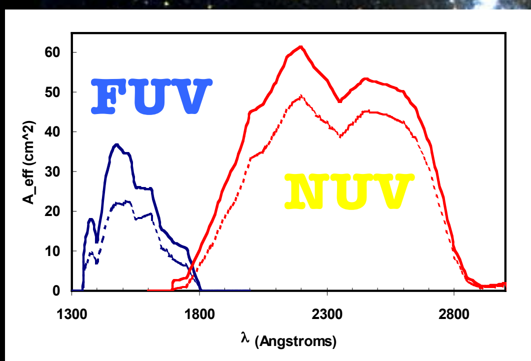
Young Stellar Populations and Star Formation in M31



Luciana Bianchi (JHU)

Princeton

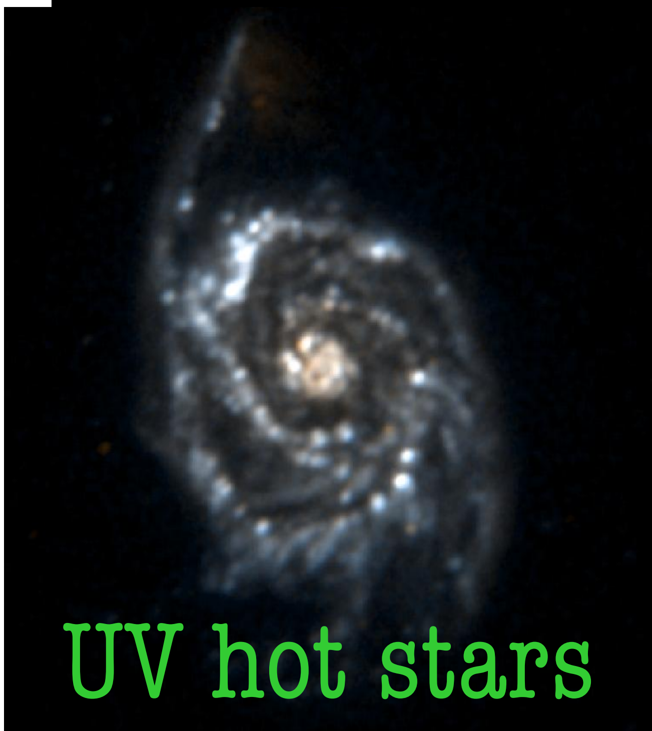
June 2012

Hot massive stars trace star formation: intensity, modalities

Introduction: UV to indentify hot massive stars
to characterize young stellar populations and IS dust
(concurrently)

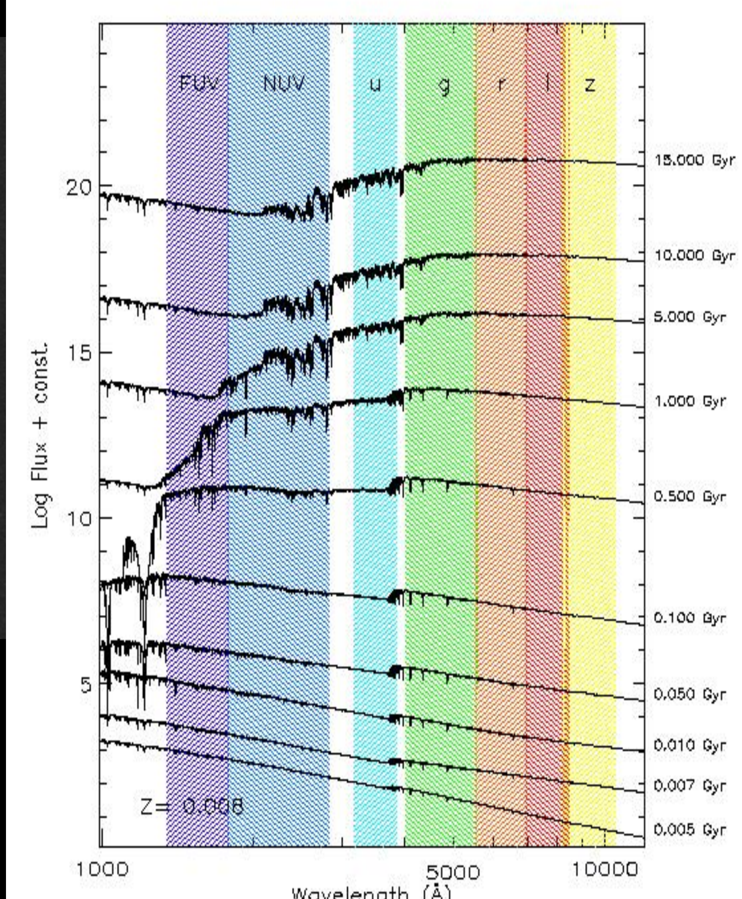
Rest UV Traces Star Formation

Over Large Range of Specific Star Formation



UV hot stars
recent SF

optical
SHF



models from Bianchi 2011

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UV - GALEX provides red-shift (<2), extinction, UV luminosity: SFRH

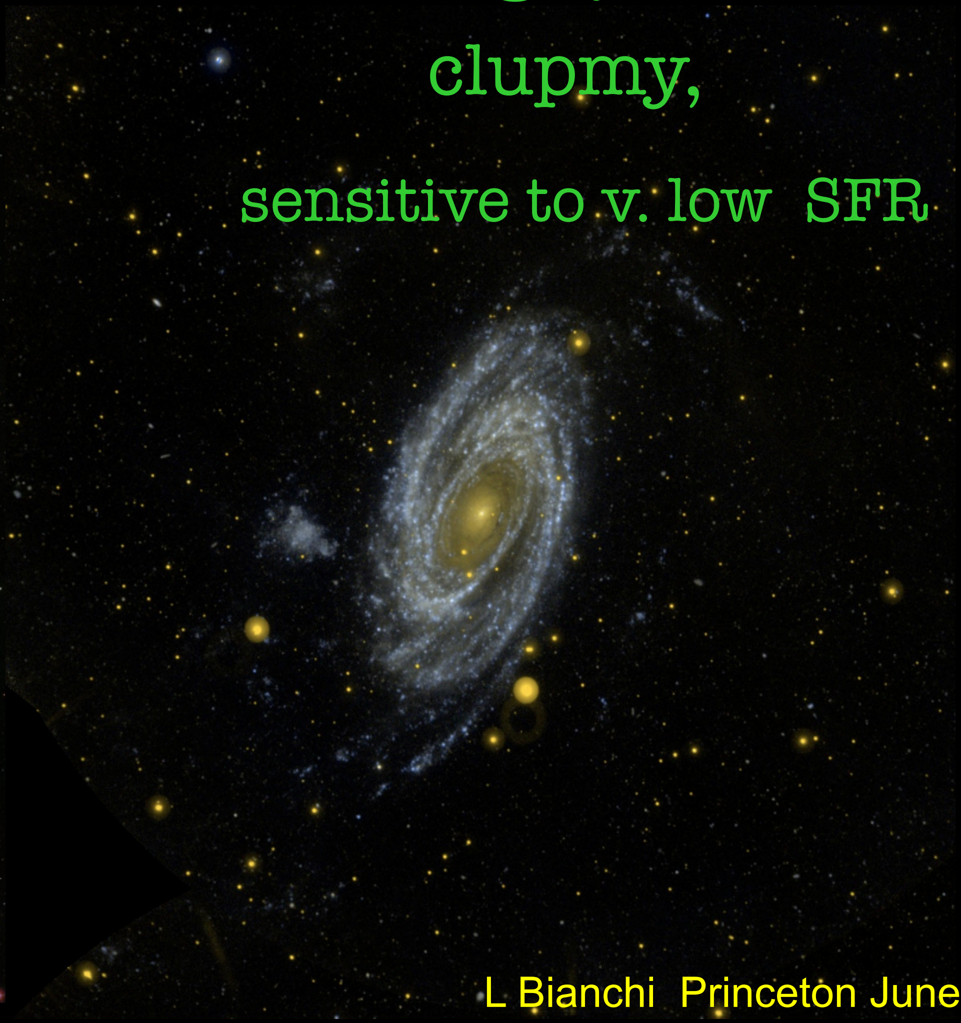
Optical

smooth

UV

clupmy,

sensitive to v. low SFR



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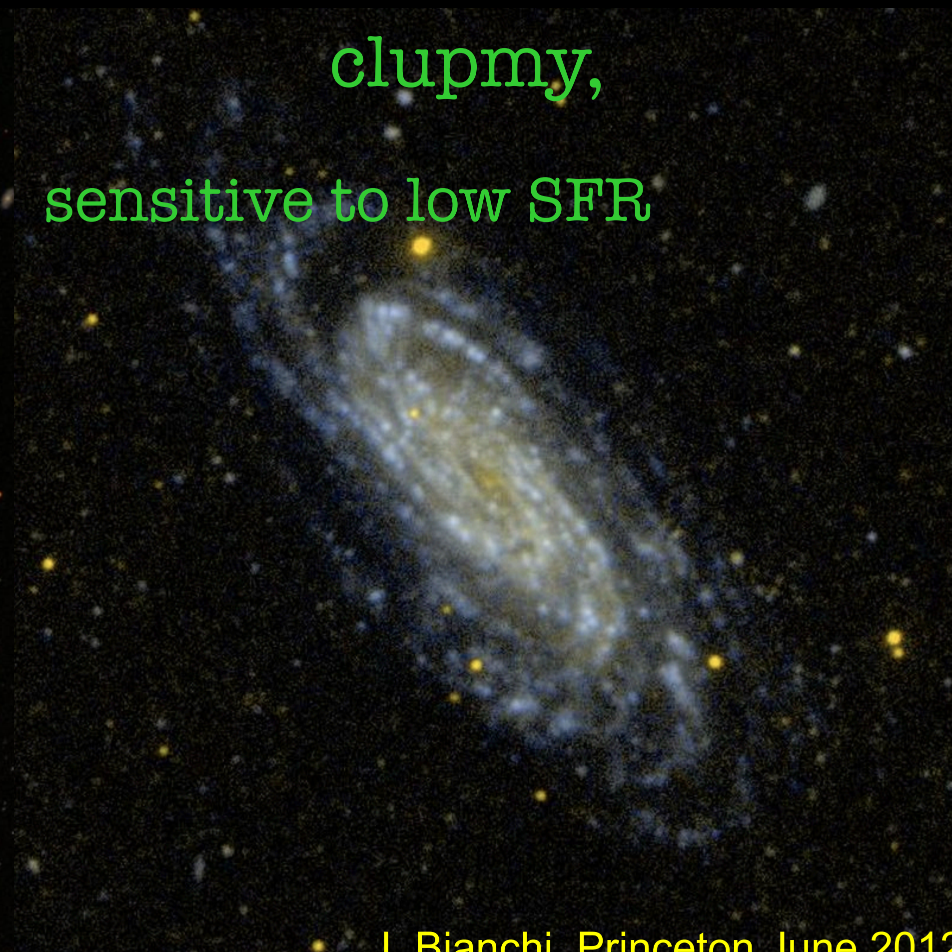
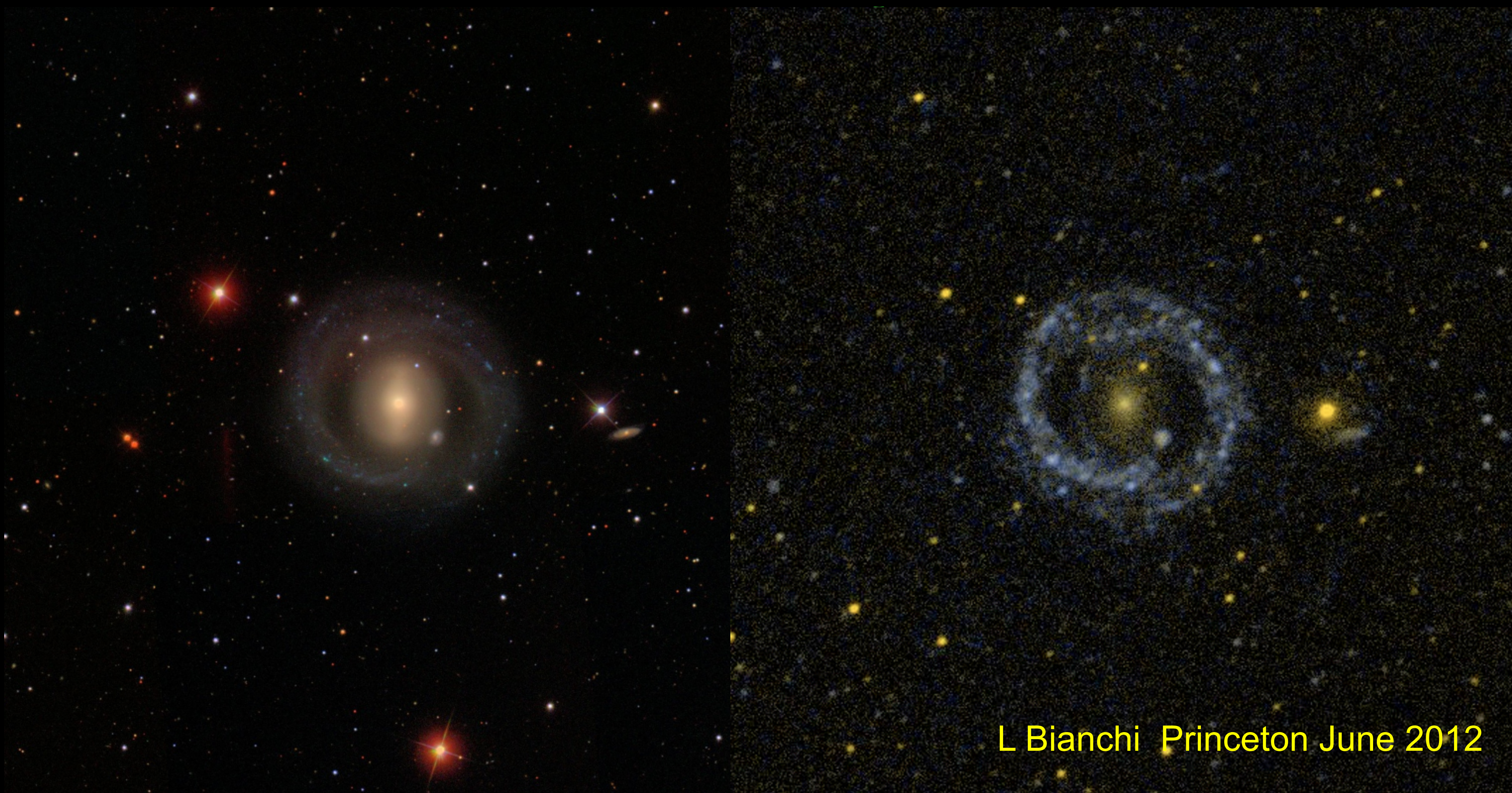
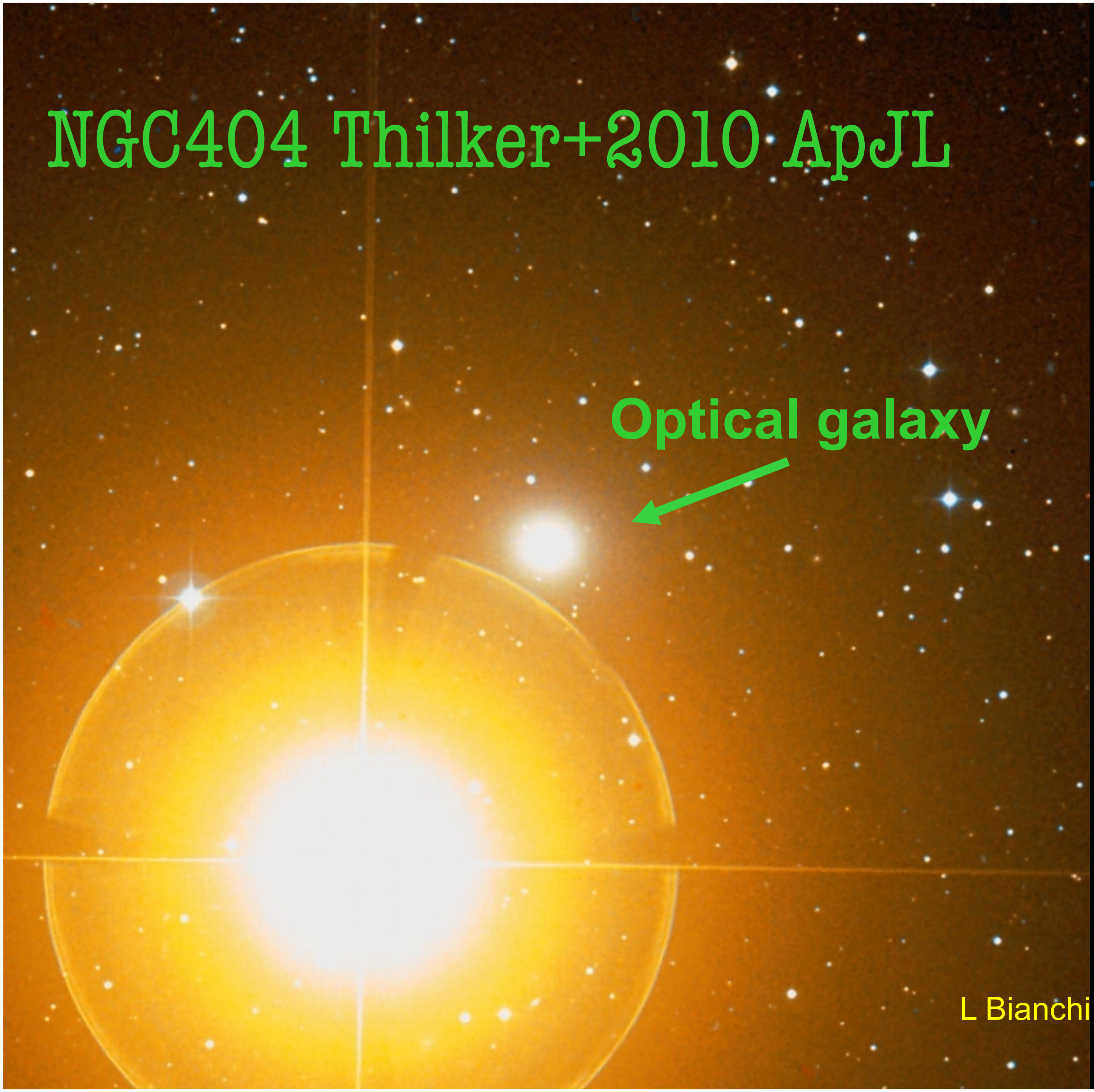
Optical | UV



