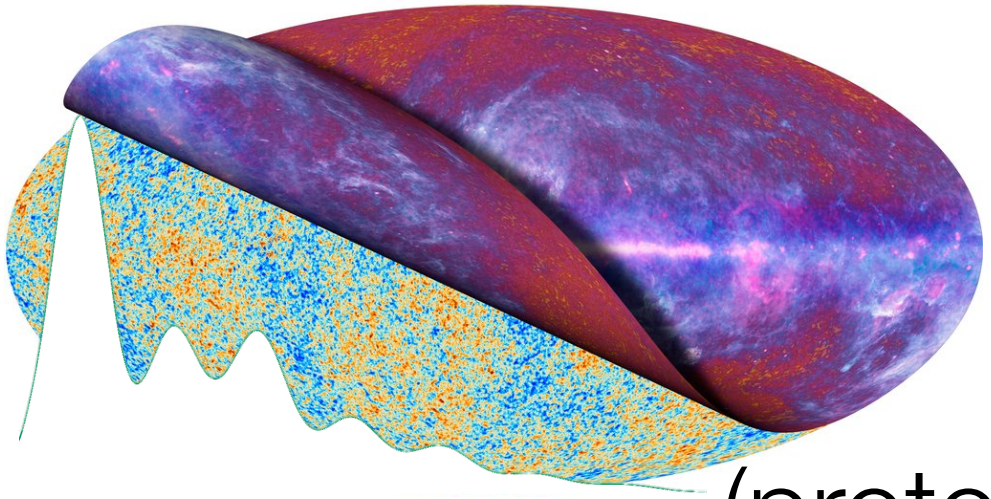

# Planck, Herschel & Spitzer unveil z>2 (proto-)cluster candidates. Prospects for JWST

planck

herschel

jwst

euclid

Introduction: high-z (proto-)clusters 1.
digging into the Planck CIB 2.
Planck & Herschel & Spitzer outcome 3.
High-z clusters: towards JWST 4.
conclusions 5.


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IAS Institut d'Astrophysique Spatiale Orsay

UNIVERSITÉ PARIS SUD Comprendre le monde, construire l'avenir®

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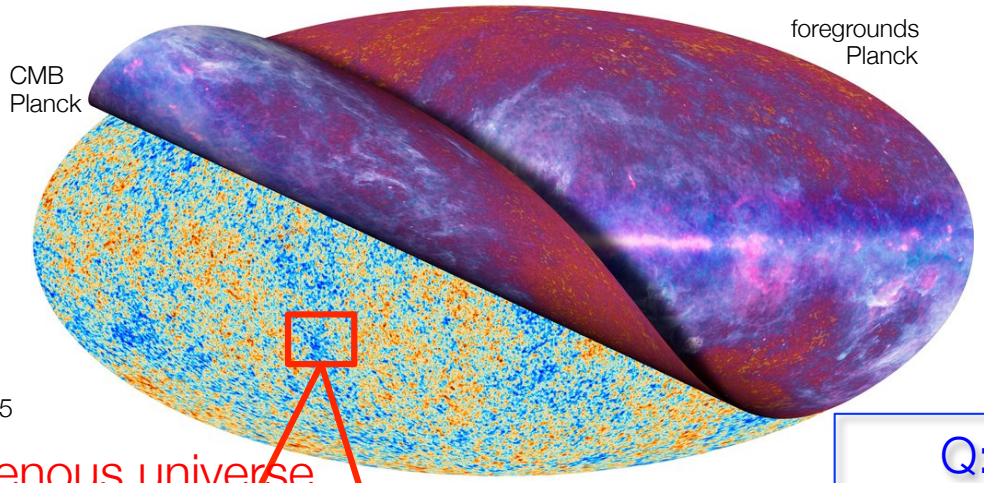
université PARIS-SACLAY

