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Ultraluminous X-ray source populations in the local universe & host galaxies

Importance of Ultraluminous X-ray sources (ULXs)

- Physics at extreme accretion rates:
Super-Eddington accretion, **beaming**

    (see Kaaret+ 2017; King 2008)

- Heating of the universe during the epoch of **reionization**

    (e.g. Jeon+ 2014)

- **Exotic** objects (see Pulsar ULXs, HyperLuminous X-ray sources, Intermediate Mass Black Holes)

    (e.g. Earnshaw+ 2016; Isreal+ 2017; Wiktorowicz+ 2015; Fürst+ 2016; Bachetti+ 2014; Madau+ 2001, Colbert+ 1999)

- Progenitors of **gravitational wave** sources

    (see Belczynski+ 2016)

Two ways (and reasons) to study of ULXs

Individual studies

- Compact Objects

- Accretion physics

difficulties...

- Measuring CO mass

- Identification of donors (e.g. Yukita+ 2017)

Statistical studies

- Host galaxy properties: formation & evolution

- Input for population synthesis

difficulties...

- ULXs are rare (e.g. Kilgard+ 2002)

- Few hosts (e.g. Swartz+ 2011)

Statistical studies of ULX populations

- Connecting the populations with bulk properties of the host galaxies such as:
  - Type
  - (Specific) star formation rate
  - Stellar mass
  - Metallicity

    Anastasopoulou+ 2018, Wang+ 2016, Plotkin+ 2014, Basu-Zych+ 2013, Swartz+ 2011; Mapelli+ 2010; Colbert 2004; Kilgard+ 2002

- # ULXs per galaxy & luminosity functions

    see Fabbiano 2006
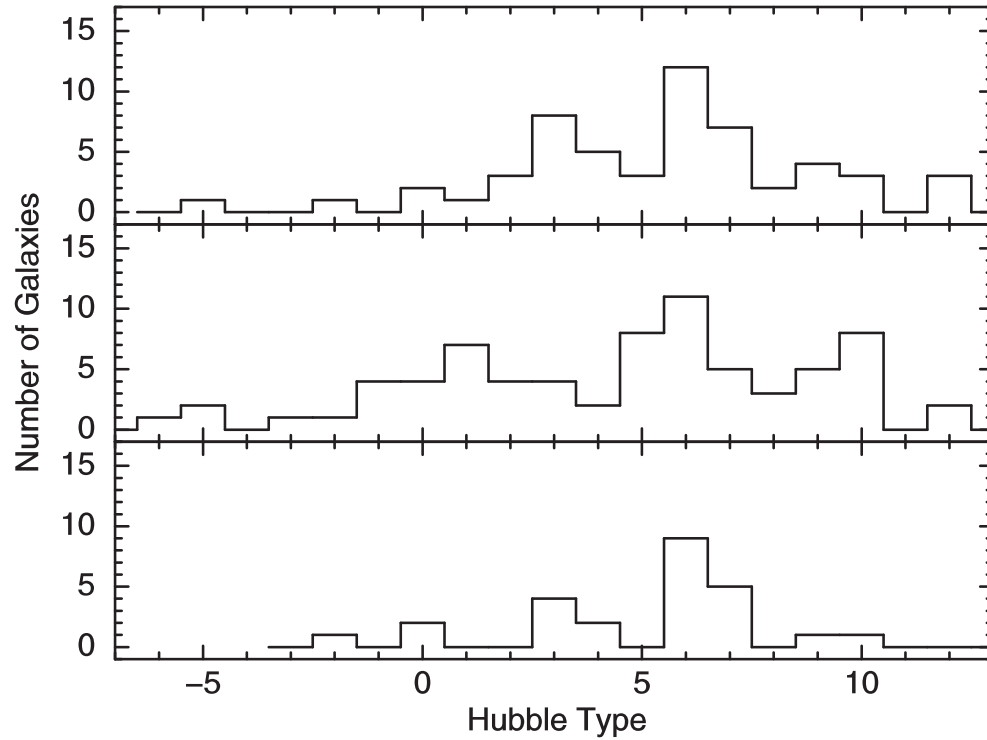
Figure 3. Distribution of revised Hubble types for (top panel) galaxies hosting ULX candidates, (middle panel) galaxies without ULX candidates, and (bottom panel) galaxies hosting ULXs with estimated luminosities in excess of 3×10^{39} erg s^{-1}.
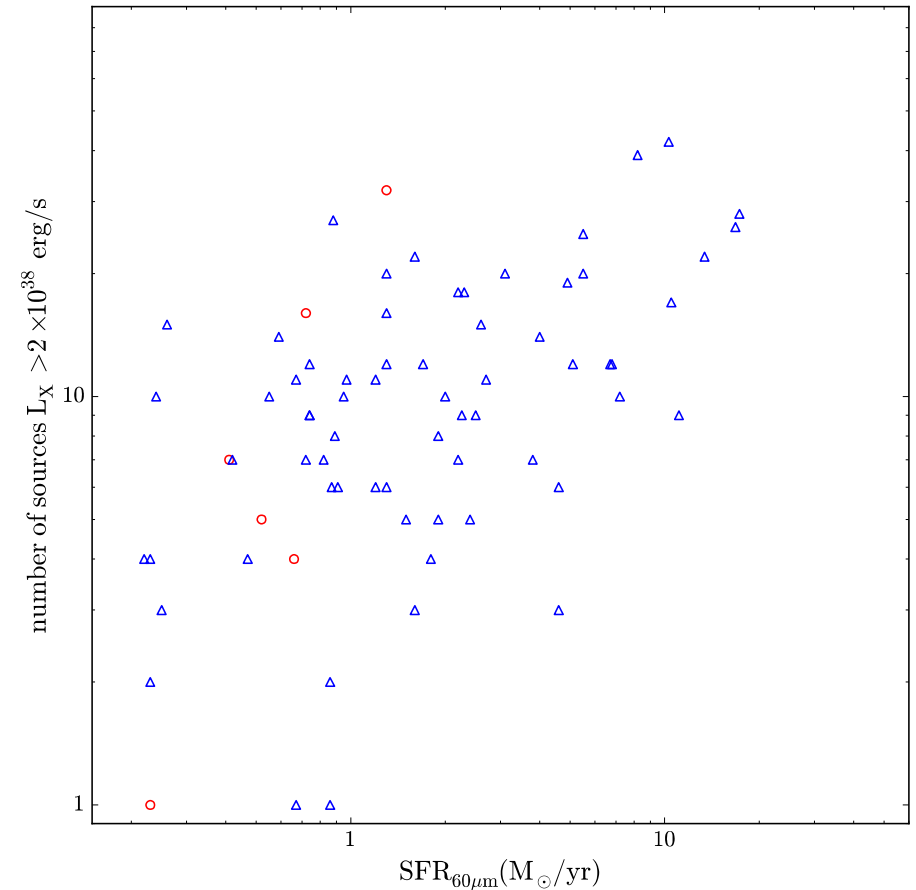
Towards a census of ULX populations and host galaxy properties

- We need a galaxy sample with:
  - all known galaxies in the local universe (< 200 Mpc)
  - accurate positions, distances
- bulk properties of galaxies (multi-wavelength data)
  - star formation rate
  - stellar mass
  - metallicity
- Cross-matching with *Chandra* Source Catalog 2.0

