X-ray emission of galactic winds at low and high redshifts using eROSITA

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with
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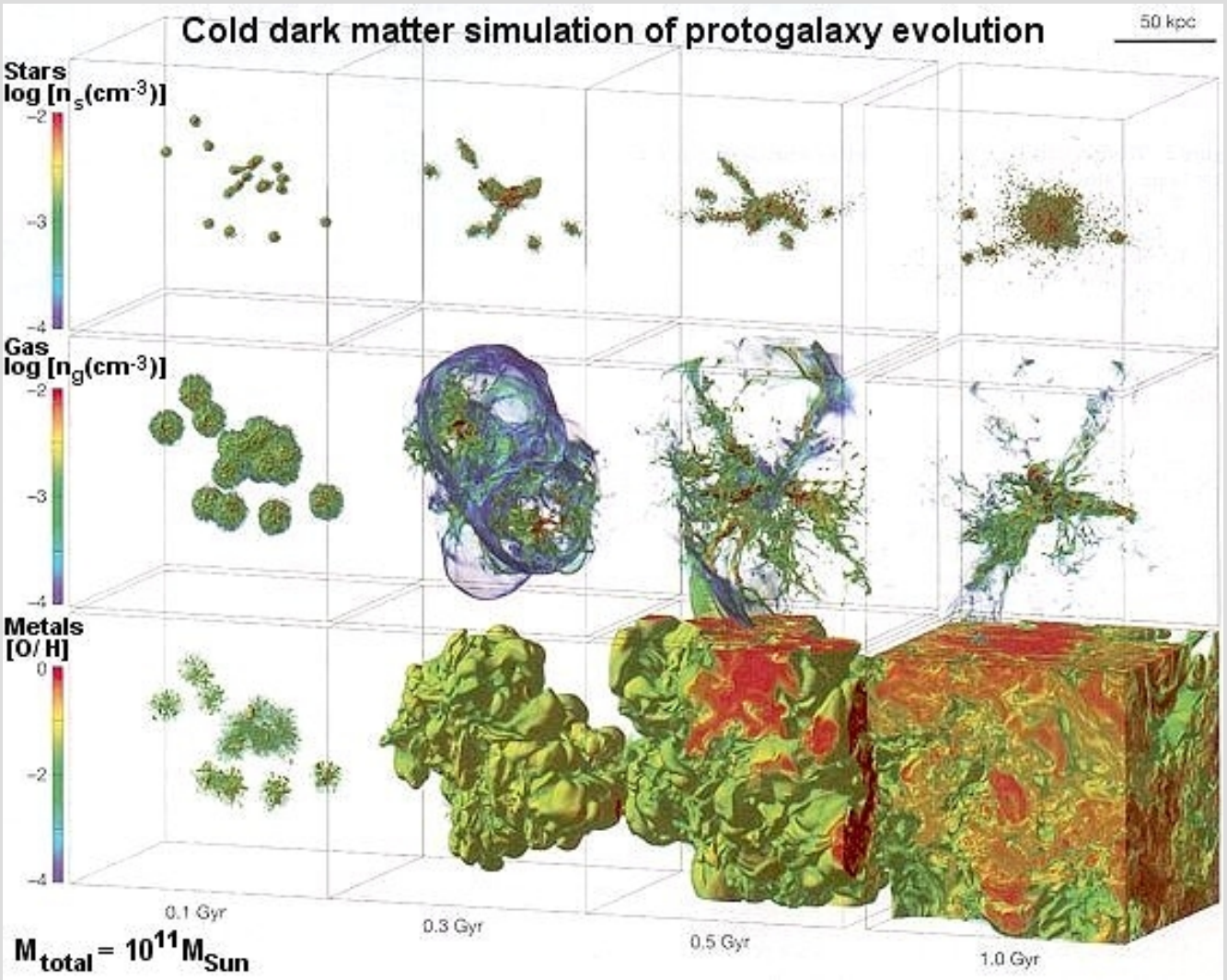
Why galactic outflows?

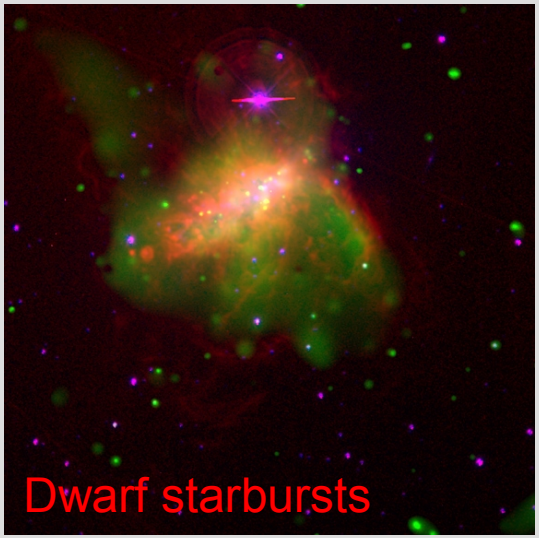


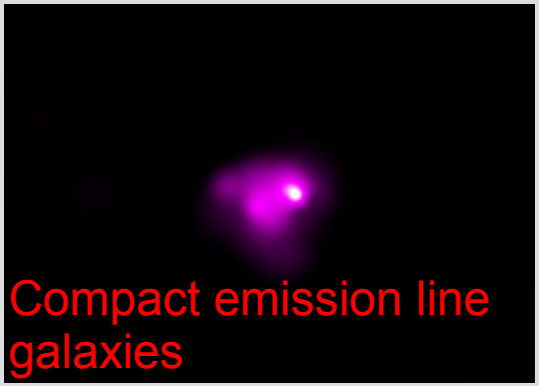
influences:

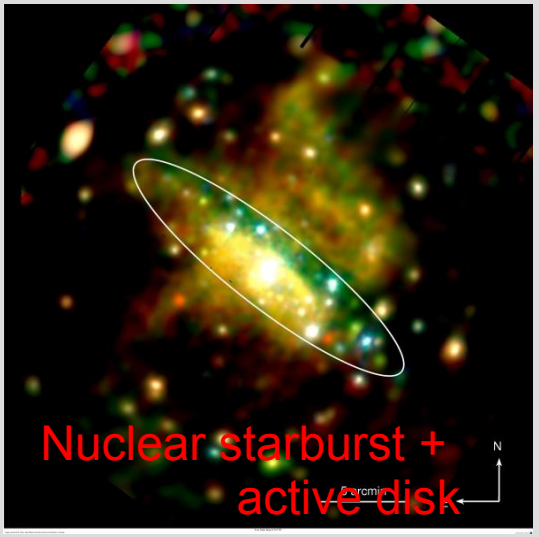
galaxy formation
galaxy evolution
metal amount
metal distribution
IGM properties
reionization
....