NGC5701

UV detect young populations even in unexpected environments





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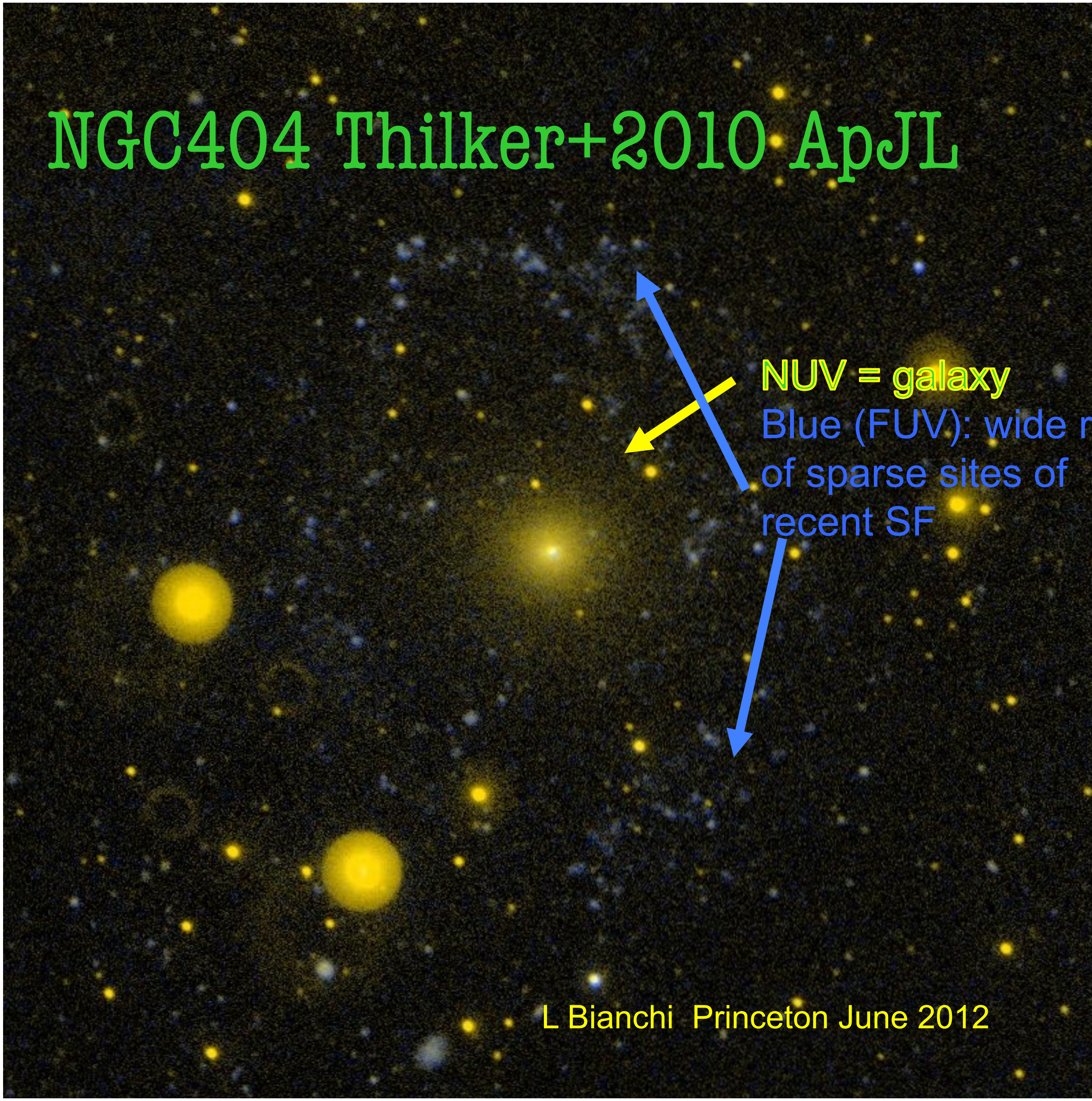
NGC404 Thilker+2010 ApJL



NGC404 : 3.3Mpc, isolated (now)

SFR density: 2 10^{-5} Msun/yr/Kpc^2

SFR = 3.5 10^{-3} Msun/yr

Gas consumption timescale (MHI/SFR) of 60 Gyr (inefficient)

FUV emission 1-4 x R_{25}

70% of the FUV flux comes from the ring, despite the very low SFR

within the galaxy HI ring (formed by a

merger event – del Rio et al 2004, AJ 128, 89)

M(HI)=1 $10^8 M_*$,75% within1-4 x D25

ANGST CMD: RGB & m.s. stars

NOT THE ONLY ONE! 10-30% ETG examined by

GALEX show residual SF, likely from external

source of gas (accretion or merging)

(some consumed quickly in the center, some disk)

M31 UV vs. Optical

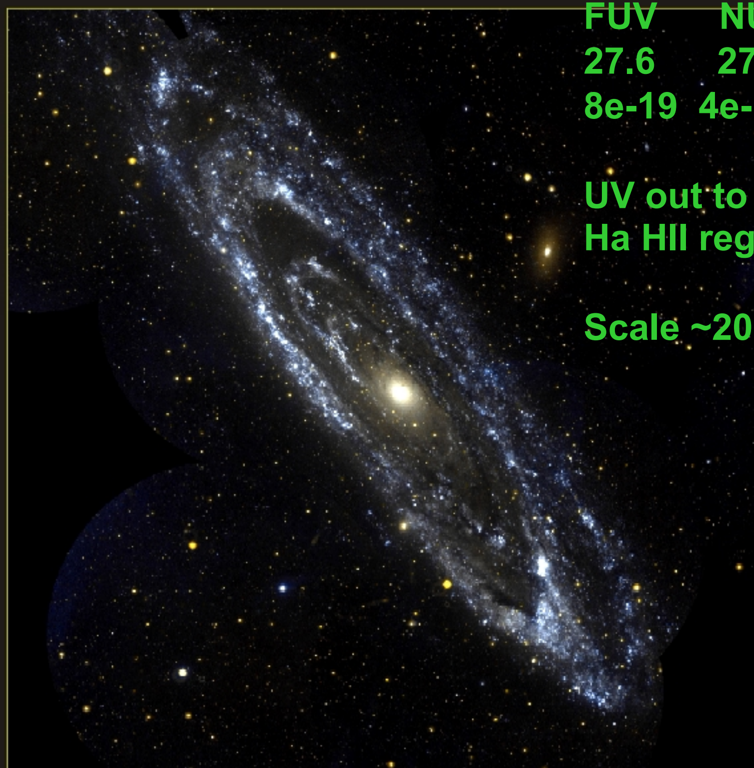
young stellar populations more compact

Limits:

FUV	NUV
27.6	27.9
8e-19	4e-19

UV out to 27kpc
Ha HII reg. 20kpc

Scale ~20pc



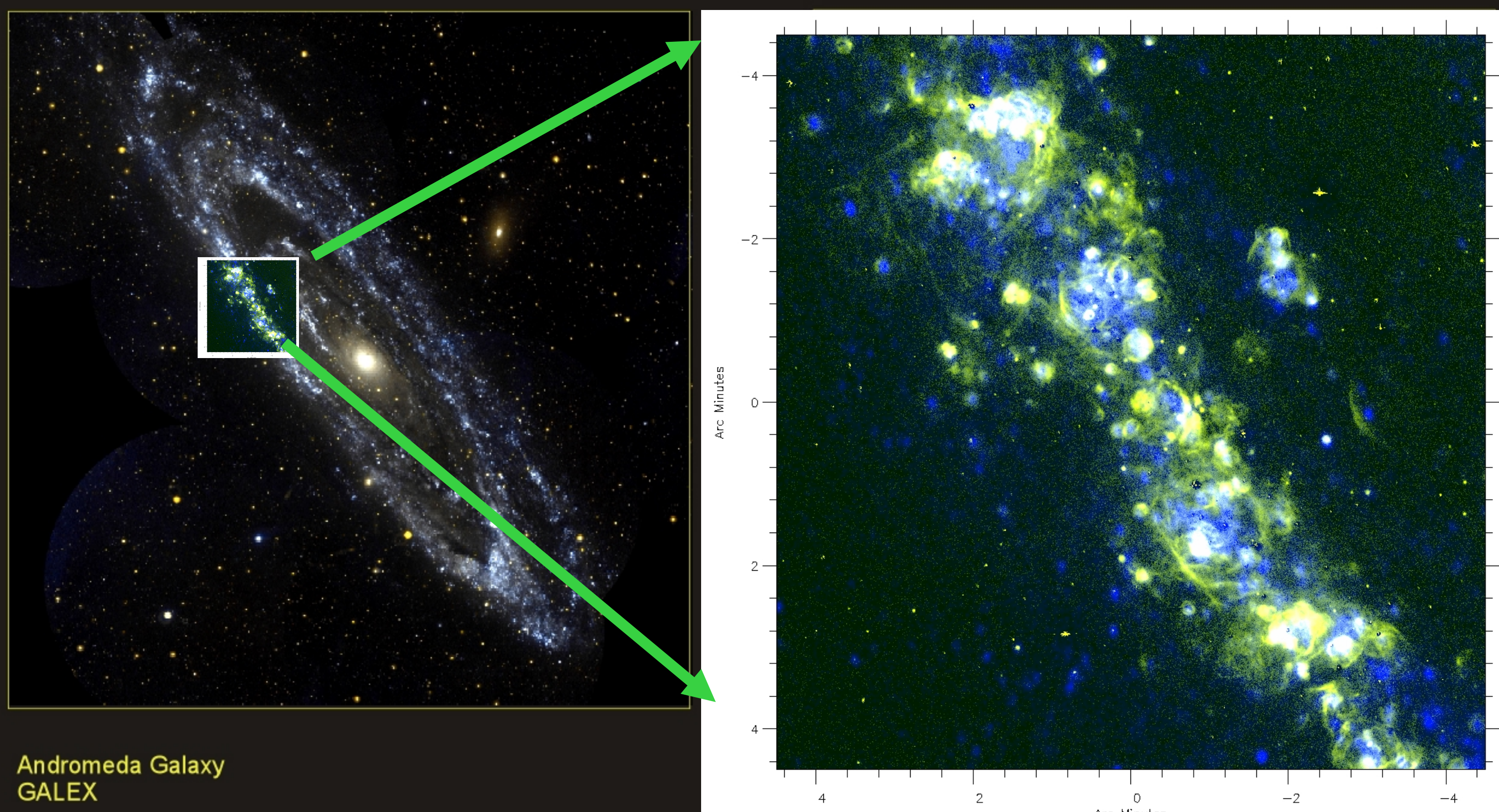
Andromeda Galaxy
GALEX

Andromeda Galaxy
Visible light image (John Gleason)

M31 UV vs. Optical

Halpha indirect SFR indicator

UV sensitive to longer time (ages ~10^{8} Myrs



Andromeda Galaxy
GALEX

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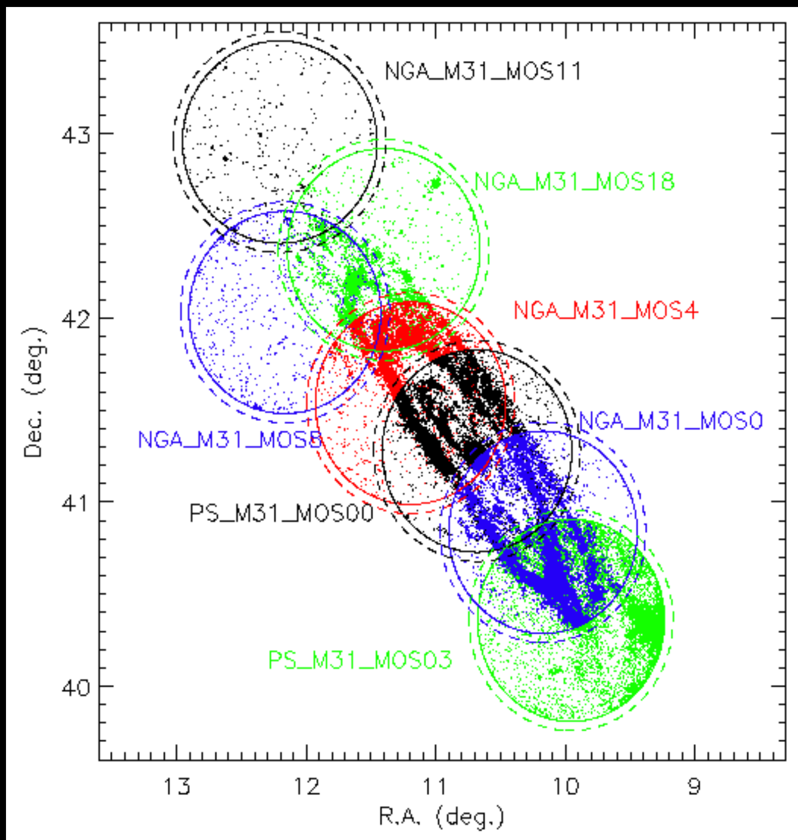
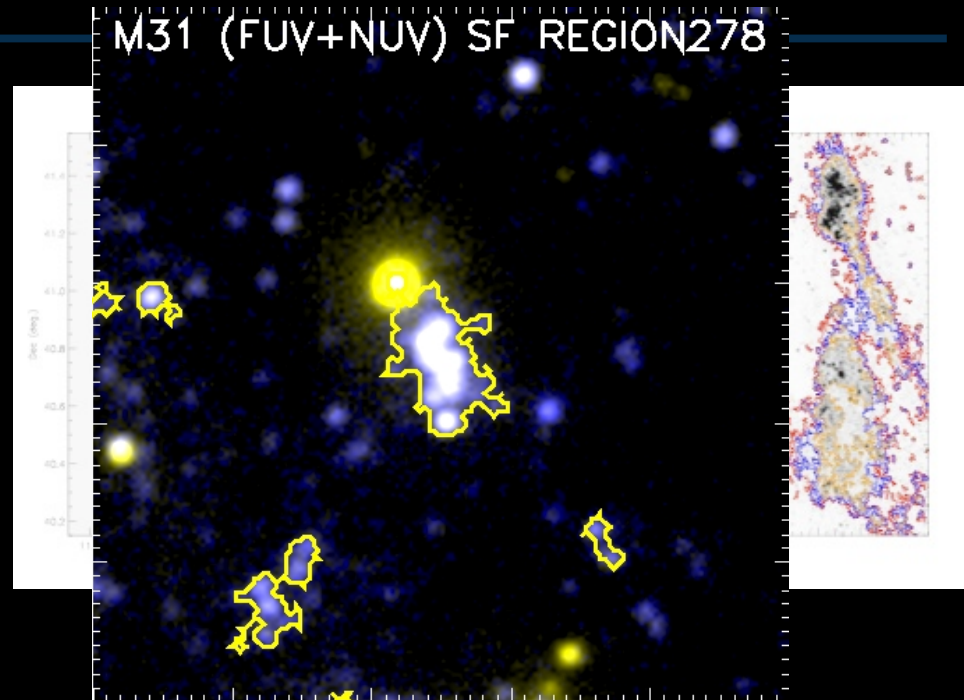
defining SF regions from FUV

Kang, et al 2009

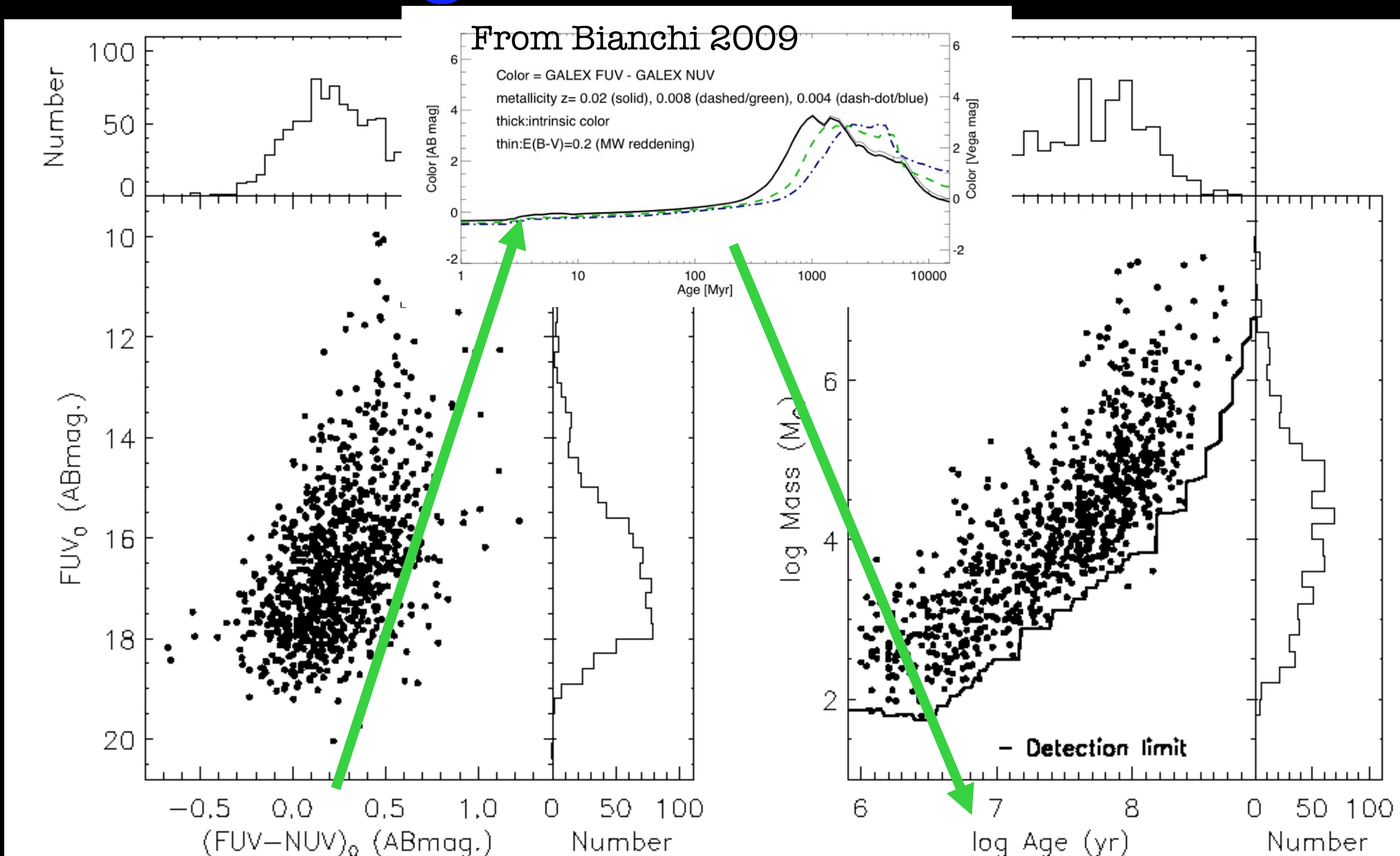




Defining SF regions from FUV:
effect of threshold; 2/3/5 σ (red/blue/orange) above mean bckg

Over a 2x **26kpc disk: 894 SF regions with area >1600pc^2 and surface brightness above ~ 26 mag/arcsec^2**

