The Evolution of the ISM in Post-Merger Galaxies

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Sansom et al 2006, MNRAS, in press. (astro-ph/0605506)

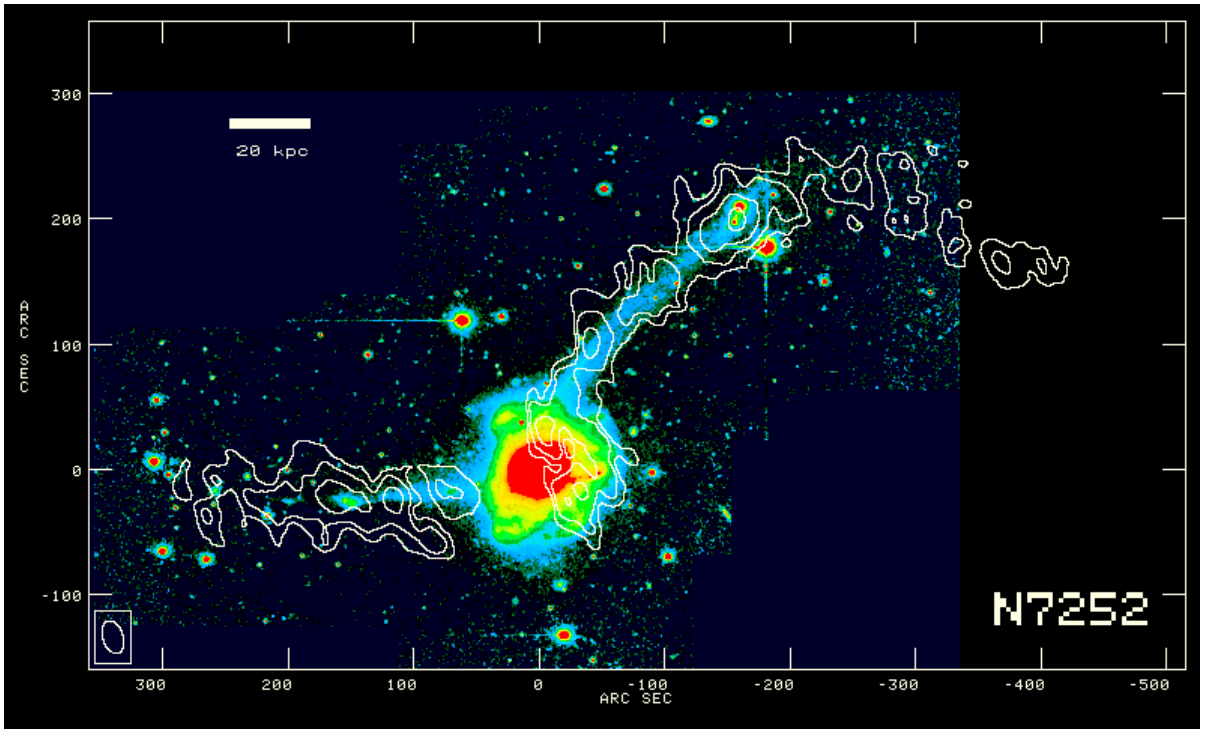
Overview

- Investigating ISM evolution through galaxy interactions.
- Mergers of cold-gas rich galaxies can form **ellipticals** (from observations and simulations).

E.g. NGC 7252

(Hibbard & van Gorkom 1996)

Colour: R-band
Contours: HI



Overview

- Many **ellipticals** have hot (X-ray emitting) gas haloes.
- Q. What happens to the cold gas in a merger?
- Q. Does the cold gas convert to hot gas?
- Q. If not, where does the gas go and how are hot gas haloes then built?

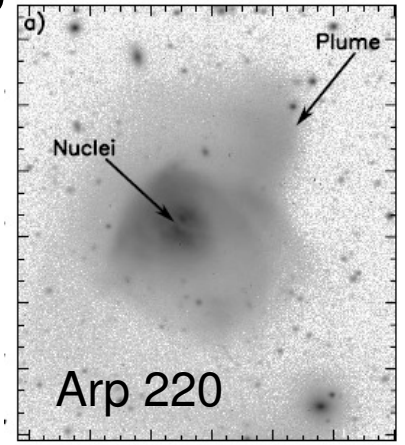
Approach: -

Measure X-ray emission versus galaxy “age” to map out the hot gas content with time.