DÉPARTEMENT Sciences de la Planète et de l'Univers

# 1. some of the challenges in cosmology




$\Delta\rho/\rho \sim 10^{-5}$
homegenous universe
z=1090

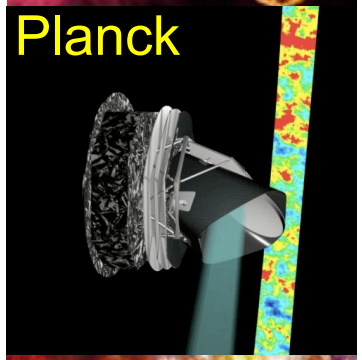
?

cosmological model ΛCDM

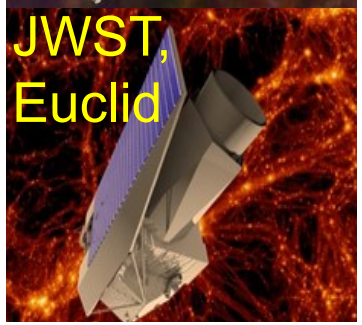
Q: processes of structure formation, esp. first clusters, mass assembly, gas cooling, star formation, galaxies ?

$\Delta\rho/\rho > 10^{20}$
inhomogeneous structured, universe
z=0

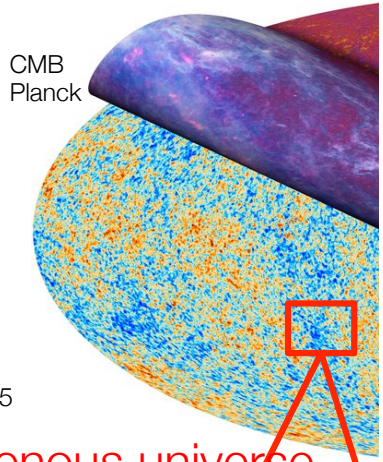
processes implying :
- fundamental forces
- dark components
- baryon physics
- cosmological parameters





# 1. some of the challenges in cosmology




$\Delta\rho/\rho \sim 10^{-5}$
homegenous universe
z=1090

$\Delta\rho/\rho > 10^{20}$
inhomogeneous structured, universe
z=0

**Table 9.** Parameter 68 % confidence levels for the base ΛCDM cosmology computed from the *Planck* CMB power spectra, in combination with the CMB lensing likelihood ("lensing").

| Parameter | *Planck* TT+lowP+lensing |
|---|---|
| $\Omega_b h^2$ | $0.02226 \pm 0.00023$ |
| $\Omega_c h^2$ | $0.1186 \pm 0.0020$ |
| $100\theta_{MC}$ | $1.04103 \pm 0.00046$ |
| $\tau$ | $0.066 \pm 0.016$ |
| $\ln(10^{10} A_s)$ | $3.062 \pm 0.029$ |
| $n_s$ | $0.9677 \pm 0.0060$ |
| $H_0$ | $67.8 \pm 0.9$ |
| $\Omega_m$ | $0.308 \pm 0.012$ |
| $\Omega_m h^2$ | $0.1415 \pm 0.0019$ |
| $\Omega_m h^3$ | $0.09591 \pm 0.00045$ |
| $\sigma_8$ | $0.815 \pm 0.009$ |
| $\sigma_8 \Omega_m^{0.5}$ | $0.4521 \pm 0.0088$ |
| Age/Gyr | $13.799 \pm 0.038$ |
| $r_{drag}$ | $147.60 \pm 0.43$ |
| $k_{eq}$ | $0.01027 \pm 0.00014$ |

