Ultra-faint dwarf galaxies: end of the missing satellite problem?

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RIA: Spanish ICTS contributions to ESA's Gaia mission
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Dwarf Galaxies in a cosmological context

- Dwarf galaxies are in the center of the missing satellite problem: Λ-CDM models predict a number of DM halos in the LG up to an order of magnitude more than the number of the observed satellites (Kauffmann et al. 1993)

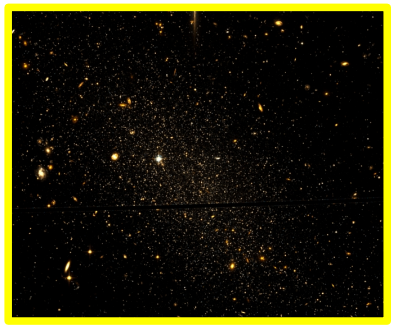
- Reionization and tidal stripping have been proposed as mechanisms that could have affected the early evolution of dwarf galaxies (Bullock et al 2000; Mayer et al. 2004)

Reionization: UV-background at the EoR stopped the star formation in low DM halos.

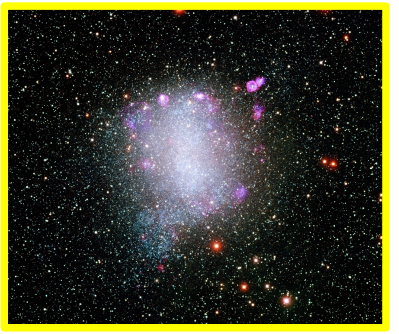
Tidal stripping: Host galaxies remove gas from satellites stopping star formation.

Dwarf Galaxies in a cosmological context

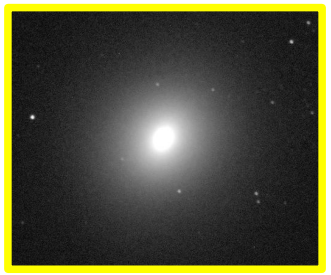
- **Spheroidal (dSph)**
  - No gas
  - No recent stellar formation
  - Low density



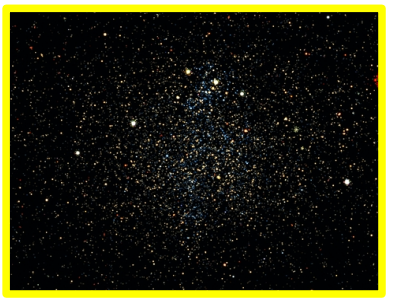
- **Irregular (dIrr)**
  - Gas, HII regions
  - Recent stellar formation
  - Medium density



- **Elliptical (dE)**
  - No gas,
  - Low recent stellar formation
  - High central density

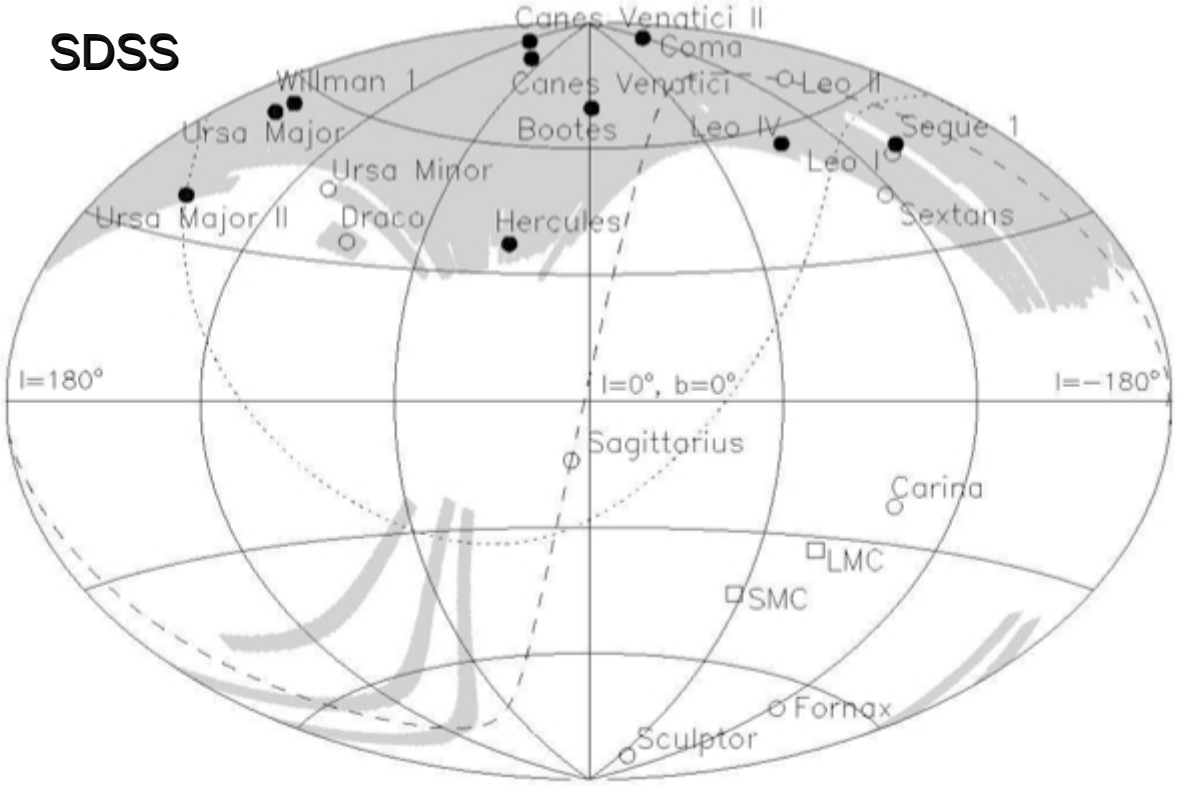


- **Transition (dIrr/dSph)**
  - No gas
  - Recent stellar formation
  - Low density



