Vivienne Wild

Timing the starburst-AGN connection

There are many theories successful in explaining the observed correlations between black holes and their host galaxies. In turn, these theories play a crucial role in explaining other observed aspects of the galaxy population, such as the red/blue bimodality. However, observational measurements of the interaction of black holes with their hosts remain scarce. I present the time-averaged growth of black holes in the 400 strongest starbursts in local galactic bulges observed in the SDSS.

These bulges have experienced a strong burst of star formation in the past 600Myr, as indicated by the strength of the Balmer absorption lines in their integrated stellar spectra. We select our sample of starbursts by fitting stellar population models to spectral indices which measure the strength 4000Å break, shape of the blue continuum, and Balmer absorption lines. The sample is complete in the sense that there is an equal number of starburst galaxies per unit age, up to an age of 600Myr after the starburst.

We use the luminosity of [OIII]λ5008Å to measure the black hole accretion rate in galaxies identified as having an AGN via the BPT diagram, carefully correcting for dust attenuation and contamination from star formation. Averaging over the whole sample of 400 galaxies, we find that there is a delay of 250Myr between the onset of the starburst and accretion onto the black hole. This coincides with the time when the mass-loss rate from supernova and OB star winds has declined to a level below the mass-loss rate from less massive stars. However 250Myr is significantly later than the onset of mass-loss from low-mass stars (about 50Myr). We suggest that mass ejected in fast supernova and OB winds is not accreted onto the black hole, and further that supernovae may prevent the accretion of mass onto the black hole between 50-250Myr after the starburst.

The luminosity of Hα provides an entirely independent measure of the instantaneous star formation in the sample, and a detailed picture of the evolution of star formation rate after a starburst. We find that the SFR declines slowly, over a typical timescale of 300Myr. We also observe 3 distinct phases of evolution of the star formation rate: (1) the “starburst” phase, a sharp spike lasting a few tens of Myr; (2) a “coasting” phase, the star formation rate remains roughly constant up to 400Myr; (3) the “post-starburst” phase, the star formation decays rapidly.

With both bulge and black hole increasing their mass by ~10% in 600Myr, the processes at work in this local starburst sample may well be relevant to the co-evolution of black holes and bulges over cosmic time. Extrapolating a simple model in which the black hole accretes ~0.5% of the mass ejected from low-mass stars formed during the starburst after 250Myr, leads to a bulge:black hole mass ratio of 400, remarkably close to the value of 700 observed in local bulges today.

Timing the starburst-AGN connection

Vivienne Wild (IAP, Paris)

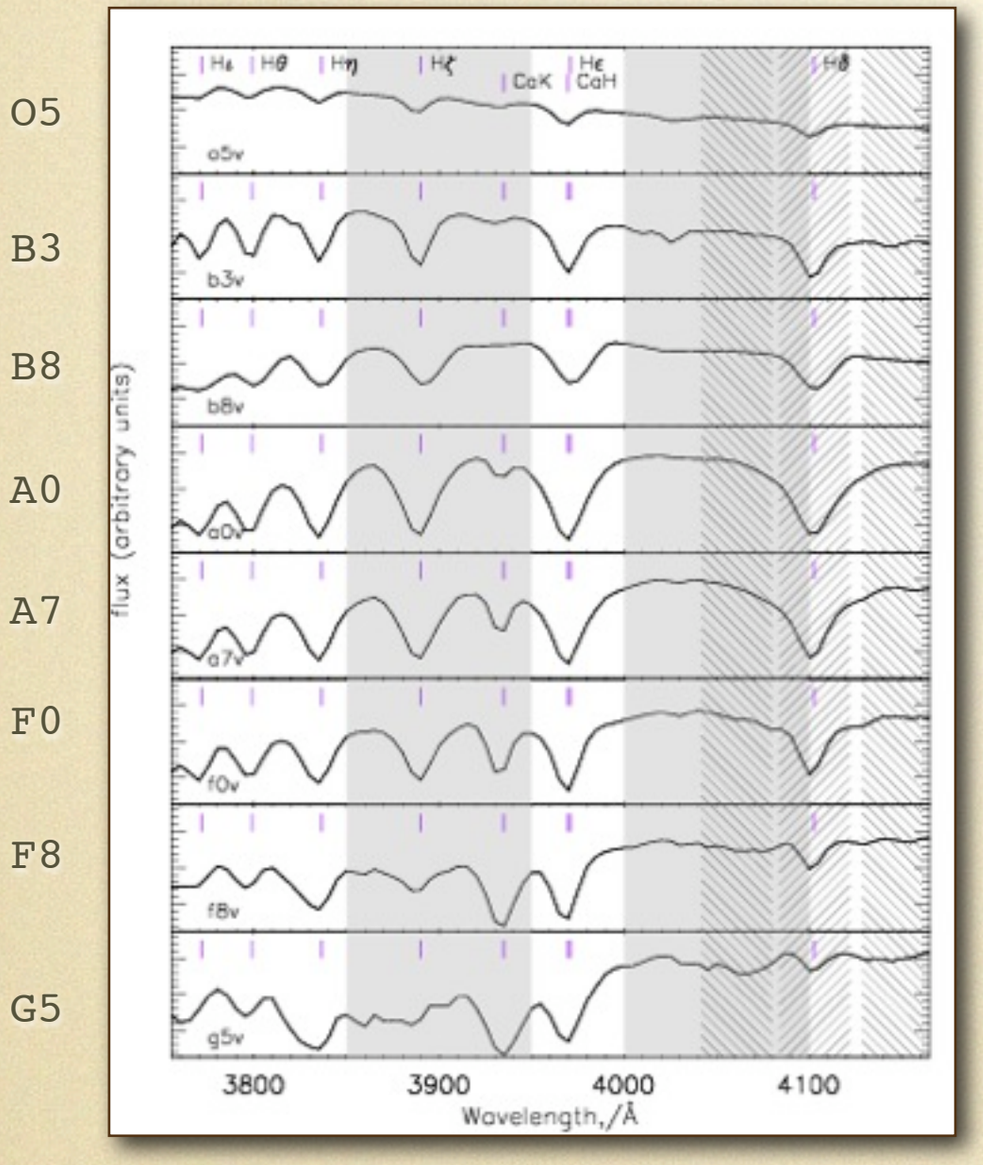
Tim Heckman (JHU)
Stephane Charlot (IAP)

Wild, Heckman, Charlot, 2010, MNRAS, 405, 933

Outline

1. Timing a starburst
   - Optical spectral features O/B - A/F - G stars
   - Optimal parameterisation of spectral features
2. The (post-)starburst sample
   - Images
   - Decline in star formation
   - Appearance of optical, narrow line, AGN
3. Black hole accretion rates from L[OIII]
   - Justification for use of [OIII]
   - Correction for contamination from star formation
4. Combine (1) and (3) to time the starburst-AGN connection

1a. Building stellar populations



	Main Sequence Lifetime	Spectral features	
O star	~10^6	Steep UV continuum He absorption	Strong UV continuum excites nebular emission lines
B star	~10^7	Some Balmer (HI) absorption	
A star	~5x10^8	Strong Balmer lines and Balmer break Ca H&K lines	A trend with temperature within A stars: T↓ Ca↑ break ↓
G star	~8x10^9	Strong metal lines Balmer series weak Strong 4000Å break	

Tuesday talk by Rosa Gonzalez-Delgado

- Galaxy spectrum = stars, IMF, star-formation history, dust
- Need a way to parameterise all this information....