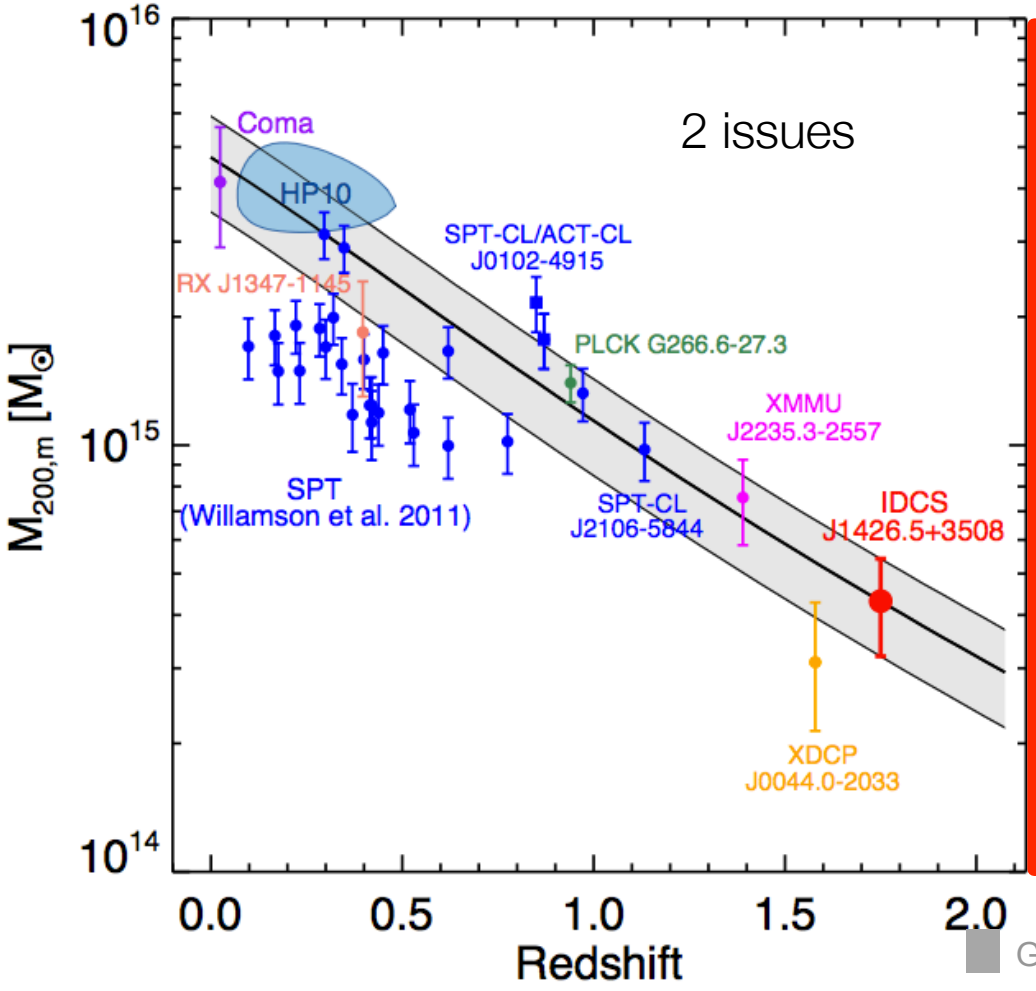
Planck Collab, 2015, 1

Age of the universe: 13.8Gyr

0.3% uncertainty !

# searching for high-z massive structures: link DM-baryons

Predictions / mesurements: massive clusters vs redshift




Q: processes of cluster - stellar mass assembly
- star formation ?
--> can we find a new way to select **highly star-forming clusters** ?

z > 2

Planck

Herschel, ALMA

then JWST,

Euclid, WFIRST

CI J0227

Brodwin et al, 2012 – Mortonson et al., 2011

Gobat CI.

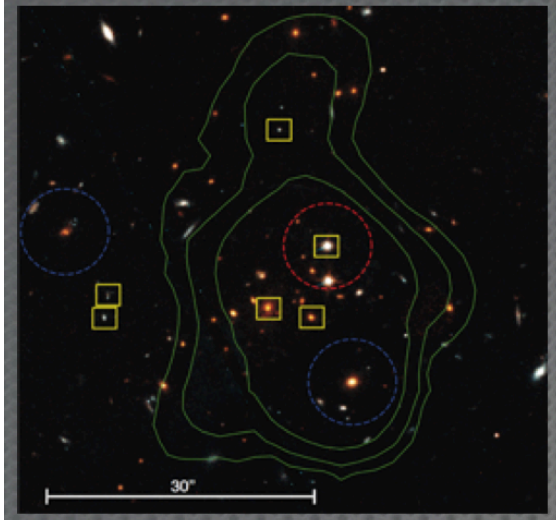
how to find z>2 clusters ?

