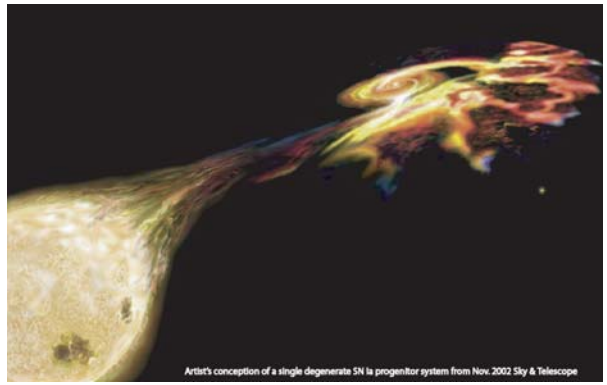
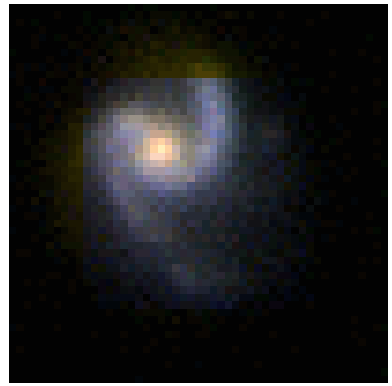
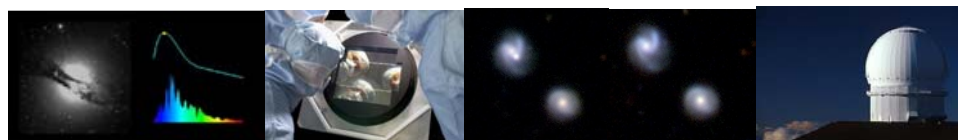




