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Remnants of massive metal-poor stars: viable engines for ULXs

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OUTLINE

1 - data: possible correlation between ULXs and star formation rate (SFR) + metallicity

2 - model: effect of metallicity on BH mass

3 – comparison data-model

4 – future perspectives

1-DATA: correlations
NULX-SFR-Z

The SAMPLE

64 GALAXIES with

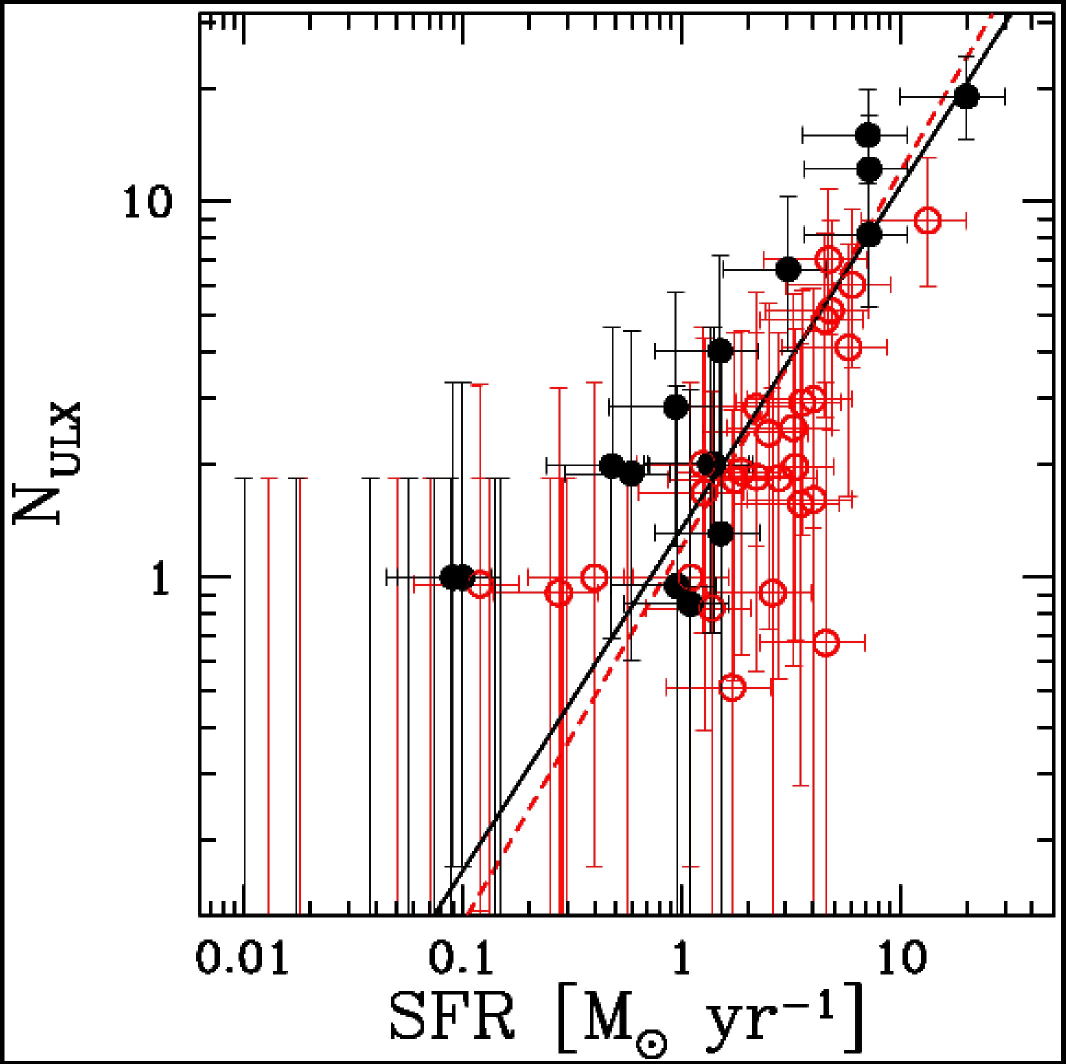
1) X-ray coverage (Rosat catalogue ->Liu & Bregman 2005, Chandra, XMM)

2) SFR measurement (Halpha, FIR, UV, radio,..)

3) homogeneous metallicity measurement and calibration (Pilyugin 2001 calibration)