Update of *Sansom et al 2000 (Fine structure age proxy); O’Sullivan et al 2001 (E/S0 galaxies - spectroscopic)*

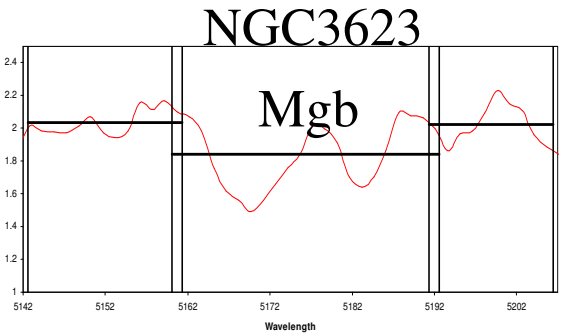
Use *XMM-Newton* for high S/N.

Observations – Galaxy "ages"



AGES

- **Dynamical** (Tidal features, modelling)
  Morphological (Shells, SB profiles)
  Probes < 2Gyr ago
- **Spectroscopic** – From optical absorption line indices
  Luminosity weighted ages of stars
  Probes ~ few Gyr ago
  Assume: merger induced starburst during formation.



DATA

- **Dynamical Ages :-**
  Read & Ponman 1998; Fricke & Papaderos 1999; Xilouris et al 2004; Hibbard etc.
- **Spectroscopic Ages :-**
  Terlevich & Forbes 2002 – Age catalogue (using 4 indices)
  Proctor & Sansom 2002 – Few E/S0 using 20 indices + non-solar element abundance ratios.

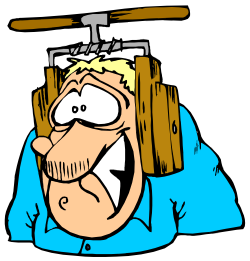
Observations – X-rays

- ROSAT – *O'Sullivan et al 2001* – X-ray catalogue
- New X-ray observations – 3 young, early-type galaxies (2004):-

***XMM-Newton* and *Chandra* observations**

Galaxy	Type	*XMM-Newton*	*Chandra*	$\log(L_X/L_B)$	Optical age
		(s)	(s)		(Gyr)
NGC 4382	S0	36057	-	-2.89	1.6
NGC 5363	E/S0	40278	-	-2.73	6.7
NGC 2865	E	-	29900	-2.80	1.0

X-ray data reductions



- Standard reductions using **SAS, FTOOLS** Installed

CIFBUILD, EVESELECT, 3σ-clipping, COMPAREOUTOFFOV,BACKSCALE, GRPPHA

- Spectroscopic fitting using **XSPEC**

Consider absorbed MEKAL (hot gas) & powerlaw (stellar contributions).

Fit 2 MOS & 1 PN detector simultaneously (no arbitrary rescaling).

Results:

