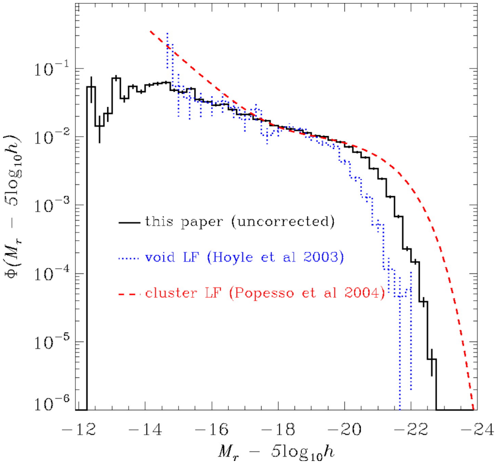
# AVOCADO and the Flavours of Dwarf Galaxies

Rubén Sánchez-Janssen

*Star Formation in Dwarf Galaxies*
Lowell Observatory Workshop
Flagstaff, AZ, June 19, 2012

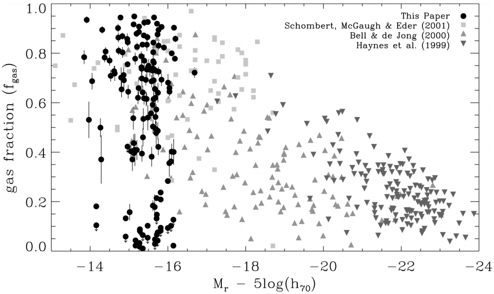
# Dwarf galaxies are key objects to constrain galaxy formation and evolution models.




Blanton et al. (2005)

Most abundant of all galaxy types.

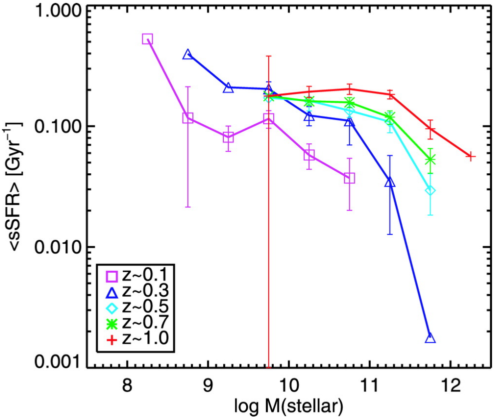
# Dwarf galaxies are key objects to constrain galaxy formation and evolution models.




Geha et al. (2006)

Low mass haloes are extremely inefficient in converting baryons to stars.

# Dwarf galaxies are key objects to constrain galaxy formation and evolution models.




Martin et al. (2007)

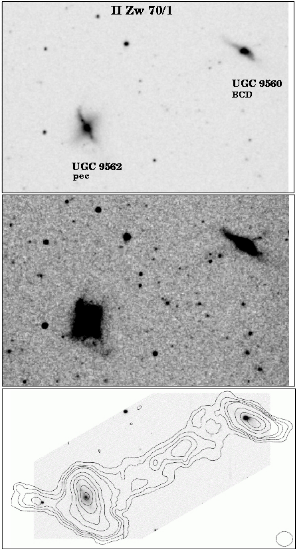
But SSFR peaks at lower redshifts for lower masses.

# Dwarf galaxies are key objects to constrain galaxy formation and evolution models.


Excellent laboratories to study SF and feedback effects:

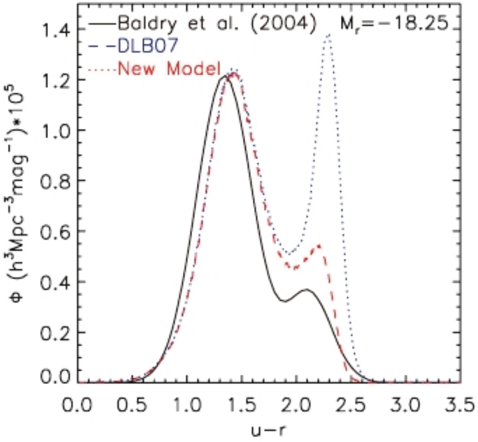
- high sSFRs
- low metallicities
- low dust content
- shallow potential wells
- turbulent motions

# Dwarf galaxies are key objects to constrain galaxy formation and evolution models.




Sensible tracers of interactions and environmental processes (e.g., Cox et al. 2000).

