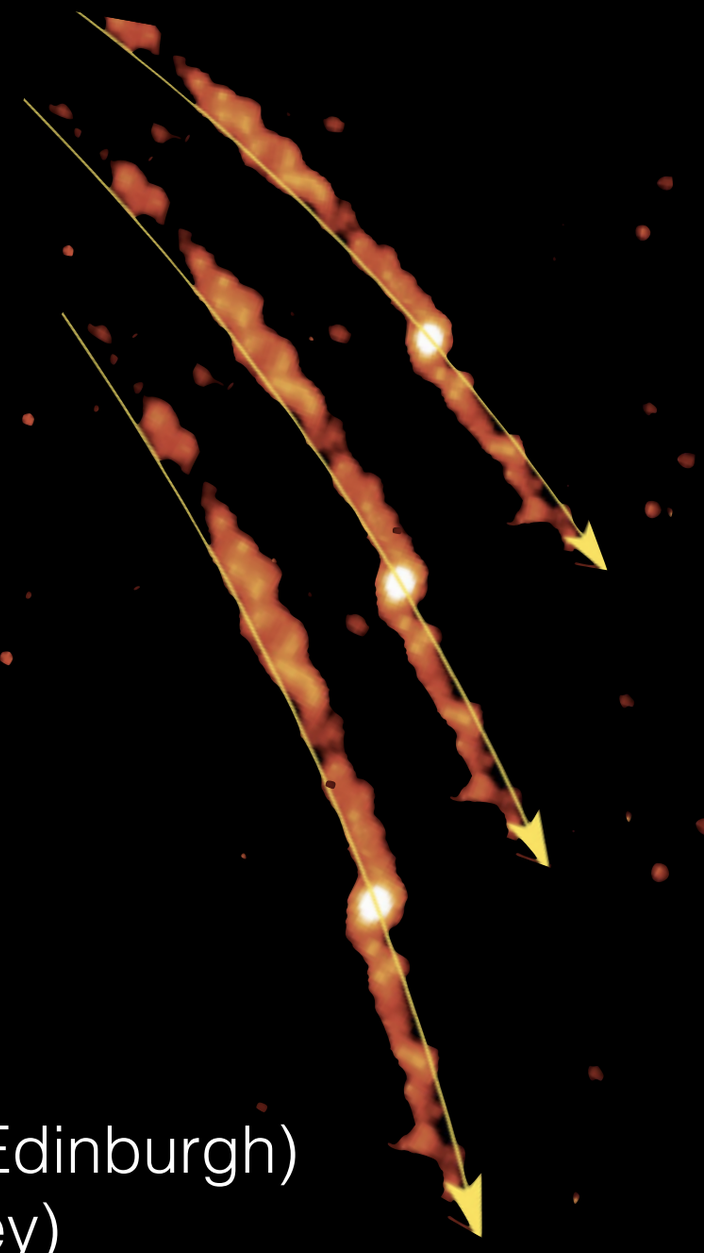
Initial globular cluster population = Final globular cluster population + Cold streams



Mark Gieles
Poul Alexander (Cambridge), Douglas Heggie (Edinburgh)
Eduardo Balbinot, Florent Renaud (Surrey)

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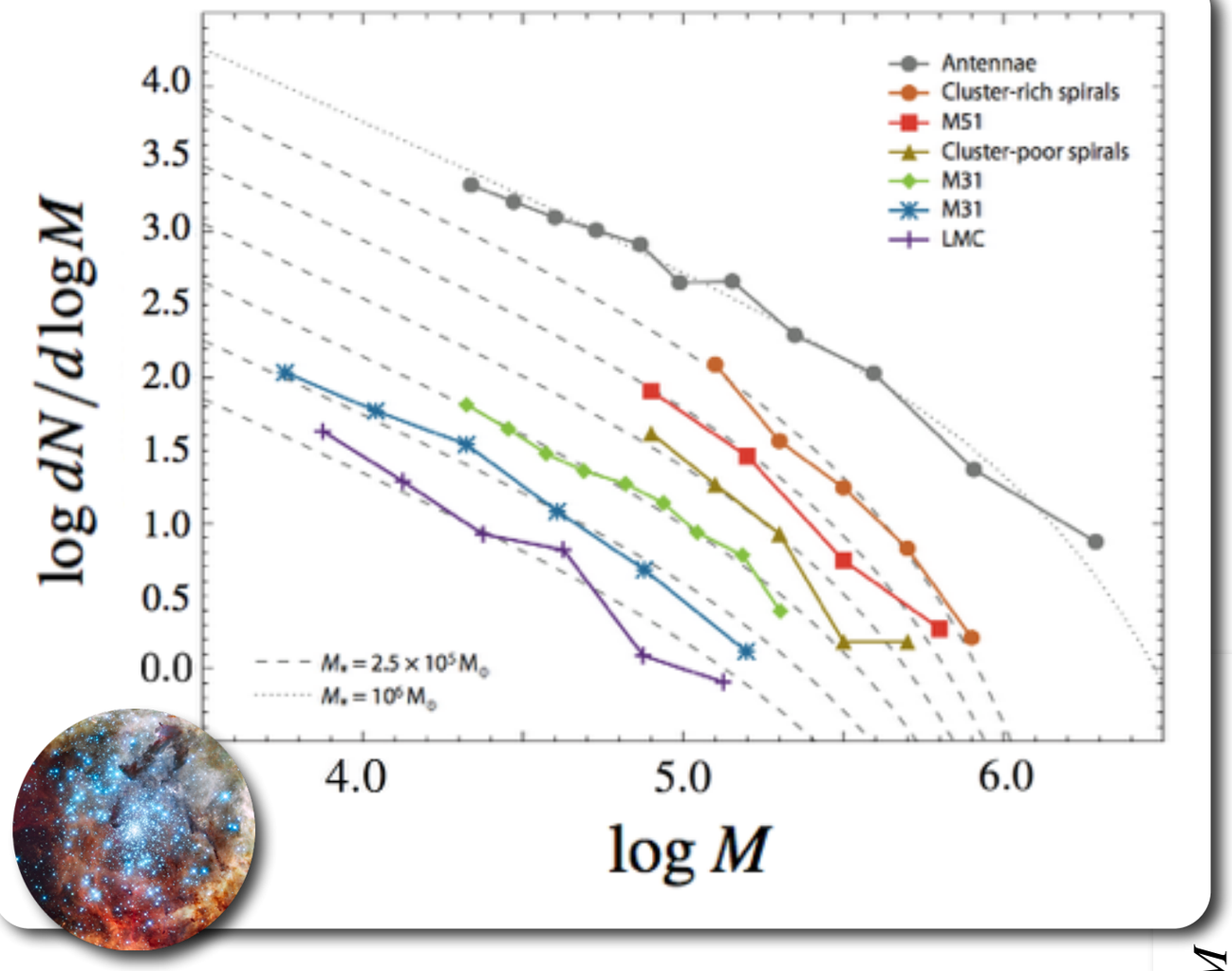
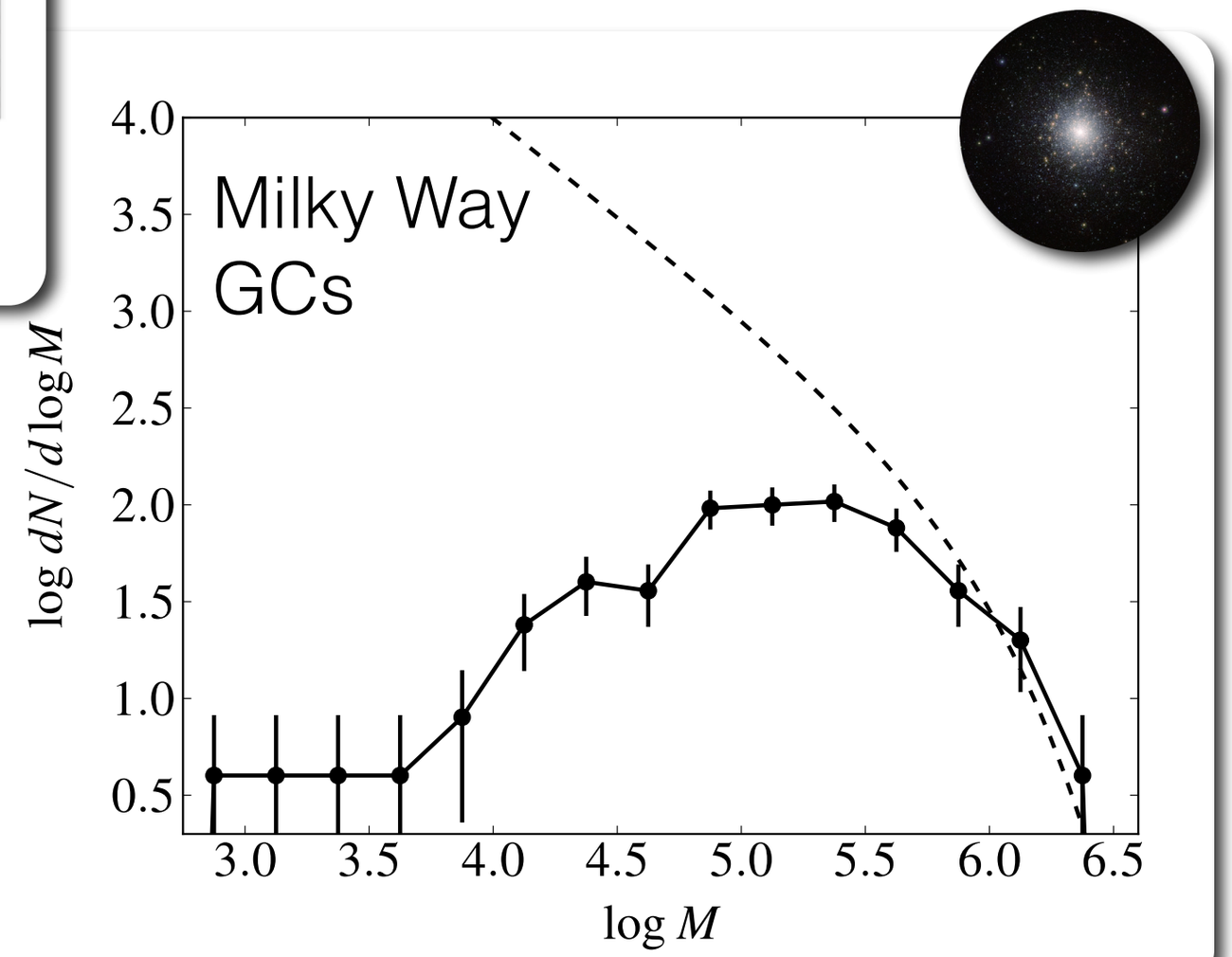
Portegies Zwart, McMillan & Gieles 2010