Effect depends on SFR, and potential well, and environment

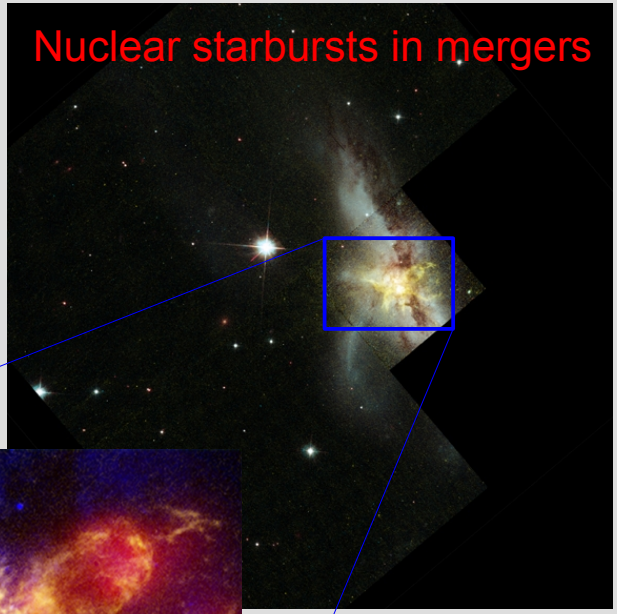
Galactic outflows/winds

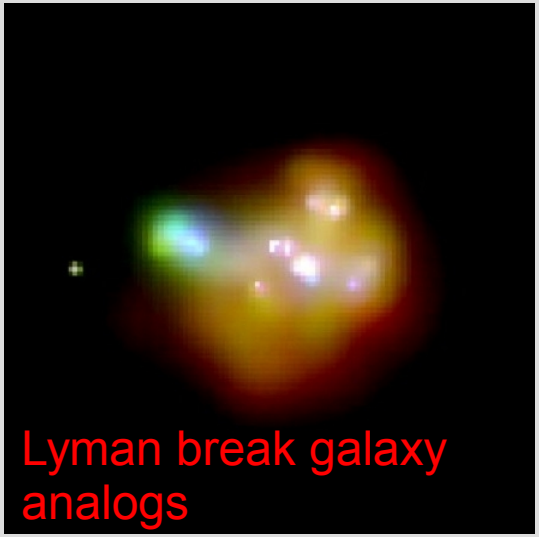

Dwarf starbursts

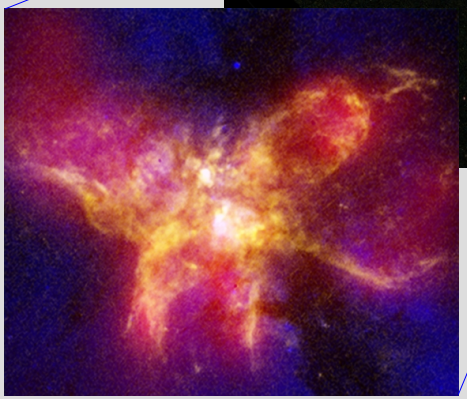

Compact emission line galaxies

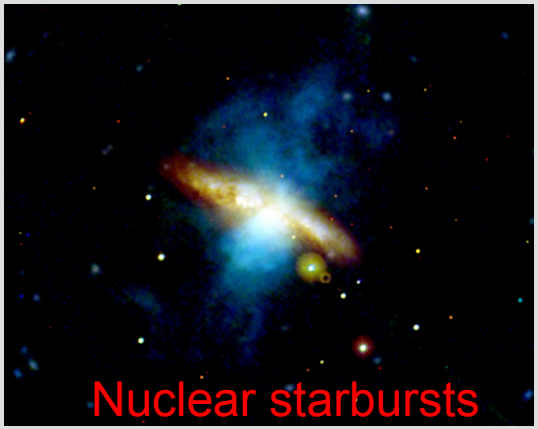


Nuclear starburst + active disk

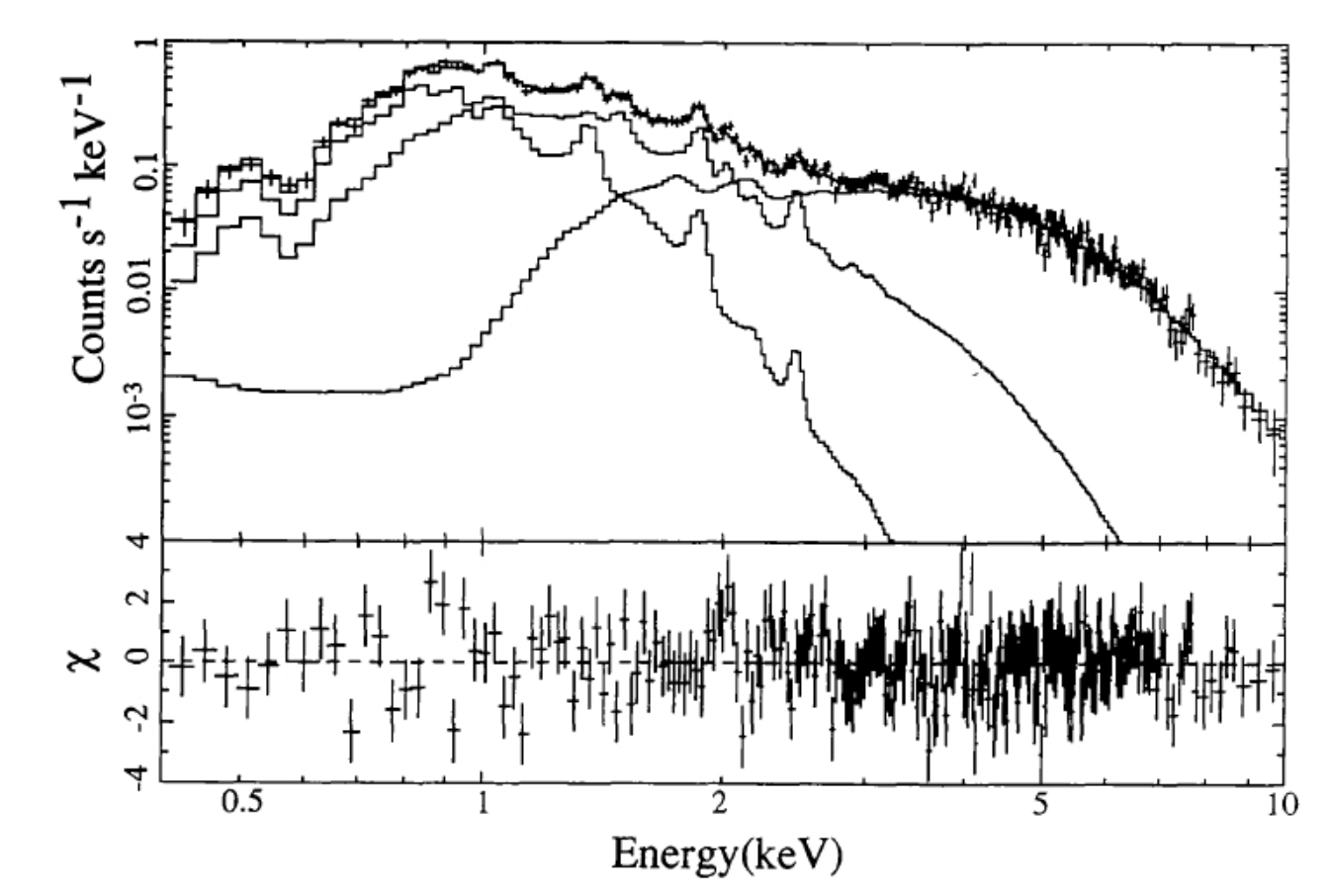

Nuclear starbursts in mergers

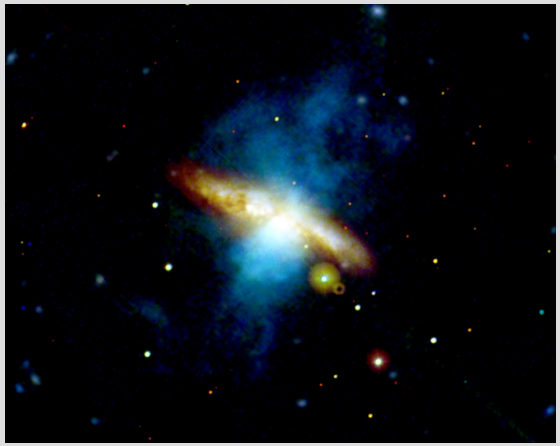

Lyman break galaxy analogs




Nuclear starbursts

What can we see?