(observationnally) rare objects can be unveiled using all-sky surveys: Planck, Euclid, and further studied with JWST, WFIRST

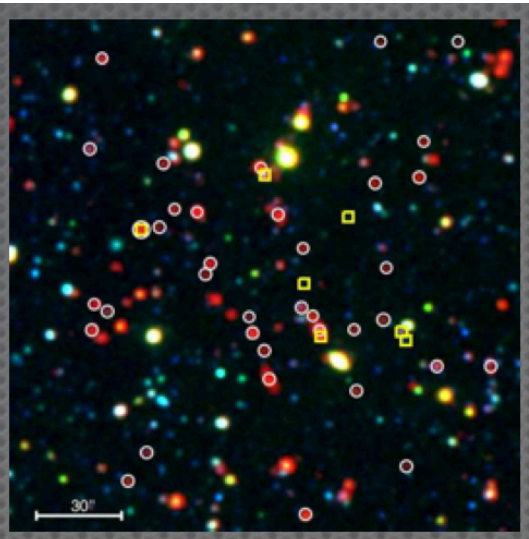
Galaxy clusters are proxies for massive DM halos

# high-z proto-clusters: status

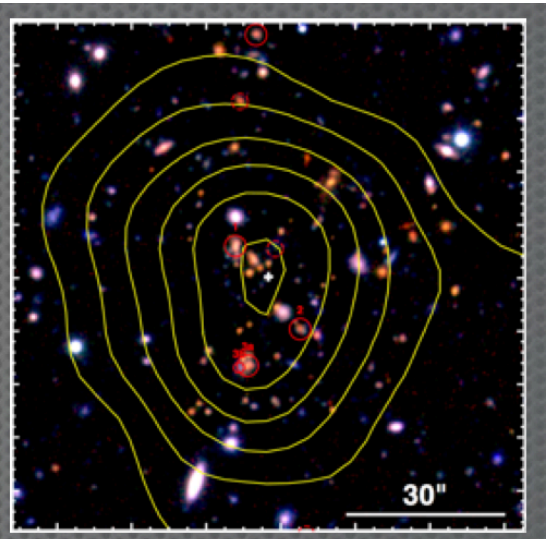
From Nina Hatch, 2015



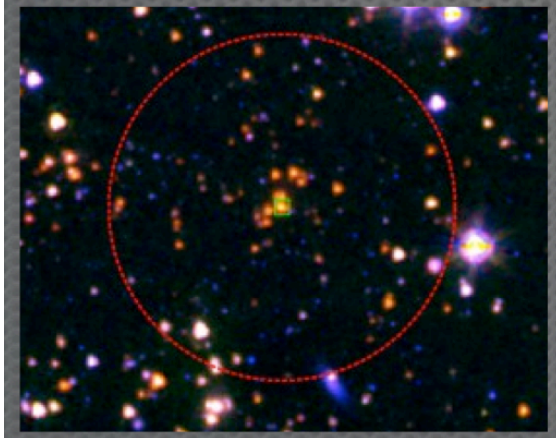

z=1.75; Stanford+ 2012



