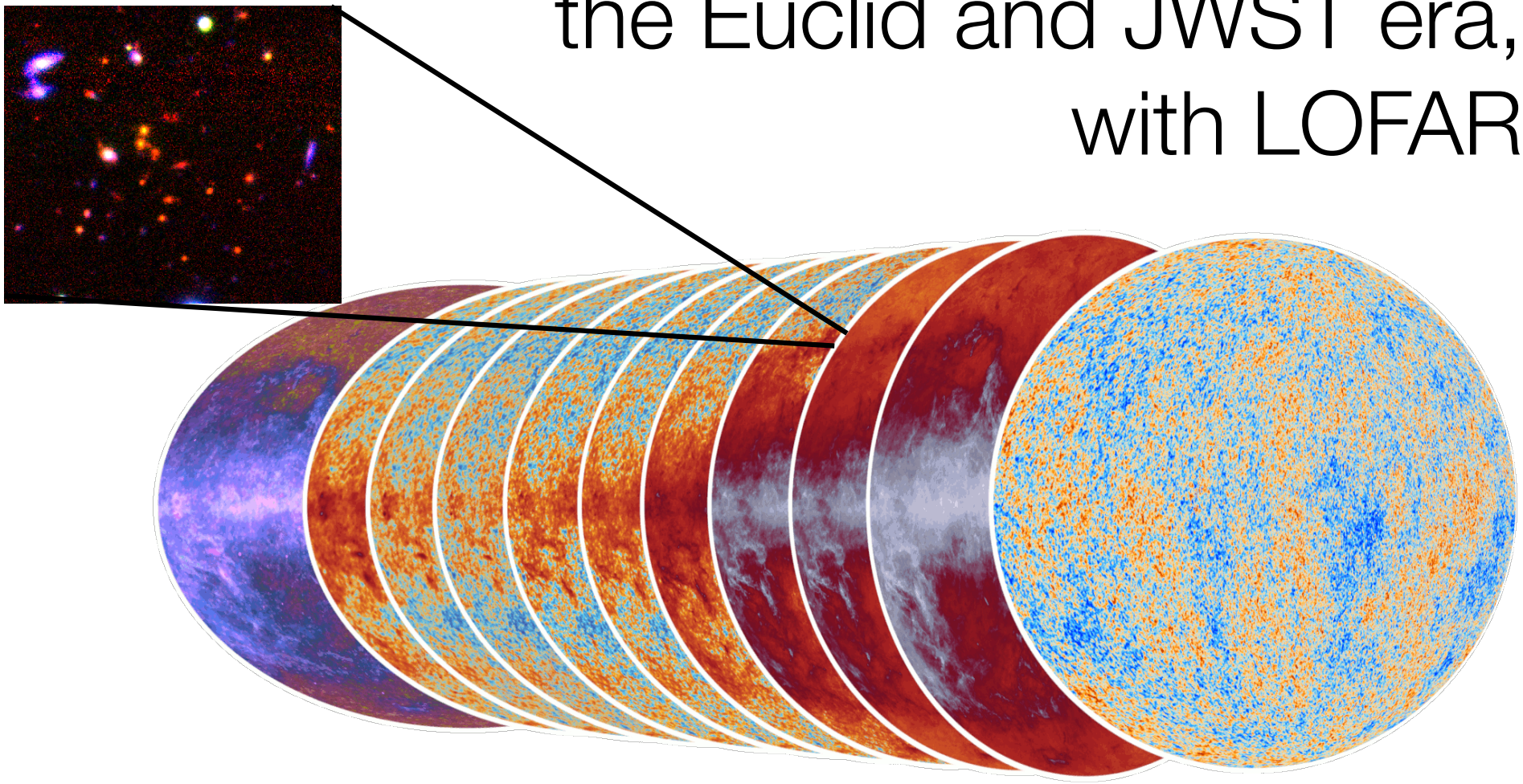
protoclusters of galaxies: from Planck to the Euclid and JWST era, with LOFAR



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http://www.ias.u-psud.fr/dole/

protoclusters of galaxies: from Planck to the Euclid and JWST era, with LOFAR

- Planck Collab, XXVII, 2015 – arXiv:1503.08773 – our Herschel / Planck study
- Flores-Cacho et al, 2015 – arXiv:1510.01585 – one of our structures
- Planck Collab, XXXIX, 2016 – arXiv:1508.04171 – the whole Planck sample
- McKenzie et al., 2017 – arXiv:1703.02074 – the SCUBA2 view
- Martinache et al., 2018 – arXiv:1810.07330 – the Spitzer view
- Kneissl et al., 2019 – arXiv:1804.06581 – ALMA view of one structure

+ Thibaut Perdereau (PhD), Clément Martinache, Mari Poletta, Matt Lehnert, Brenda Frye, Geneviève Soucail, Helmut Dannerbauer, Alessandro Rettura et al.

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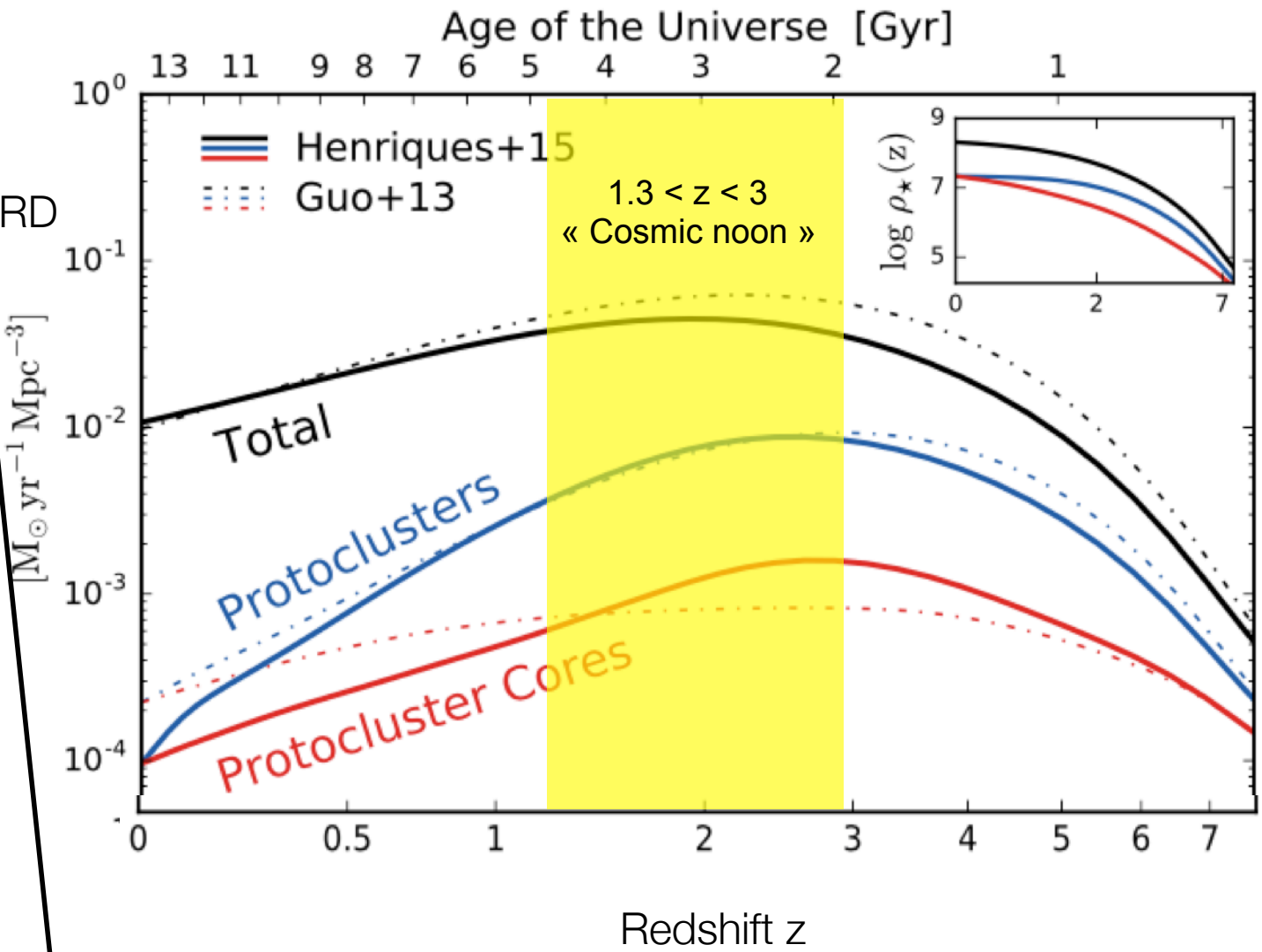
1. star formation in high-z clusters

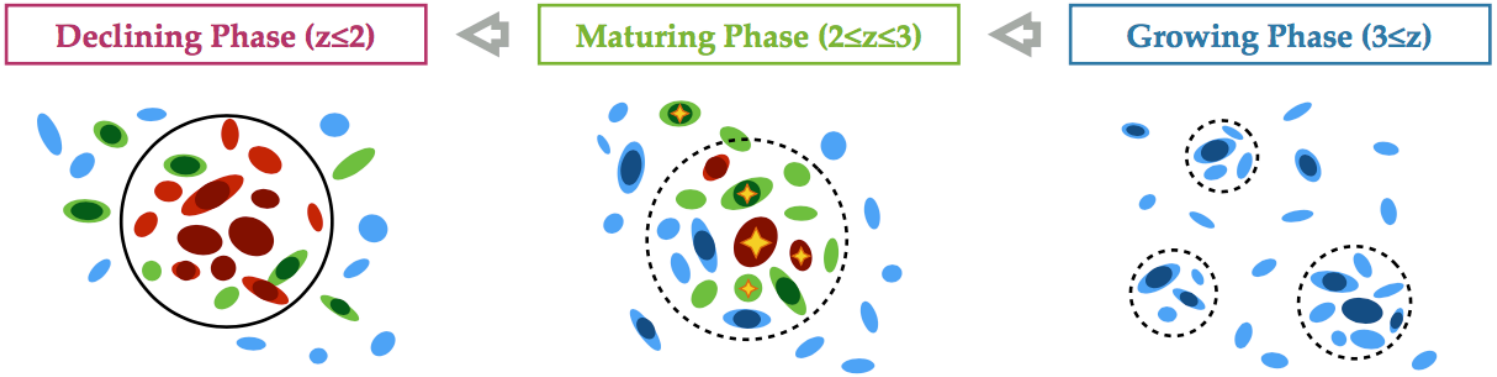
Protoclusters occupy a cosmic volume of at most 5% at z<7.

At z>2 they account for 20-50% of the total SFR.