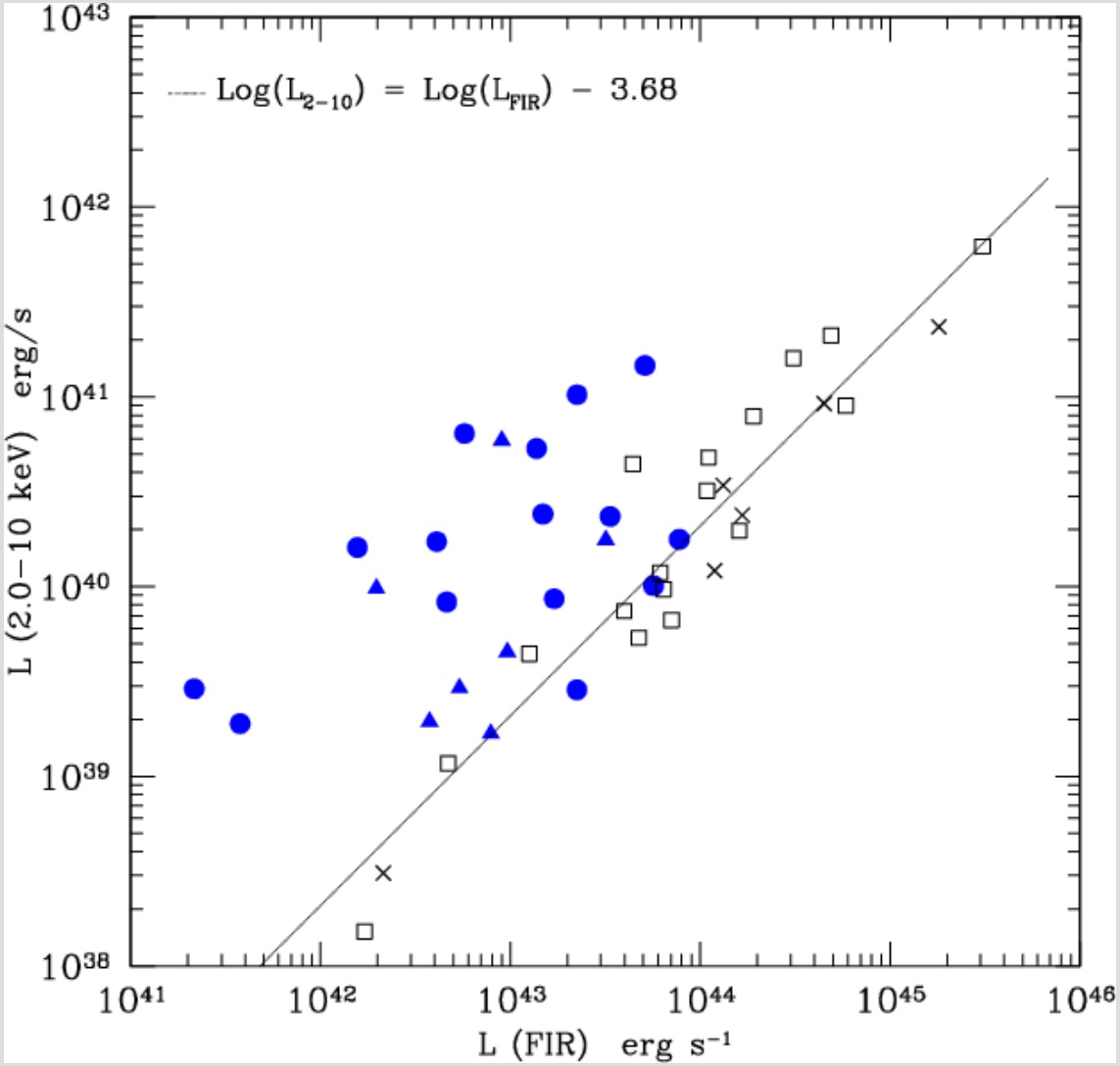
M82
Tsuru et al. 1997

X-ray spectrum of starburst galaxies:

0.1 - 2 keV emission dominated by line emission of hot gas (several temperatures. non-equilibrium...)

2.0 - 10 keV emission dominated by powerlaw emission of (high-mass) X-ray binaries (e.g. Persic & Rephaeli 2002, Pereira-Santaella et al. 2011), with some contribution by very hot gas and SNR.

X-ray luminosity



2-10 keV emission at rest frame
is **good** massive starformation tracer

Independent of dust !

AGN add X-ray flux

But unclear if there is evolution
of the relation with
metallicity and mass
(and therefore redshift)

Ranalli et al. 2003
see also Grimm et al. 2003,...

Open Symbols: normal galaxies
Filled symbols: LINER and AGN

Starbursting dwarf galaxies

NGC 1569 CXO and Hα (Martin et al. 2002)

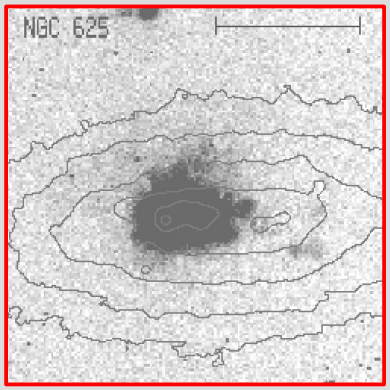
Observations only for the "classical" examples (less than ~15)