M31: ages, masses of SF regions from integrated measurements



CMD (dereddened)

ages, masses for the 894 SF regions

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M31: SFr

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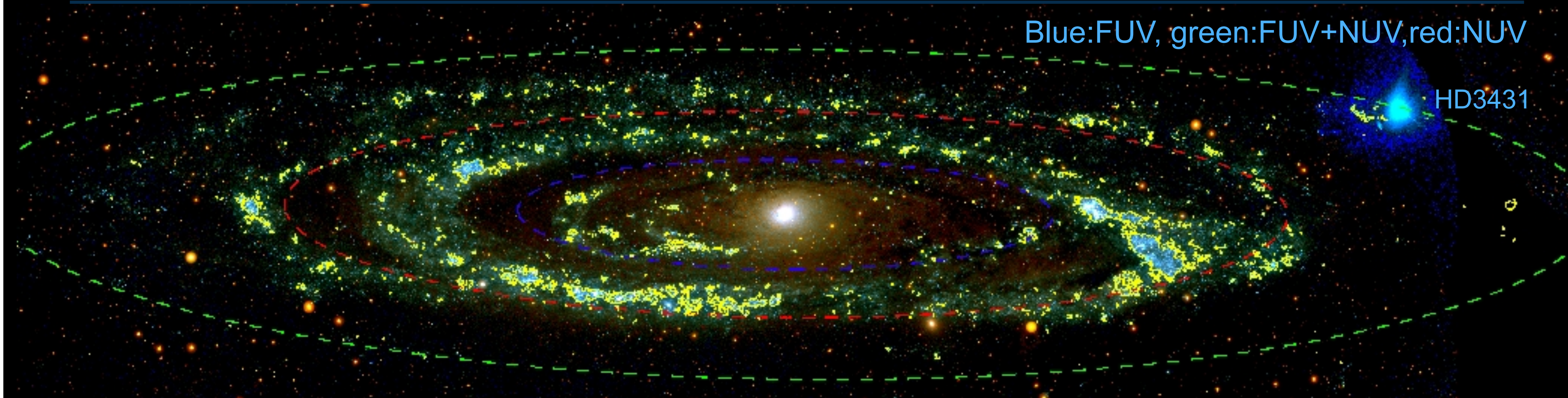
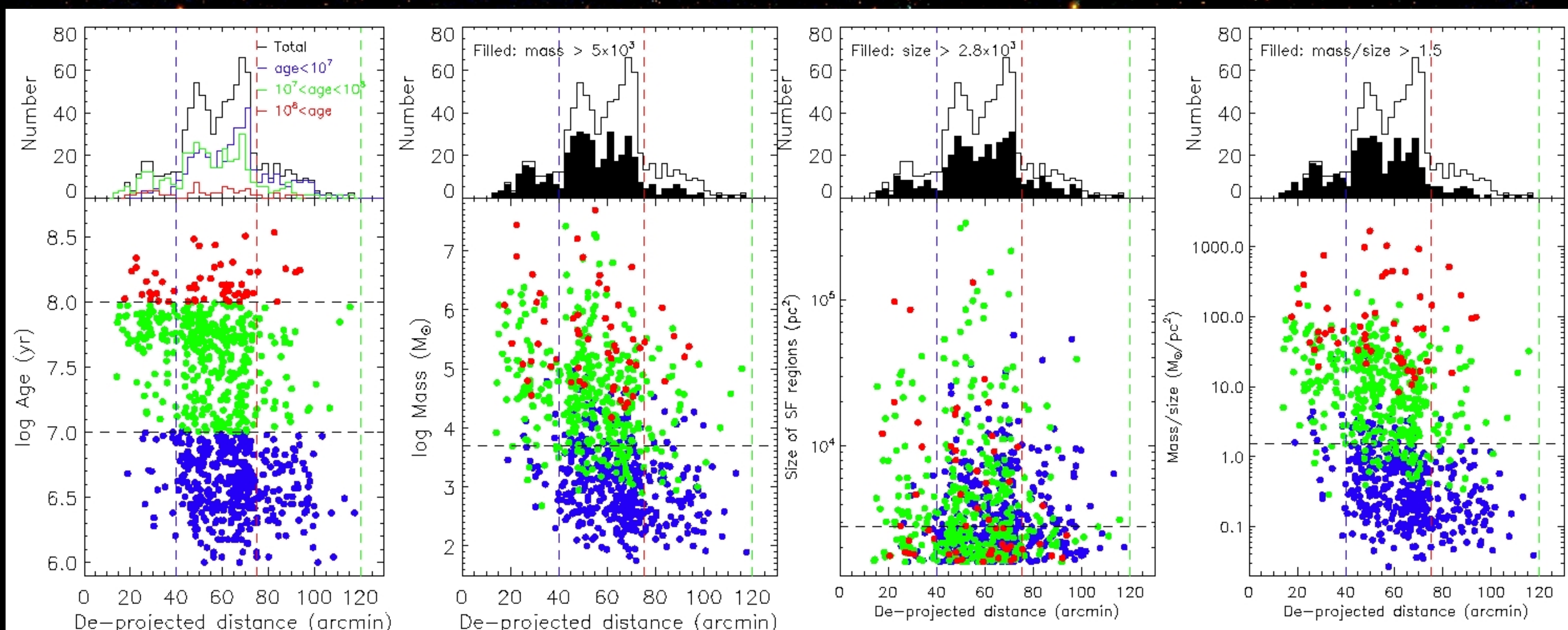
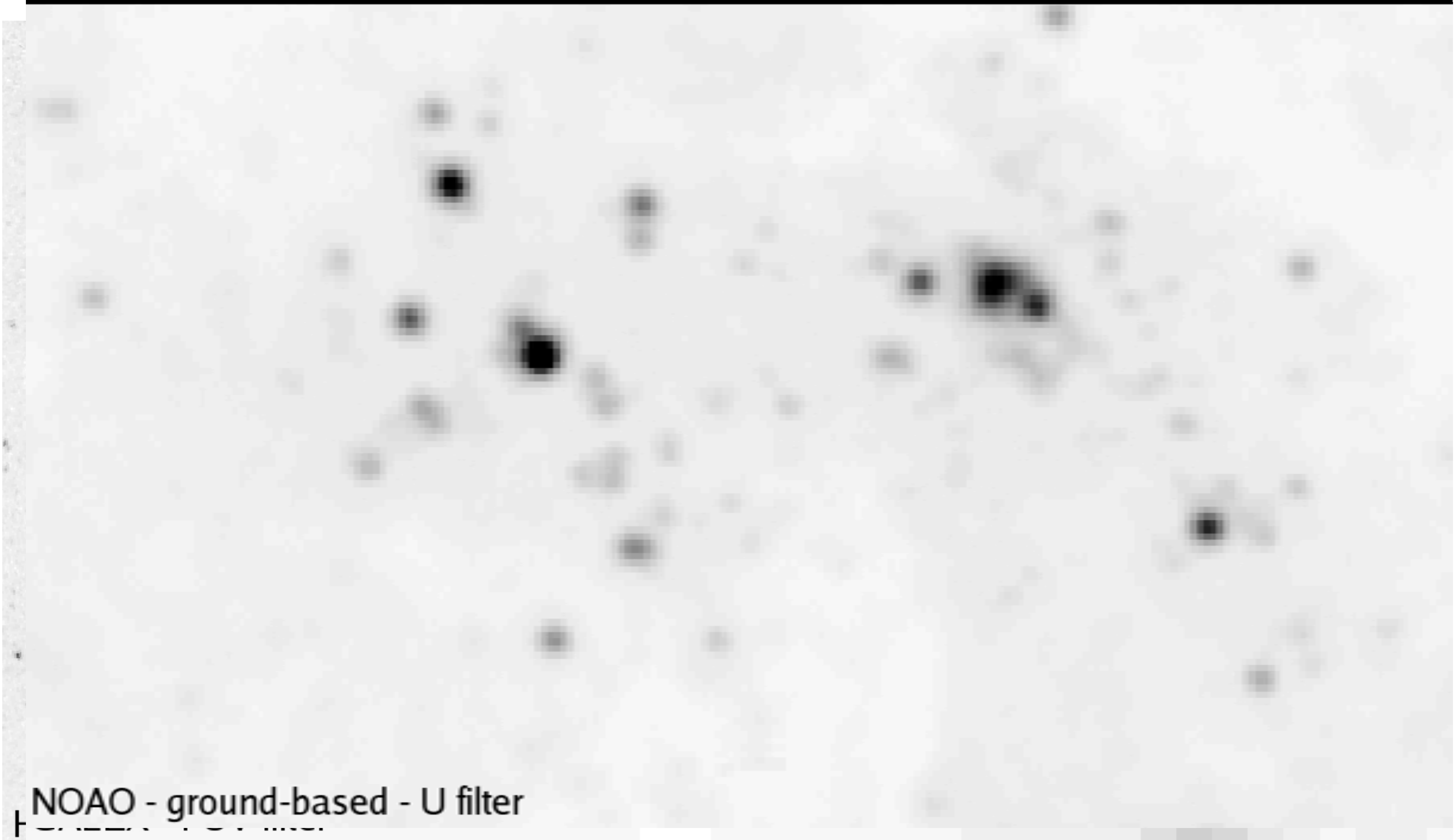
Dashed ellipses at
9, 17, 27kpc deprojected



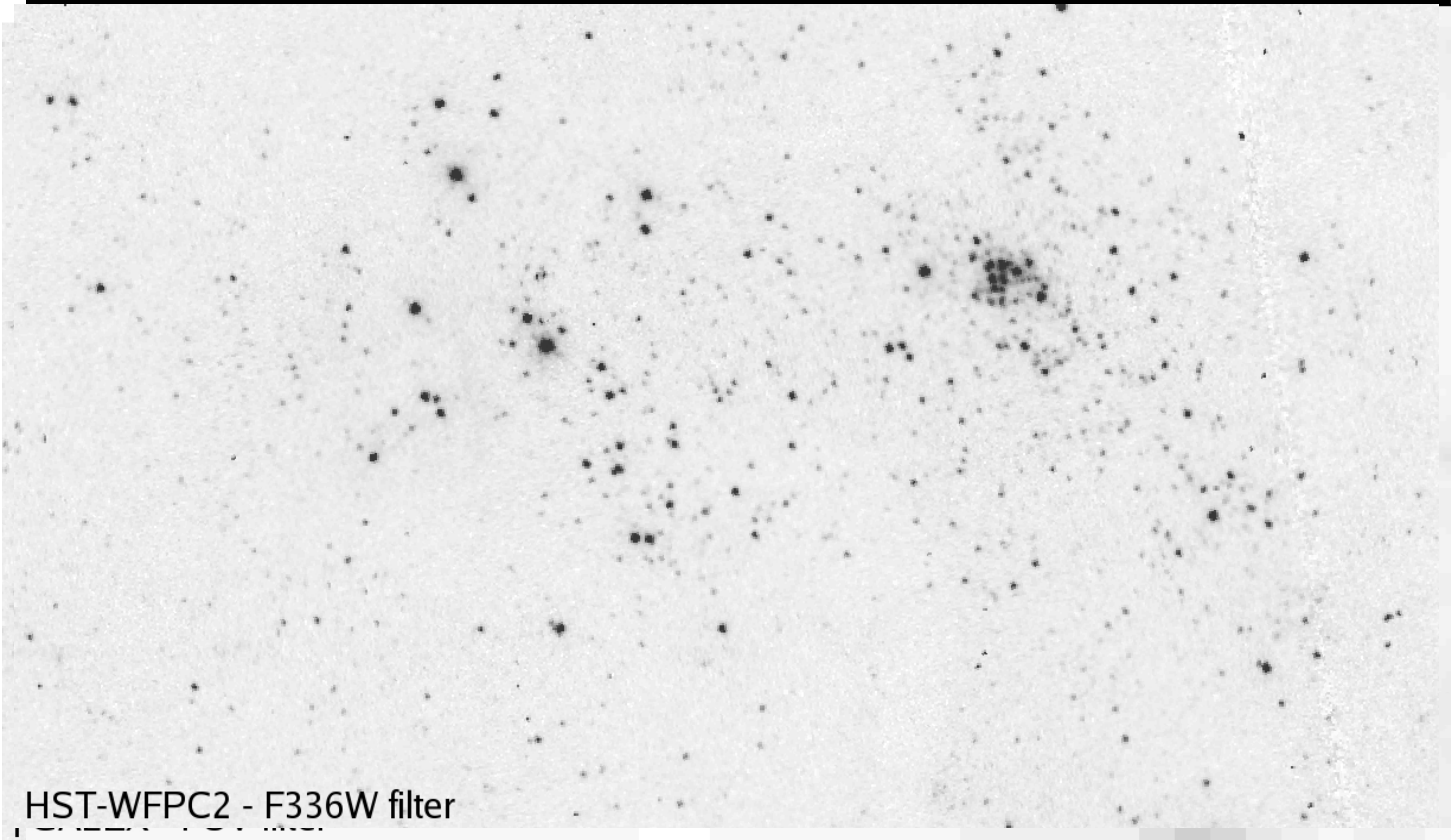


HST is needed for (i) resolving individual stars

Scales: at M31: .26 / 3-5/ 12 pc



Scales at M31: .26 / 3-5/ 12 pc



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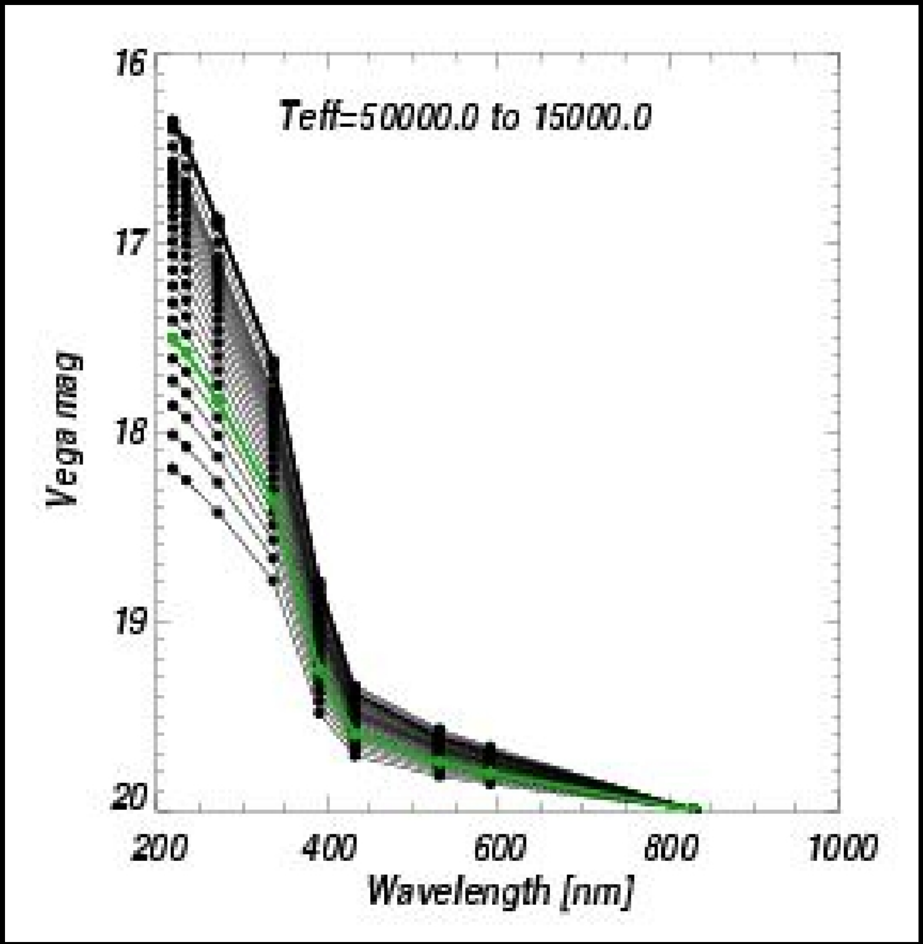
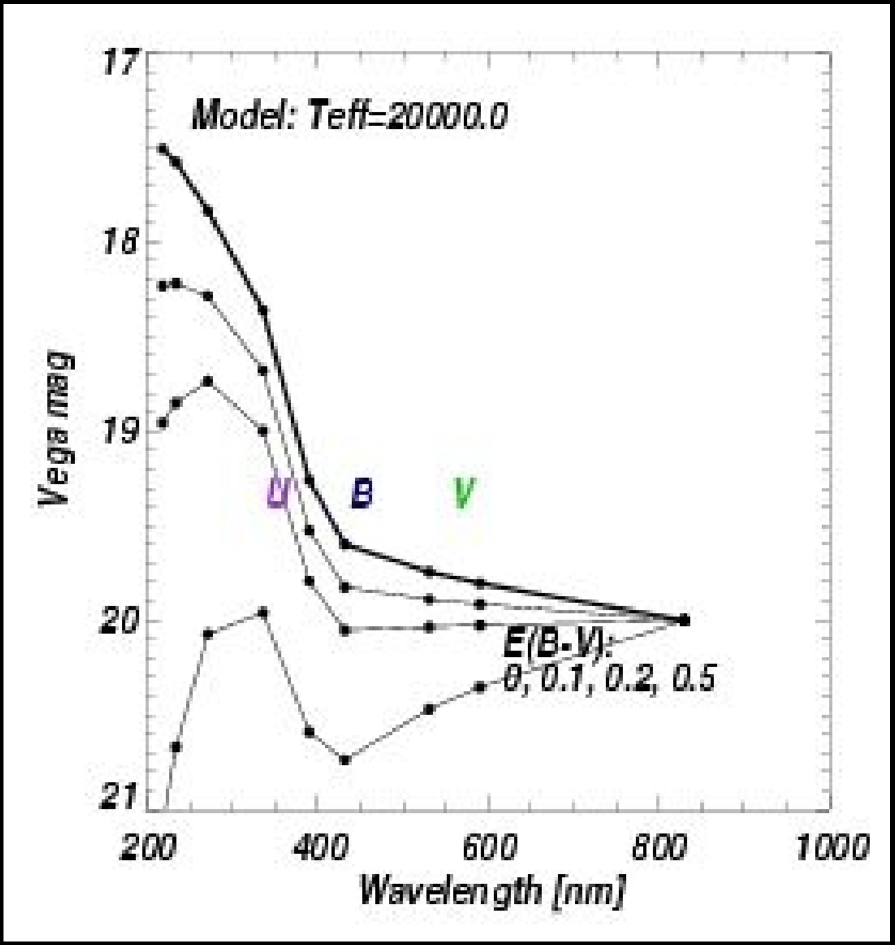
Scales: at M31: .26 / 3-5/ 12 pc

HST is needed for (ii) UV colors sensitive to hot Teff, and help remove Reddening-Teff degeneracy





Stellar models in various HST broad-band filters (Bianchi 2012, 2011)

hot Teff and dust

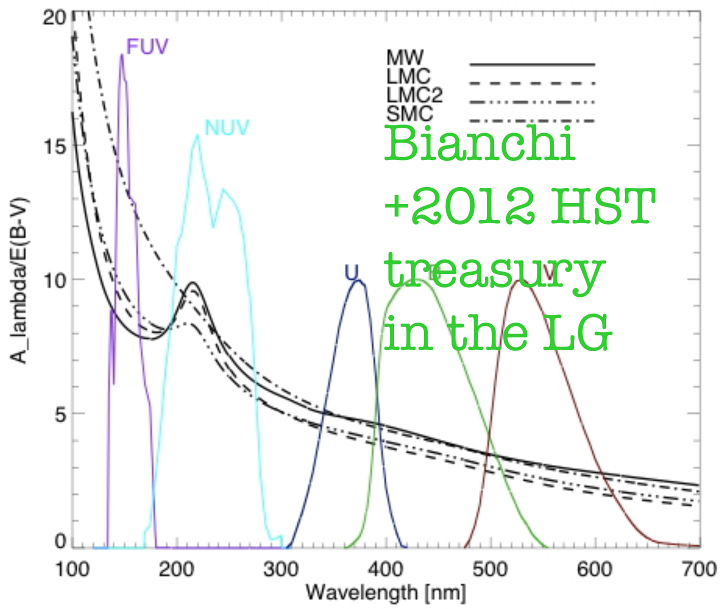


Fig. 4 Selective extinction A_λ/E_{B-V} for some known, and largely differing, types of IS dust, shown with passbands of *GALEX* NUV & FUV, and classical U B V filters (the transmission curves are normalized arbitrarily for visibility).