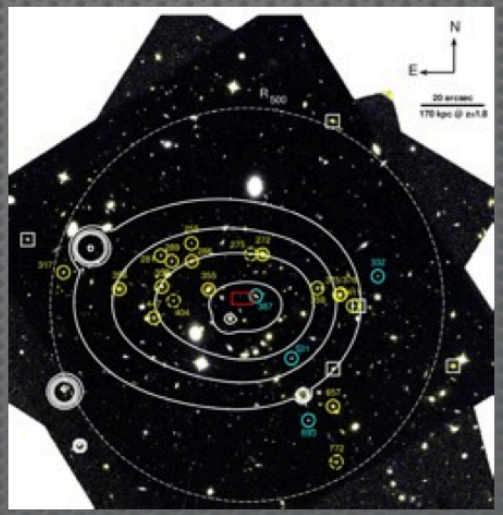

z=1.89; Zeimann+ 2012



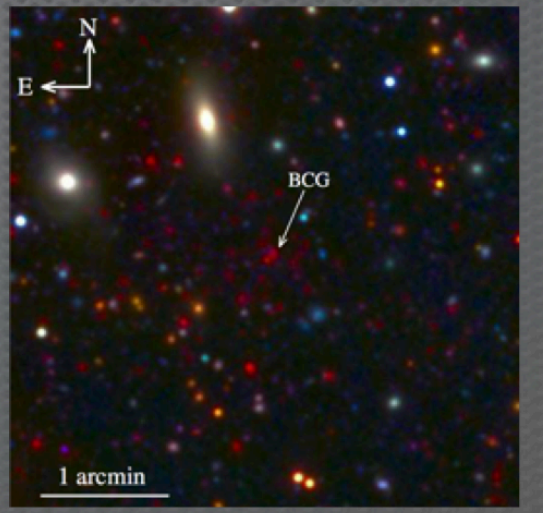

z=1.58; Fassbender+ 201



z=1.58; Cooke+ 2015



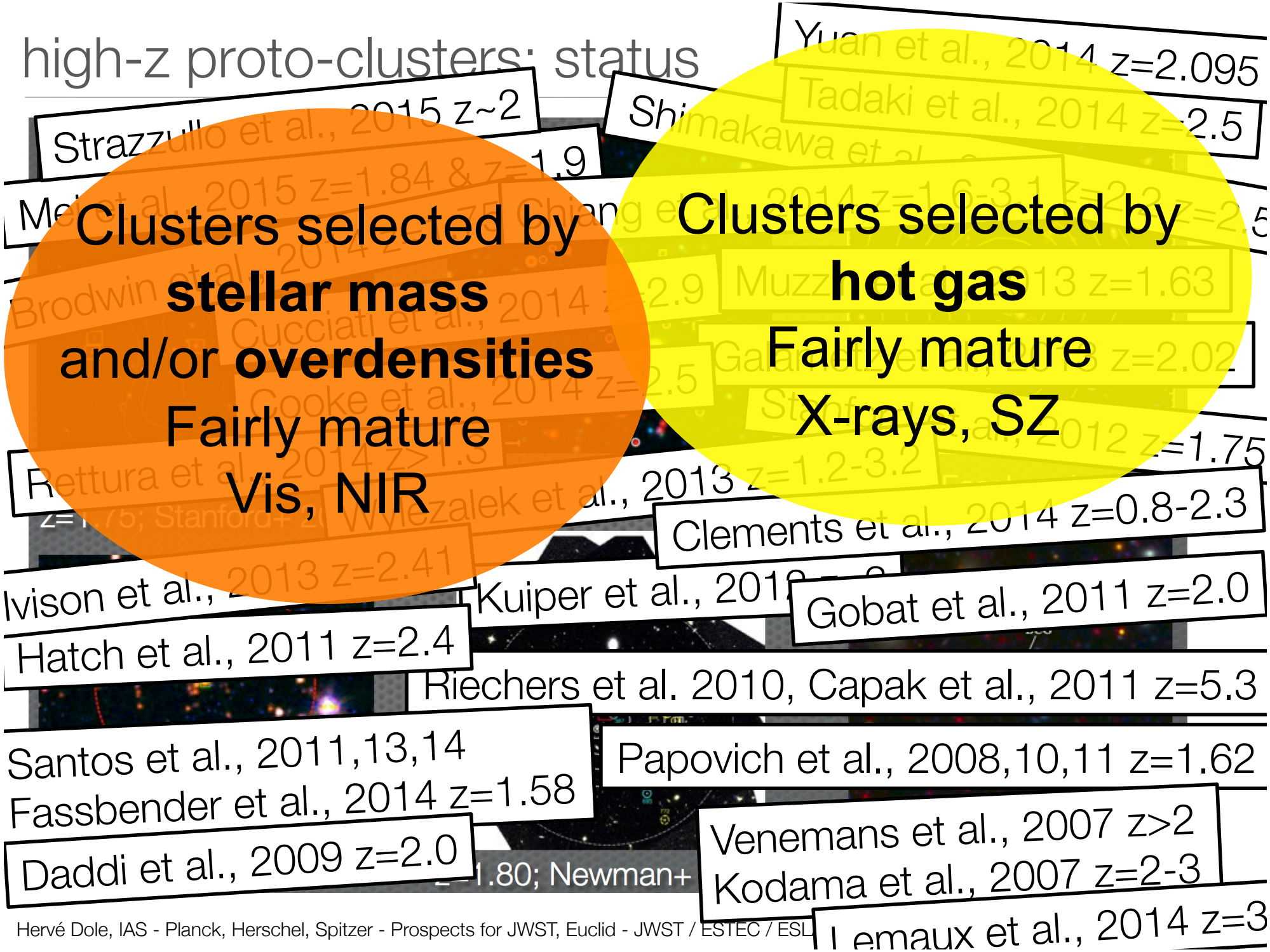