Galaxy sample

HyperLEDA galaxies with

- v < 14000 km/s ➡ ~ 163 000 galaxies out of 5.3M

- astrometry ~ 1 arcsec

Toulouse, 2018/5/22
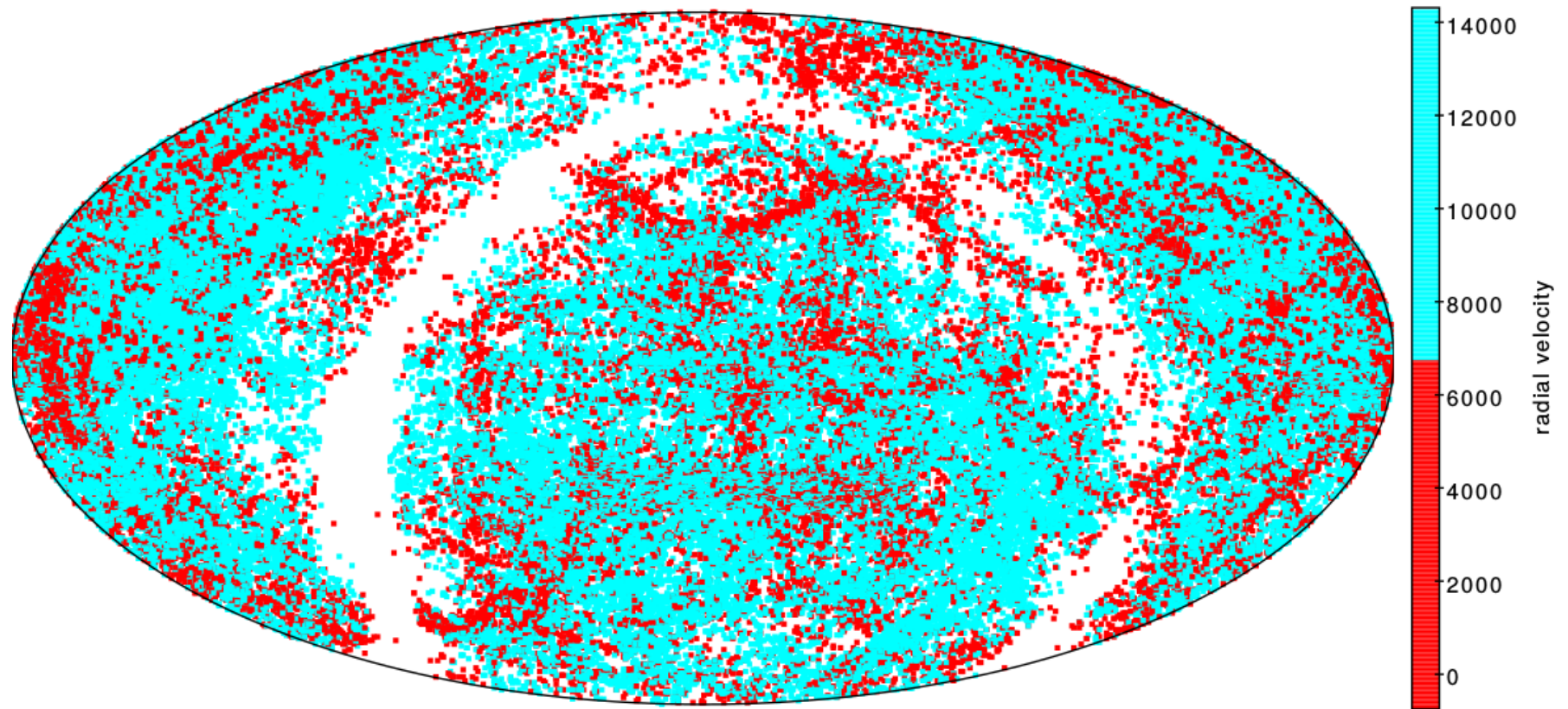
NED-D: selecting redshift-independent distances

- 200 K measurements for 77 K galaxies, with 76 distance indicators (e.g. Kurtz et al. 2002)

- Clearing the sample from

  - GCs, galaxy clusters, supernovæ, streams, etc.

  - inaccurate and understudied indicators

- Multiple measurements from same reference. ~600 filters

NED-D: merging redshift-independent distances

- Multiple measurements for each galaxy.

- Removing outliers (5σ)

- Gaussian mixture. Weights based on (i) uncertainty and (ii) year

Toulouse, 2018/5/22
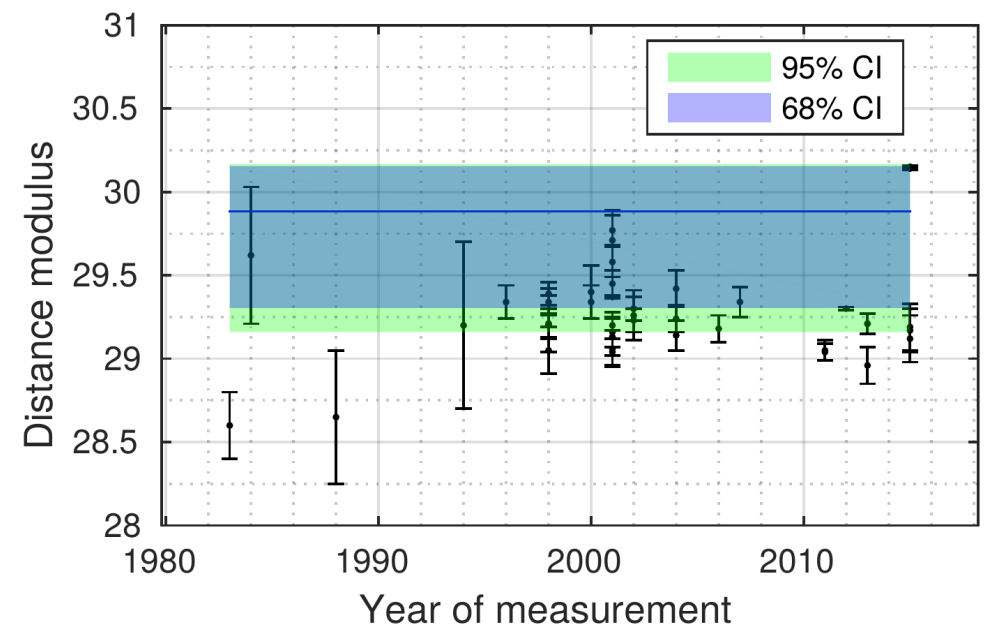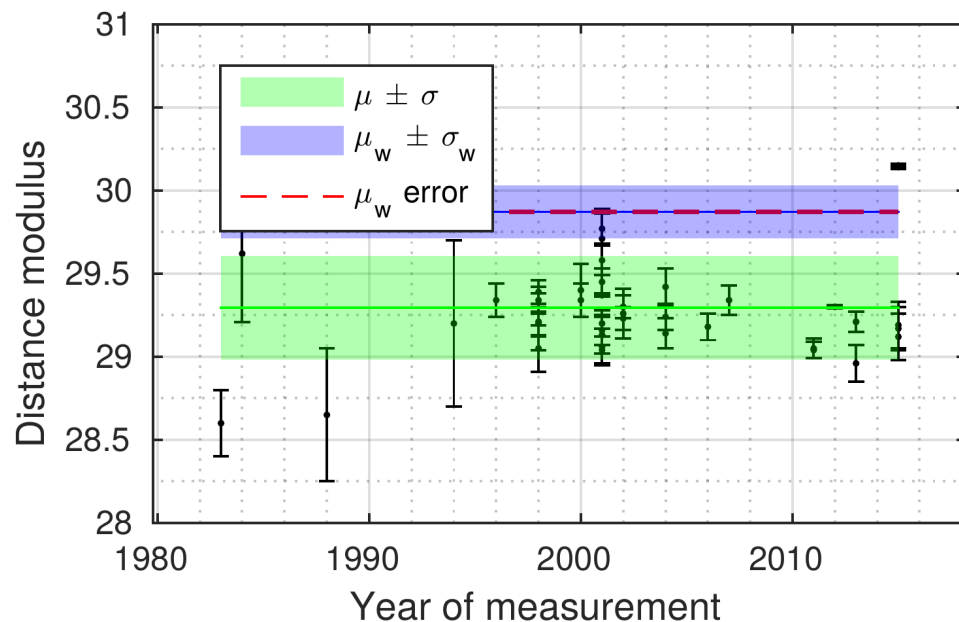
Hubble law independent distances from redshift