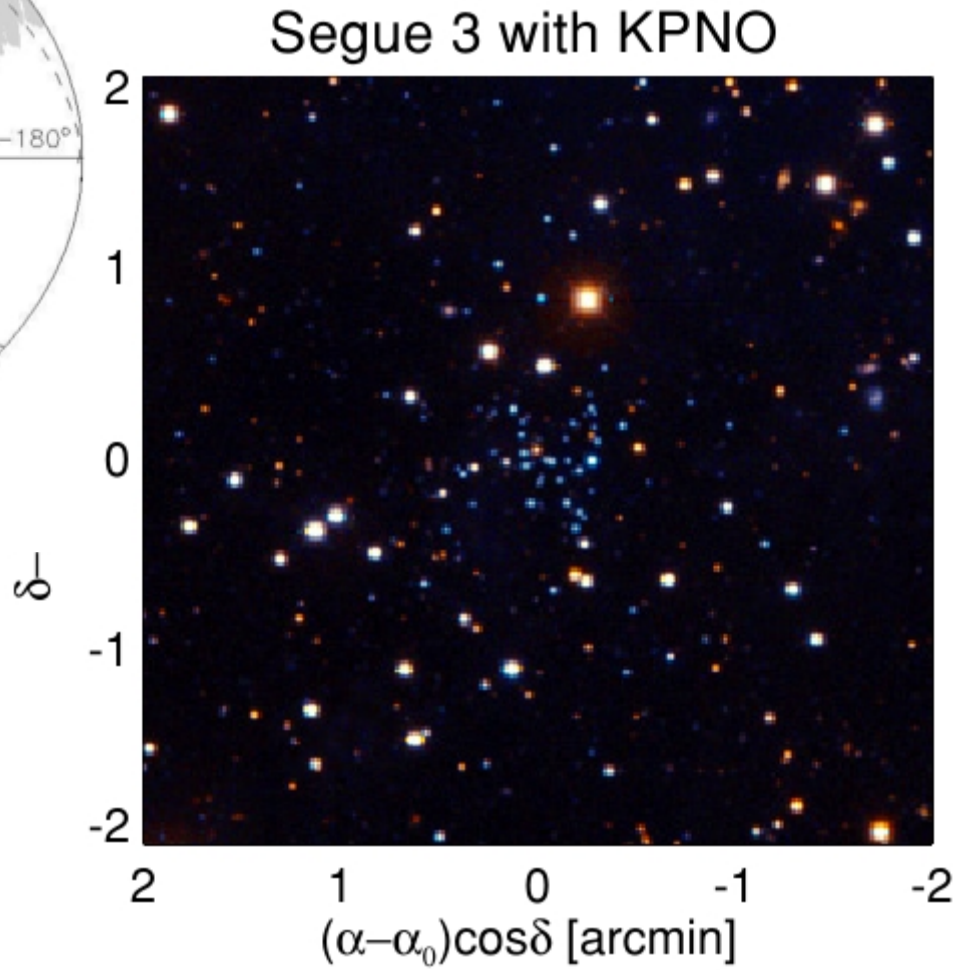
What is a Ultra-faint Dwarf Galaxy?

SDSS



Belokurov et al. (2007)

SDSS limits: 22.5 mag (g)
22.0 mag (r)

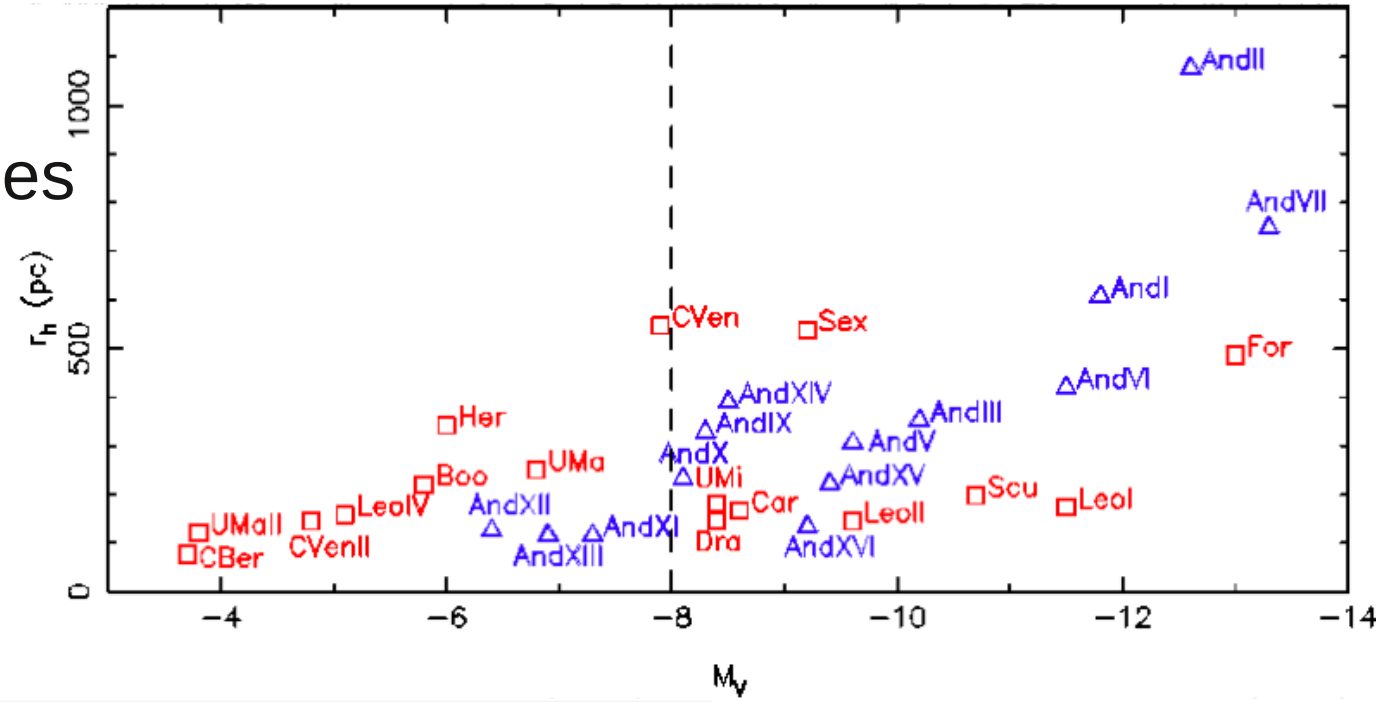


Belokurov et al. 2010

What is a Ultra-faint Dwarf Galaxy?

McConnachie & Irwin 2005

- Very faint dwarf galaxies
- Close to the M.W.
- 10^3 ~ 10^5 L⊙
- Old and metal poor.



Name	Dist. (kpc)	$(M-m)_0$ (mag)	r(1/2) (pc)	$\mu_{0,V}$ $(mag/('')^2)$	$M_{tot,V}$ (mag)	Discover (SDSS)	Follow up
U.Maj. I	97	19.93	300	29.5		Willman et al. 2005	Subaru
U.Maj. II	32	17.53	123		-4.0	Zucker et al. 2006	CFHT
C.Ven. I	223	21.74	581	27.8	-7.9	Zucker et al. 2006	Subaru
C.Ven. II	150	20.88	132		-4.8	Belokurov et al. 2007	
Böot. I	60	18.89	241		-5.9	Belokurov et al. 2006	Subaru
Böot. II	42	18.12	33	29.8	-3.1	Walsh et al. 2007	6.5m-MMT
C.Ber.	44	18.22	74		-3.7	Belokurov et al. 2007	CFHT
Herc.	132	20.60	274		-5.7	Belokurov et al. 2007	LBT
Leo IV	160	21.02	128		-5.0	Belokurov et al. 2007	Sub./MMT
Leo V	180	21.28	42	27.5	-4.3	Belokurov et al. 2008	INT@WFC
Leo T	420	23.12	151		-7.7	Irwin et al. 2007	LBT
Pisc. II	182	21.30	60		-5.0	Belokurov et al. 2010	
Segue 1	23	16.81	29	27.6	-3.0	Belokurov et al. 2007	SDSS
Segue 2	35	17.72	34		-2.5	Belokurov et al. 2009	6.5m-MMT
Segue 3	17	16.15	3		-1.2	Belokurov et al. 2010	4-Mayall

Ultra-faint dwarf galaxy detection with Gaia

- We are working in a method to detect Ultra-faint dwarf galaxies by using data mining in Gaia.

- The method combines spatial and velocity distribution of the stars.

- Tens of UFDs could be detected with this method.

