THE PROPAGATION OF UNCERTAINTIES IN STELLAR POPULATION SYNTHESIS MODELING. I. THE RELEVANCE OF UNCERTAIN ASPECTS OF STELLAR EVOLUTION AND THE INITIAL MASS FUNCTION TO THE DERIVED PHYSICAL PROPERTIES OF GALAXIES

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Overview

- Stellar population synthesis (SPS) relies on:
  - Stellar evolution calculations from MS to death
  - Spectral libraries
  - Dust models
  - IMF
- Each has uncertainty, can affect predictions of physical properties

Overview

- Results

  1. Stellar masses at z~0 carry errors of ~0.3 dex, and at z~2, 0.6 dex for bright red galaxies

  2. Current stellar evol. models and/or stellar libraries cannot characterize metallicity dependence of TP-AGB

  3. Estimates of uncertainty in IMF slope imply ~0.4 K-mag uncertainty in L evolution per unit redshift

  4. Dist. of metallicities affects predictions blueward of V

  5. Non-solar abundance still untested

SPS modeling

- Convolution of SSP with SFH (and dust)
- Stellar evolution: Padova models (Marigo et al. 2008)
- Spectral library: BaSeL3.1 (Westera et al. 2002)
  - TP-AGB stars from Lancon & Wood (2000)
  - Unknown metallicity, assume no L-dependence
- IMF: Dokkum (2008)
  - Note: Log slope of IMF at MSTO determines L evolution of passive system – should be continuous

SSPs

- Spectrum of coeval pop:

$$S(t, Z) = \int_{M_i^l}^{M_i^u(t)} \Phi(M_i)\Lambda[L(M_i, Z, t), T(M_i, Z, t), Z]\, dM_i,$$

- Mass of coeval pop:

$$M(t) = \int_{M_i^l}^{M_i^u(t)} \Phi(M_i)\, M_{\rm evol}(M_i) dM_i \; + \; M_{\rm rem},$$