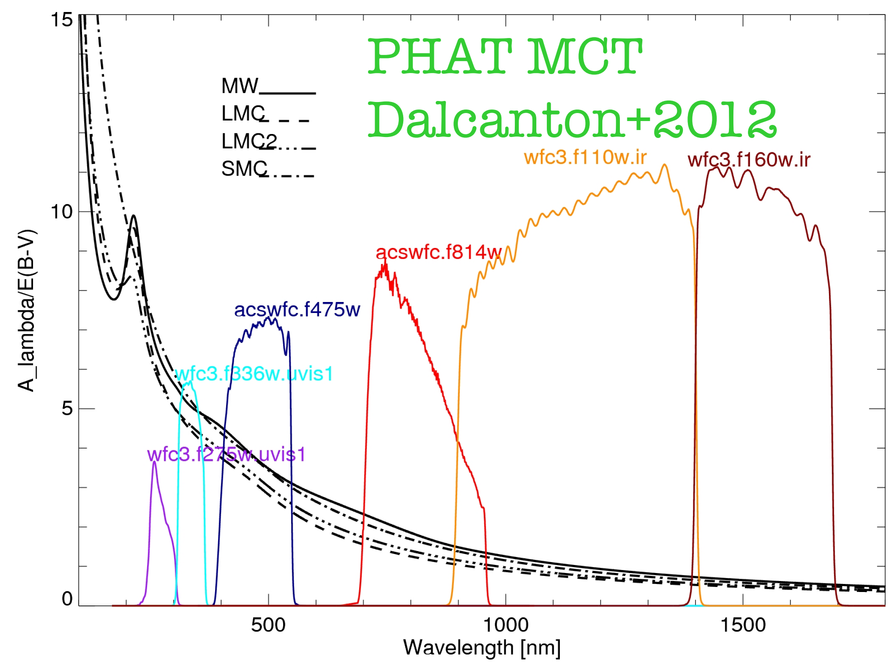


Table 2 Broad-band reddening for different IS dust

	Type of selective extinction[a]			
	MW	LMC	LMC 2	SMC
$E_{FUV-NUV}/E_{B-V}$	0.11	1.08	2.00	4.60
A_{FUV}/E_{B-V}	8.06	8.57	9.02	12.68
A_{NUV}/E_{B-V}	7.95	7.49	7.02	8.08
A_U/E_{B-V}	4.72	3.96	4.11	4.61
A_B/E_{B-V}	4.02	3.26	3.46	3.85
A_V/E_{B-V}	3.08	2.34	2.54	2.93
E_{U-B}/E_{B-V}	0.70	0.70	0.66	0.76

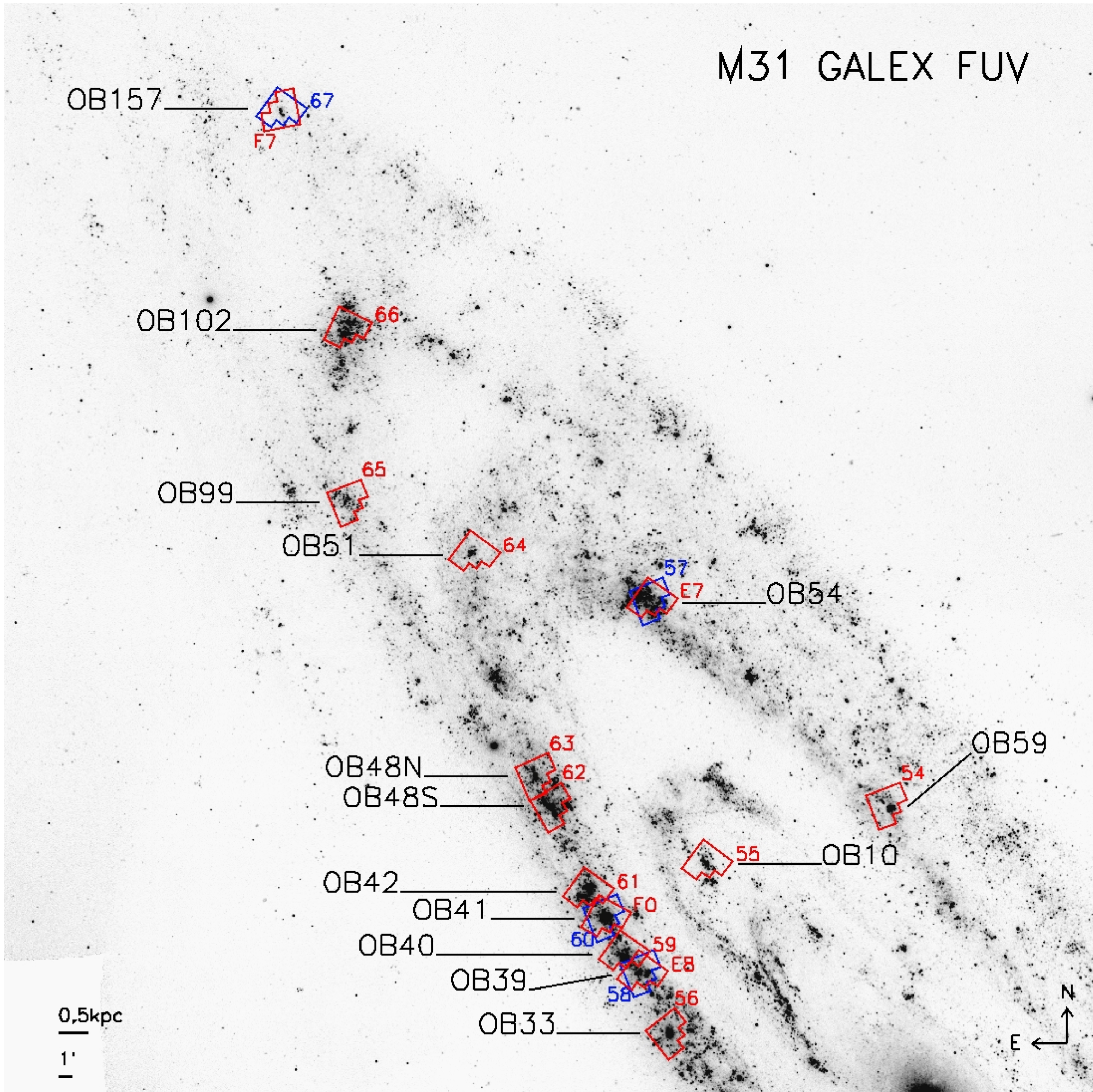
[a] "MW" indicates the typical extinction curve for MW (from Cardelli et al. 1989), for LMC 2 the curve of Misselt et al. (1999) was used, for LMC average dust (outside LMC 2) and SMC, the extinction curves were taken from Gordon & Clayton (1998). The quantities for each broad-band are derived by applying the filter passbands to progressively reddened models for stars with $T_{\rm eff}$ between 30,000K and 15,000K, and comparing unreddened and reddened model colors with E_{B-V} =0.4. The mean values are given, the dispersion is always less than 1% within this $T_{\rm eff}$ range)

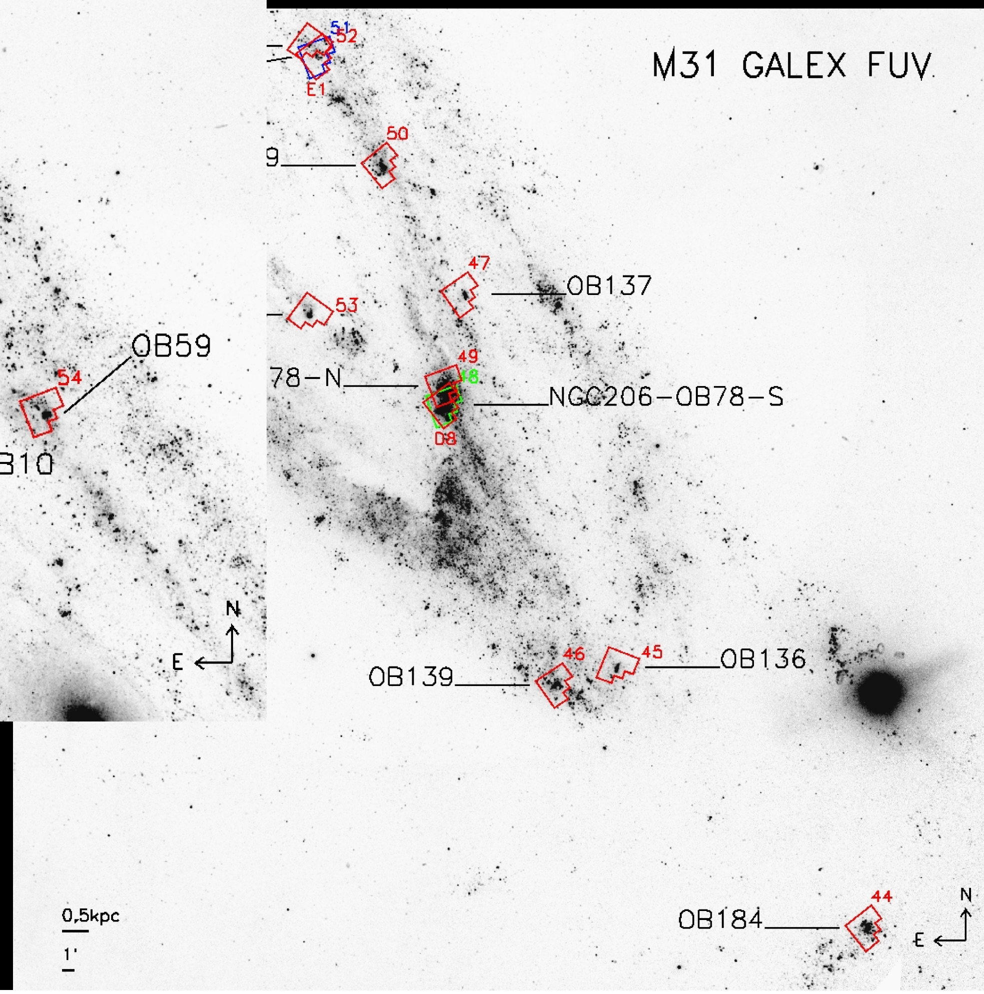
Sensitivity to Teff, E(B-V) and type of selective extinction