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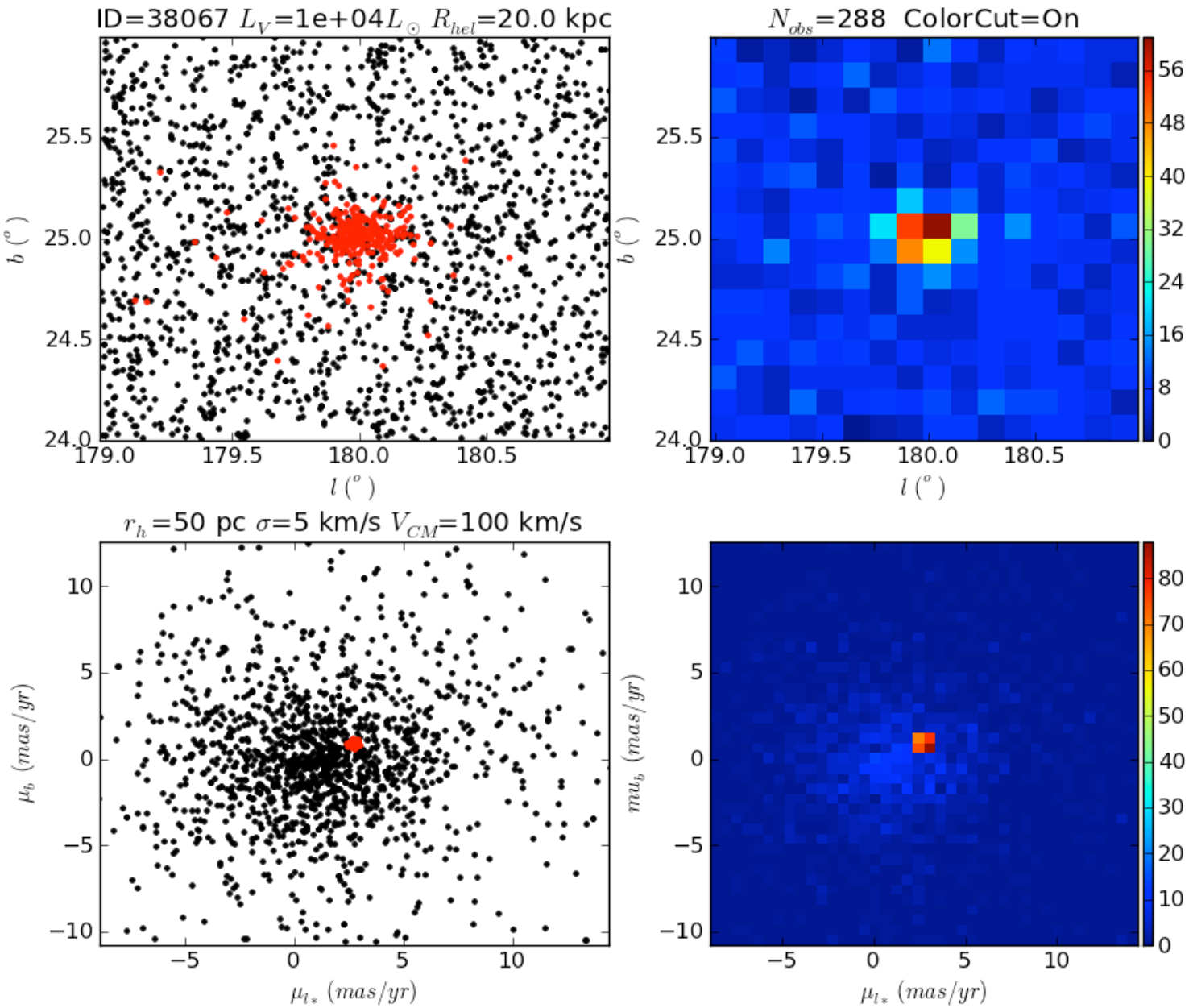
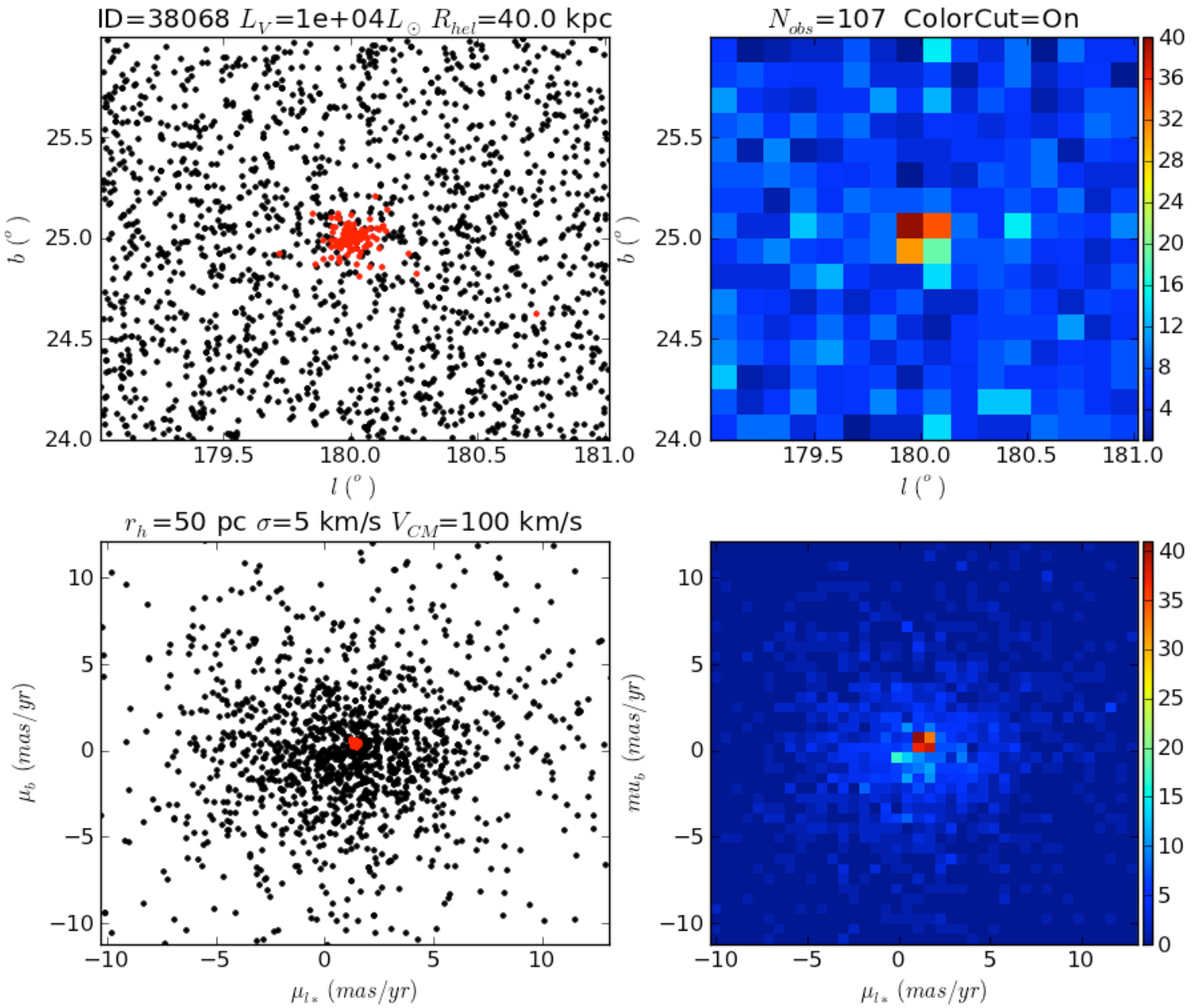
Ultra-faint dwarf galaxy detection with Gaia