- New v_{vir}

- Virgo Cluster

- local average

- Intrinsic scatter

- Under/over-fitting: optimal bandwidth

16003 galaxies
(62K measurements, 1177 publications)
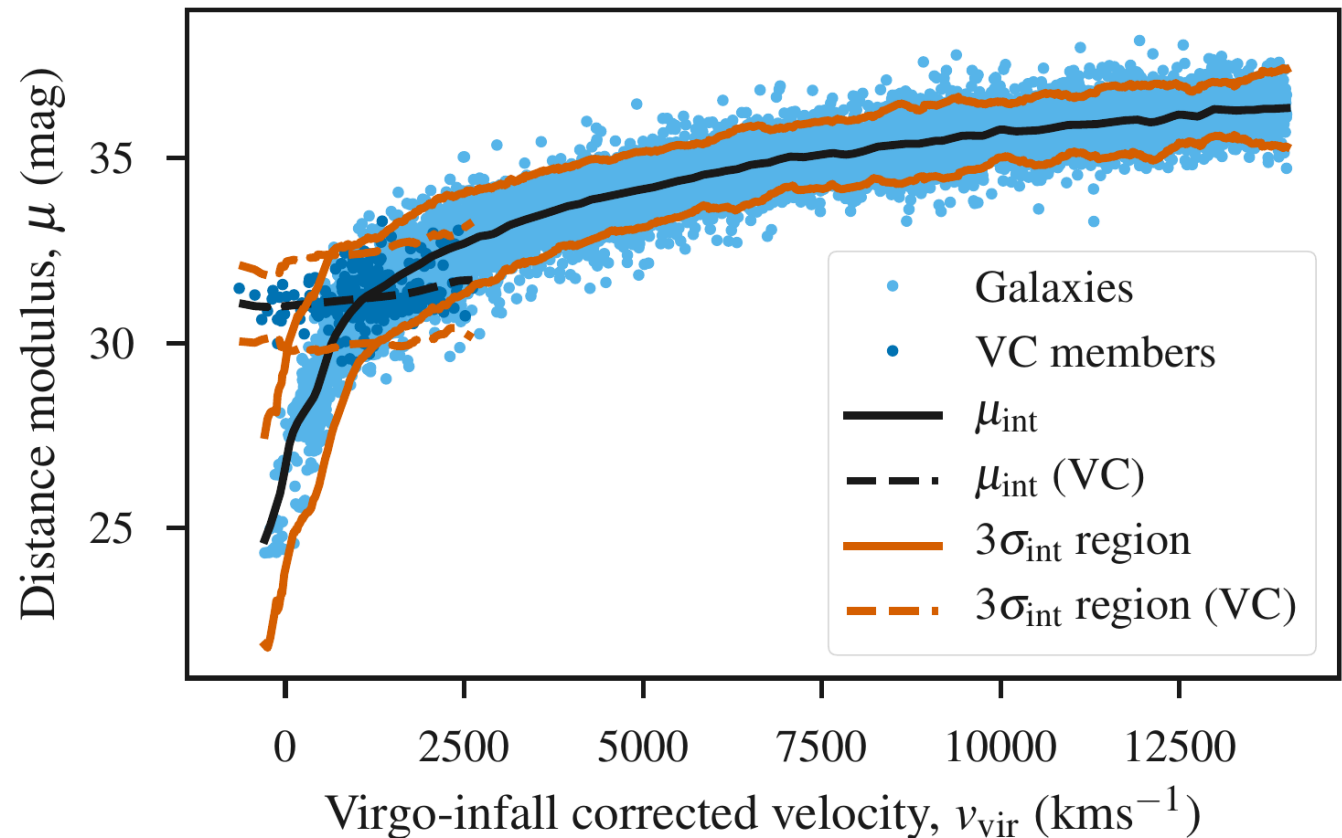
Multi-wavelength catalogues

- ***IRAS* Revised Bright Galaxy Sample** (Sanders et al. 2003)

- **Revised *IRAS* Faint Source Redshift Catalogue** (Wang et al. 2014)
  - *IRAS*
  - *WISE*
  - *SDSS*
  - *GALEX*
  - *2MASS*
  - *Planck*
  - *AKARI*

- ***GSWLC*** (Salim et al. 2016)
  - *GALEX*
  - *SDSS*
  - *WISE*
- ***FIREFLY*** population synthesis models for *SDSS* footprint (Comparat et al. 2017)
- ***WISE* forced-photometry** for SDSS footprint (Lang et al. 2016)
- ***2MASS* Extended Source Catalogue** (Skrutskie et al. 2006)
- ***2MASS* Large Galaxy Atlas** (Jarret et al. 2003)
- ***NED***

ULXs from Chandra Source Catalog 2.0

- Preliminary results. Not yet including

  - All sources

  - Proper source fluxes

  - Target galaxy coverage and sensitivity maps

  - Variability

- Separation from host galaxy center

- Background source counts

  - Using *ChaMP* logN−logS (Kim et al. 2007)

  - Accounting for uncertainties in background parameters and host's distance

  - Subtraction of background (Bayesian model)

- **With** / **without** central region (hosted SMBH contamination)

Toulouse, 2018/5/22

Galactocentric distances (all sources)

Galactocentric
parameter

=

Deprojected distance
from center

/

semi-major axis (D_{25})
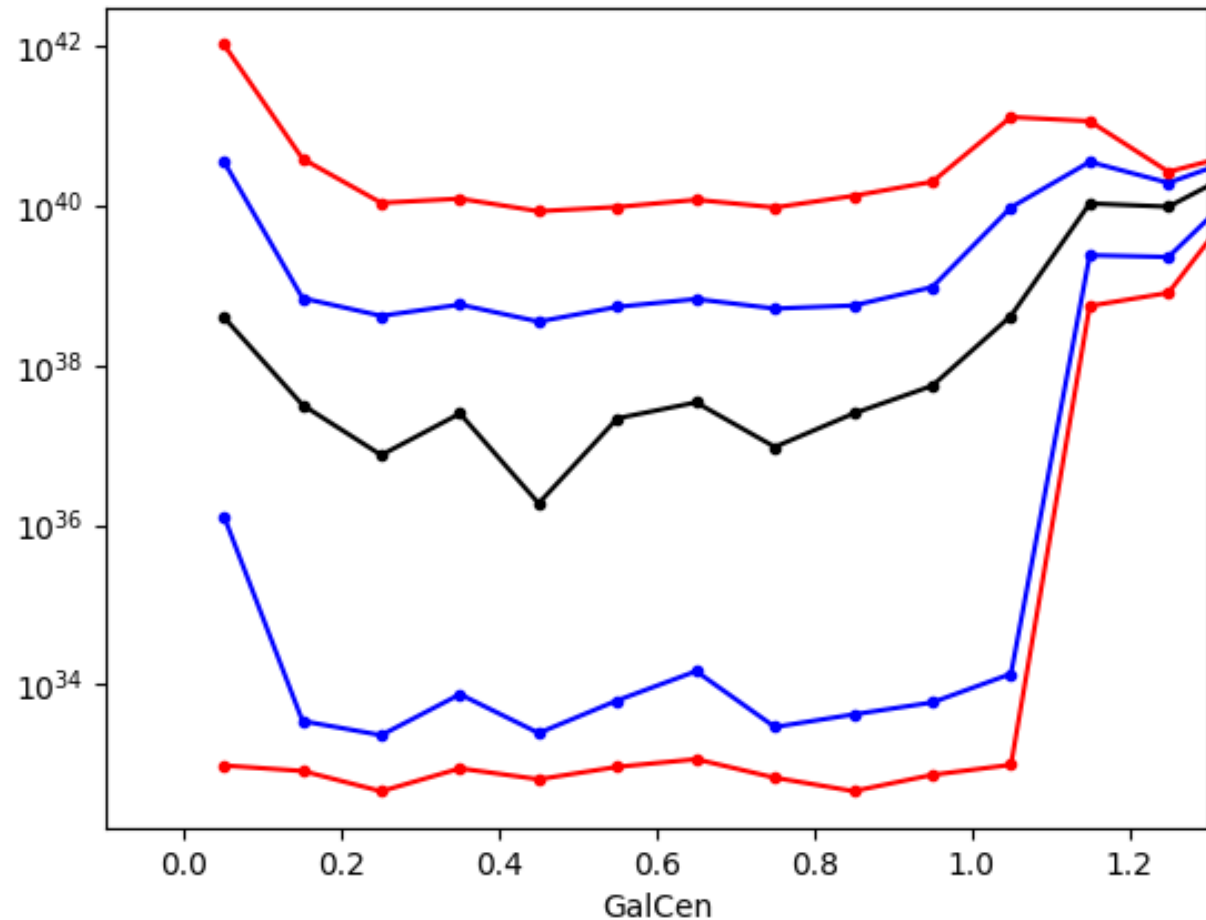
Galactocentric distances (off center)