4) spiral&irregular no ellipticals

N_{ULX}-SFR



$$\delta = 0.91^{+0.25}_{-0.15}$$

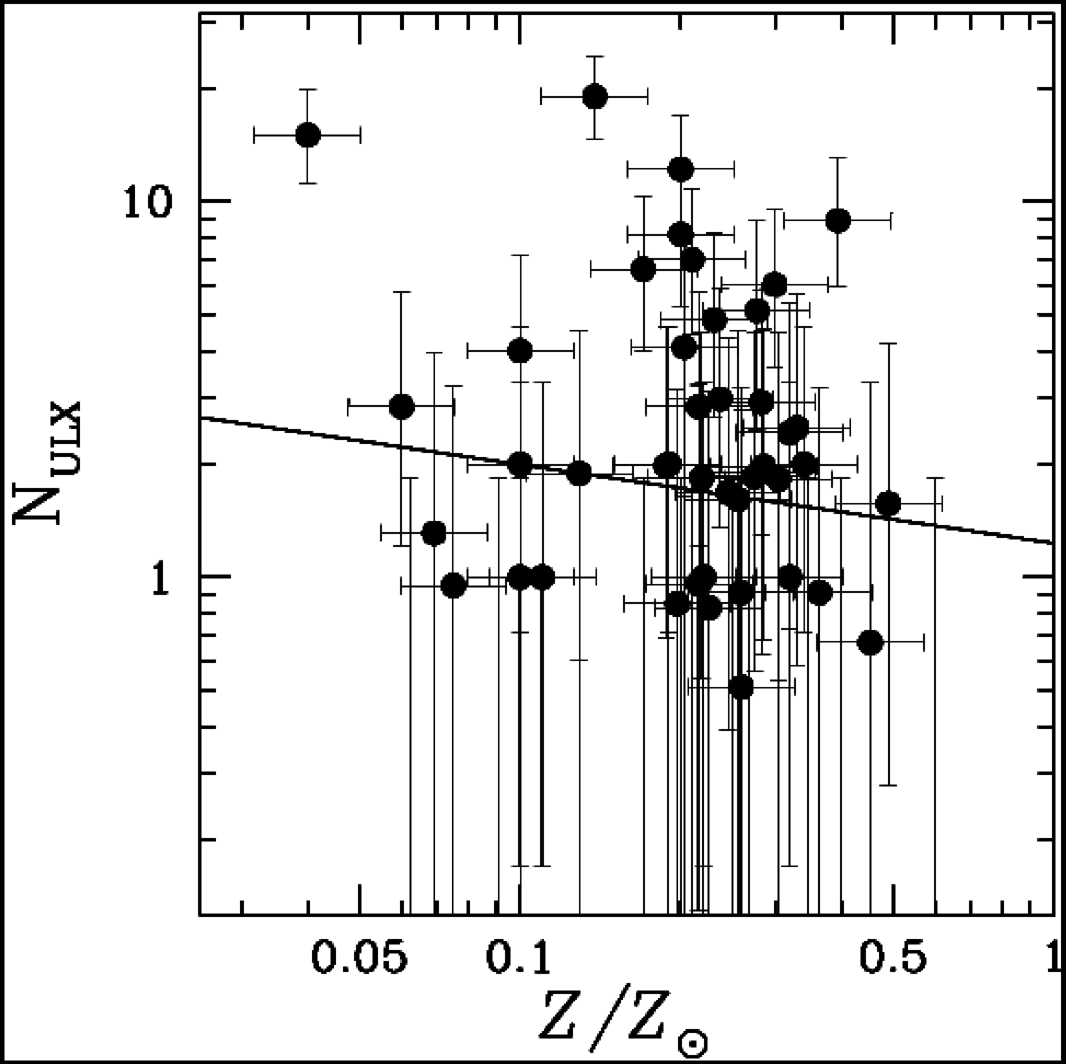
$$\zeta = 0.13^{+0.10}_{-0.14}$$

consistent with e.g. Grimm, Gilfanov, Sunyaev 2003 (see also Stefano Mineo's talk)

$$N_{ULX} = 10^{\zeta} \left(\frac{\text{SFR}}{M_\odot \ \text{yr}^{-1}} \right)^{\delta}$$