Bianchi 2011
ApSS 335 51

L Bianchi
Princeton June 2012

Bianchi HST treasury





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Bianchi HST treasury

.3x30fields ~9kpc^2

Bianchi et al 2012, AJ

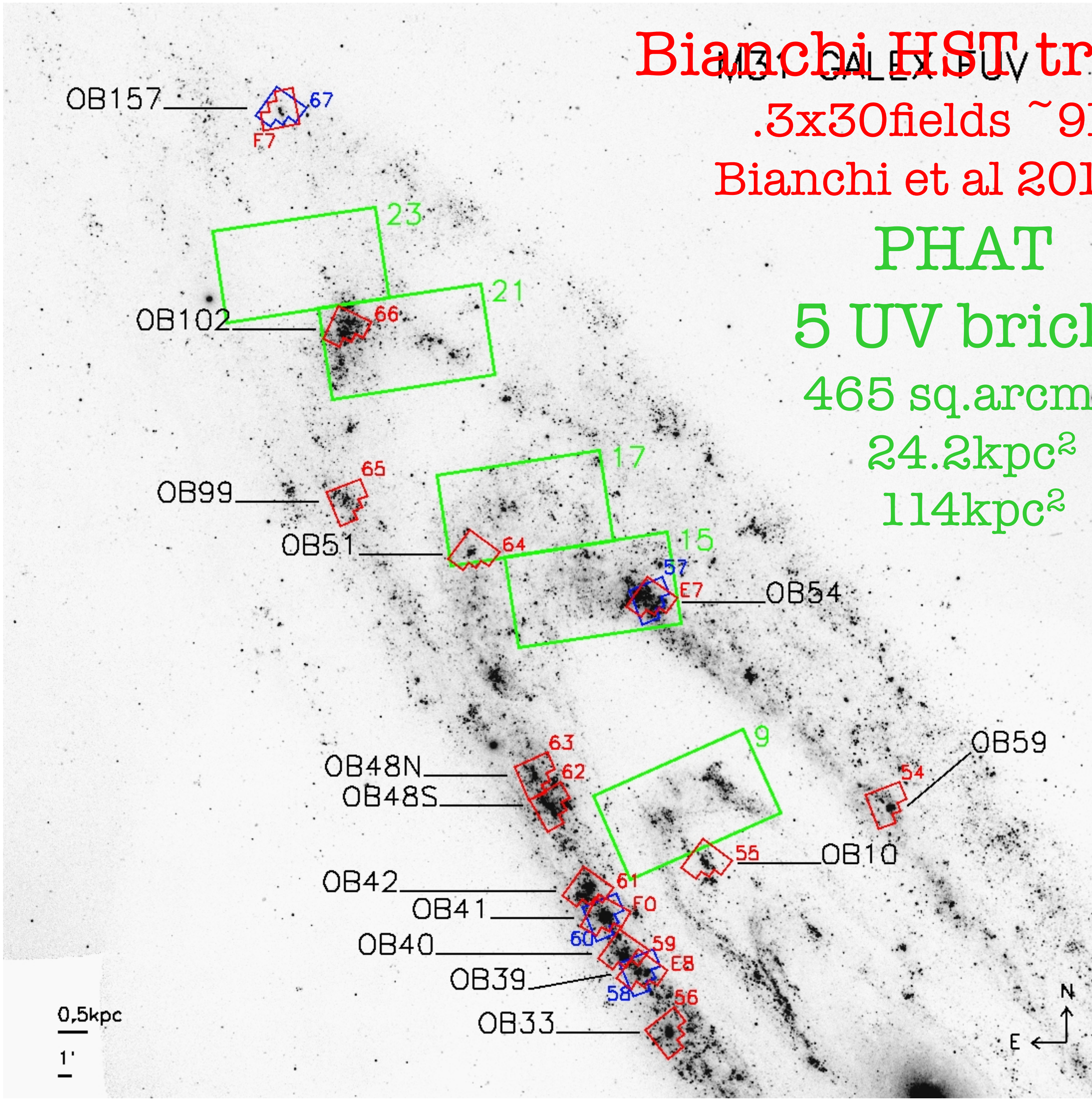
PHAT

5 UV bricks

465 sq.arcmin

24.2kpc^2

114kpc^2



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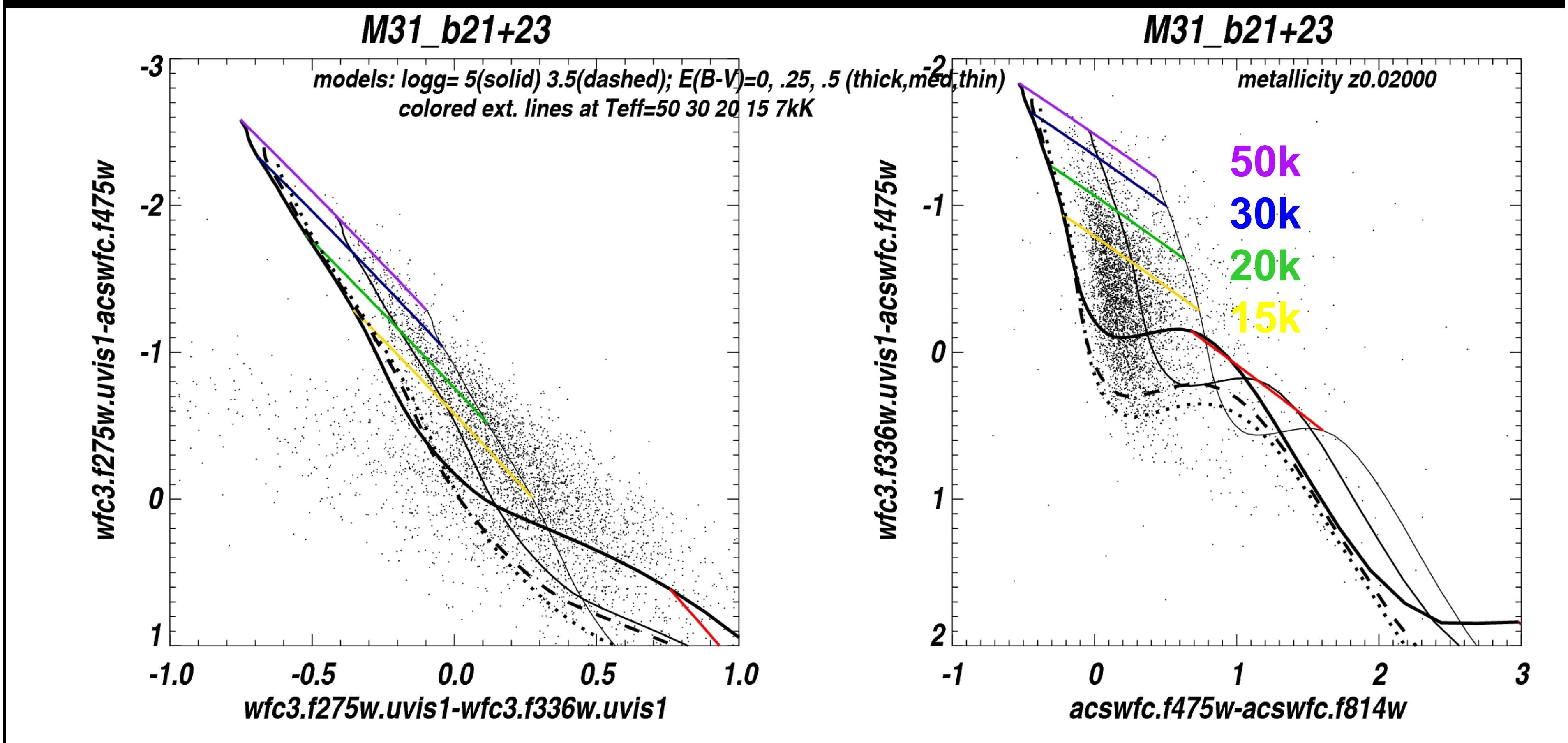
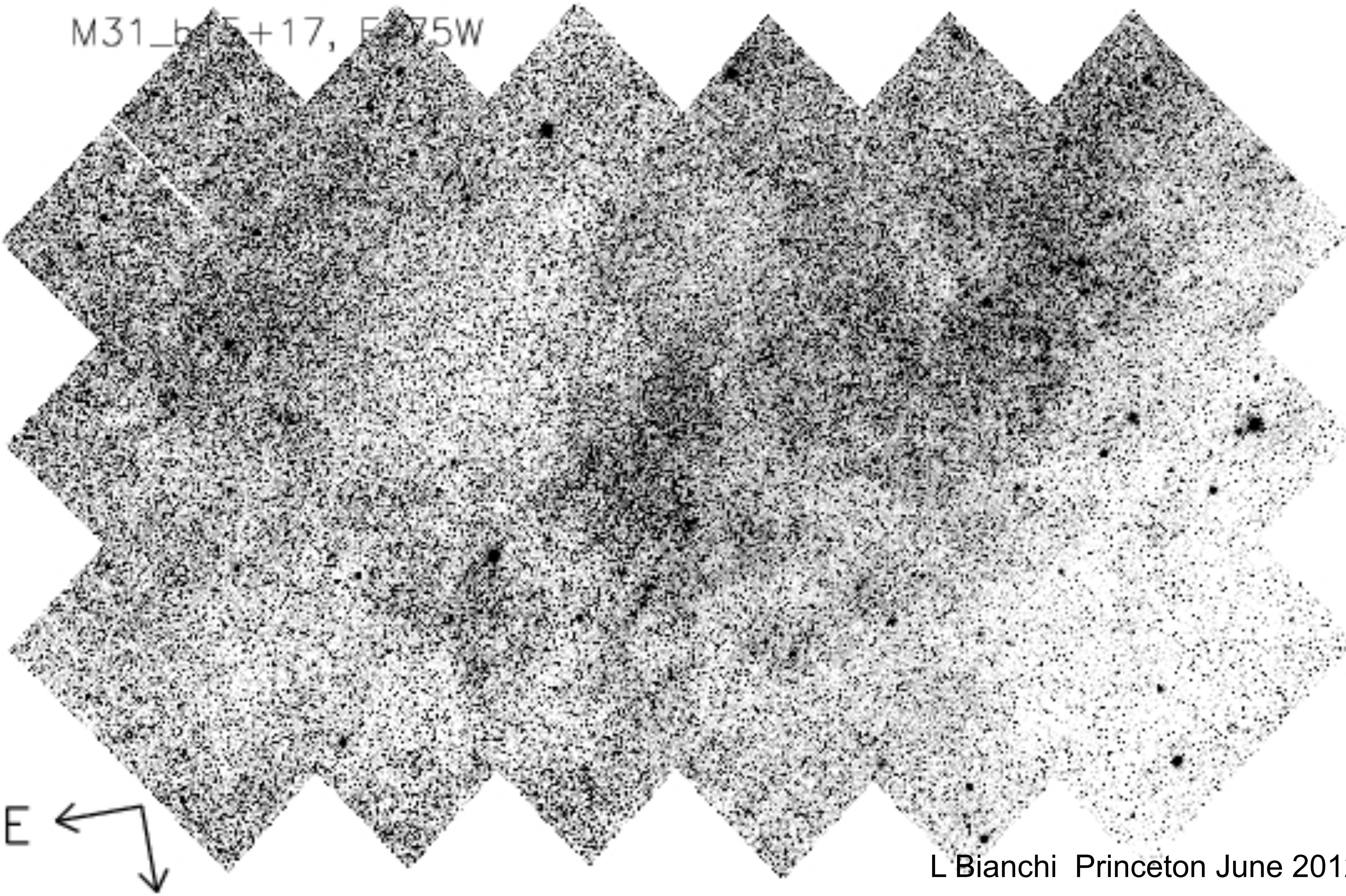
UV bands improve sensitivity to hot Teff and extinction



PHAT Brick 15 : we analyse SED of single stars



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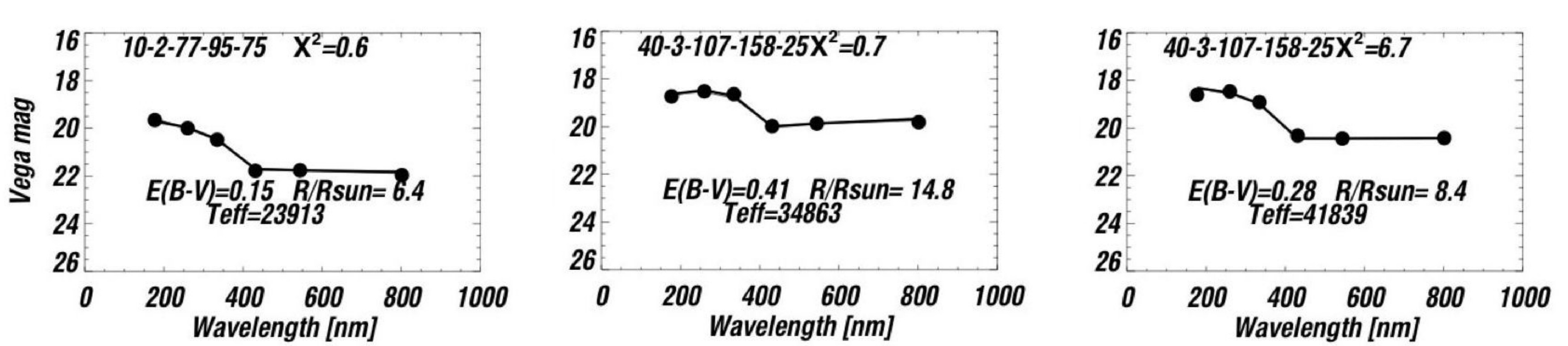
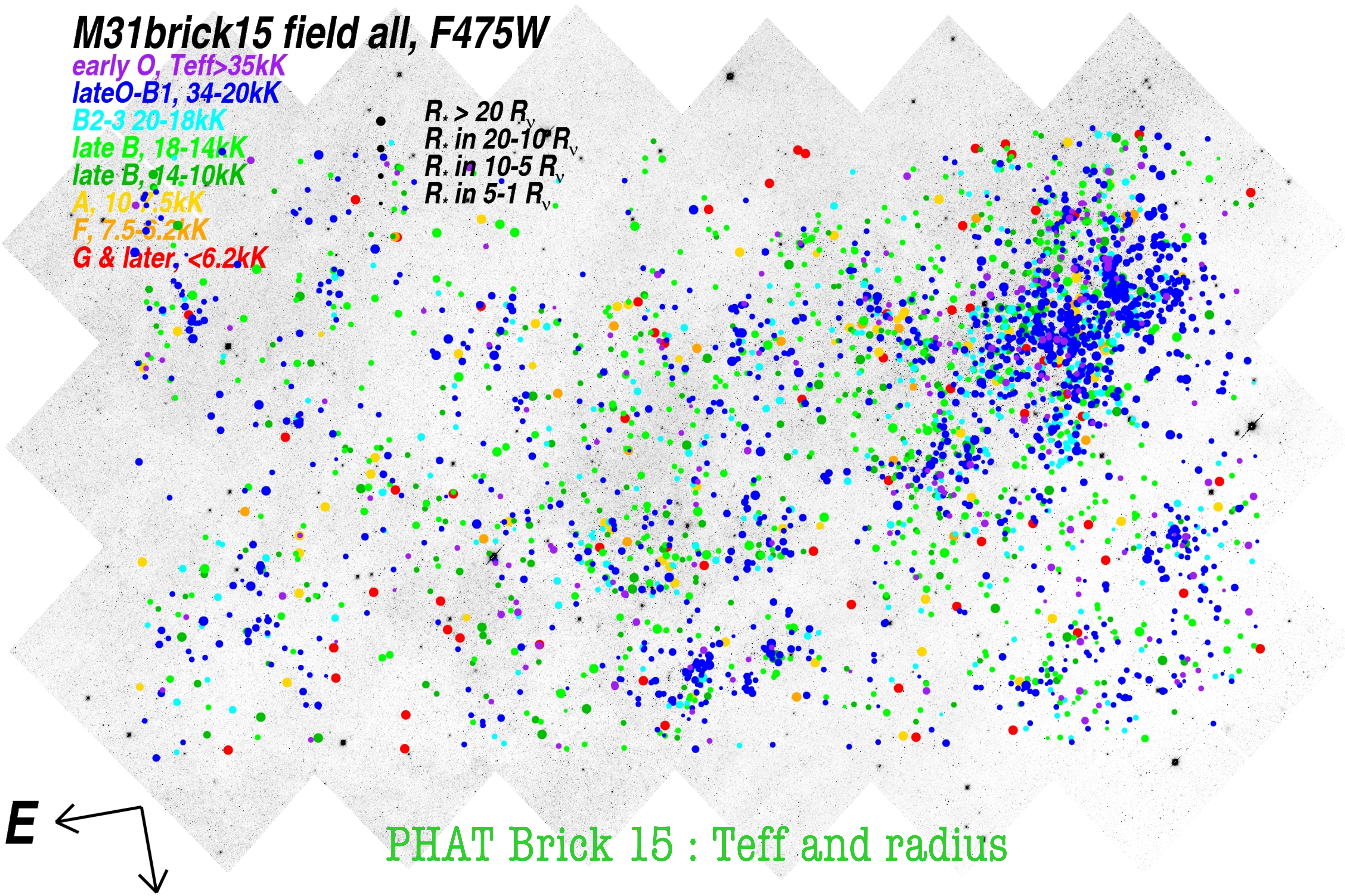
SED fitting → Teff, E(B-V) → Radius, Lbol

Results depend on metallicity or extinction type





PHAT Brick 15 : Teff and radius

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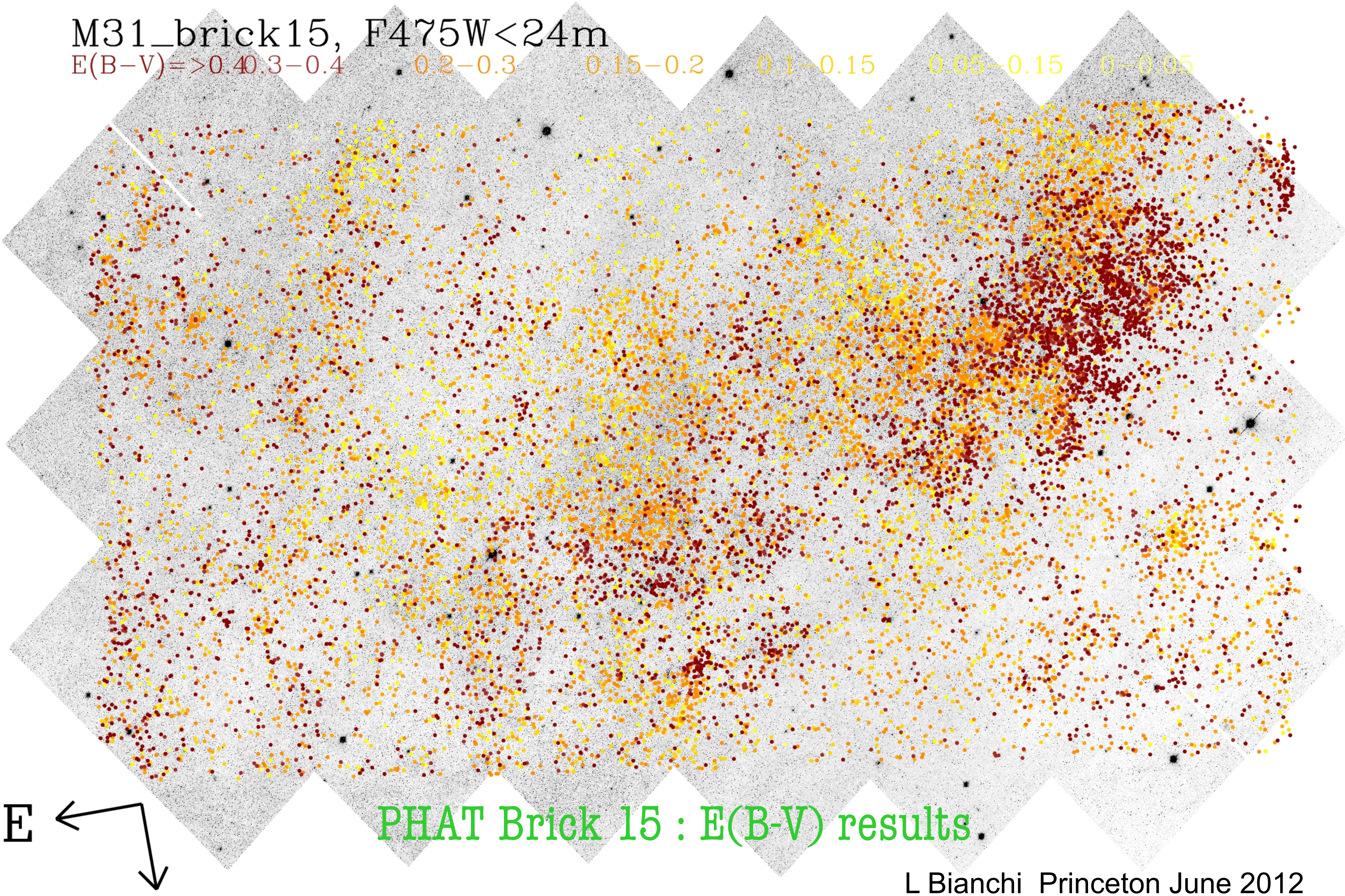
[redacted]