Mateu et al. 2012

Ultra-faint dwarf galaxy detection with Gaia



Mateu et al. 2012

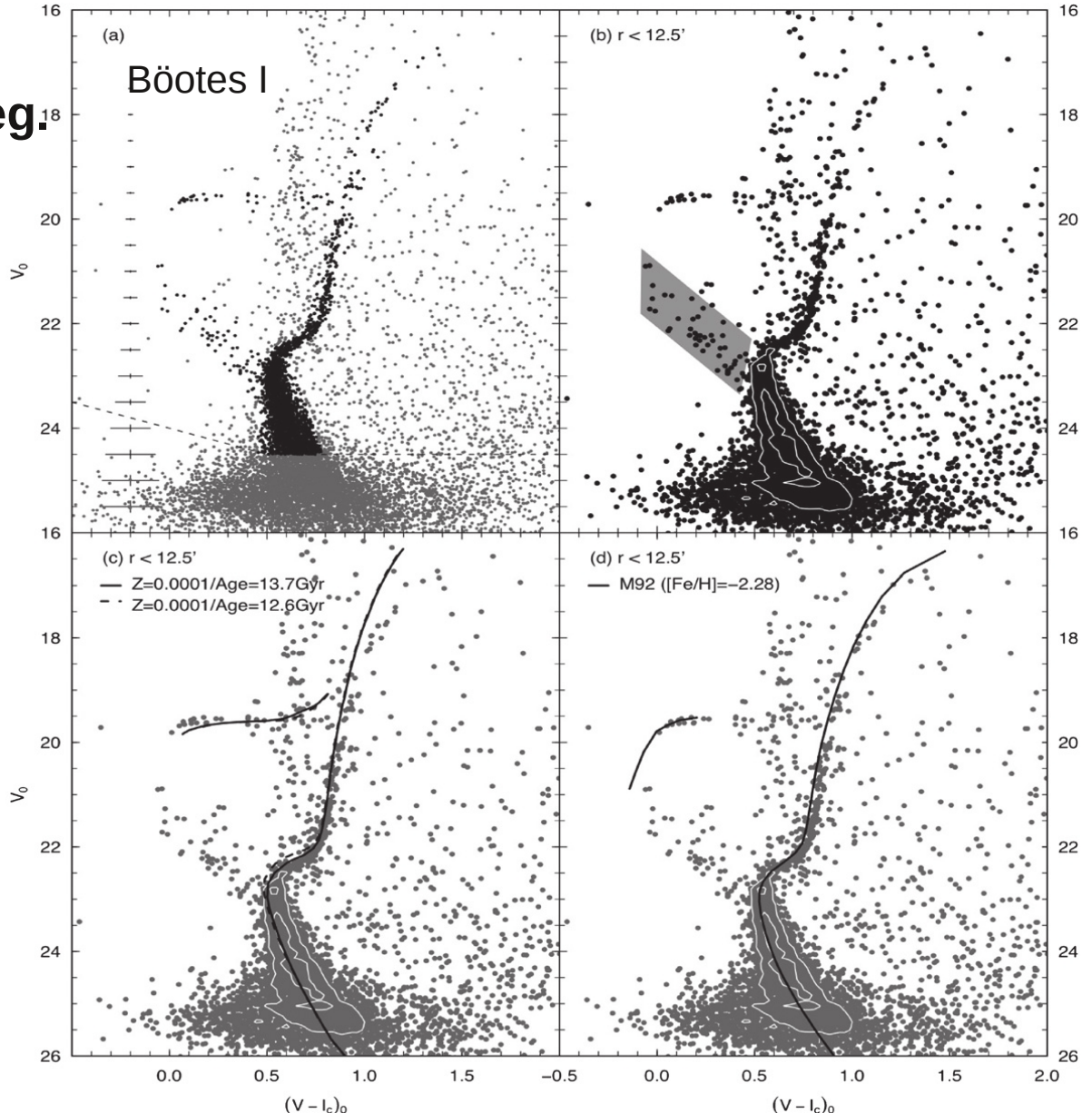
Observing Ultra-faint dwarf galaxies from ground-based telescopes

Subaru
Suprime-Cam (8 m @ ~ 0.5 x 0.5 deg.

Integration time:

V: 600 s
Ic: 3000 s

Okamoto et al (2012)