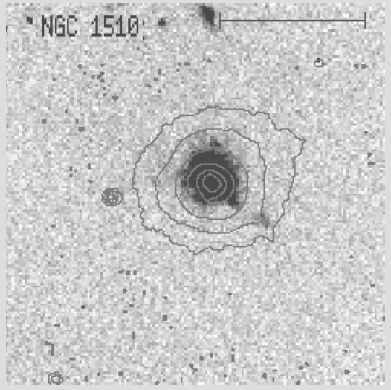
Huge open parameter space

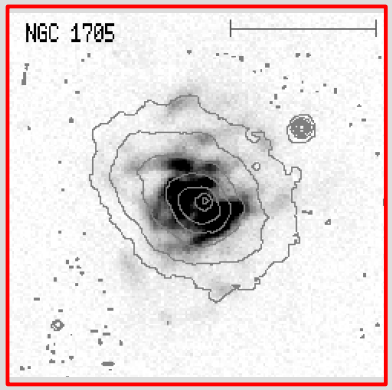
→ high specific SFR galaxies

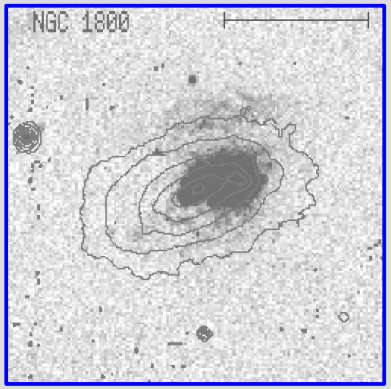
Starbursting dwarf galaxies

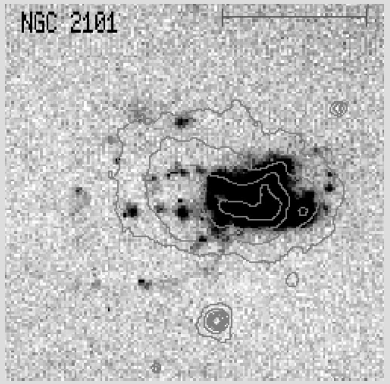
One test sample:
Nearby Irr2 galaxies

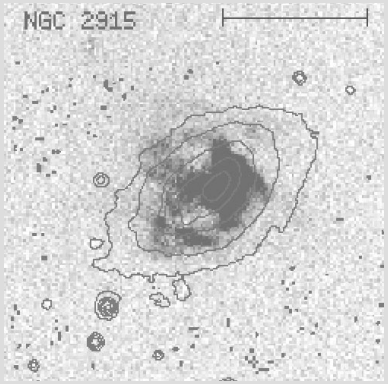


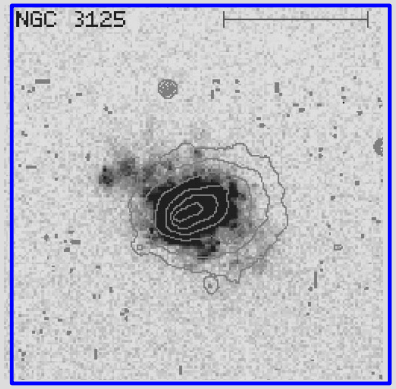


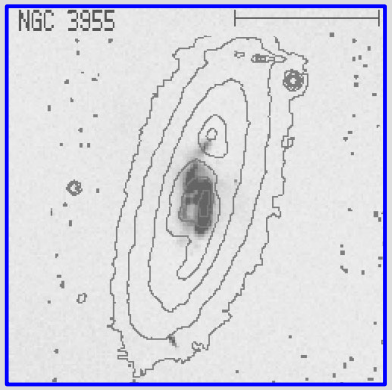


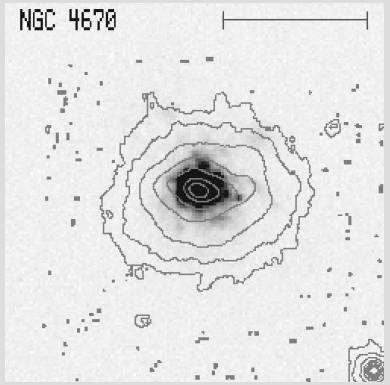