MM et al. 2010

N_{ULX}-Z



$\eta = -0.21 \pm 0.27$

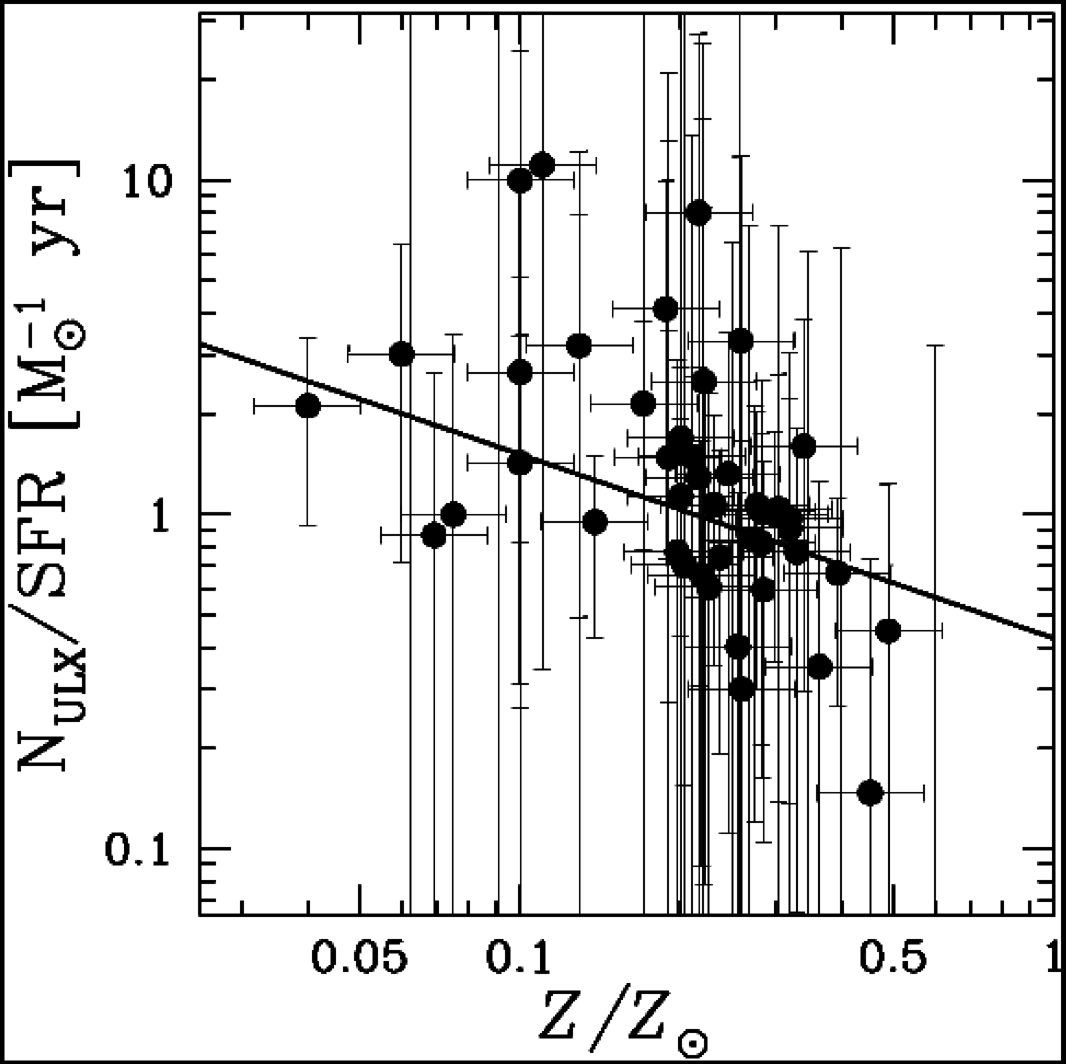
$\theta = 0.09 \pm 0.20$

NOT statistically significant!!

$$N_{ULX} = 10^{\theta} \left(Z/Z_\odot \right)^{\eta}$$

MM et al. 2010

N_{ULX}/SFR-Z



$$\iota_1 = -0.55 \pm 0.23$$

$$\kappa_1 = -0.37 \pm 0.18$$

With F-test significant at 96% confidence level

$$\left(N_{ULX} \frac{M_\odot\ yr^{-1}}{SFR} \right) = 10^{\kappa_1} \left(Z/Z_\odot \right)^{\iota_1}$$

MM et al. 2010

NULX/SFR-Z

Possible role of metallicity (less important than SFR) in forming ULXs

consistent with previous studies:
Pakull & Mirioni (2002), Cropper et al. (2004), Zampieri et al. (2004), Swartz et al. (2008); Mapelli, Colpi & Zampieri (2009); Zampieri & Roberts (2009), etc.

2 – MODEL: possible explanations

Main problem with ULXs:
isotropic Luminosity above Eddington limit for ~7 Msun compact objects

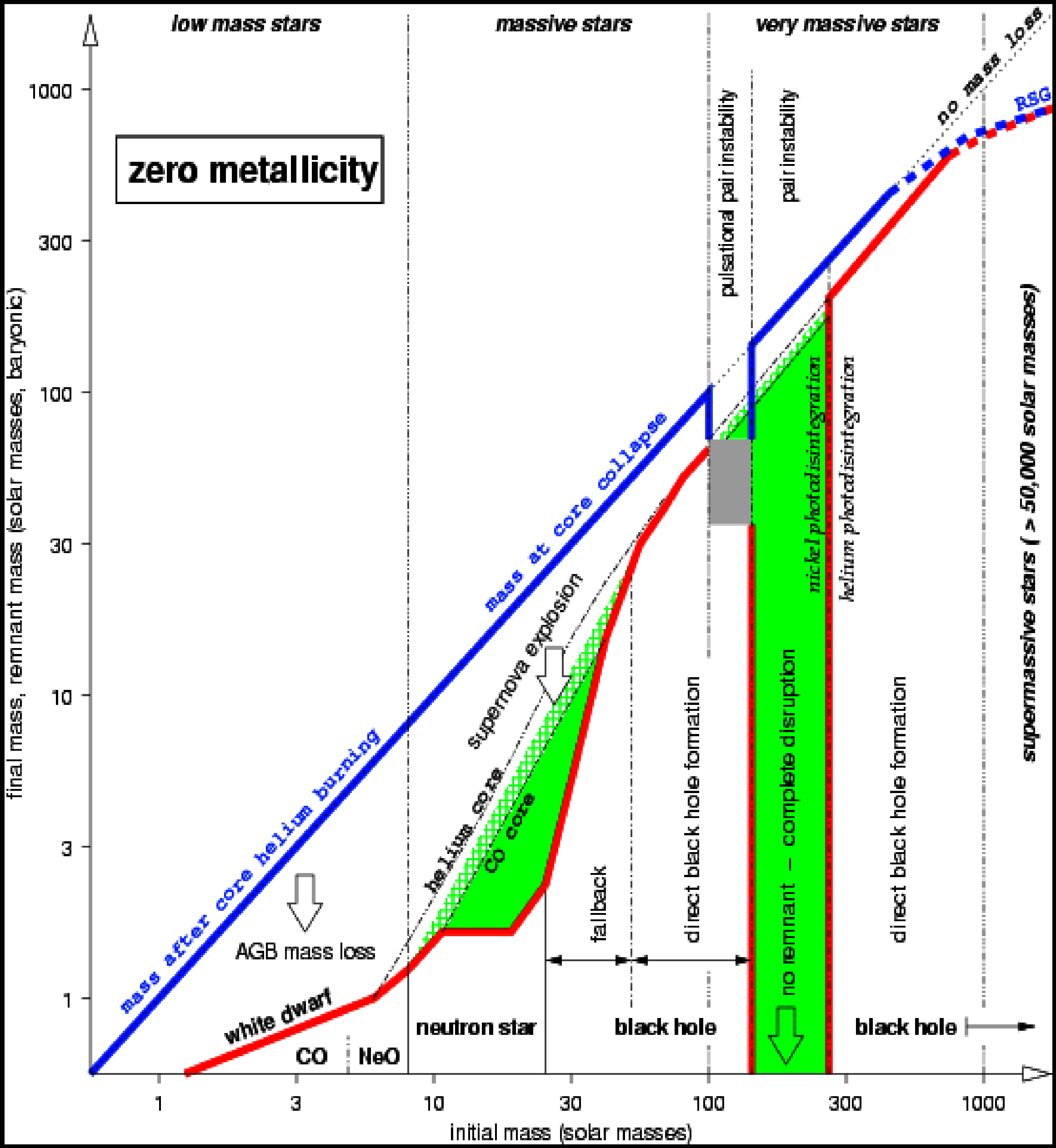
Is there any way to produce stellar BHs with mass > 10 Msun?
LOW METALLICITY

What prevents stellar remnants from having large masses?