Chiang et al., 2017

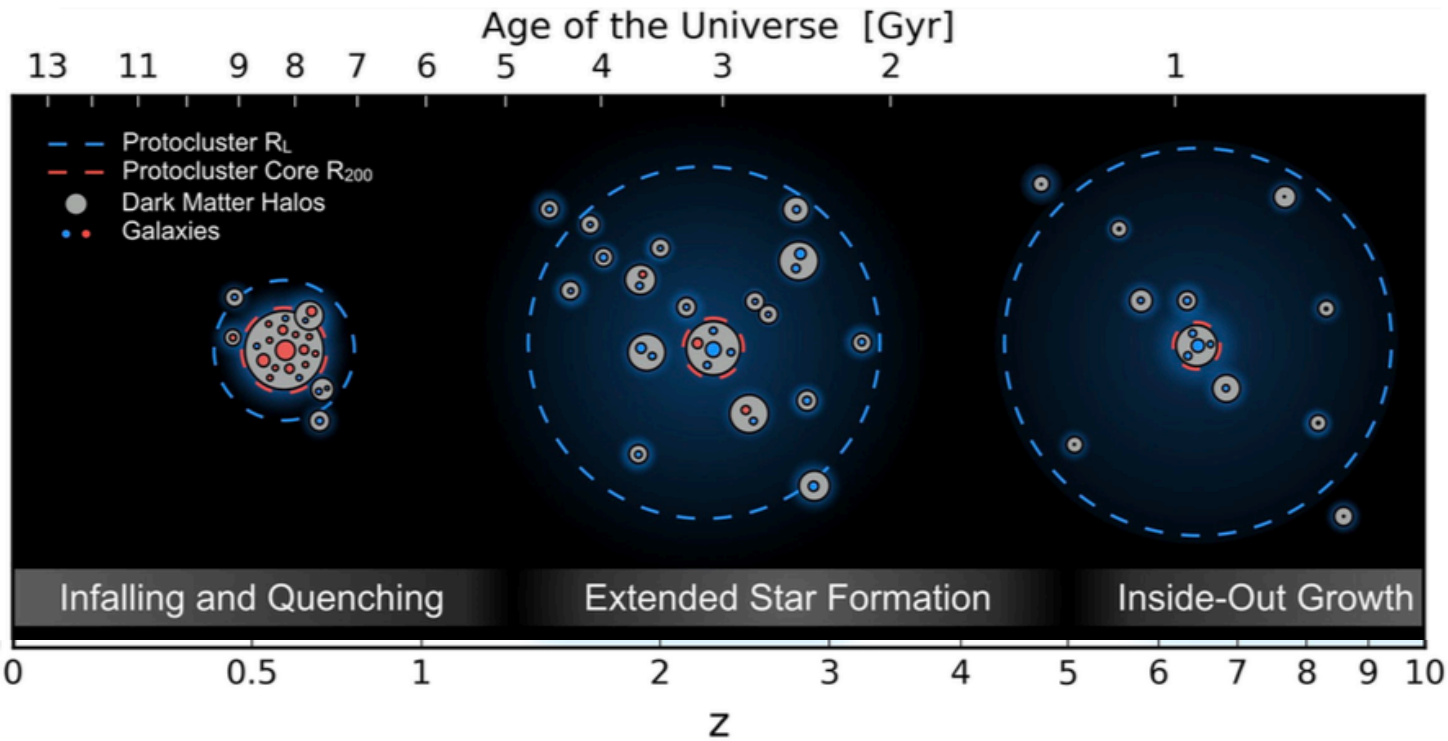
protoclusters, clusters: formation scenarii



Schimakawa et al., 2018
arXiv:1809.08755

	Declining Phase	Maturing Phase	Growing Phase
Galaxies	Starvation / Environmental quenching	Energetic AGN feedback	Massive galaxy formation
Halo Gas	Cold gas depletion / Superheated plasma	Pre-heating / Core collapse	Cold gas stream in hot gas

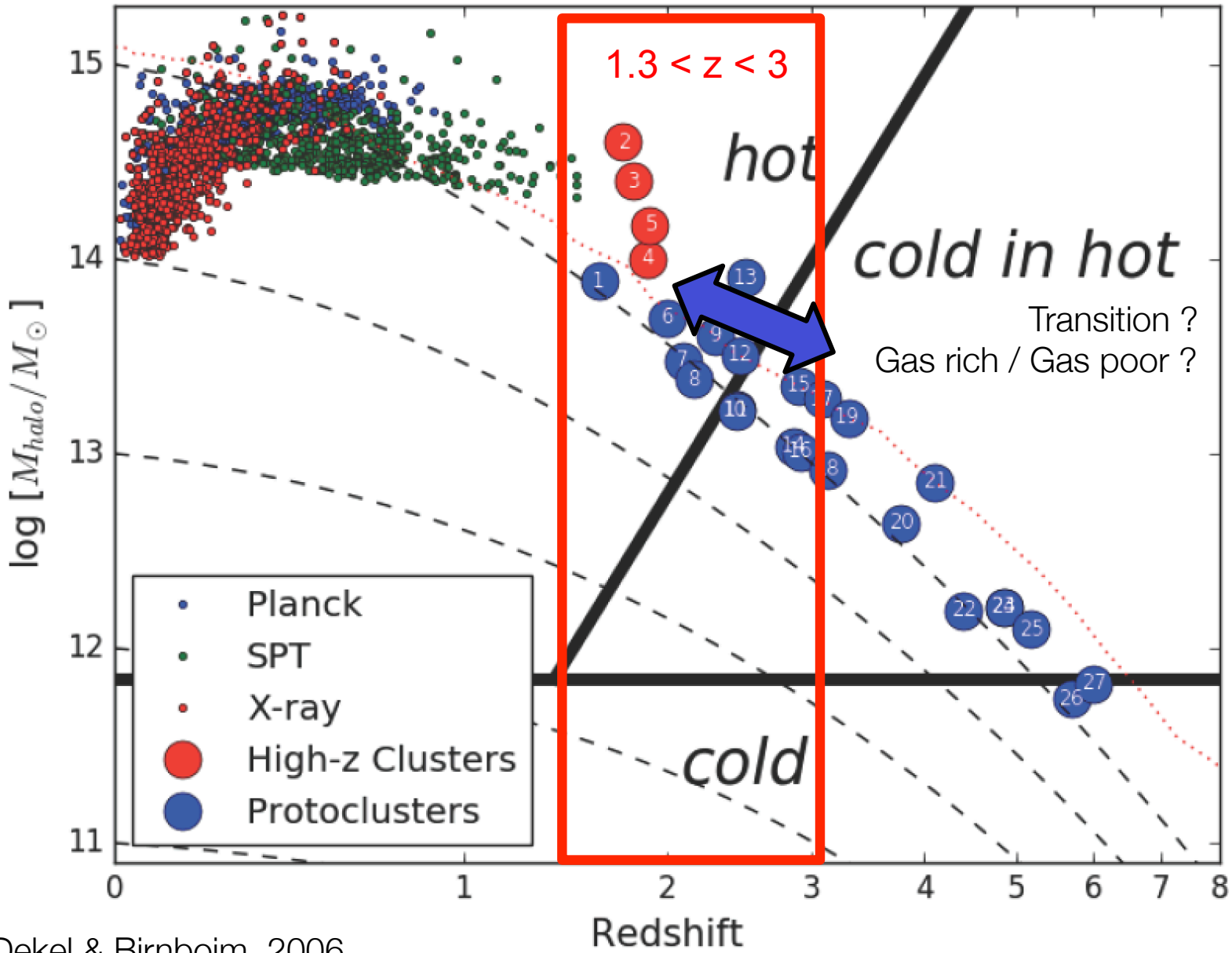
But how to explain the coexistence at z~2 or z~2.5 of X-Rays (proto)clusters vs SF protoclusters at the same time ?



Chiang et al., 2017
arXiv:1705.01634

low-z, high-z clusters ? Protoclusters ?

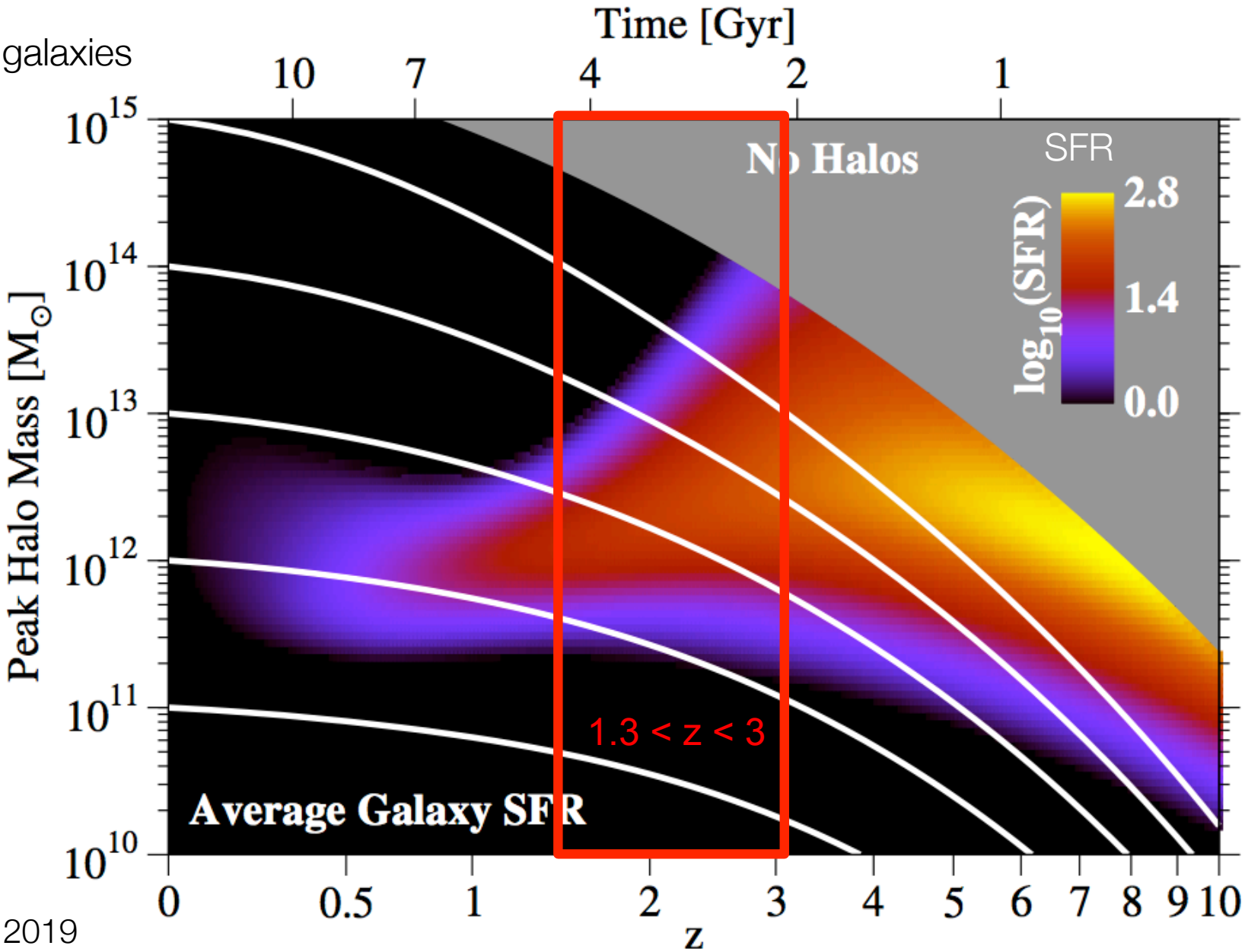
Halo mass



Overzier, 2016
adapted from Dekel & Birnboim, 2006

low-z, high-z clusters ? Protoclusters ?