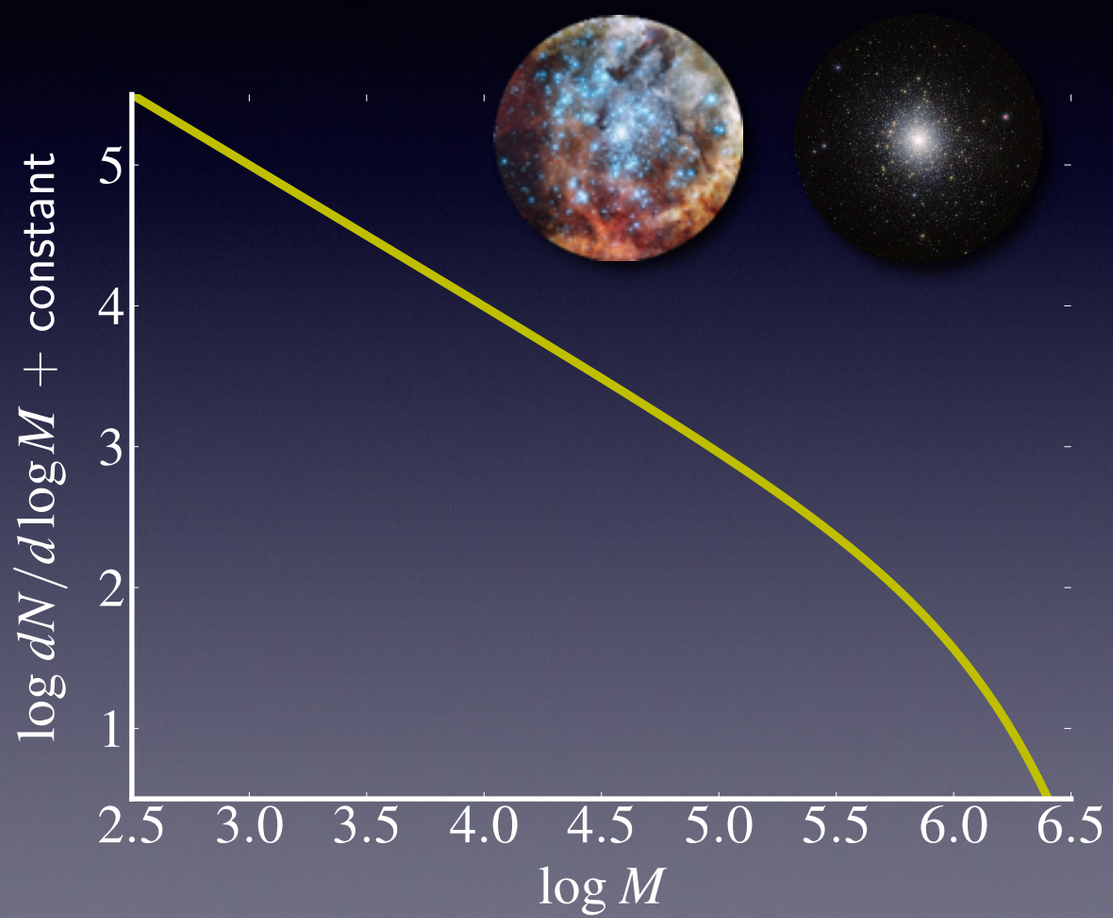




Harris 1996

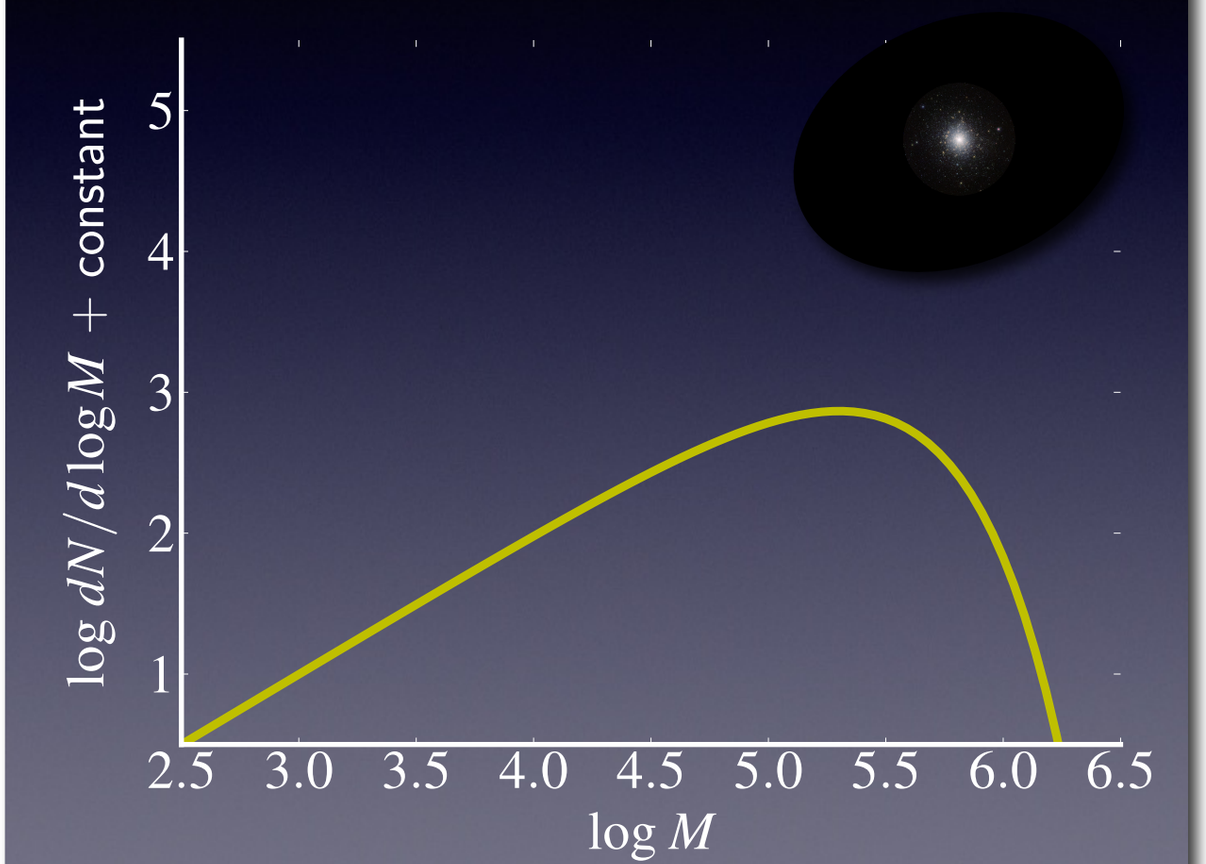
Formation?

GCs form in gas-rich discs at high redshift
(Ashman & Zepf; Kravtsov & Gnedin 2005)



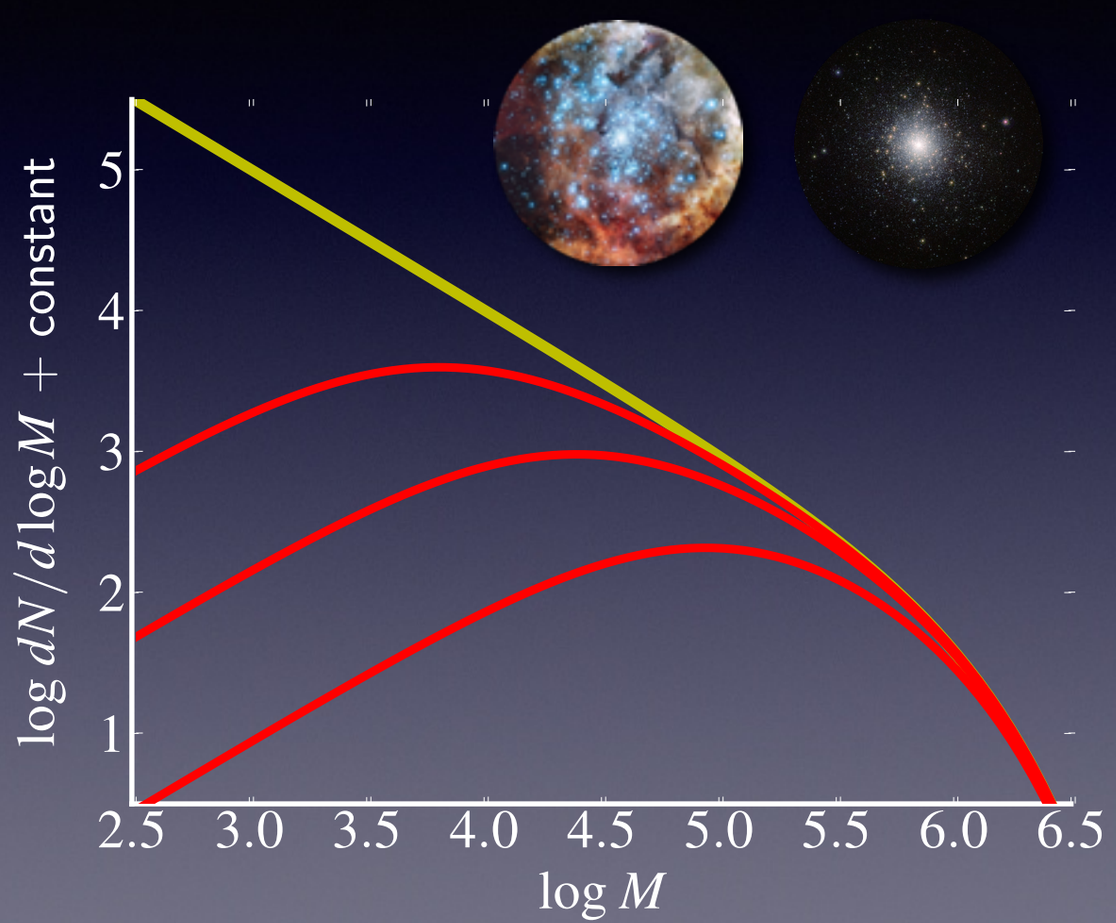
High Jeans mass in dwarf galaxies
(Peebles & Dicke ‘68; Bromm & Clarke ‘02)

Instability and inefficient cooling at low Z
(Fall & Rees 1985)