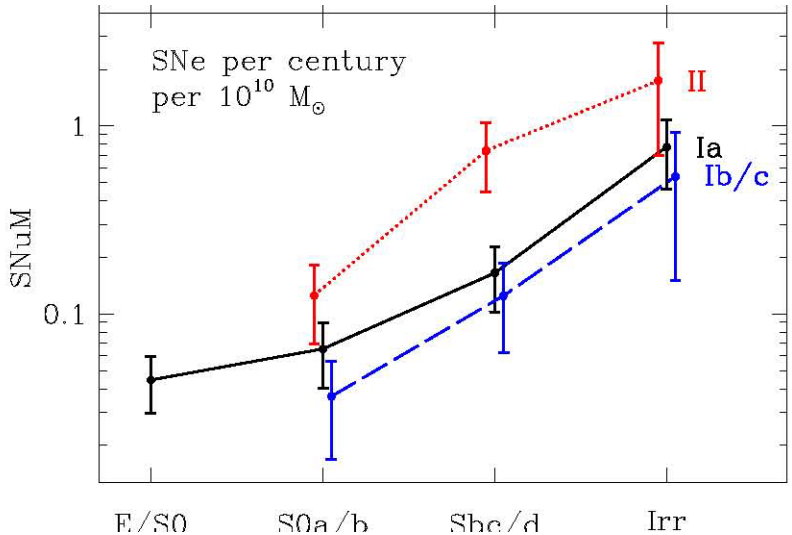
SN Ia Rates and Host Galaxy Properties

Chris Pritchet, U. Victoria

KITP Mar 2007



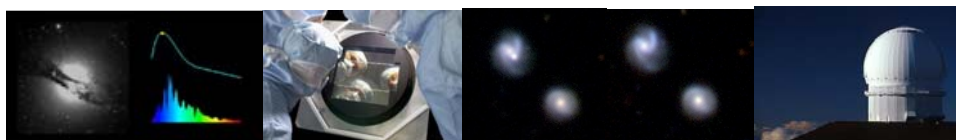
SNeIa in Star-Forming Galaxies

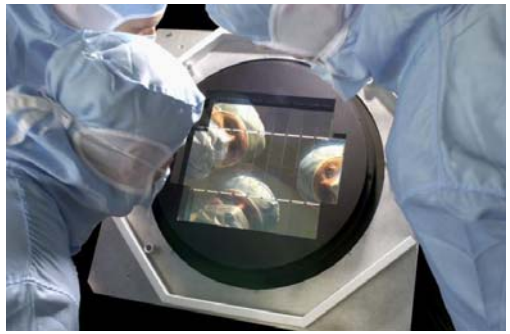


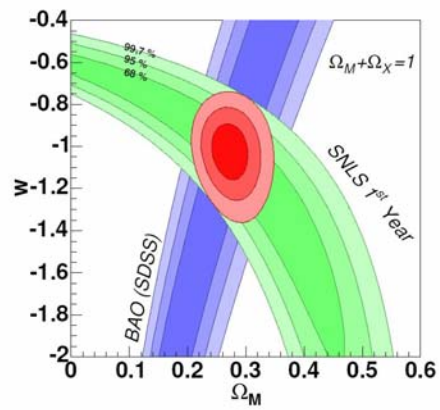
Mannucci et al 2006

$$\text{SN rate} = A \cdot M + B \cdot SFR$$

Scannapieco and Bildsten 2006

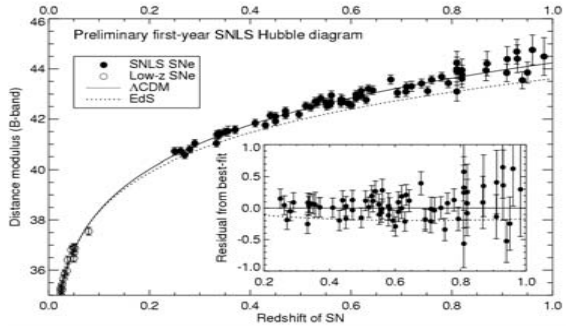


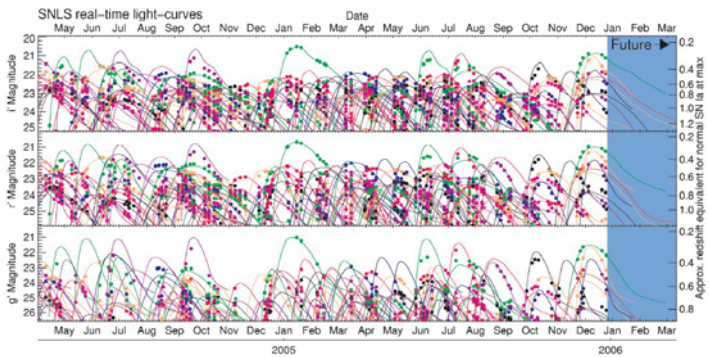


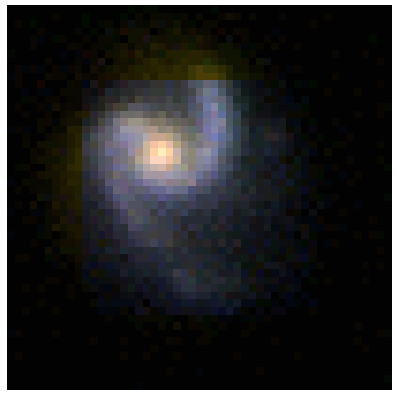


SNLS

>500 spectroscopically confirmed SNeIa by 2008, 0.2<z<1.0







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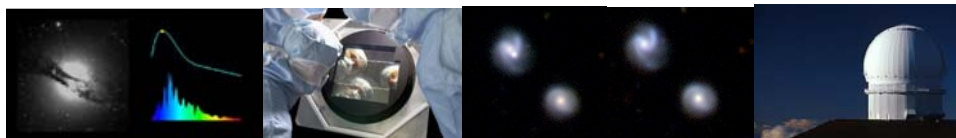
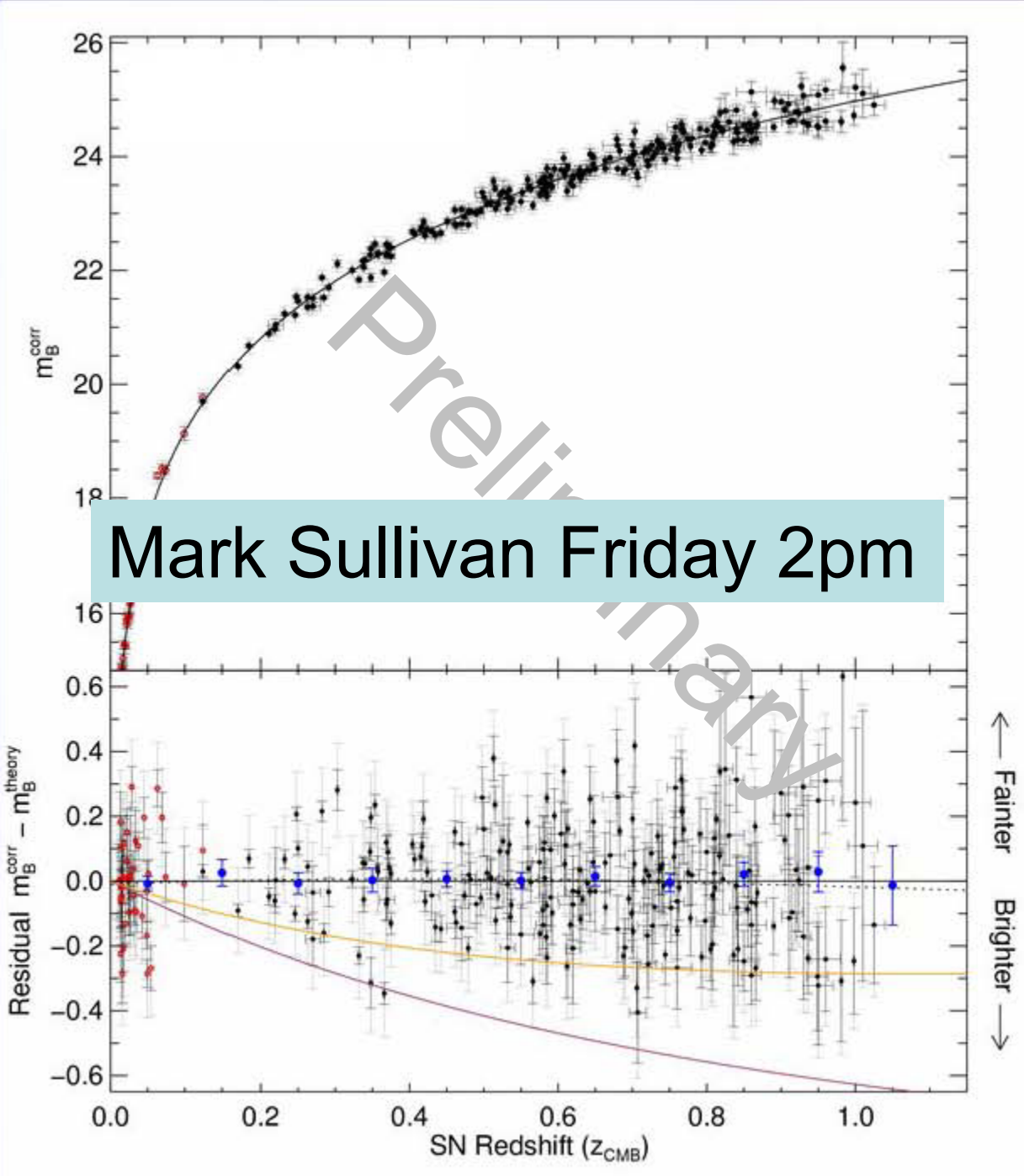


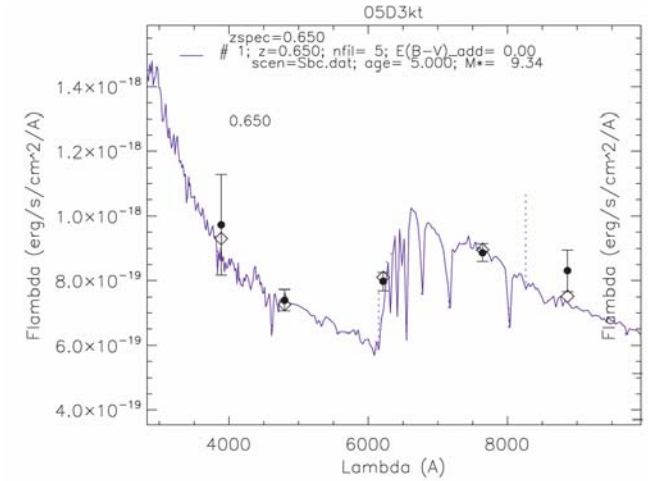
SNLS 3rd year analysis

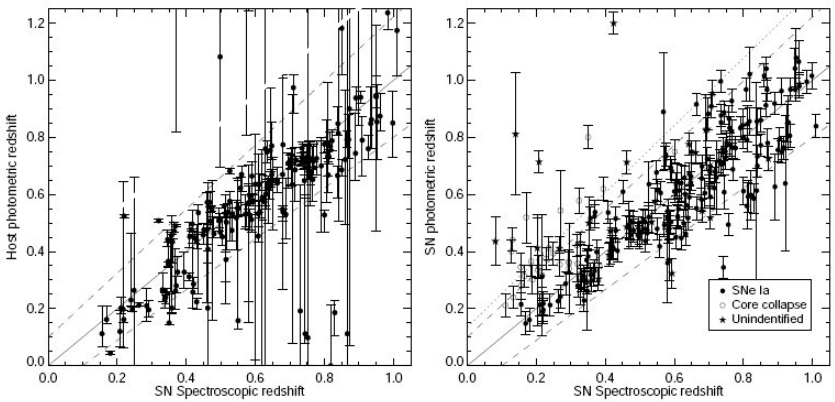
- **Sullivan et al 2007**



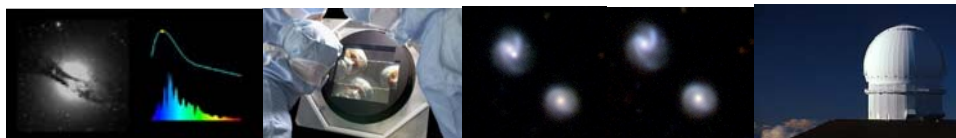
Sullivan et al 2006 - SNIa rate per unit mass vs SFR

- Pegase evolutionary models fitted to all galaxy SED's (Le Borgne et al 2005)



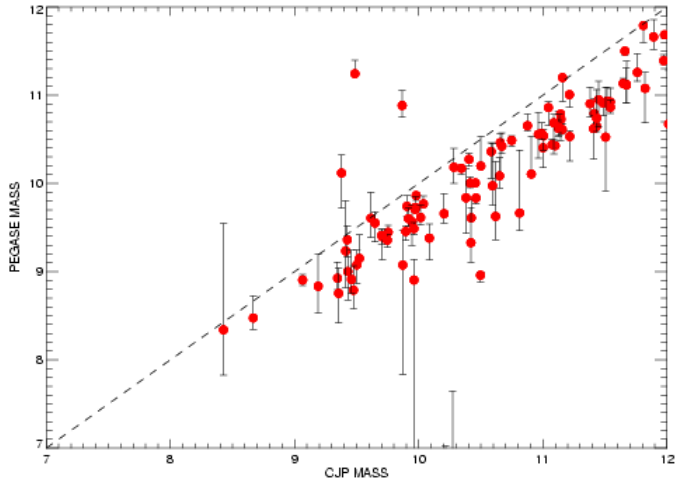


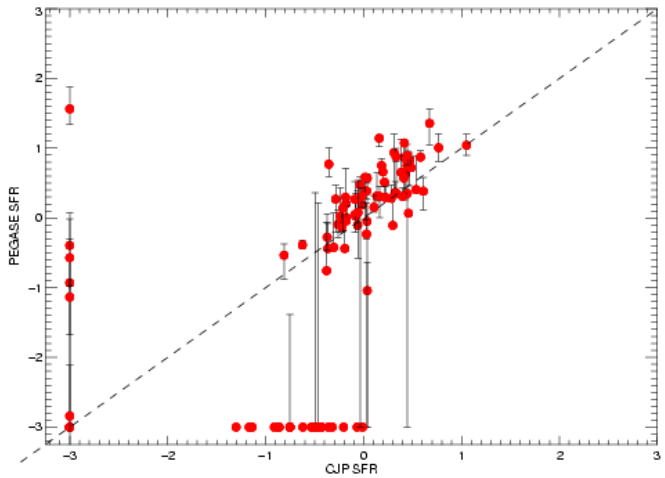
- Best fit model gives photo z, SED type, mass, SFR for each field or host galaxy

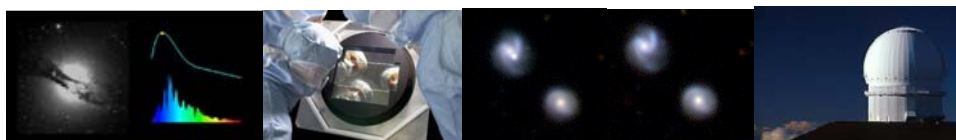


Mass, SFR (2)