1-component models don't fit

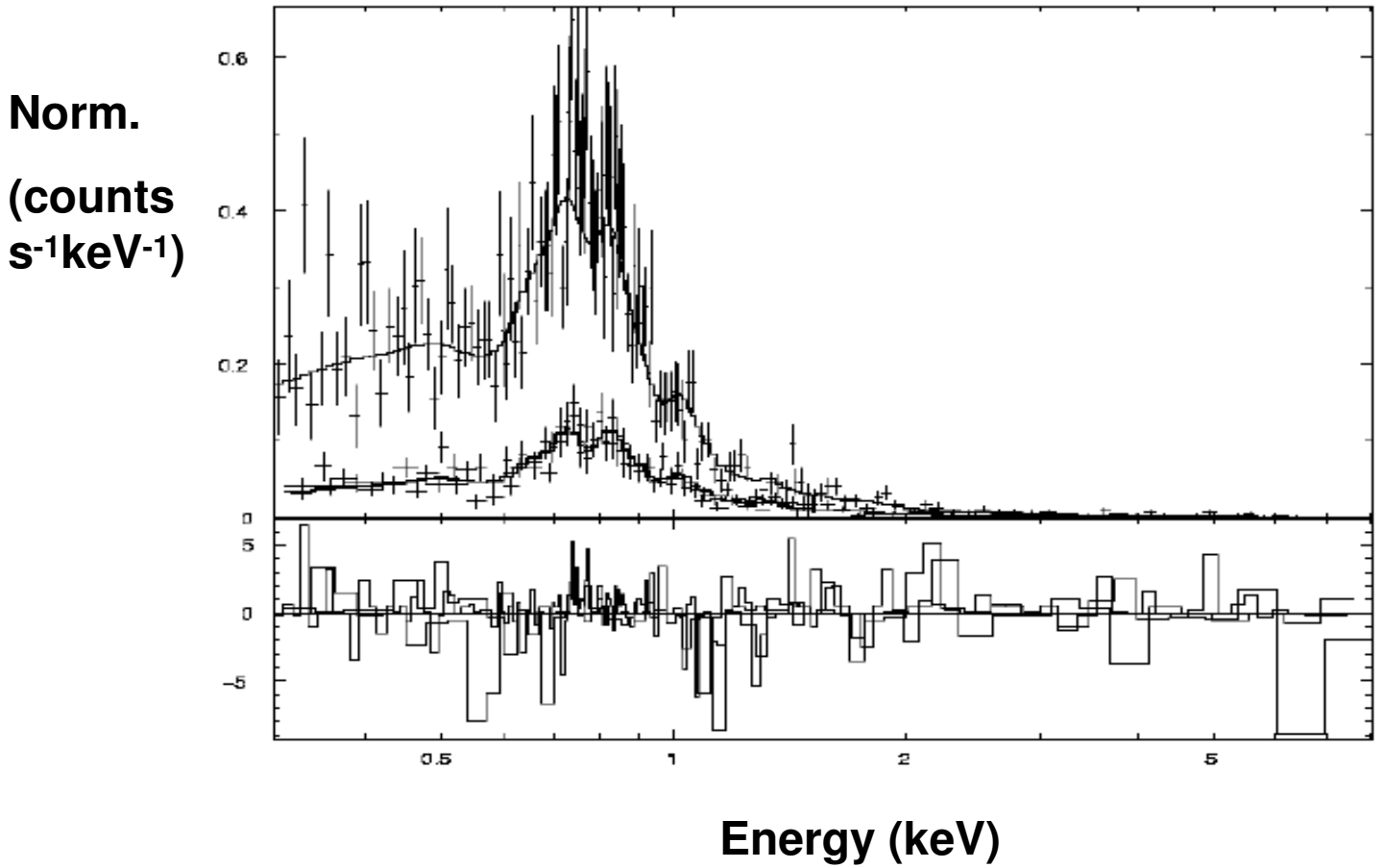
2-component models fit with MEKAL + powerlaw (χ_ν^2~1.15)

MEKAL component (kT=0.3-0.6 keV) <half flux.

Hot gas abundance poorly constrained.

