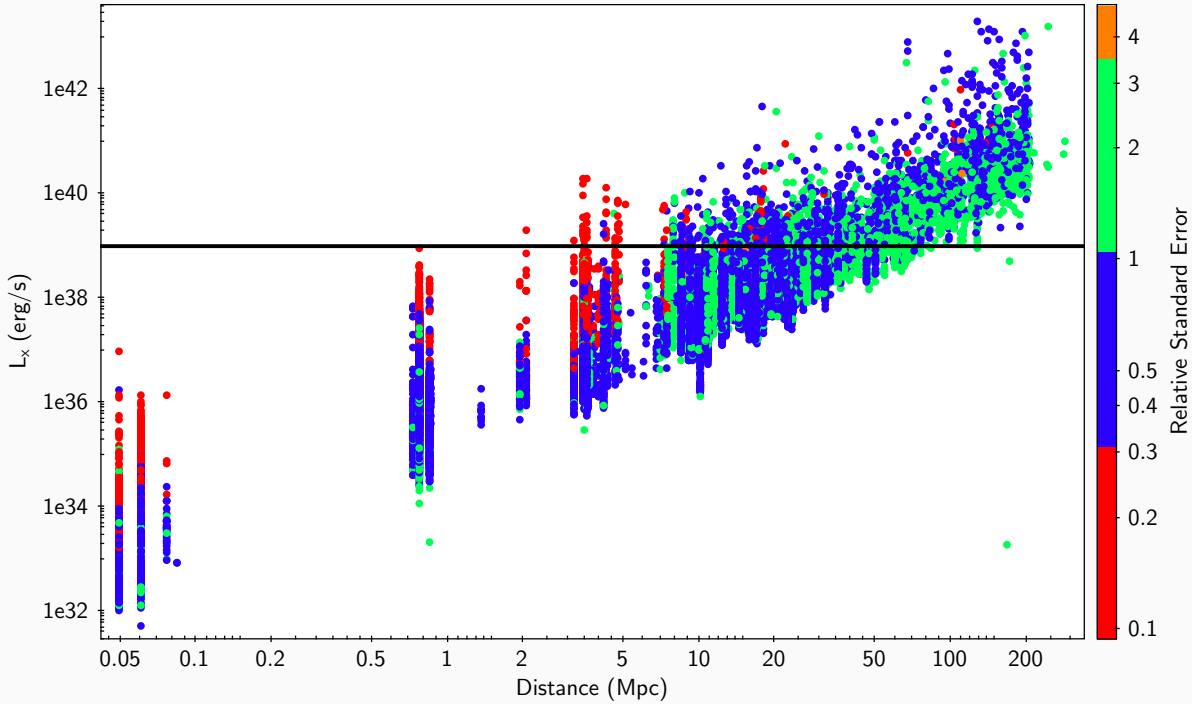