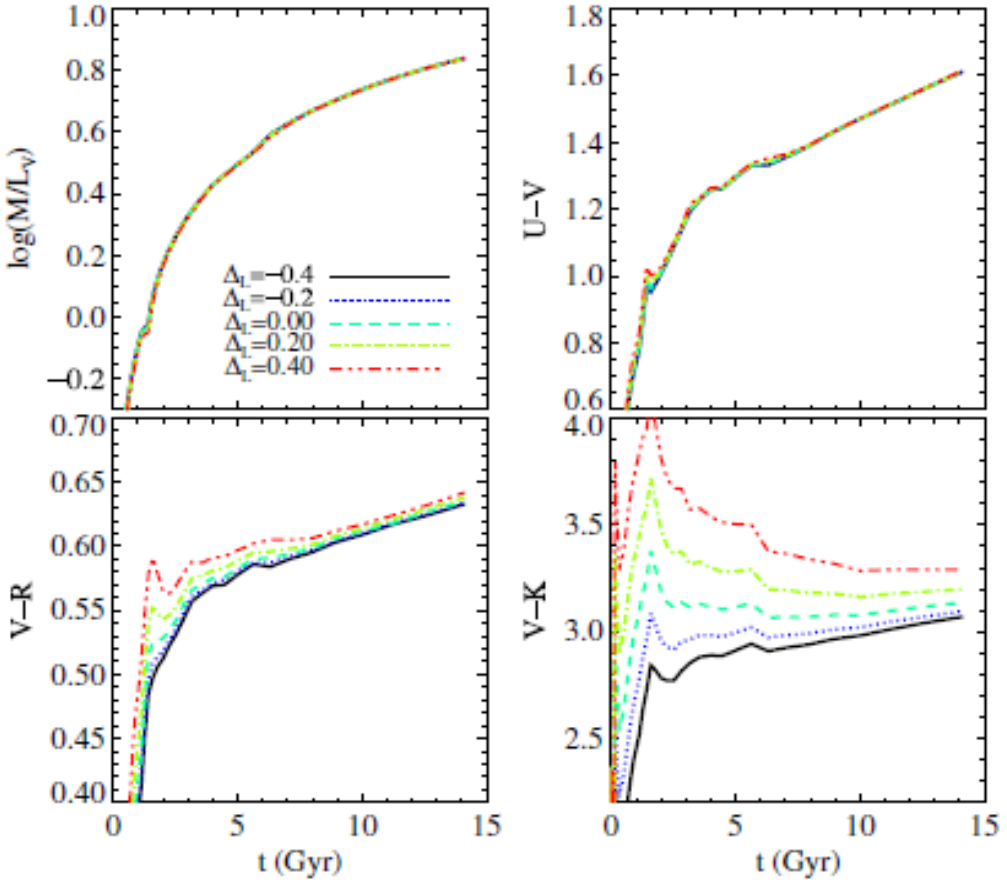
Isochrone synthesis

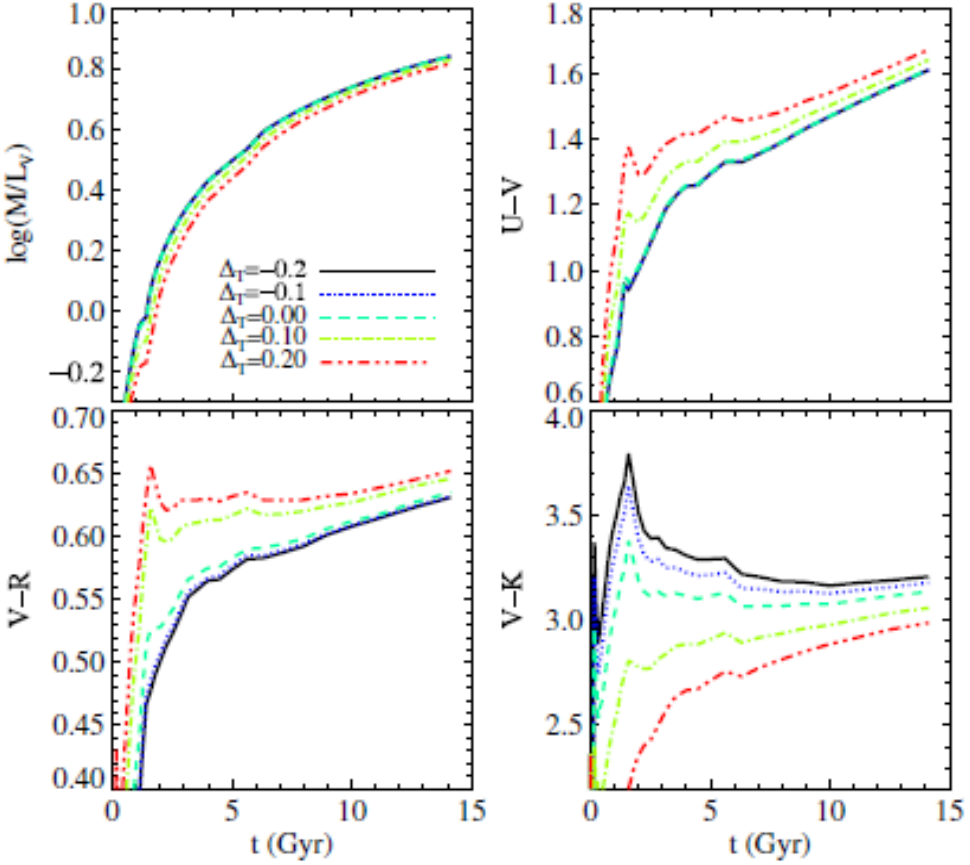
- Time-dependent flux of galaxy with stars of varying ages