NGC 4382 XMM-Newton spectrum

+ Two component fit



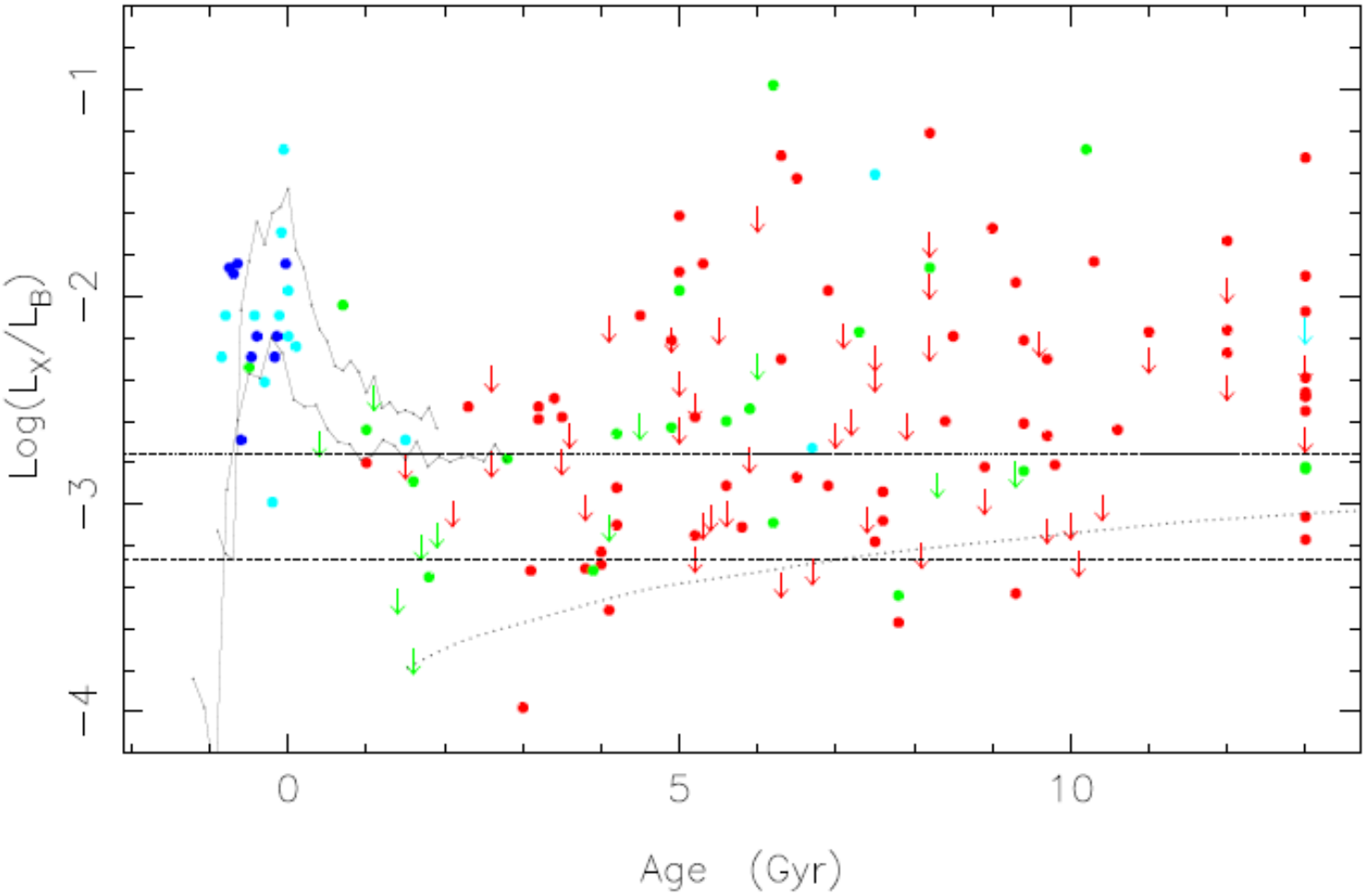
New data from literature

- **NGC 4365, 4382** *Sivakoff et al. 2003 – Chandra*
- **NGC 3585, 4494, 5322** *O'Sullivan & Ponman 2004 – XMM-Newton & Chandra*
- **NGC 3921, 7252** *Nolan et al 2004 – XMM-Newton*
- **NGC 1600** *Sivakoff et al 2004 – Chandra*
- **NGC 1700** *Statler & McNamara 2002 – Chandra*
- **NGC 4636** *Matsushita et al 1998 – ASCA*
- ***NGC 3256*** *Jenkins et al 2004 – XMM-Newton*