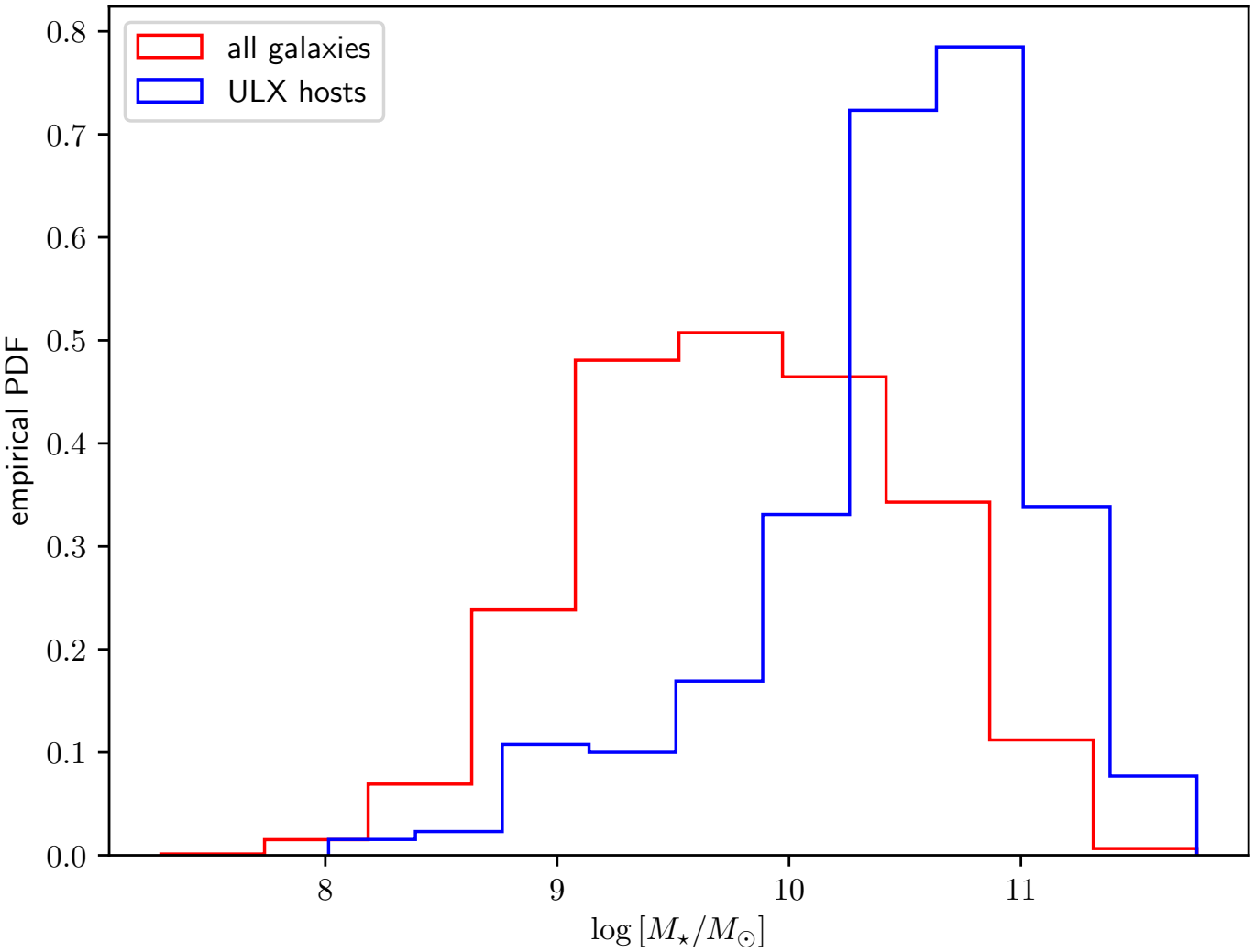