PHAT Brick 15 : E(B-V) results

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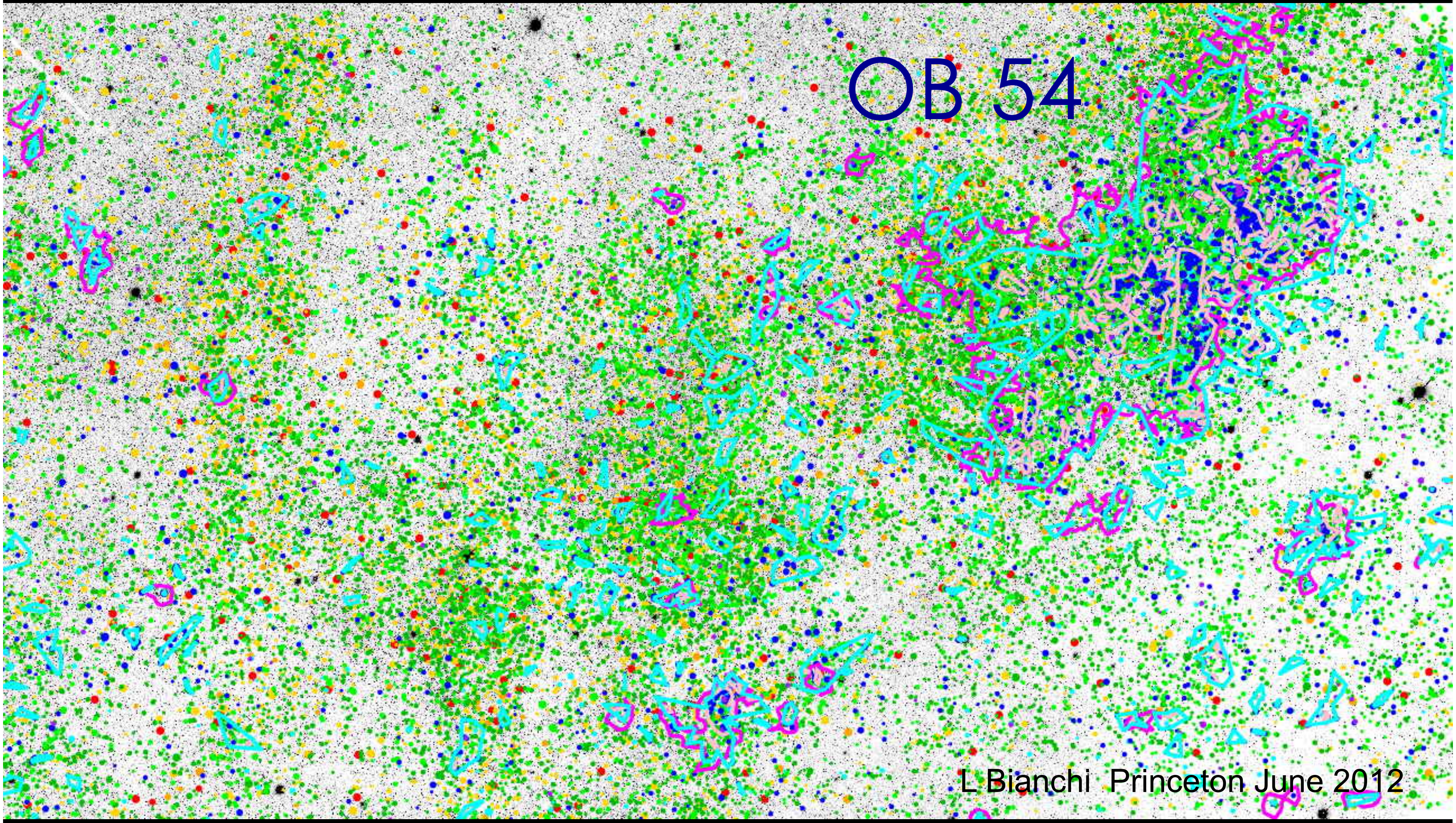
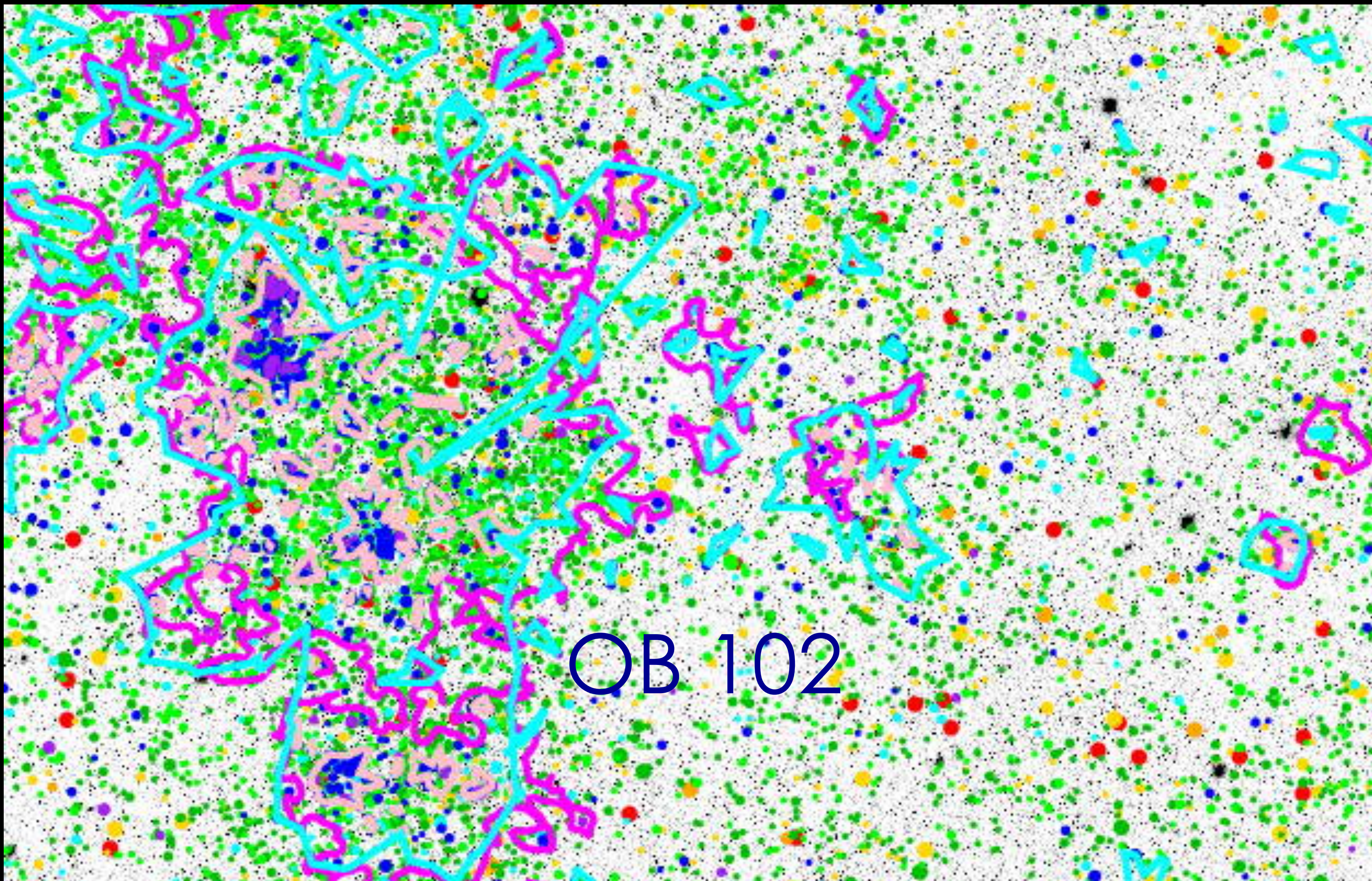
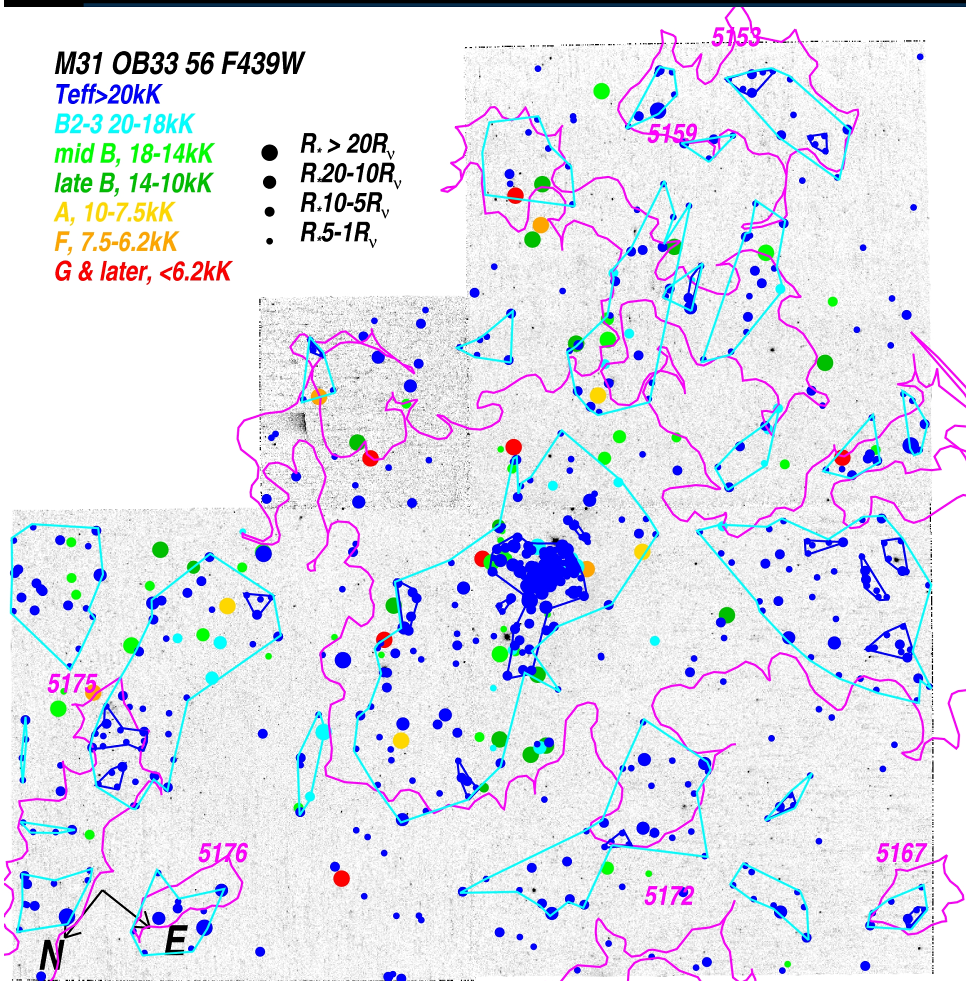
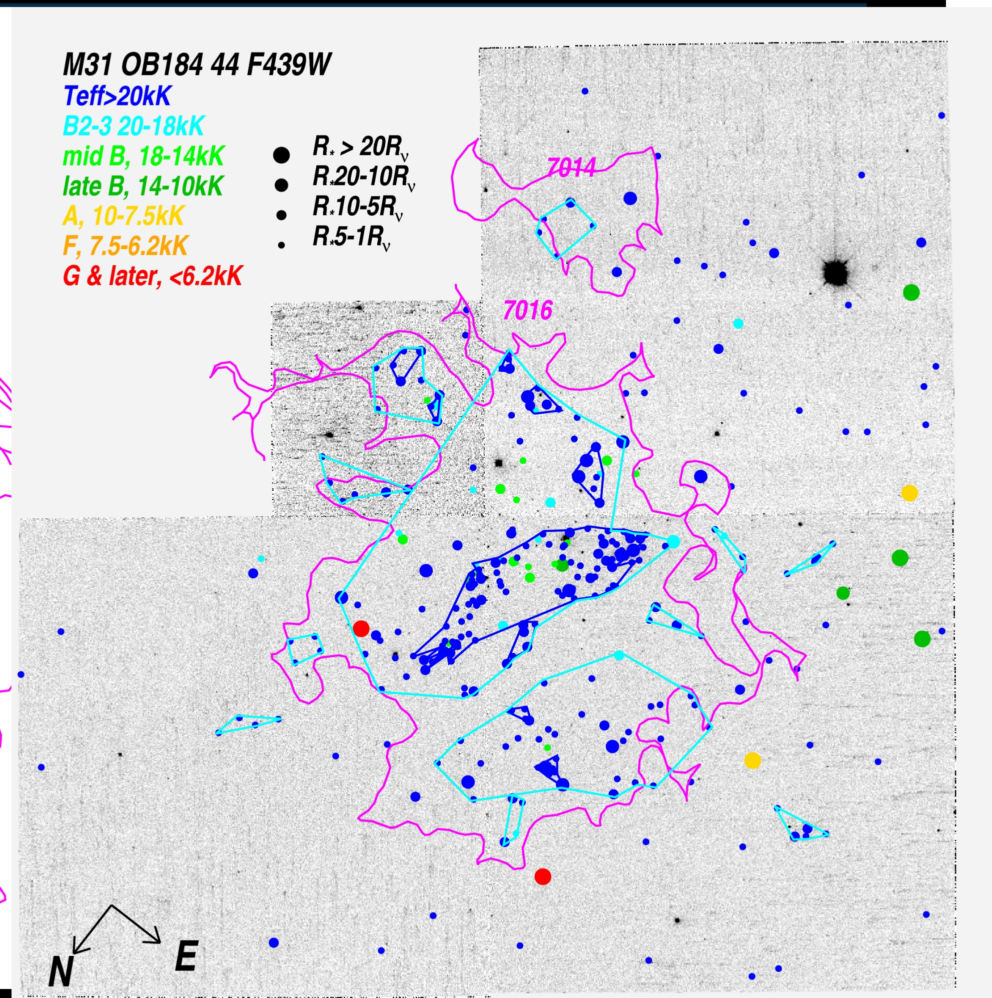
Clustering of hot stars: compact groups arranged within large complexes: contours of OB associations (ld=3 pink, 6 cyan) from Bianchi et al




OB 102

Clustering of hot stars from Bianchi treasury fields





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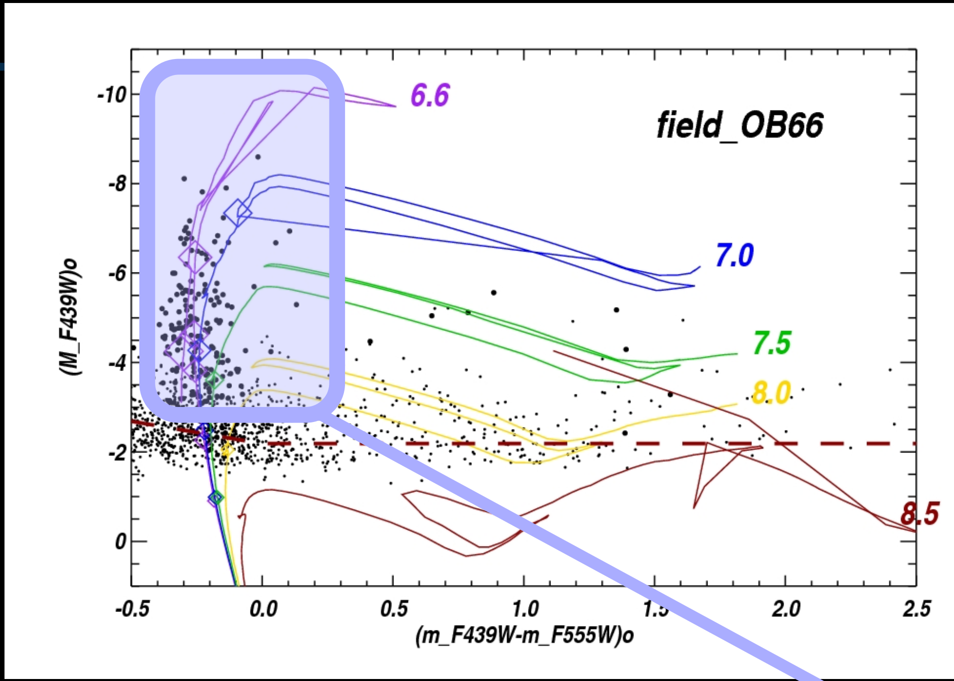
Mass from stellar content



stars to ~8Msun (B3V)

IMF

Mass of association 0.1-Mup

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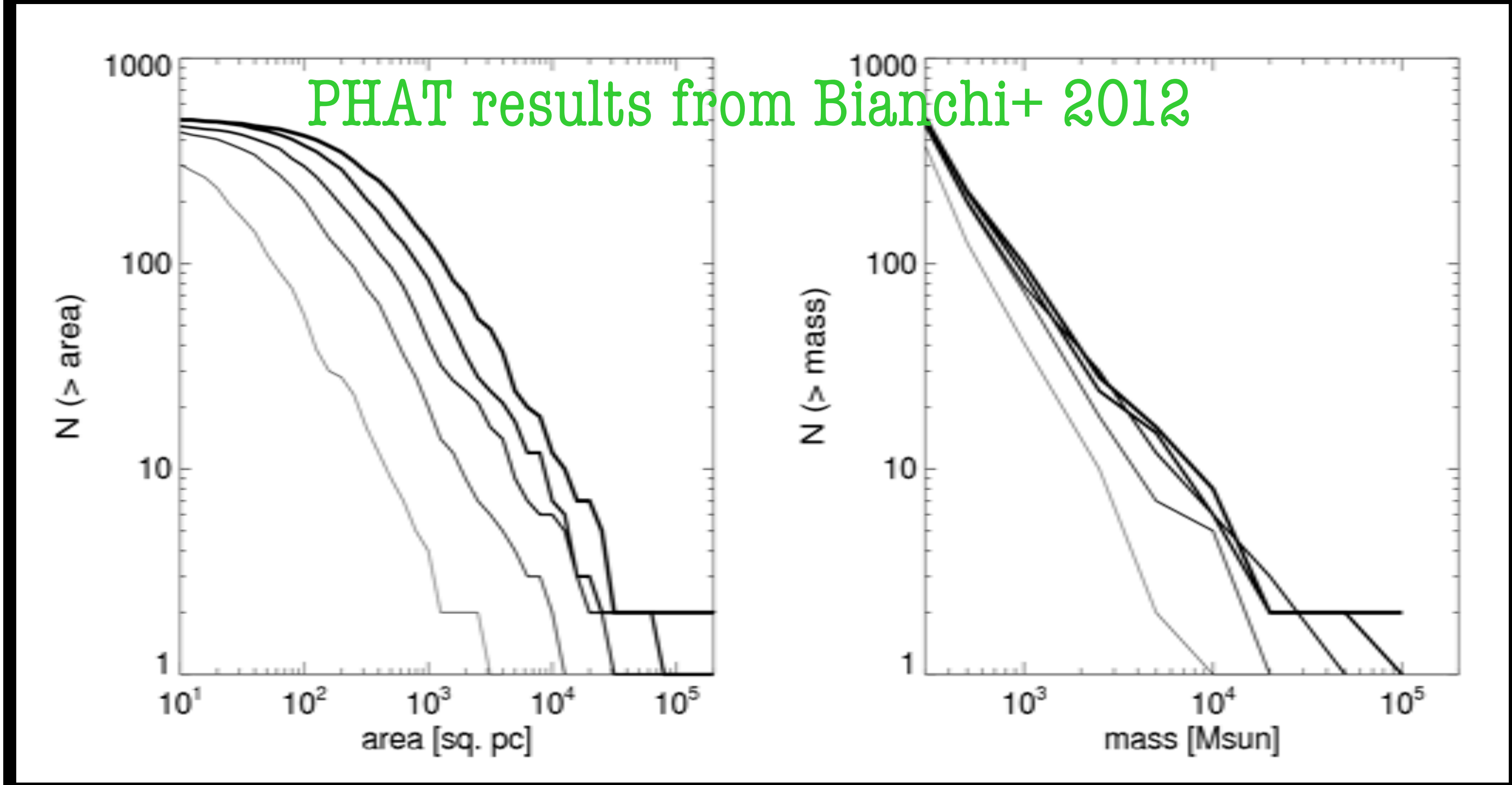
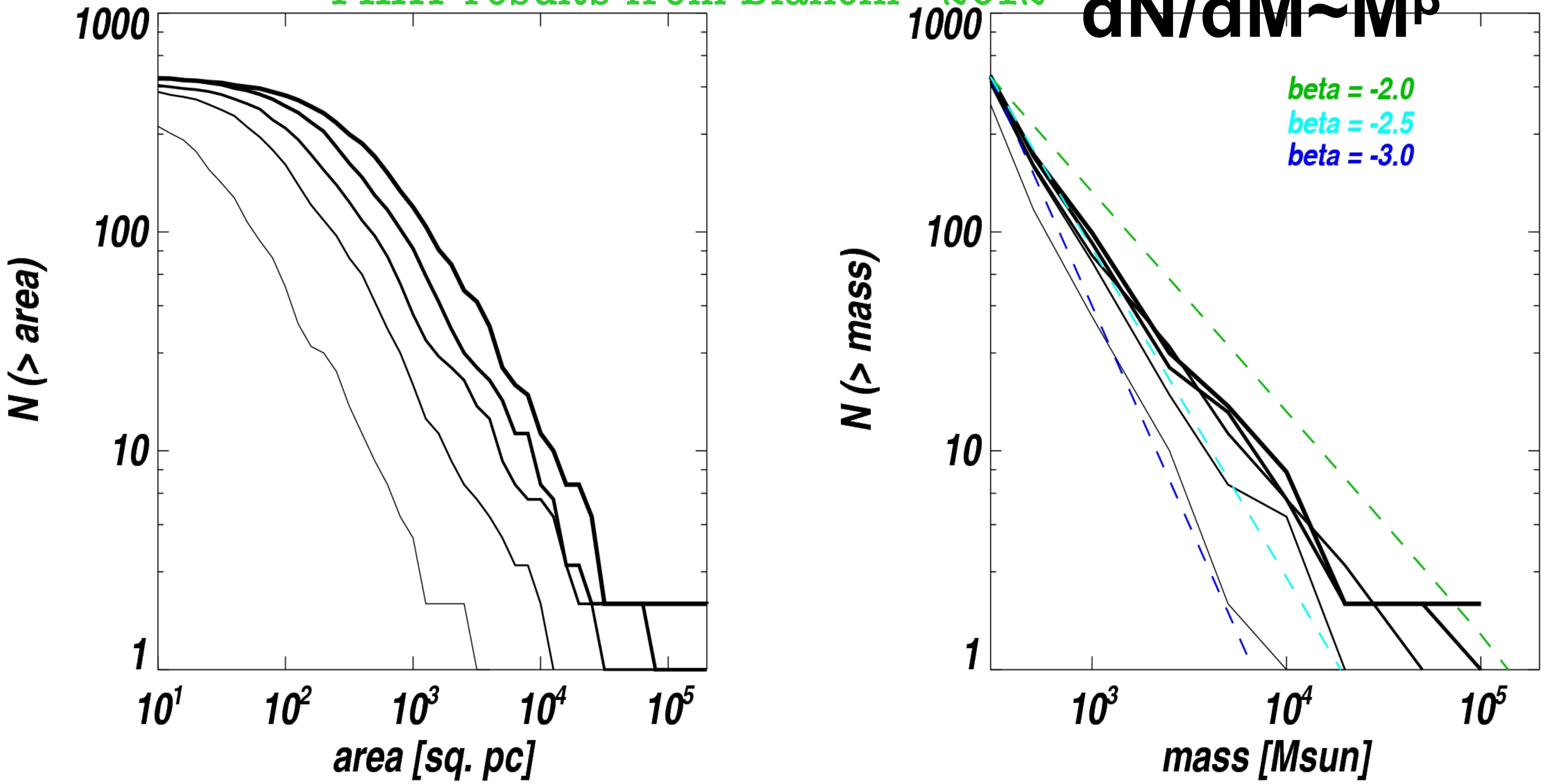
Is the mass function universal?