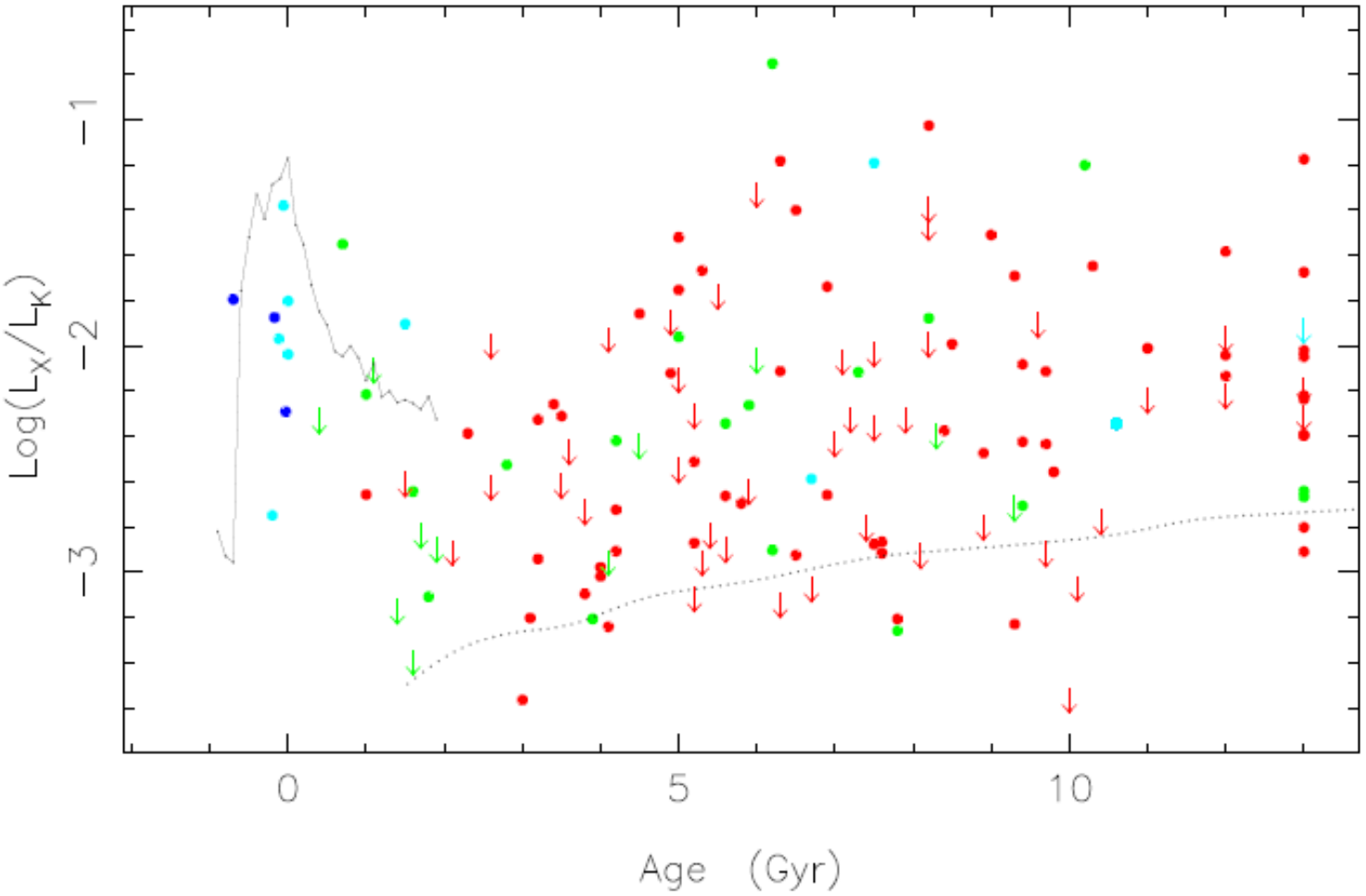
- **NGC 5102** *Kraft et al 2005 – Age estimate*
- **NGC 4473 4621** *Caldwell et al 2003 – Age estimate*

Log(L_X/L_B) versus Age

●=S ●=Irr ●=S0 ●=E



Log(L_X/L_K) versus Age



(Stellar)

Models of L_X evolution

Tom Cox et al (2006) modelled X-ray emission versus time:

~ -1.5 Gyr to ~ +3 Gyr relative to coelescence.

(Arp 220 is at t=0 Gyr).

Curved lines show their models (with different normalisations: constant L_B or changing L_B).