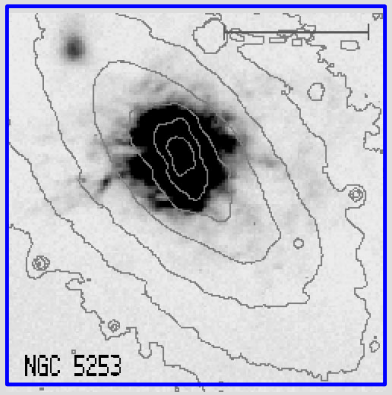








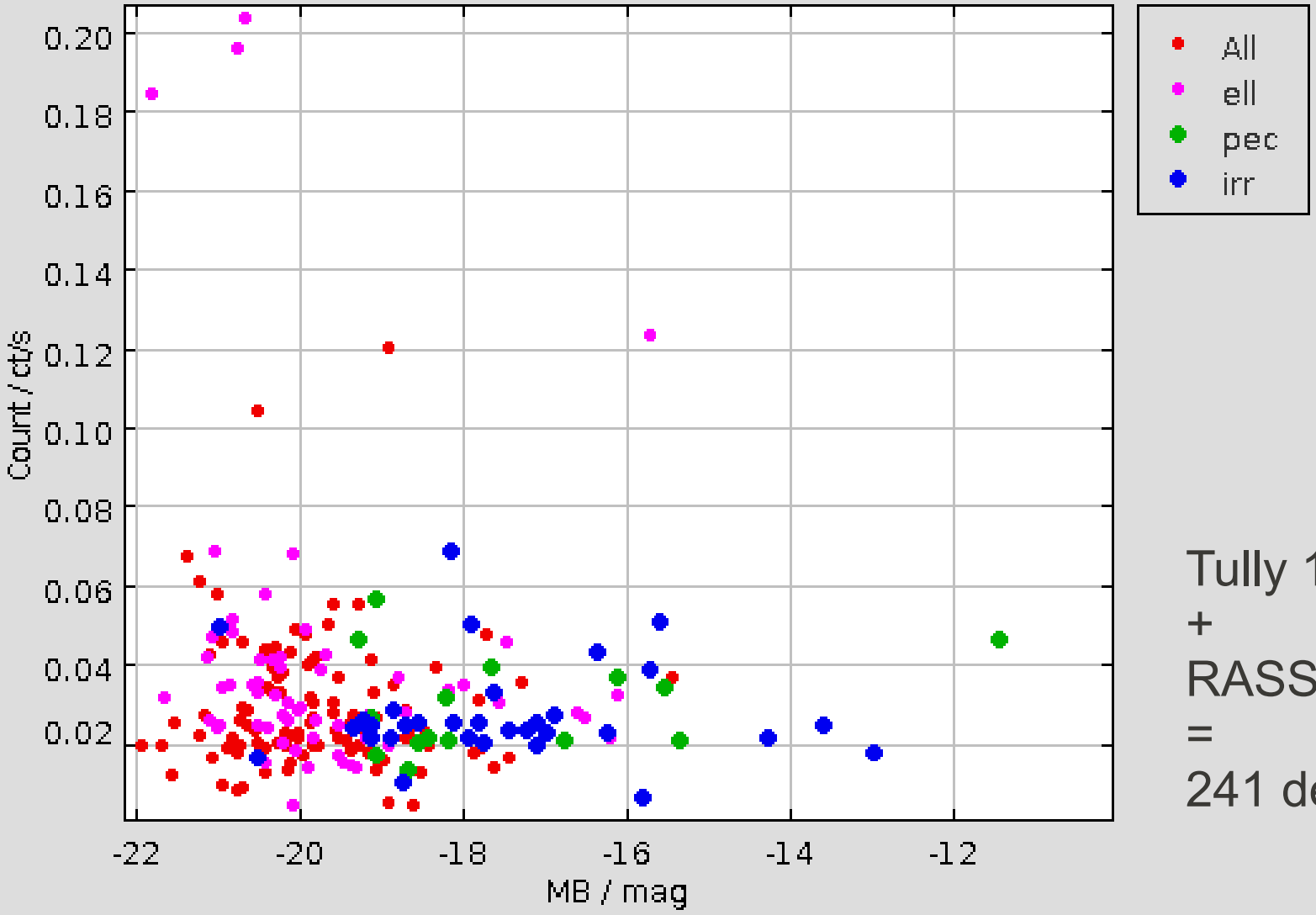




XMM-Newton & CHANDRA
ROSAT

Pictures from
Marlowe et al. 1998

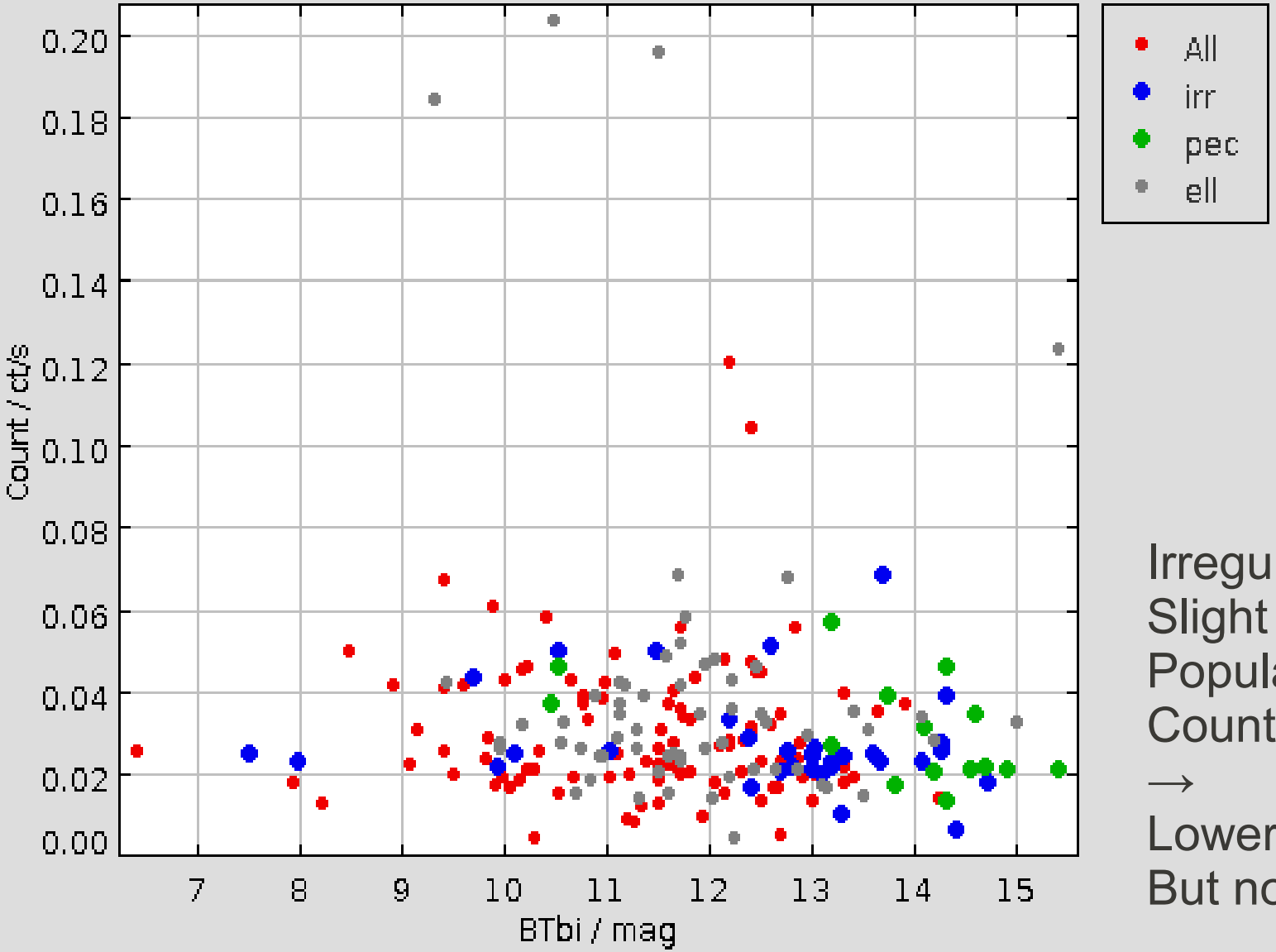
Detection rate with ROSAT



Tully 1988
+
RASS
=
241 detections

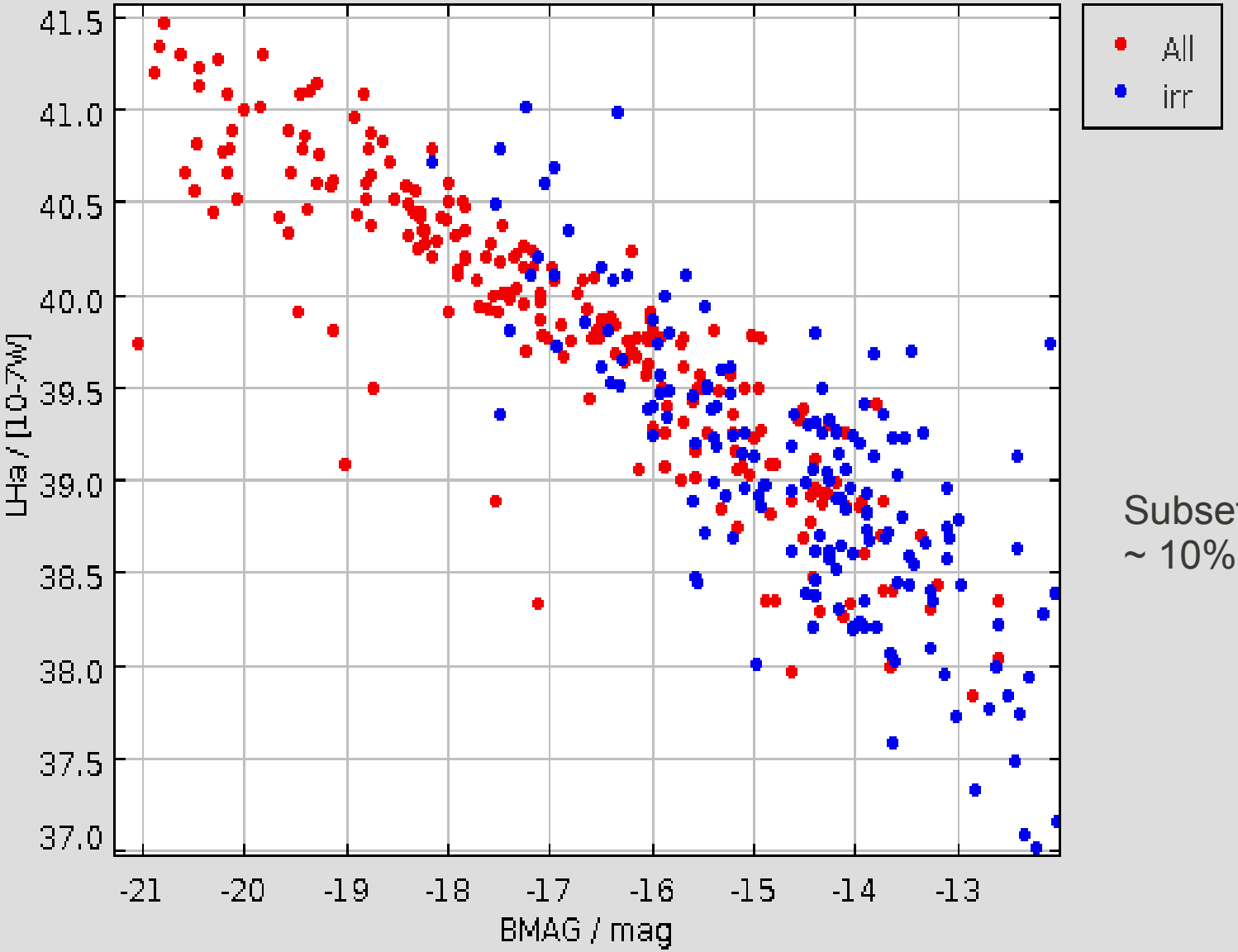
Galaxies within
~40Mpc
Vr = 3000 km/s

Detection rate with ROSAT



Irregular galaxies
Slight tendency to
Populates the lower
Count rates
→
Lower absolute,
But not specific SFRs