- Astrometry

    galaxy ≤ 1"

    source ≤ 1"

- Off-center: >3"

- All statistics are computed for the sample with/without nuclear sources
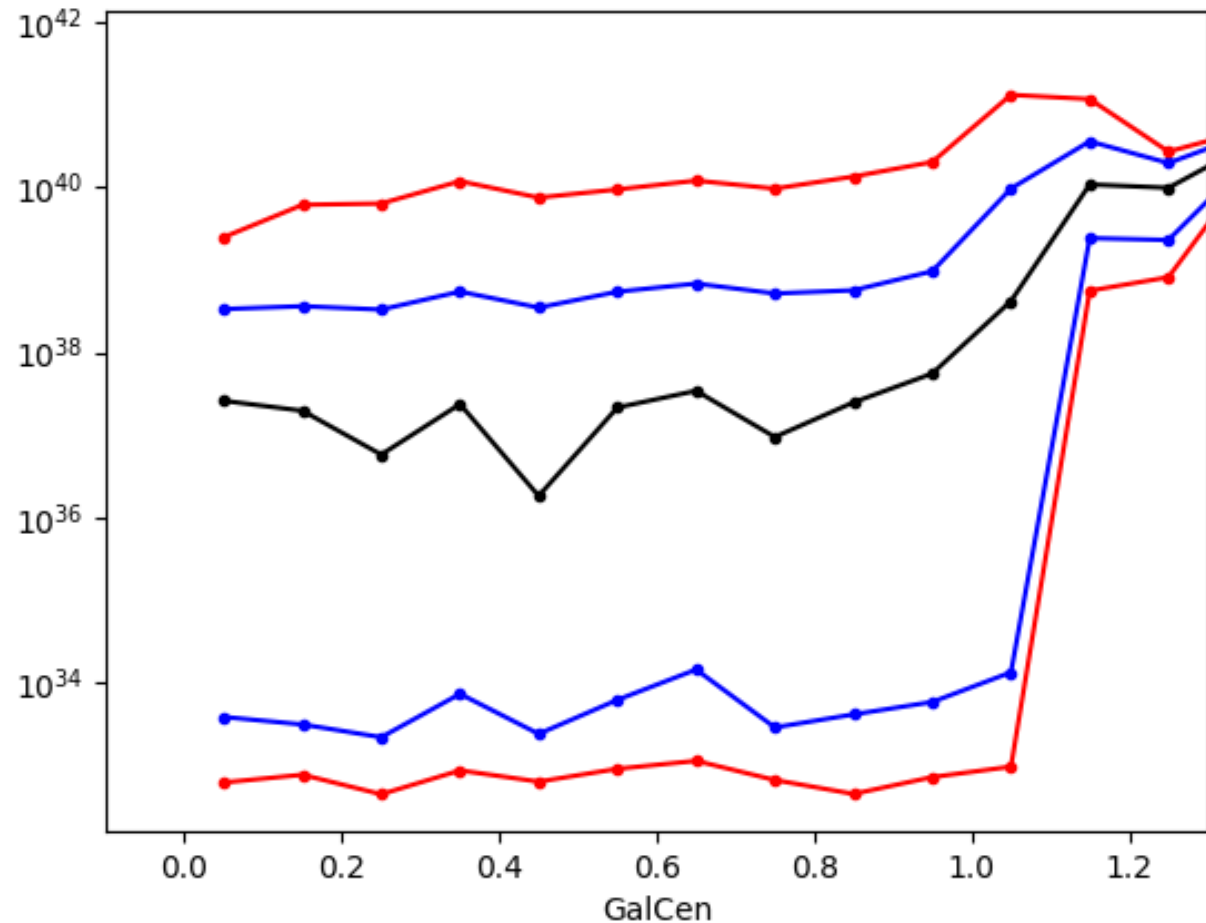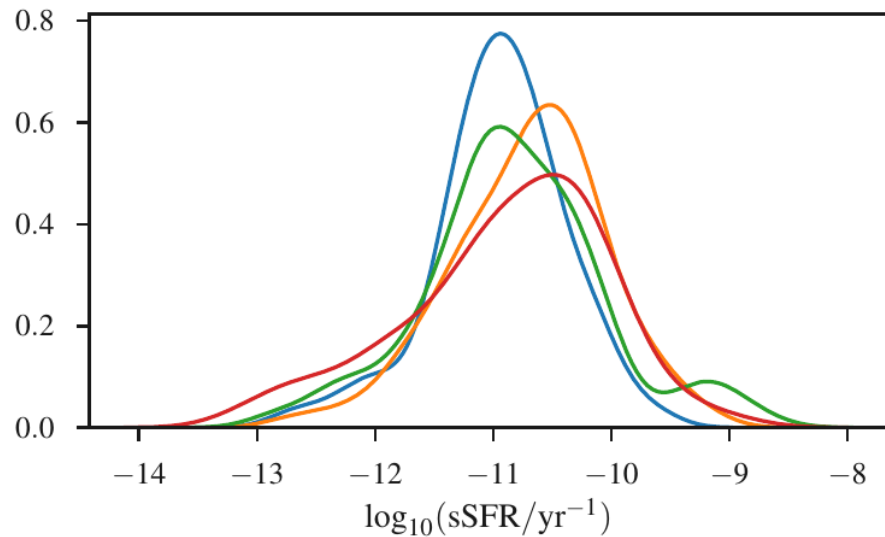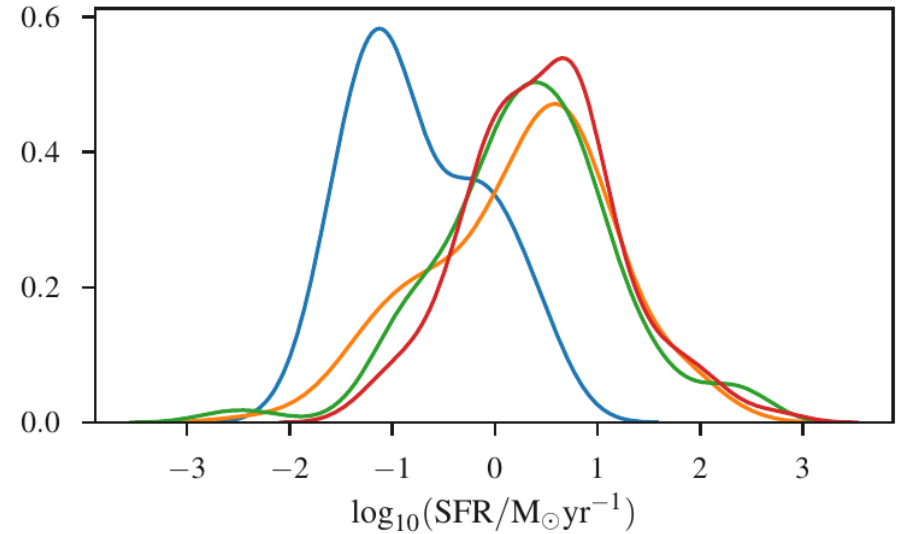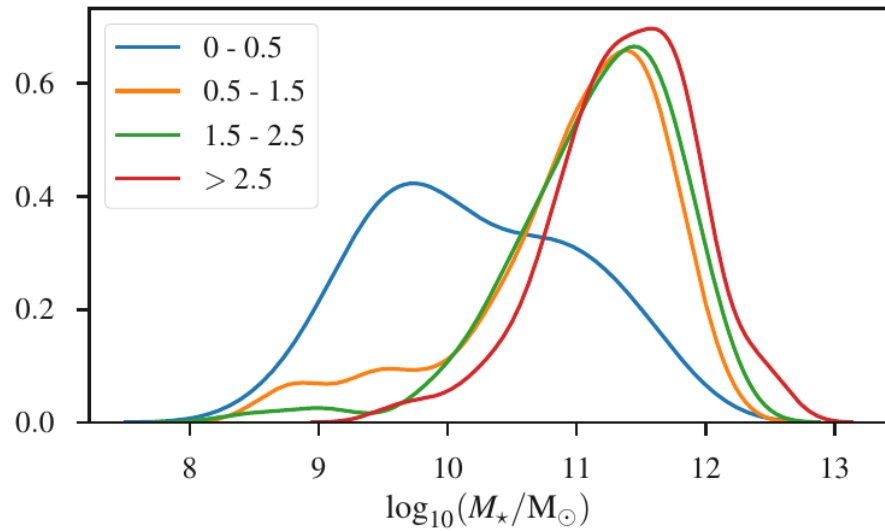