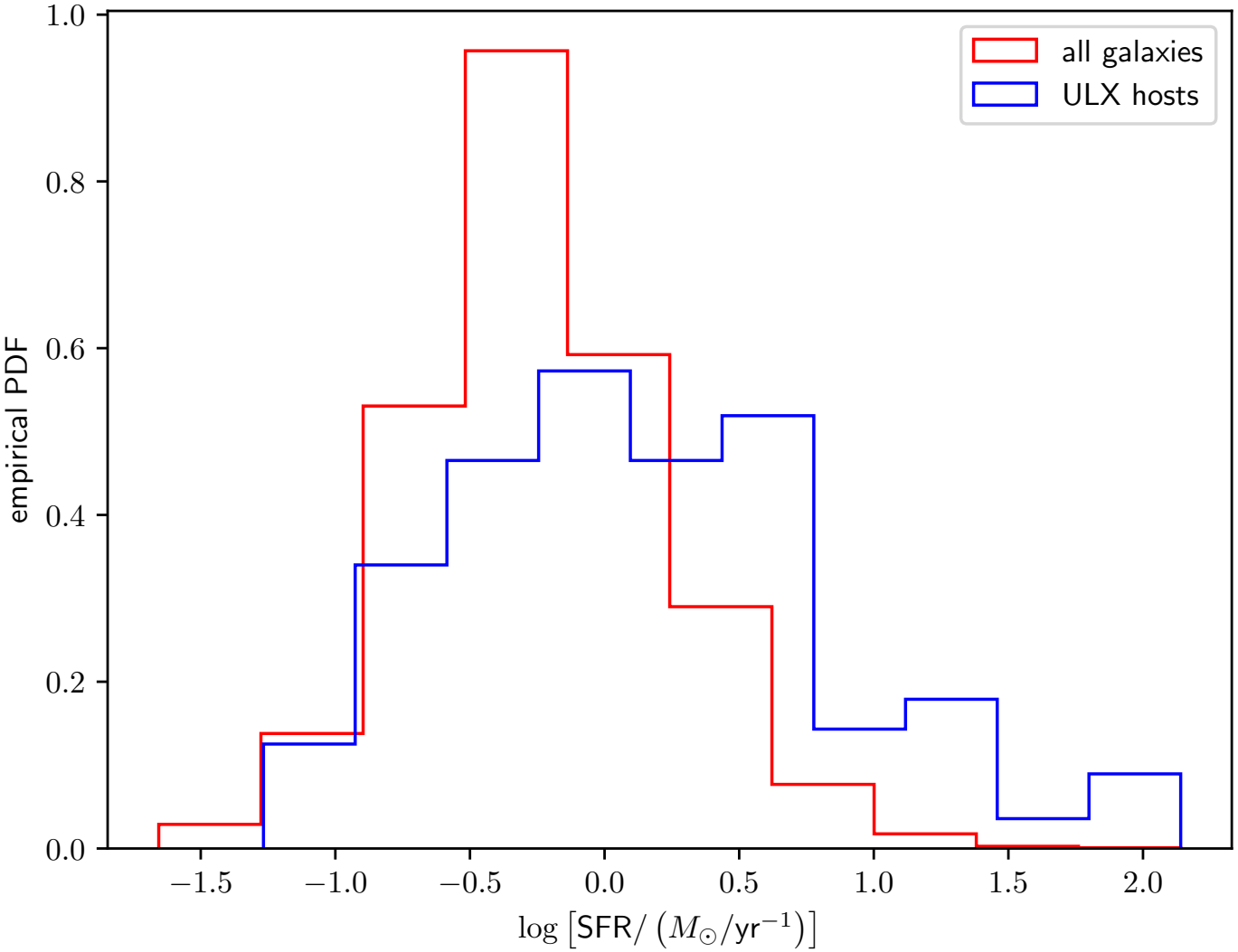