Is the mass function universal?

PHAT results from Bianchi+ 2012

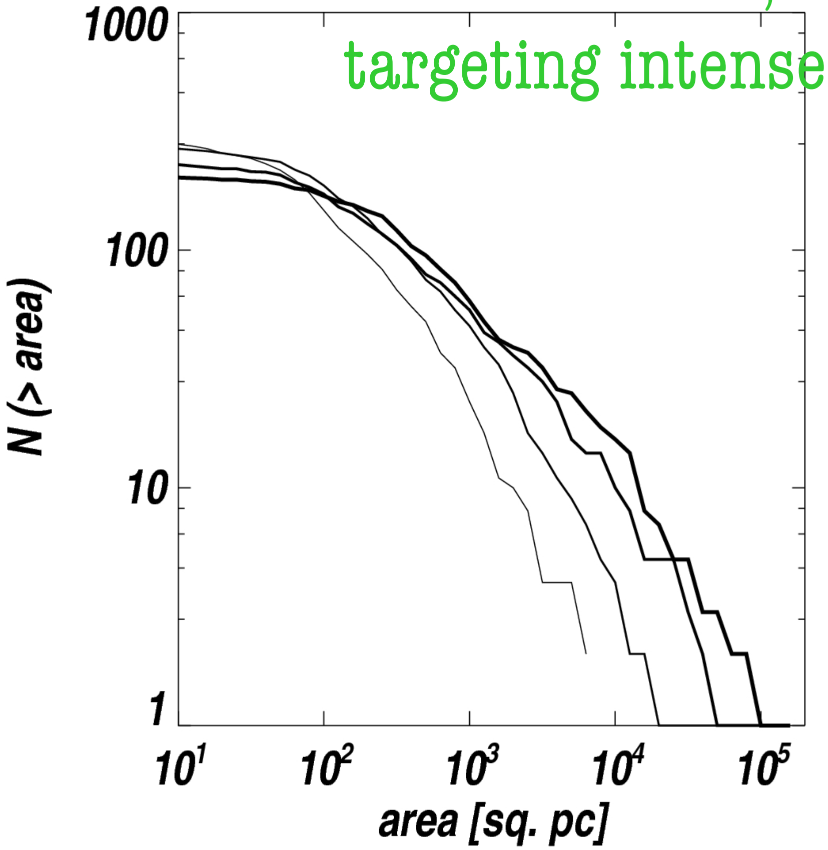
$dN/dM \sim M^{\beta}$

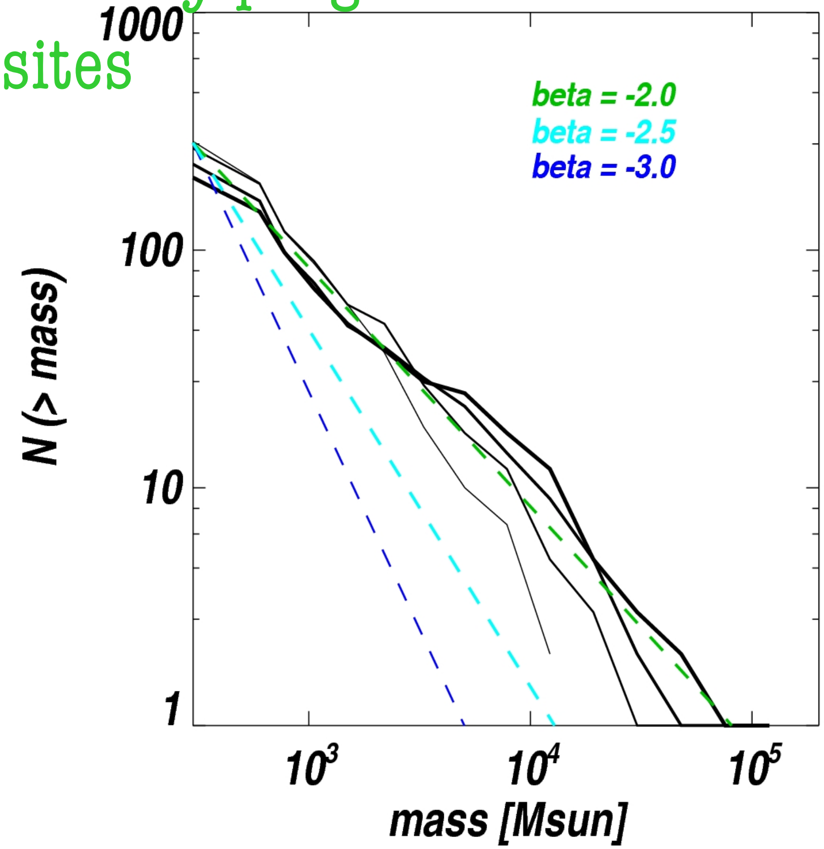


For stellar clusters β ~-2 (Zhang & Fall 1999, Lada&Lada2003, Hunter+2003 β -2.3

Is the mass function universal? does it depend on environment?

results from Bianchi+ 2012, AJ: treasury program targeting intense SF sites



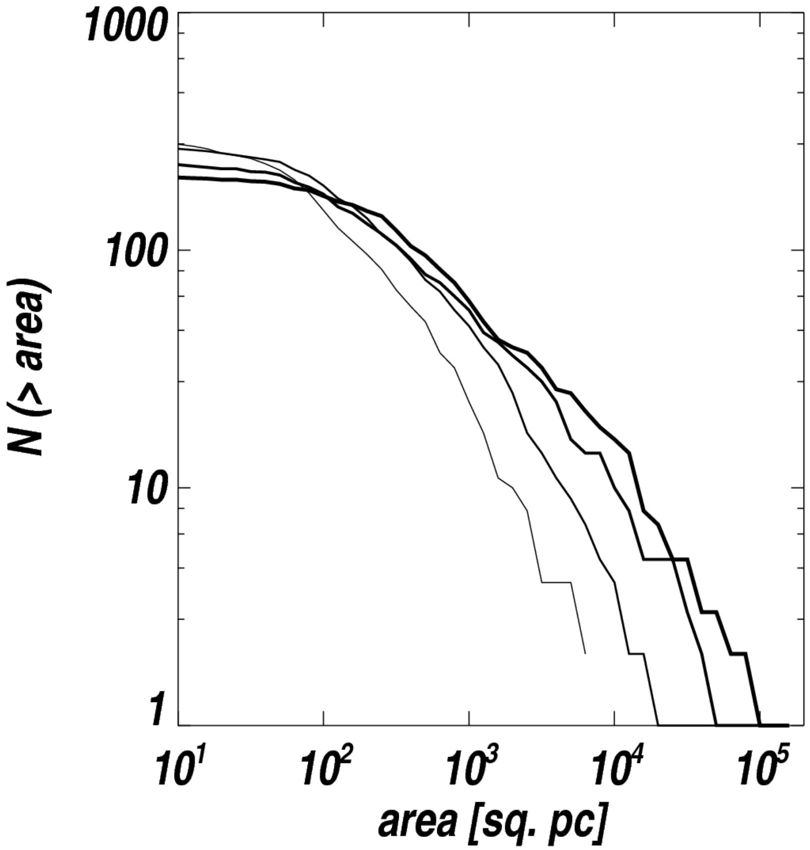


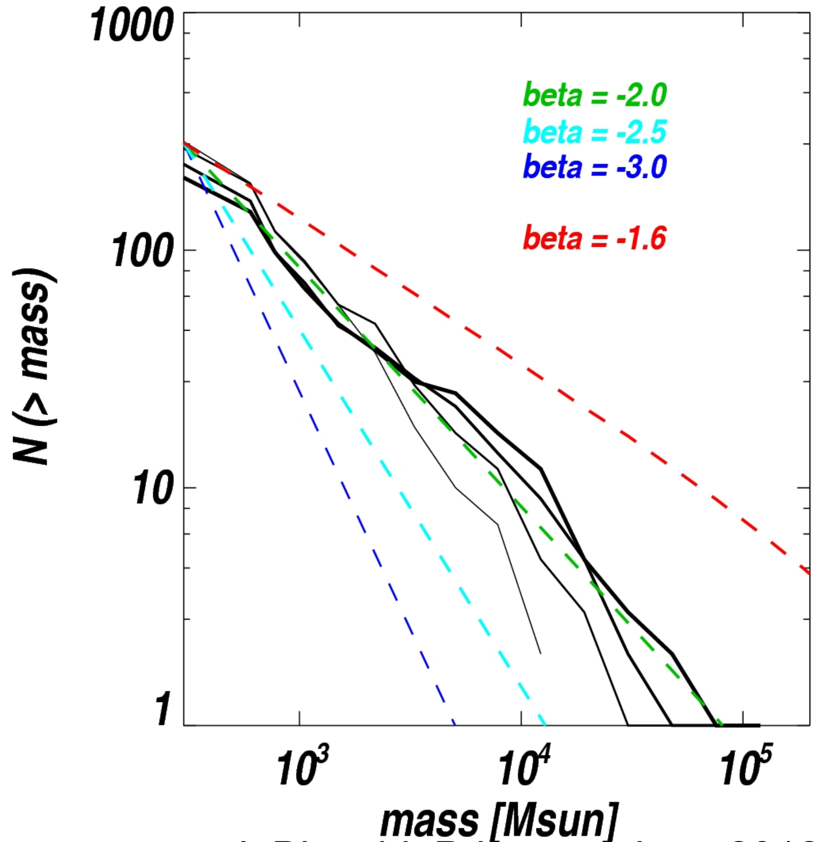
GMC (the parents) also power laws

Muller+2008 CO map IRAM 23"—90pc (of Nieten+2006) plus PdBI 4"-0.8"—15-3pc): β=-1.6

HELGA (Herschel) Fritz+2011, Smith+2012;

BIMA: Blitz+2006: (resol. 26-36pc): β=-1.55 +/- 0.2





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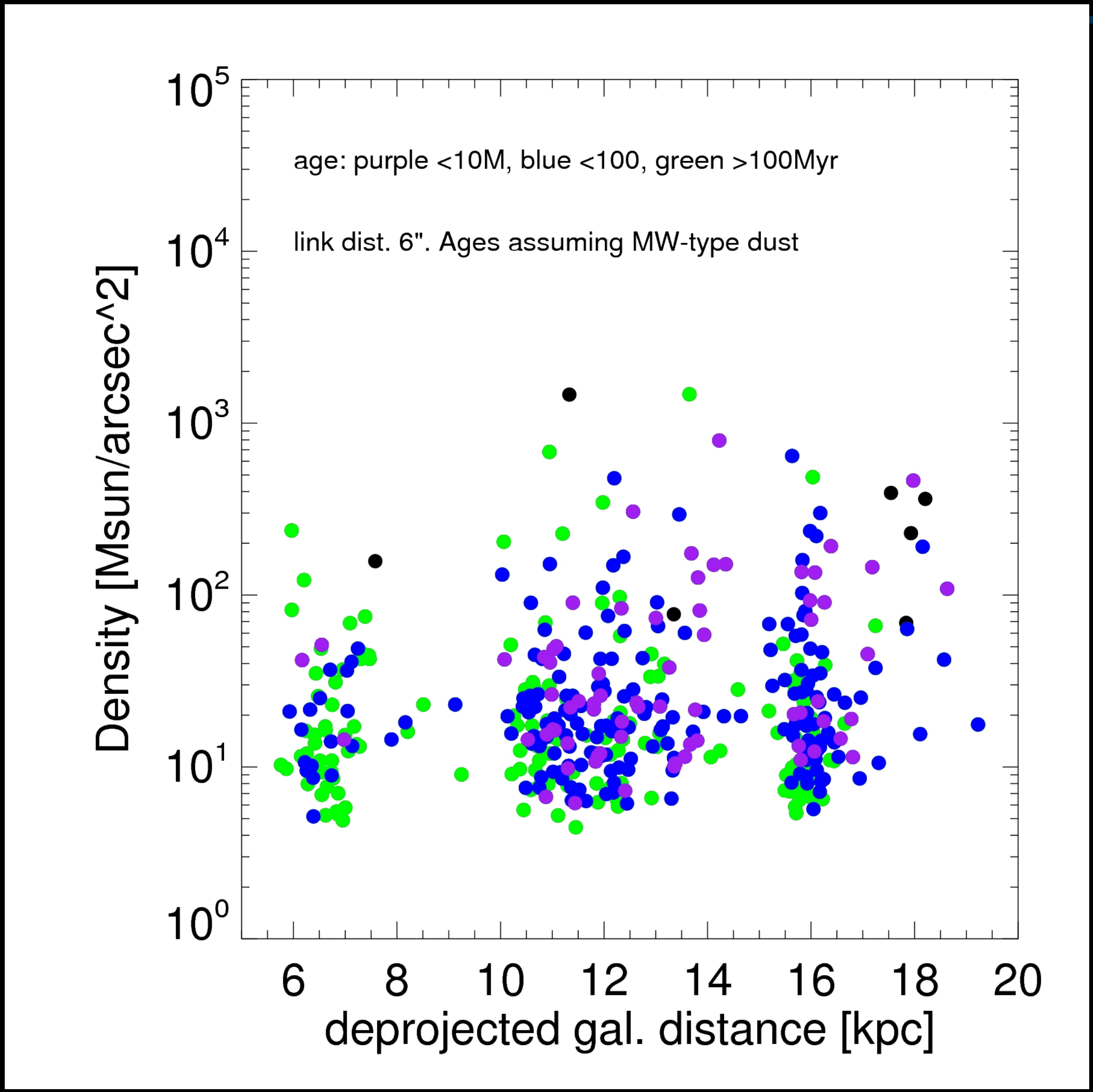
Ages: are the more compact associations younger?



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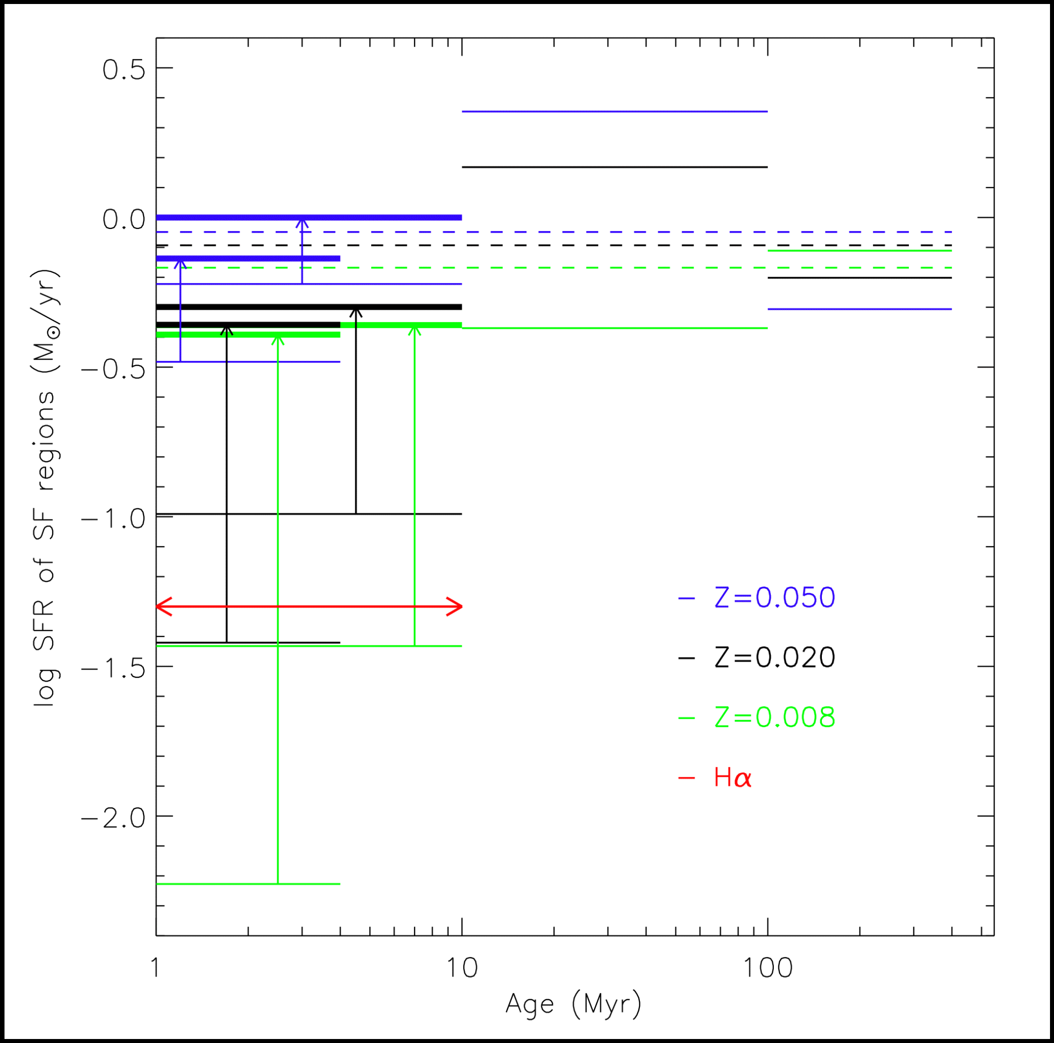
SFR: M31 results depend on ext.type, metallicity



Kang et al. 2009, ApJ, 703, 714

Over a 26kpc rad: ~4 10^{-4} Msun/yr/kpc^2 (Kang+ 2009)

From PHAT: SFR density ~ 10 / 5 10^{-4} Msun/yr/kpc^2 (projected/ deprojected over 114 kpc^2) (Bianchi +2012)