Background contamination
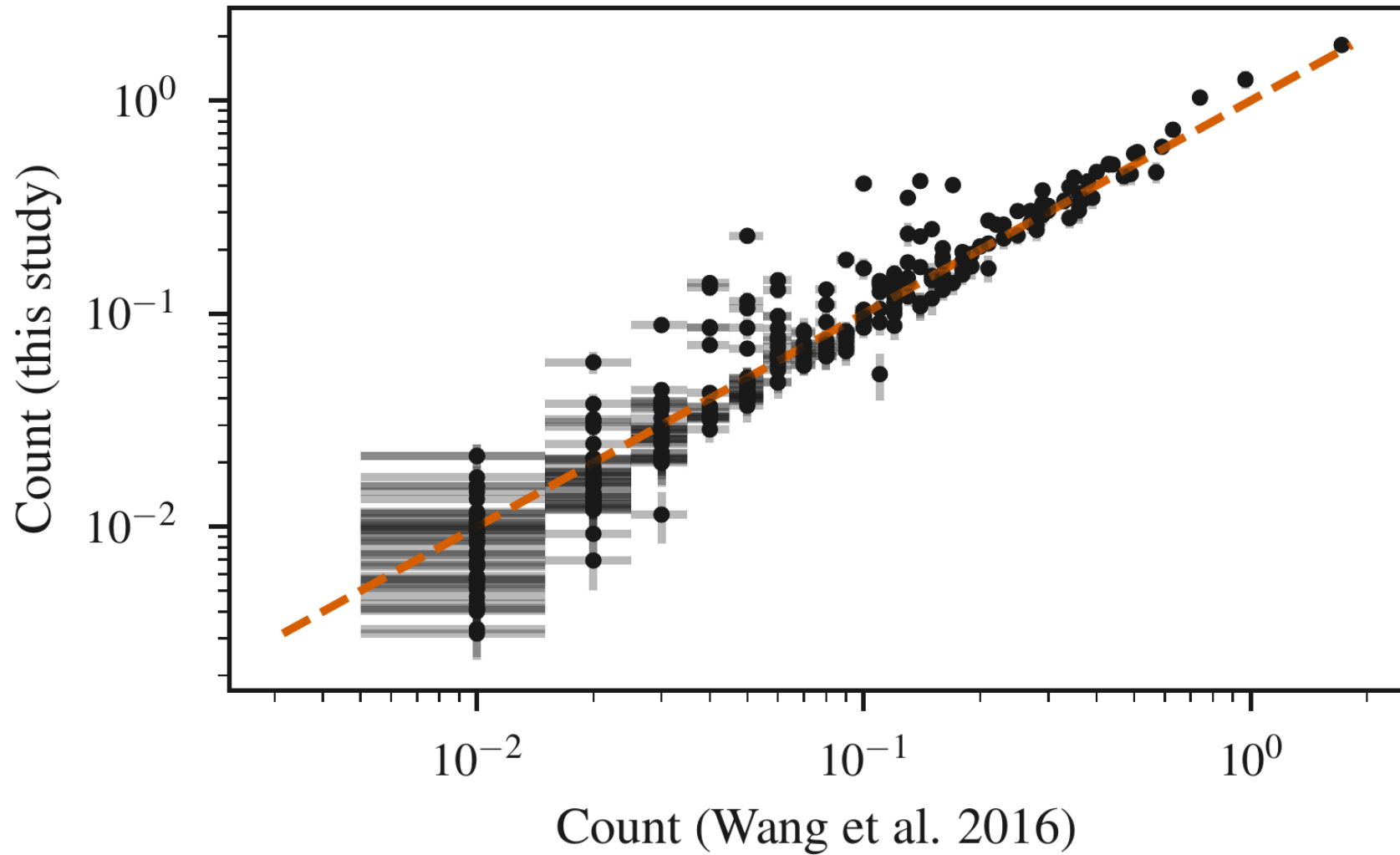
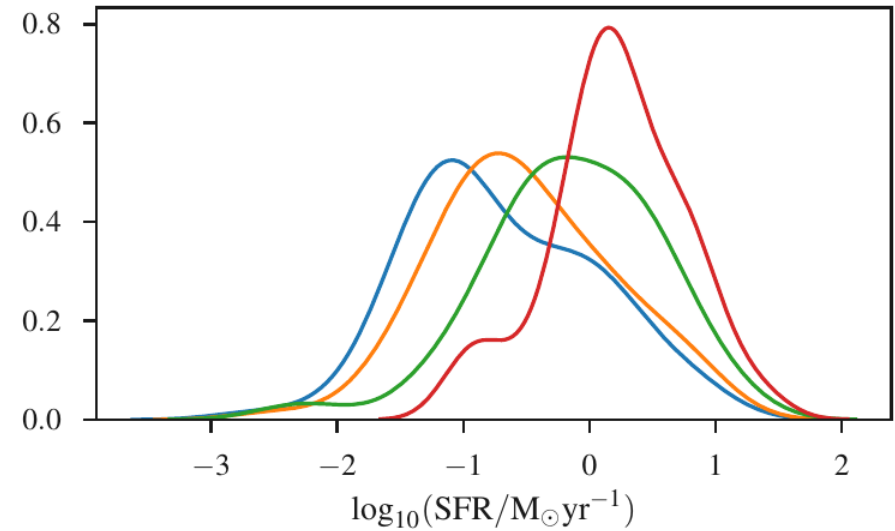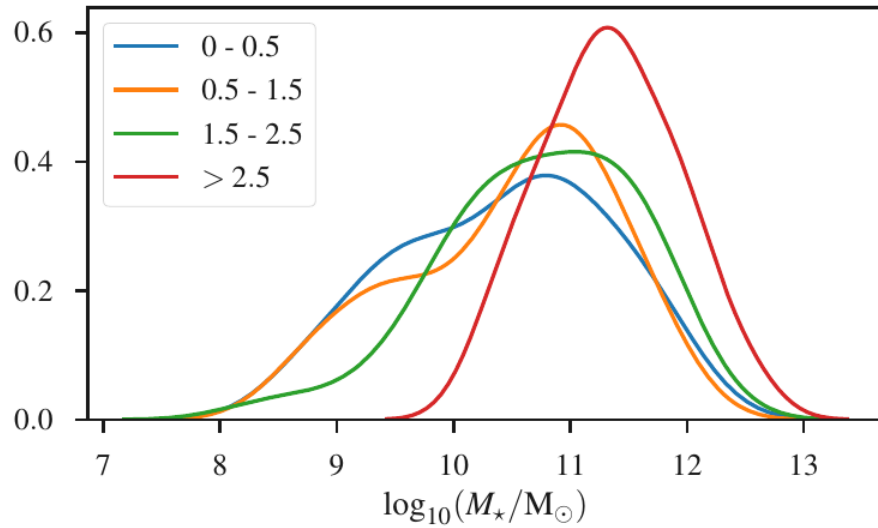# Position of X-ray sources (not only ULXs)
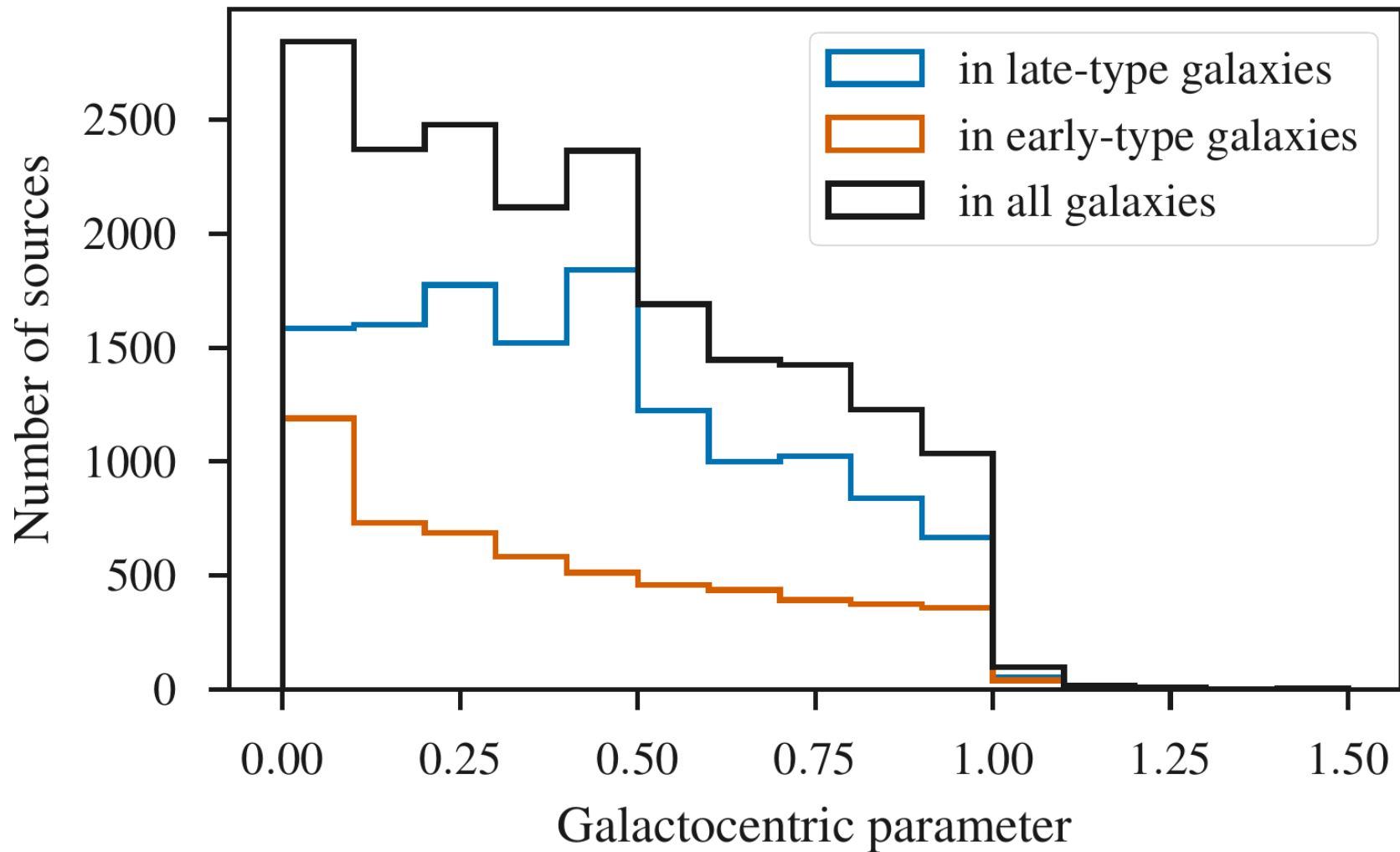
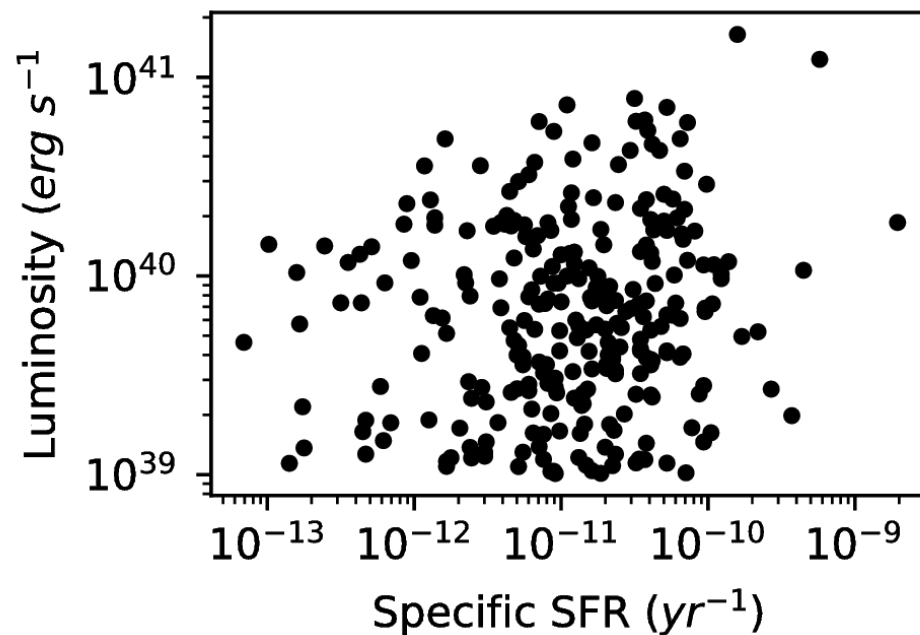