Star formation rates

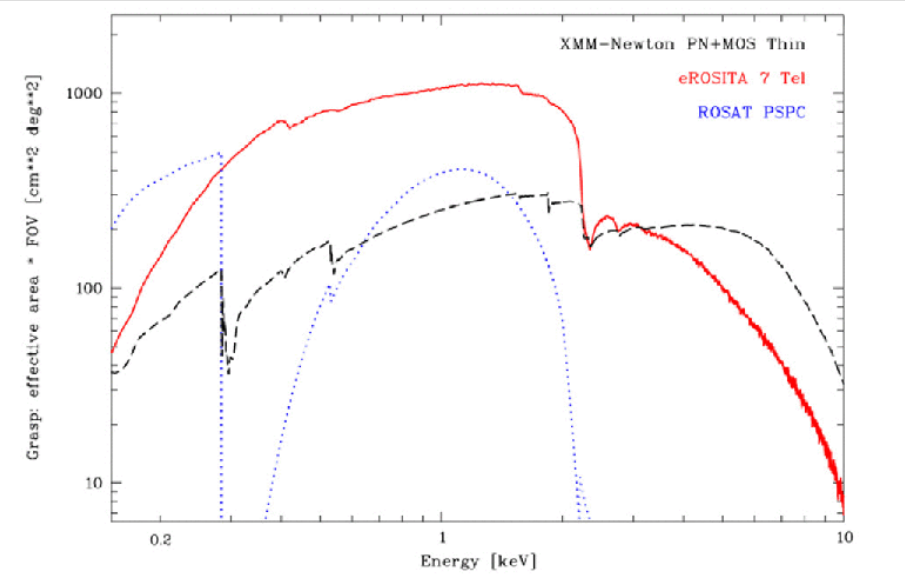


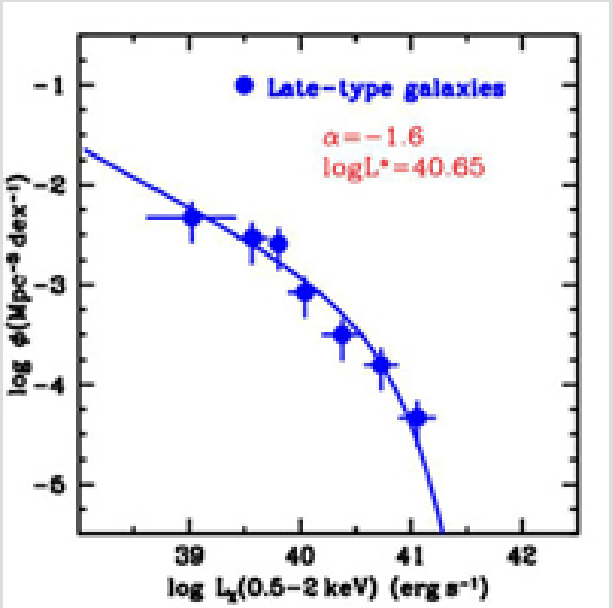
Subset of high SFR dwarfs
~ 10% of sample

Local Volume (D<11 Mpc)

Adapted from Kennicutt et al. 2008

Zero order estimate for eROSITA





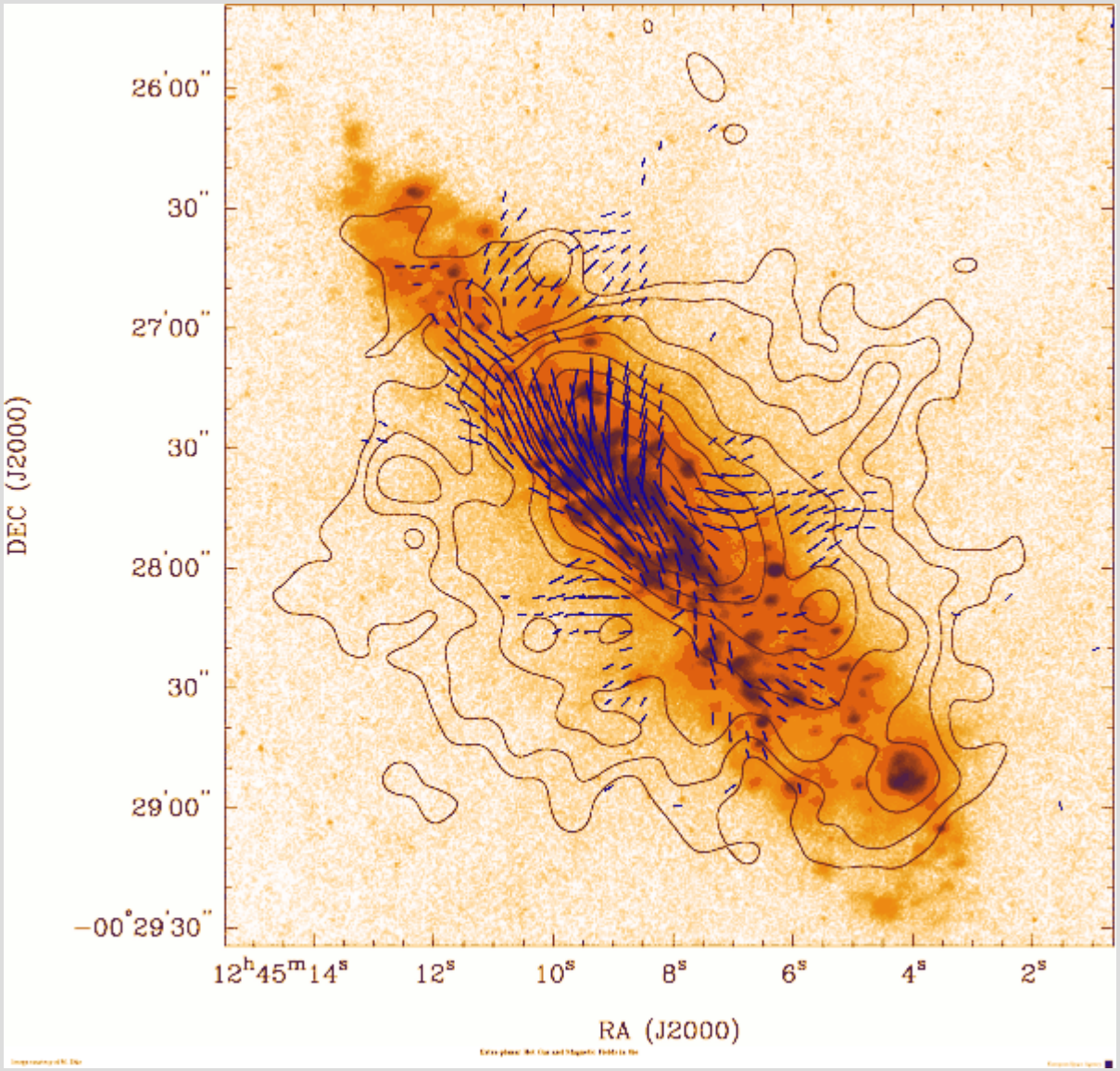
Georgantopoulos et al. 2005,
Georgakakis et al, 2006

Rough scaling :

* RASS: 10% of detected 240 galaxies are dwarf irregulars
  Okay, some dominated by one bright X-ray binary...
* Factor 30 in sensitivity means factor ~5 larger distance, factor 25 larger volume
* or factor 30 detected fainter fluxes at same distance
* ~10 % of dwarf galaxies have high specific SFR
* X-ray (and optical) LF of starforming galaxies is strongly rising toward low luminosities

→ > 100 eROSITA detections of starbursting dwarf galaxies
Well, surface brightness sensitivity, spectrum, foreground absorption ....
Still, there will be many detections, some with good spectra !!