$$F(t) = \int_0^t \Psi(t - t')S(t', Z)e^{-\hat{\tau}_\lambda(t')}\, dt'$$

Important Unknowns

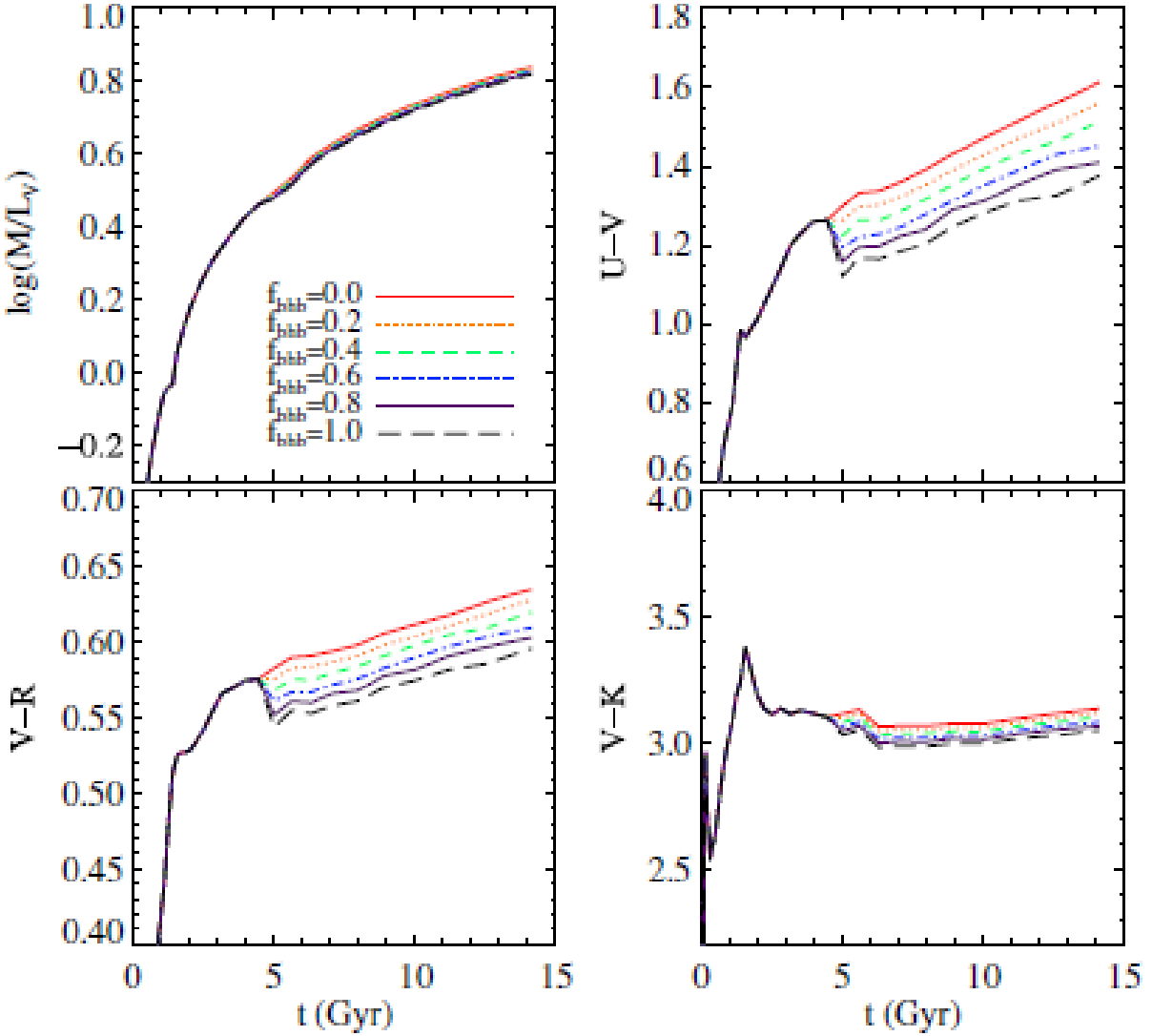
- TP-AGB parametrization:
  - ΔT and ΔL
- Motivation: many uncertain steps required
  - L and T must be specified, as funct. of Z
  - L, T, and Z converted to spectrum, using observed spectra
  - Only interested in transforming a theoretical TP-AGB star into observable properties (can be combination of uncertainties)


log(M/L_V)
U−V
V−R
V−K
t (Gyr)
t (Gyr)
Δ_L=−0.4
Δ_L=−0.2
Δ_L=0.00
Δ_L=0.20
Δ_L=0.40


log(M/L_V)
U−V
V−R
V−K
t (Gyr)
t (Gyr)
Δ_T=−0.2
Δ_T=−0.1
Δ_T=0.00
Δ_T=0.10
Δ_T=0.20