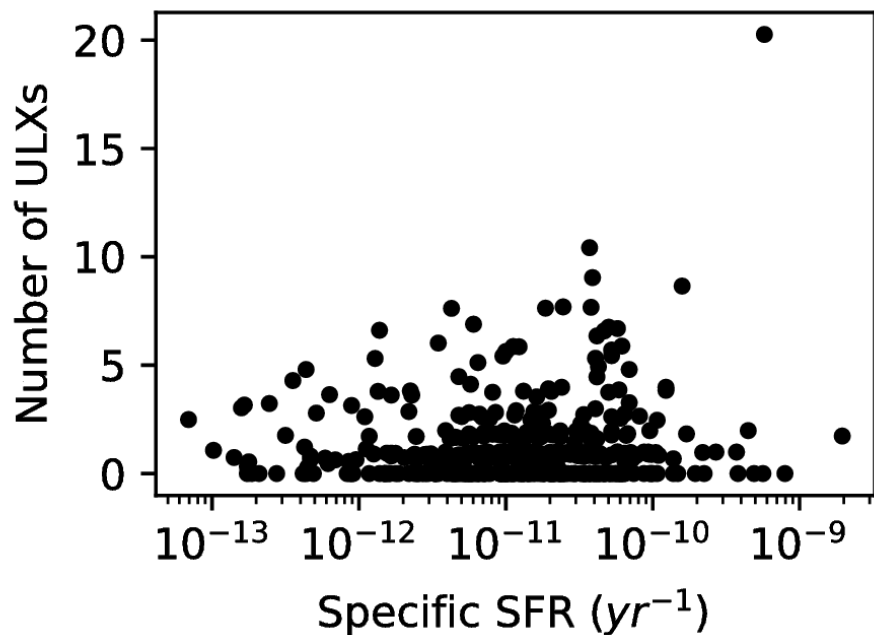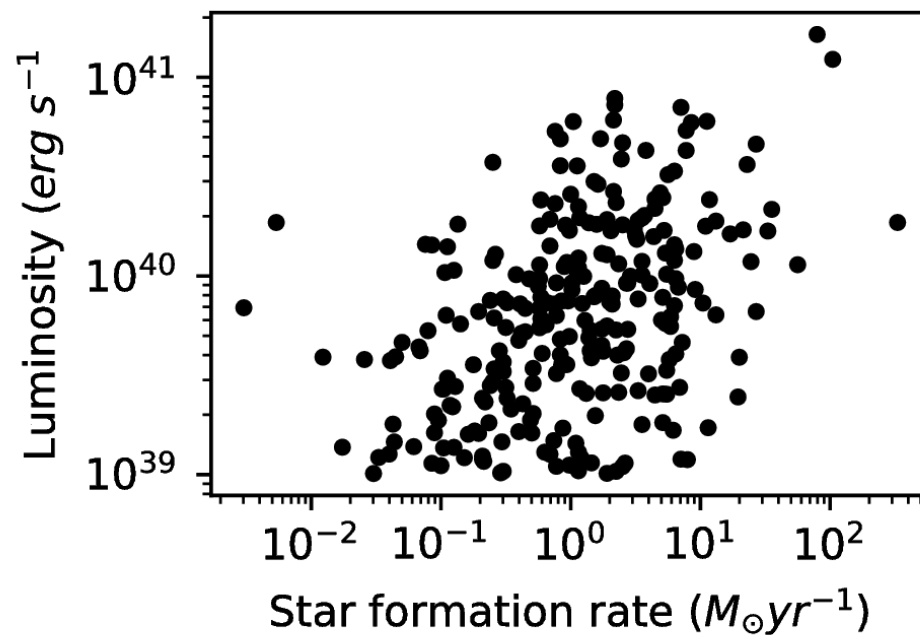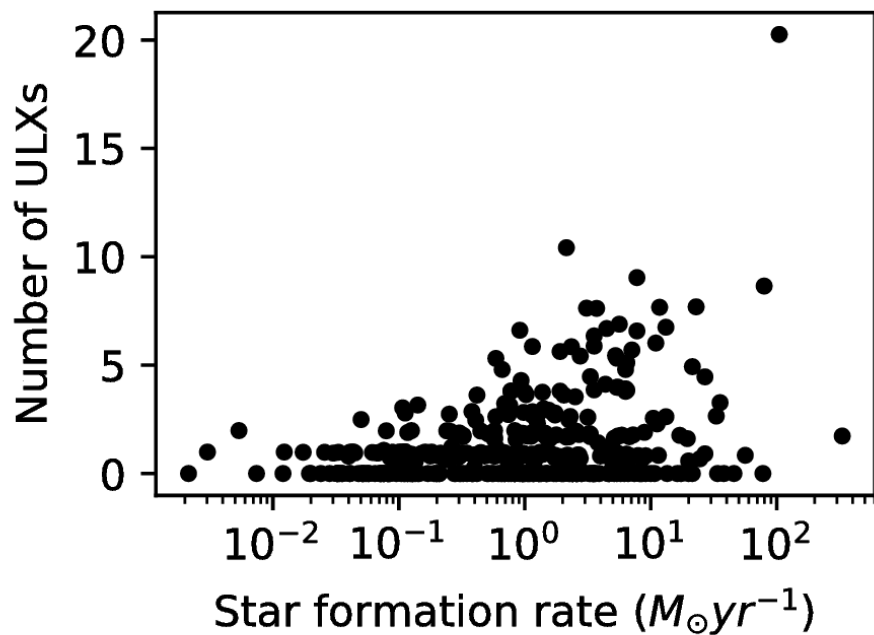# 311 ULX hosts with type and D < 40 Mpc
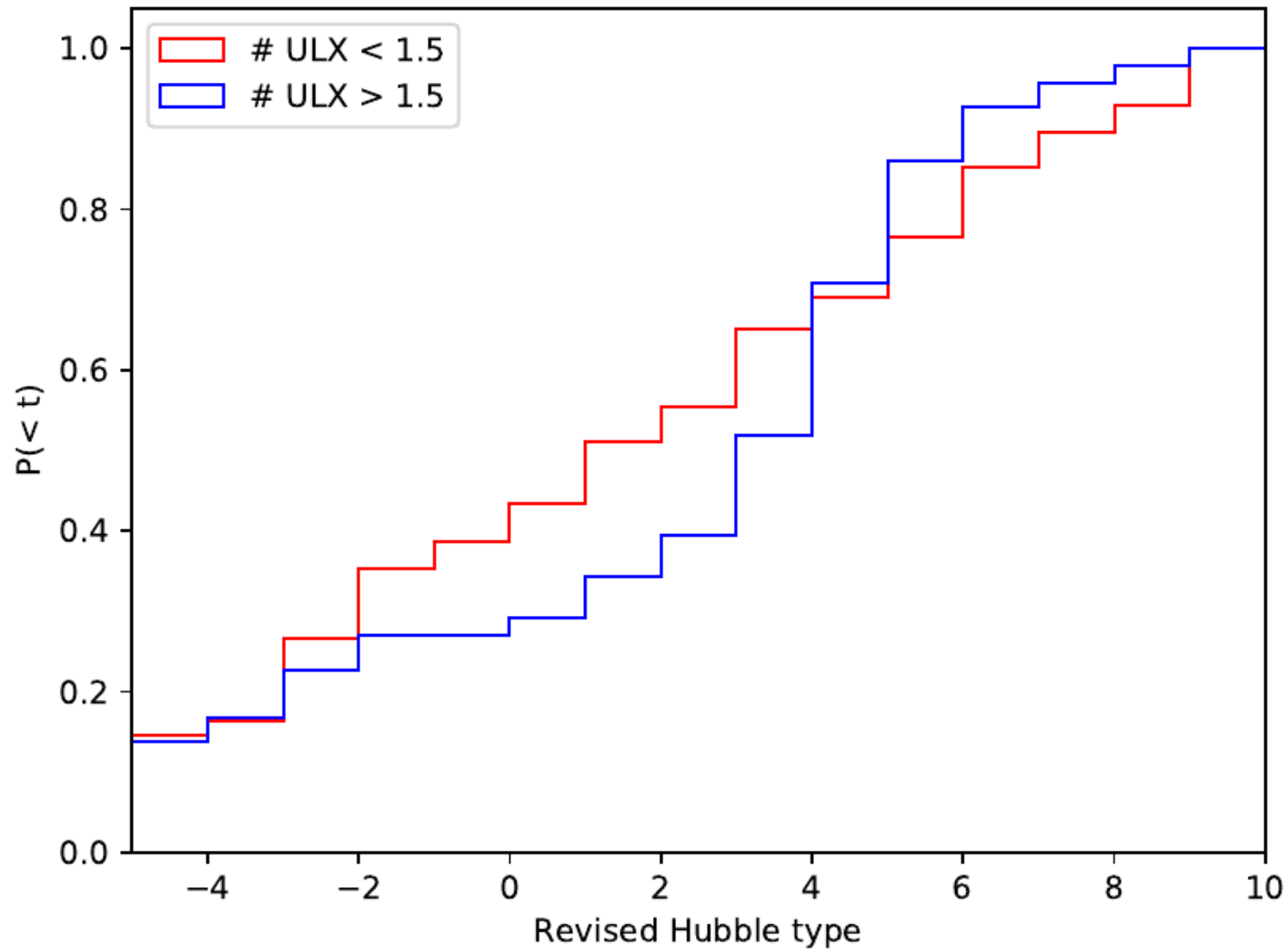
Fraction of galaxies in type bins, based on # ULXs
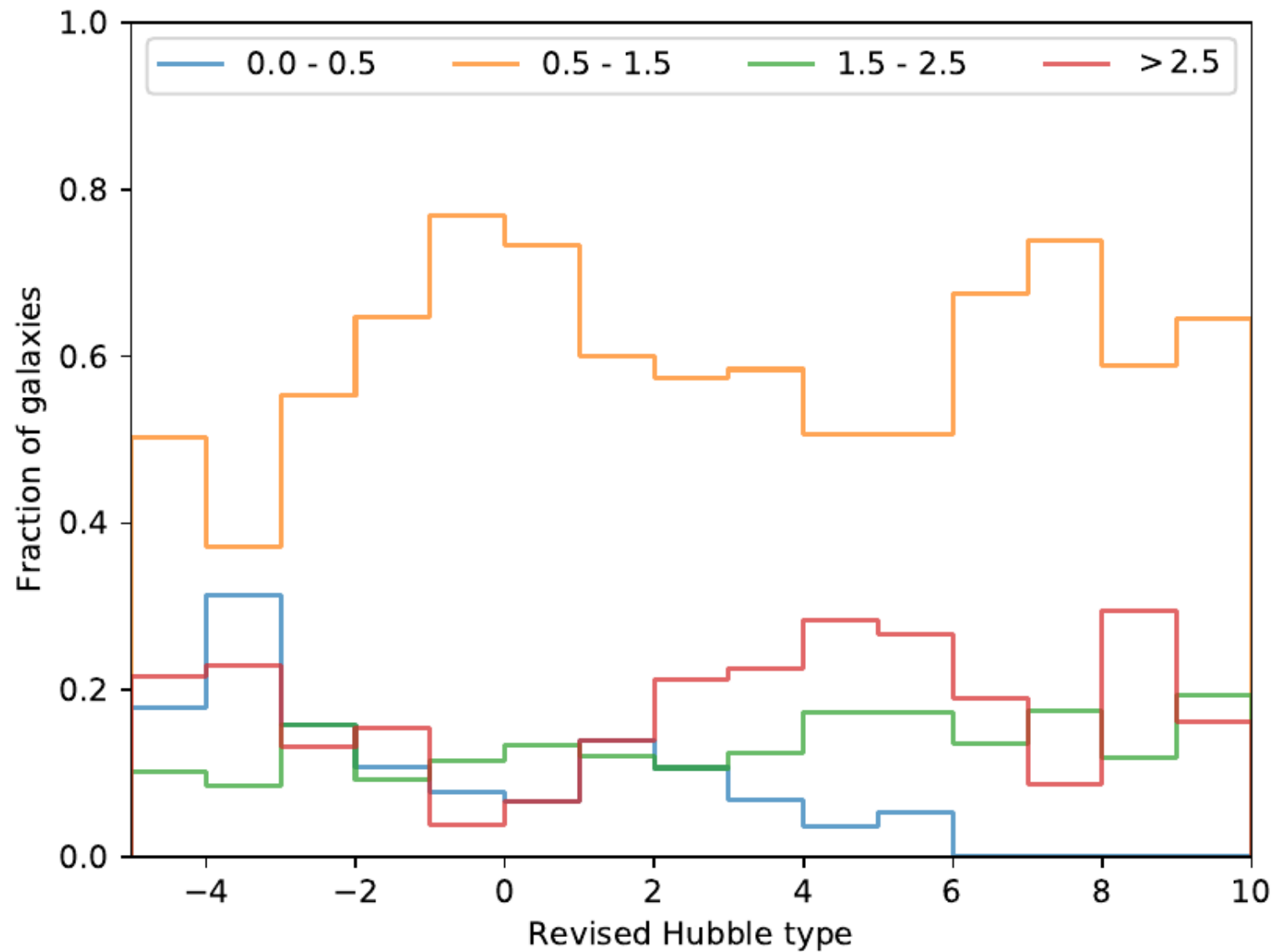