1b. Stellar populations with PCA

Espec 3 →

+

Espec 2 →

+

Espec 1 →

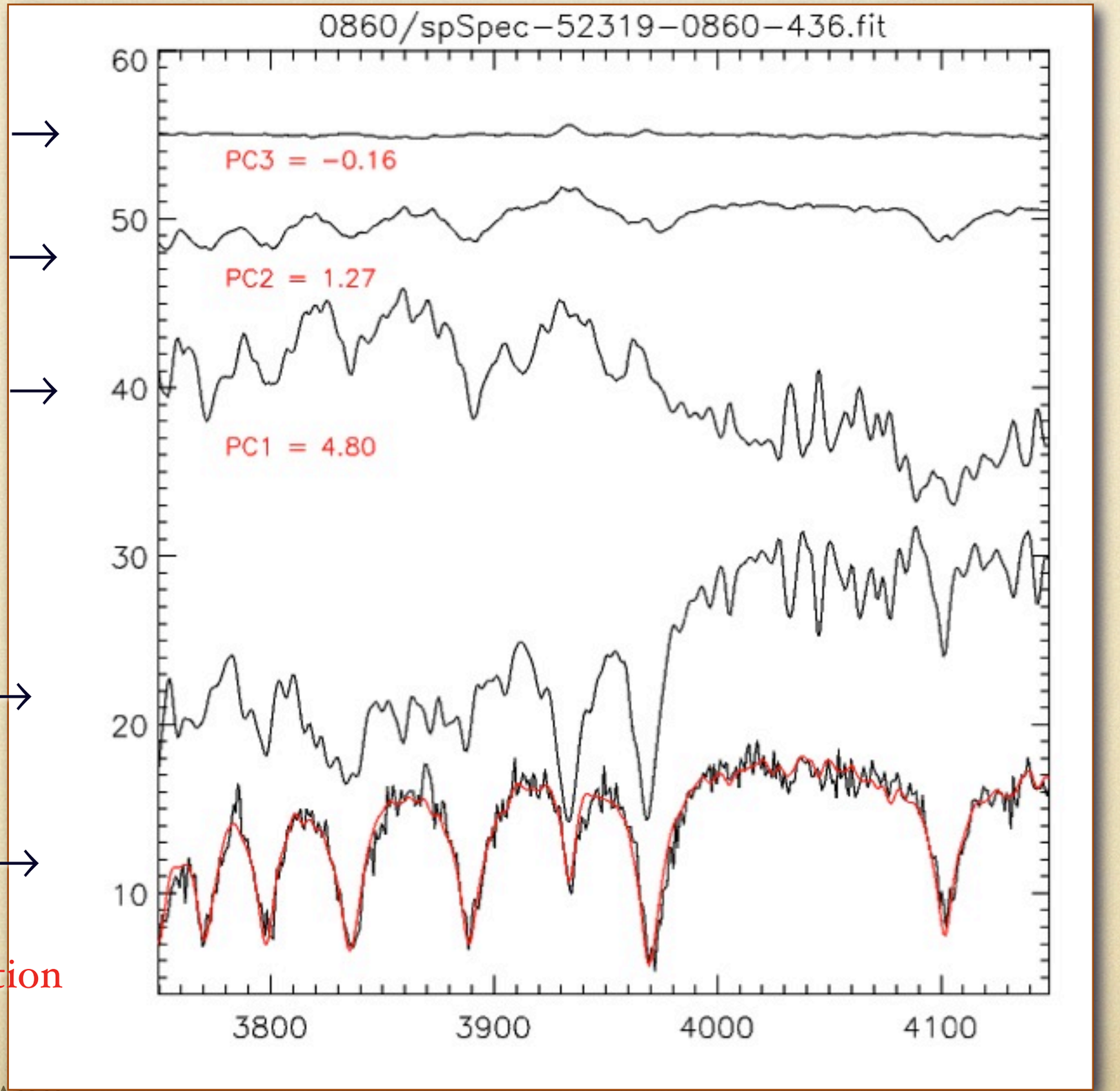
+

Mean →

=

Galaxy →

PCA reconstruction



Excess Ca II

Excess Balmer Absorption

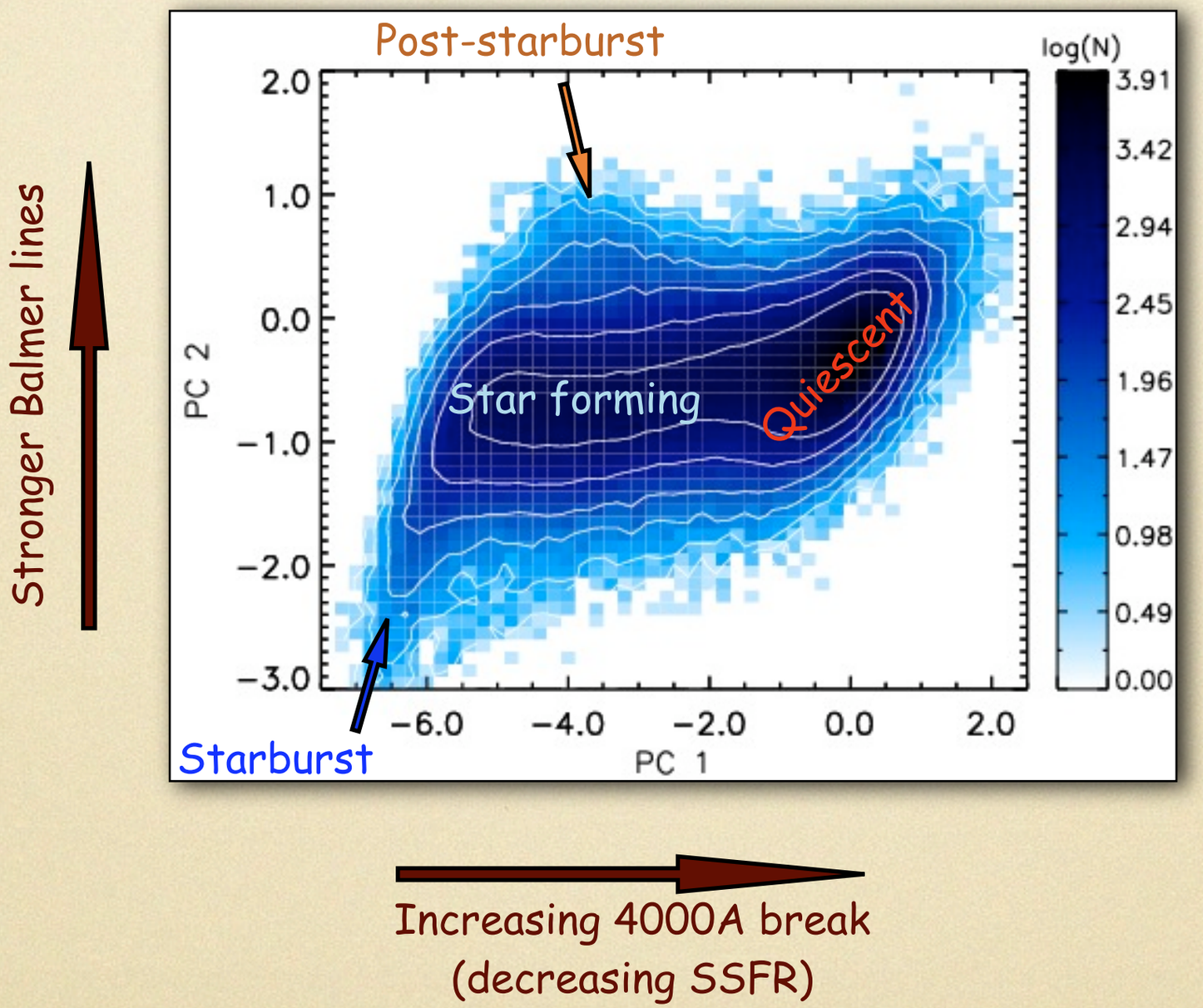
D4000 ∝ 1/Hδ

Wild et al. 2007

Bruzual & Charlot 03 pop synth models

1c. Stellar populations with PCA

Distribution of 3750-4150Å spectral shape in all SDSS DR7 galaxies



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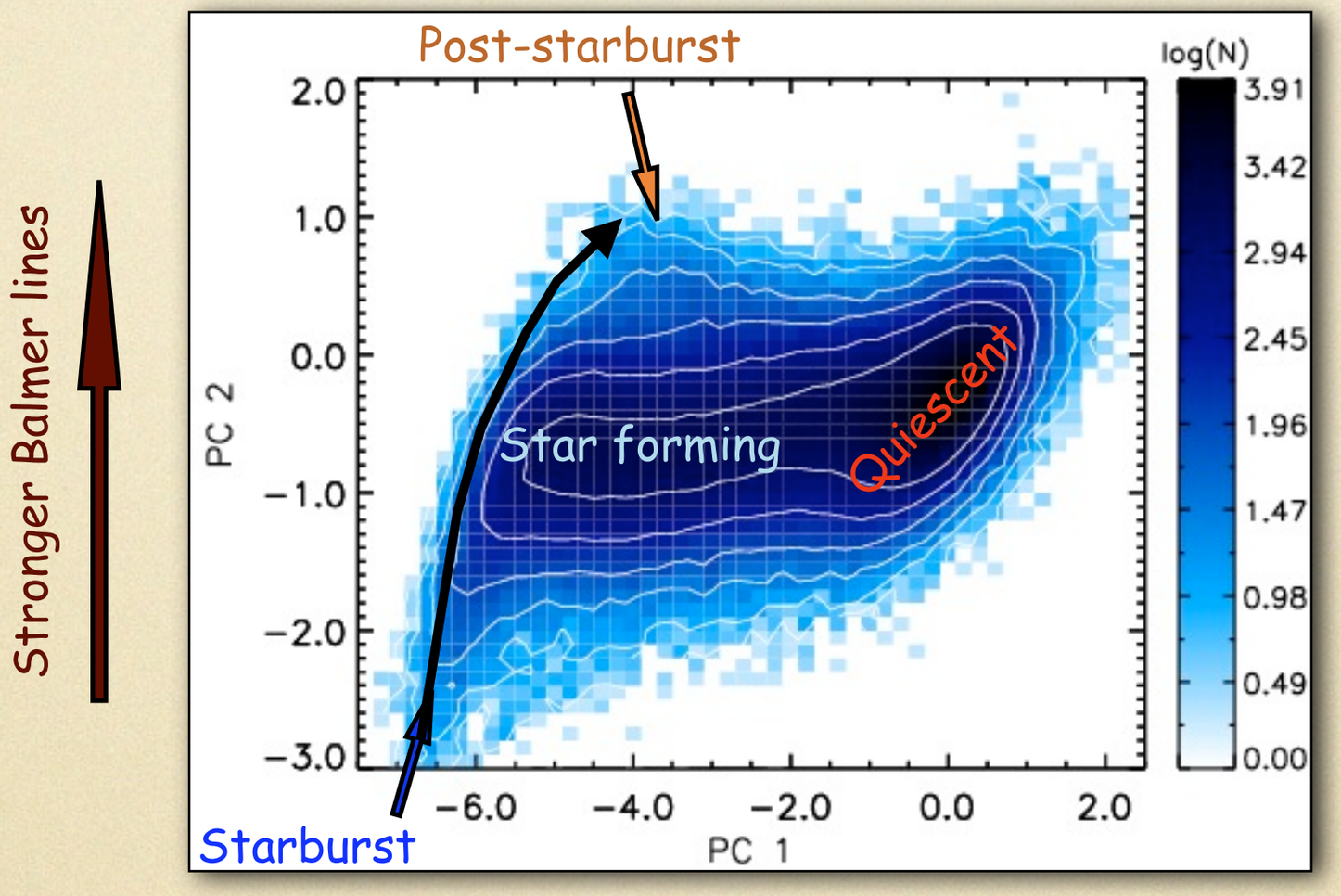
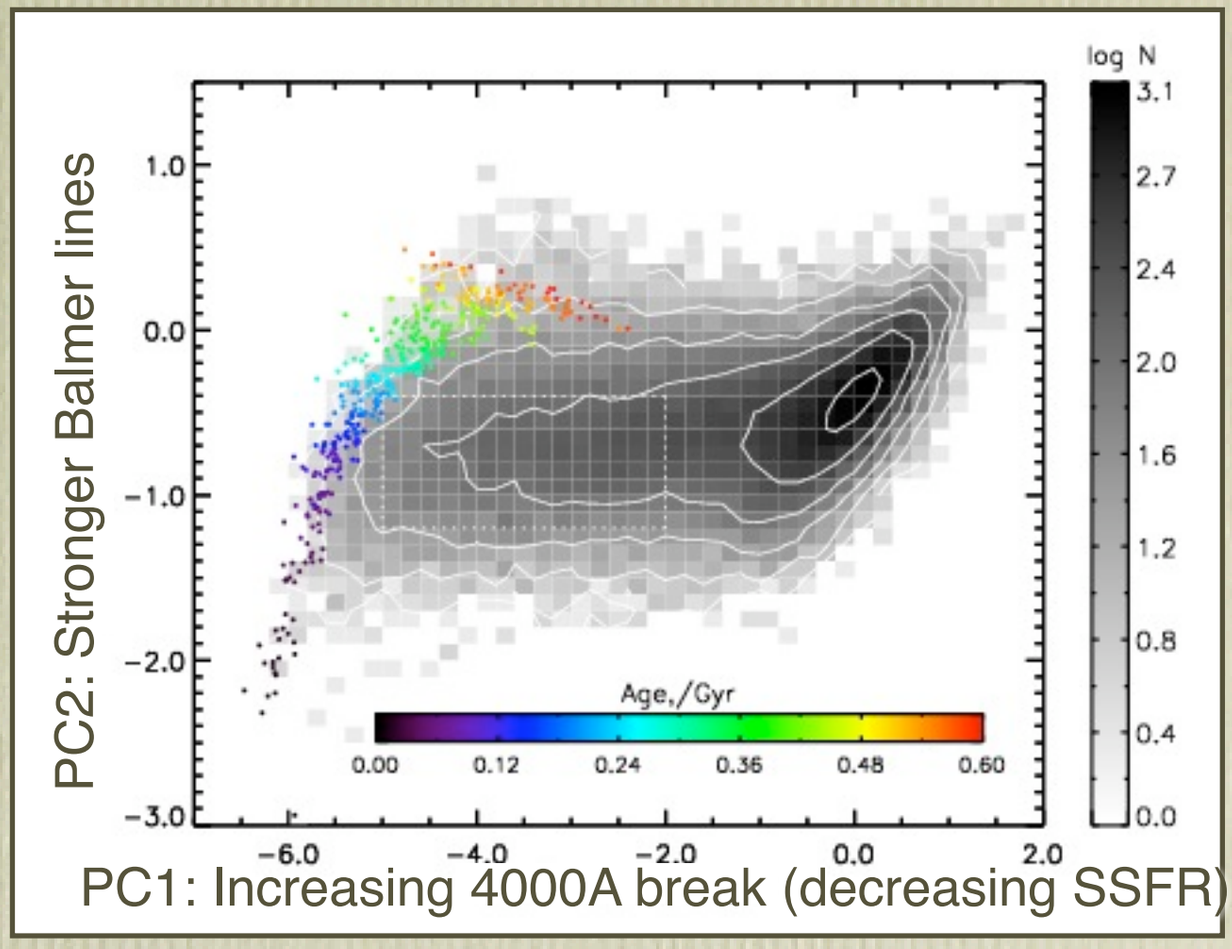