Figure 5: Luminosity of the X-ray sources in our galaxies. **Line**: ULX lower limit

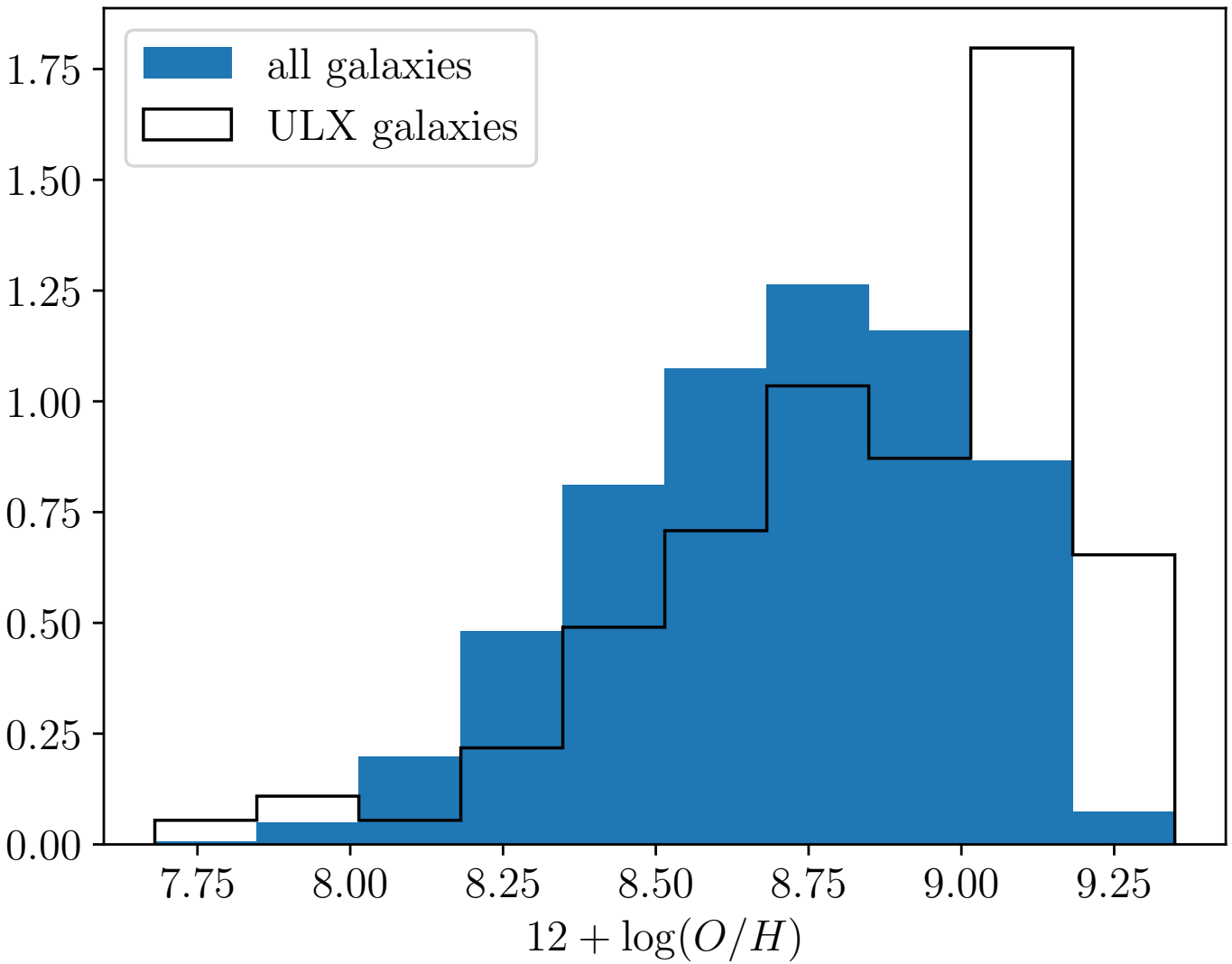
Stellar mass



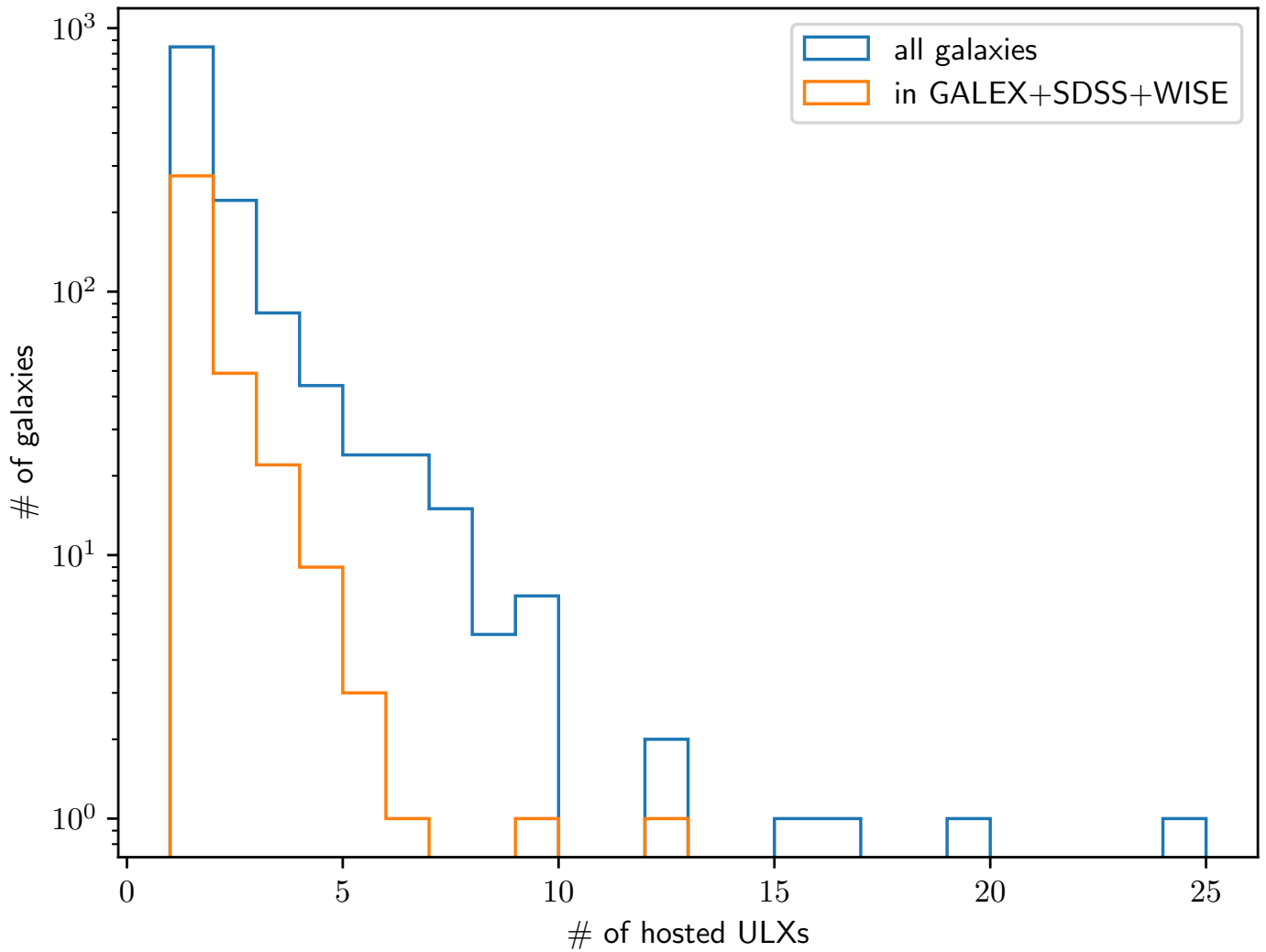
Star-formation rate



Metallicity



Number of ULXs per galaxy



Next steps...

1. Compute as a function of SFR, sSFR, $M_\star$ and metallicity:
   - # of ULXs per galaxy
   - ratio of sources $\frac{N\left(10^{38} < L_X < 10^{39}\right)}{N\left(> 10^{39}\right)}$ reflecting the slope of the LF)
   - rate of hyperluminous X-ray sources (HLXs; $L_X > 10^{40}$)
2. Detailed SED modeling to add age to the parameters
3. Method to address confusion effects:
   - semi-analytical approach
   - simulations with population synthesis

Summary

- A catalog of all observed galaxies in the nearby universe + distances
- Hundreds of parameters. To be enriched in the future.
- The most up-to-date catalog of ULXs.
- Occupation fraction as a function of host galaxy parameters.
- Models to account for source confusion.