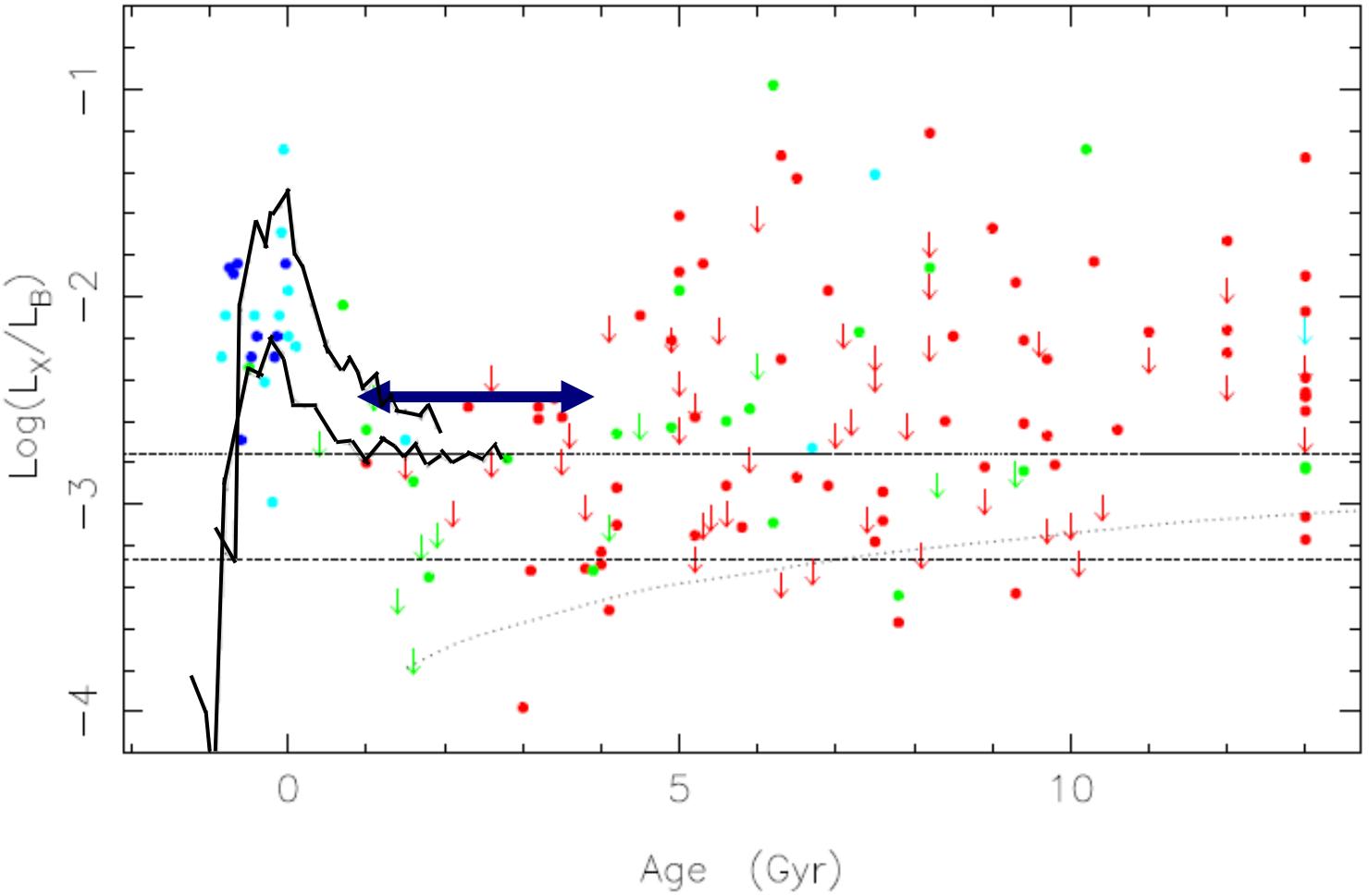
L_K from 2MASS.