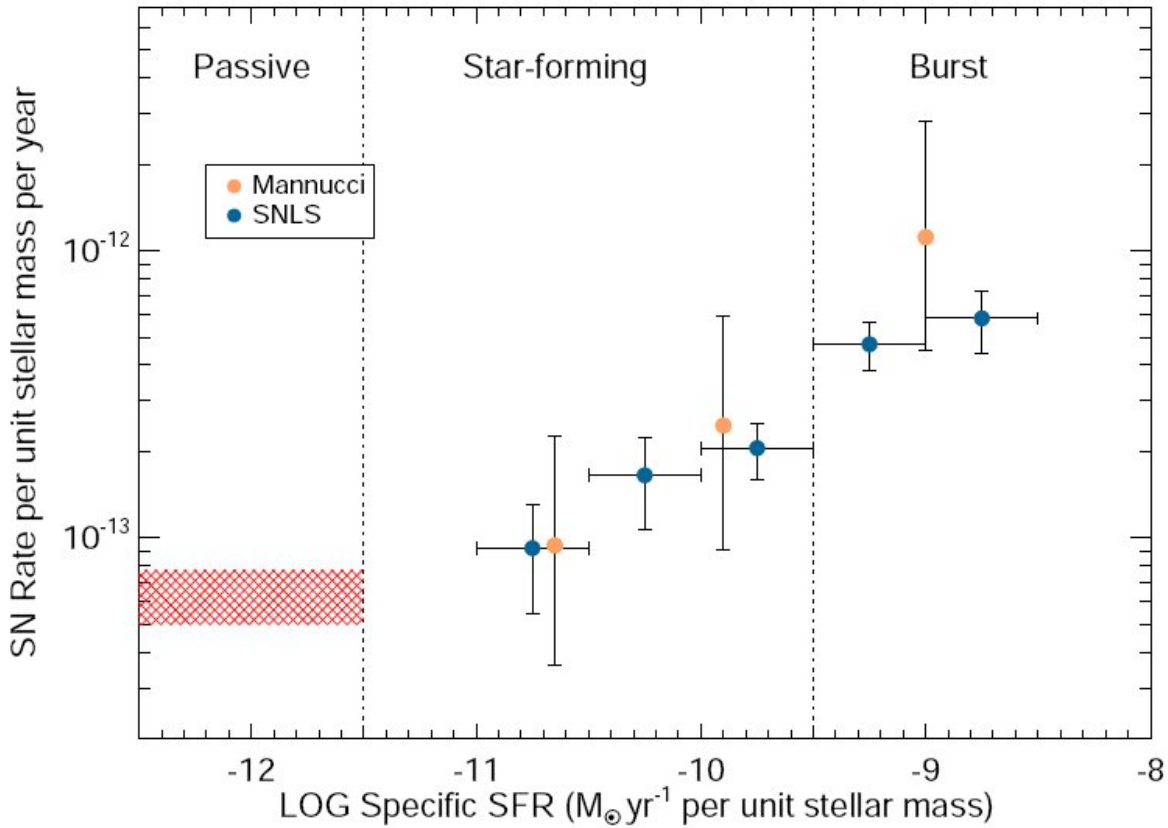
- Photo z, SED type from empirical galaxy spectra (Gwyn et al 2005)
- Mass by fitting SED type to Buzzoni models
- SFR from observed 280nm UV flux



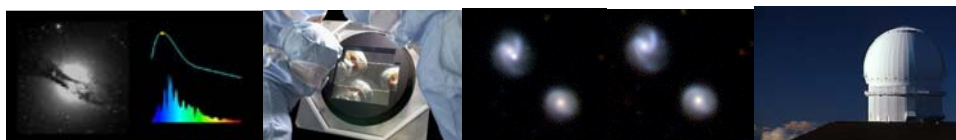




SN Ia rate depends on SFR



- Mannucci low z confirmed

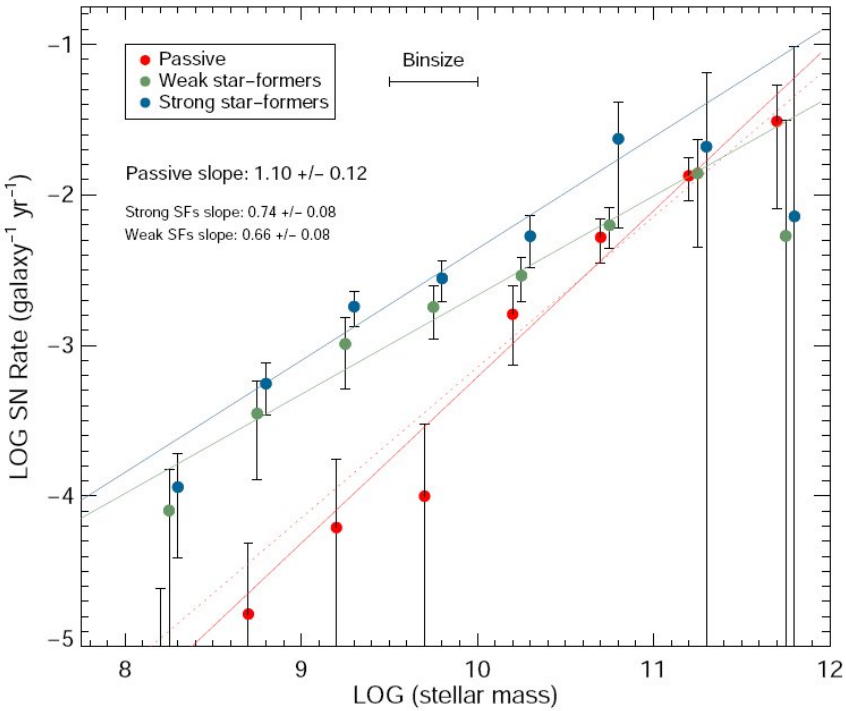


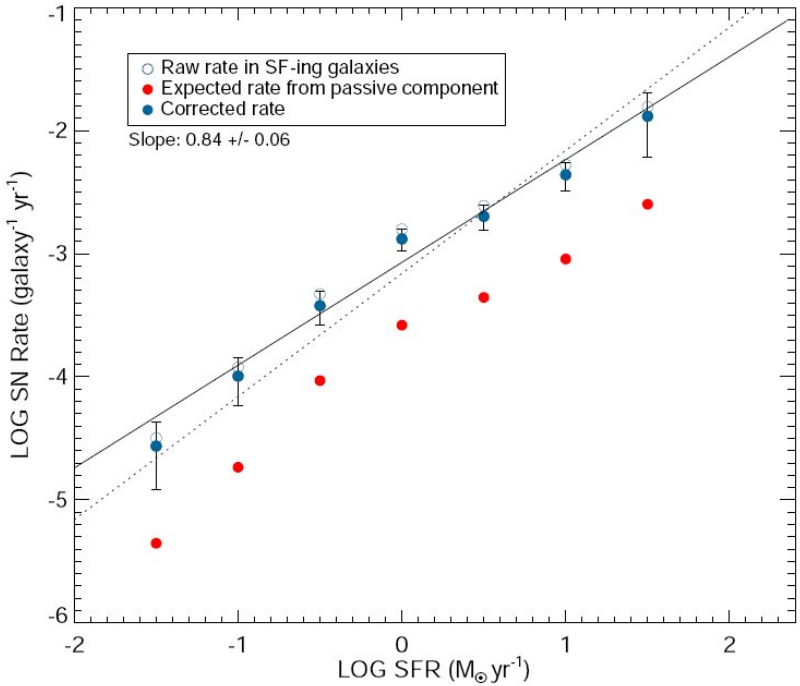
$$\text{SN rate} = A \cdot M^{m} + B \cdot SFR^{n}$$

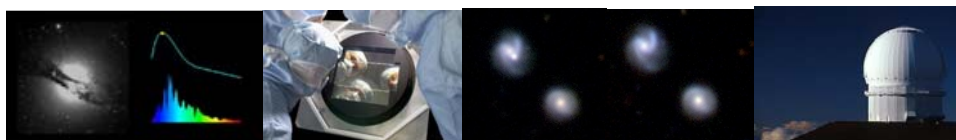
m = 1.10+-0.12, n = 0.84+-0.09
A=5.1E-14 SNe/yr/Msun
B=4.1E-4 SNe/yr/(Msun/yr)
B needed at 99.99% confidence

cf. Scannapieco and Bildsten 2005 (m=1, n=1)