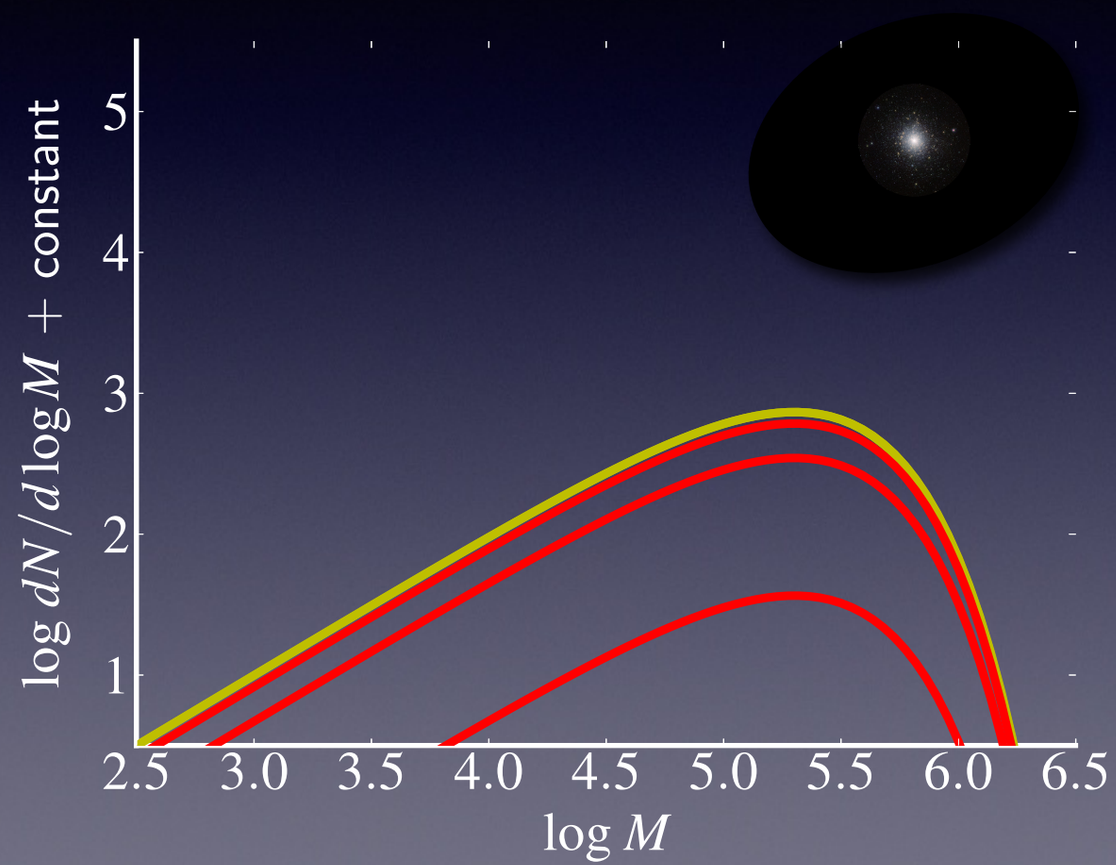


Evolution?

Fall & Zhang 2001; Jordán et al. 2007; Gieles 2009; Kruijssen & Portegies Zwart 2011

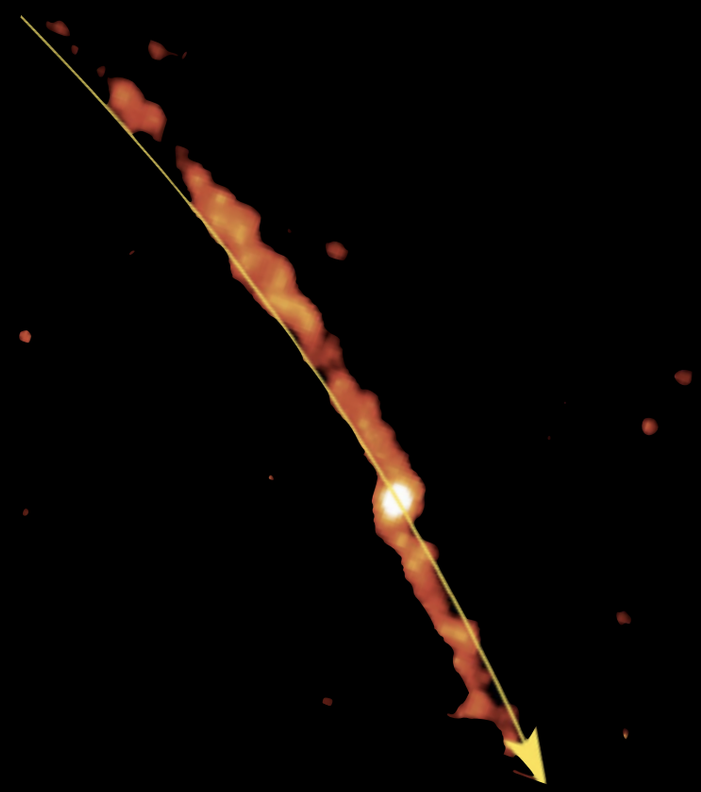


Vesperini 2000; Vesperini et al. 2003; Baumgardt+ 2008



Initial globular cluster population = Final globular cluster population + Cold streams

✔ evolution



✔ properties!

✔ properties!

✔ properties!