# Dwarf properties are (still) poorly understood.




## Theory and simulations

Hard to simulate the complex small-scale baryon physics, e.g.:

- too many red dwarfs (Bertone+08).
- too high stellar mass (Sawala+10).

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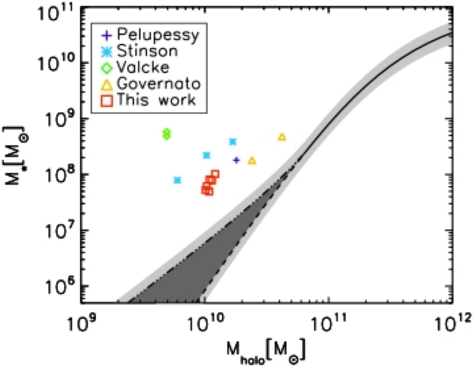


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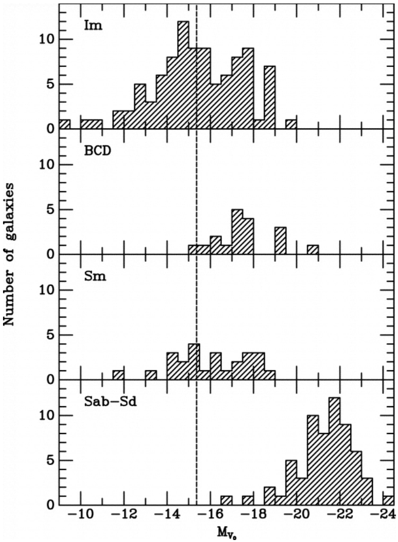


Hunter & Elmegreen (2006)

## Observations

- Intrinsic faintness has prevented studies of statistically significant (>1000) samples.
- Poorly characterised at $\uparrow z$ (especially in the field).

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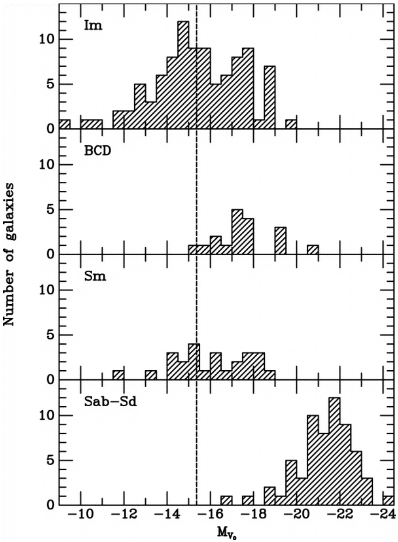


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# AVOCADO

# AVOCADO

## A Virtual Observatory Census to Address Dwarfs Origins

- R. Sánchez-Janssen (ESO, Chile)
- **R. Amorín (IAA, Spain)**
- M.L. García-Vargas (Fractal, Spain)
- J.M. Gomes (CAUP, Portugal)
- M. Huertas-Company (GEPI, France)
- M. Mollá (CIEMAT, Spain)
- P. Papaderos (CAUP, Portugal)
- E. Pérez-Montero (IAA, Spain)
- **J. Sánchez Almeida (IAC, Spain)**
- F. Jiménez (SVO)
- C. Rodríguez (SVO)
- E. Solano (SVO)

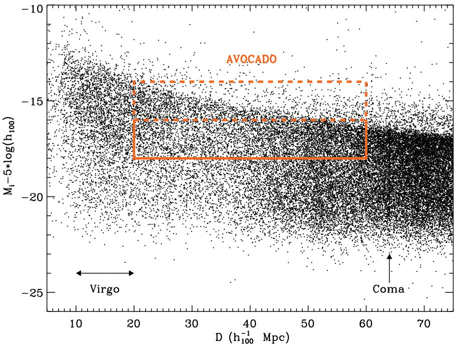
**A V**irtual **O**bservatory **C**ensus to **A**ddress **D**warfs **O**rigins

To construct a homogeneous, multiwavelength dataset for a statistically significant sample of several thousands nearby dwarfs.

- Analyse UV-to-NIR SEDs.
- Analyse optical spectra.
- Structure and morphology.
- Role of environment.