Bivariate fits give m,n close to 1



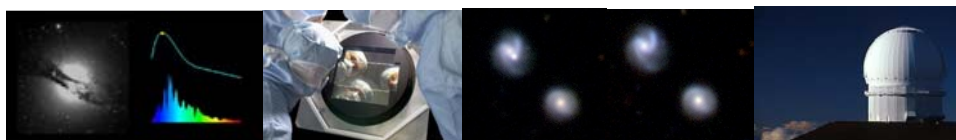


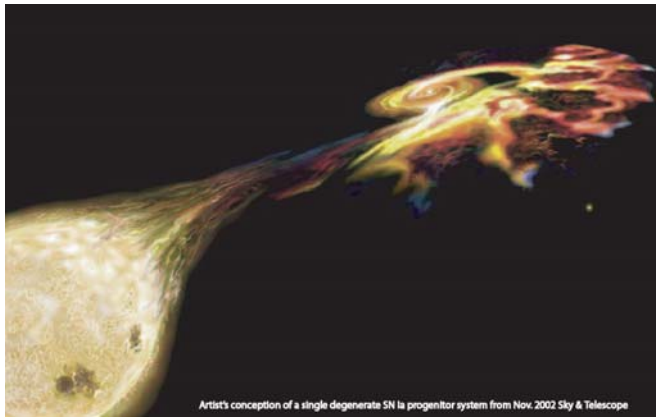


Meaning of A·M + B·SFR

$$SNR/M = A + B(SFR/M)$$

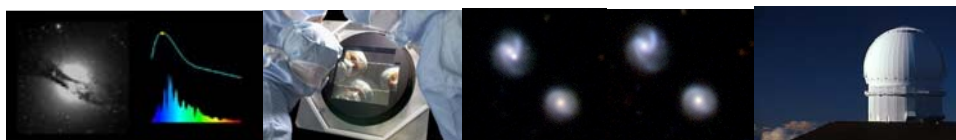
- Does this imply two paths to SNeIa? …
- … or is there a simple unifying picture that can be used to understand the A+B prescription for the SNIa rate?
- Why do the A and B values have the values that are observed?
- Continuum of delay times – more natural?





Toy Model

- Single degenerate scenario
- Delay time depends on evolutionary timescale of secondary - T(evol) ≈ T(ms)
- Simple SFR(t) to allow for range of ages



Analytical Model - Burst

Assumption:

- Fraction of binaries producing SNeIa is independent of mass

Results:

- SNIa rate from a starburst decreases with time
- Factor of ~100x in mean stellar age (100Myr – 10Gyr) gives factor of ~10x in SN Ia rate, as observed

$$\text{mass fcn} \quad \frac{dN}{dM} \propto M^{a}$$

$$\text{evol timescale} \quad \tau \propto M^{b}$$

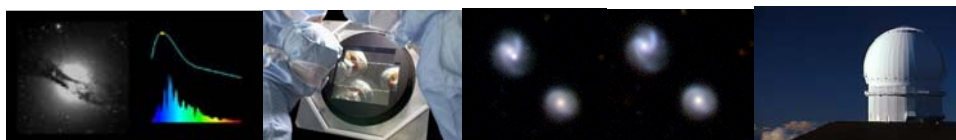
$$a \cong -2.35, \quad b \cong -2.5$$

$$M \propto \tau^{1/b}, \frac{dM}{d\tau} \propto \tau^{1/b-1}$$

$$\frac{dN}{d\tau} = \frac{dN}{dM} \cdot \frac{dM}{d\tau}$$

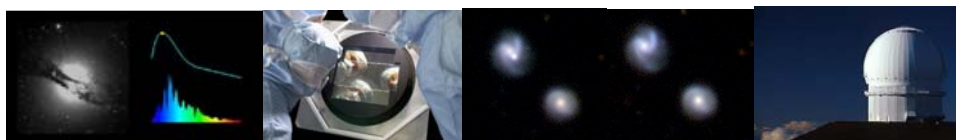
$$\propto \tau^{(a-b+1)/b}$$

$$\propto \tau^{-0.5\pm}$$



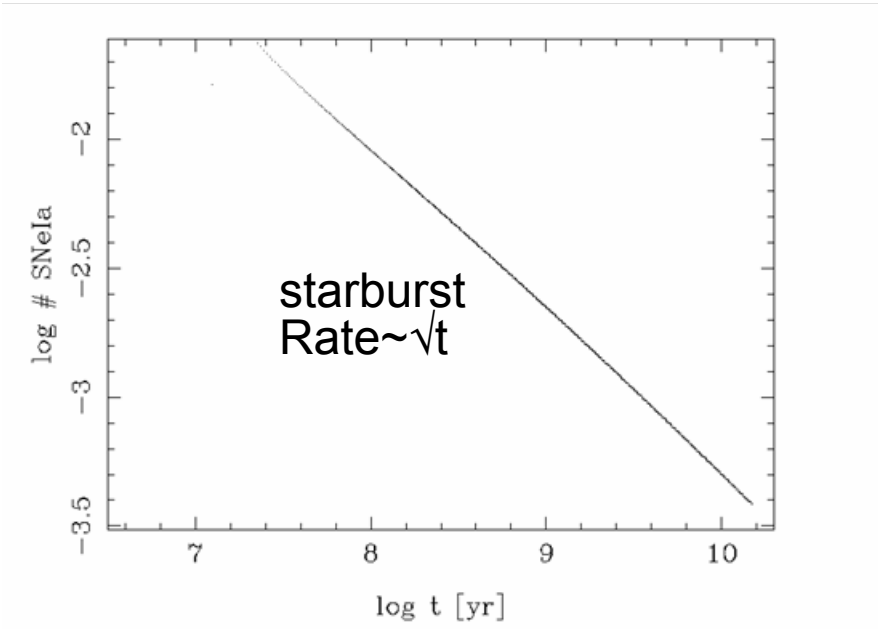
Numerical Model

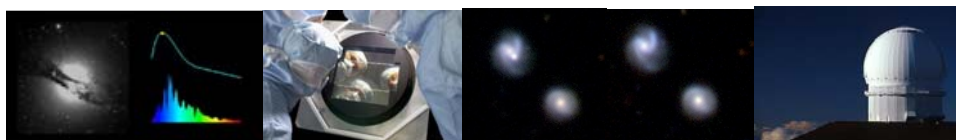
- Salpeter mass function (or Kroupa)
- SFR ~ $t^{-\eta}$
  - $\eta = 1$ is taken to be an SSP (E/S0)
  - $\eta = -1$ is an Irr starburst
- Correct evolutionary timescales (not just power law in mass)
- Numerical integration or Monte Carlo



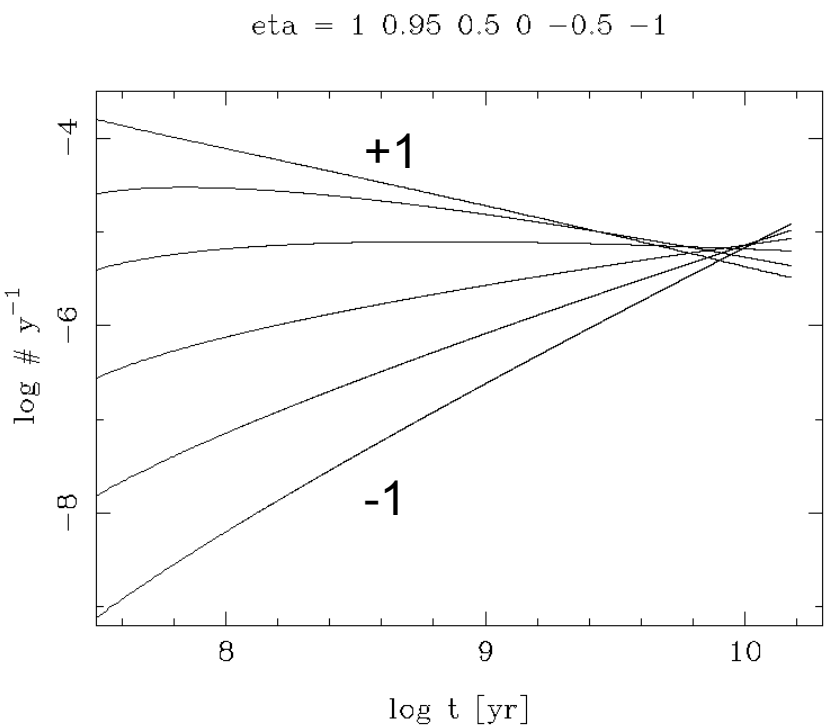
Rate vs time

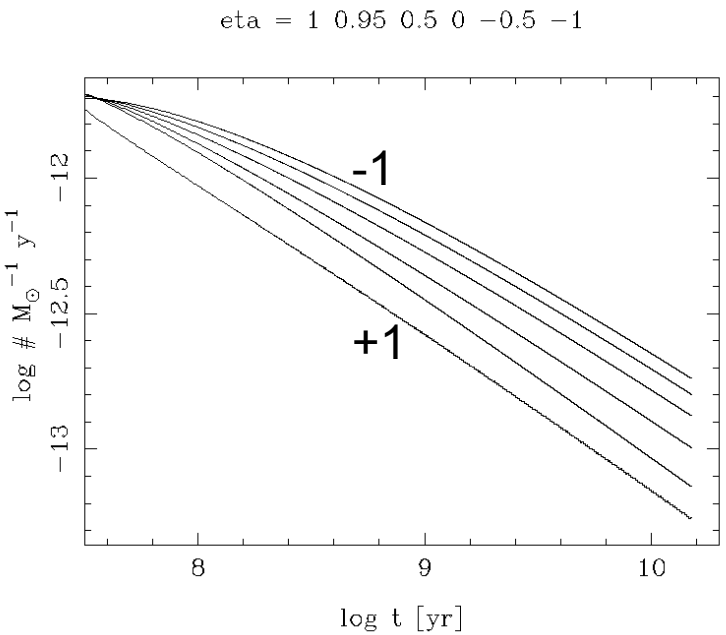
- Rate at which stars leave main sequence
- This is the distribution of delay times for a burst