Observing Ultra-faint dwarf galaxies from ground-based telescopes

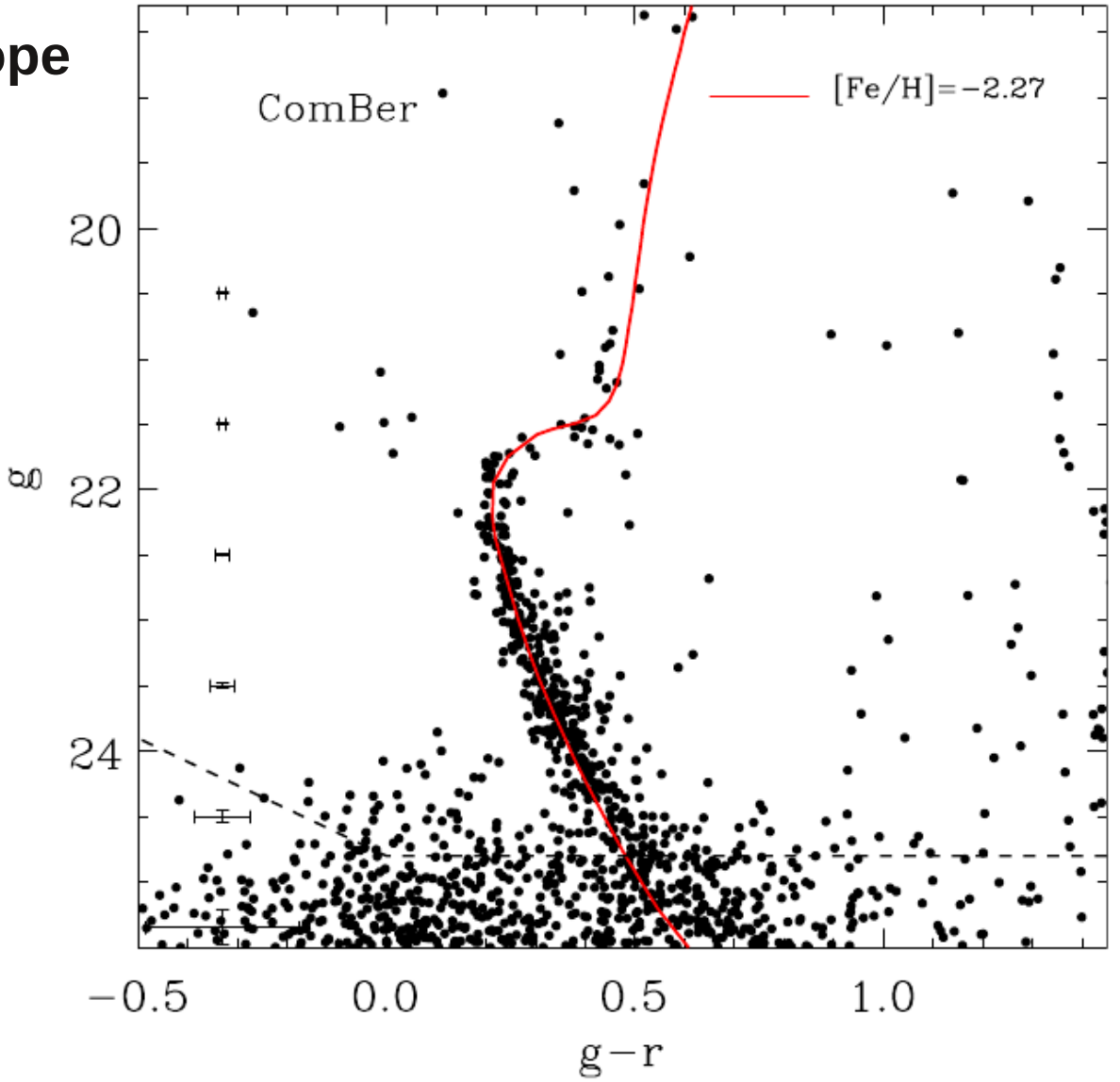
Canada-France-Hawaii Telescope

MegaCam (3.5 m@ 1 sq deg.)

Integration time:

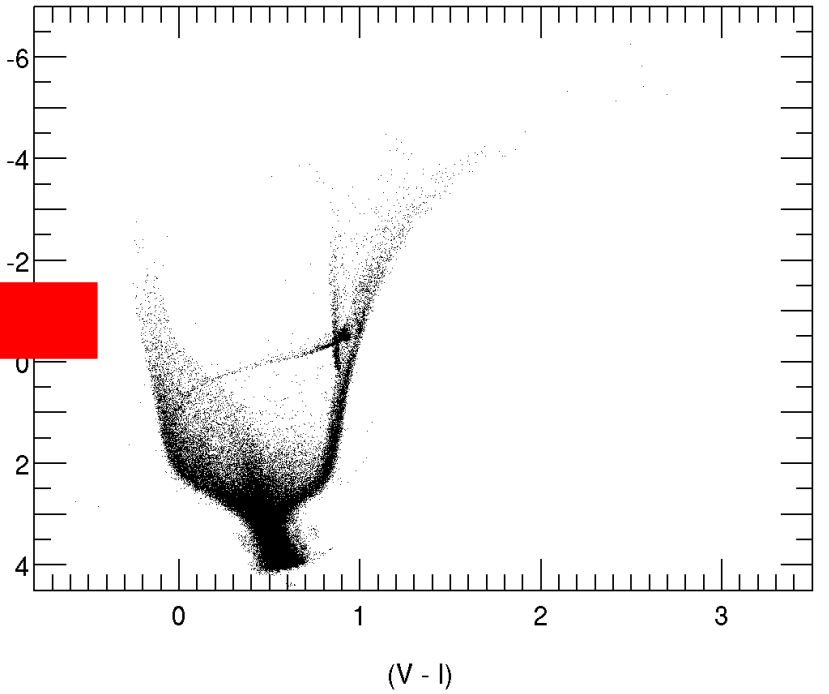
g: 11880 s
r: 20592 s

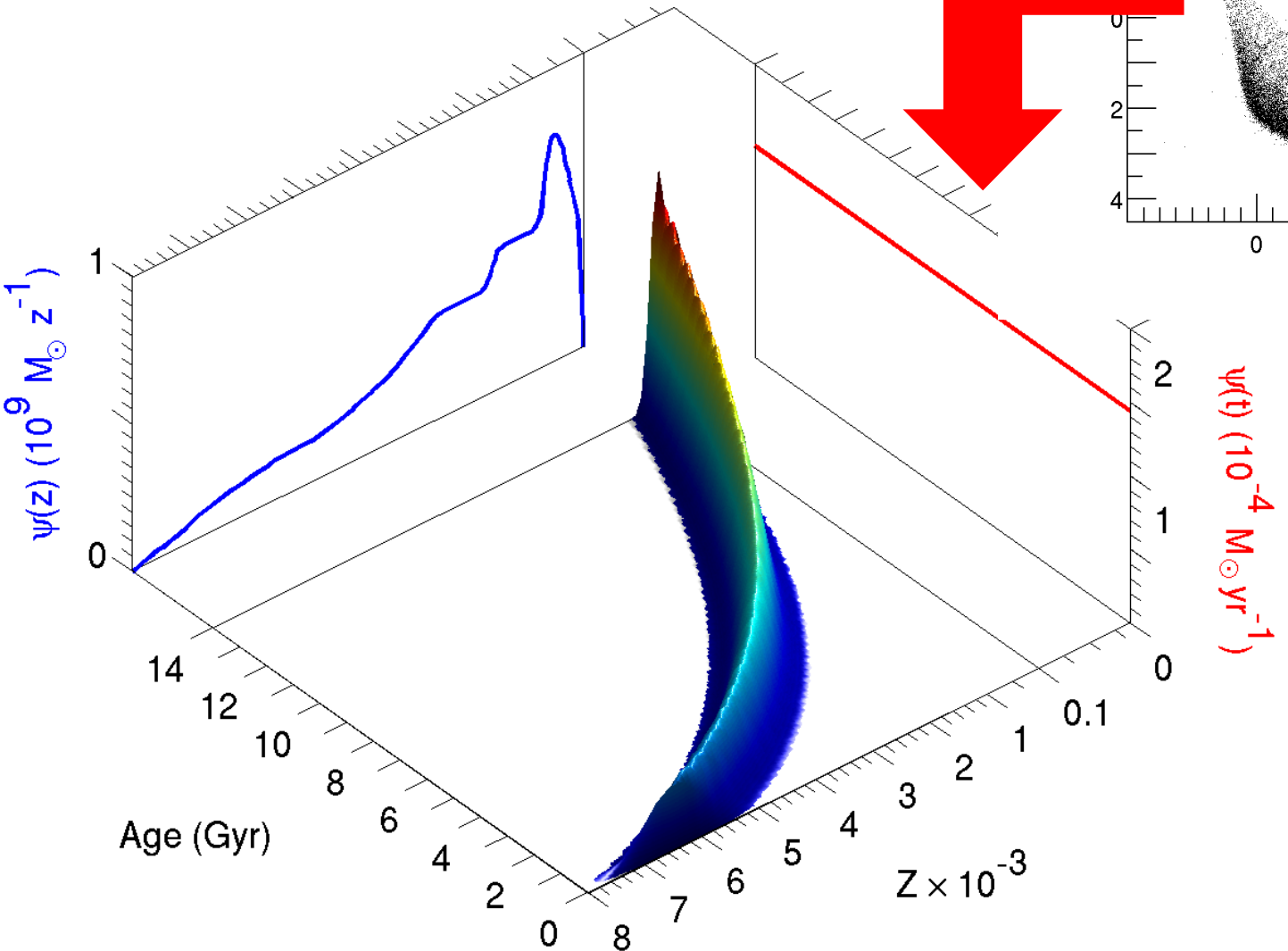
Muñoz et al (2010)