2a. A complete sample of starbursts



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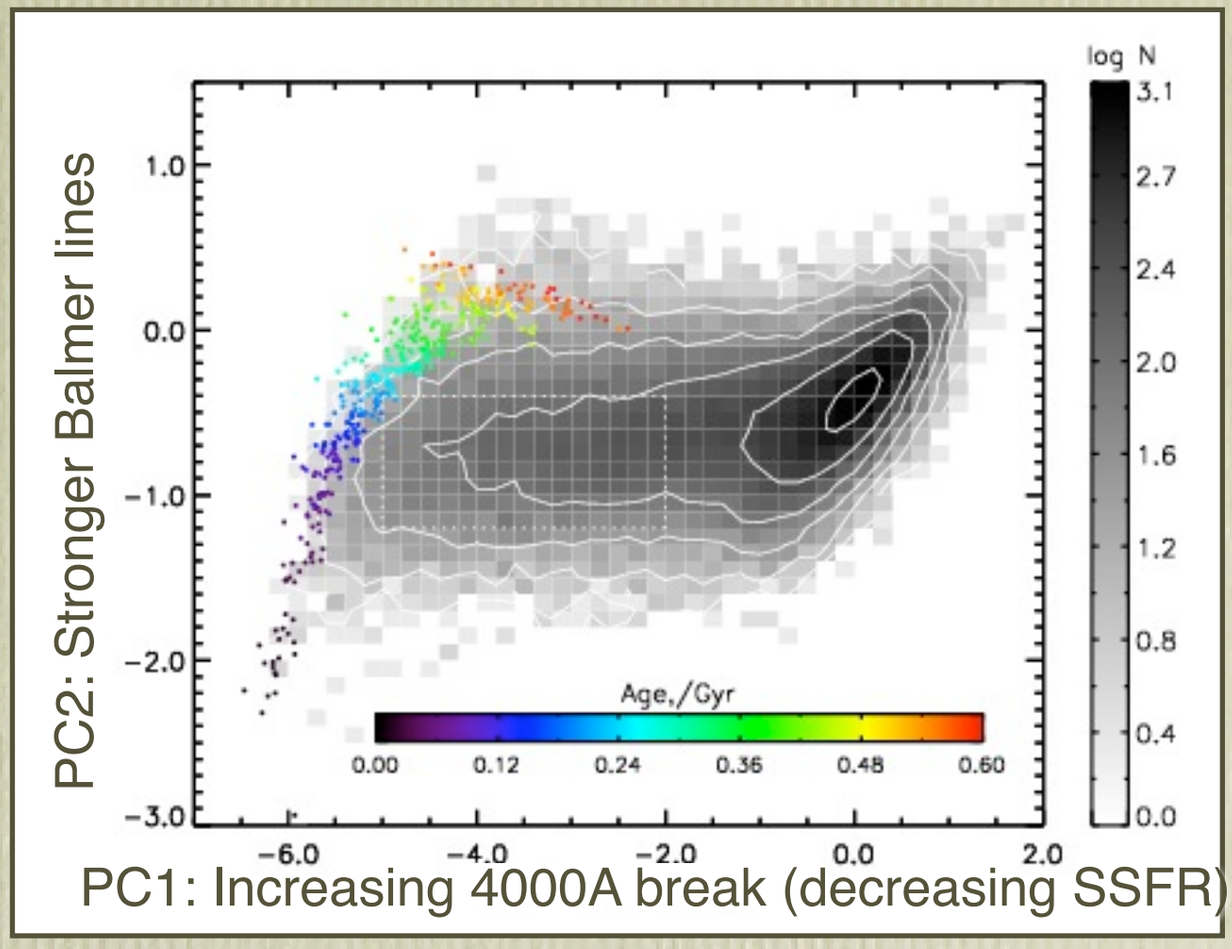

- 400 strongest starburst to post-starburst bulge-galaxies in local Universe
  - $0.01 < z < 0.07$ (3” SDSS fibre => 0.6 - 4 kpc diameter)
  - Stellar surface mass density $> 3 \times 10^8$ $M_\odot$ /kpc^2 (where majority of $L[OIII]_{AGN}$ originates)
  - Complete to 600Myr: constant number per unit starburst age
  - Starburst stellar mass fractions ~10-20% (continuum fits and Ha luminosities agree)

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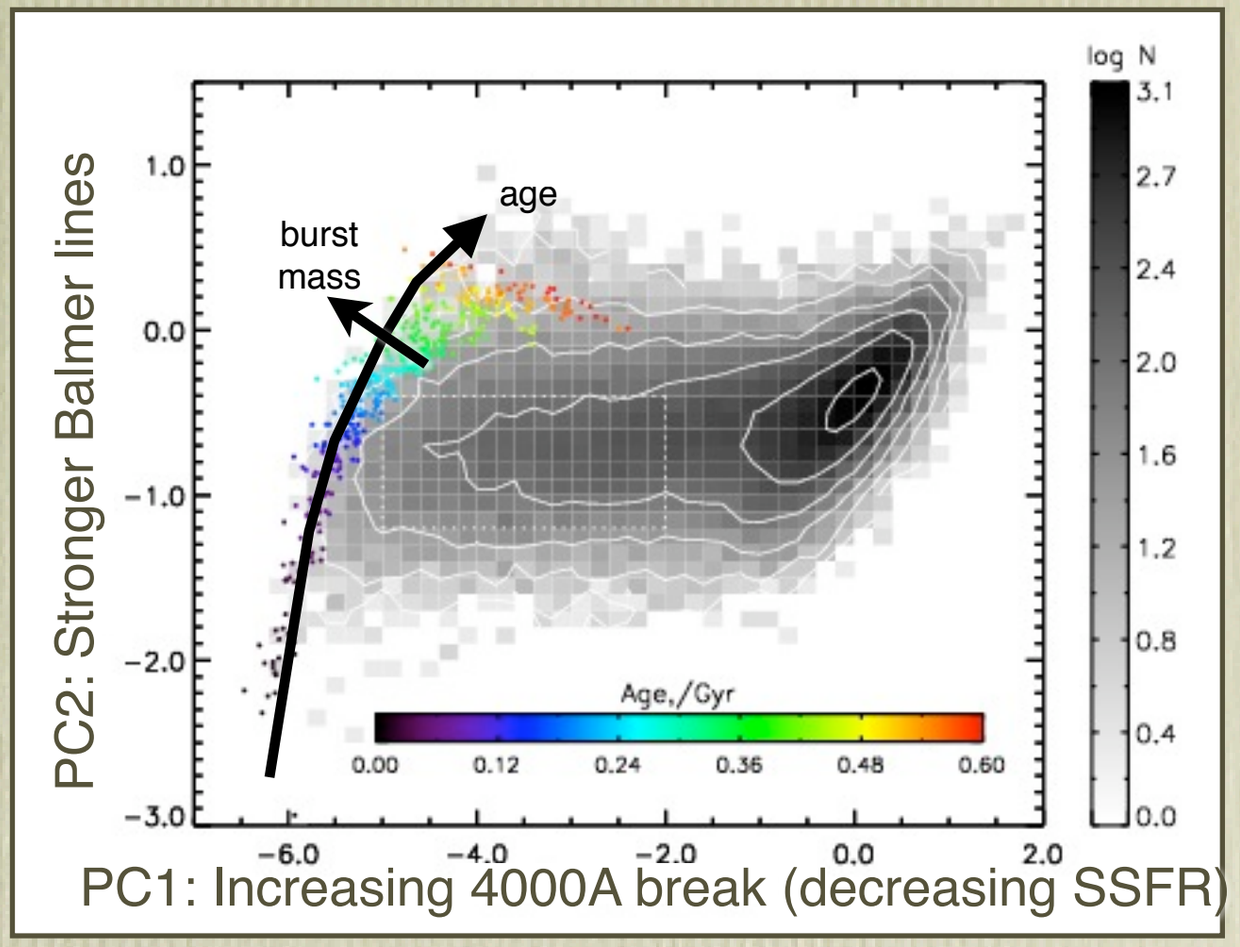

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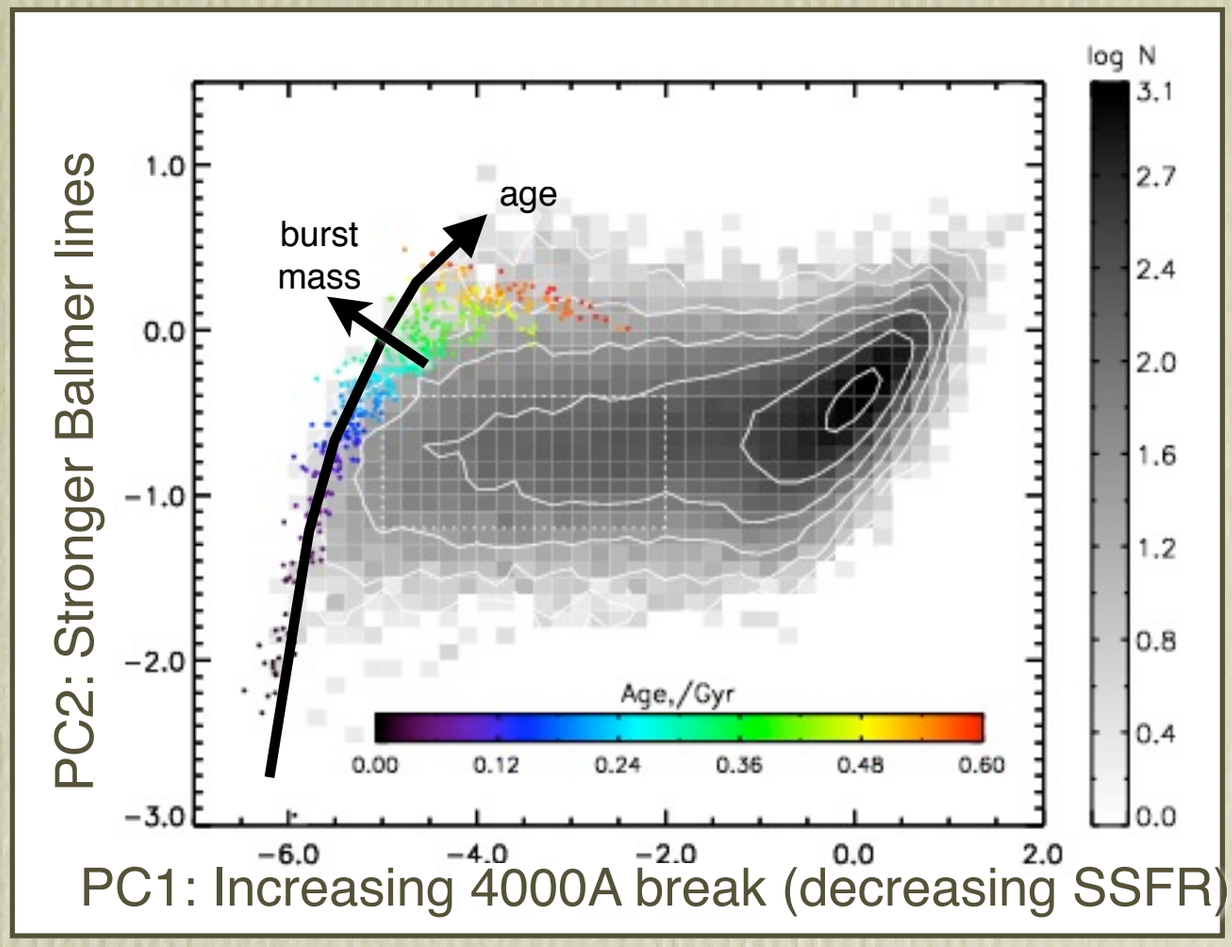
2a. A complete sample of starbursts

Aim: Use the stellar continuum to time the age of the starburst, and emission lines to see when the black hole accretes....