*"A Virtual Observatory Census to Address Dwarfs Origins. AVOCADO I. Science goals, sample selection and analysis tools"*
R. Sánchez-Janssen et al. (A&A submitted)

# AVOCADO: an 'all-sky' sample of thousands dwarfs




- Nasa-Sloan in SDSS-DR7 (Blanton+11)
- $20 < \mathrm{D} < 60\ h_{100}^{-1}$ Mpc
- $M_i - 5 log\, h_{100} > -18$.
- $\approx$ 6500 dwarfs
  - $\approx$ 5000 $M_i < -16$ (volume-limited for $\mu_{r,50} < 24$).
  - $\approx$ 1500 $-16 < M_i < -14$.

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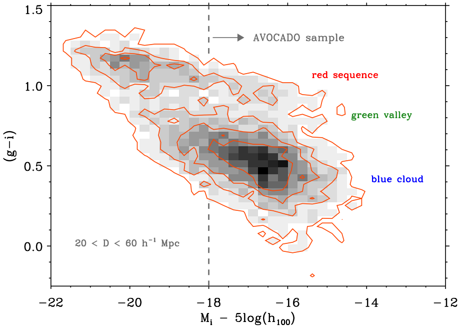


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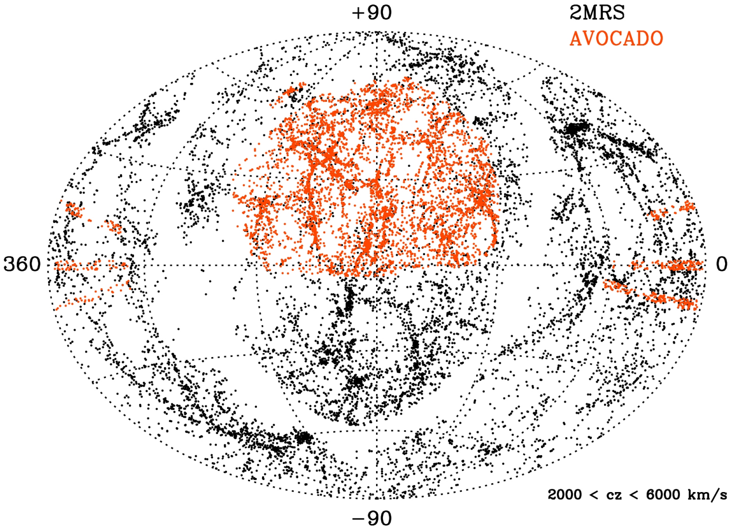
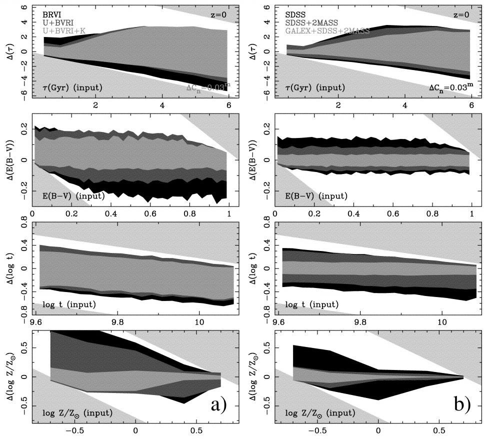


# AVOCADO: UV-to-NIR SEDs



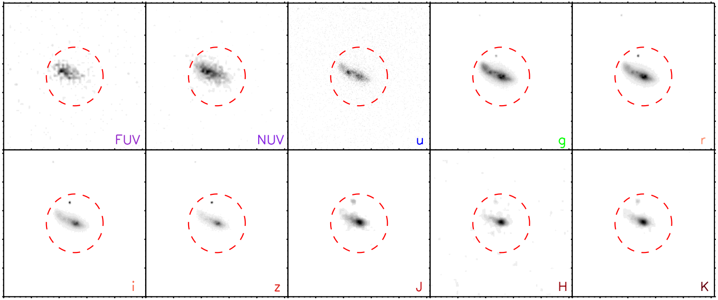

Gil de Paz & Madore (2002)

## The importance of wavelength coverage

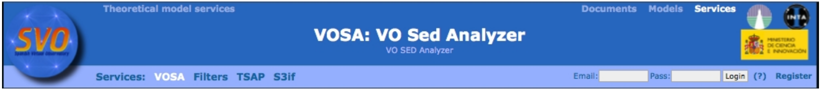
- UV: SFH, age, dust.
- NIR: age, metallicity, stellar mass.
- Wider wavelength baselines → lower uncertainties.