Science with Ultra-faint dwarf galaxies

1 - A color-magnitude diagram (CMD) reaching the oldest main sequence turnoffs **(o-MSTO)** with good accuracy





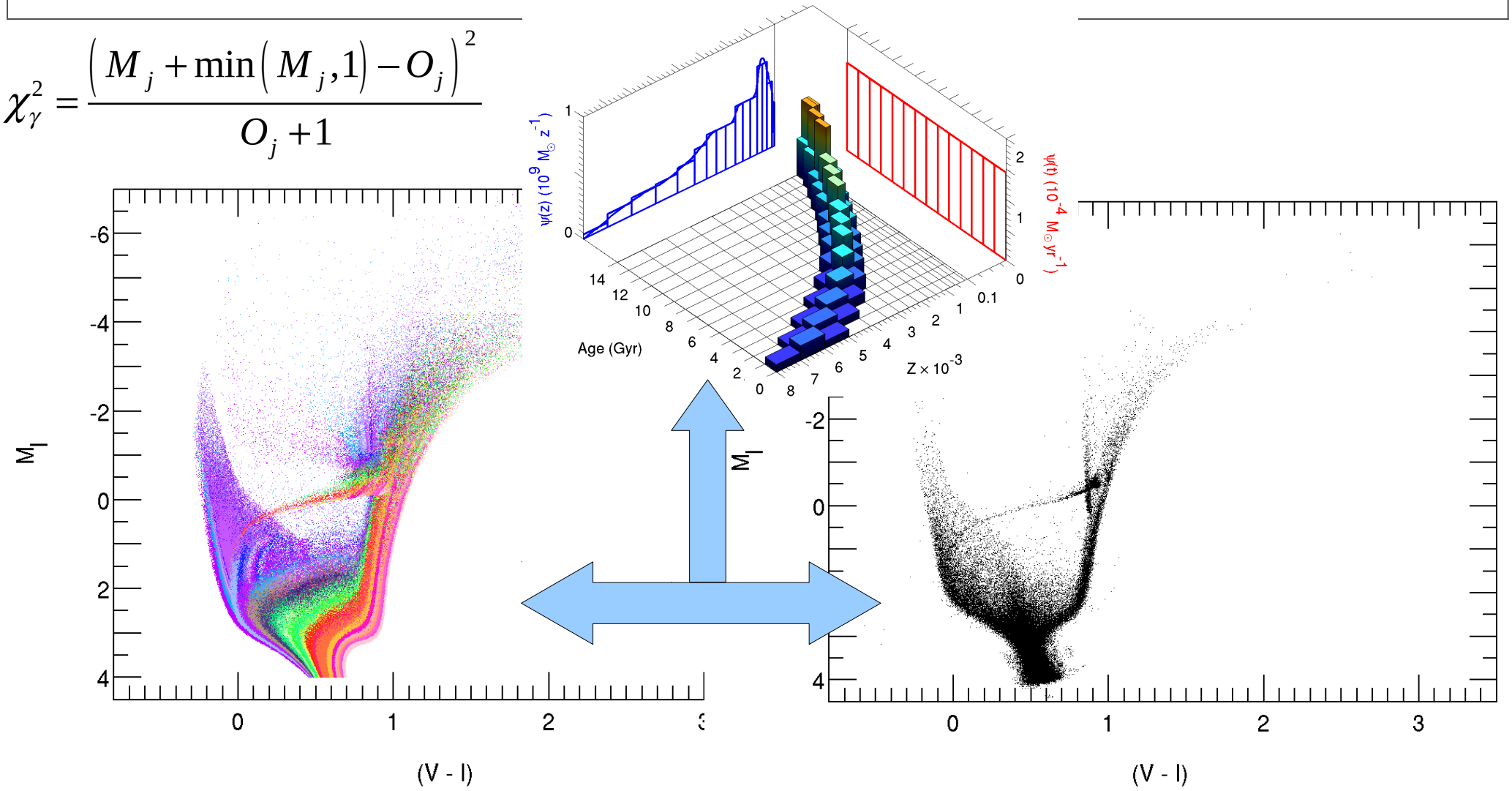
2 - A method to **quantitatively** retrieve the SFH from comparison with a model

Aparicio & Hidalgo (2009)

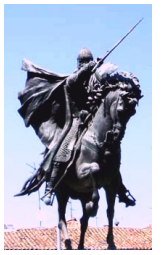
Science with Ultra-faint dwarf galaxies

2) The distributions of simple populations of a model CMD is compared with the distributions of stars in the observed CMD.
3) By using a merit function, we can retrieve a quantitative estimate of the star formation rate and the chemical evolution law.

$$\chi^2_\gamma = \frac{\left(M_j + \min\left(M_j, 1 \right) - O_j \right)^2}{O_j + 1}$$