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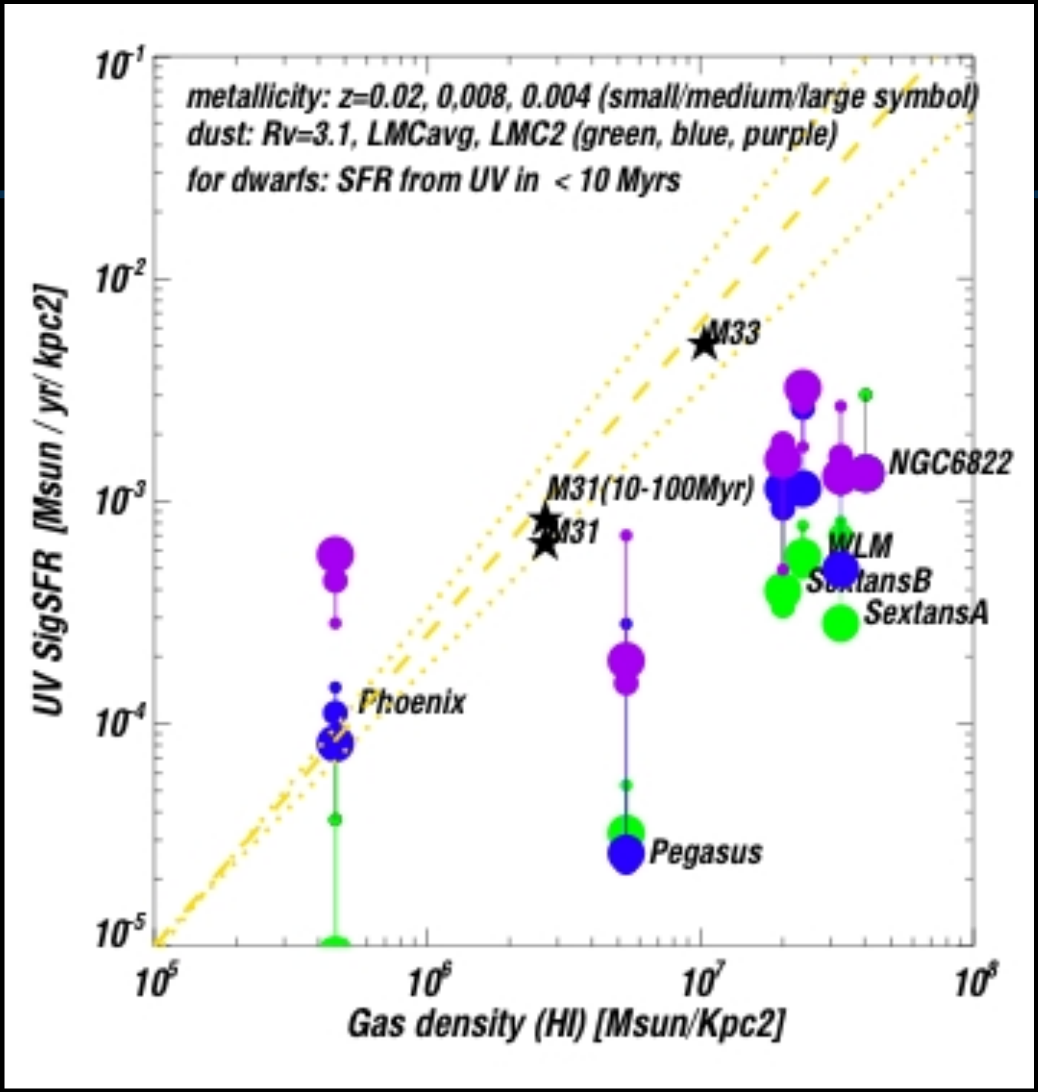
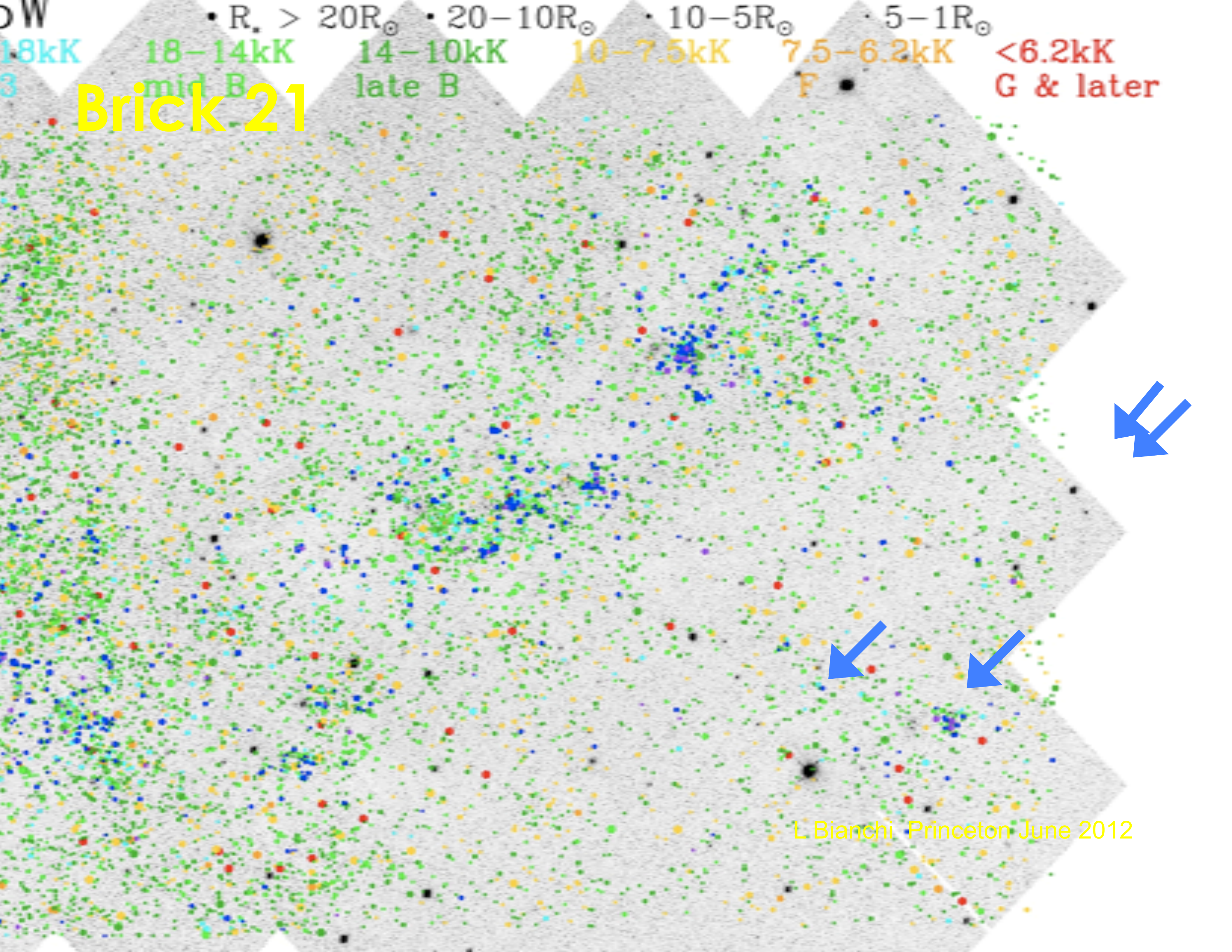
M31 SF efficiency 2x MW



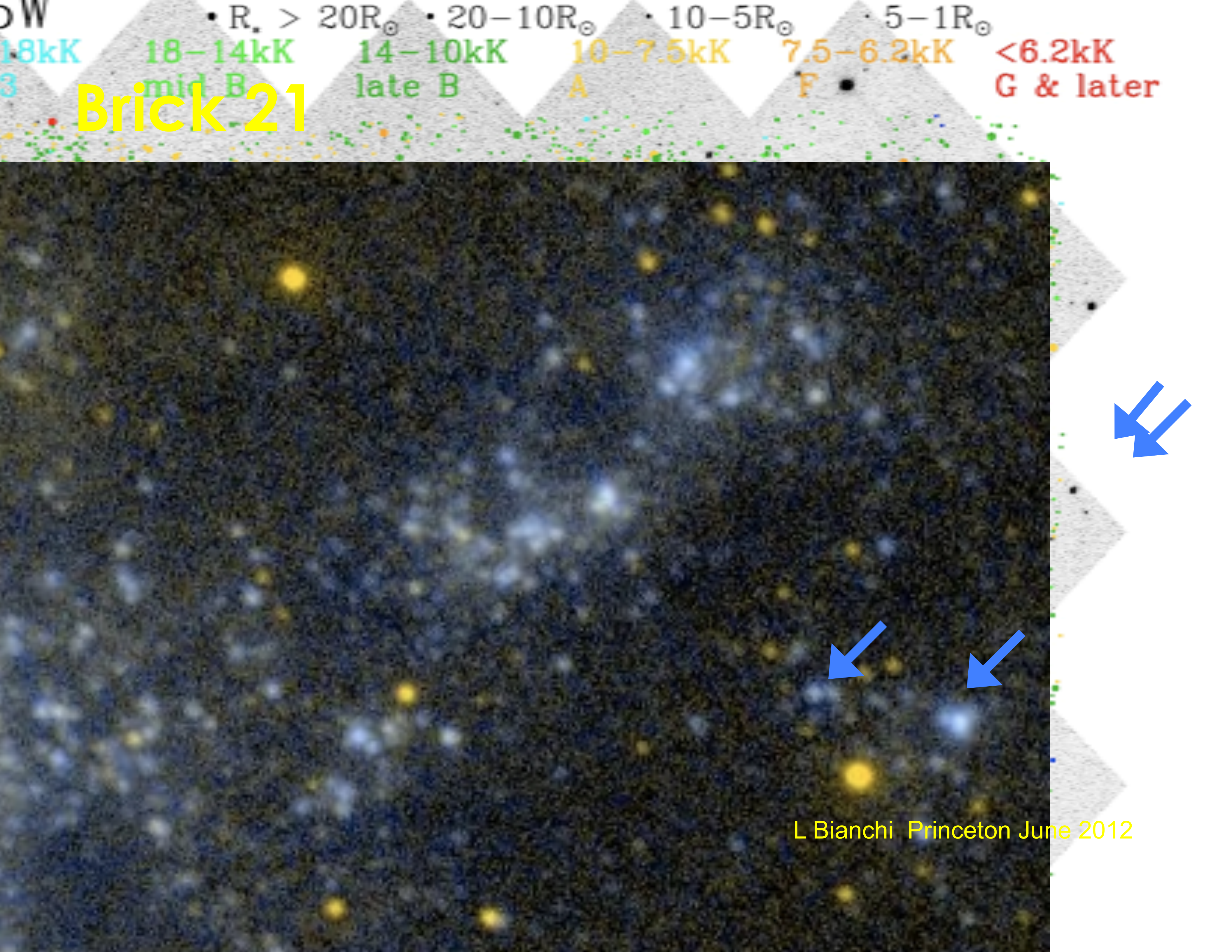
Sensitivity of the results to reddening (dust type) and metallicity: example from the LG dwarfs (Bianchi et al. 2011 ApSS, 2012, AJ).
The Kennicutt law (yellow) was defined for disk galaxies.

Next steps and goals:

- Spectroscopy : follow up to HST photometry (PHAT team: GuhaThakurta, Dalcanton, Weisz..)
- to find recipe & calibrate SFR indicators (UV, Halpha, and 'combined' indicators like UV+IR)
- Multi-scale, multi-wavelengths
- IMF (S.Weisz in PHAT team, ...), SFH
- Understanding co-evolution of dust & SF : how does SF work where and when



W
• R* > 20R⊙ • 20−10R⊙ • 10−5R⊙ • 5−1R⊙
18kK 18−14kK 14−10kK 10−7.5kK 7.5−6.2kK <6.2kK
mid B late B A F G & later
Brick 21
L.Bianchi Princeton June 2012



• R. > 20R⊙ • 20−10R⊙ • 10−5R⊙ • 5−1R⊙
18kK 18−14kK 14−10kK 10−7.5kK 7.5−6.2kK <6.2kK
mid B late B A F G & later
Brick 21
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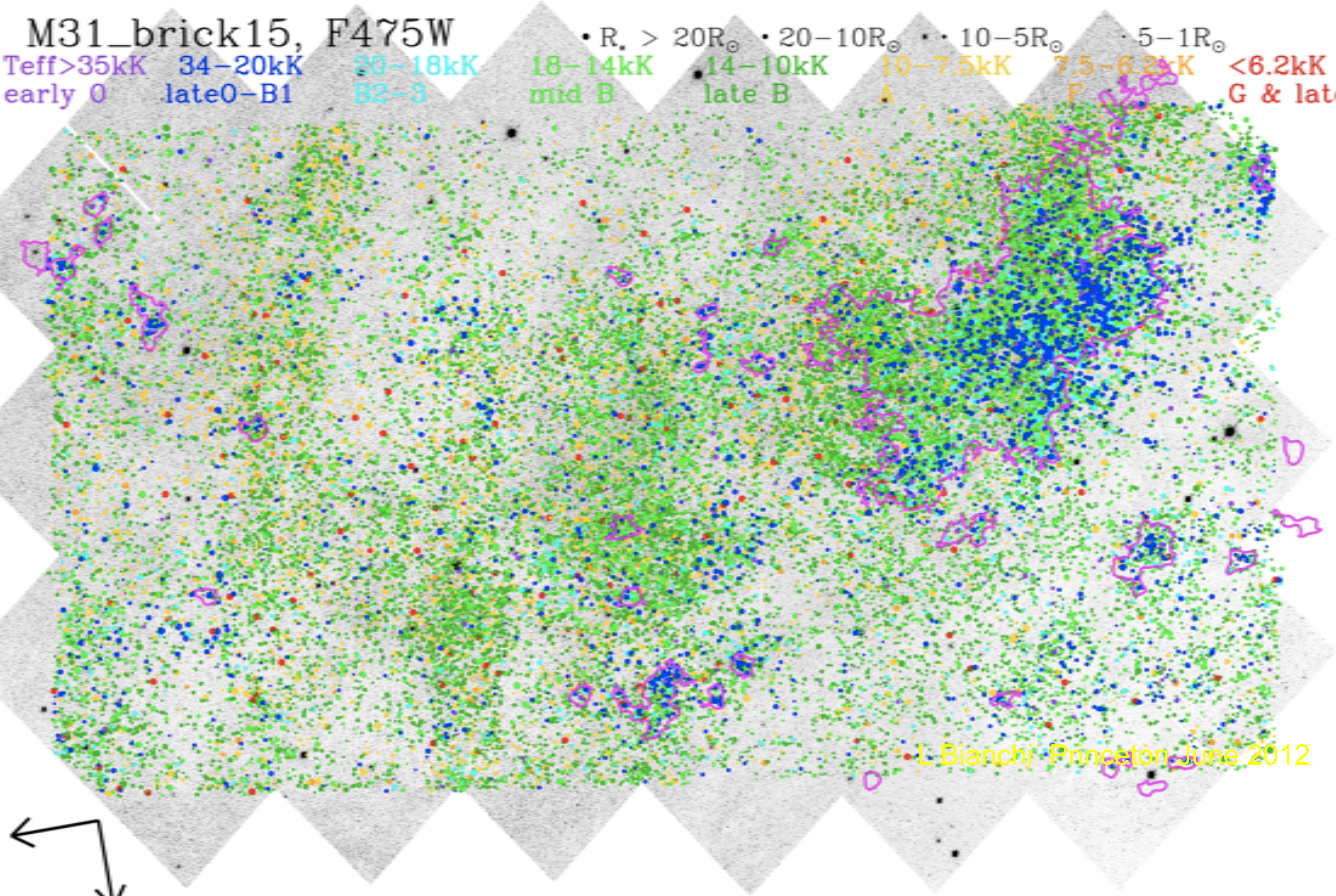
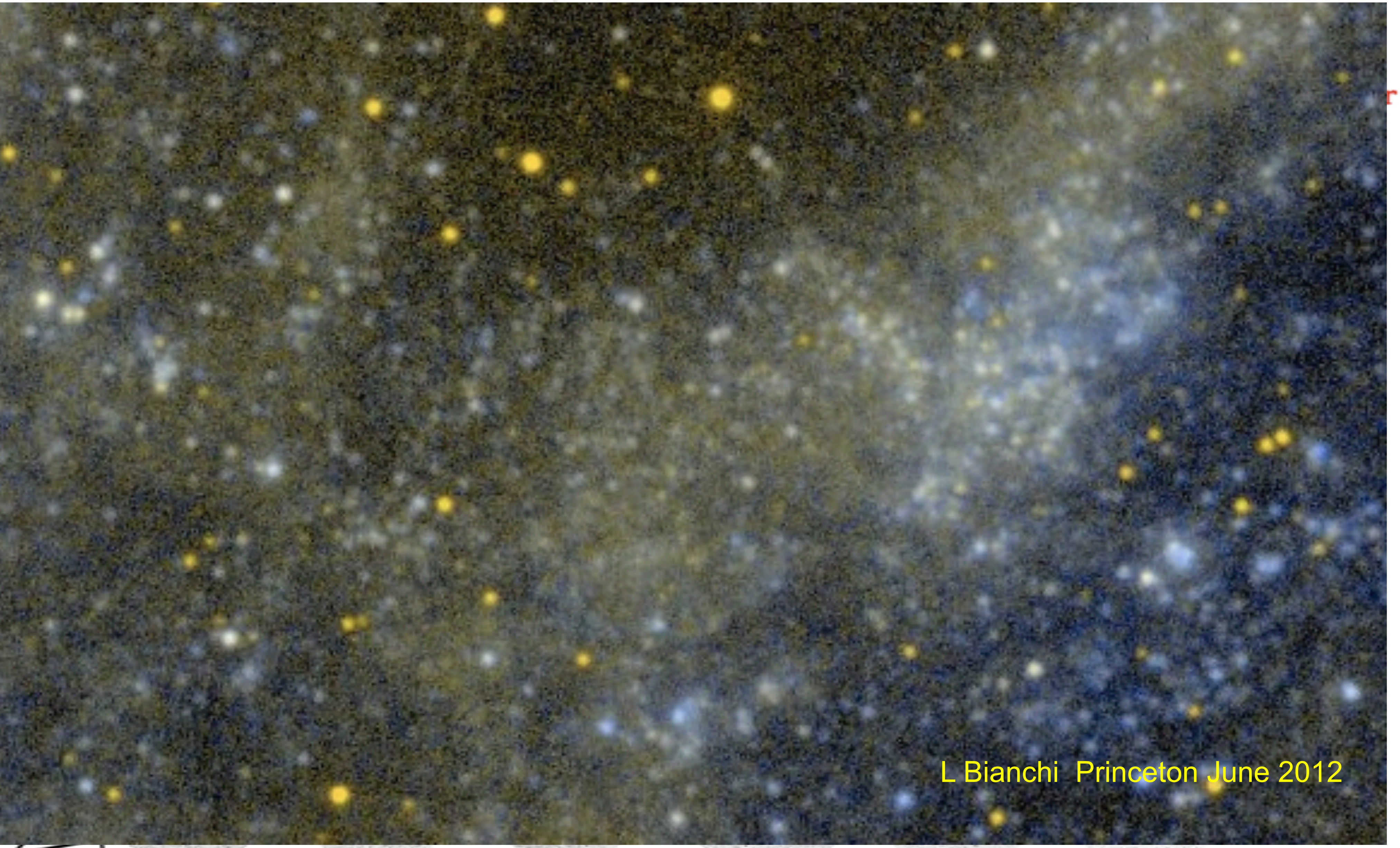
Brick 15 GALEX SF regions from FUV (Kang+ 2009)



Brick 15 GALEX SF regions from FUV (Kang+ 2009)



THANKS !!

> To the organizers
> To the audience
> To my collaborators:

Yongbeom Kang, P. Hodge, J.Dalcanton & PHAT team, GALEX team, D.Thilker, ...