RESULTS

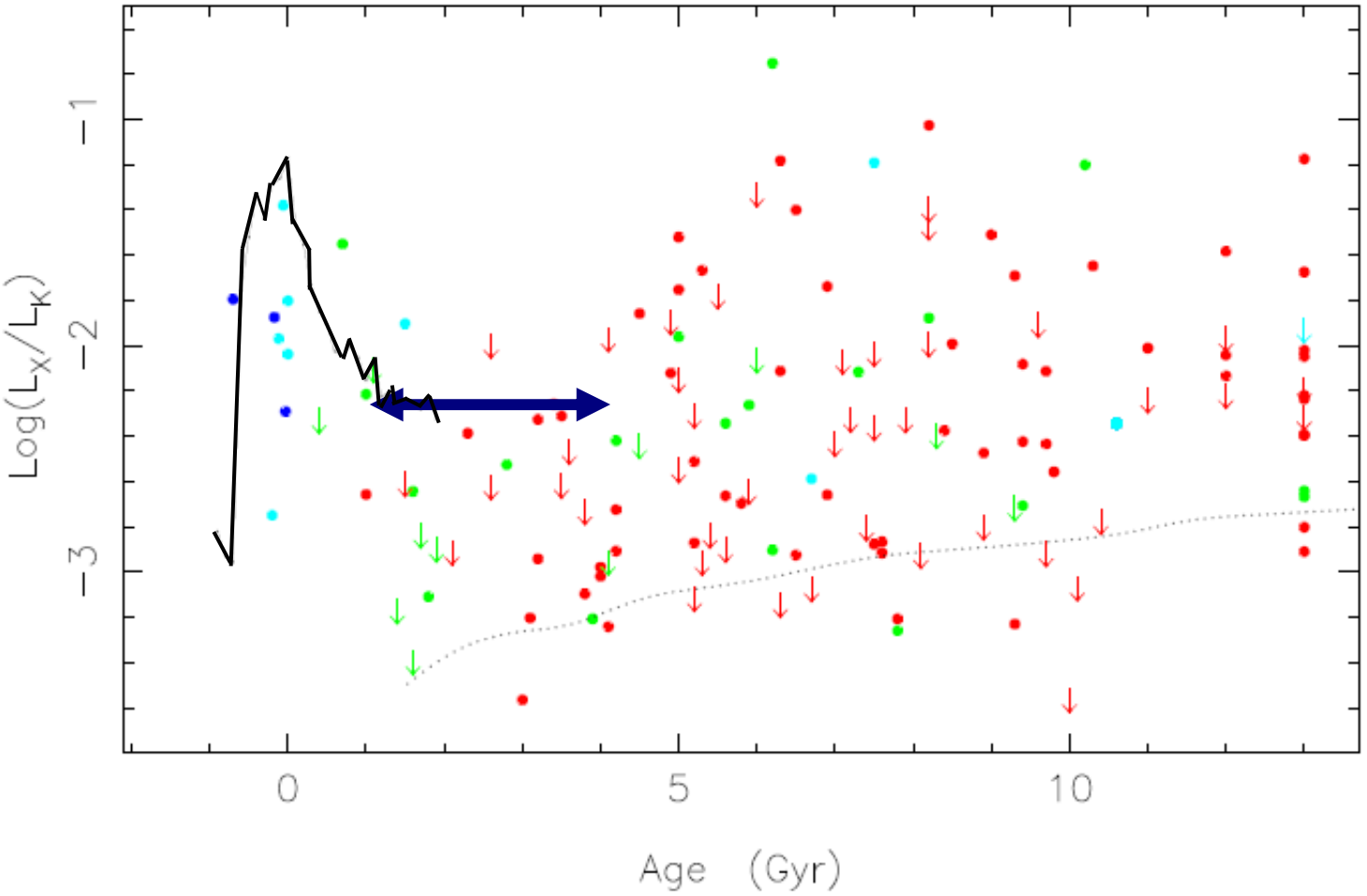
- Models fit quite well – slight excess of X-rays in post-merger models c.f. data.
- Data shows a dearth of X-ray luminous E/S0 galaxies at <4 Gyr post-merger.