Simple model for GC evolution

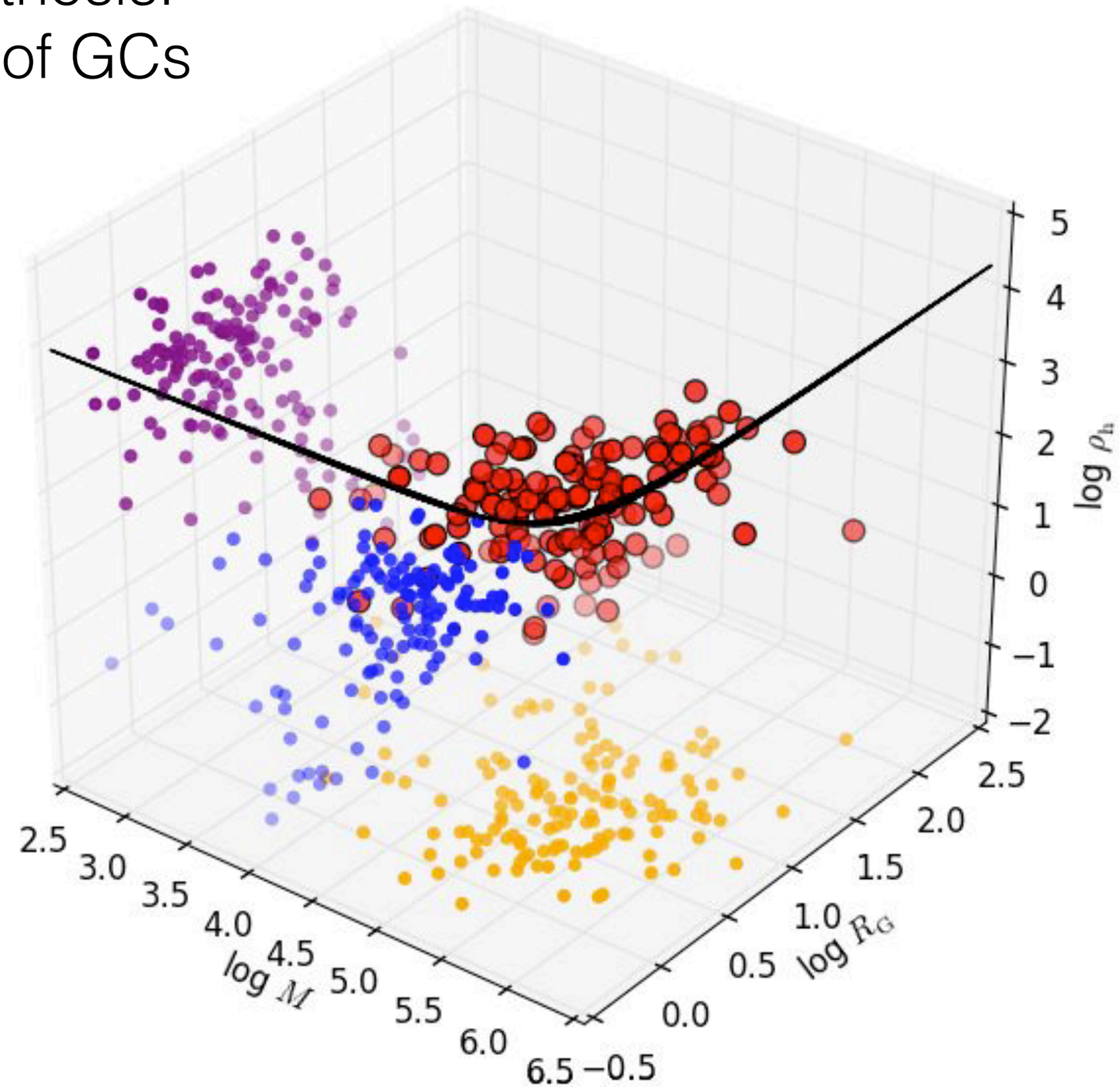
Gieles, Heggie & Zhao 2011

$$\frac{\dot{E}}{E} = -\frac{\zeta}{\tau_{\rm rh}}$$

Hénon 1961, 1965, 1975

GC population synthesis: The “HR diagram” of GCs

Gieles, Heggie & Zhao 2011



Milky Way GCs from Harris 1996, 2010

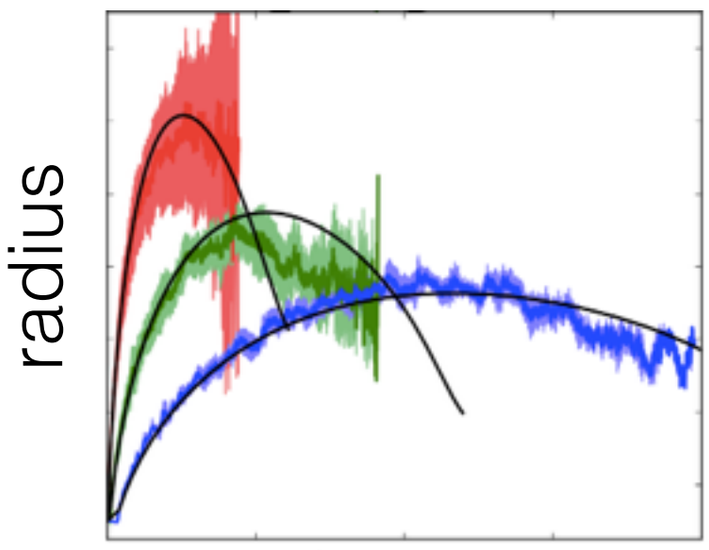
EMACSS

Evolve Me A Cluster of StarS

http://github.com/emacss

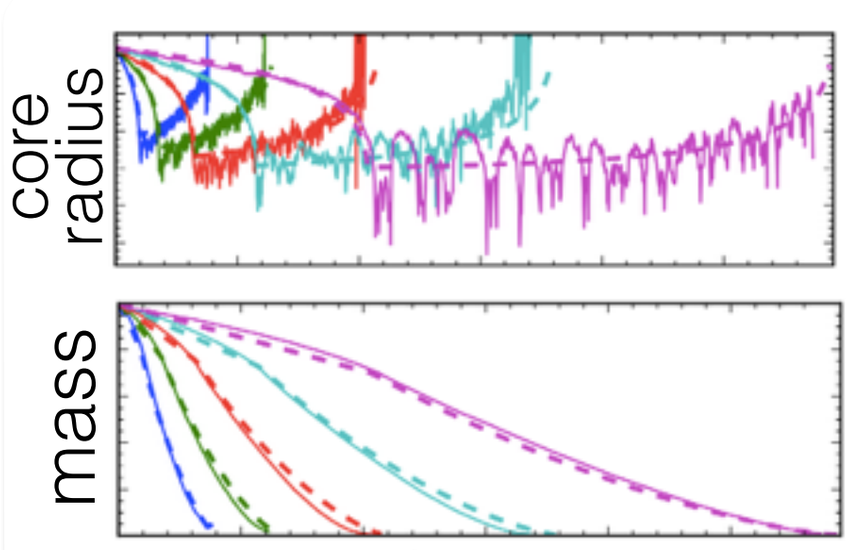
Solve coupled differential equations for time derivatives of M, N, r_h, r_c, R_G
Effort independent of N
Result benchmarked against direct N-body models (Aarseth's **NBODY6**)