# Photometry within $2\, r_{petrosian}$

- Allows for measurements below catalogs detection limits.
- 10-point SEDs from 0.15 to 2.2 $\mu$m.



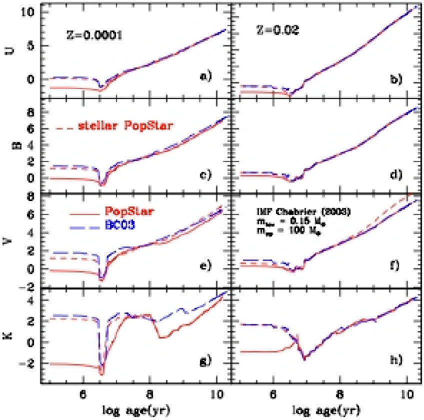
# VOSA: **V**irtual **O**bservatory **SED** **A**nalyzer




*http://svo.cab.inta-csic.es/theory/vosa/*

- User-provided photometric catalogues.
- Query public catalogues accesible from VO.
- Query VO-compliant stellar population models.
- Estimate optimal model(s) reproducing the data.
    - traditional $\chi^2$
    - Bayesian approach with flat priors (e.g., Kauffmann et al. 2003; Salim et al. 2007)

# VOSA: PopStar evolutionary synthesis models




## Mollá, García-Vargas & Bressan (2009)

- Nebular continuum (H, He) significantly affects colours of very young, metal-poor SPs.
- Impact on derived parameters ($M_\star$!).

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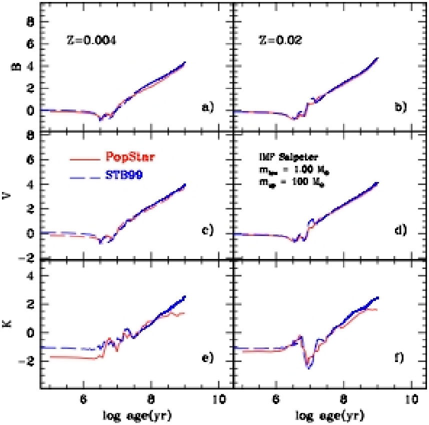


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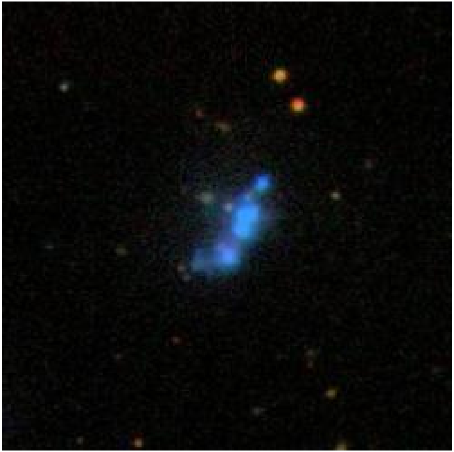

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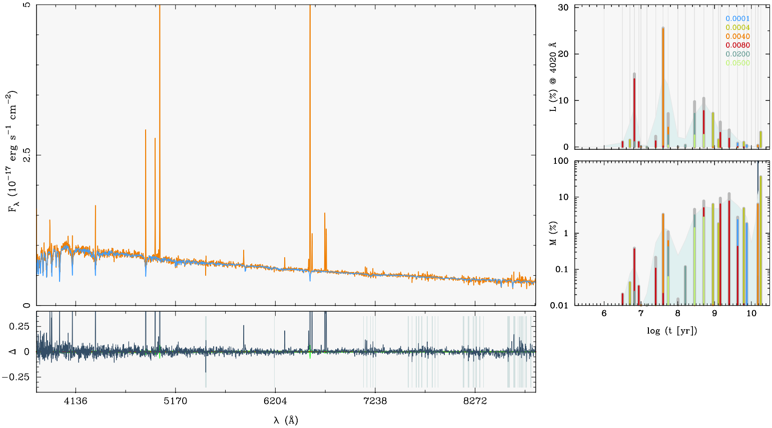
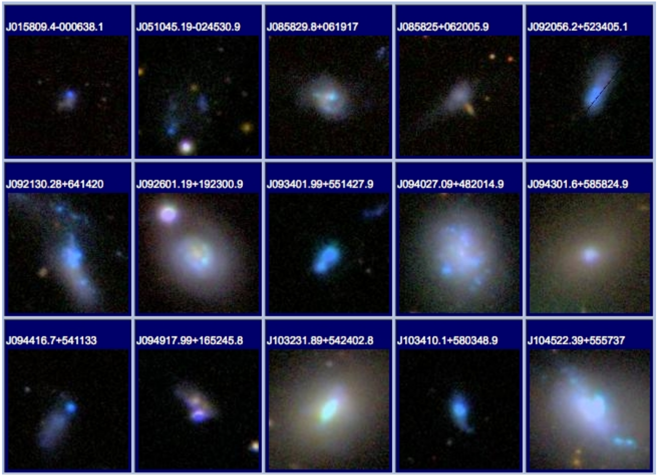
# AVOCADO: analysis of SDSS spectra