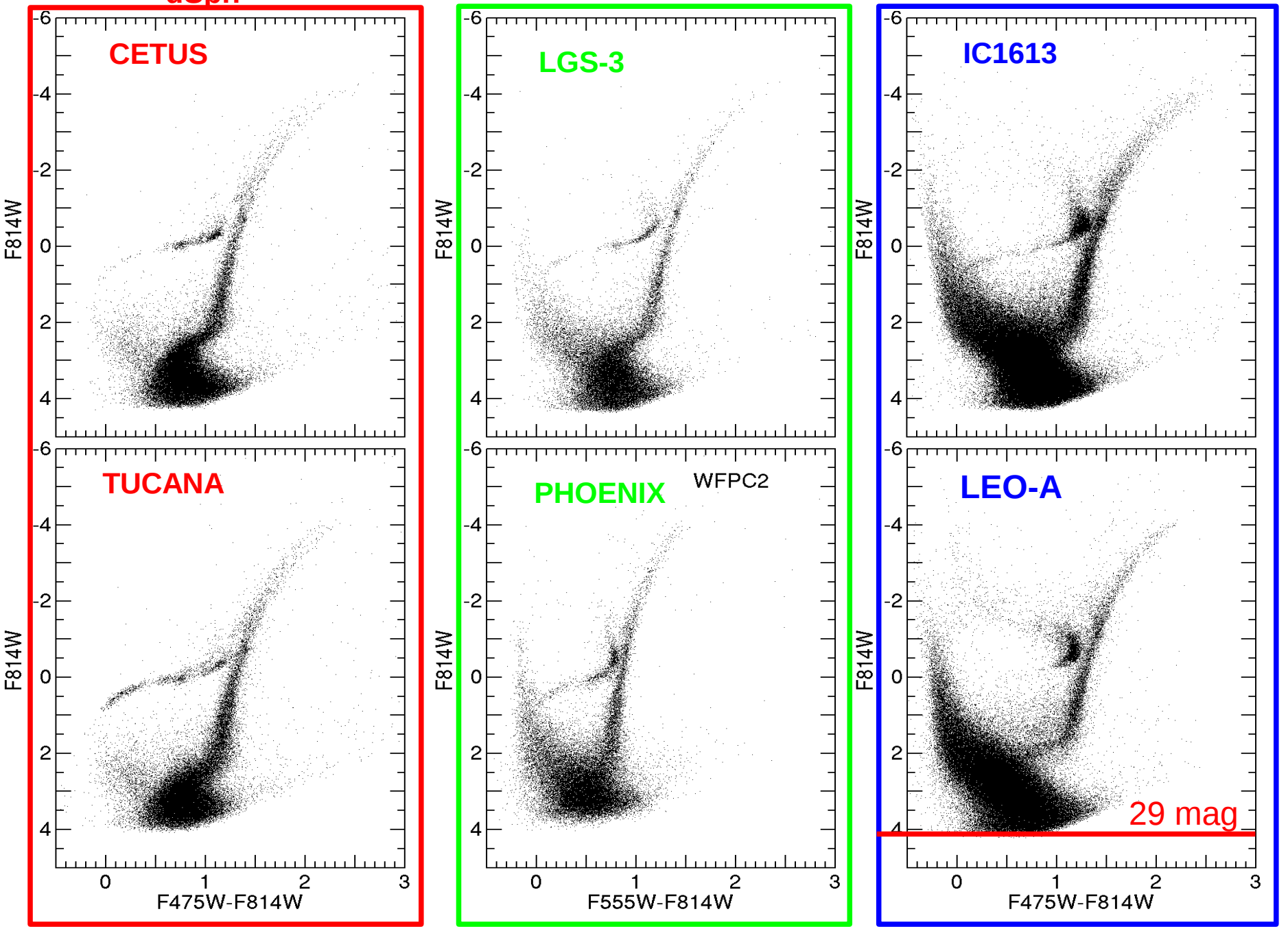
Science with Ultra-faint dwarf galaxies



dSph

tran

dIrr



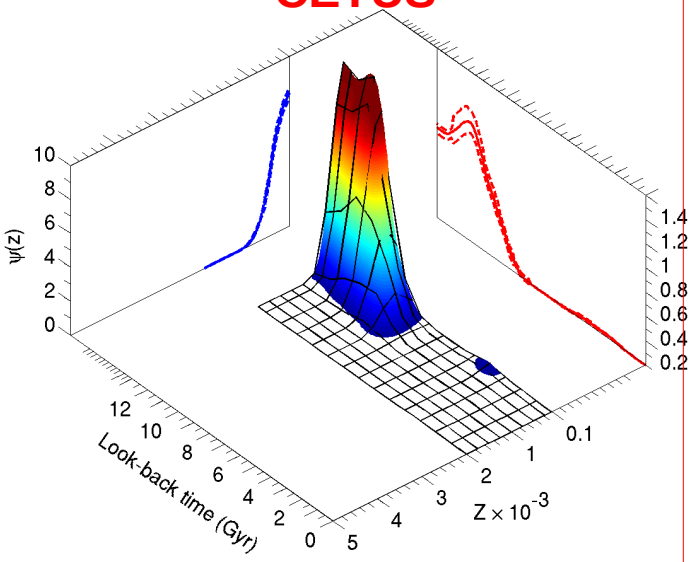
Local Constrains from Isolated Dwarfs

P.I.: Gallart, Aparicio, Cole

Science with Ultra-faint dwarf galaxies

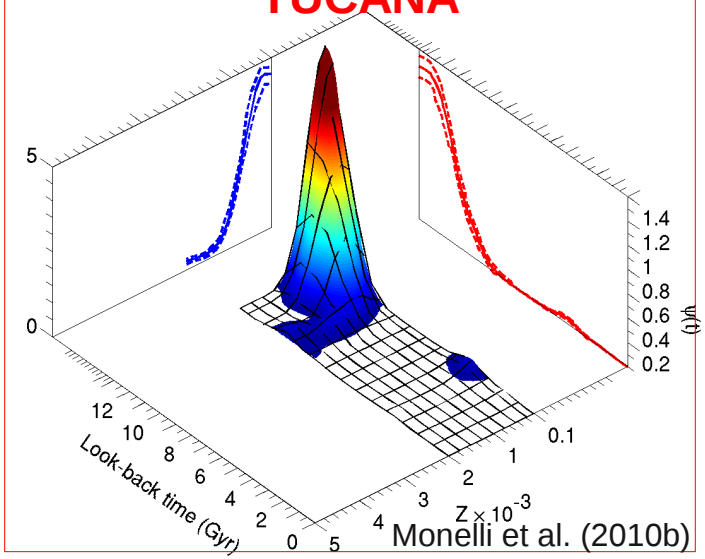
dSph

CETUS



Monelli et al. (2010a)

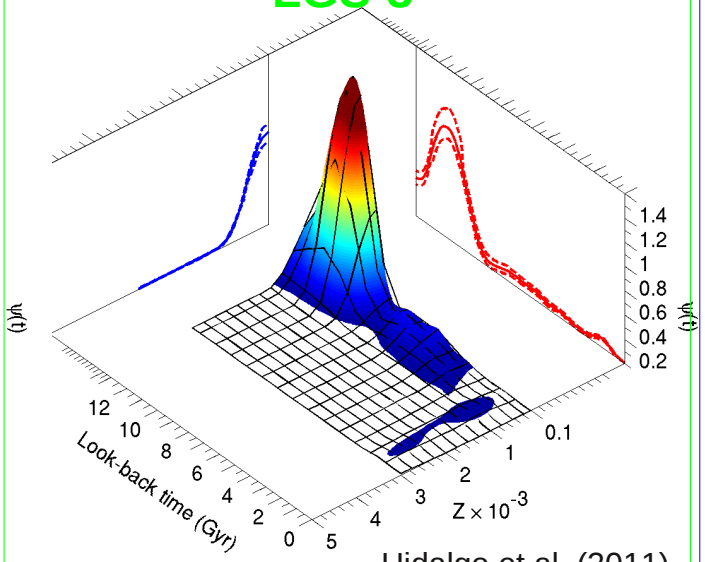
TUCANA



Monelli et al. (2010b)

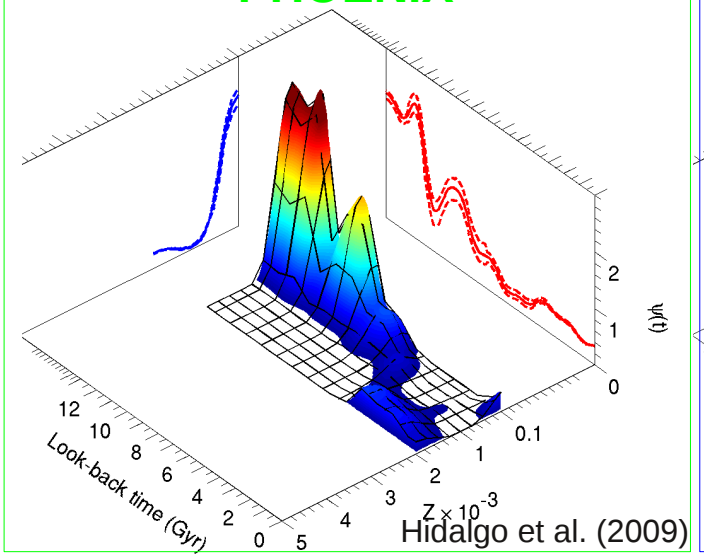
tran

LGS-3



Hidalgo et al. (2011)