Mass losses due to winds and SN explosion

Is there any way to reduce mass losses and avoid SN explosion?

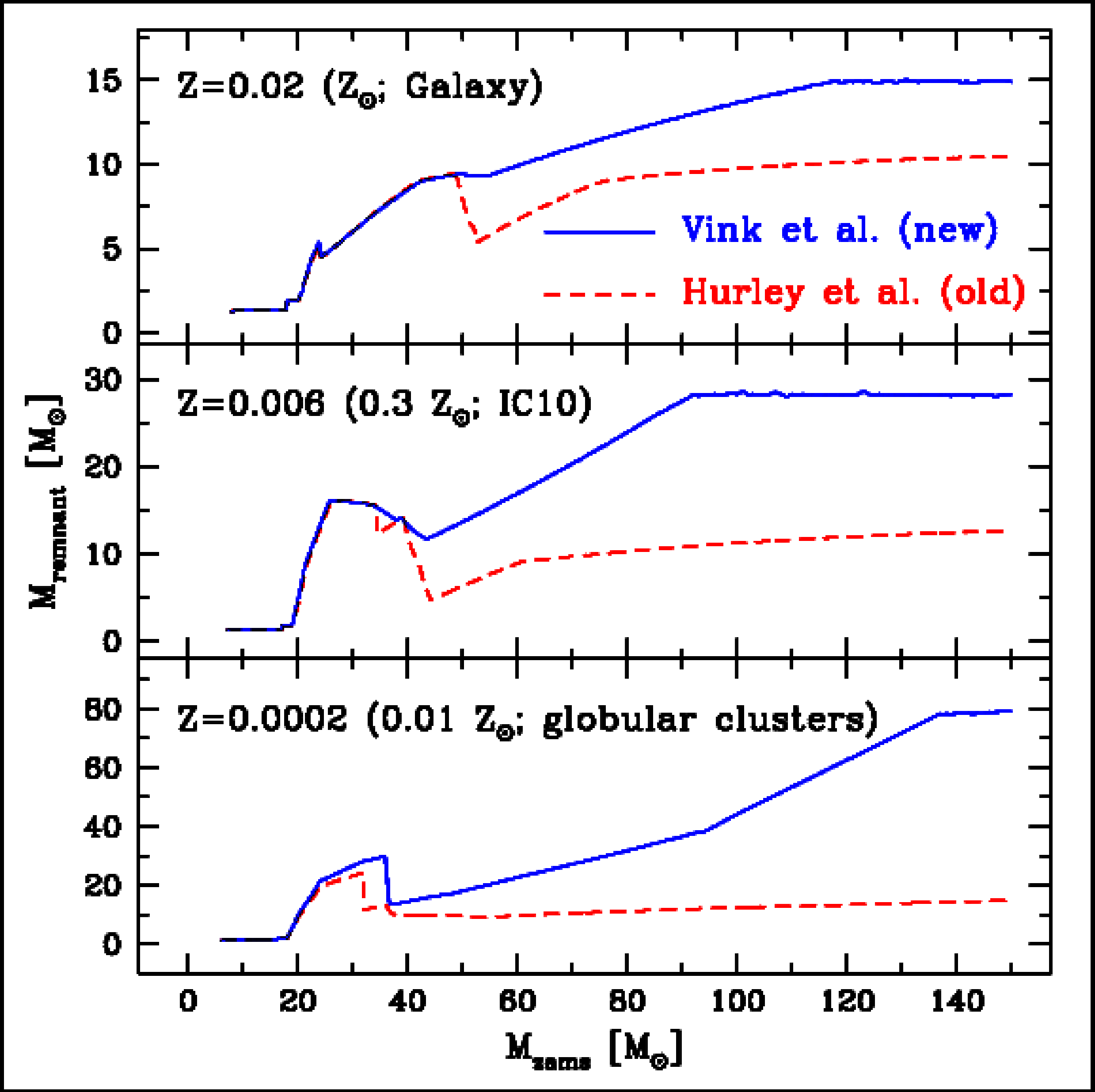
low metallicity



(Heger et al. 2002)

1) Stars with final mass > 40 Msun directly collapse into BHs (Fryer 1999; Heger et al. 2003)

2) stars with low metallicity (<~0.4 Zsun) lose less mass and may have final mass > 40 Msun (Portinari, Chiosi Bressan 1998; Belczynski et al. 2010)



30-80 Msun BHs are sufficiently massive to explain most of observed ULXs

Can we estimate the number of these BHs? from SFR + lifetime of companion + IMF:

$$N_{\rm BH} = A \int_{m_{\rm prog}(Z)}^{m_{\rm max}} m^{-\alpha} {\rm d}m$$

$$A = \frac{{\rm SFR} \quad t_{\rm co}}{\int_{m_{\rm min}}^{m_{\rm max}} m^{1-\alpha} \, {\rm d}m}$$