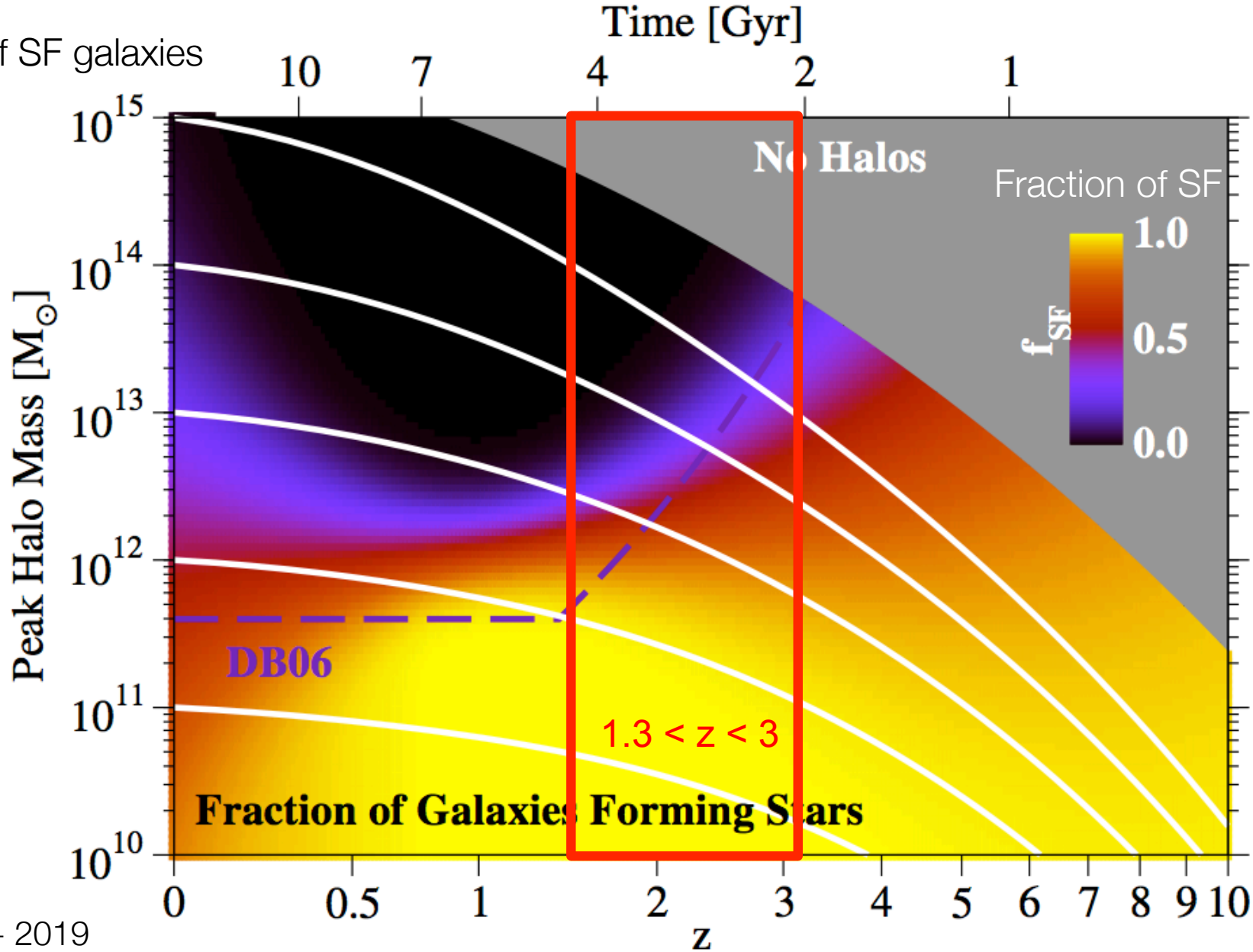
SFR in galaxies



Behroozi+ 2019

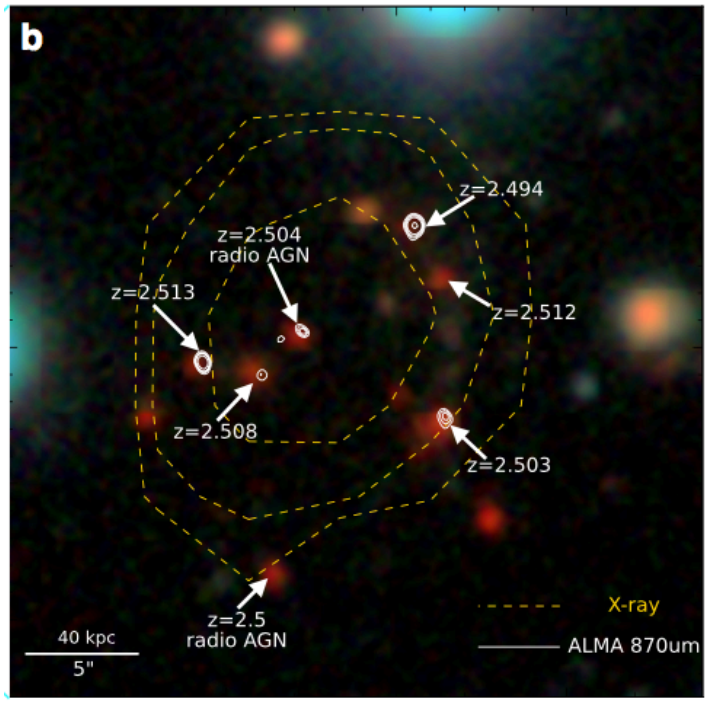
low-z, high-z clusters ? Protoclusters ?

Fraction of SF galaxies

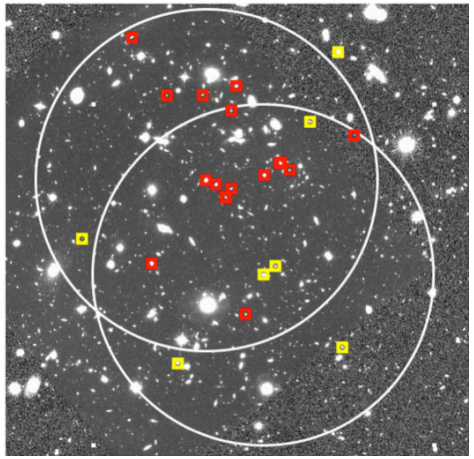


Behroozi+ 2019

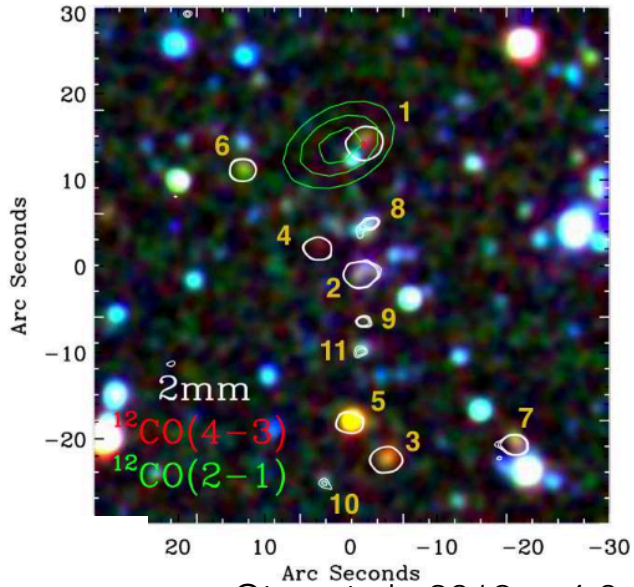
few examples of famous (proto)clusters



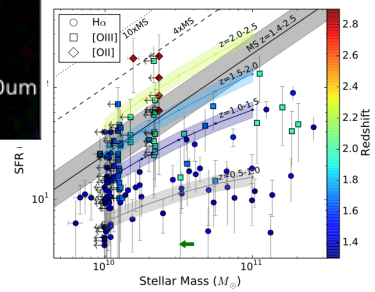
Wang et al., 2016 z=2.5



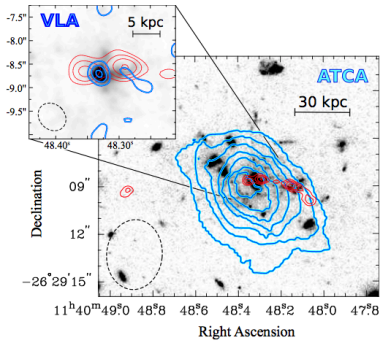
Mei et al., 2015 z=1.9

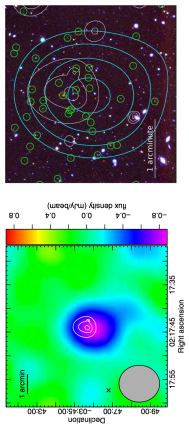


Oteo et al., 2018 z=4.0

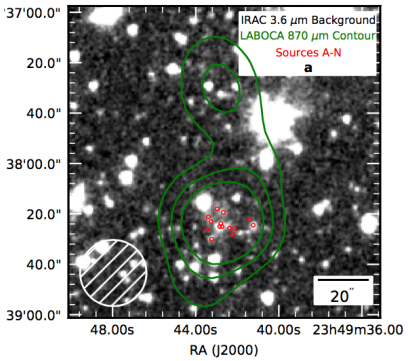


Noirot et al., 2018
z<2.8

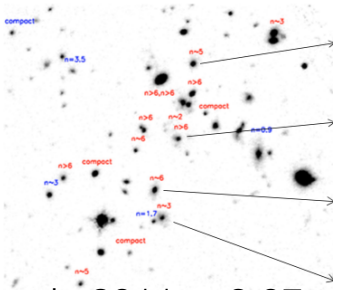




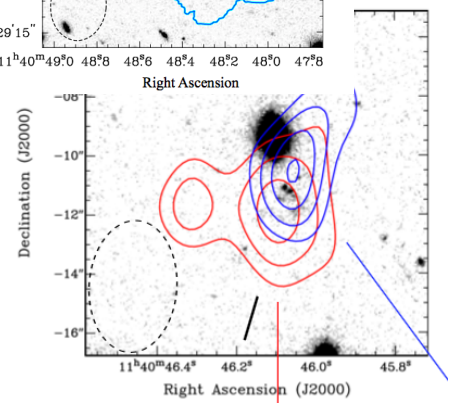
Mantz et al., 2014 z=1.9



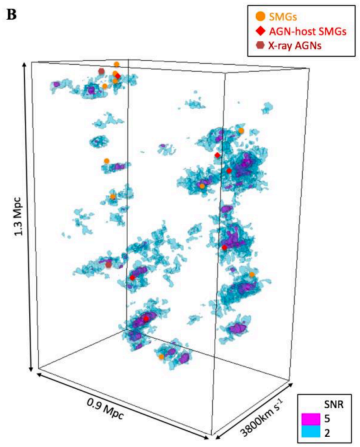
Miller et al., 2018 z=4.3



Gobat et al., 2011 z=2.07



Dannerbauer et al., 2017
Emonts et al., 2018 z=2.16



Umehata et al., 2019
z=3.1

Noirot et al., 2018 z=1.4-2.8

Oteo et al., 2018 z=4.002

Flores-Cacho et a

Strazzullo et al., 2015, 2018 z~2

Yuan et al., 2014 z=2.095

Mei et al., 2015 z=1.84

Miller et al., 2018 z=4.3

Chiang et al., 2014 z=1.6-3.1

Brodwin et al., 2014 z=1.75

Cucciati et al., 2014 z=2.9

Muzzin et al., 2013 z=1.63

Galametz et al., 2013 z=2.02

Cooke et al., 2014 z=2.5

Stanford et al., 2012 z=1.75

Rettura et al., 2014 z>1.3

Wylezalek et al., 2013 z=1.2-3.2

Clements et al., 2014,16 z=0.8-2.3

Ivison et al., 2013 z=2.41

Kuiper et al., 2012 z~3

Gobat et al., 2011 z=2.0

Hatch et al., 2011 z=2.4

Wang et al., 2016 z=2.5

Riechers e

Capak et al., 2011 z=5.3

Santos et al., 2011,13,14

Papovich et al., 2008,10,11 z=1.62

Fassbender et al., 2014 z=1.58

Venemans et al., 2007 z>2

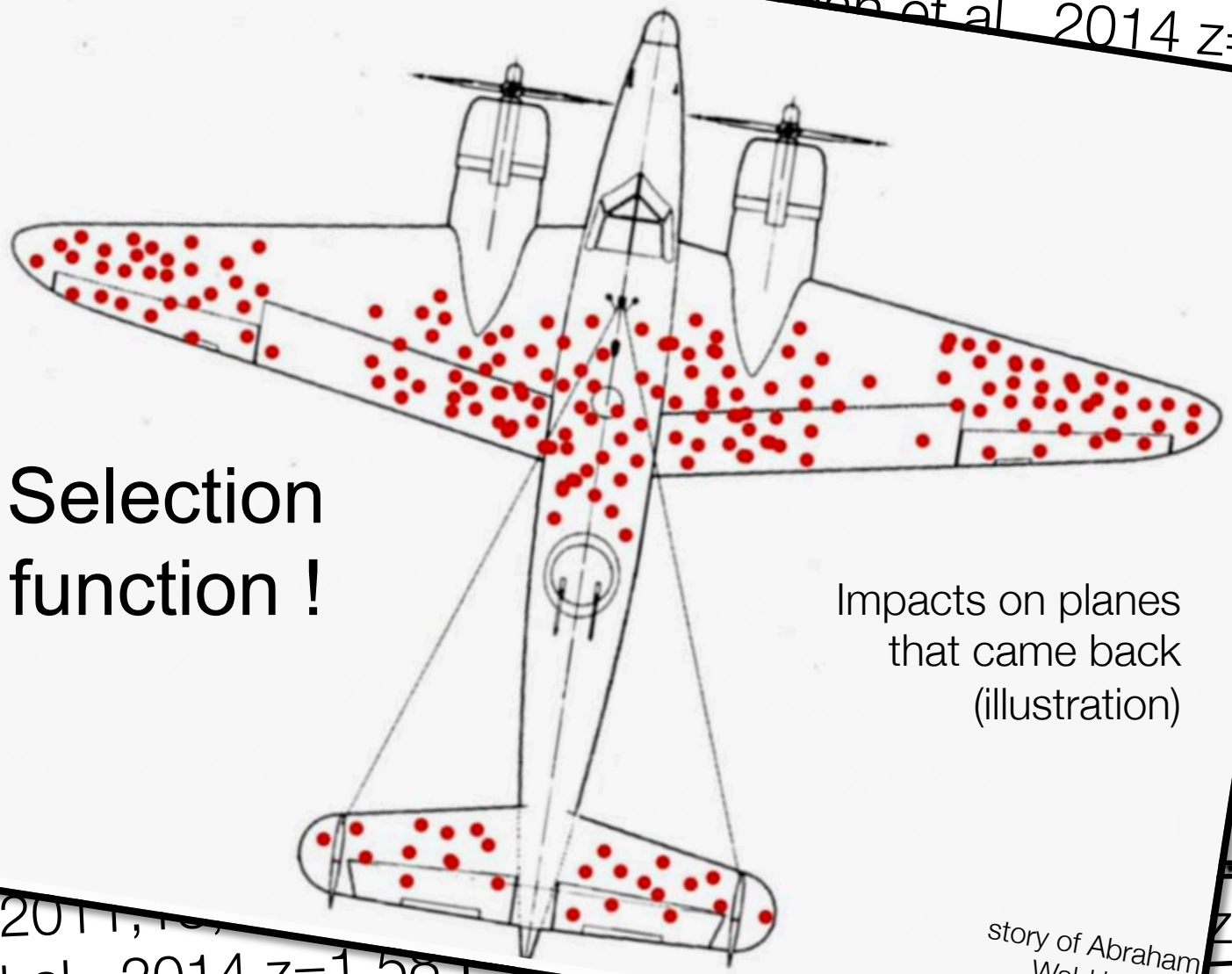
Daddi et al., 2009 z=4.05

Kodama et al., 2007 z=2-3

Martinez et al., 2014 z=1.