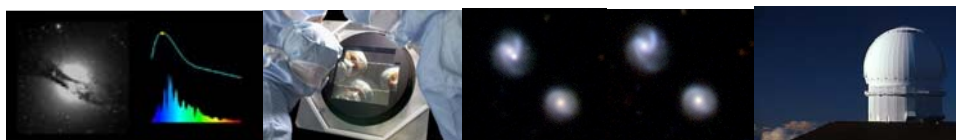




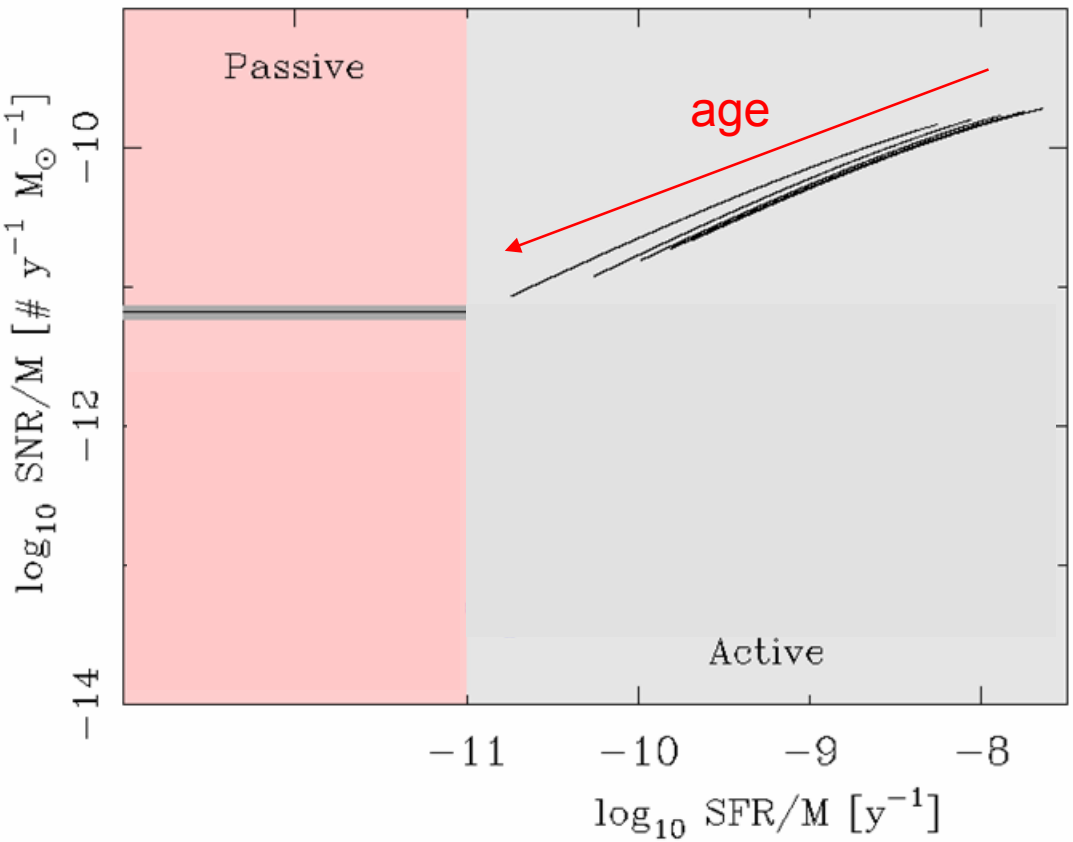
Rate vs time


eta = 1 0.95 0.5 0 −0.5 −1
+1
-1
log # y^{-1}
−4
−6
−8
8
9
10
log t [yr]


eta = 1 0.95 0.5 0 −0.5 −1
-1
+1
log # M$_\odot^{-1}$ y^{-1}
−12
−12.5
−13
8
9
10
log t [yr]

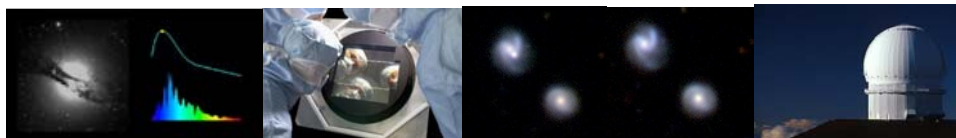


Predictions of model



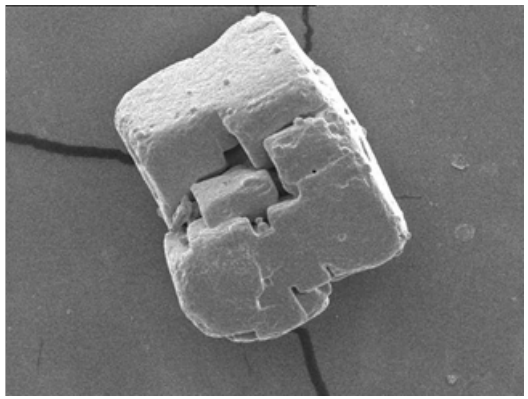
η

SFR~$t^{-\eta}$



Normalization

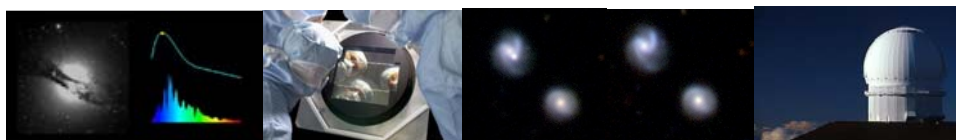
"cum grano salis"