- Stellar populations properties through Starlight spectral synthesis.
- The properties of the ionised gas through the study of emission lines.



# AVOCADO: structure and morphology




BCDs from Gil de Paz et al. (2003)

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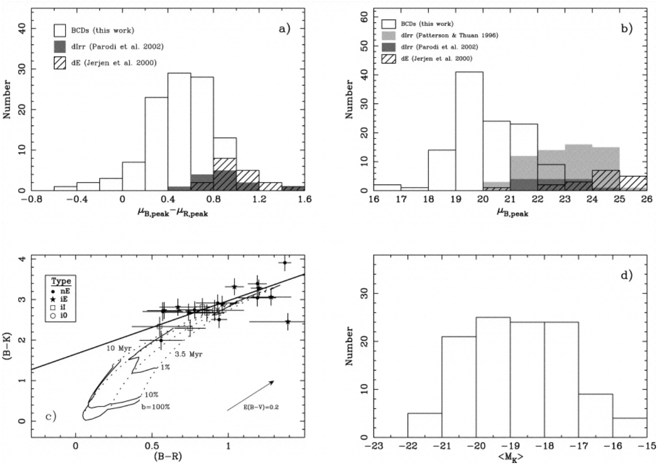


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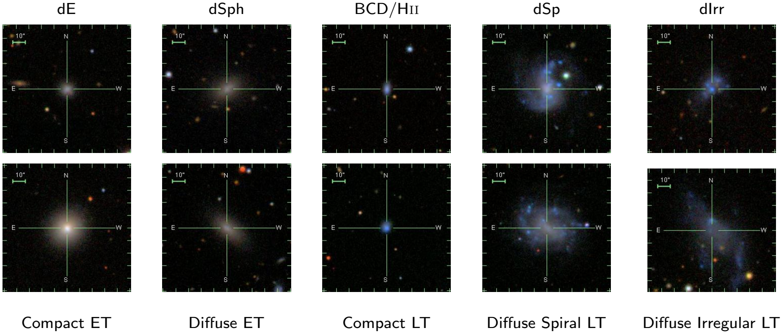
# AVOCADO: structure and morphology

- Quantitative parameters: A, C, S, Gini, $M_{20}$, $\mu_e$, $\epsilon$...
- galSVM (Huertas-Company et al. 2008, 2011)



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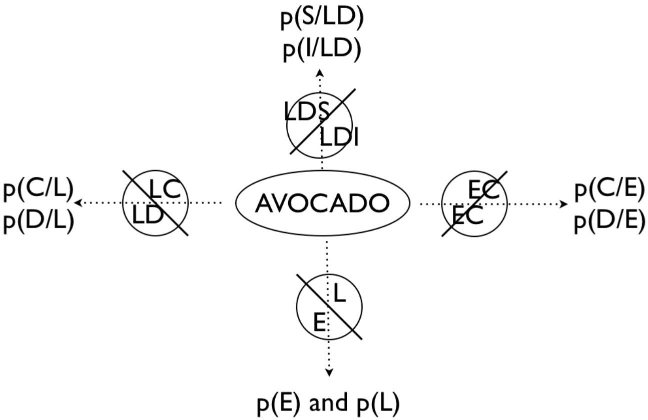
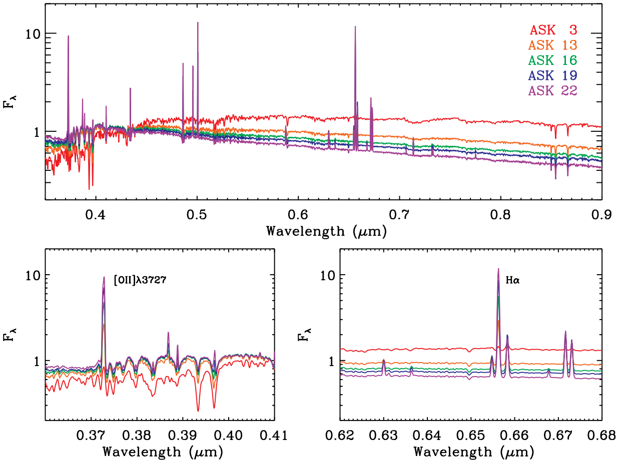