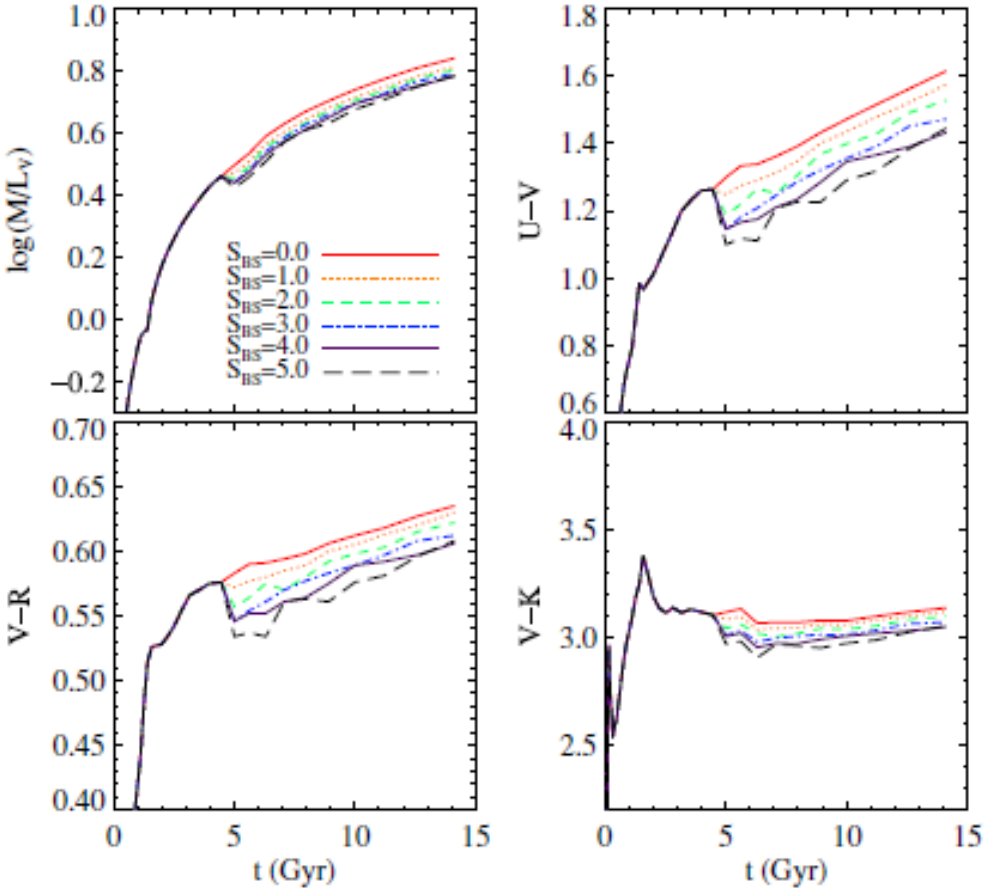
Horizontal Branch

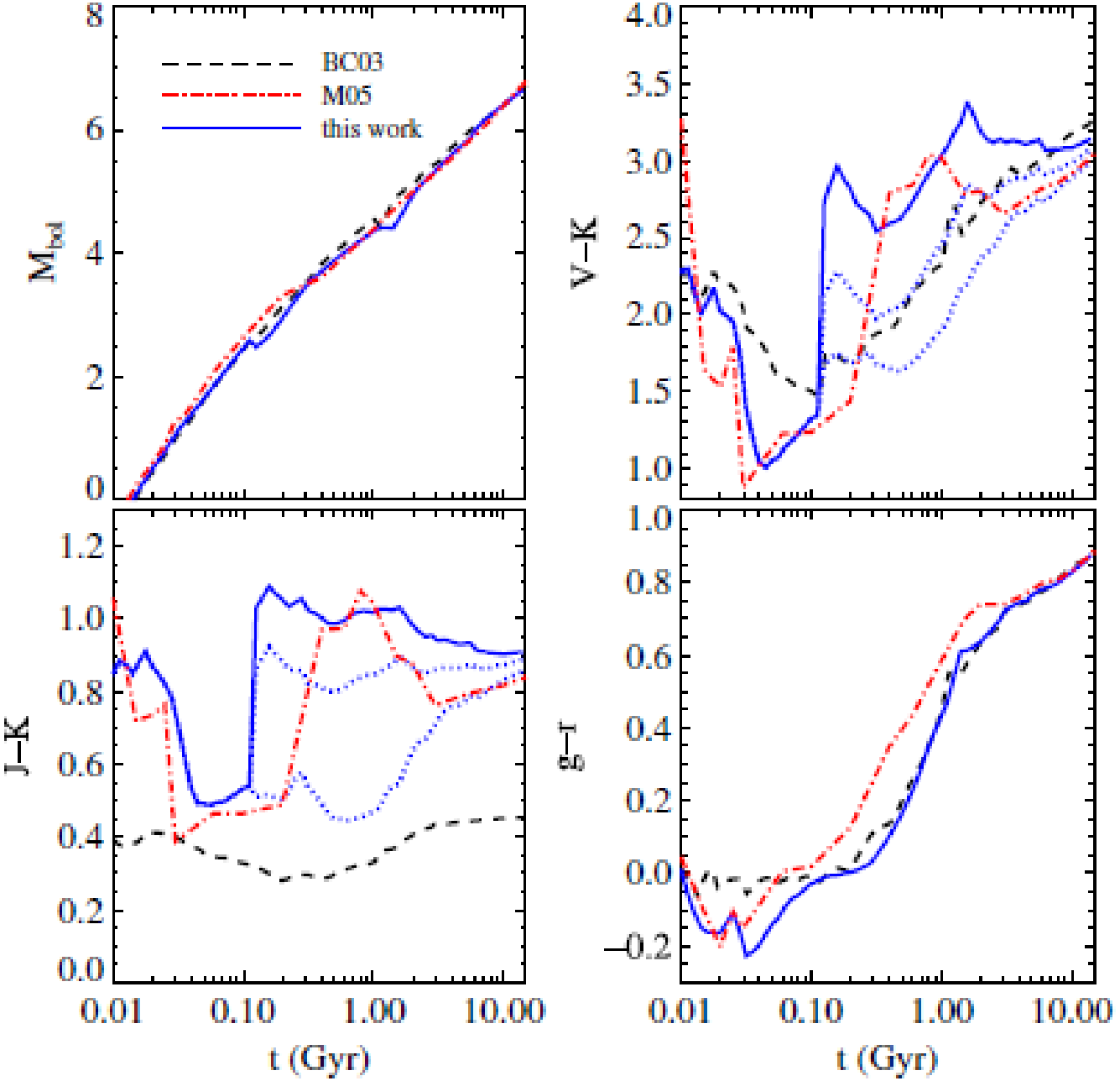
- Low mass ($\leq M_{sun}$) stars burning He in core
  - Metal rich clusters: Red HB stars (clump)
  - Metal poor clusters: range of T
- T very sensitive to mass loss – uncertain
- Allow fraction of blue HBstars (f_{BHB}) to vary


log(M/L_V)
U−V
V−R
V−K
t (Gyr)
t (Gyr)
f_btb=0.0
f_btb=0.2
f_btb=0.4
f_btb=0.6
f_btb=0.8
f_btb=1.0

Blue Stragglers

- Origin still mystery
  - Primordial binary evolution
  - Collisional merging
- $S_{BS}=N_{BS}/N_{HB}$
- Less luminous than HB stars