v1: Energy balance



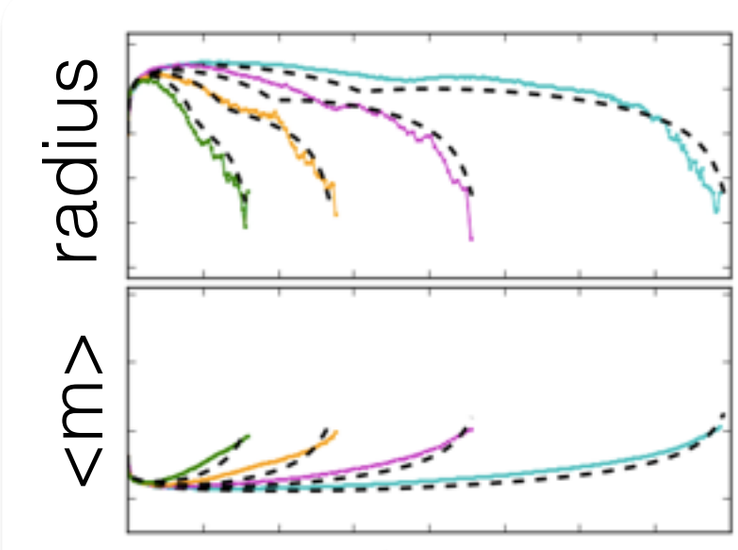
Alexander & Gieles 2012

v2: Core collapse



Gieles+ 2014

v3: IMF + stellar Ṁ



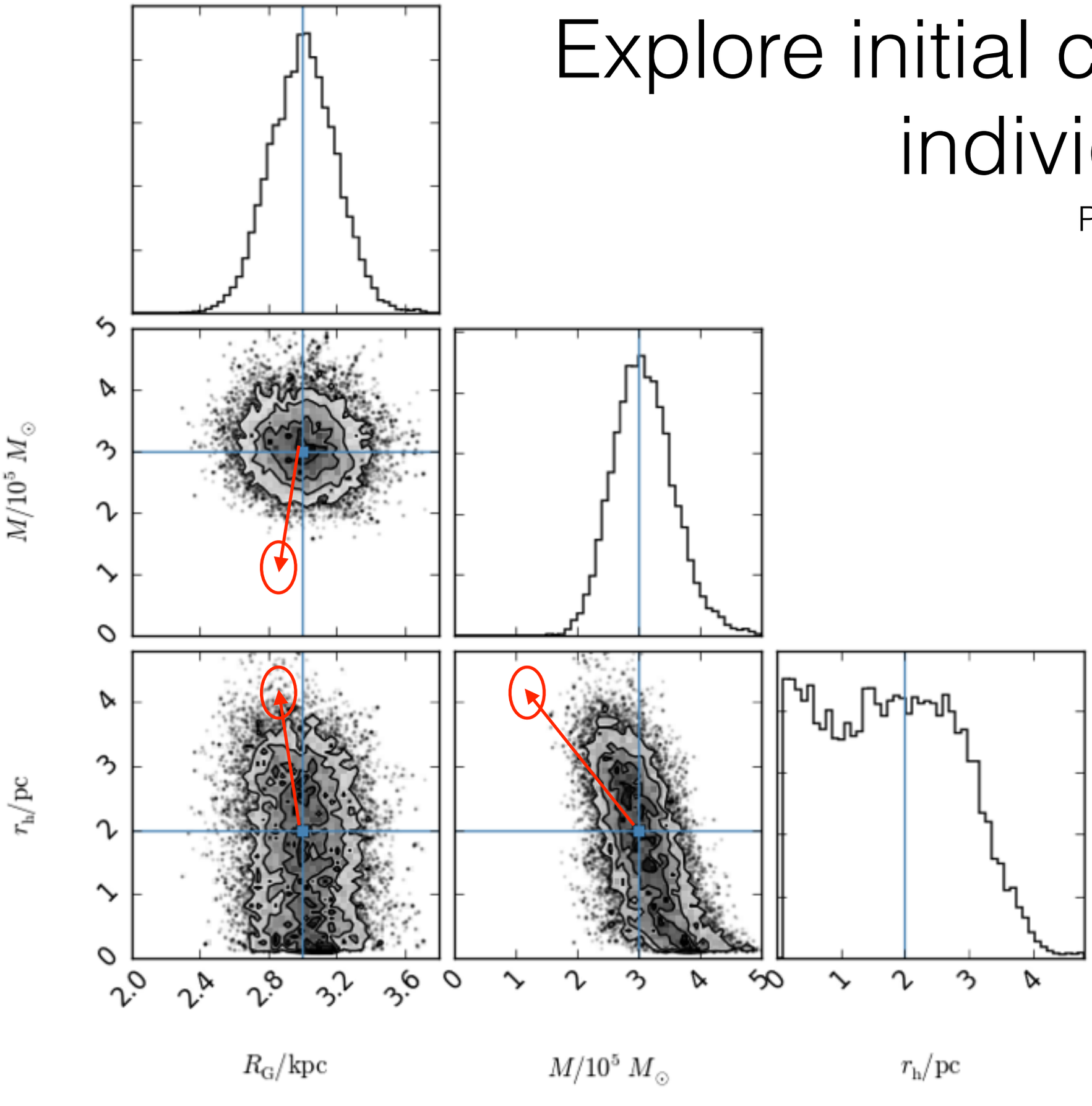
Alexander+ 2014

http://github.com/emacss

few 100 models per second

Explore initial conditions individual GCs

Pijloo et al., submitted



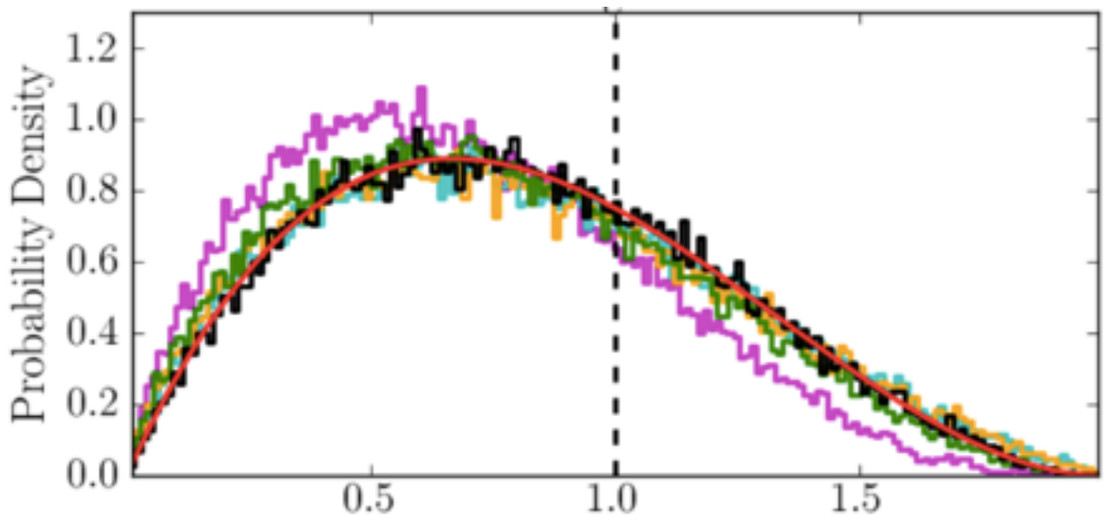
Population fitting

- Use posteriors of individual GC fits as “observations” (Hogg et al. 2010)