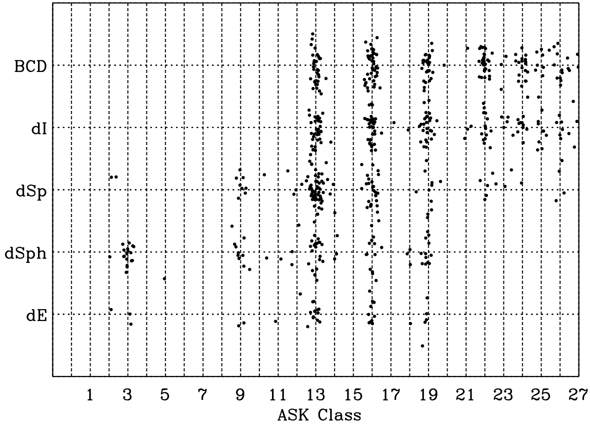

$$P(dE) + P(dSph) + P(BCD) + P(dSp) + P(dIrr) = 1$$

# AVOCADO: the relation between morphological and spectral types



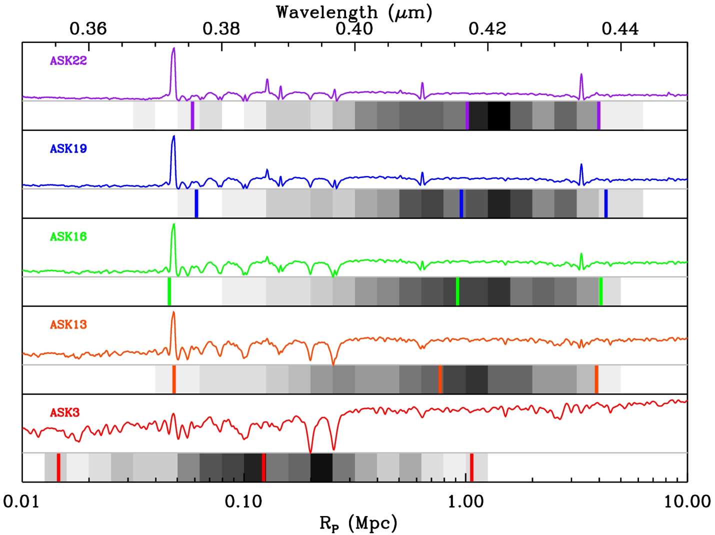

AVOCADO template spectra (Sánchez Almeida et al. 2010)

# AVOCADO: the relation between morphological and spectral types



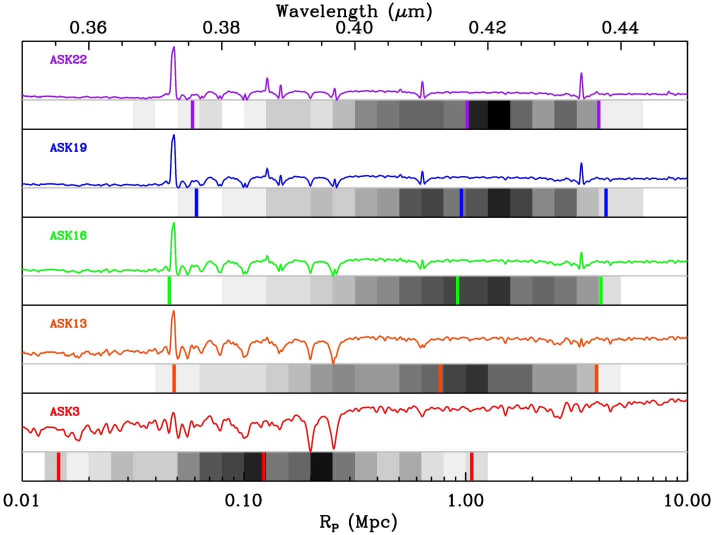
# The strong environmental trend of (quiescent) dwarfs