BC03
M05
this work
M_{bol}
V−K
J−K
g−r
t (Gyr)
t (Gyr)
0.01
0.10
1.00
10.00

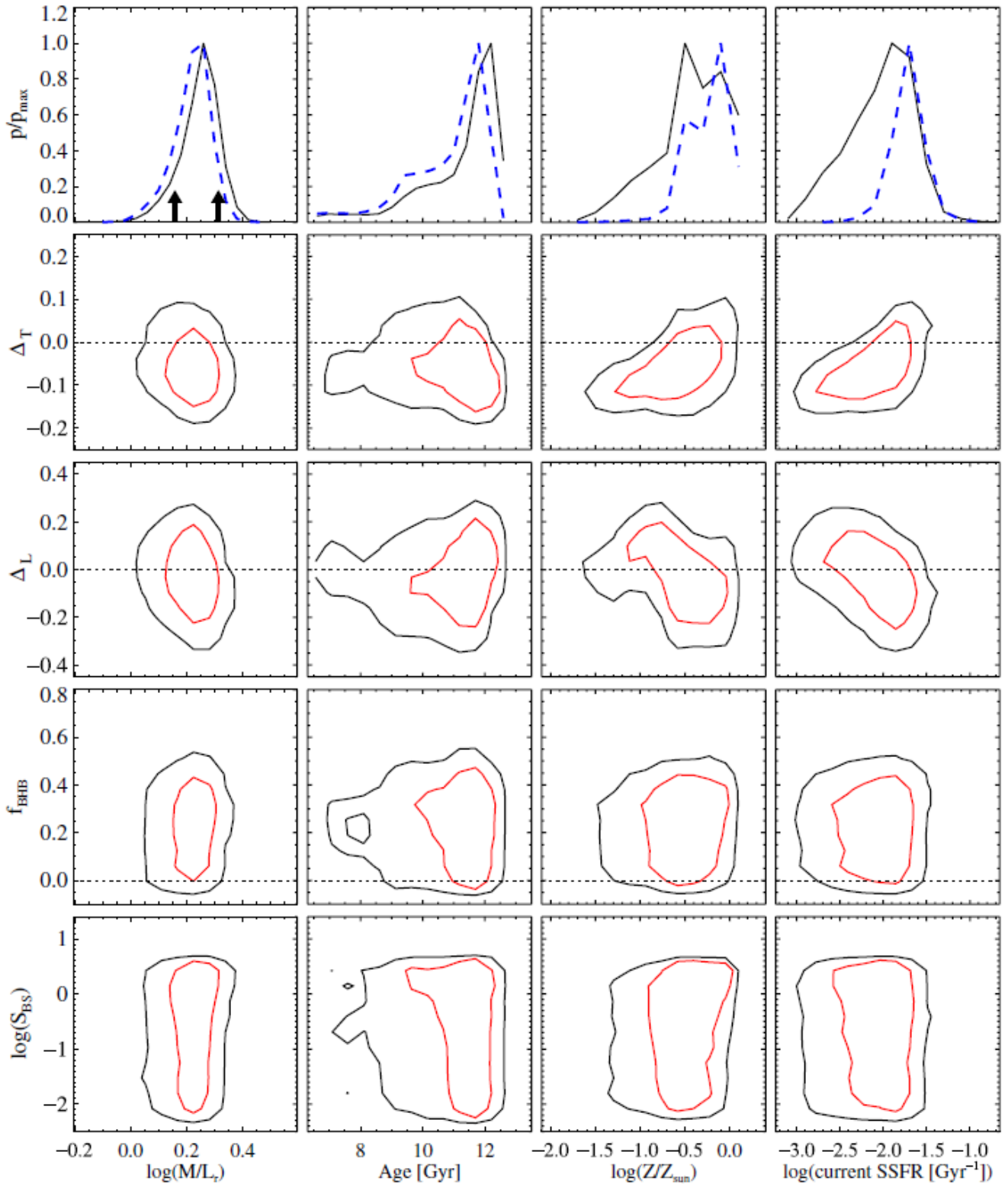
Fitting to SDSS/2MASS data

- At z~0, bright/faint red/blue galaxy classes
- Few z~2 galaxies from Maraston (2006)
- Fits performed with Monte Carlo Markov Chain algorithm (Dunkley et al. 2005)

Table 1
Summary of SPS Parameters

Parameter	Description	Range
Δ_T	Shift in $\log(T_{\rm eff})$ along the TP-AGB	$[-0.2, 0.2]$
Δ_L	Shift in $\log(L_{\rm bol})$ along the TP-AGB	$[-0.4, 0.4]$
$f_{\rm BHB}$	Fraction of blue HB stars	[0.0, 0.5]
$S_{\rm BS}$	Specific frequency of BS stars	[0, 10]
τ	SFR e-folding time (Gyr)	$[0, \infty)$
C	Fraction of mass formed in a constant mode of SF	[0, 1]
$T_{\rm start}$	Age of universe when SF commences (Gyr)	[0.0, 5.0][a]
$\hat{\tau}_1$	Extinction surrounding young stars	$[0, \infty)$
$\hat{\tau}_2$	Extinction surrounding old stars	$[0, \infty)$
Z	Stellar metallicity	[0.0001, 0.030]
m_c	Characteristic mass of the IMF	[0.08, 2.0]

Note.
[a] The upper bound on the value of $T_{\rm start}$ is set to $T_{\rm univ}$ for galaxies at a redshift where the age of the universe is younger than 5 Gyr.


p/p_max
Δ_T
Δ_L
f_BHB
log(S_BS)
log(M/L_r)
Age [Gyr]
log(Z/Z_sun)
log(current SSFR [Gyr^-1])

Uncertainties not included

- Limitations in stellar spectral libraries
- Non-solar abundance ratios
- MSTO or RGB (time of onset)
- AGN contamination