# HMXB, ULX and star formation

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Grimm, Gilfanov, Sunyaev, MNRAS, accepted (astro-ph/0205371)

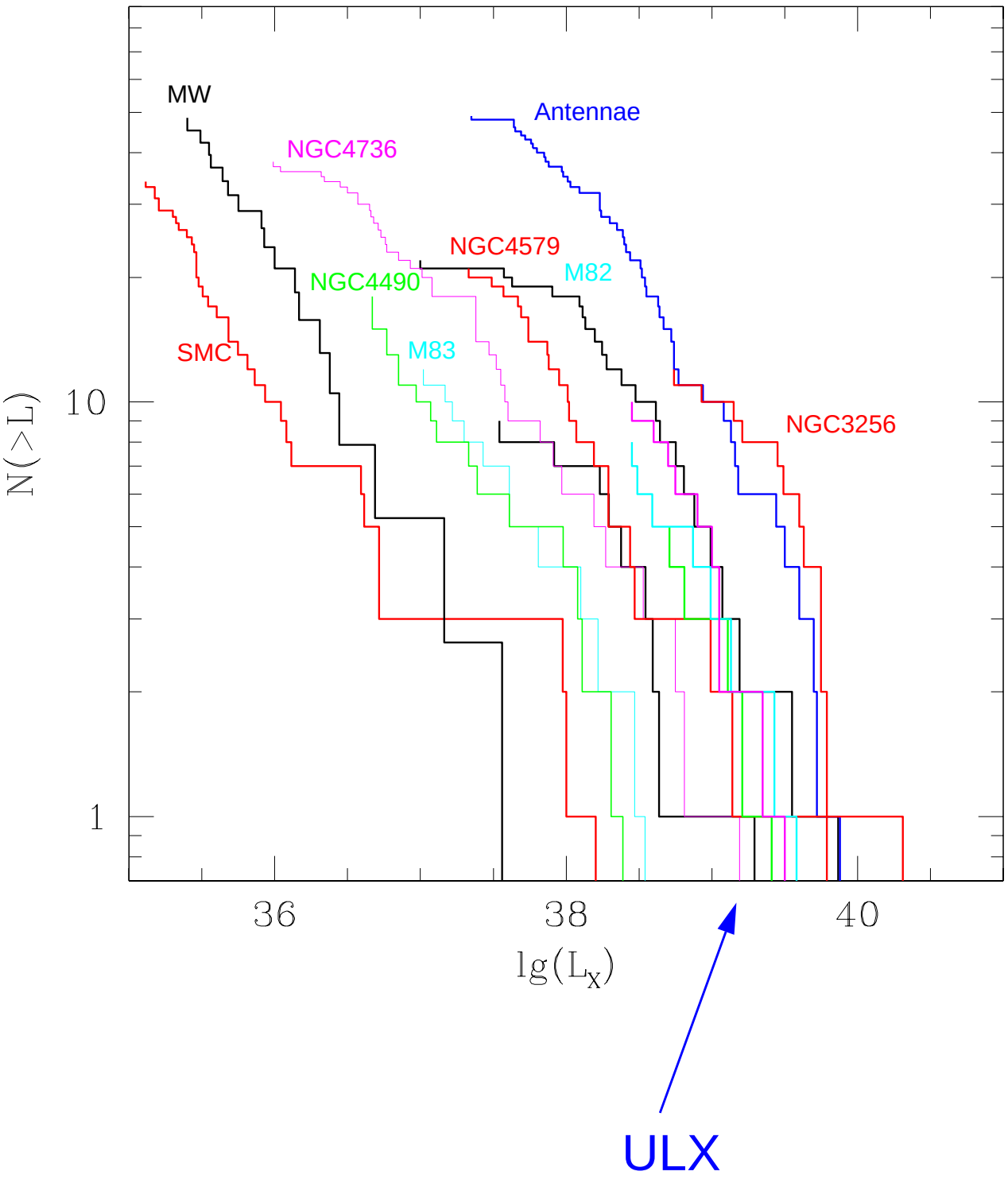
# X-ray binaries

- dominate X-ray emission from normal galaxies (no AGN, no X-ray gas)
- harbor NS or BH
  => progenitor star M>8 $M_{sun}$
- evolutionary time scales
  HMXB $\tau \sim 10^6 - 10^7$ yrs
  LMXB $\tau \sim 10^9 - 10^{10}$ yrs
- relation to star formation
  HMXBs are good star formation tracer
- SFR of massive stars, M>8 $M_{sun}$

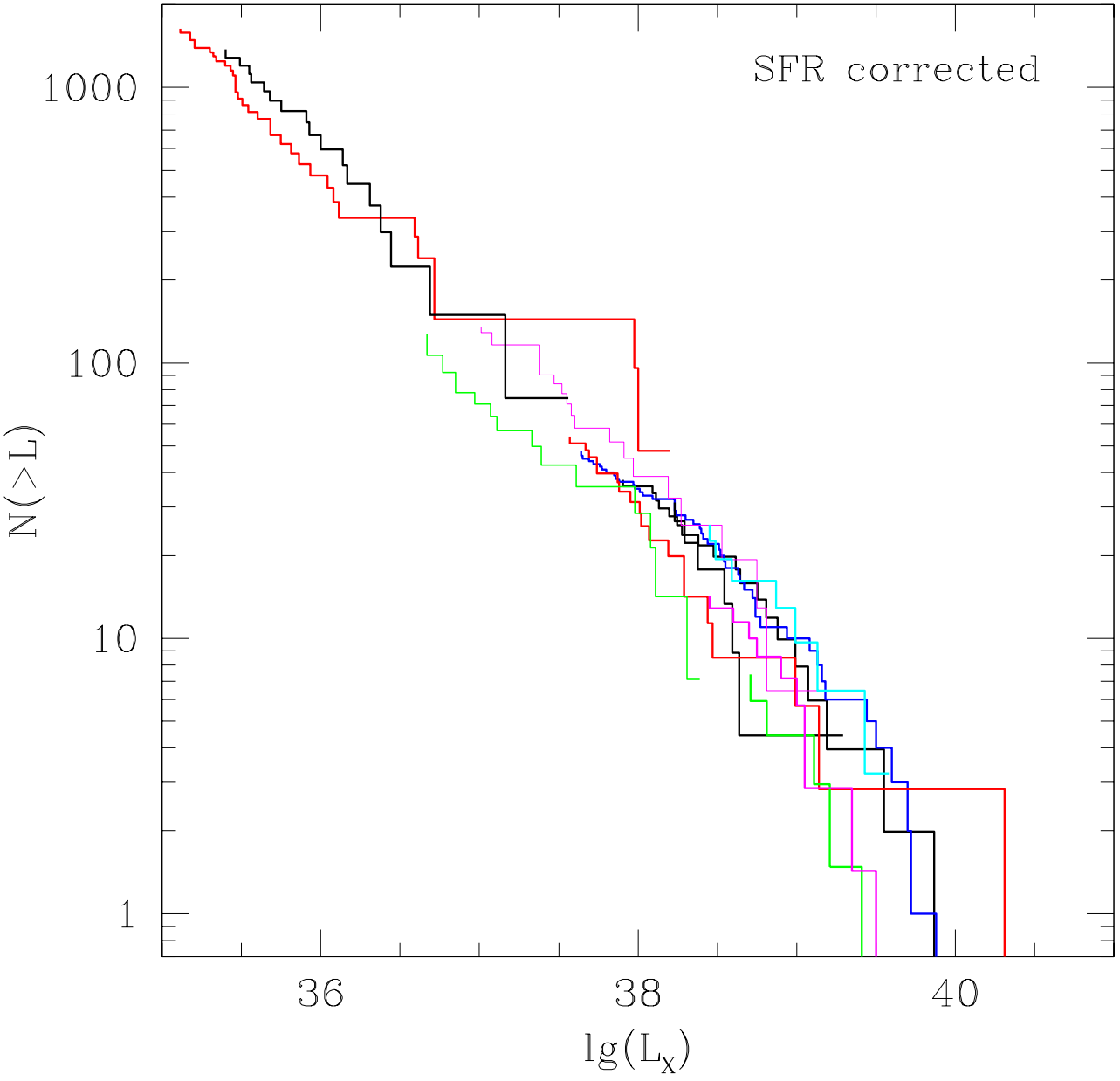
# Sample of starforming galaxies (luminosity functions)