- Distance to $(M_K^* + 1)$ companions in the 2MRS (Huchra et al. 2011)



# The strong environmental trend of (quiescent) dwarfs

- 99.3% of quiescent dwarfs have $L \gtrsim L^*$ companions within 1.5 Mpc



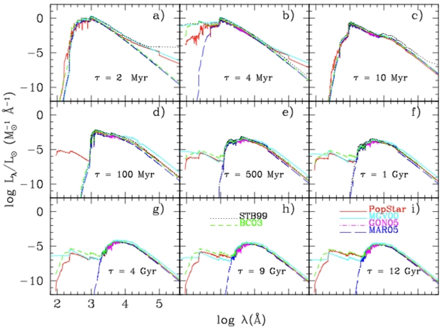
# AVOCADO

**A benchmark dataset for comparisons with numerical simulations and high redshift studies of dwarf galaxies**

- The universal distribution of dwarf morphological types (Huertas-Company et al.)
- The structural properties dwarfs' stellar component (Papaderos et al.)
- The properties of the ionised gas in star-forming dwarf galaxies (Amorin et al.)
- The characteristics of stellar populations and star formation histories of the AVOCADO sample (Gomes et al.)

Thanks!

# VOSA: PopStar evolutionary synthesis models



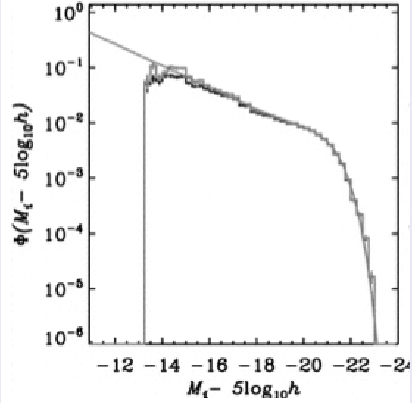

**Mollá, García-Vargas & Bressan (2009)**

- Padova isochrones.
- NLTE atmosphere models for hot stars: O+B+WR (early ages) and post-AGB+PNe (intermediate to old ages).
- Variety of IMFs (Salpeter, Kroupa, Chabrier, Ferrini).
- $5 < \log(t) < 10.18$
- $1/200 < Z/Z_{\odot} < 2.5$

# AVOCADO: the sample

## $M_i - 5log\, h_{100} > -18$

- $L_i < 0.1\, L_i^*$ (Blanton et al. 2005).
- Break of stellar TF relation (McGaugh et al. 2000).
- Importance of turbulent motions (Sánchez-Janssen et al. 2010).



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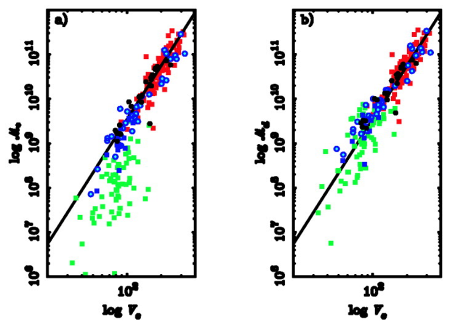

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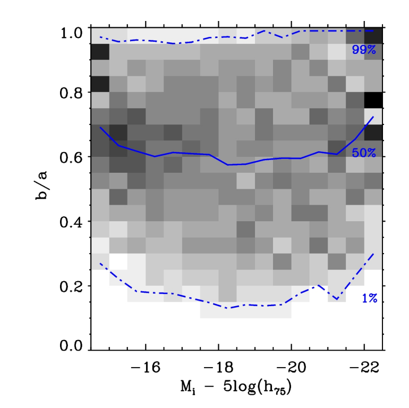


# VOSA: Bayesian outputs (age, $Z/Z_\odot$, $M_\star$)

## Model Bayes analysis

**180.4562378_+2.4214680**

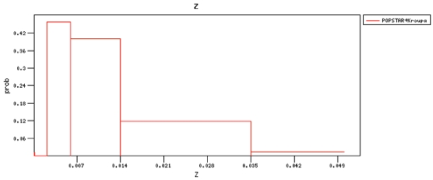
Here you can see, for each model, the relative probability found for each parameter.
Only those with a probability higher than 1e-5 are shown.