z=1.80; Newman+ 2014



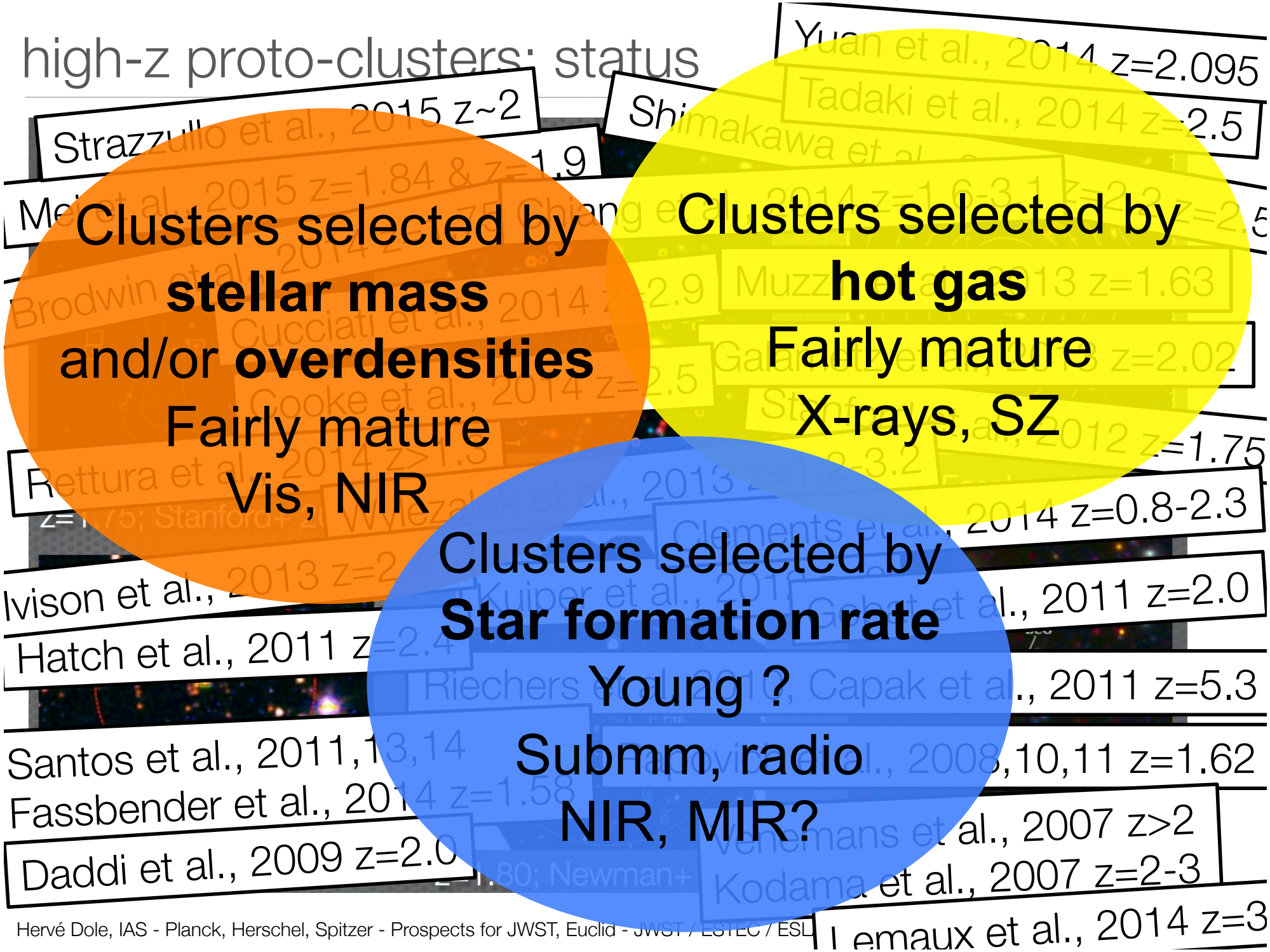

z=1.7; Webb+ 2015

# high-z proto-clusters: status

# high-z proto-clusters: status

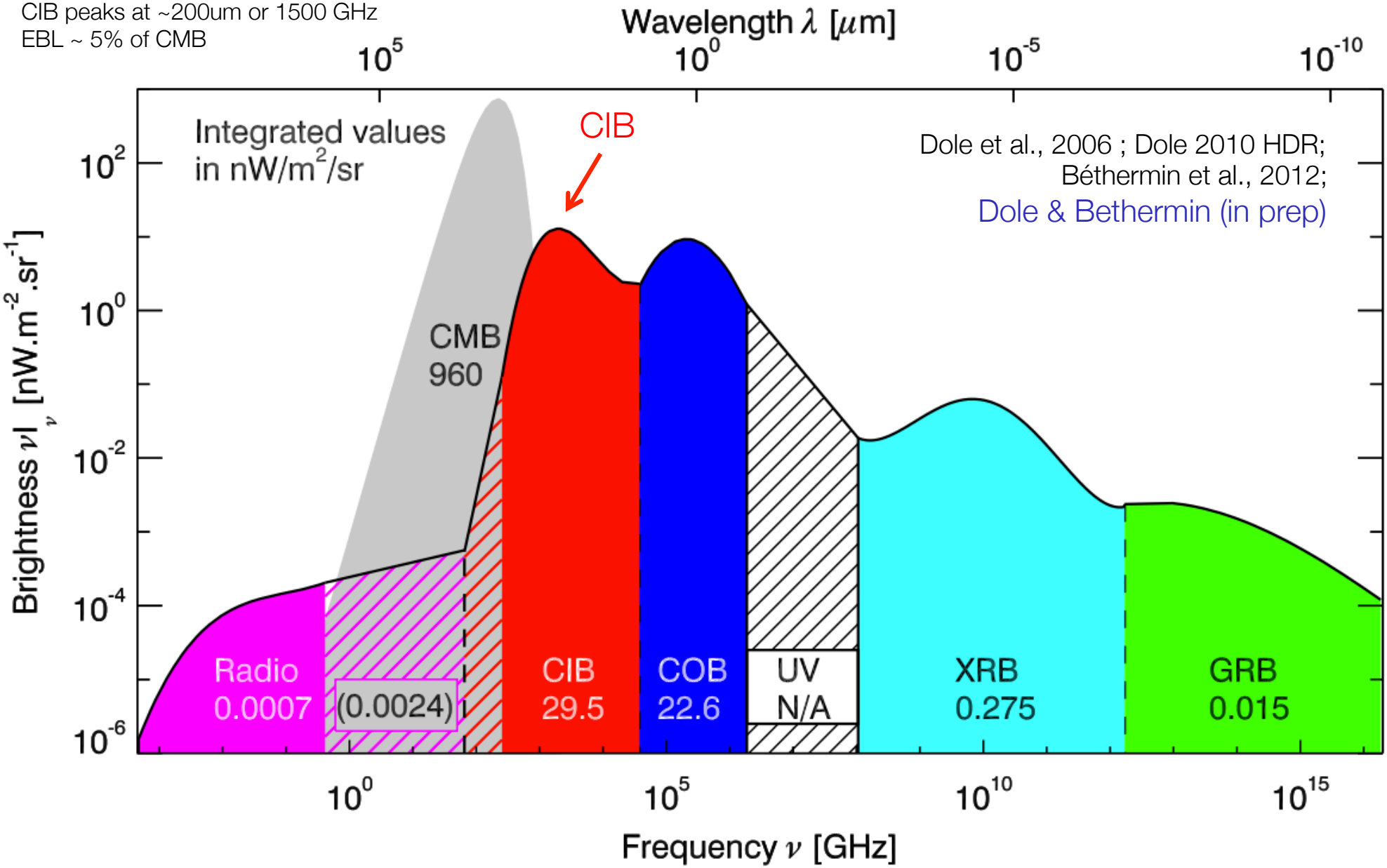