Lemaux et al., 2014 z=3

Selection function !



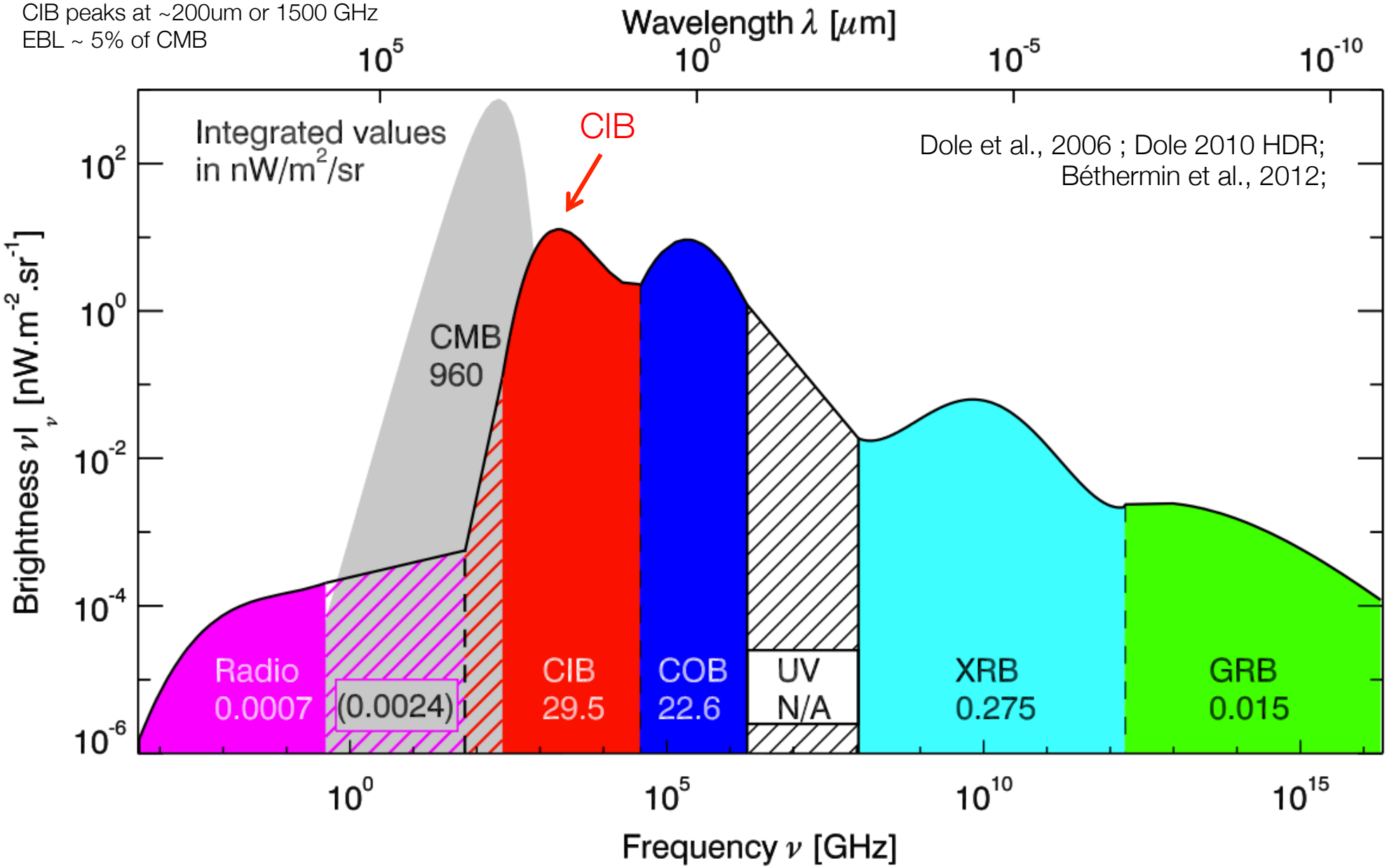
Impacts on planes that came back (illustration)

story of Abraham Wald in WWII
https://en.wikipedia.org/wiki/Survivorship_bias

Noirot et al., 2
Strazzullo et a
Mei et al., 20
Brodwin et a
Rettura e
Wang et al.
Ivison et a
Hatch et
Santos et al., 2011
Fassbender et al., 2014 z=1.58
Daddi et al., 2009 z=4.05
Marrtz et al., 2014 z=1.
et al., 2018 z=4.002
Flores-Cacho et a
Yuan et al., 2014 z=2.095
z=2.0
z=5.3
z=1.62
z>2
Venemans
Kodama et al., 2007 z=2-3
Lemaux et al., 2014 z=3

2. Extragalactic Background Light SED

CIB > COB
CIB peaks at ~200um or 1500 GHz
EBL ~ 5% of CMB

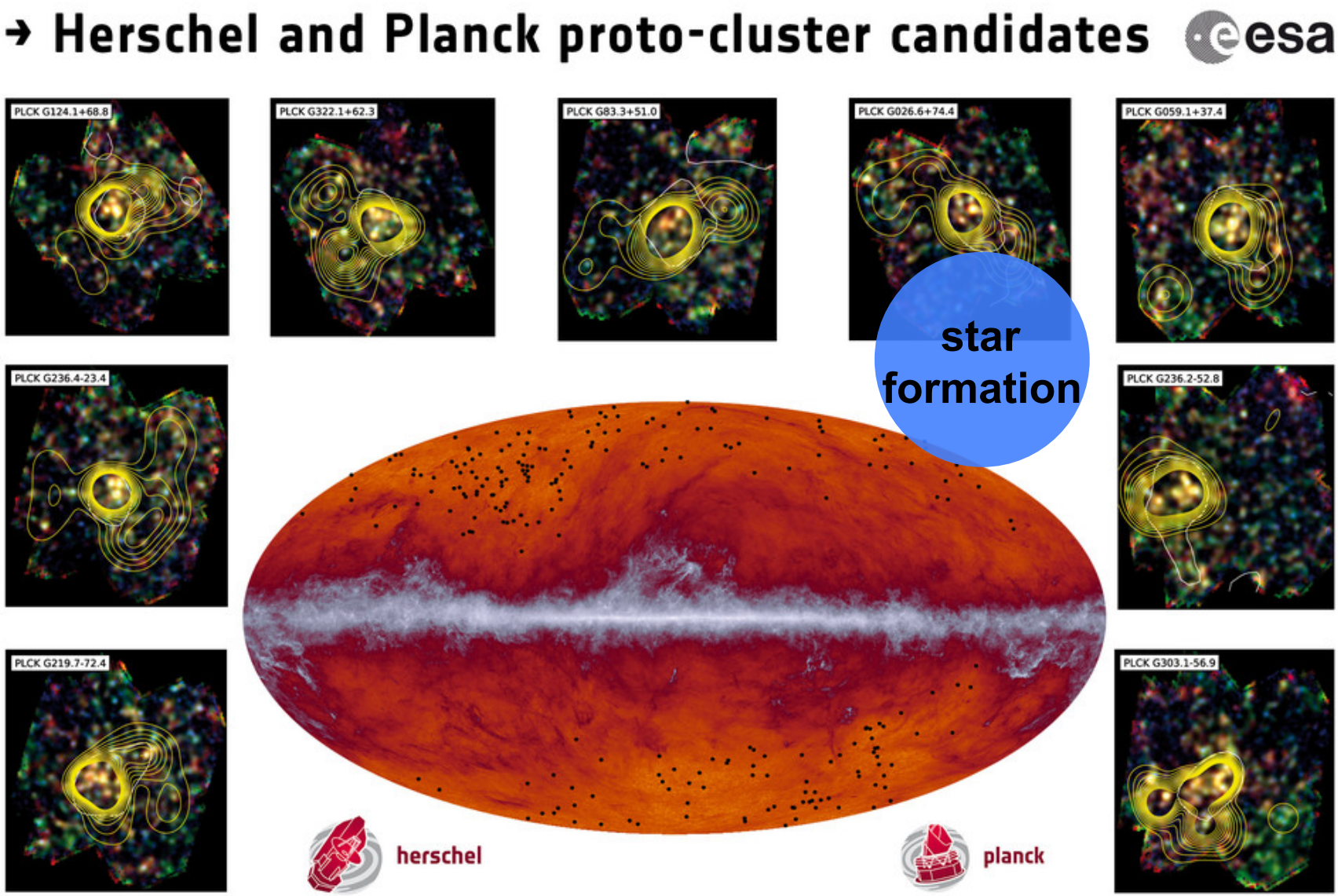


2. high-SFR high-z clusters: Planck+Herschel

Planck selection:

Cold spots of the CIB

Color selection



Thèse: David Guéry

Planck Collab., 2015, Int XXVII, arXiv:1503.08773 – Herschel study
Planck Collab., 2016, Int XXXIX, arXiv:1508.04171 – Planck sample
Press Releases: ESA, NASA, INSU, A&A

2. from Planck to Herschel to Spitzer

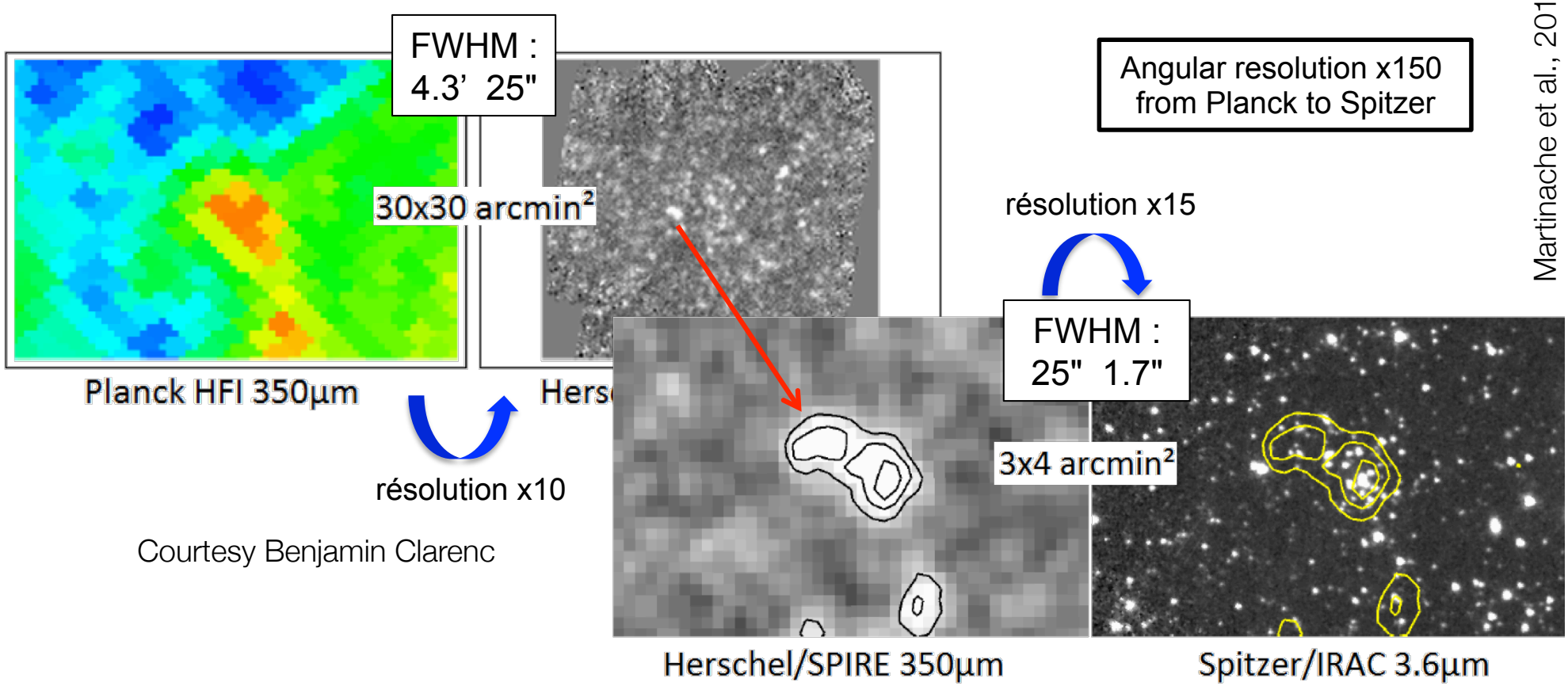
***Planck* / HFI** – 2151 candidates (FIR/mm)
Planck int. results XXXIX, Planck collab., 2016