| Galaxy | D, Mpc | SFR, $M_{sun}$/year |
|---|---|---|
| NGC3256 | 35.0 | 44.0 |
| Antennae | 19.3 | 7.1 |
| M100 | 20.4 | 4.8 |
| M51 | 7.5 | 3.9 |
| M82 | 5.7 | 3.6 |
| M83 | 3.8 | 2.6 |
| NGC4579 | 23.5 | 2.5 |
| M74 | 12.0 | 2.2 |
| Circinus | 3.7 | 1.6 |
| NGC4736 | 4.5 | 1.1 |
| NGC4490 | 8.6 | 1.0 |
| Milky Way | – | 0.25 |
| SMC | 0.06 | 0.15 |

# Luminosity functions

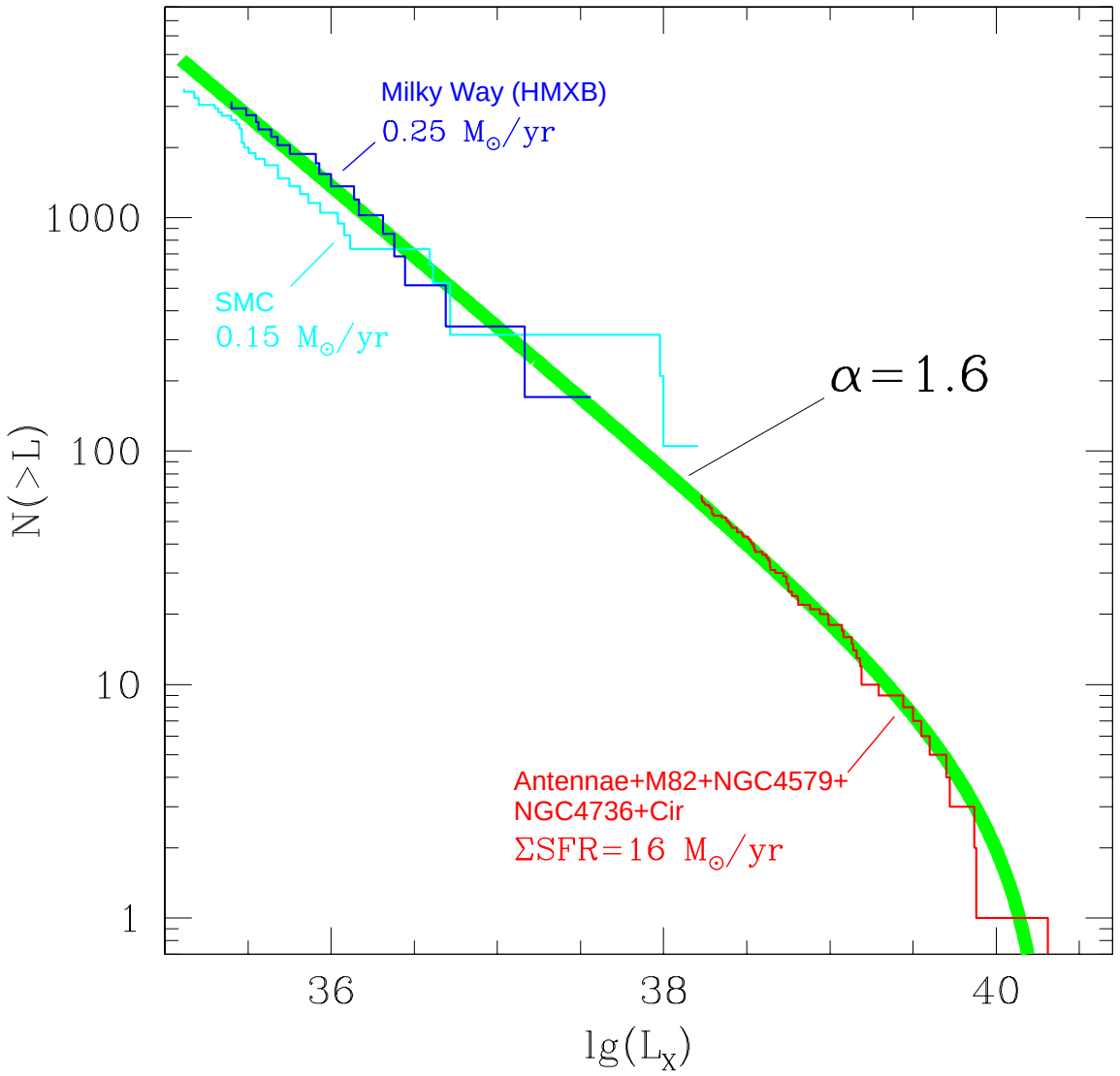