- Assume log halo for Milky Way with V_c = 220 km/s
- Assume isotropic orbits for GCs
- Marginalise over unknown eccentricity
- Fit 6 parameter model to 150 Milky Way GCs

$$\frac{dN}{dR_{\rm G}} \propto R_{\rm G}^{2-\beta_1}(R_{\rm s}+R_{\rm G})^{\beta_1-\beta_2},$$

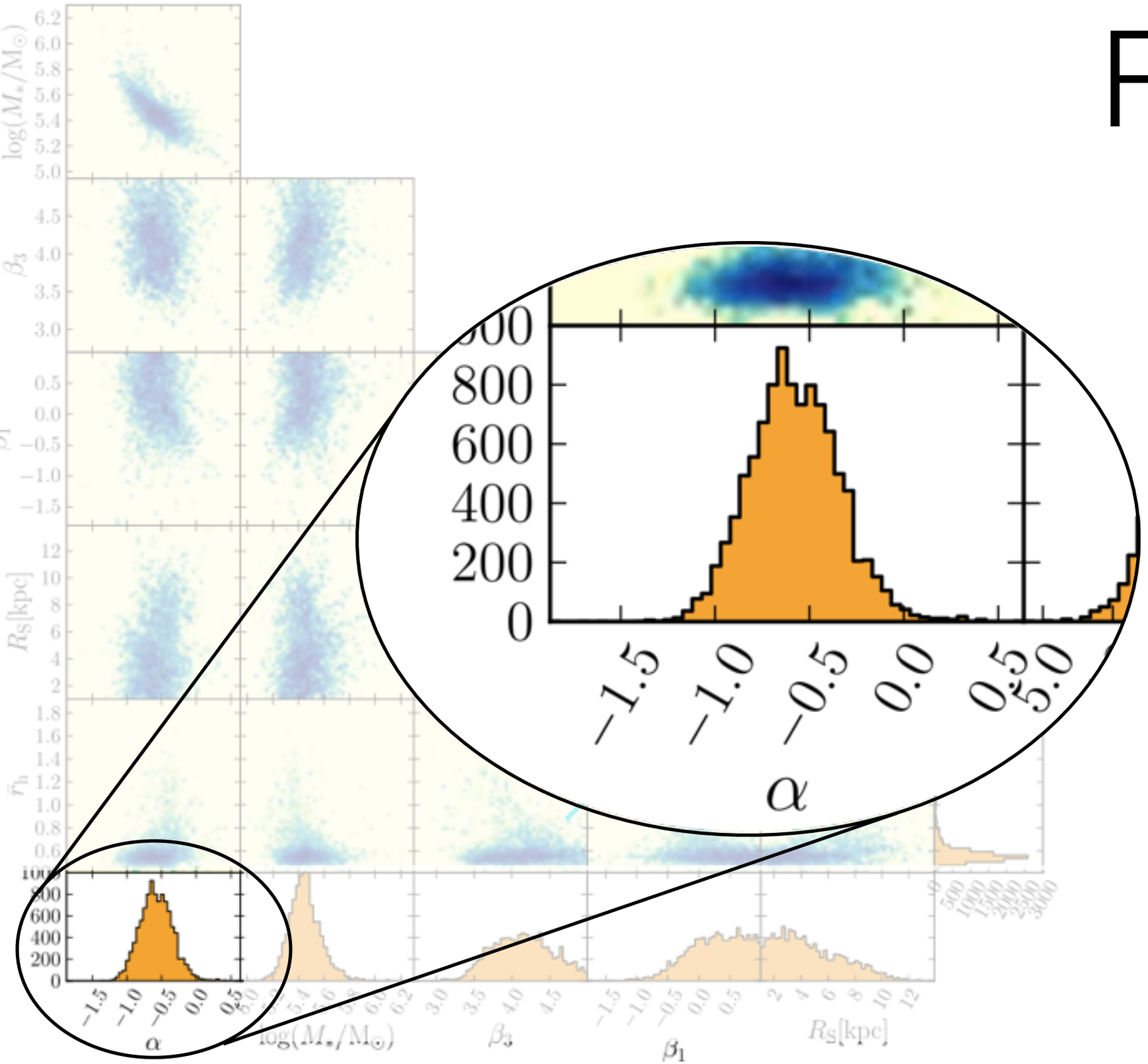
$$\frac{dN}{dM} \propto M^{\alpha}\exp\left(-\frac{M}{M_*}\right),$$

$$r_{\rm h} \rightarrow \begin{cases} \text{Constant}, \\ \text{Constant density}, \\ \text{Constant tidal density} \end{cases}$$