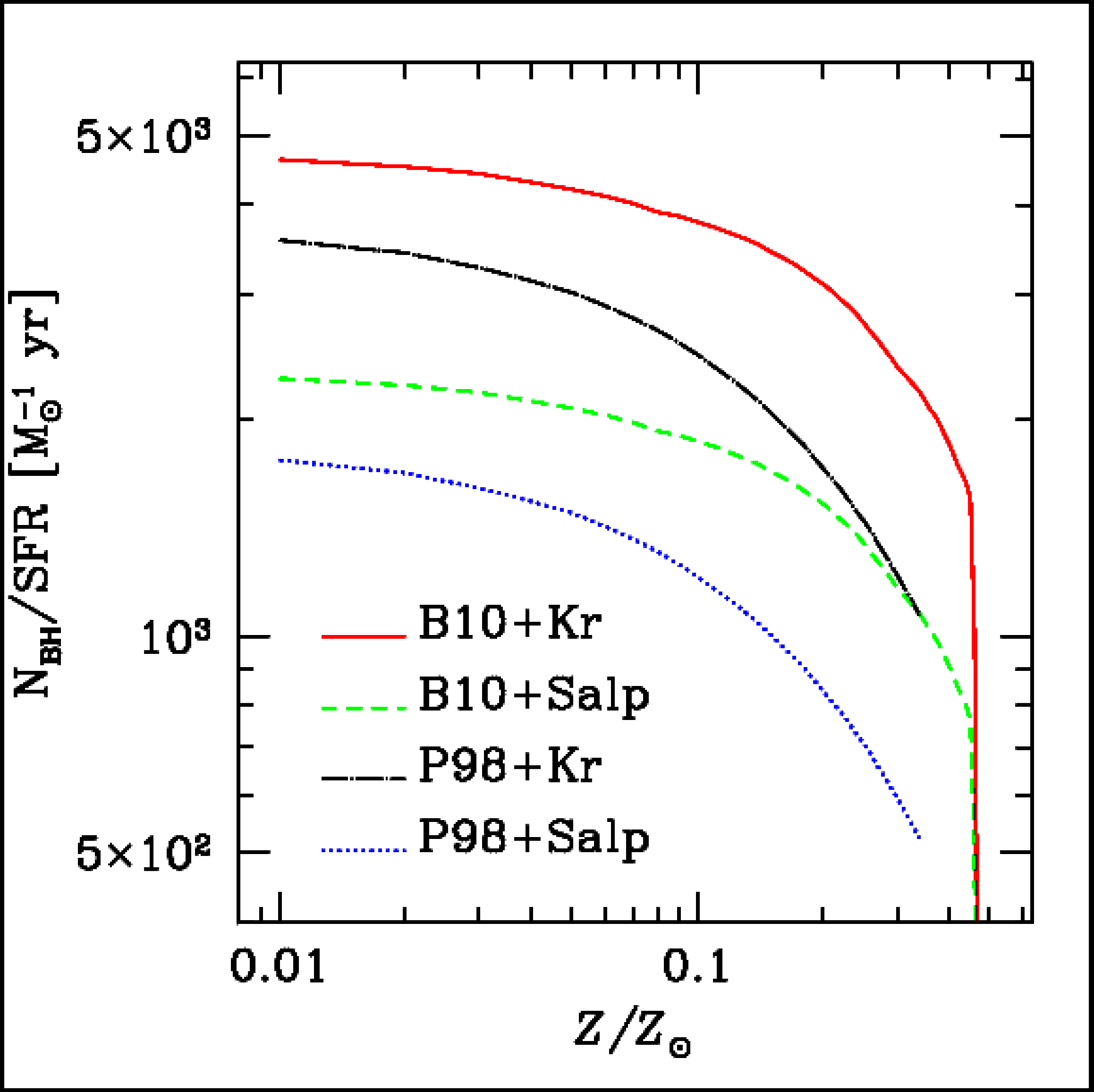
~10^5 massive BHs in Cartwheel for

→ **SFR=20 Msun yr^-1, $t_{\rm co}$=10^7 yr,**

Salpeter or Kroupa IMF

MM, Colpi & Zampieri 2009

N_{BH}/SFR-Z



MM et al. 2010

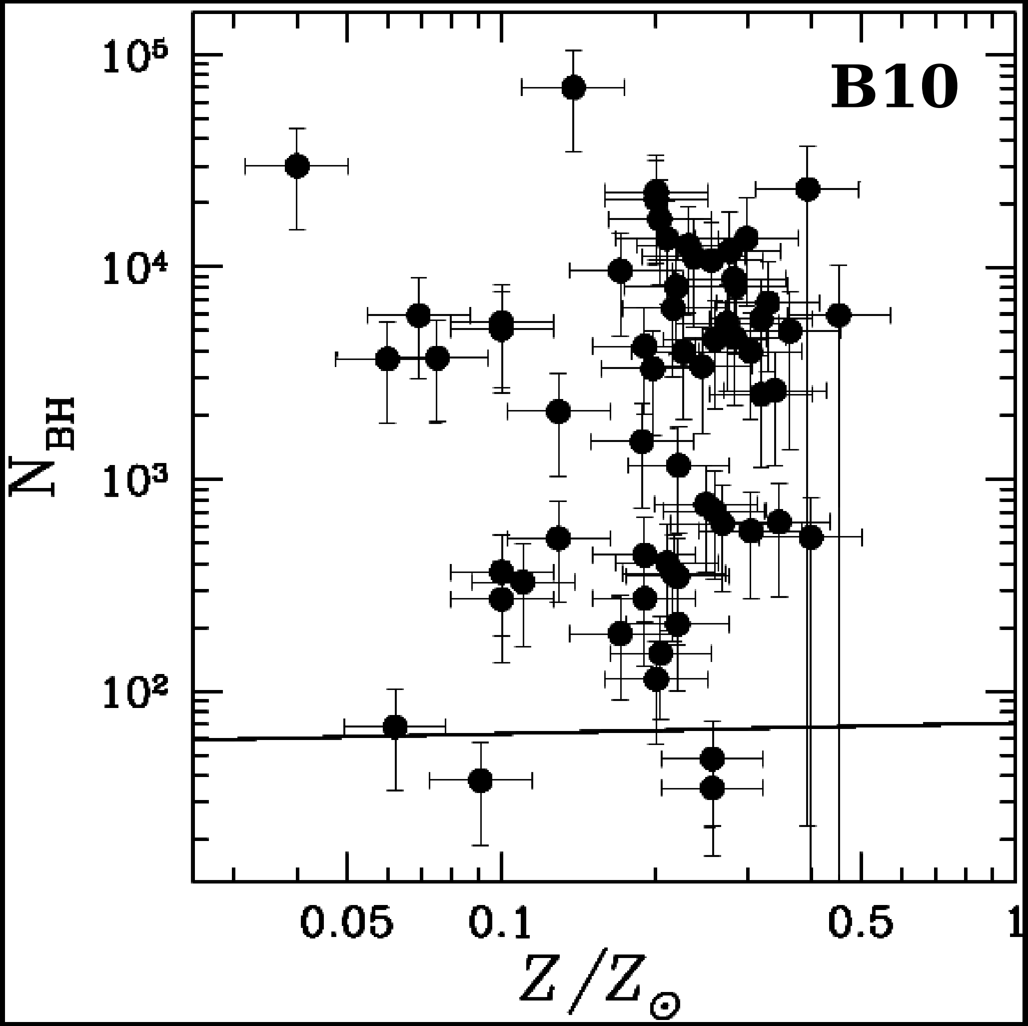