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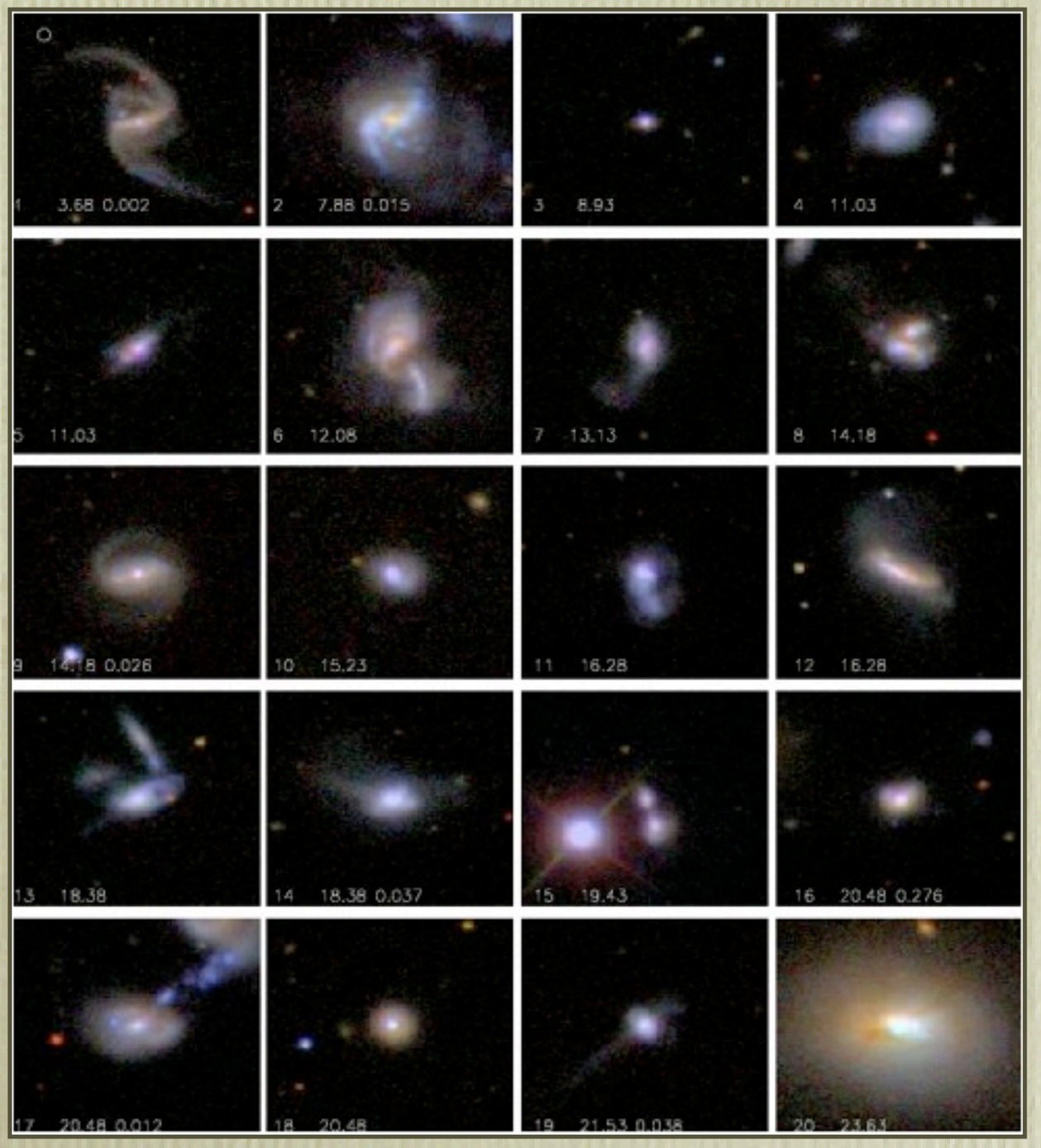
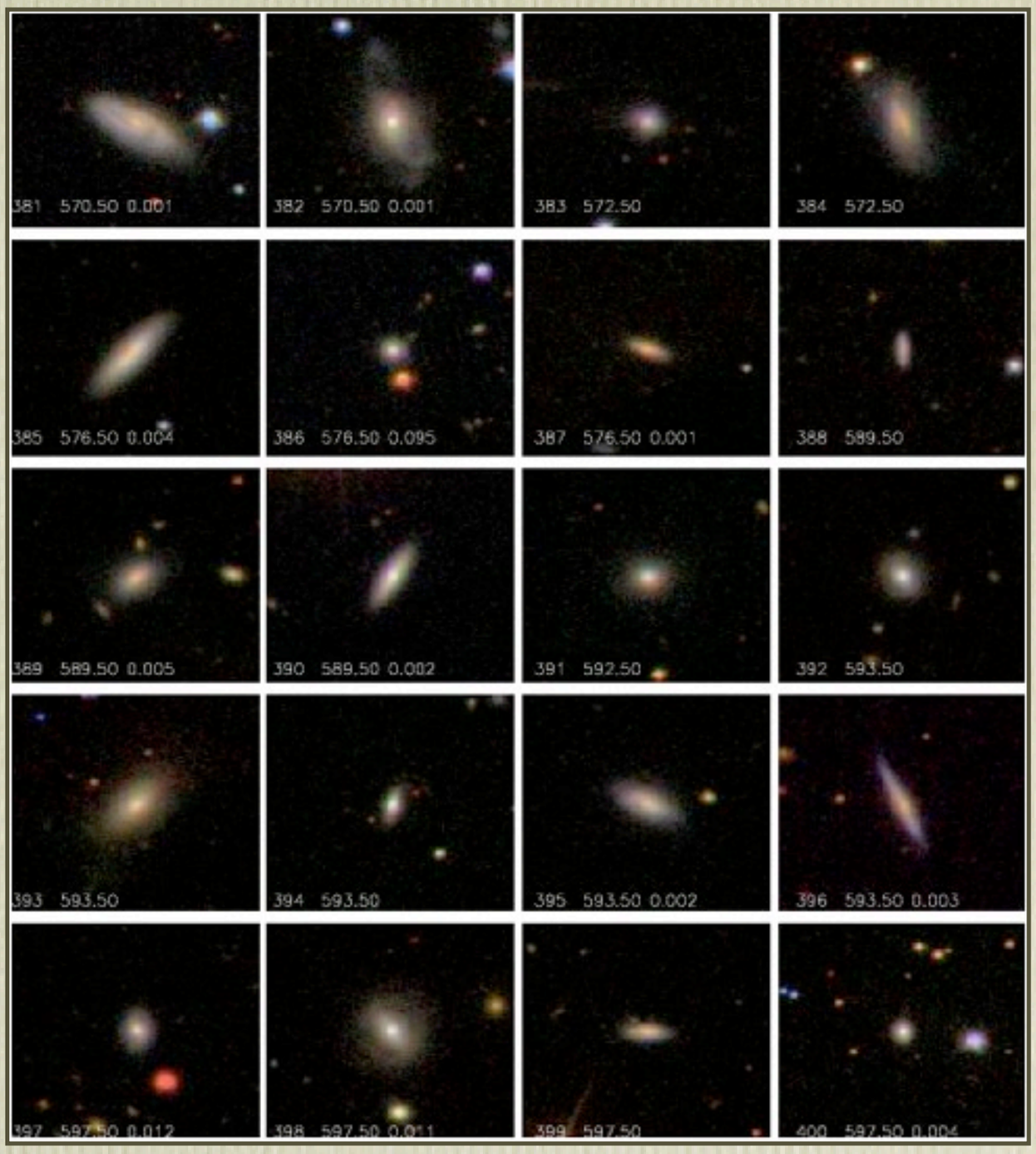
2b. Images of (post)-starbursts