***Herschel* / SPIRE** – 228 observed (FIR ↔ dust) 98% success
Planck int. results XXVII, Planck collab., 2015

***Spitzer* / IRAC** – 82 observed (NIR ↔ stellar component)
Martinache et al., 2018

Martinache et al., 2018 arXiv:1810.07330

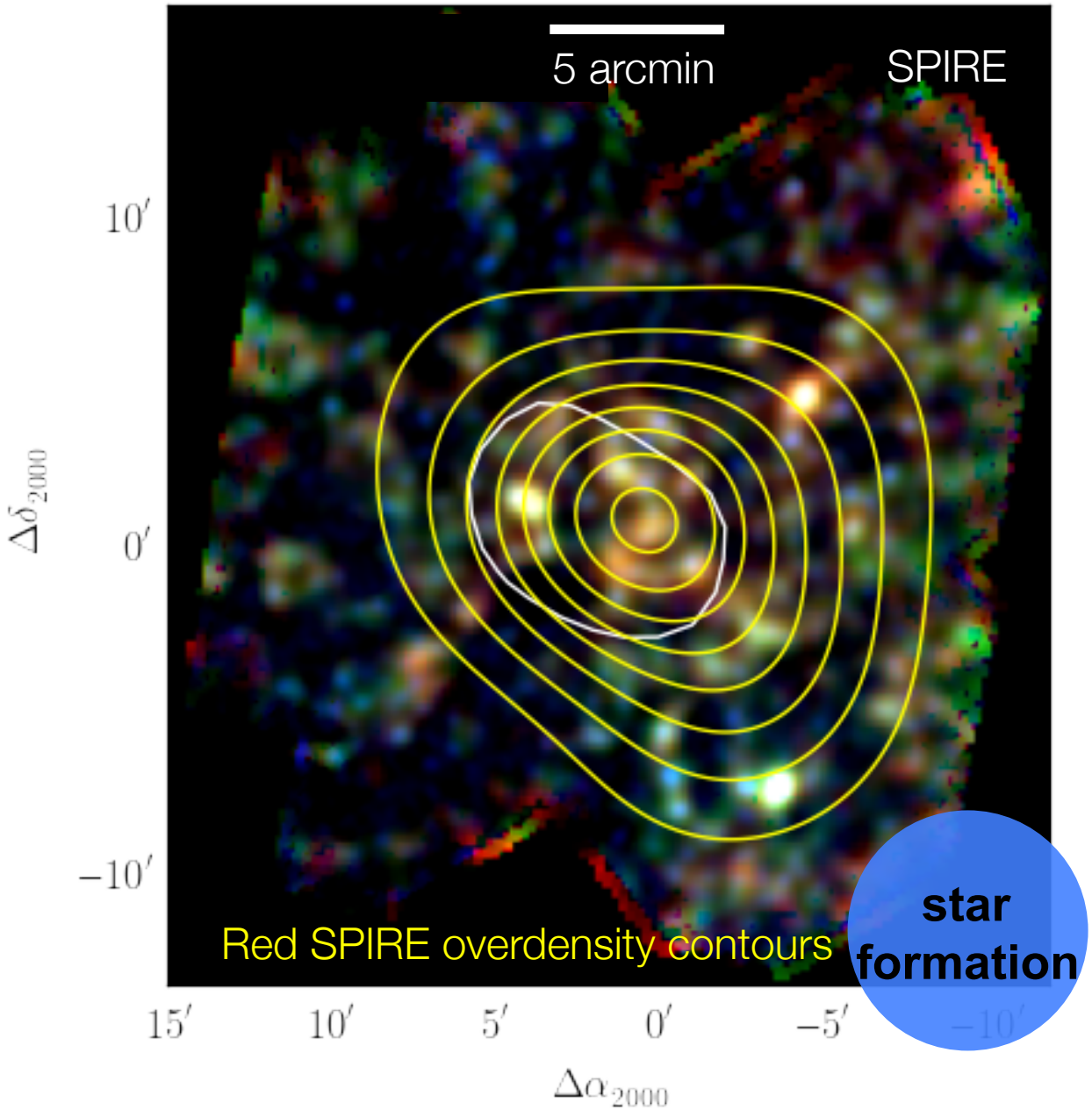
Angular resolution x150 from Planck to Spitzer



Courtesy Benjamin Clarenc

3. the case of one field: Herschel & Spitzer

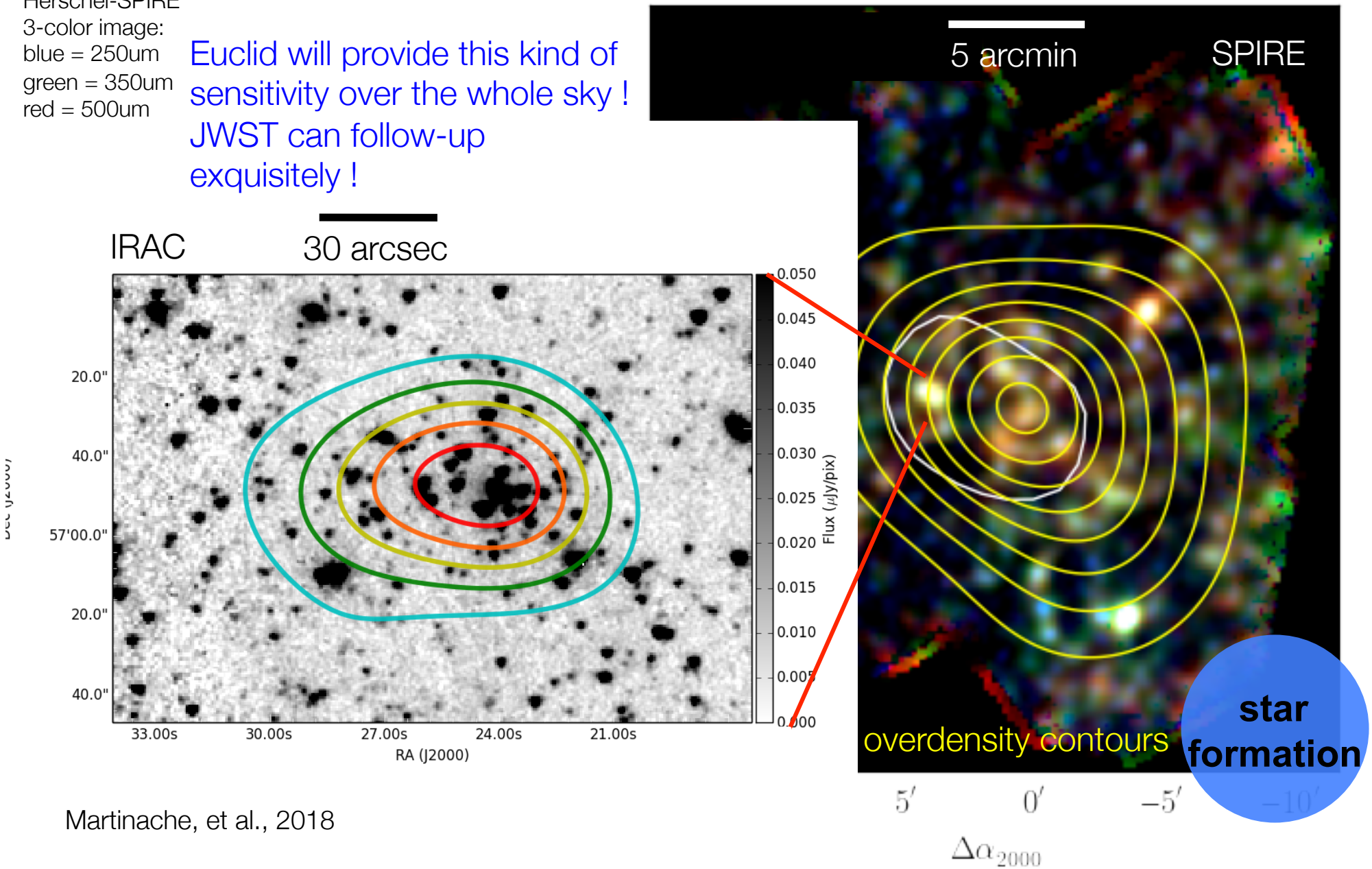
Herschel-SPIRE
3-color image:
blue = 250um
green = 350um
red = 500um



3. the case of one field: Herschel & Spitzer

Herschel-SPIRE
3-color image:
blue = 250um
green = 350um
red = 500um

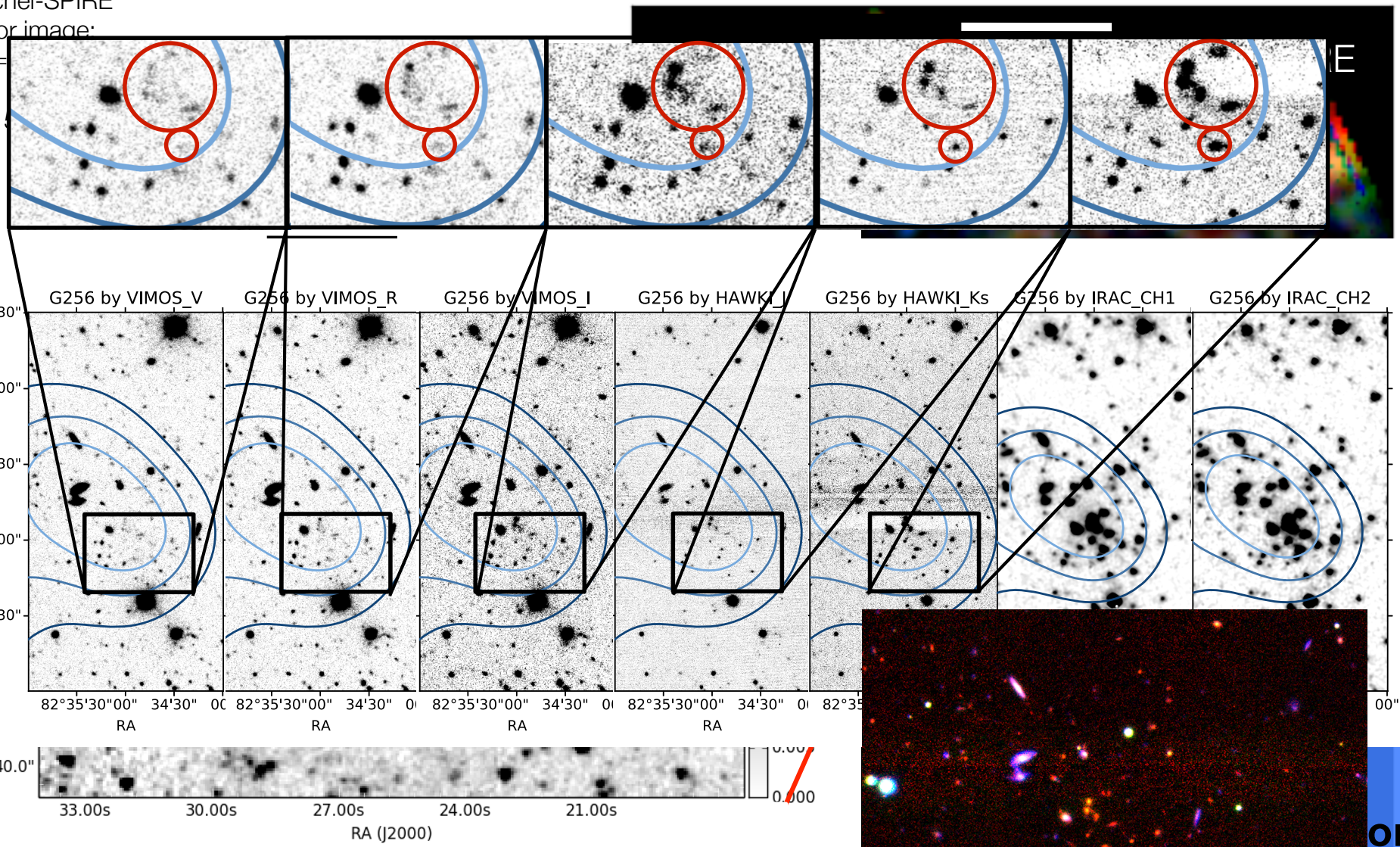
Euclid will provide this kind of sensitivity over the whole sky !
JWST can follow-up exquisitely !