# Luminosity functions
# SFR corrected



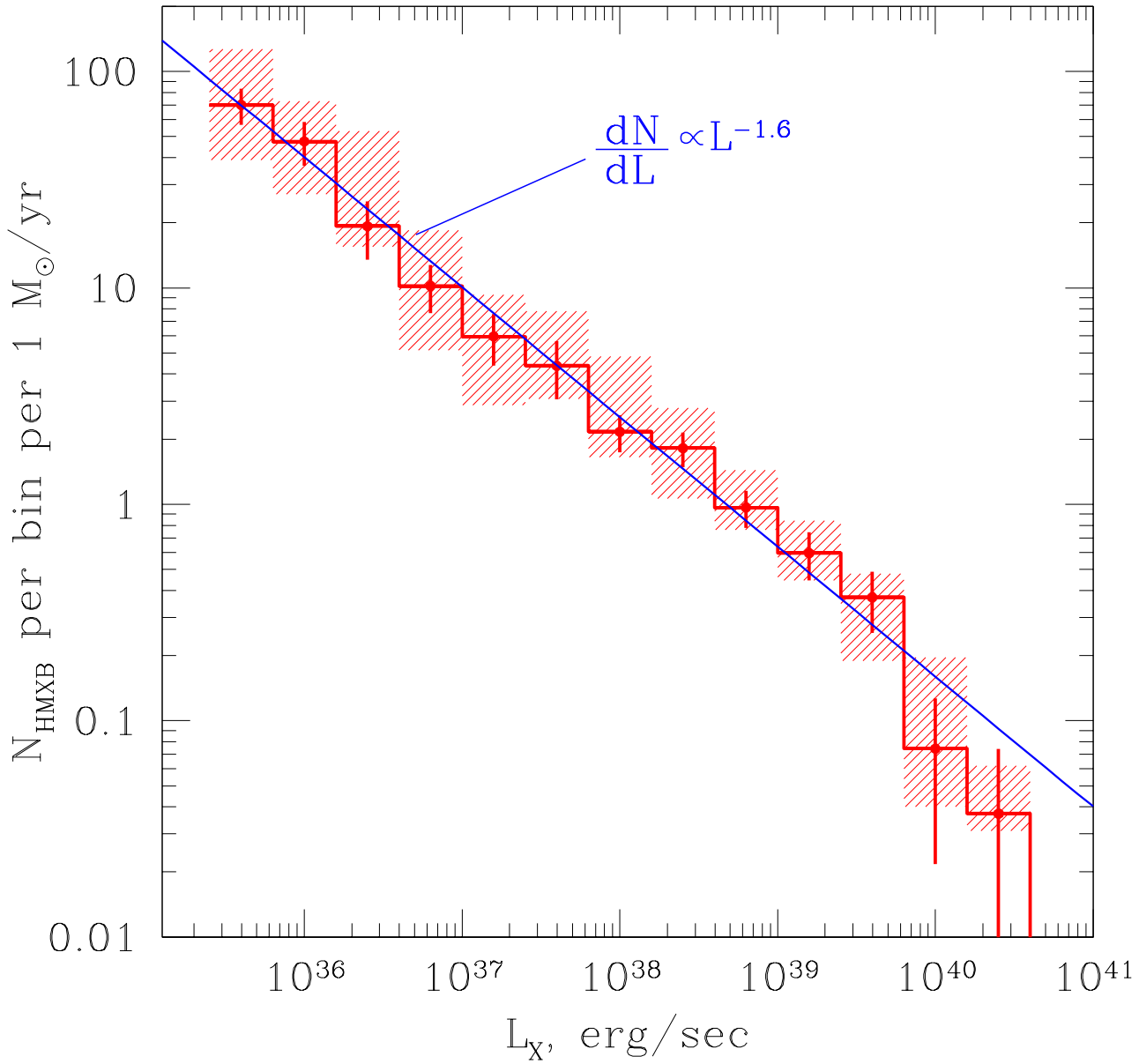

SFR range: 0.15–7 $M_{sun}$/year

# “Universal” luminosity function ?




- $\frac{dN}{dL_{38}} = 3.3 \times SFR \times L_{38}^{-1.6}$
- no strong non-linear effects
- evidence for cut-off @ L~few $10^{40}$ erg/sec

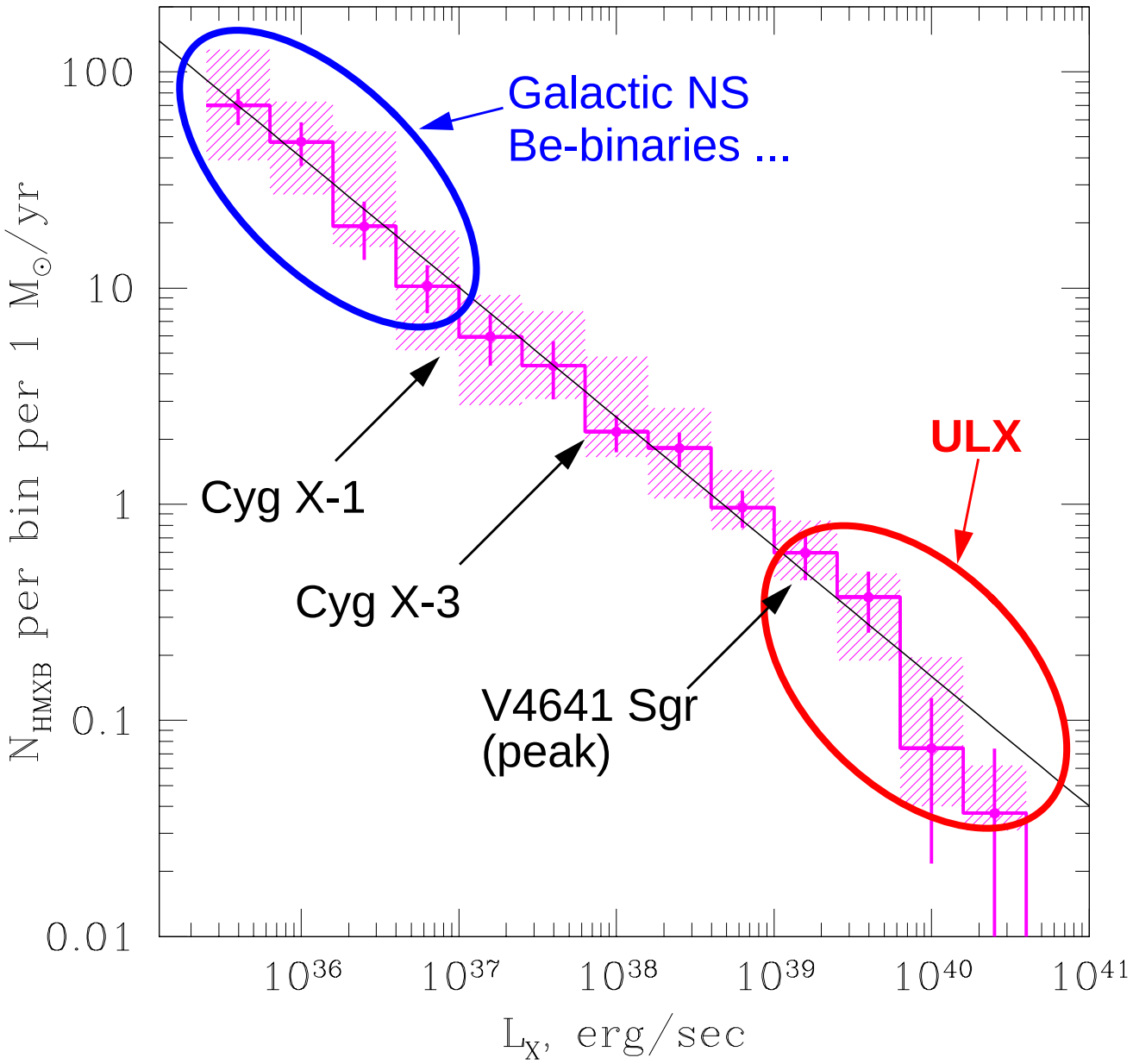
# HMXBs luminosity function
# Differential form