0 - 25 Myr



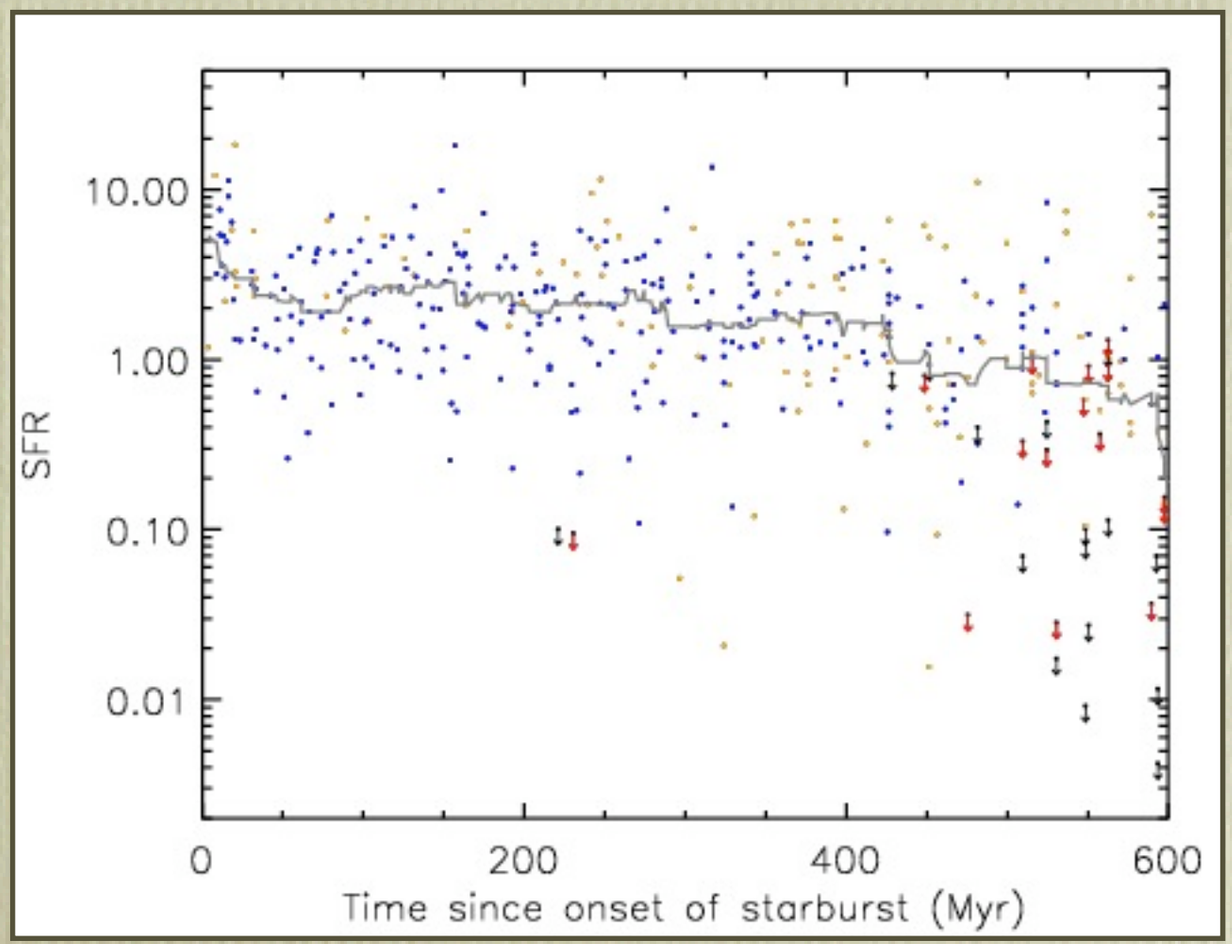
570 - 600Myr

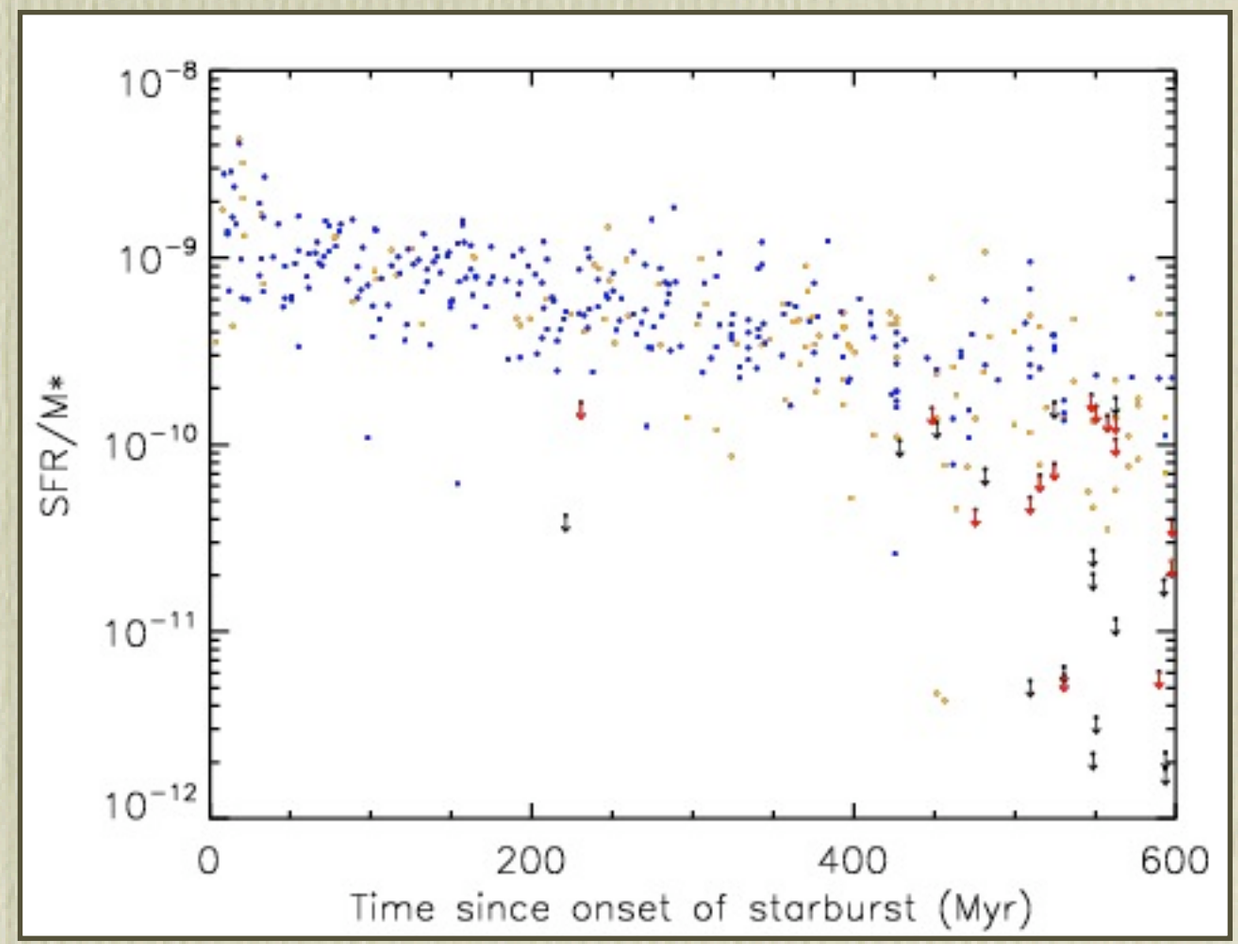


2c. Decline in SFR in starbursts

- 3 phases:
  - Peak ~ 50 Myr
  - Slow decline ~ 350 Myr
  - Rapid decline into post-starburst phase

See S. Jogee's talk Tuesday: typical x2 enhancement in SFR over 600Myr





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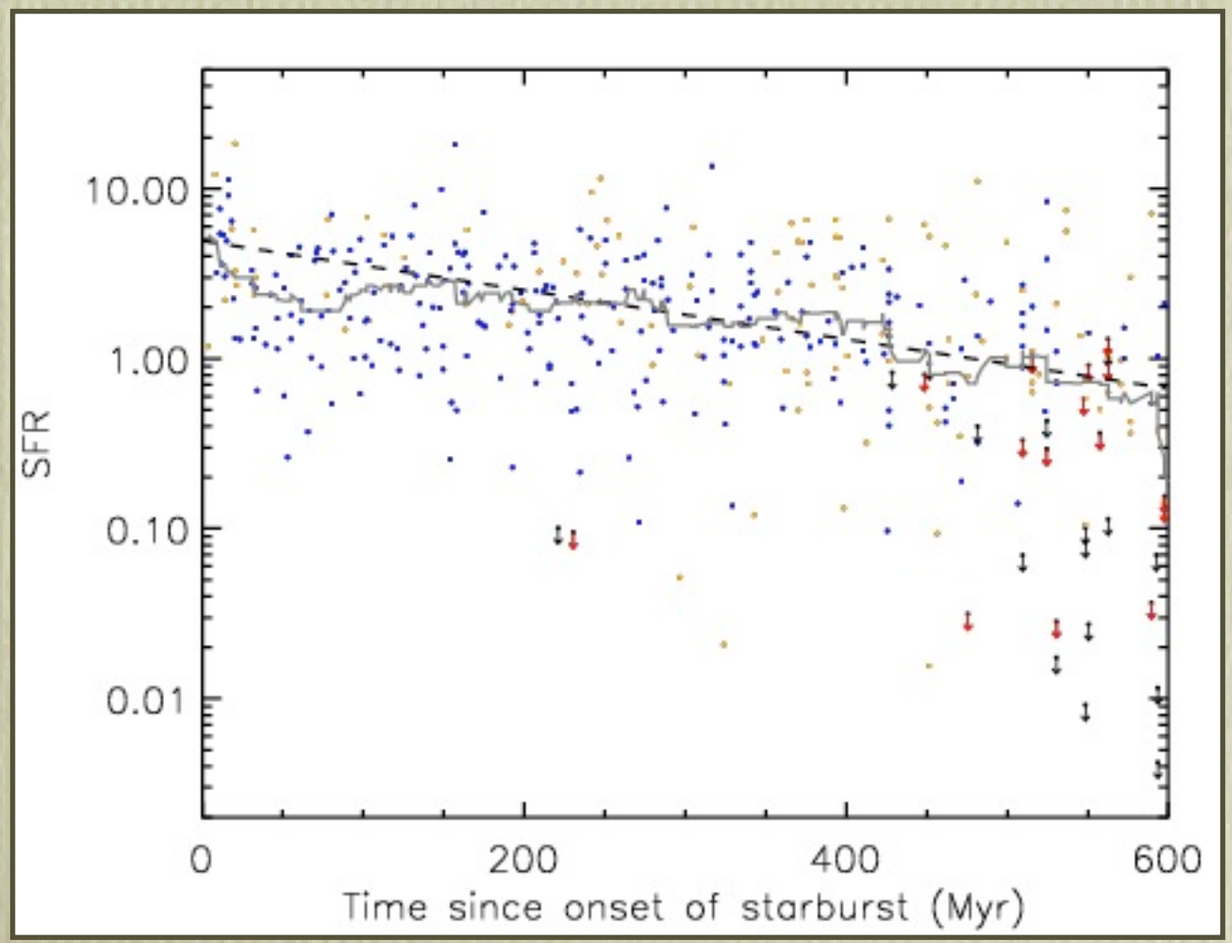
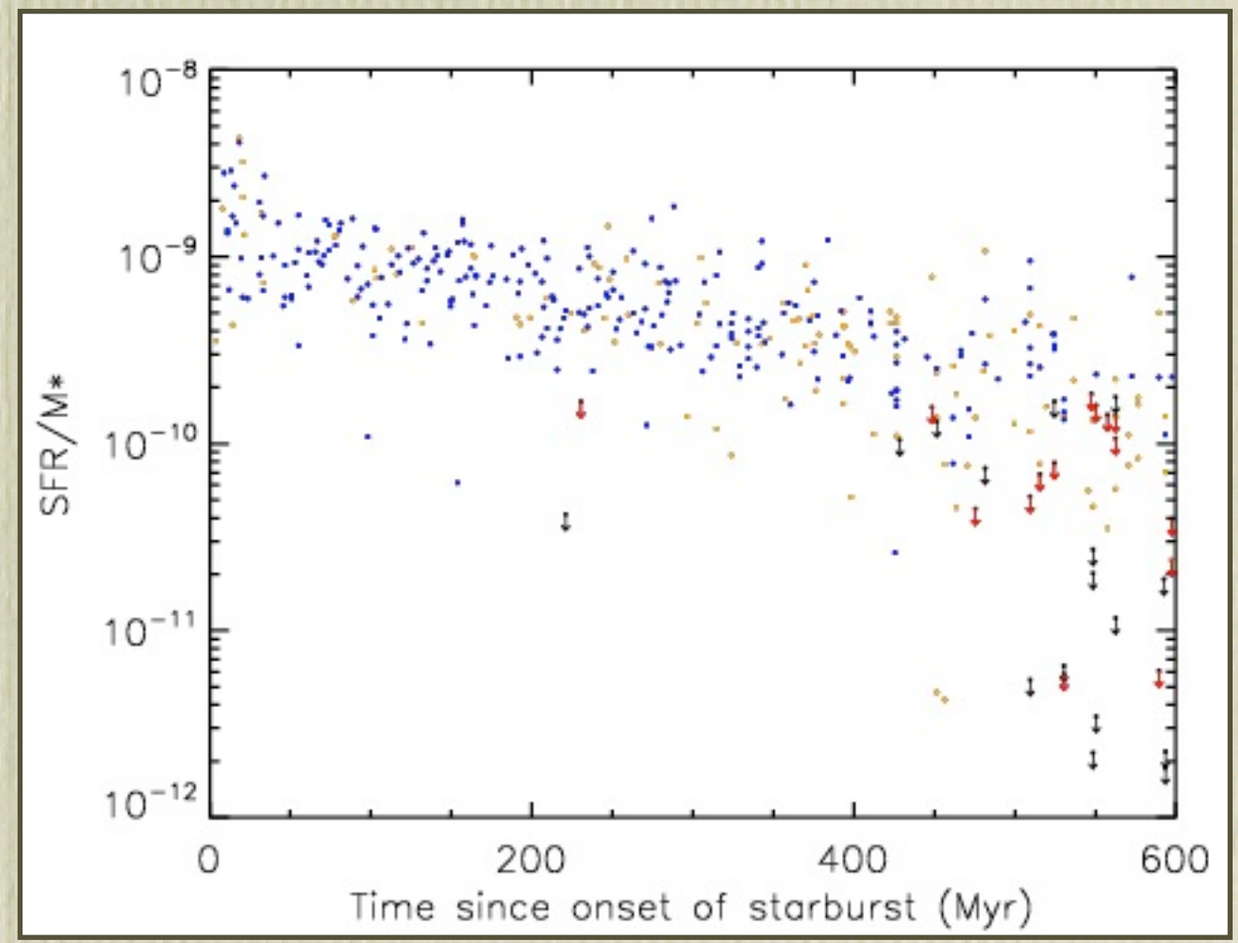
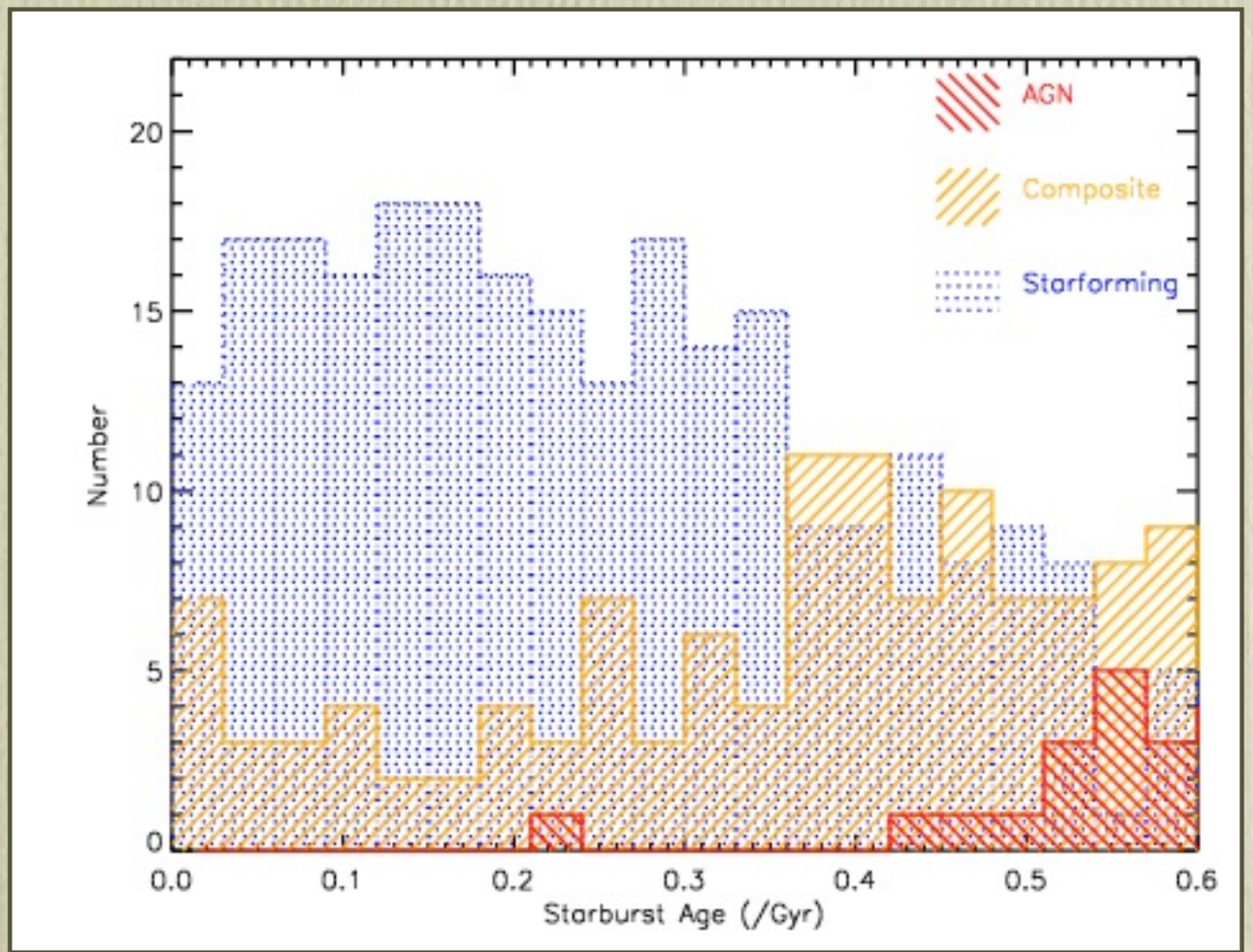