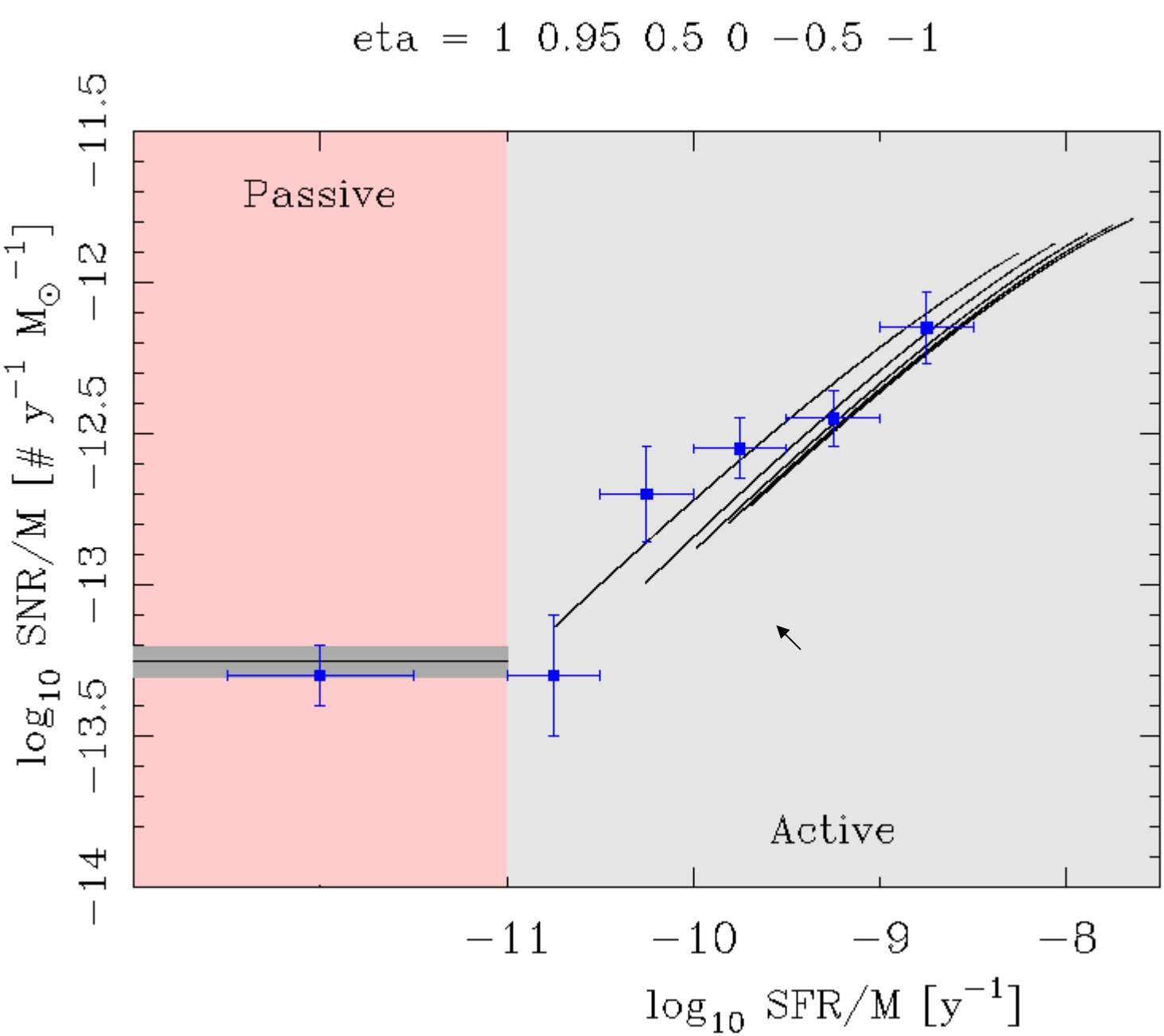


(1e10 Msun)
<[Fe/H]>=-0.5

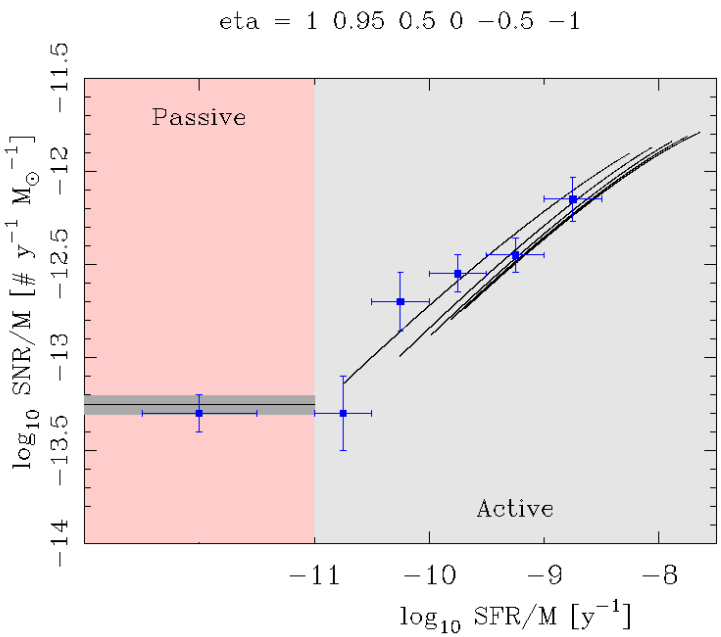
{ 1e10 Msun
Salpeter mass fcn
1-9 Msun for SNIa
0.6 Msun Ni56 per SNIa } X f_{SNIa} → 6×10^6 M_{sun} Fe peak

Fraction 0.0083 of all stars in the mass range 1-9 Msun become SNeIa.

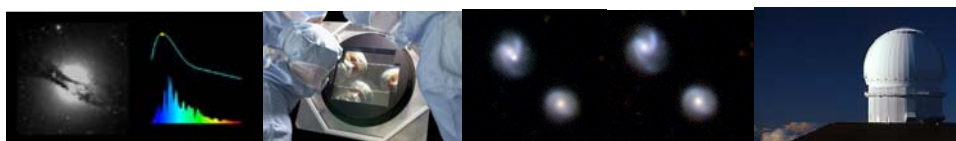


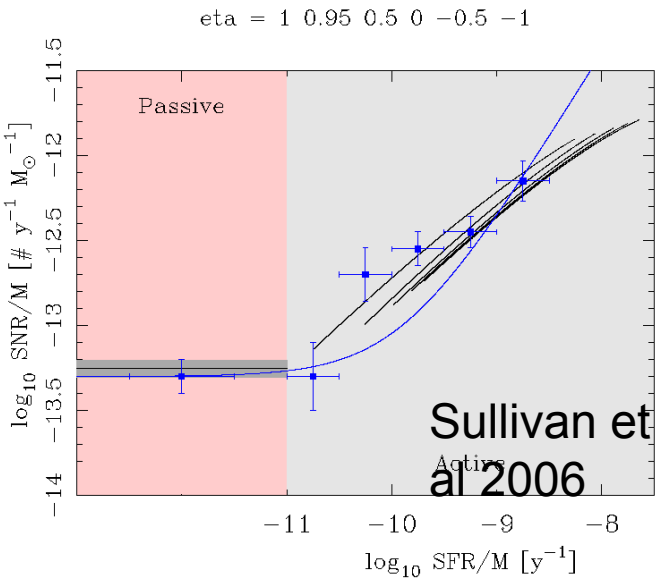

eta = 1 0.95 0.5 0 −0.5 −1
Passive
Active
−11.5
−12
−12.5
−13
−13.5
−14
log10 SNR/M [# y−1 M⊙−1]
−11
−10
−9
−8
log10 SFR/M [y−1]

Meaning

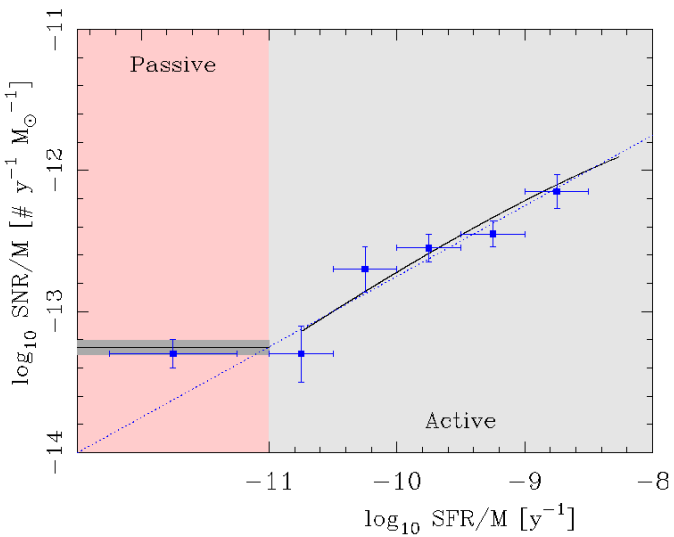


- Single component model – not A+B
- Continuous distribution of delay times
- Rate in active and passive galaxies both explained
- Only physics is evol timescales
- Single free parameter normalization - f_{SNIa}





A +B (SFR/M) or …?

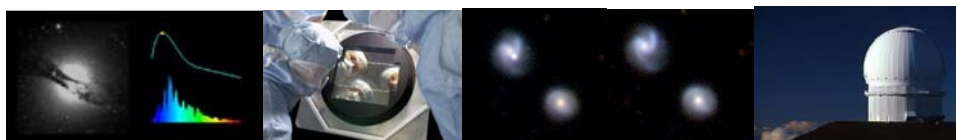


$$\frac{SNR}{M} = Cf(\tau,\eta) \cong Cf(\tau)$$

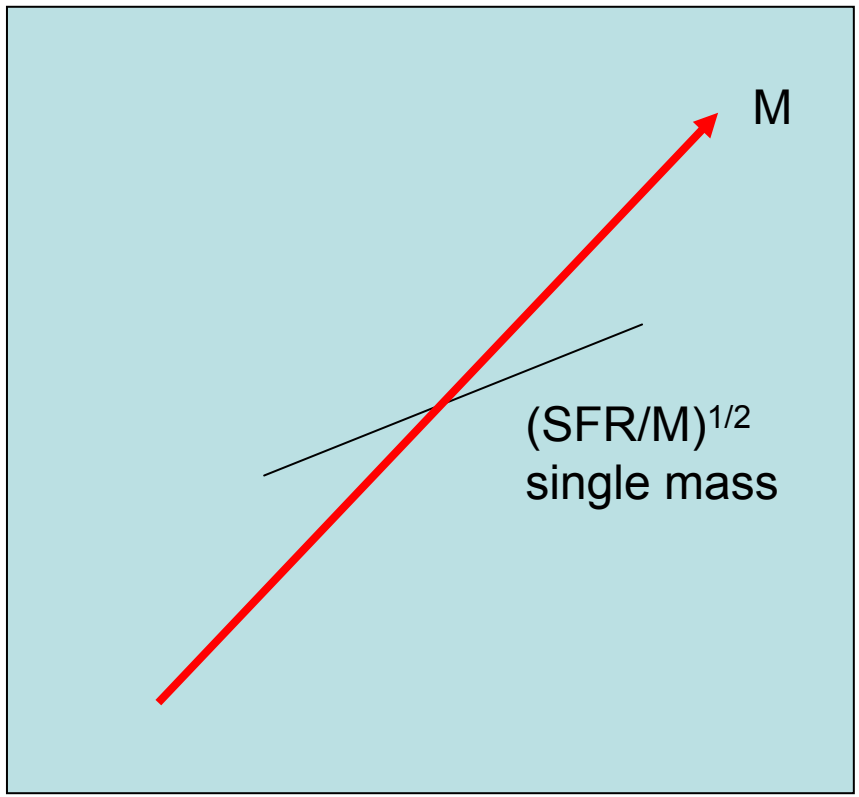
$$\approx \max\left[1.8\times10^{-8}(SFR/M)^{1/2},\ 5\times10^{-14}\right]$$

Units are $M_{sun}^{-1}y^{-1}$

This is not a 2 component model!