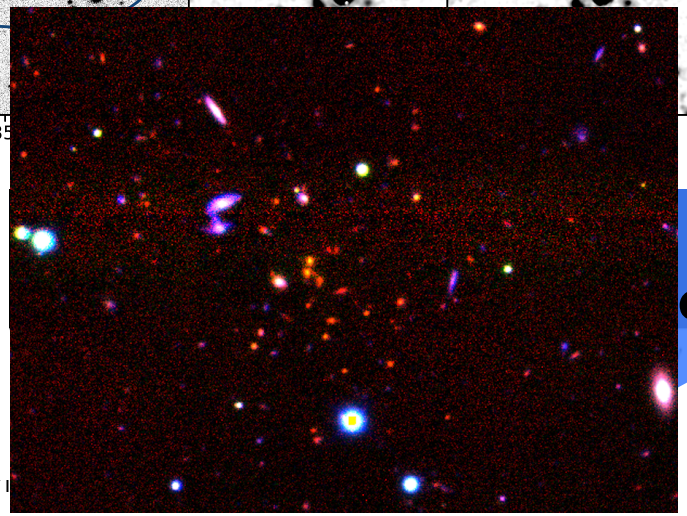


Martinache, et al., 2018

3. the case of one field: Herschel & Spitzer

Herschel-SPIRE
3-color image:
blue =
green
red =





Martinache, et al., 2018

Thesis of Thibaut Perdereau

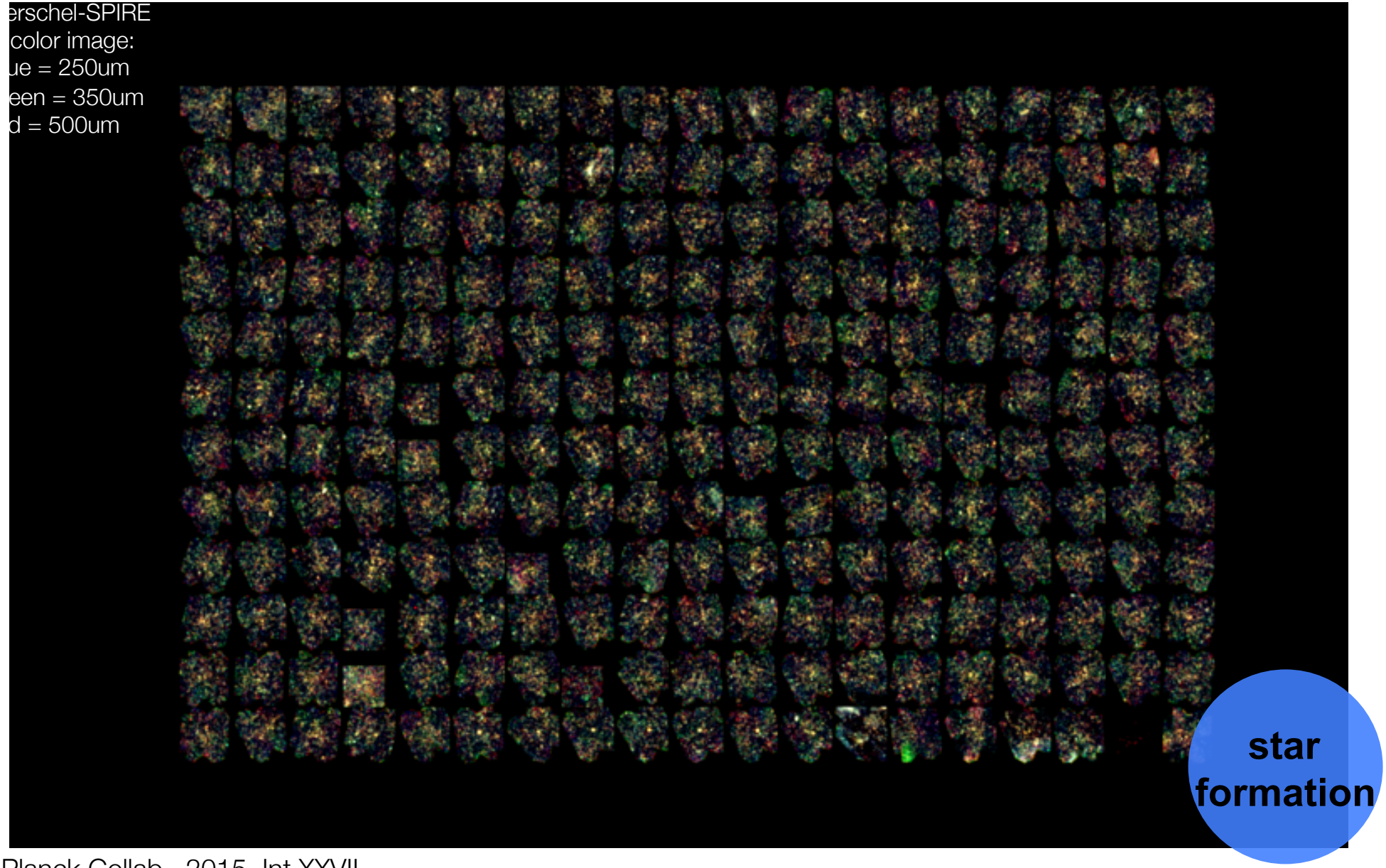
3. and we have a few fields

Herschel-SPIRE
3-color image:
blue = 250um
green = 350um
red = 500um

star formation

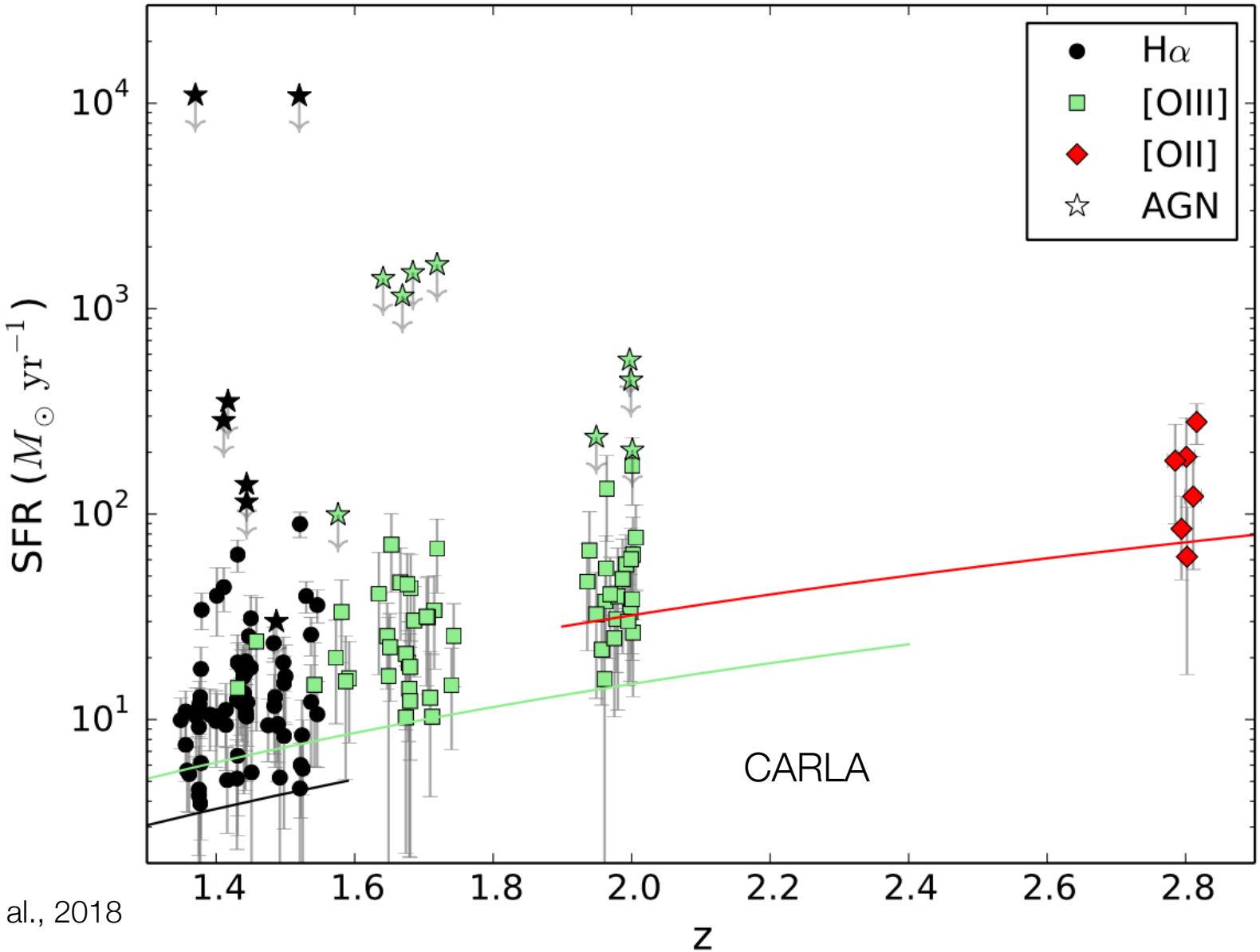
Planck Collab., 2015, Int XXVII, arXiv:1506.01962