2d. AGN in starbursts

- 3’’ SDSS fibre: Starburst+AGN = composite line ratios
- Pure AGN line ratios only after ~ 500Myr



See Lisa Kewley’s talk, Tuesday

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- Use [OIII] to give bolometric luminosity of AGN
  - correlates with numerous direct measures of L_{bol} (Mulchaey et al. 1994)
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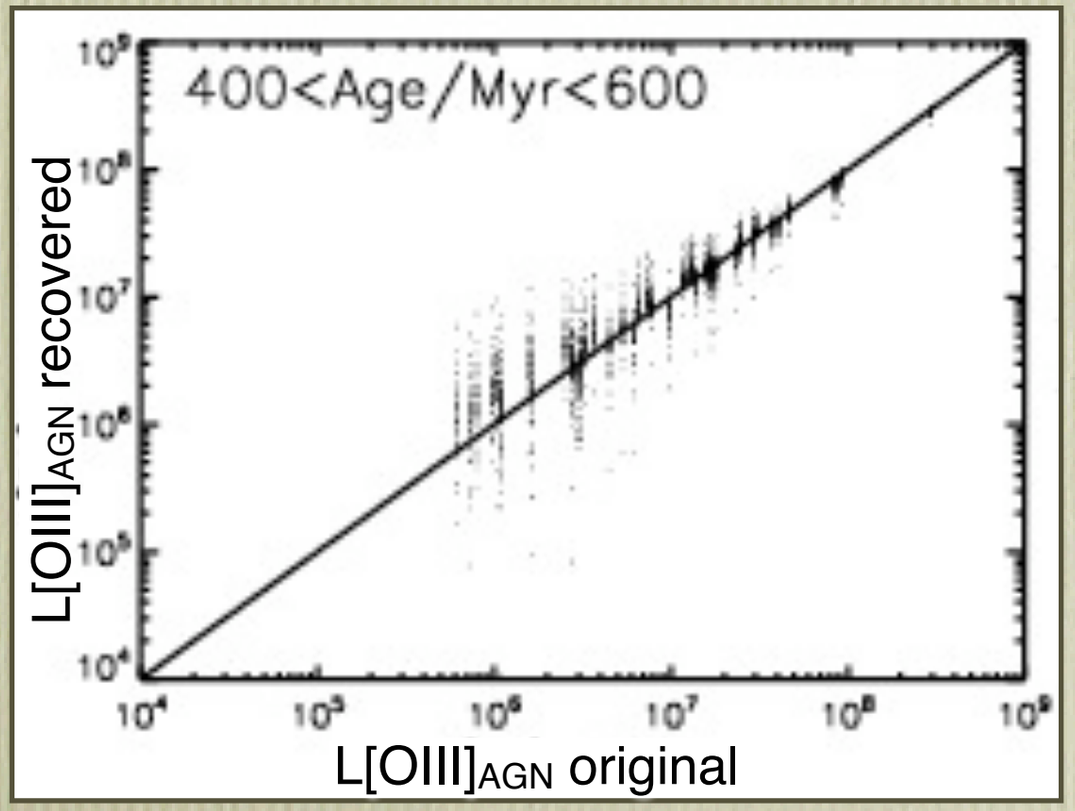