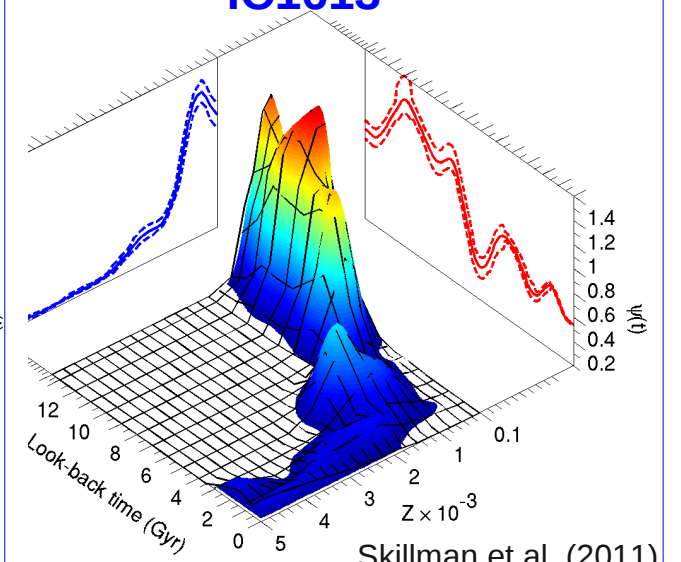
PHOENIX



Hidalgo et al. (2009)

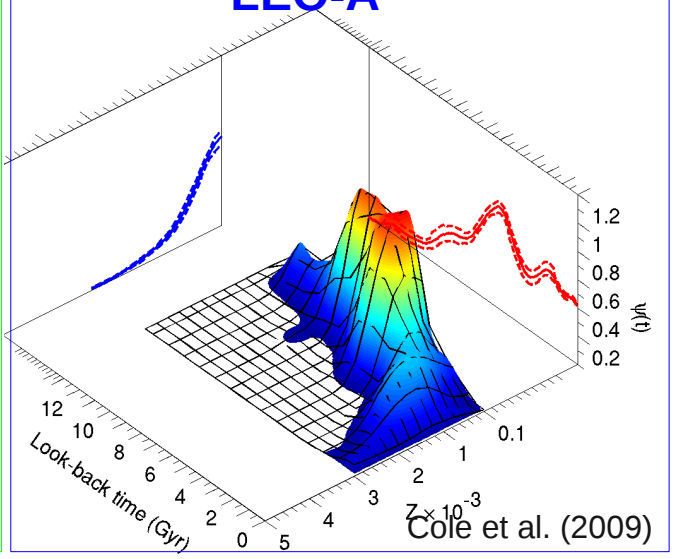
dIrr

IC1613



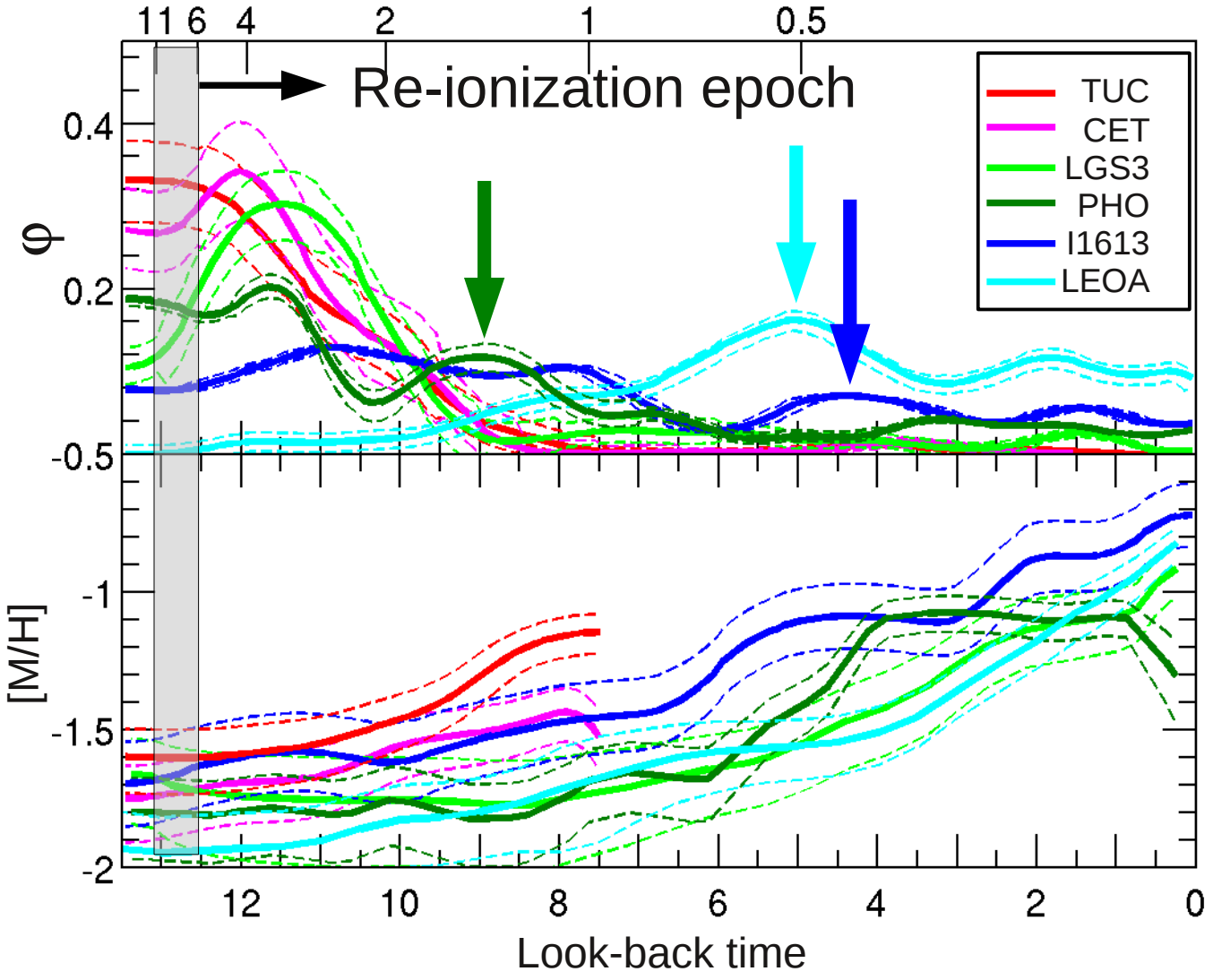
Skillman et al. (2011)

LEO-A



Cole et al. (2009)

Science with Ultra-faint dwarf galaxies



Reionization seems to have not stopped the star formation
In any of these galaxies.

Ultra-faint dwarf galaxies: end of the missing satellite problem?

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SUMMARY

1.- Ultra-faint dwarf galaxies could be the answer to the missing satellite problem.

2.- With Gaia we could detect tens of ultra-faint dwarf galaxies by combining position and radial velocity of the stars

3.- Deep CMD form ground-based telescopes can be used to obtain the SFHs of these objects:

- Affected by reionization?

- Tidal stripped?

- Building blocks of the M.W. ?