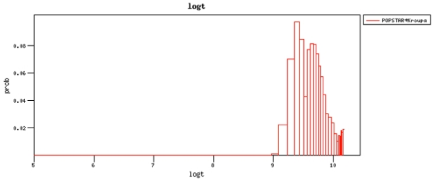
**POPSTAR with Kroupa (2002) IMF**

| Z | Probability |
|---|---|
| 0.0001 | 0.010163 |
| 0.004 | 0.458014 |
| 0.008 | 0.401042 |
| 0.02 | 0.117780 |
| 0.05 | 0.013001 |

| logt | Probability |
|---|---|
| 8.95 | 0.000050 |
| 9 | 0.000772 |
| 9.18 | 0.022175 |
| 9.3 | 0.070049 |
| 9.4 | 0.097057 |
| 9.48 | 0.084595 |
| 9.54 | 0.042622 |
| 9.6 | 0.077246 |
| 9.65 | 0.081158 |
| 9.7 | 0.080674 |
| 9.74 | 0.074050 |
| 9.78 | 0.064985 |
| 9.81 | 0.057158 |
| 9.85 | 0.044014 |
| 9.9 | 0.029984 |
| 9.95 | 0.028086 |
| 10 | 0.023583 |
| 10.04 | 0.015994 |
| 10.08 | 0.009992 |
| 10.11 | 0.014325 |
| 10.12 | 0.014157 |
| 10.13 | 0.013132 |
| 10.14 | 0.018047 |
| 10.15 | 0.016852 |
| 10.18 | 0.019244 |

| FluxType | Probability |
|---|---|
| total | 1.000000 |



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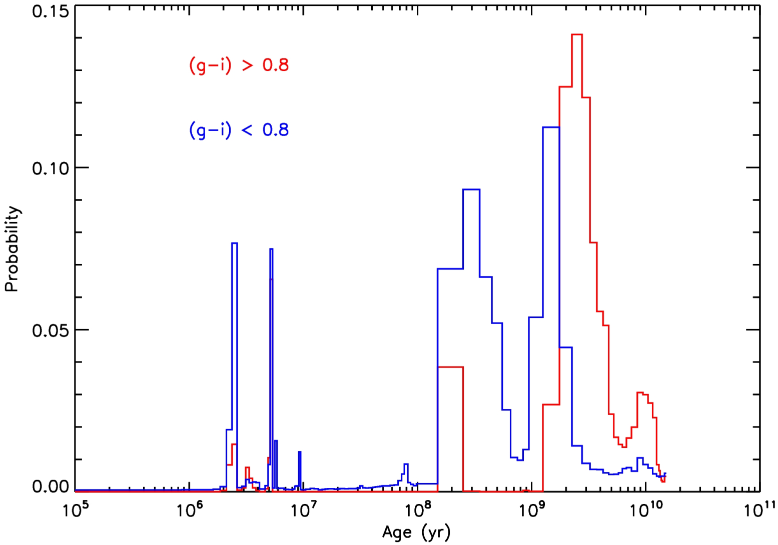
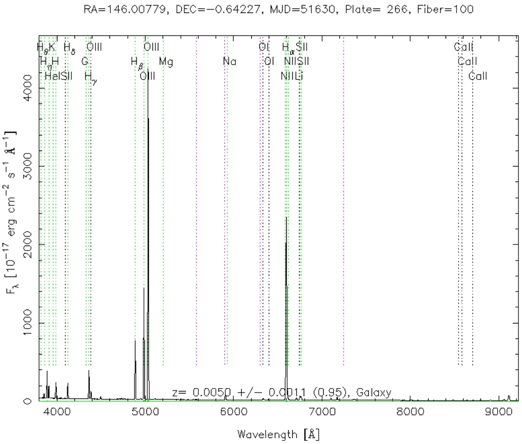


# VOSA and PopStar: future

- Variety of SFH ($e^{-\tau}$, attenuated burts...)
- Include effects of dust.
- Include emission line flux (e.g., Martin-Manjon et al. 2010).



Sánchez-Janssen et al. (2010)