- all data, weighted ~$SFR^{-1}$
- uncertainties: 20% distance, 30% SFR

# “Normal” NS/BH and ULX

## The same family ?



# HMXB can be used to measure SFR in other (distant) galaxies

$$\frac{dN}{dL_{38}} = 3.3 \times SFR \times L_{38}^{-1.6}$$

distant, unresolved galaxies

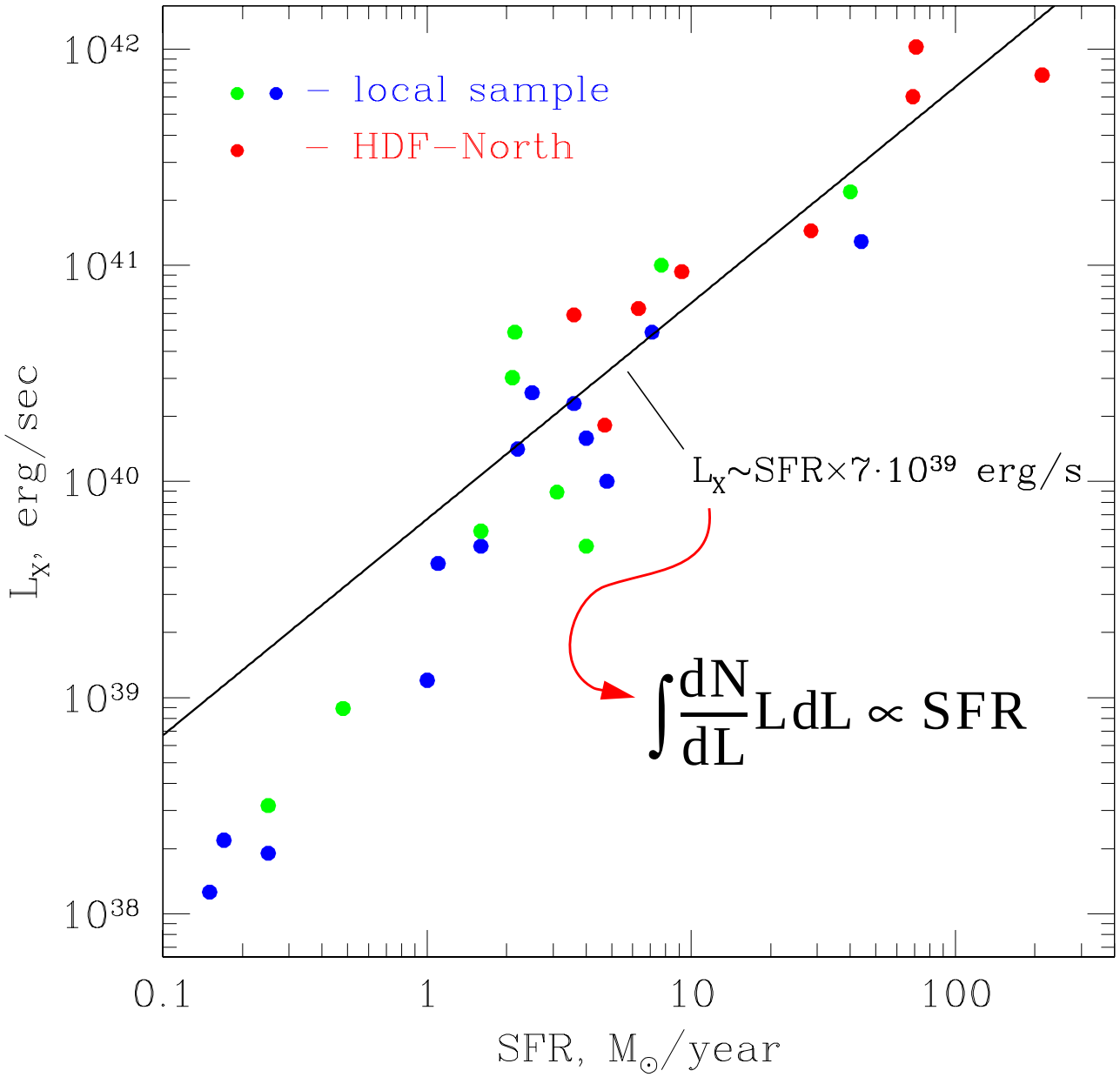
=> total $L_X$ only

# Extended sample

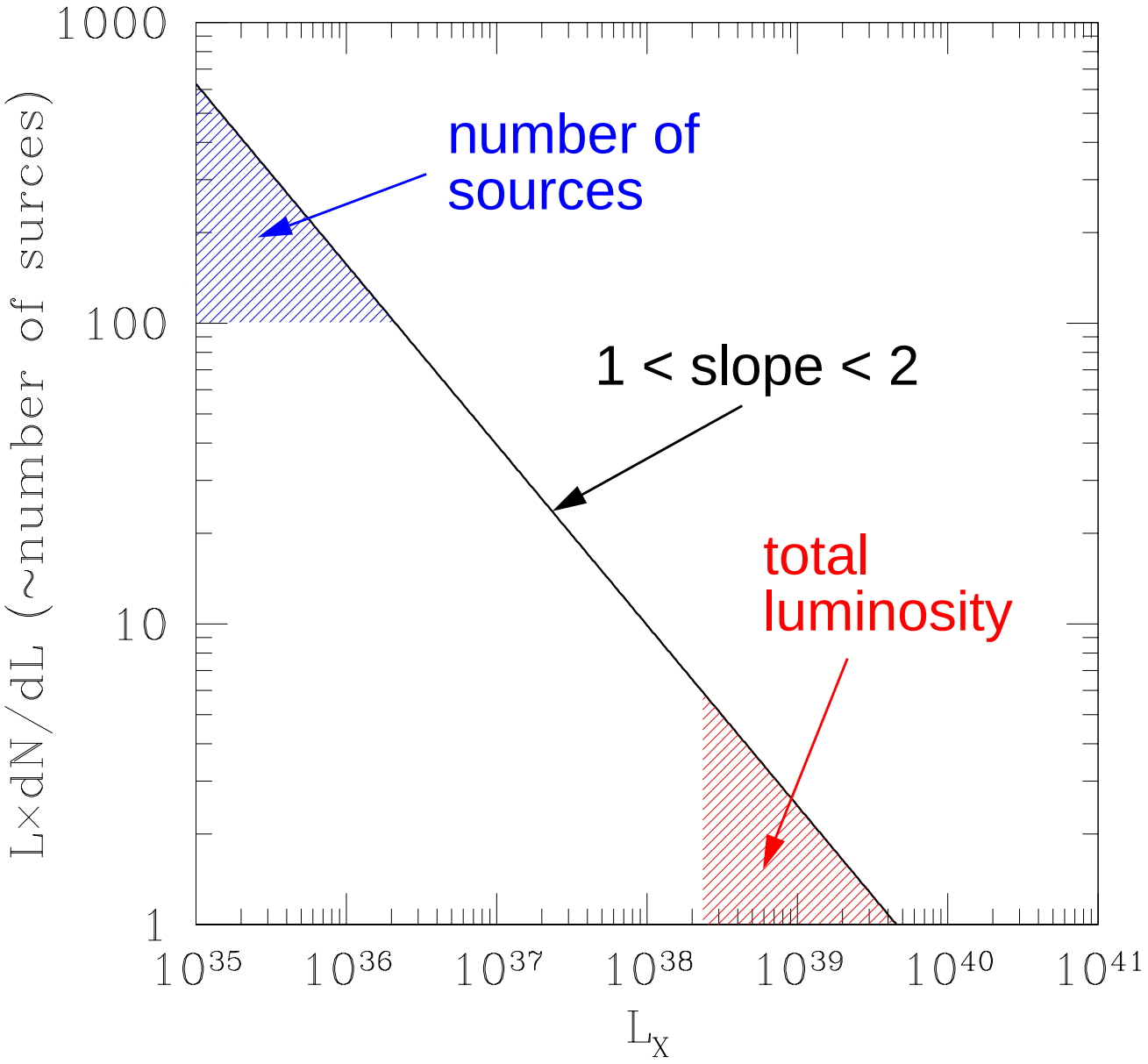
- more nearby galaxies (mostly ASCA)