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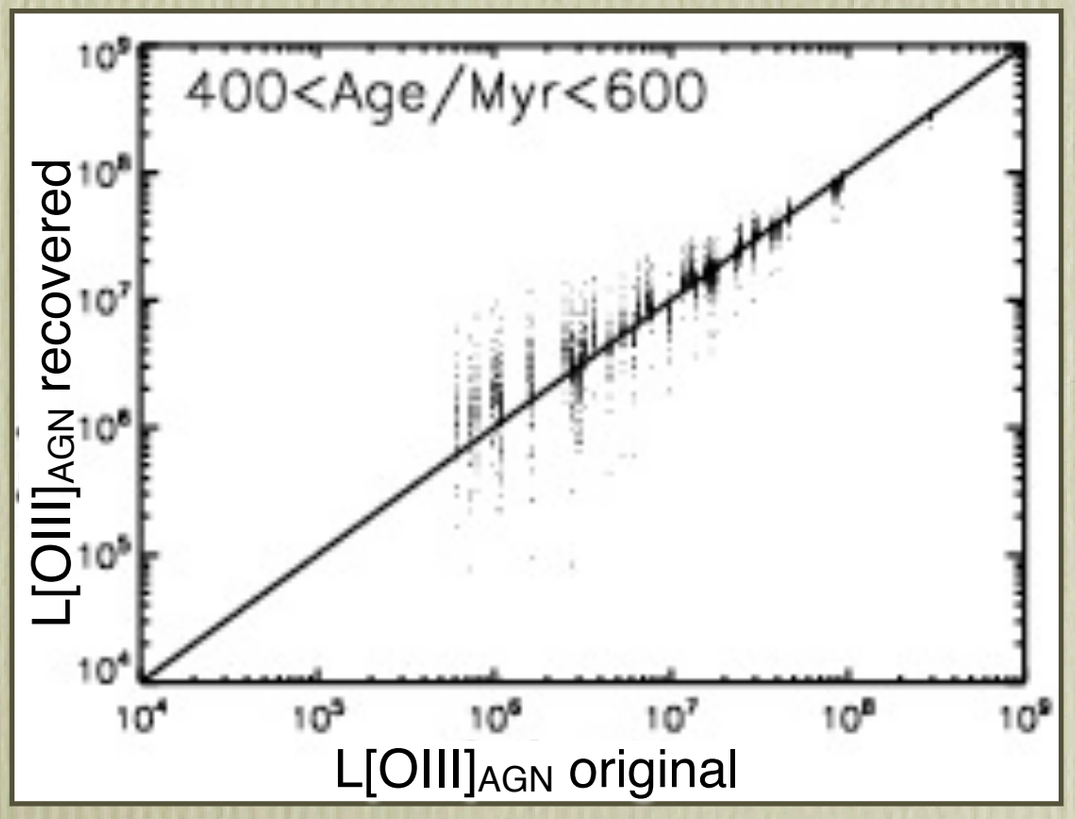
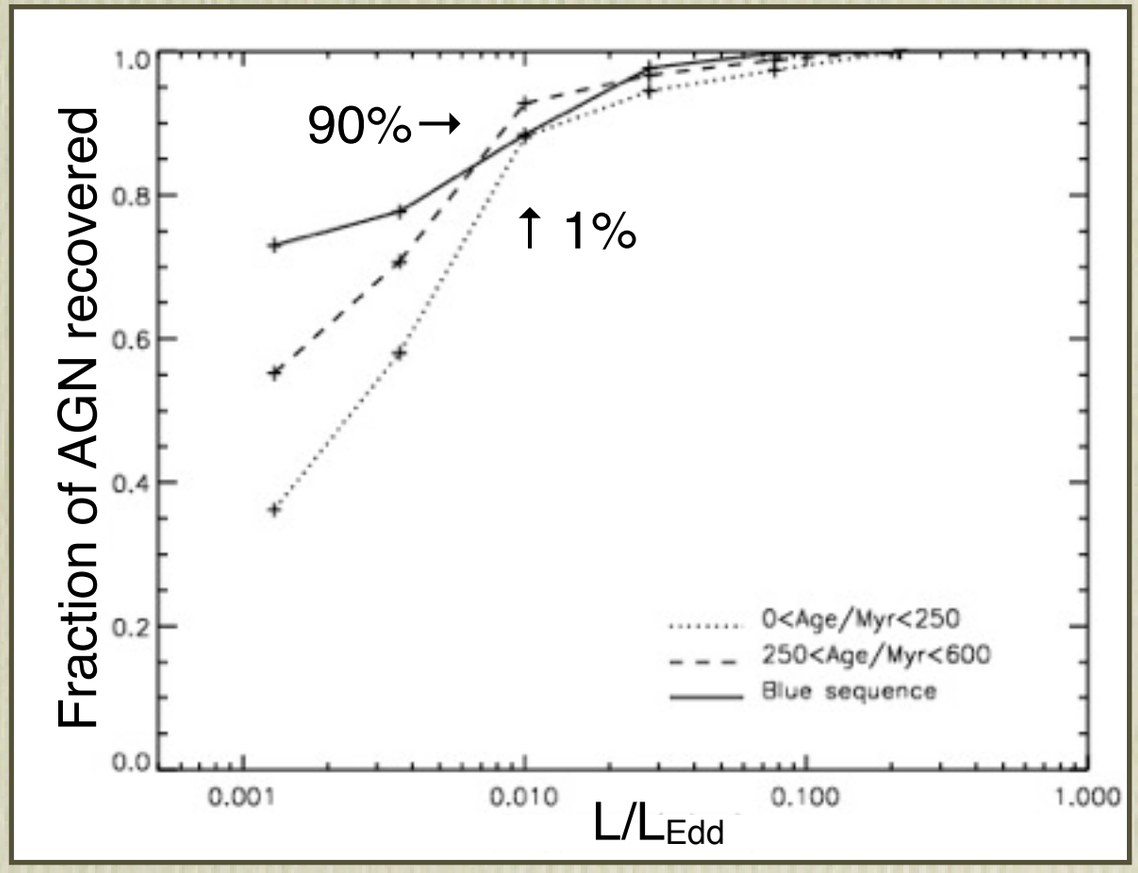
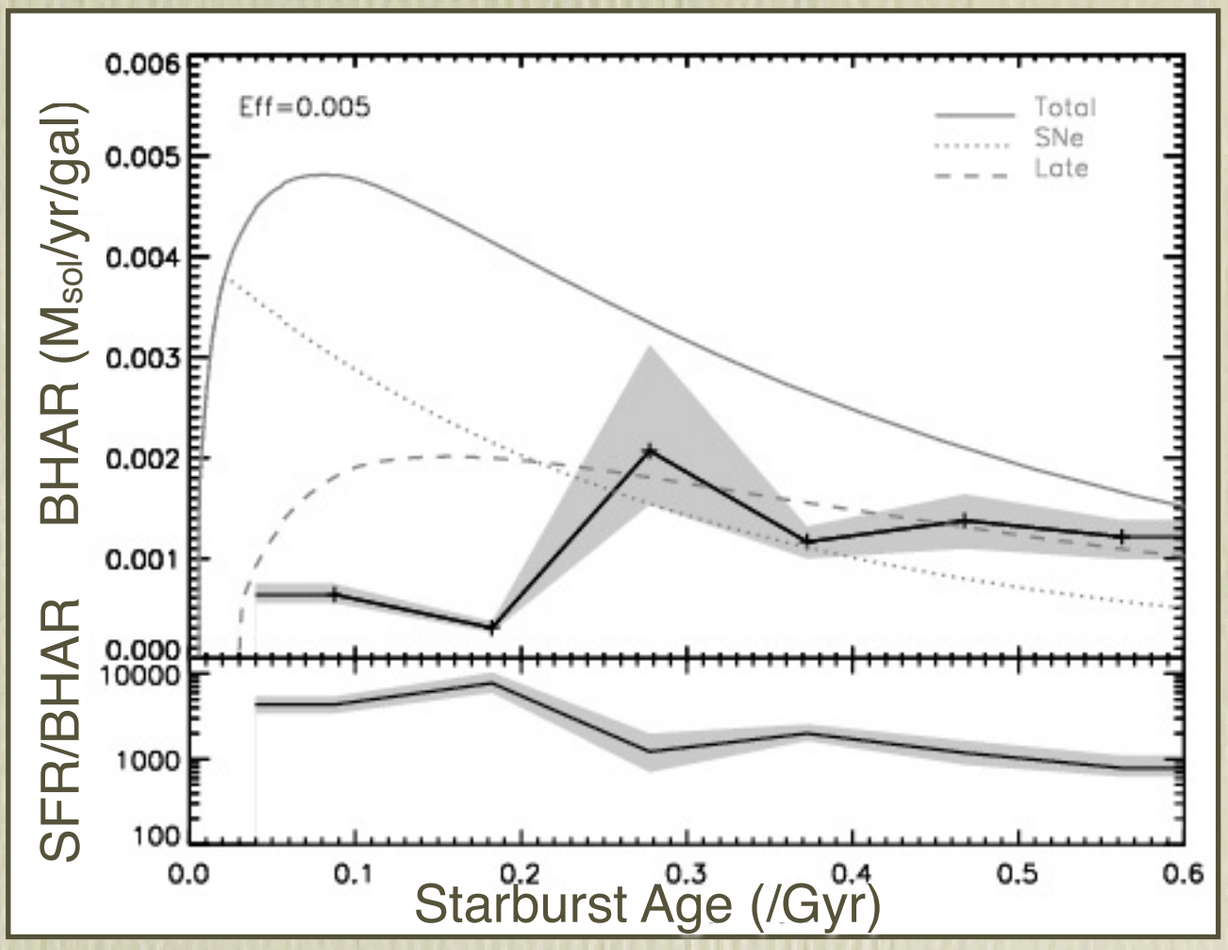