Nuclear starburst galaxies, strong SFR disks



Again:
Mostly observed are the famous examples,

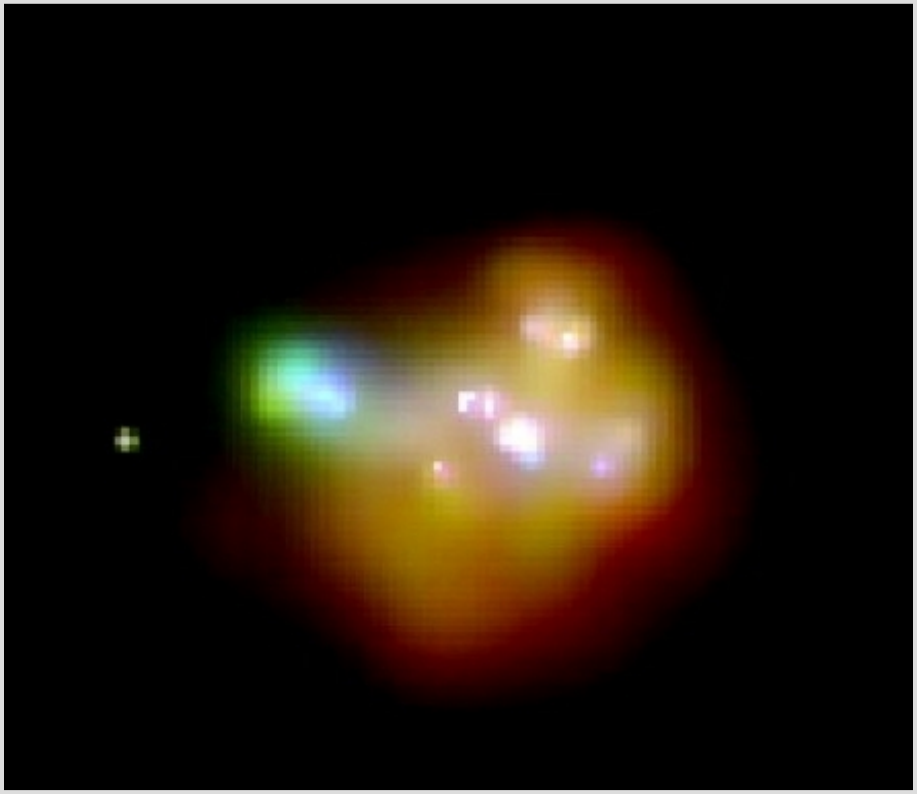
Some larger sample work e.g. Strickland et al. 2002

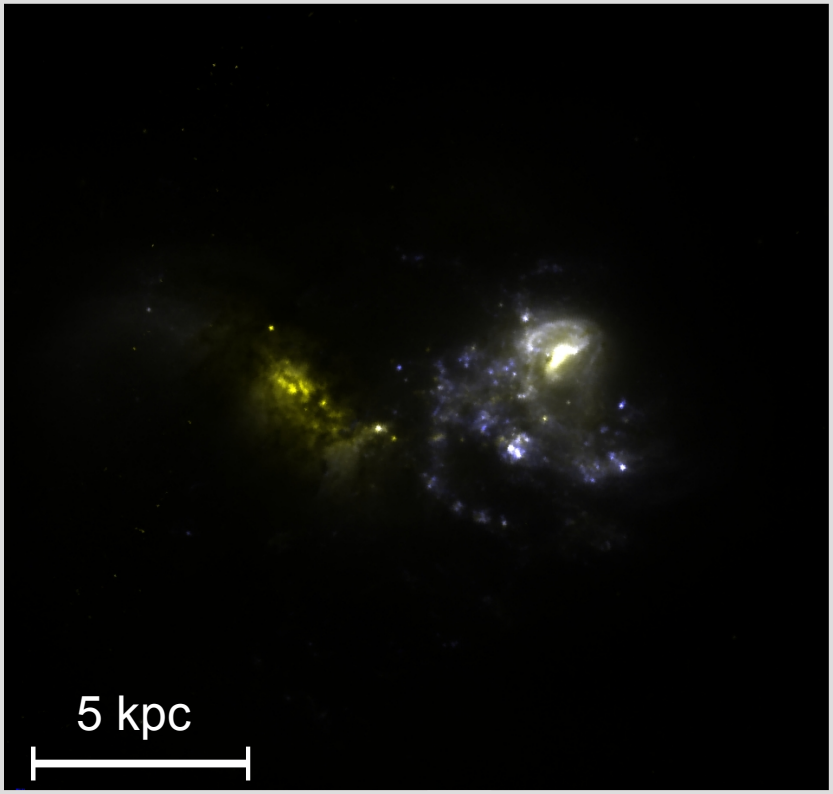
But there are many unchecked and/or unrecognized candidates even within 20 Mpc

Clear link with radio continuum measurements of magnetic field

NGC 4666 (XMM-Newton,Ha, B-field) Ehle, Dahlem, et al.

Lyman Break Galaxy Analogs



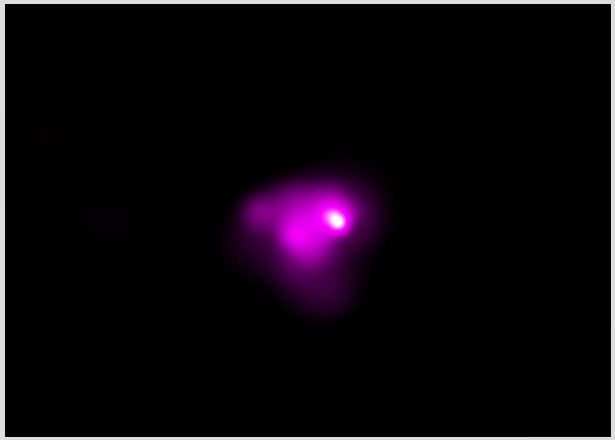


CHANDRA X-ray color image (0.5-1.0 keV, 1-2keV, 2-8 keV) of the Lyman Break Galaxy Analogon VV114 (adapted from Grimes et al. 2006)

HST ACS color image of VV114 (F435W and F814W) (Bomans et al., in prep.).

Will be detected in eROSITA All Sky Survey

Lyman Break Galaxy Analogs



and UV bright redshifted starbursts
(e.g. Hoopes et al. 2007)

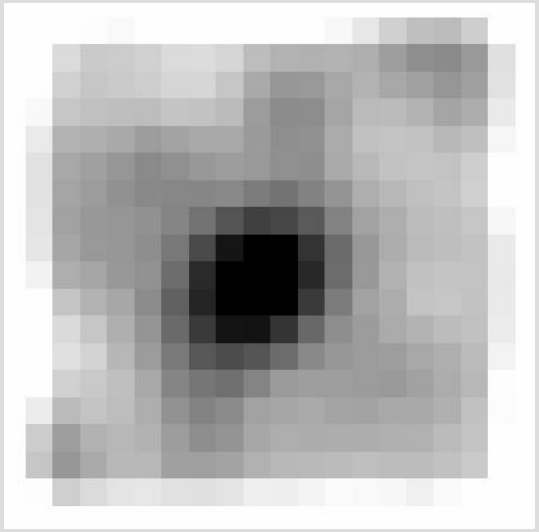
and redshifted compact emission line galaxies...
(e.g. Kakazu et al. 2007)

Most will be to faint for a eROSITA detection

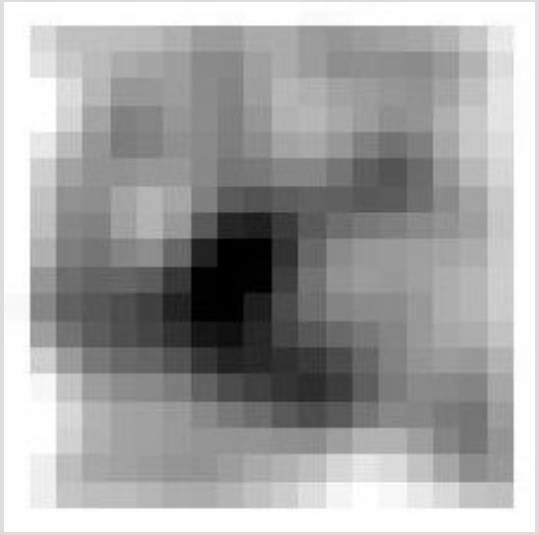
But we have optical/UV selected samples !