- Hubble Deep Field North (Chandra)
  z~0.2-1.2

- AGN contamination!
  selection based on NON-X-ray data only
- LMXB contamination

# Total luminosity $L_X$ (due to HMXB)

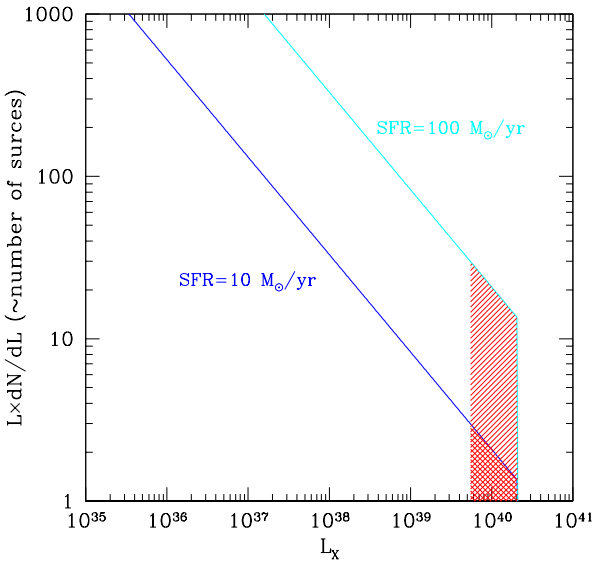


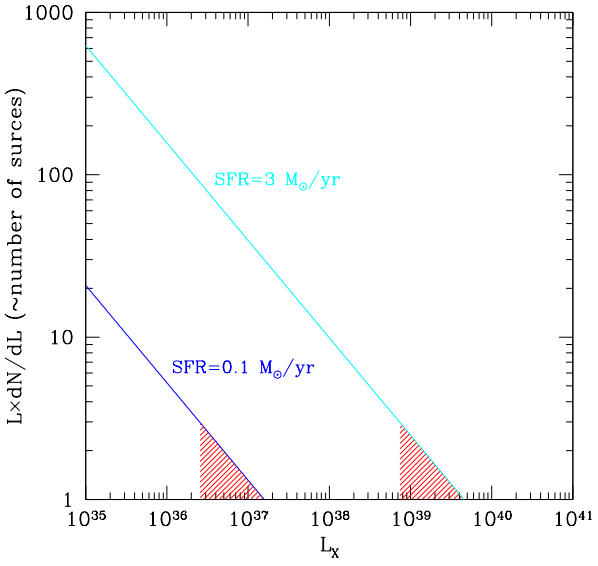
# if LF is a power law

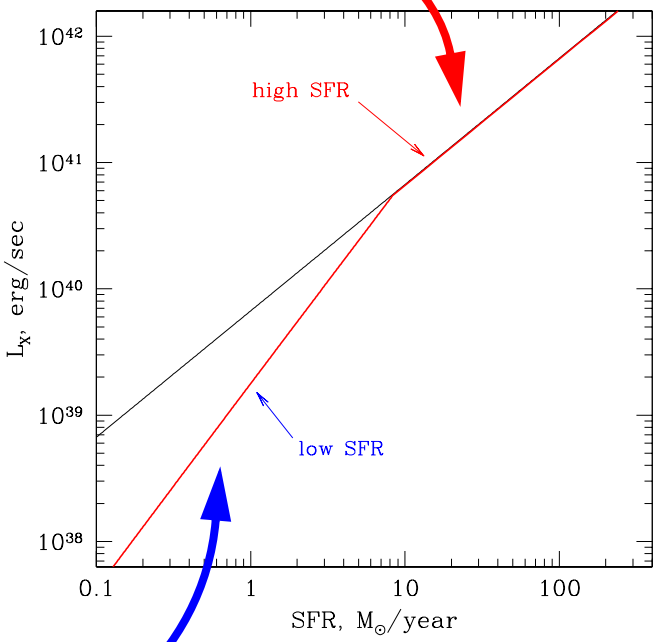


$$\frac{dN}{dL} = SFR \times L^{-\alpha} \not\Rightarrow L_{tot} = A \times SFR$$