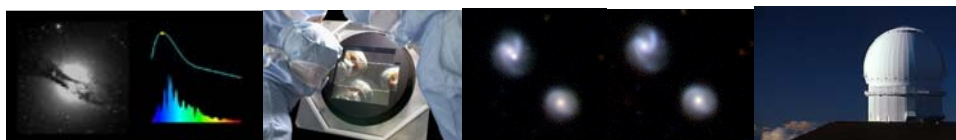
Why A M + B SFR fitted?



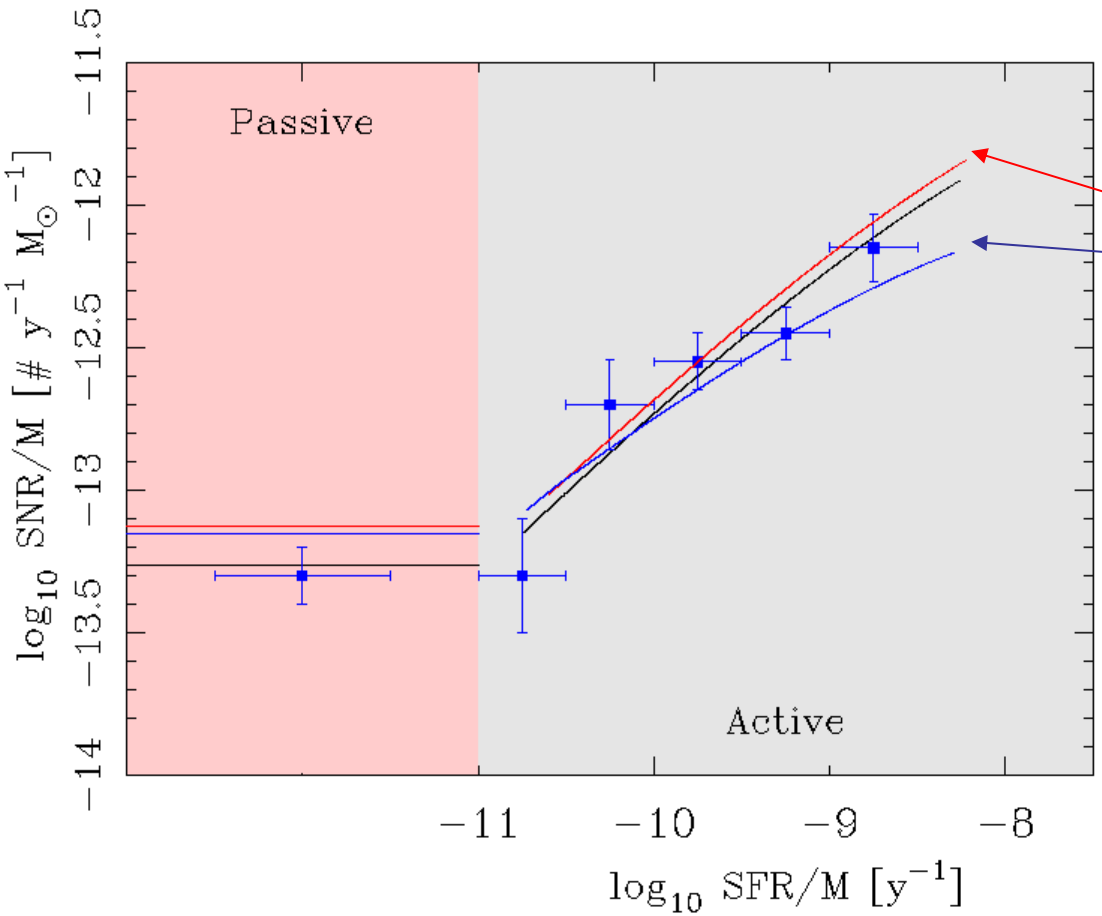
$$\frac{SNR}{M} = Cf(\tau)$$

$$\therefore SNR = Cf(\tau)M$$

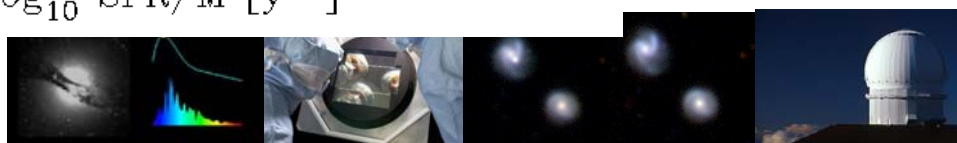
- Mass stretches f(SFR/M)
- Slope closer to 1
- Observed slope is <1 - expected …