→ stacking analysis

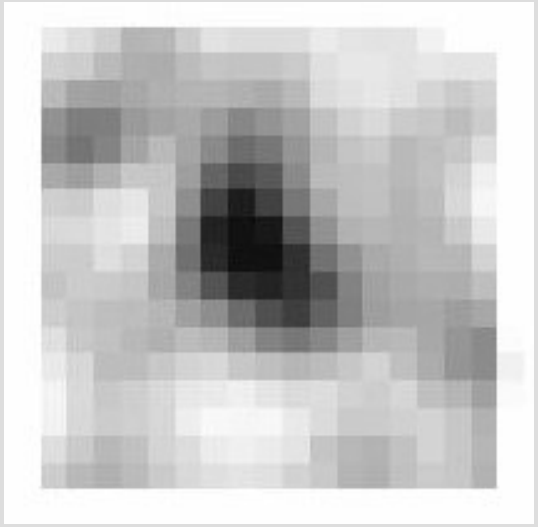
Stacks



0.5<z<1.0
detection



1.0<z<2.0
detection



2.5<z<3.0
detection

CXO 4 Msec data of CDFS
1.0<z<2.0 SWIFT UVOT selected LBGs (35 in stack) show complex structure:
- less reliable astrometry? (needs more checks)
- or fainter secondary clumps (dwarf galaxies) detected?
- or extension due to hot outflows?

0.5<z<1.0 sample is not selected for high SF (100 in stack)!
- contribution from non-starburst “normal” galaxies and hot gas halos of elliptical galaxies?

2.5<z<3.0 LBGs (200 in stack)

Bomans, Zinn & Blex, in prep.

eROSITA vs RASS for starburst galaxies

* eROSITA All Sky Survey about 30 times more sensitive than RASS

  → larger survey volume, more faint emission of outflows

* eROSITA has carbon edge advantage (remember: outflows have soft spectra!)

* no significant gain in spatial resolution → detect via optical/UV selected source lists

* X-ray specta !

* nice lines in the soft part → diagnostics from survey data

eROSITA for starbursts / galactic outflows !

* more than 100 dwarf starbursts with outflows in survey data in local universe expected

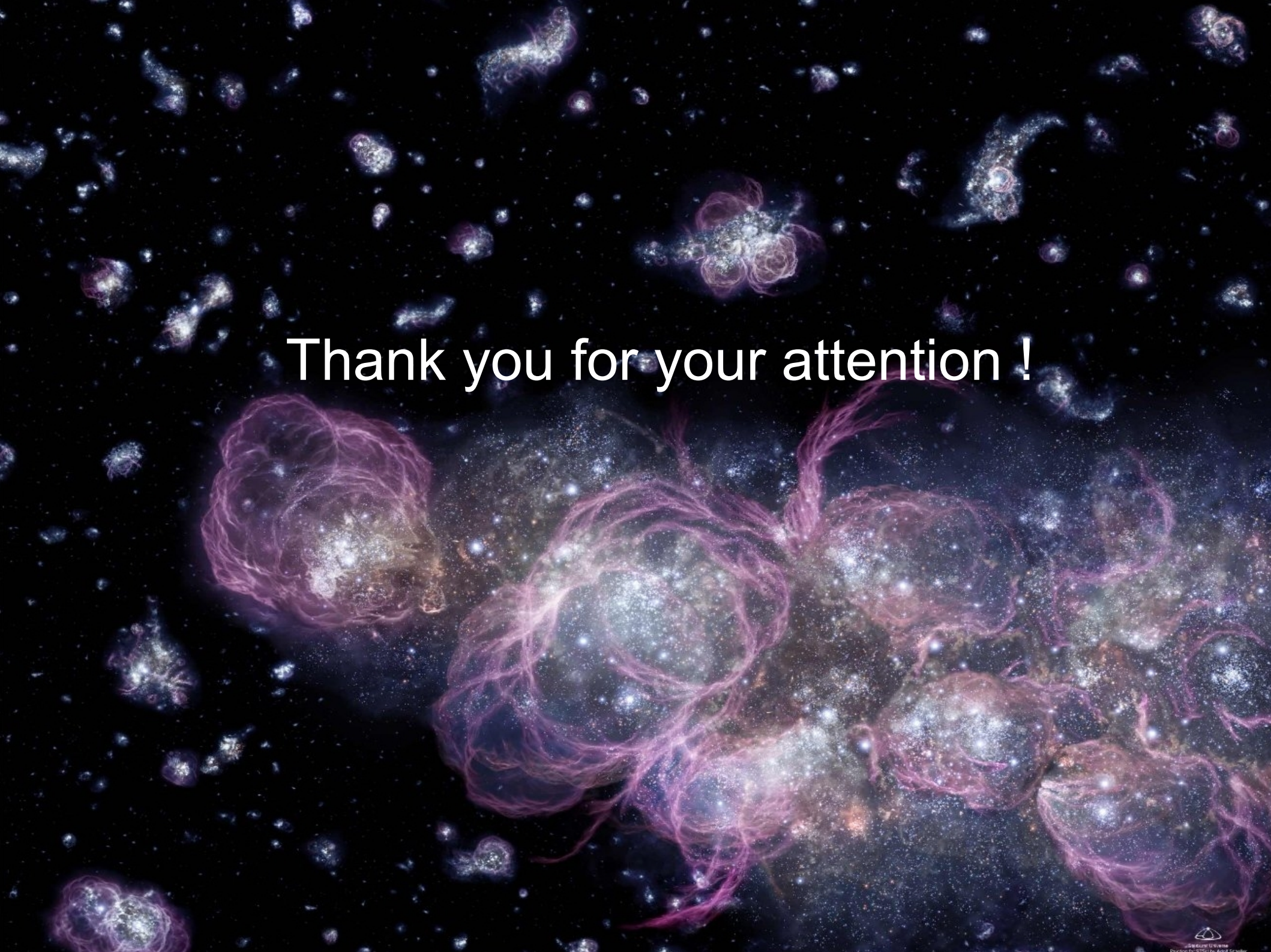
* optical/UV source lists → stacking analysis for Lyman break galaxy analogs
  and compact strong emission line galaxies out to at least z~0.5

* potential for many new nuclear starburst galaxies with outflows

* multiple starbursts in (compact) galaxy groups

* Lyman break galaxies at z~1...4 in the deep spots of survey?

* strong synergy with LOFAR (tracing synchroton emission halos, magnetic fields)


Thank you for your attention !