- high SFR –> linear regime



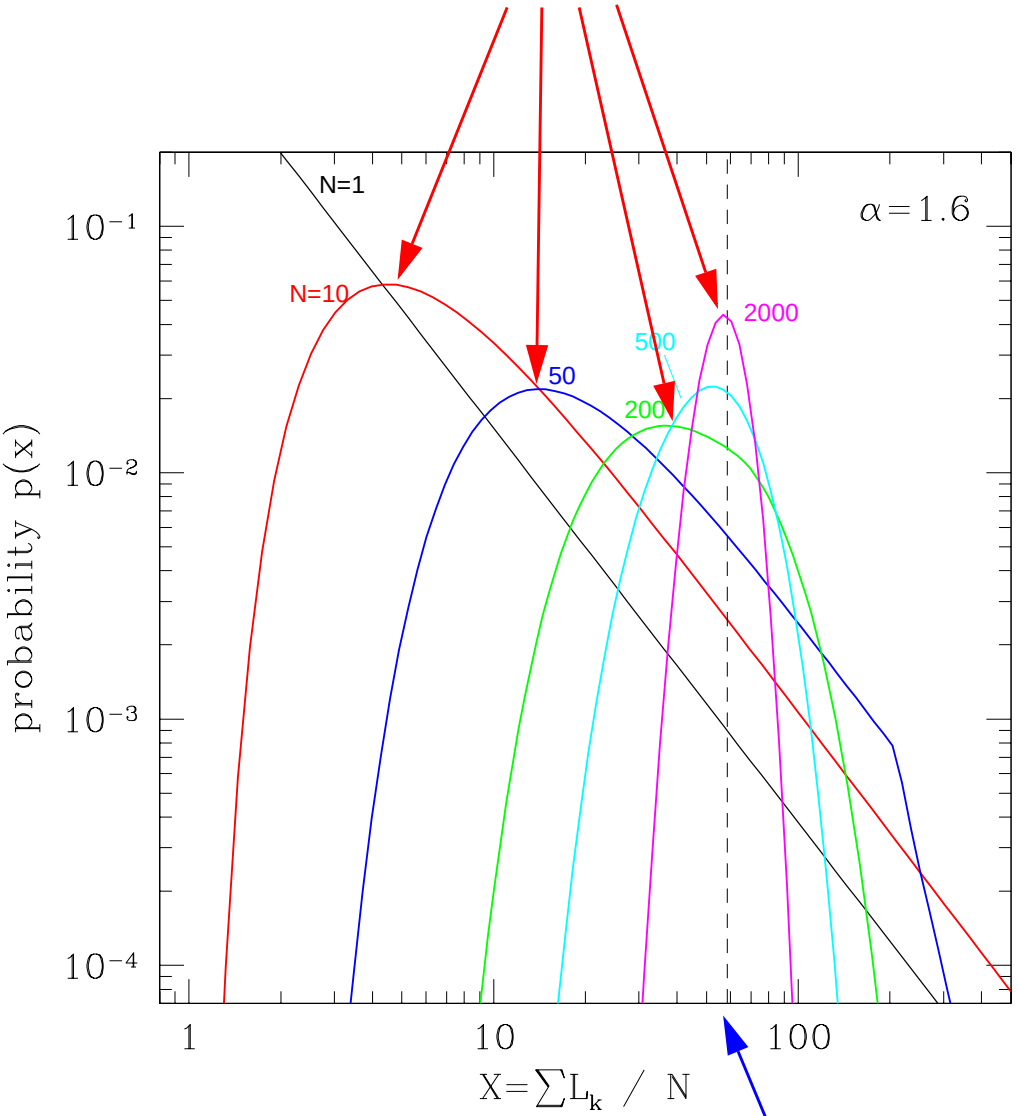




- low SFR –> non-linear regime

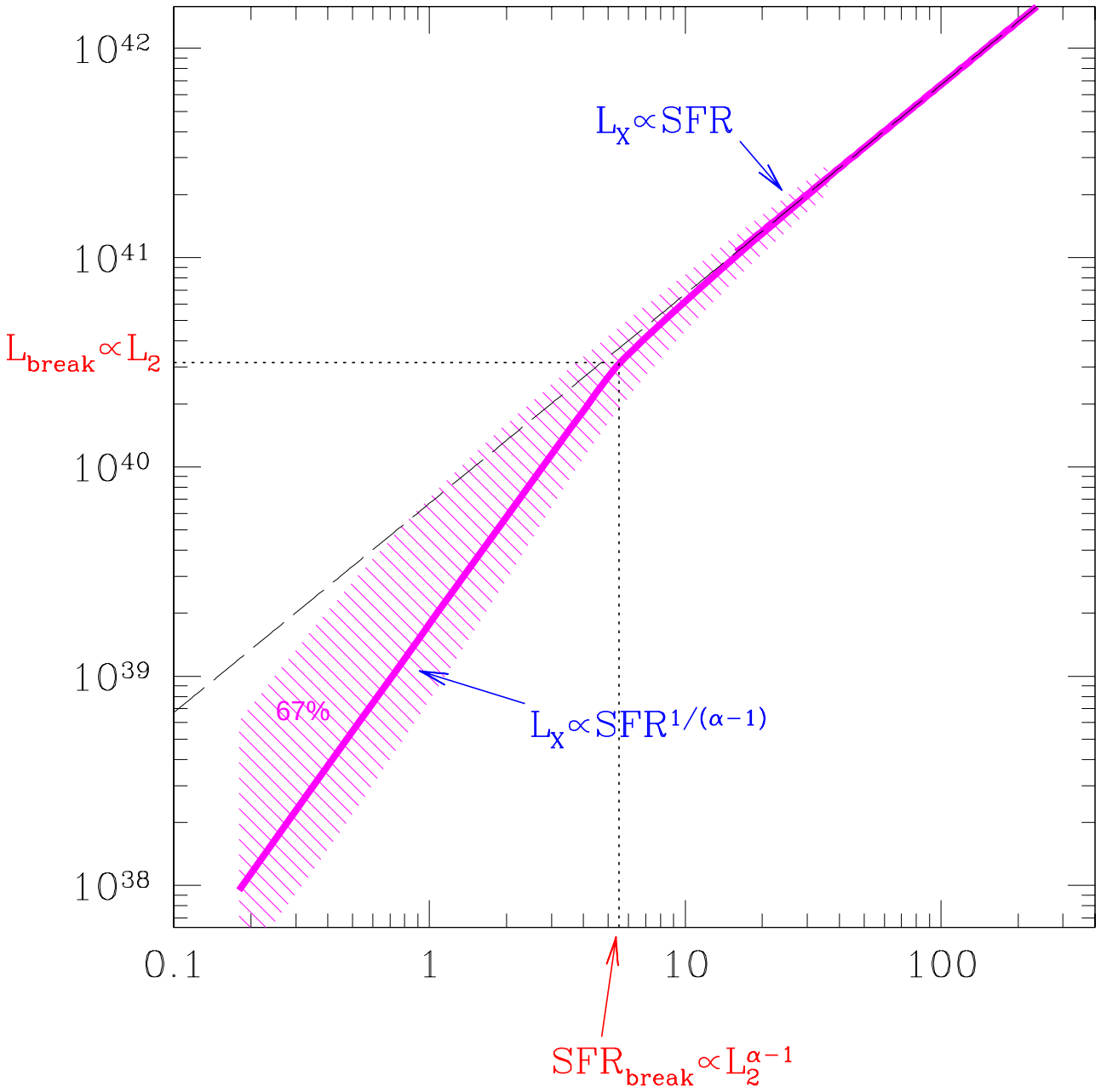
# Probability distribution for collective luminosity