3. and we have a few fields



Planck Collab., 2015, Int XXVII

4. SFR vs z: samples

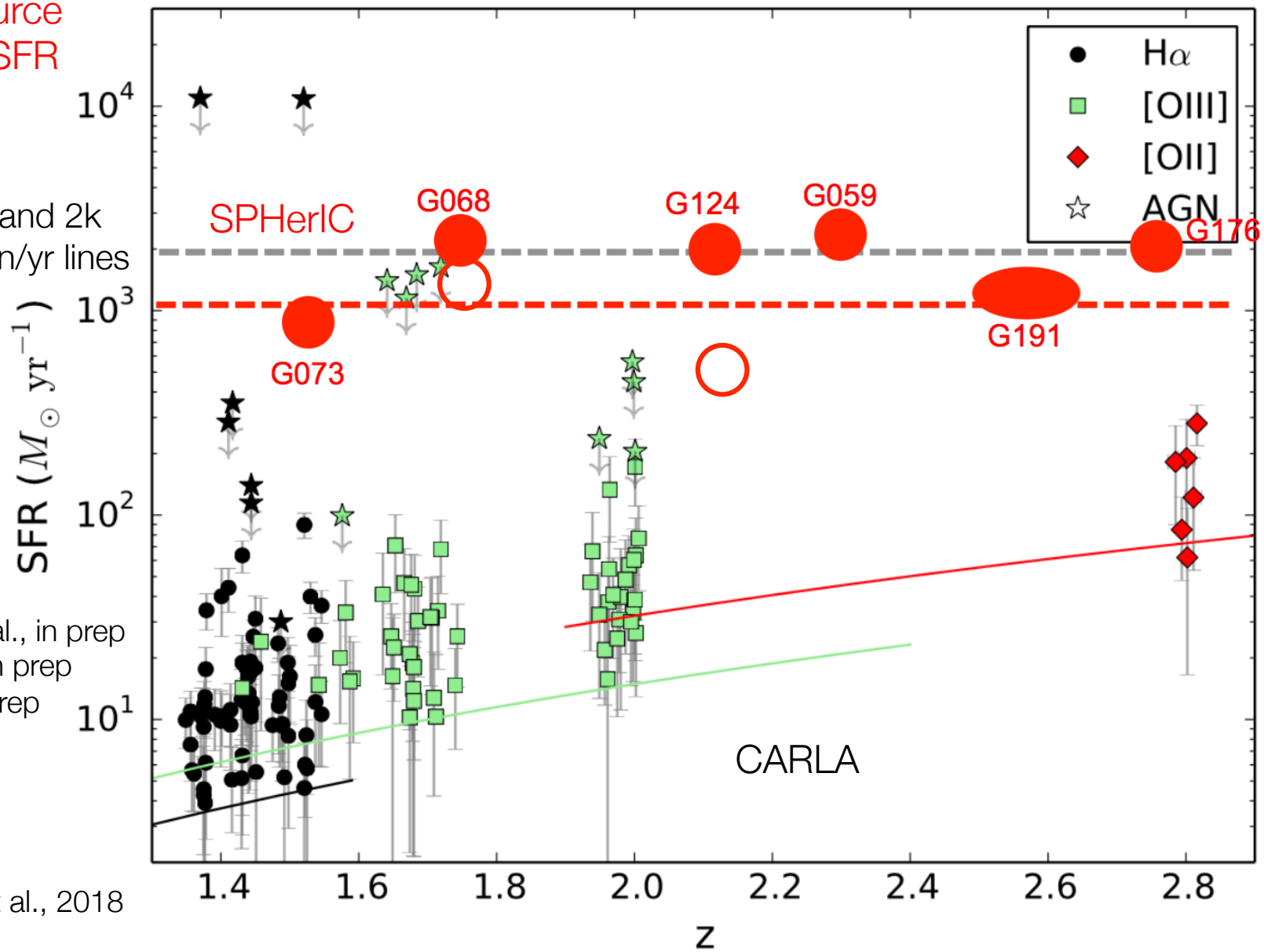


Noirot et al., 2018

4. SFR vs z: samples

Single source (SPIRE) SFR

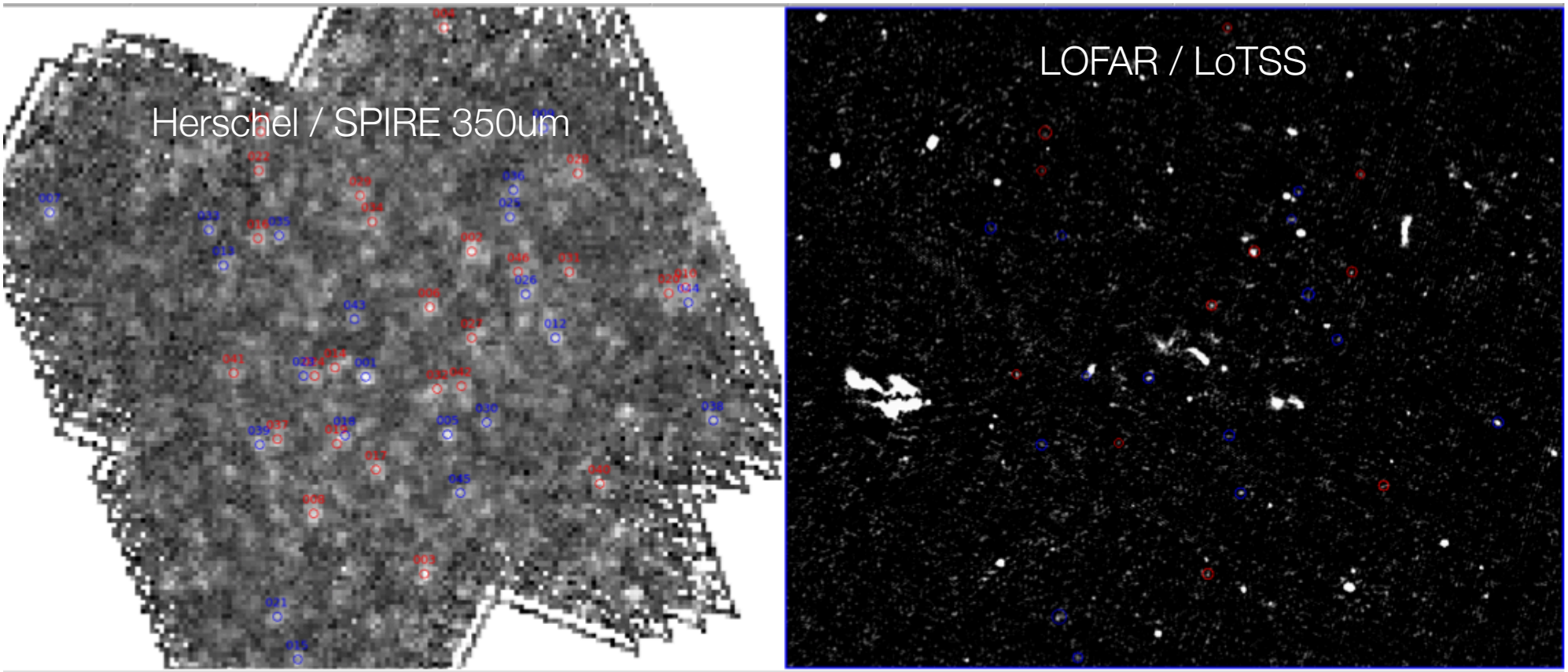
1k and 2k Msun/yr lines



Martinache et al., in prep
Poletta et al., in prep
Dole et al., in prep

Noirot et al., 2018

5. LOFAR helps ! LoTSS identifications



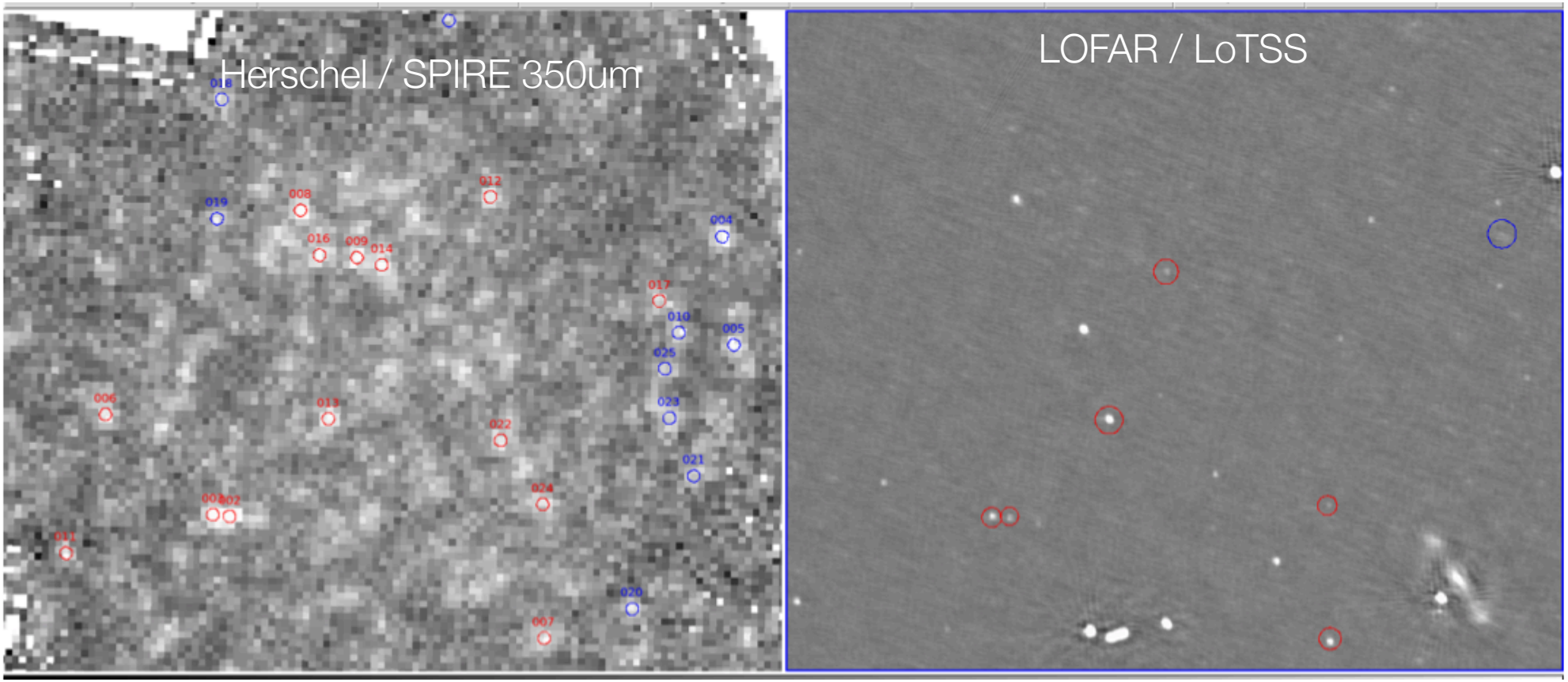
G193

Red Herschel sources
Blue Herschel sources

With help from Cyril Tasse !

Thanks to 1st year students of Univ. Paris-Sud: Elise Lagarde, Tassadit Rebrab, Marguerite Boscq, Pierre Nonnon

5. LOFAR helps ! LoTSS identifications



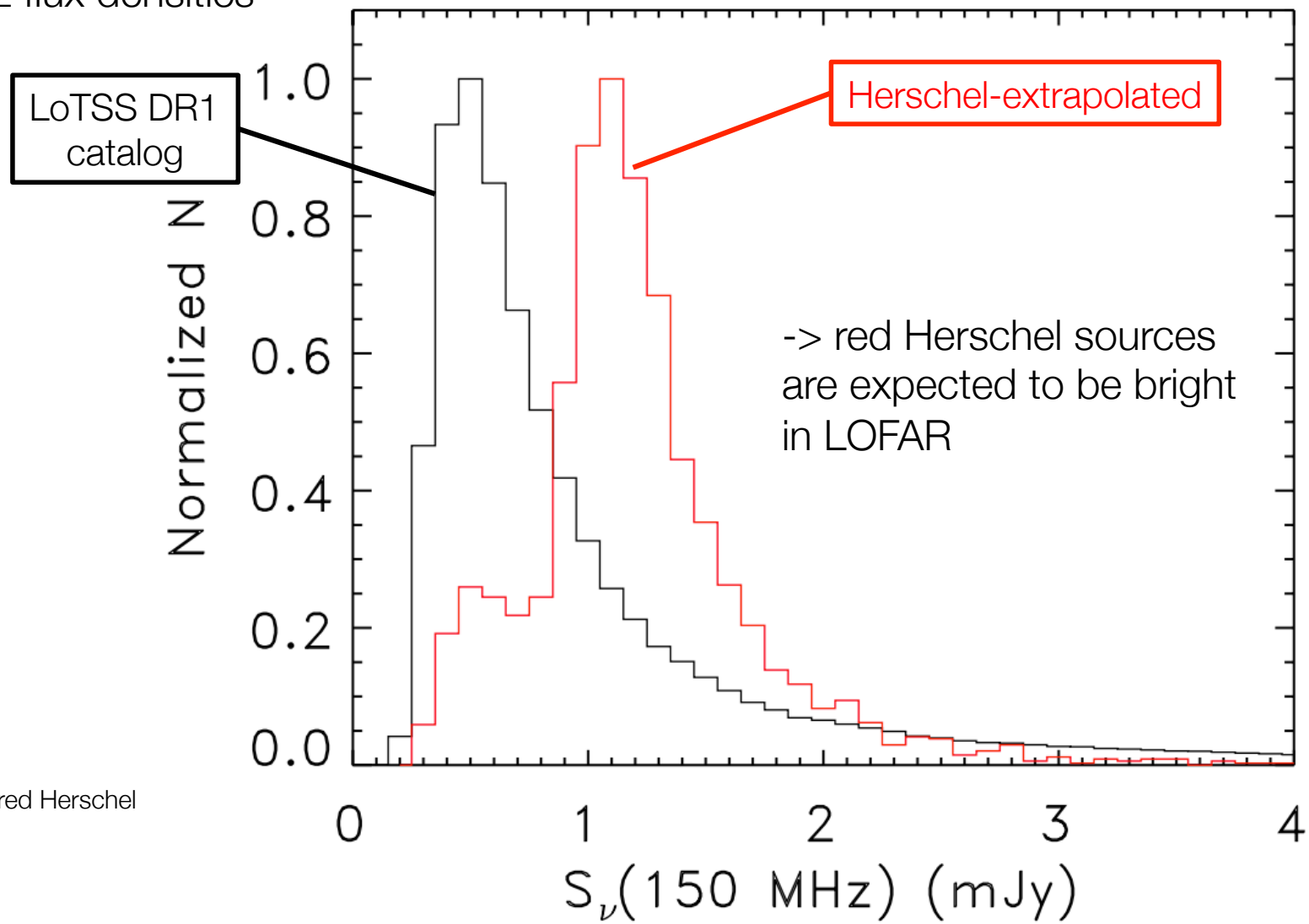
G095

With help from Cyril Tasse !