3 – comparison data - model

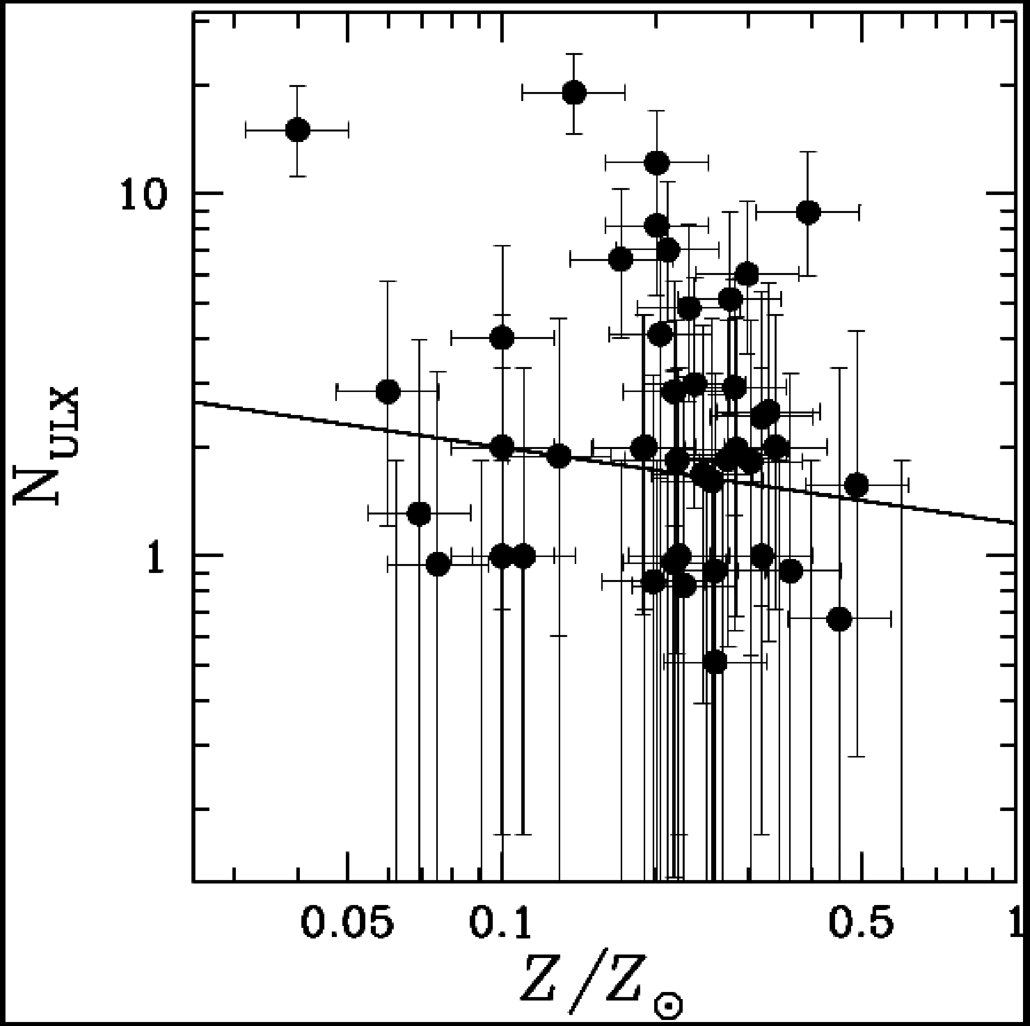
N_{BH}-SFR

In the DATA: N_{ULX} scales with SFR
(slope = 0.91 +/- 0.2)

In the model: We DO assume that N_{BH} scales with SFR (slope = 1)