**most probable value (mode)**




$$\langle L \rangle = \int_{L_1}^{L_2} \frac{dN}{dL} L\,dL \propto SFR$$ => **expectation (mean) value**

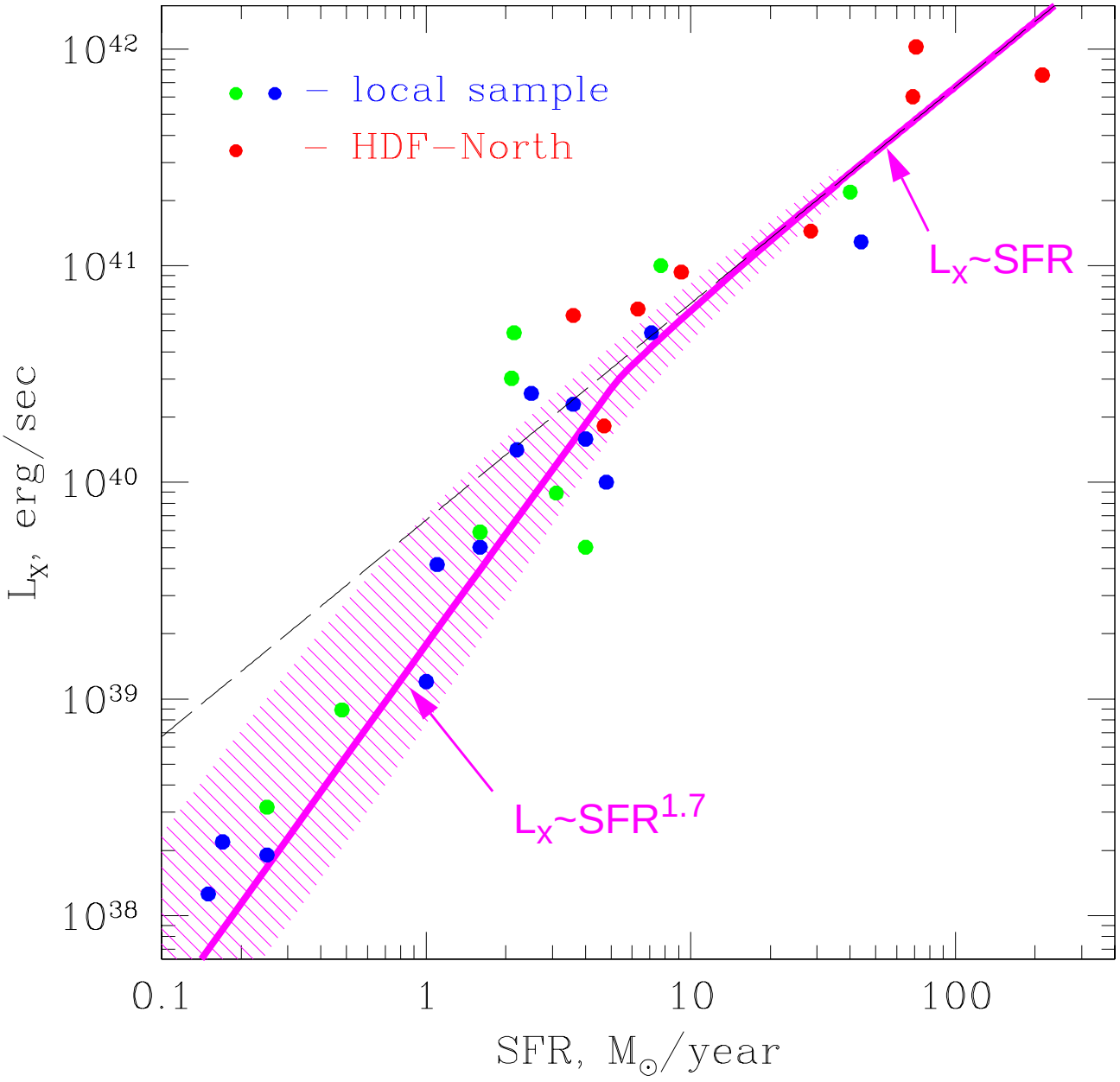
# Predicted $L_X$–SFR relation




$L_2$– high luminosity cut-off in LF

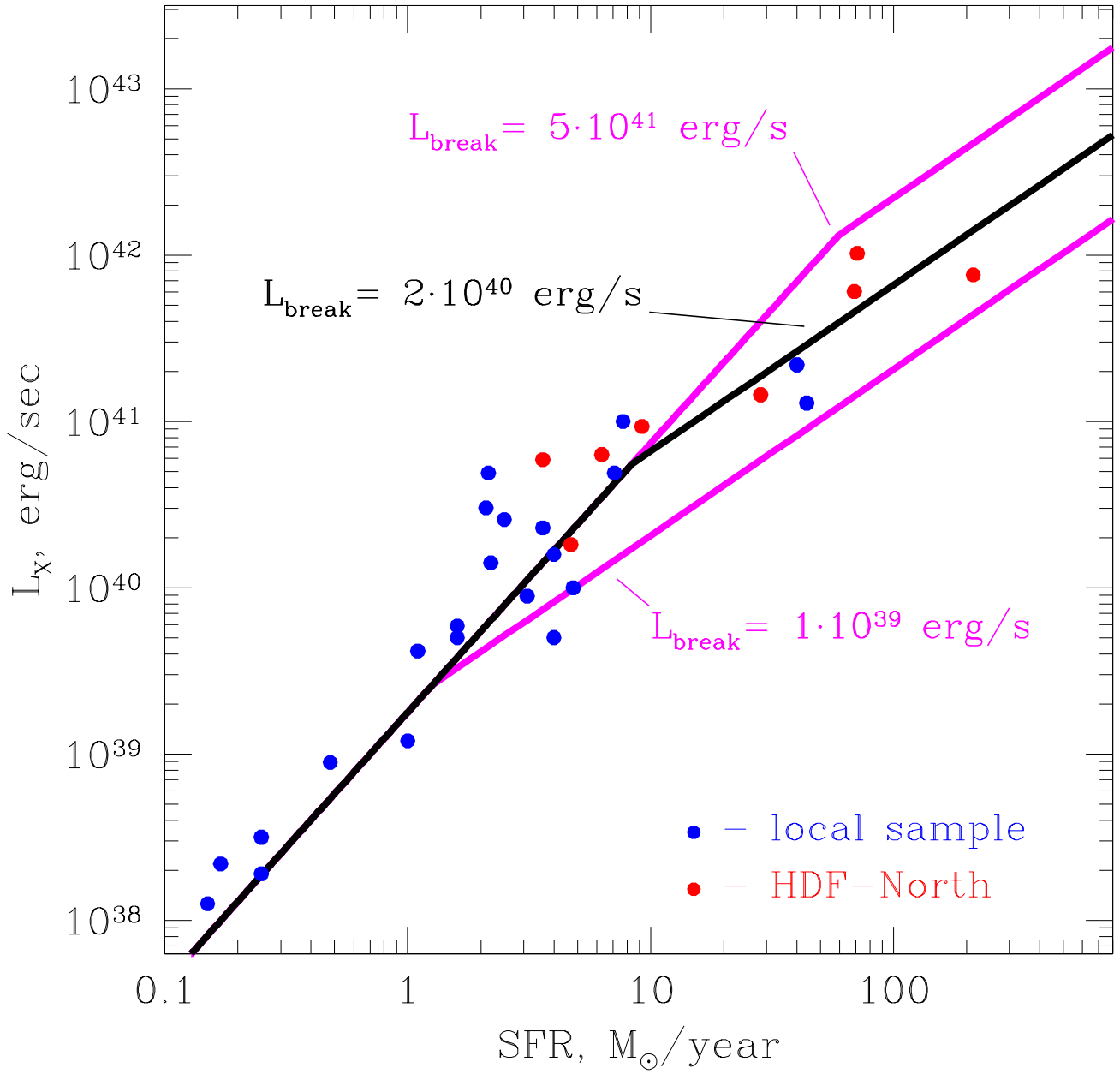
$\alpha$ – slope of LF

# $L_X$–SFR relation



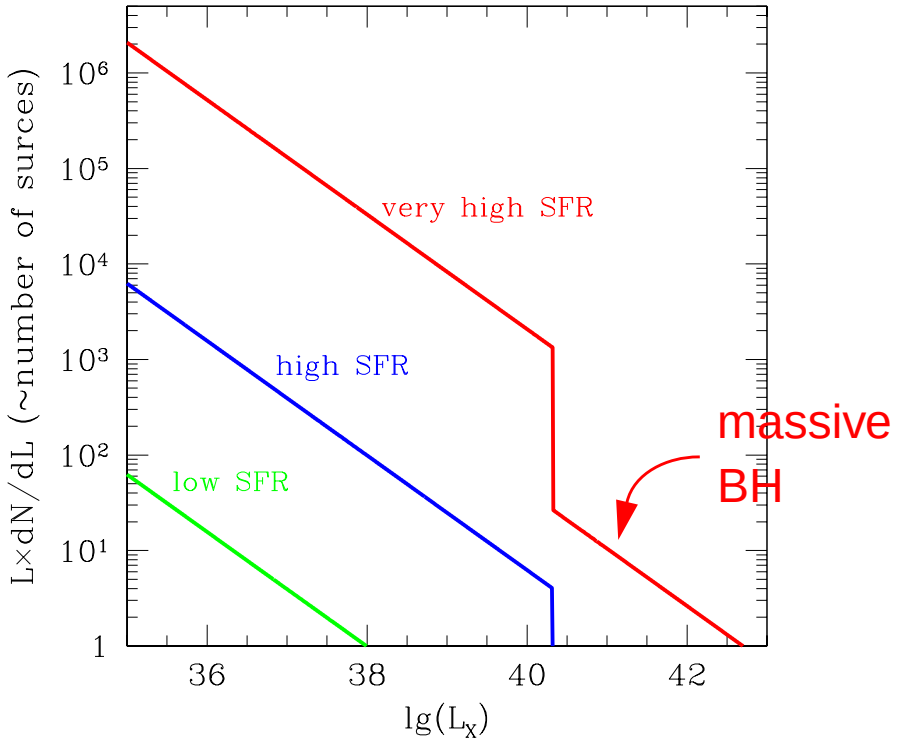

- **Low SFR - non-linear regime due to effects of statistics**

# Break in the luminosity function

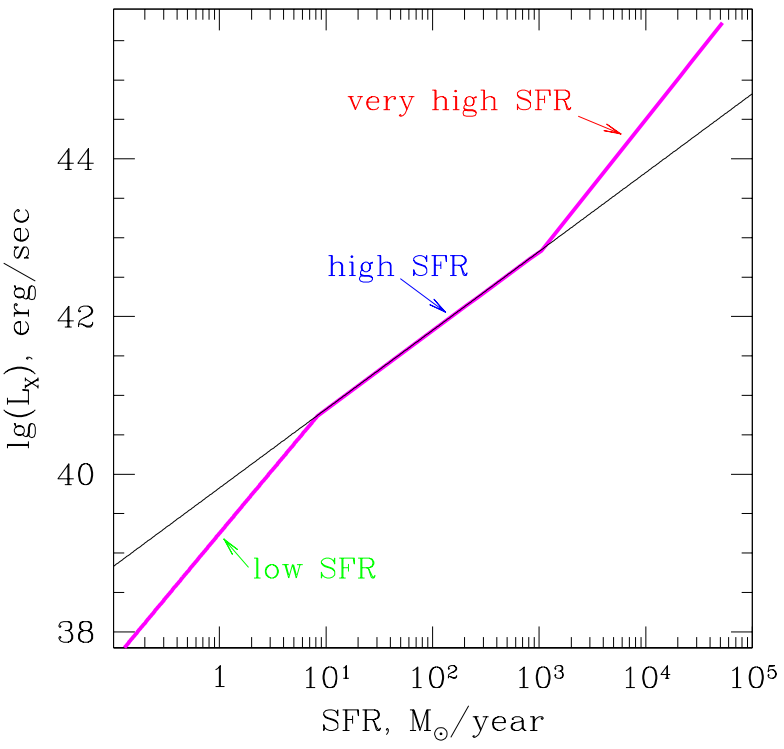


# Intermediate mass black holes ???

- luminosity function




- Lx–SFR relation



# Conclusions

- HMXBs are an SFR indicator

$$SFR \approx \frac{L_X}{7\times10^{39}\,\mathrm{erg/s}} \quad @ \quad SFR > 4.4 M_{sun}/yr$$

$$SFR \approx L_X^{0.6} \quad @ \quad SFR < 4.4 M_{sun}/yr$$

- ~universal luminosity function of HMXBs

$$\frac{dN}{dL_{38}} = 3.3 \times SFR \times L_{38}^{-1.6}$$

- ULX are members of the same population
- break in the HMXBs luminosity function @$L_X$~few $10^{40}$ erg/s