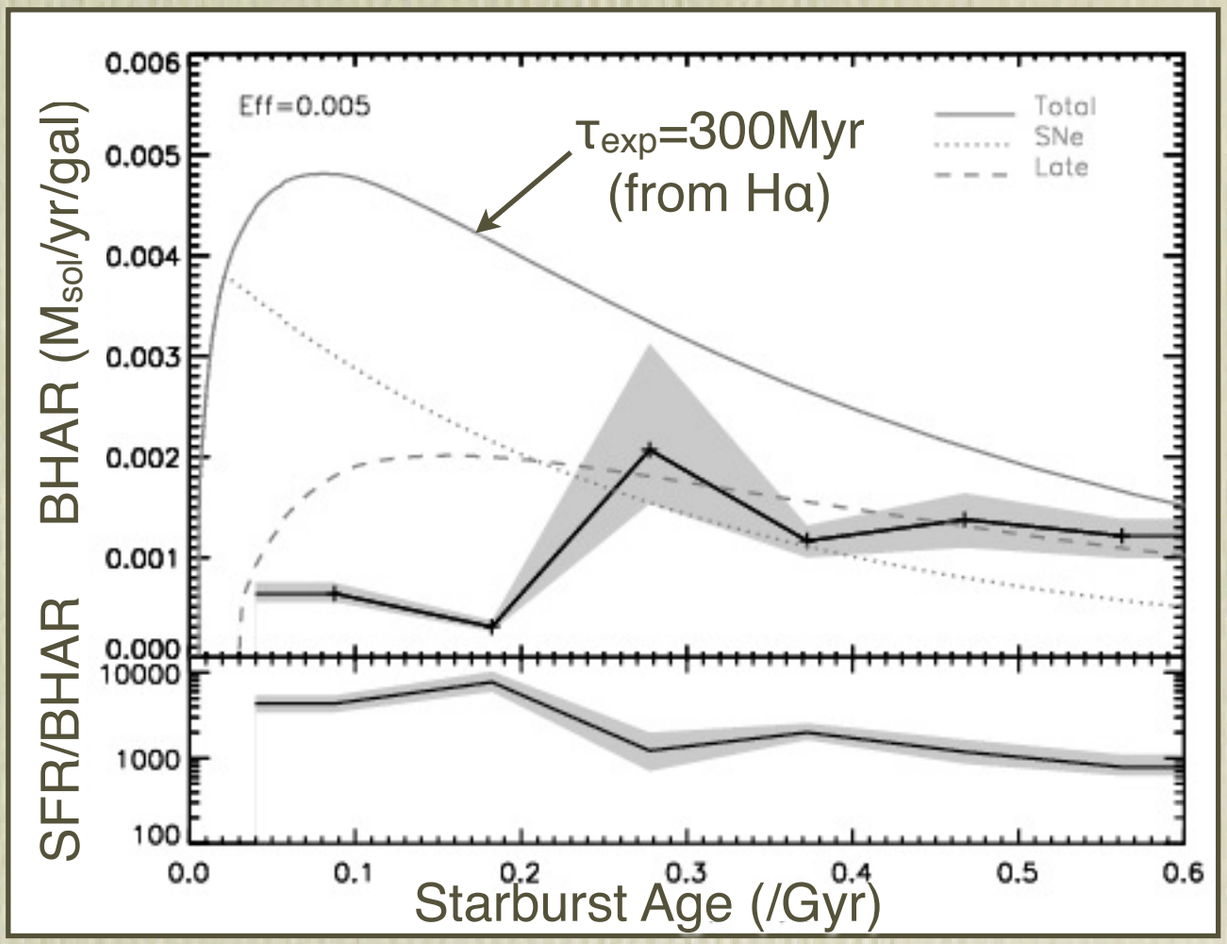


3b. Globally averaged BHAR

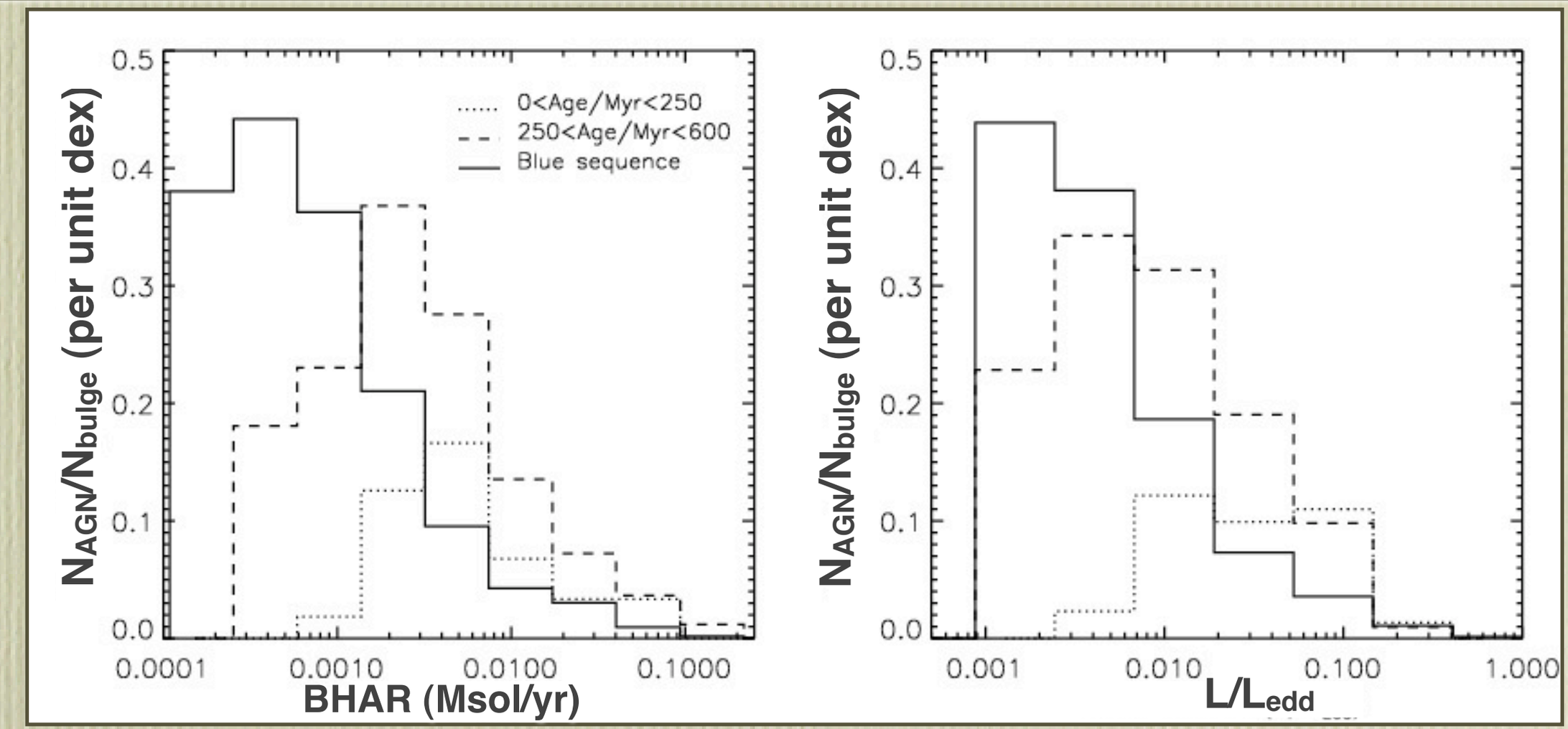


3b. Globally averaged BHAR

- First 200 Myr
  - Fast stellar ejecta from high-mass stars
  - Low average BHAR
- After 50 Myr
  - Slow stellar ejecta from low-mass stars
- After 200 Myr
  - Black holes start to accrete
  - Accretion efficiency: ~1% of low mass stellar ejecta (Ciotti & Ostriker 07; Kauffmann & Heckman 09)



3b. Where is the deficit coming from?

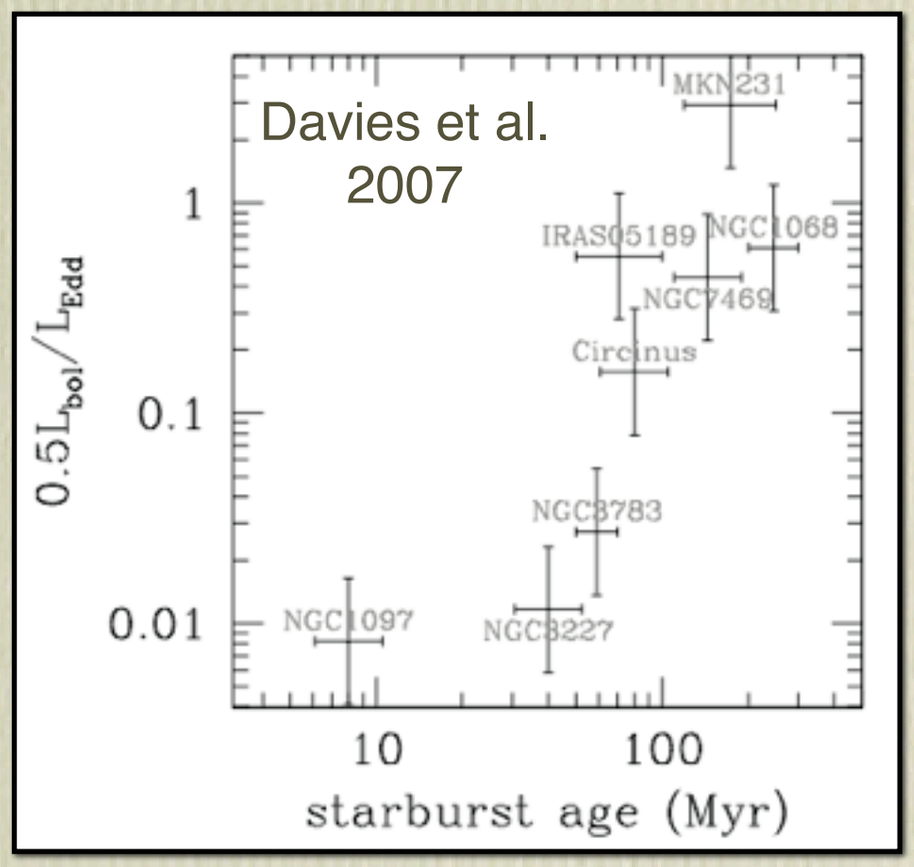


Histograms are corrected for incompleteness in the AGN sample

- Starbursts have more high accretion and high growth-rate AGN episodes compared to ordinary starforming bulges
  - Enhancement less pronounced in the youngest starbursts

Delay in AGN fueling?

- Similar delay seen in nearby, mostly Type 1 AGN
  - (Davies et al. 2007)
- AGN fueled by slow ejecta from low-mass stars?
  - (Norman & Scoville 88, Ciotti & Ostriker 07)
  - 40 Myr offset at most
- Need another factor:
  - SNe feedback??
  - dynamical delay due to merging cores??
  - gas infall time??

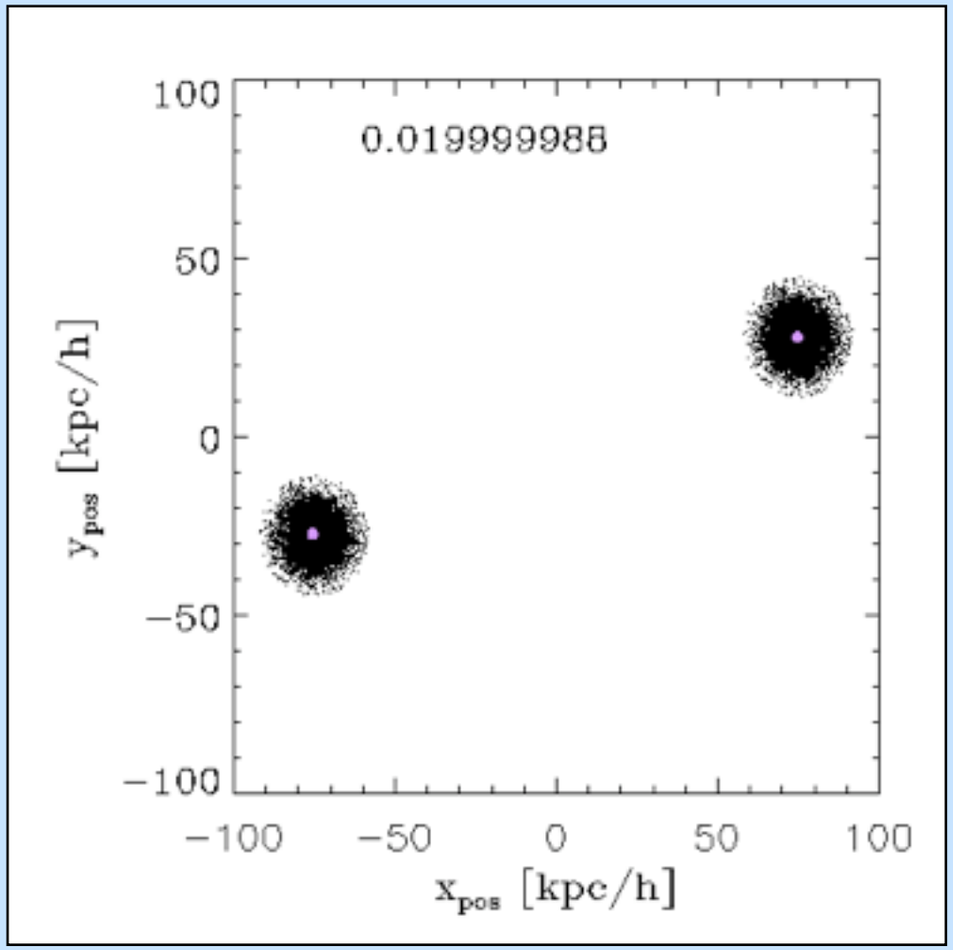


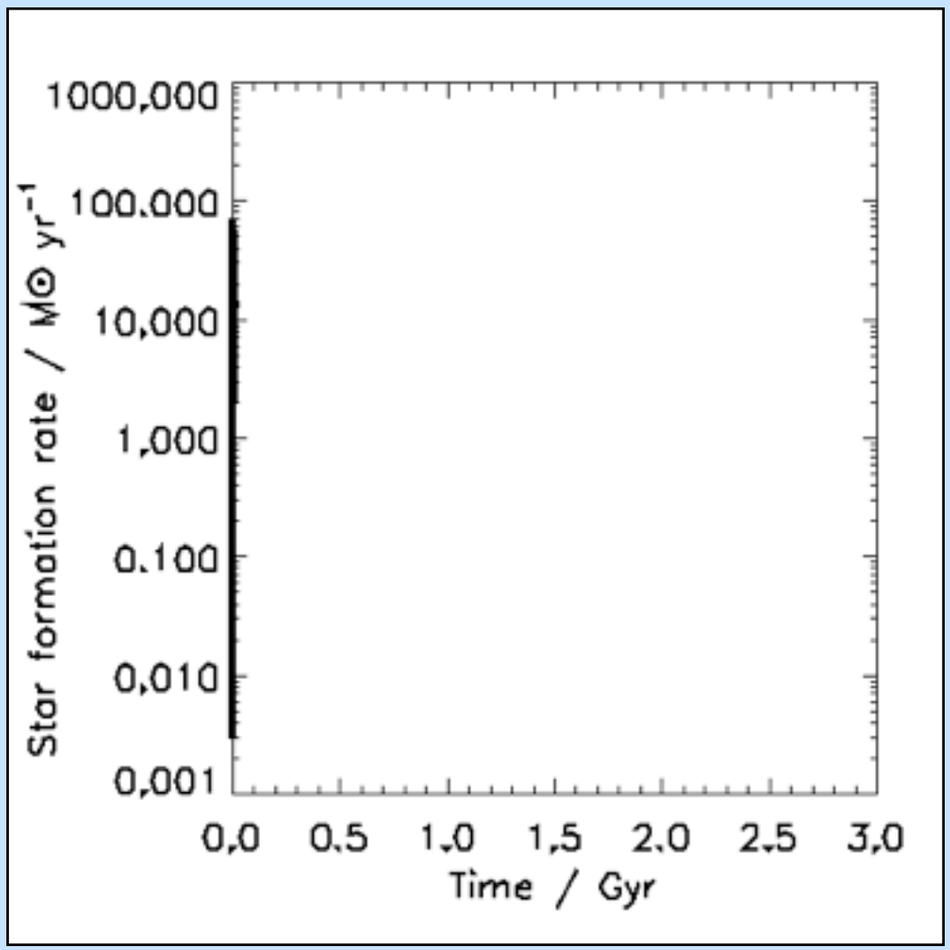
Vivienne Wild, IAP Paris

Conclusions

- > 60% of local black hole growth occurs in bulges with unspectacular recent star formation histories (e.g. Wild et al. 2007)
  - The strong starburst+black hole growth scenario is not the dominant, source of low-z black hole growth
- But... a starburst-AGN connection does exist at low-z
  - Enhancement in occurrence of high accretion rate AGN in starbursts compared to star-forming bulges
  - Average black hole accretion increases rapidly ~250Myr after starburst
  - Extrapolation to 10 Gyr gives M_{bulge}/M_{BH} close to that observed at present day
- SB-AGN connection: dominant route for BH growth at high-z?
  - Important: where the SMBHs we see today gained most of their mass.
  - Higher gas fractions, densities, merger-rates between gas-rich galaxies?

Johansson et al. 2009





Wild, Walcher, ...