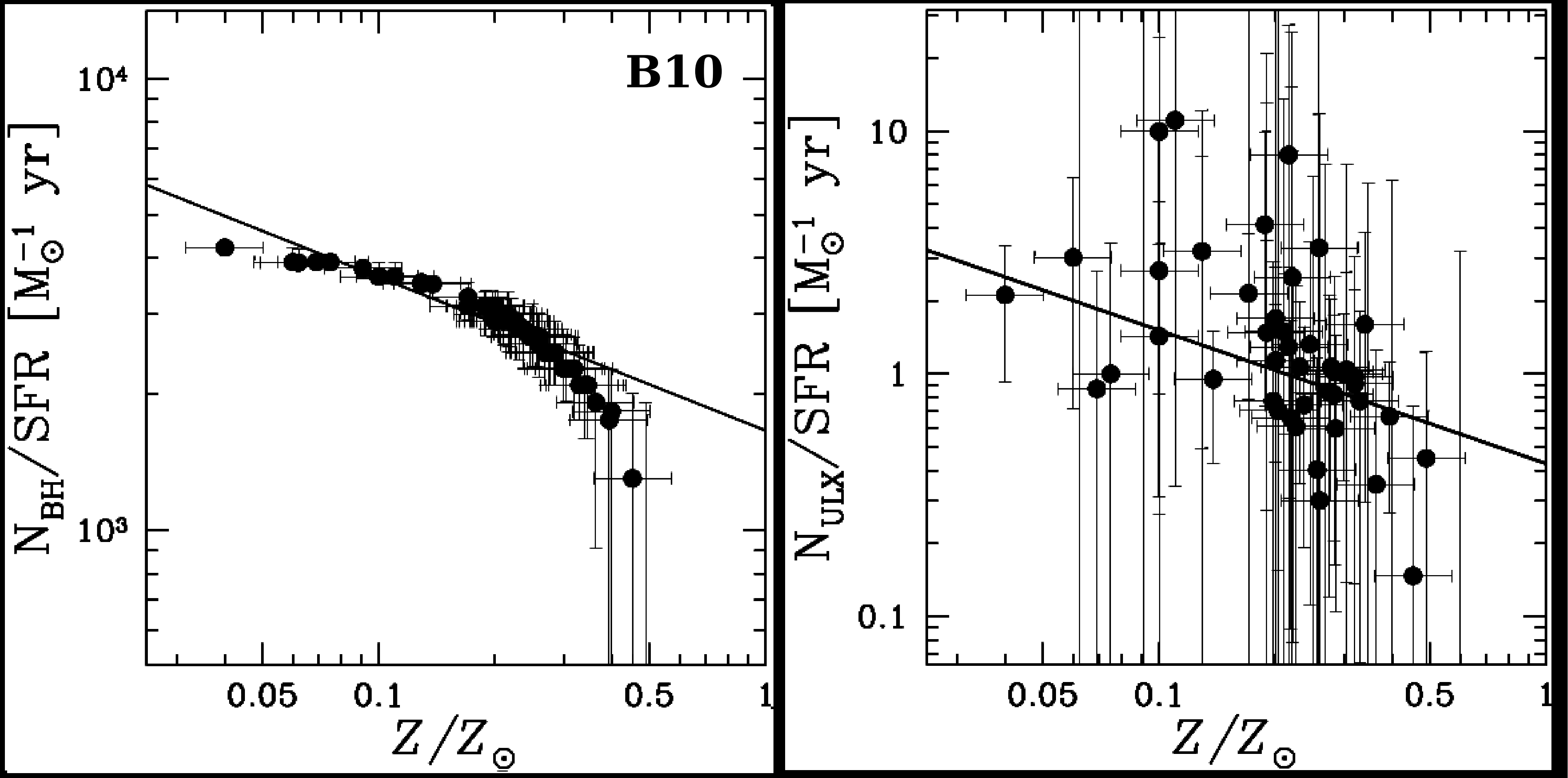
N_{BH}-Z





Not statistically significant in model & data

N_{BH}/SFR-Z

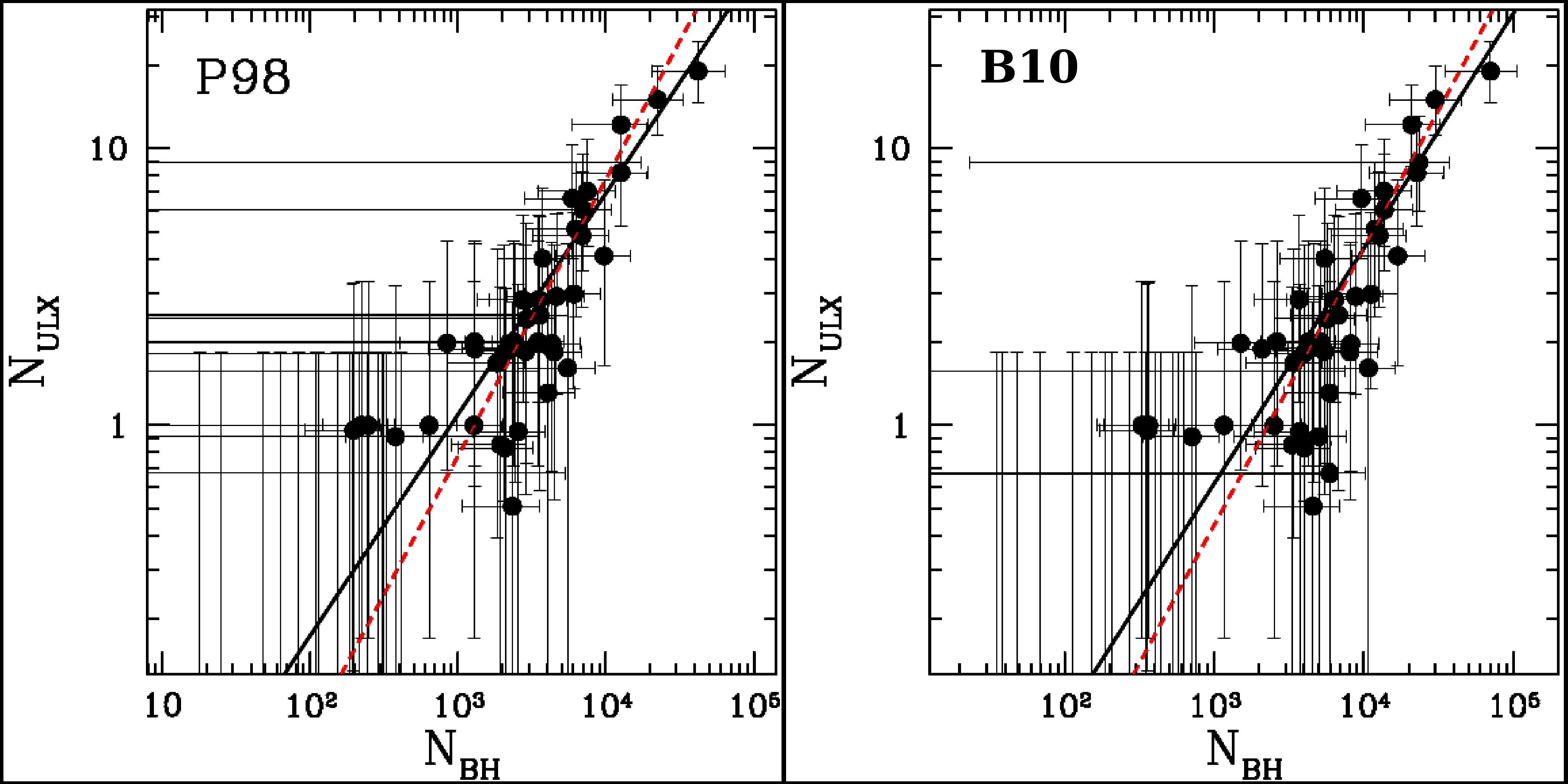


Slope of the model= -0.6 — -0.34

Slope of the data = -0.55 +/- 0.2

NBH-NULX

$$N_{ULX} = 10^{\gamma}\, N_{BH}^{\beta}$$



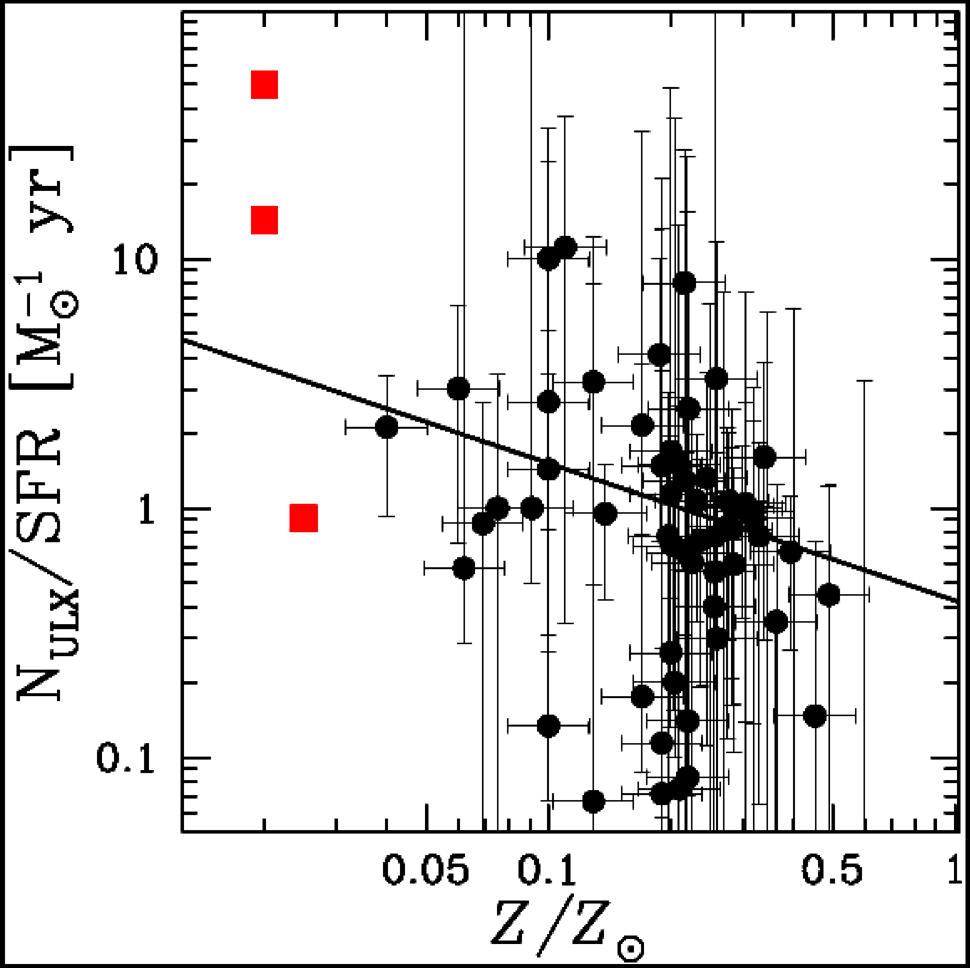
$$\beta = 0.80^{+0.16}_{-0.12} \quad \Big| \quad \beta = 0.85^{+0.19}_{-0.13}$$

$$\gamma = -2.36^{+0.45}_{-0.62} \quad \Big| \quad \gamma = -2.76^{+0.53}_{-0.76}$$

4 – future perspectives

1) New metallicity measurements, in order to increase the sample and reduce errors

2) Observations of metal deficient galaxies



(X-ray data from Thuan et al. 2004)

3) How can HMXBs form including BHs born through direct collapse?

4) Alternative scenarios predicting N_{ULX}-Z relation (e.g. Mass transfer more efficient in low metallicity, Linden et al. 2010)

CONCLUSIONS:

1) ULX occurence correlates with SFR

2) N_{ULX}/SFR may anticorrelate with Z

3) 1+2 may be explained by the formation of massive BHs in low metallicity environments

4) new measurements are needed and the theoretical model must be refined


THANKS