Thanks to 1st year students of Univ. Paris-Sud: Elise Lagarde, Tassadit Rebrab, Marguerite Boscq, Pierre Nonnon

6. LOFAR helps ! « easy » detections ?

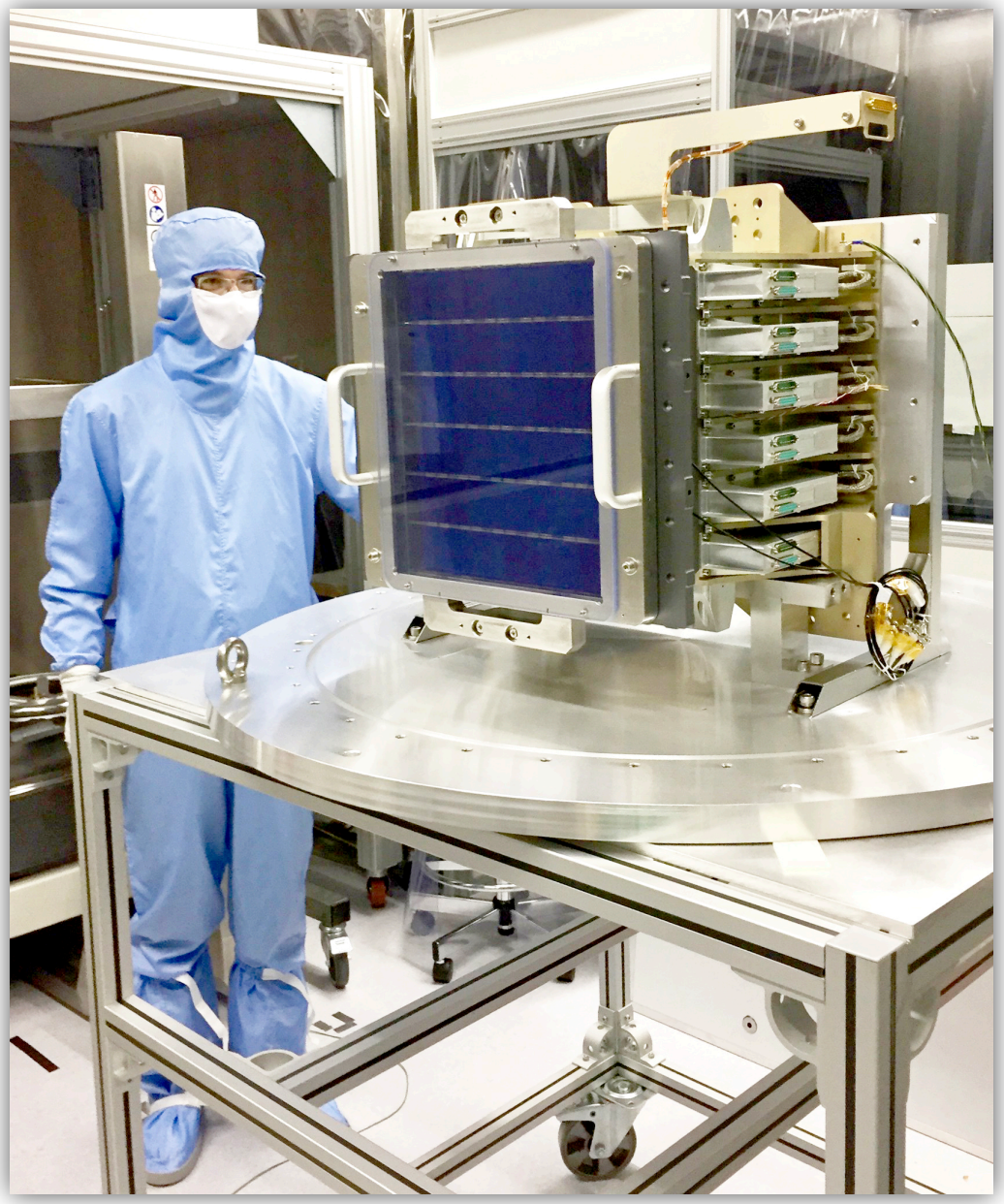
150 MHz flux densities



Extrapolation of red Herschel sources fluxes
T=30K
mBB fit
qIR/radio = 2.34
get 1.4GHz
Slope 0.7 to get to 150MHz

Courtesy Mari Poletta, INAF

7. how Euclid can help: stellar component



2 main scientific goals:

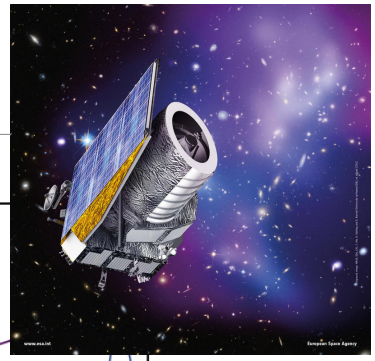
- Dark matter
- Dark energy

And lots of « legacy science »

4 bands: VIS, Y, J, H.

Launch: 2022.

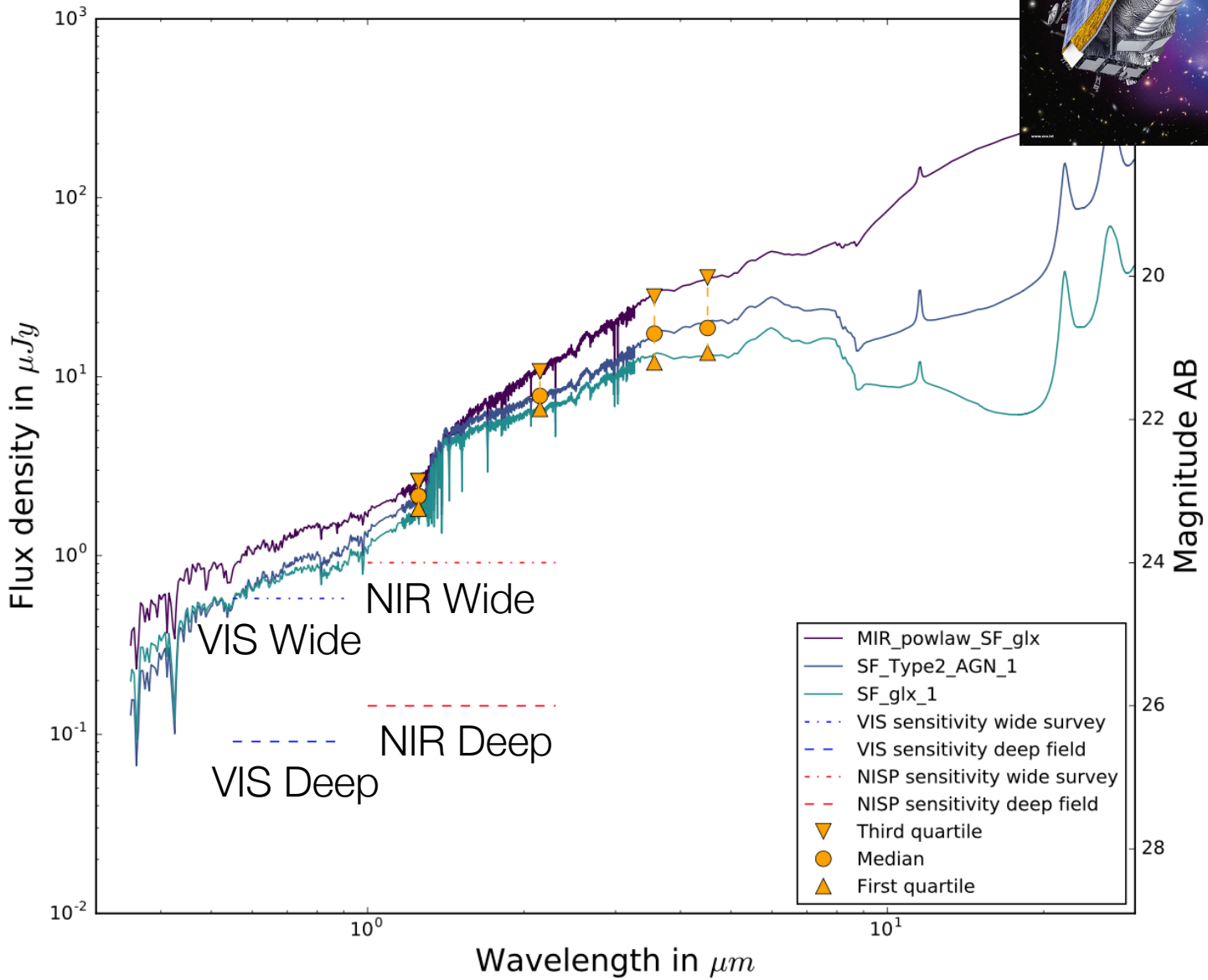
7. Euclid great potential



Wang+16
z=2.5 cluster

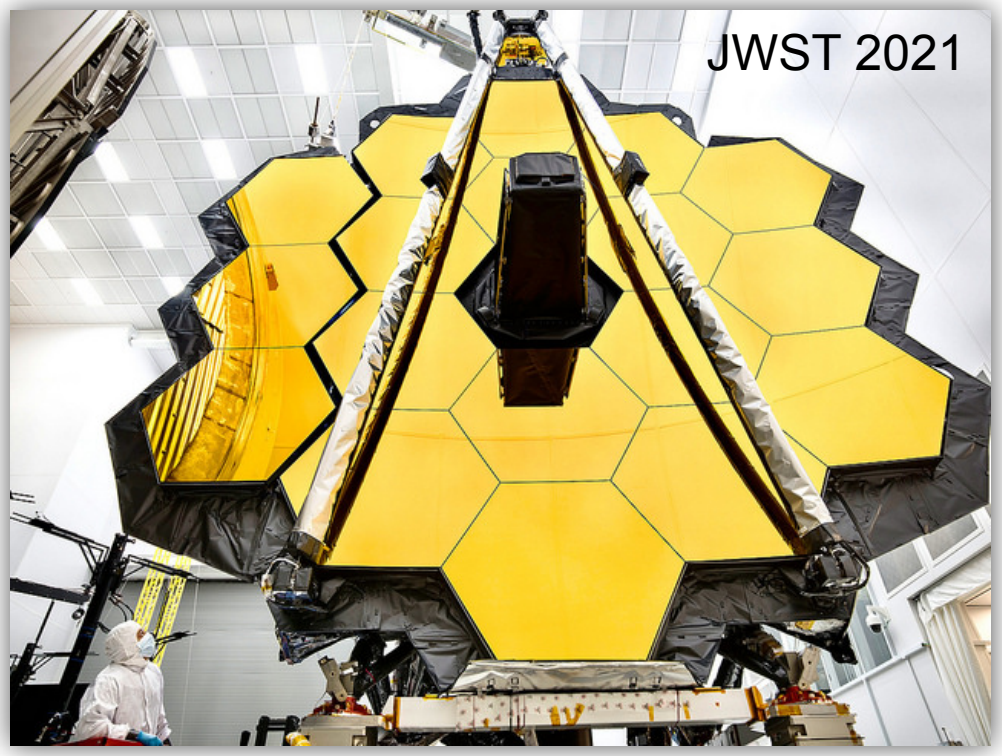
=> Euclid data will be full of those clusters !

+ ground based surveys, LSST



Louis Legrand, Clément Martinache, Benjamin Clarenc, T. Etourneau, H. Dole

8. conclusions, perspectives



8. conclusions, perspectives

Protoclusters are important:

- Significant contribution to the SFR at z>2
- Structure formation, dark matter and baryons
- Fate of the gas ?

- Planck SPHerIC sample: 100s of extreme structures selected **over the whole sky**, extreme SFR, z>1.5
- Nicely complements other selections
- LOFAR brings new informations at z>1.5

- Euclid **over the whole sky**, JWST
- **LOFAR and others: key to identify and study them**
- [So other facilities: SZ, mm, IR, X …]

- Towards a coherent view on the patchy landscape of protoclusters