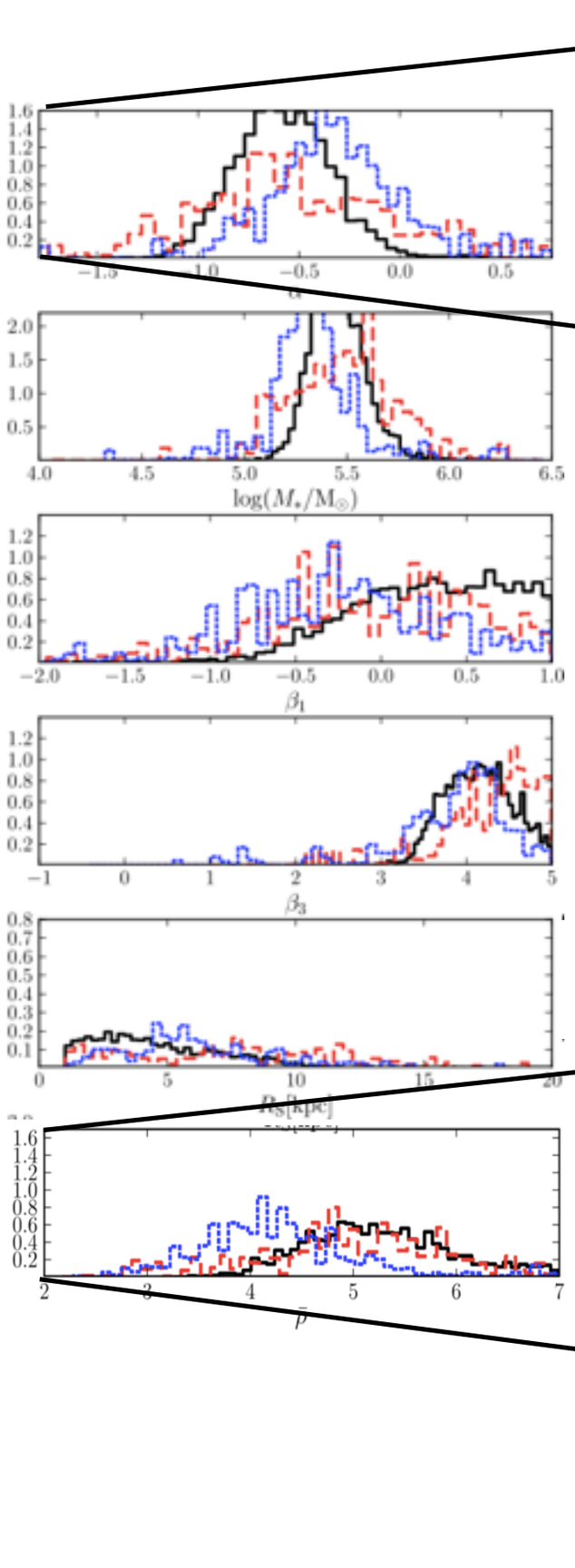
$T_{dis}(ecc)/T_{dis}(circ; R_G)$

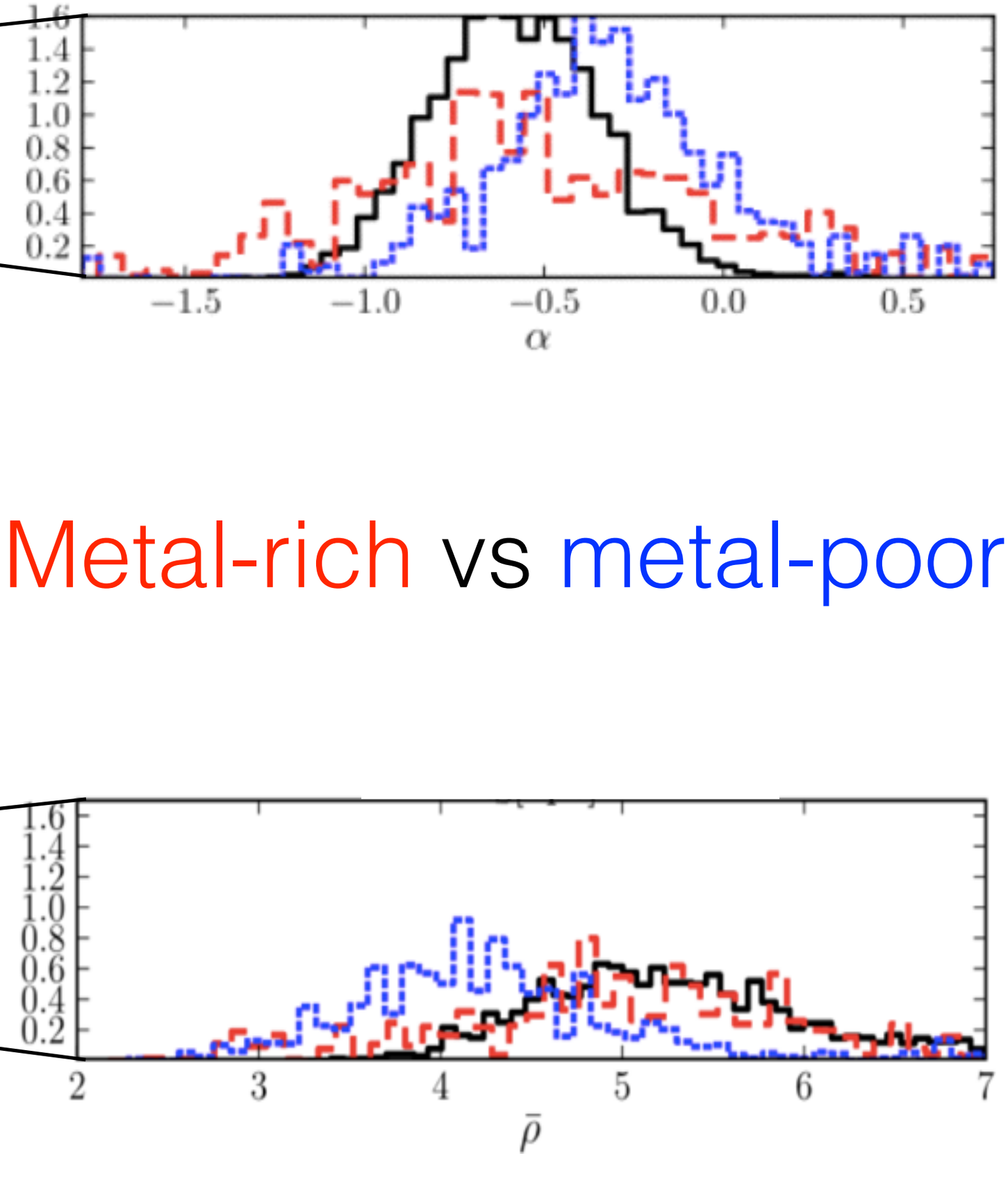
Result

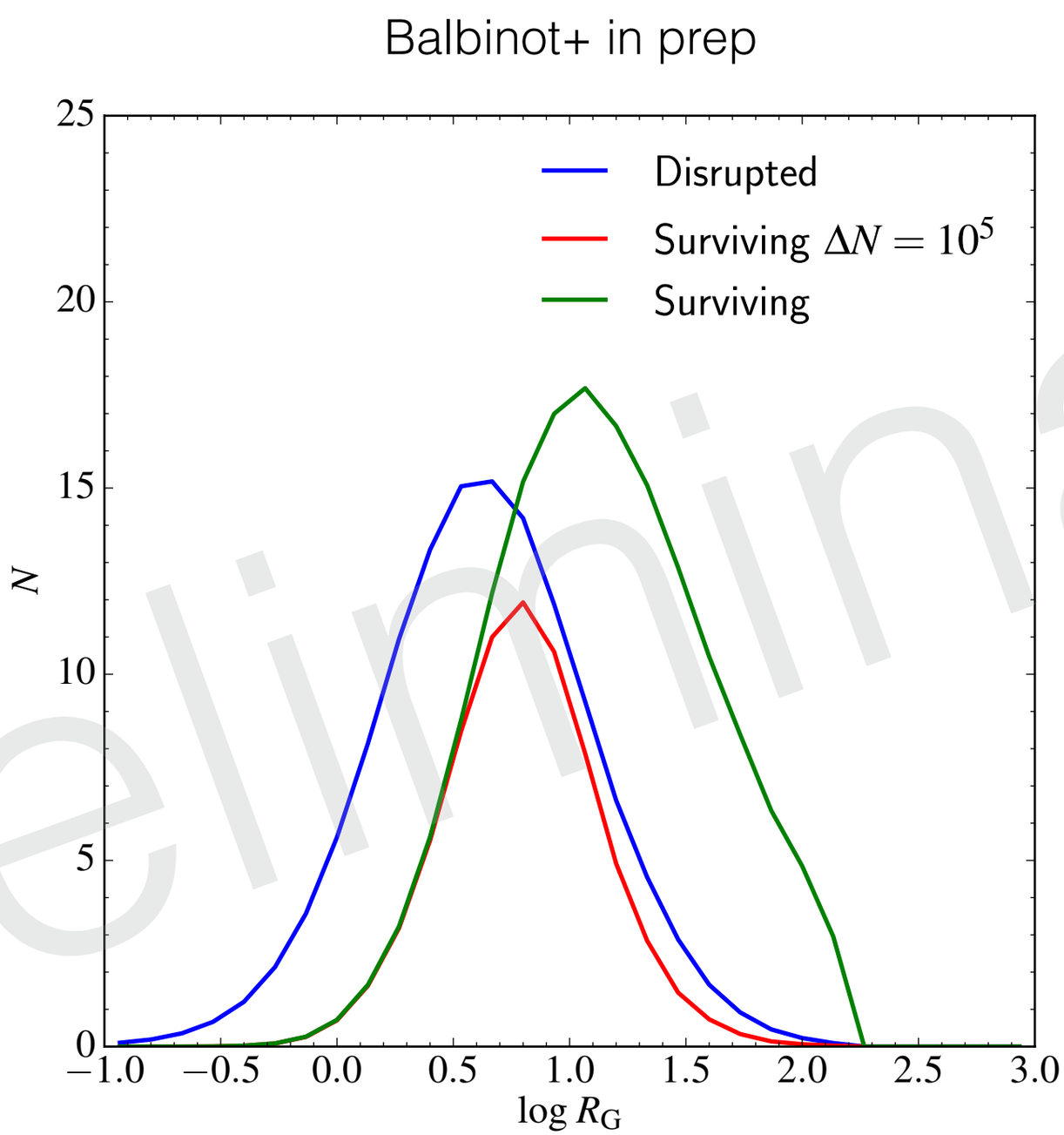


Alexander+ to be submitted

Metal-rich vs metal-poor



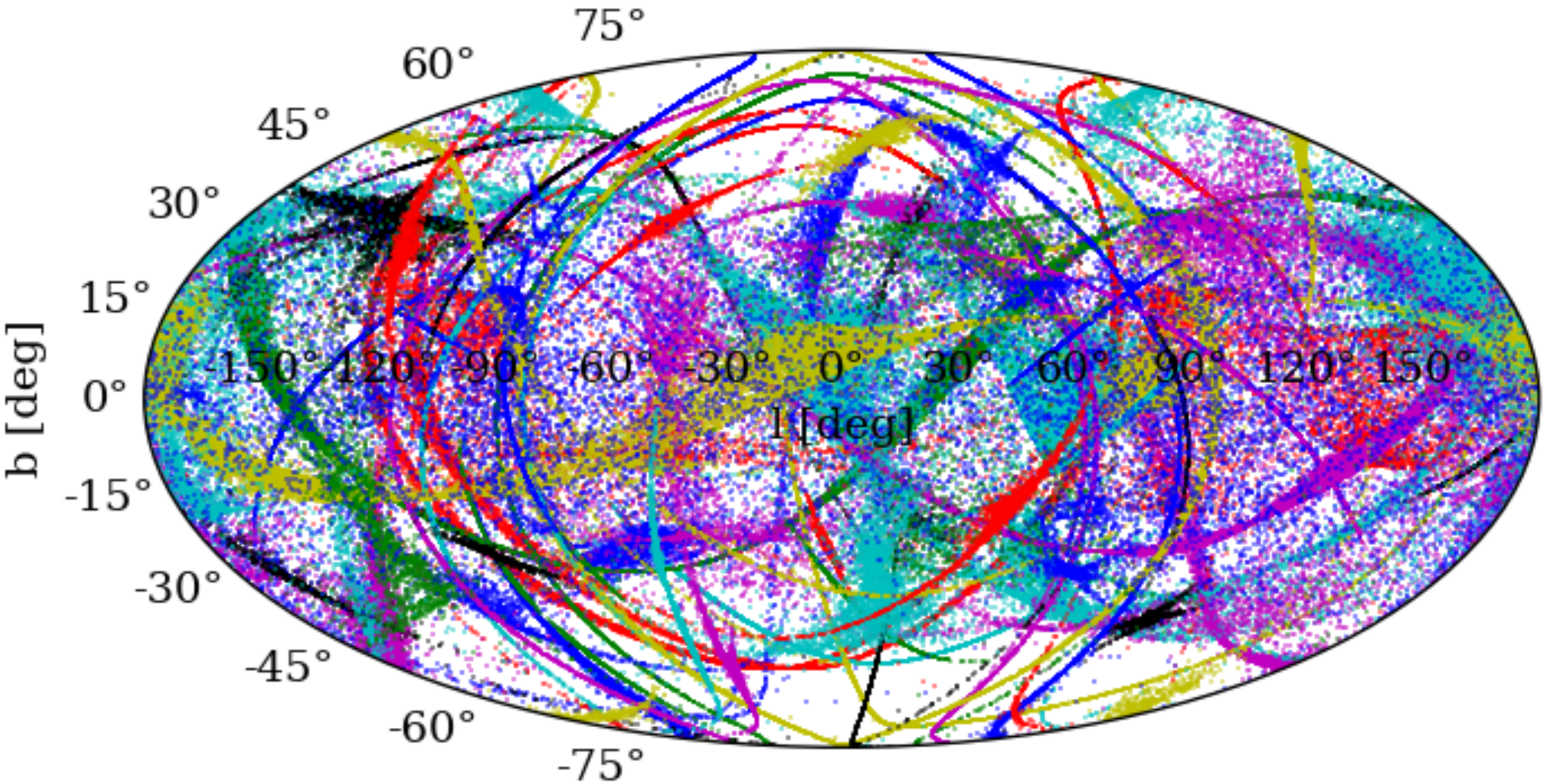




25% of cold streams found already

Implication for number of ultra faint star clusters: talk by Filippo Contenta

Streakline method (Küpper) + EMACSS



Balbinot+ in prep

=9.0

Future work: GC formation and evolution within the cosmological context

Model: Oscar Agertz

with: Florent Renaud, Filippo Contenta, Oscar Agertz

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