Observed sources with L > 10^{39} erg s^{-1}
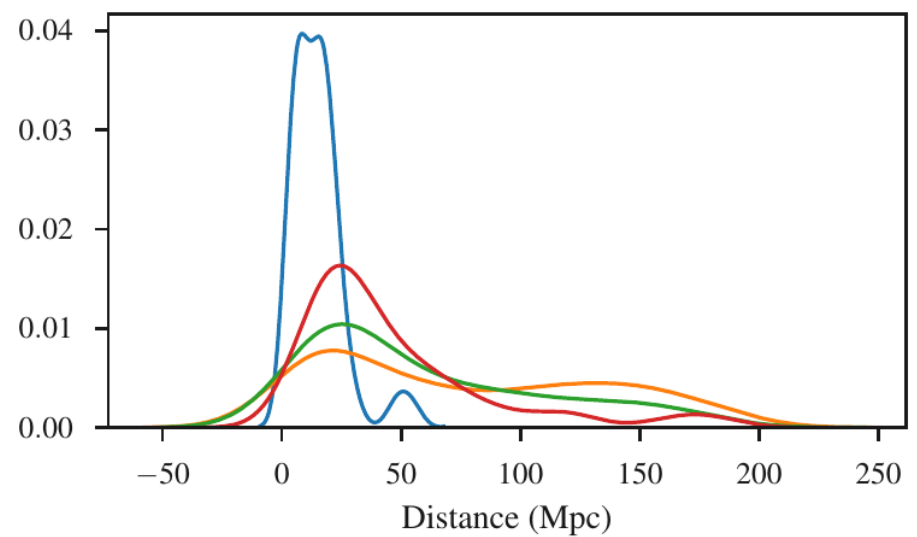
D < 30 Mpc, excluding central regions
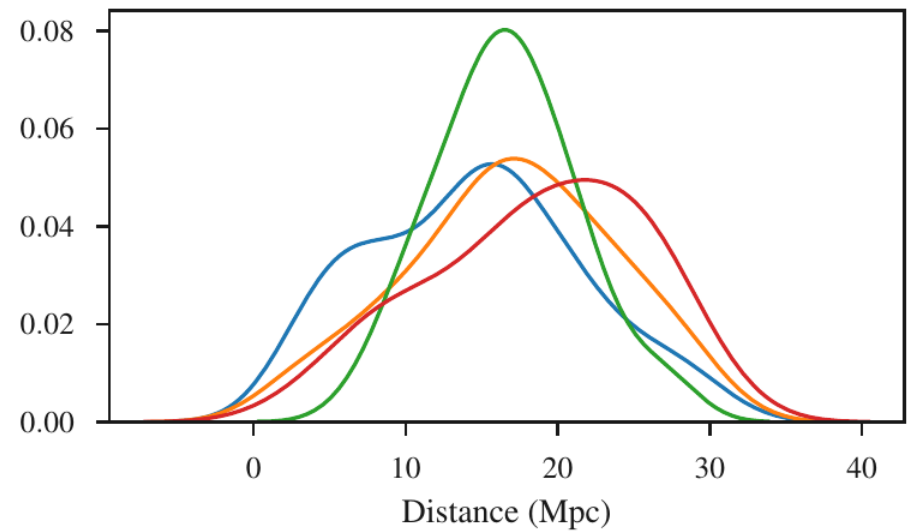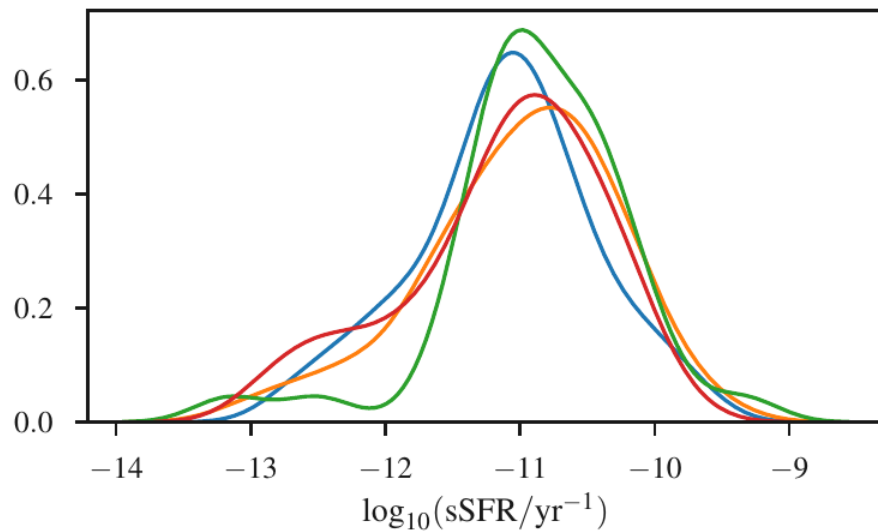
Number and total luminosity of ULX populations vs (s)SFR

Summary & future steps

- A **master catalog** of galaxies that can be used for future studies & other high energy catalogues

- ULX population properties **vs** host properties

- Better statistics when **CSC 2.0** is out...

- **Metallicity** effect

- **Luminosity Functions**

- Source **confusion** corrections (Bayesian model)

Thank you