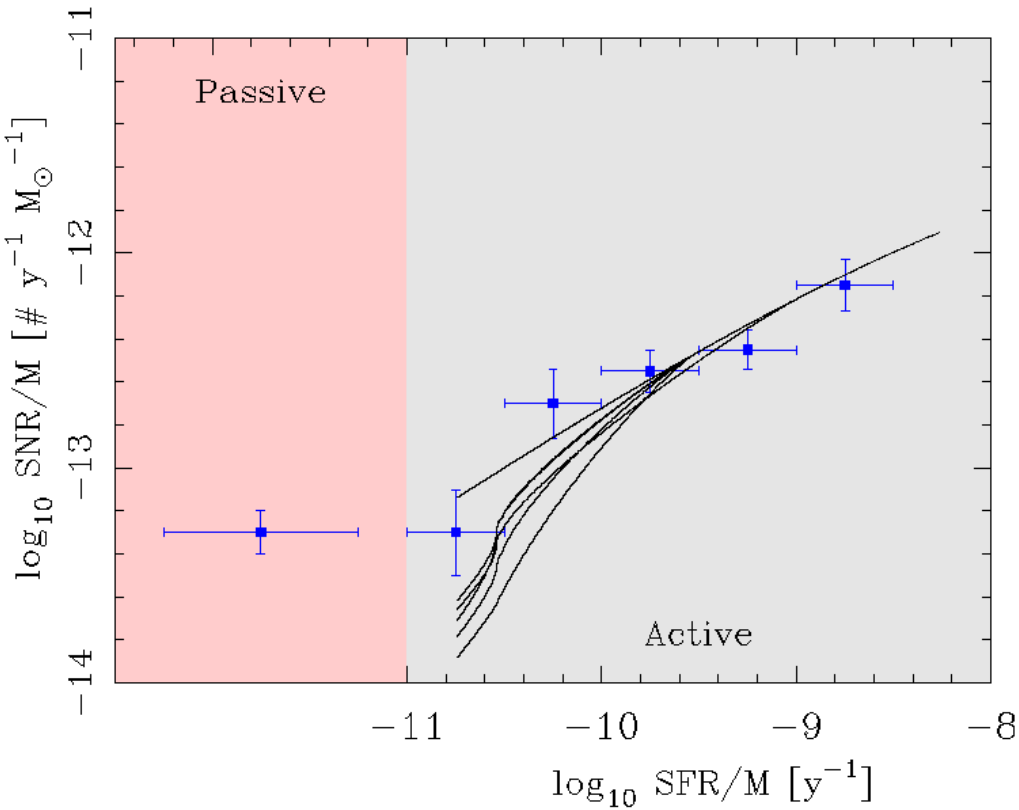
IMF effects

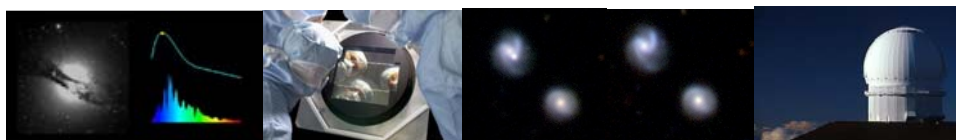


Kroupa 2006



Decreasing efficiency at low mass





DD Scenario

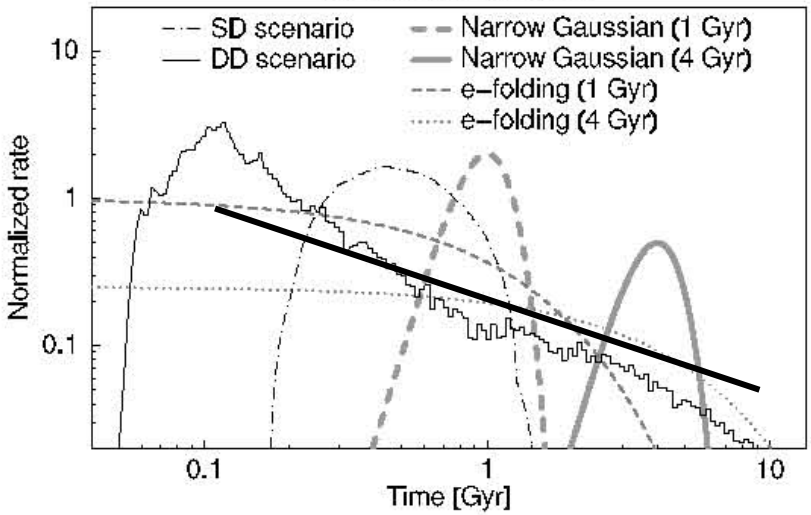
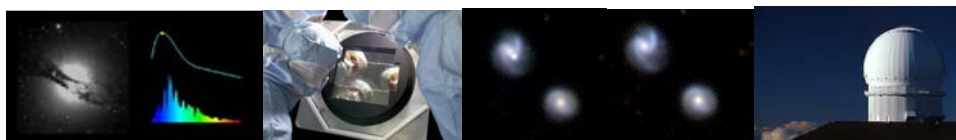


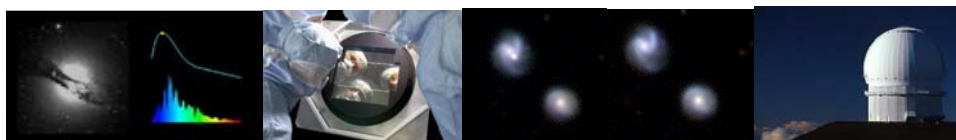
Figure 1. Theoretical time delay distributions (Han & Podsiadlowski 2004) compared to parametrized time delay distributions used in the analysis. The best-fitting model in S04 corresponds to the 'narrow Gaussian' distribution with a mean time delay of 4 Gyr

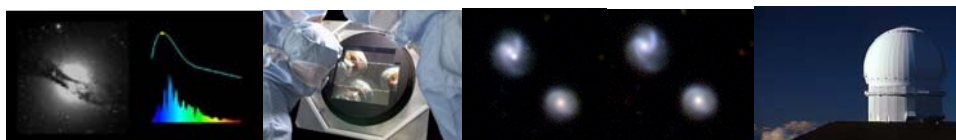
Han & Podsiadlowski 2004

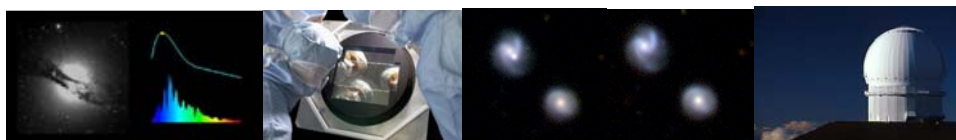


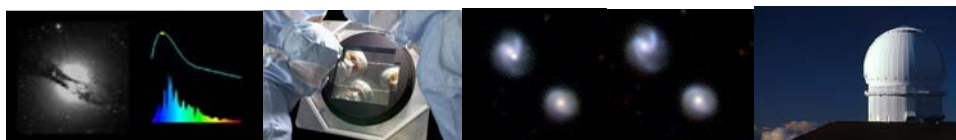
Conclusions

- SNIa rate depends on SFR
- SNR/M ~ C $(SFR/M)^{1/2}$ or C' (passive)
  - one parameter model fits active and passive
  - excellent fit to data – better than A + B SFR/M
  - Based on stellar evolutionary timescales
  - Continuous delay time distribution
- Prediction:
  - SNIa rate will correlate with mean age from population models



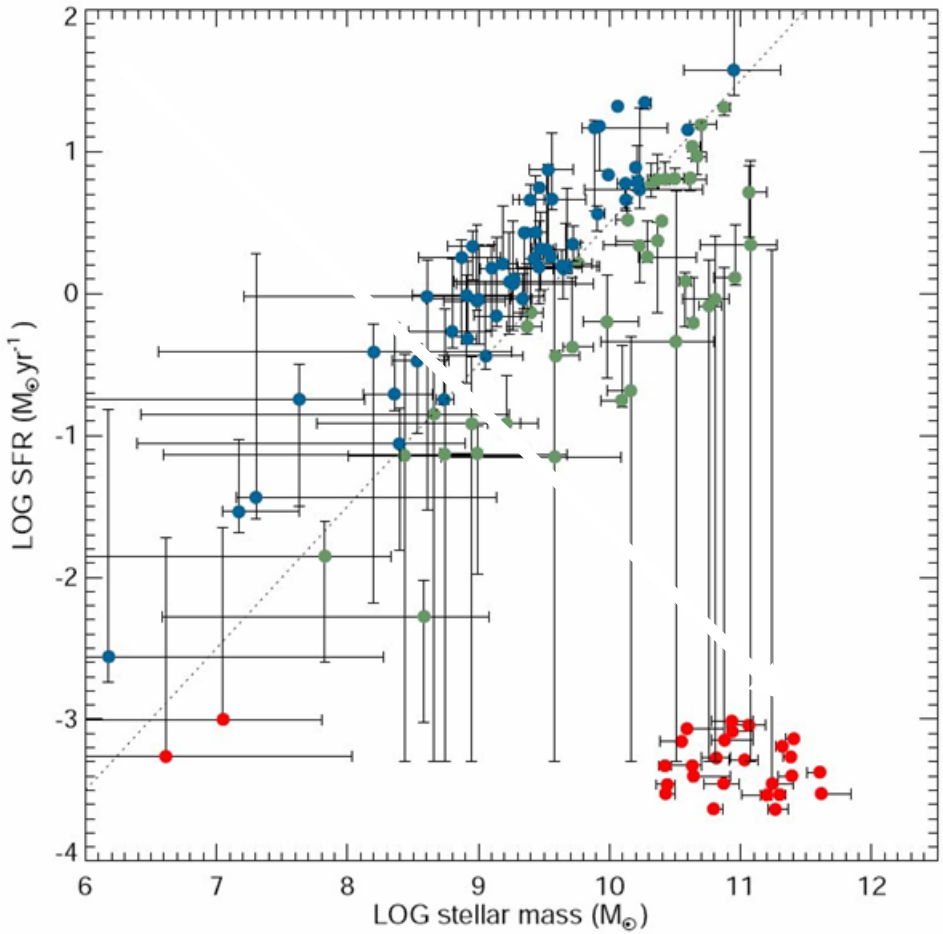


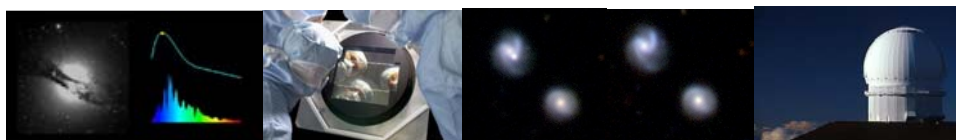




SFR vs. Mass – 3 groups

- Gas consumption timescale M/SFR



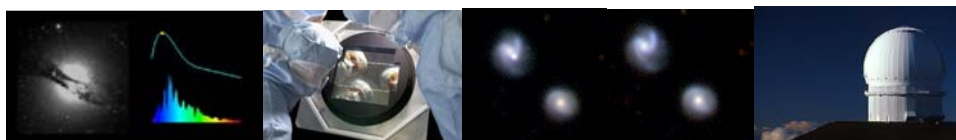


Calculating rate

- Rate per unit mass for the k'th group of objects

$$(rate\ /\ mass\ )_k = \frac{f}{\Delta t} \cdot \left[\frac{N_{SN}}{\sum_{\mathrm{i=all\ gals}} M_i} \right]_k$$

- f=incompleteness, doesn't matter when comparing different types of galaxies with the same time sampling



Normalization

- Mass fraction of Fe = 1.2E-3 for solar abundances
- 0.6 Msun of Fe-peak elements per SNIa
- Salpeter IMF, 10^10 Msun of stars
  - 2.8E10 stars (0.1-100Msun)
  - Fraction by number that are 1-9 Msun is ???
- So 10^10 Msun produces 2.8e10 x 0.12 x0.6 =2.0e9 Msun Fe if all stars 1-9Msun become SNeIa
- Actual Fe mass is only 0.0012 x 10^10 = 1.2e7 Msun
- **Therefore a fraction 0.0083 of all stars in the mass range 1-9 Msun become SNeIa.**