Log(L_X/L_B) versus Age

●=S ●=Irr ●=S0 ●=E



Log(L_X/L_K) versus Age

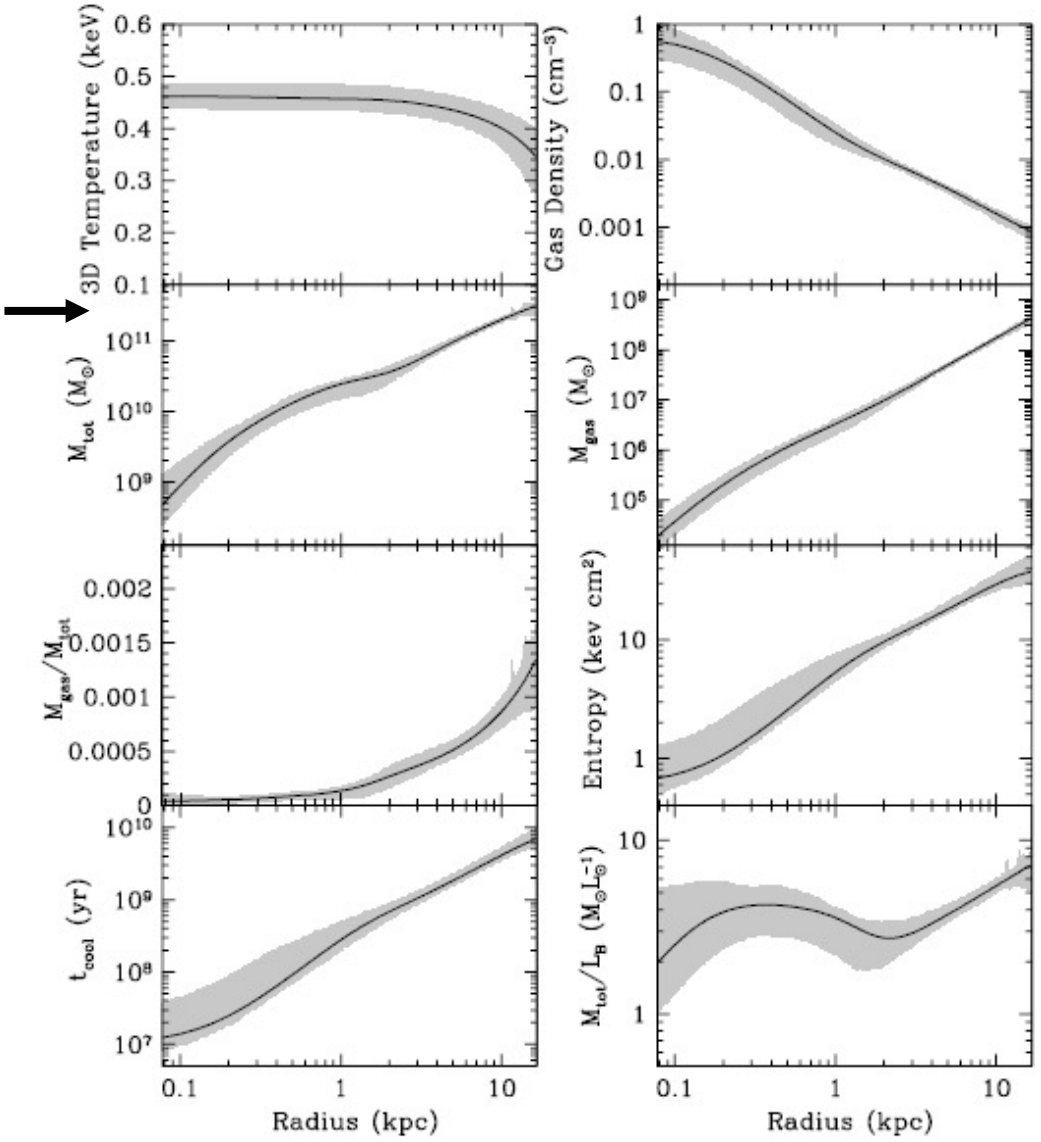


(Stellar)

Mass distribution in NGC 4382

(XMM-Newton & Chandra data combined)

M_{total} ~3 $\times 10^{11}\, M_\odot$



M_{gas} ~5 $\times 10^{8}\, M_\odot$

M/L~3

Conclusions

- There is a dearth of hot gas in early-type galaxies with spectroscopic ages <4 Gyrs.
- Luminous hot gas haloes only appear in galaxies older than this.
- M/L ratio in NGC 4382 is dominated by baryons within r~10 kpc), but rising with radius.

Future

- Measure and plot individual **X-ray components** versus age (hot gas, stellar sources)
- Evolution of **HMXB, LMXB** and other stellar contributions to L_X with time, following a merger
- Evolution of **temperature** and **composition** of gas
- Better **age** measurements (higher S/N optical data)
- Implications for **feedback** -
  - **Are we seeing gas removed in post-merger galaxies (via star formation and/or AGN activity)?**
  - **How are hot haloes built up?**