# high-z proto-clusters: status

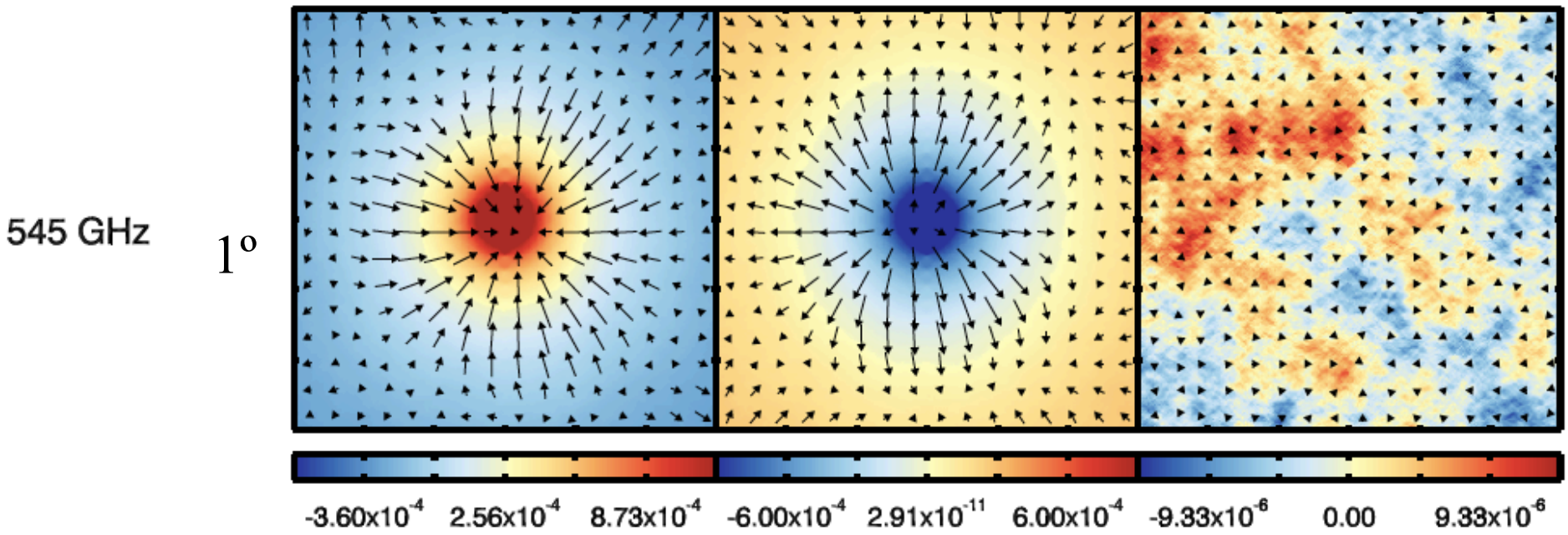


# 2. Extragalactic Background Light SED

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



# CIB peaks correspond to mass peaks…

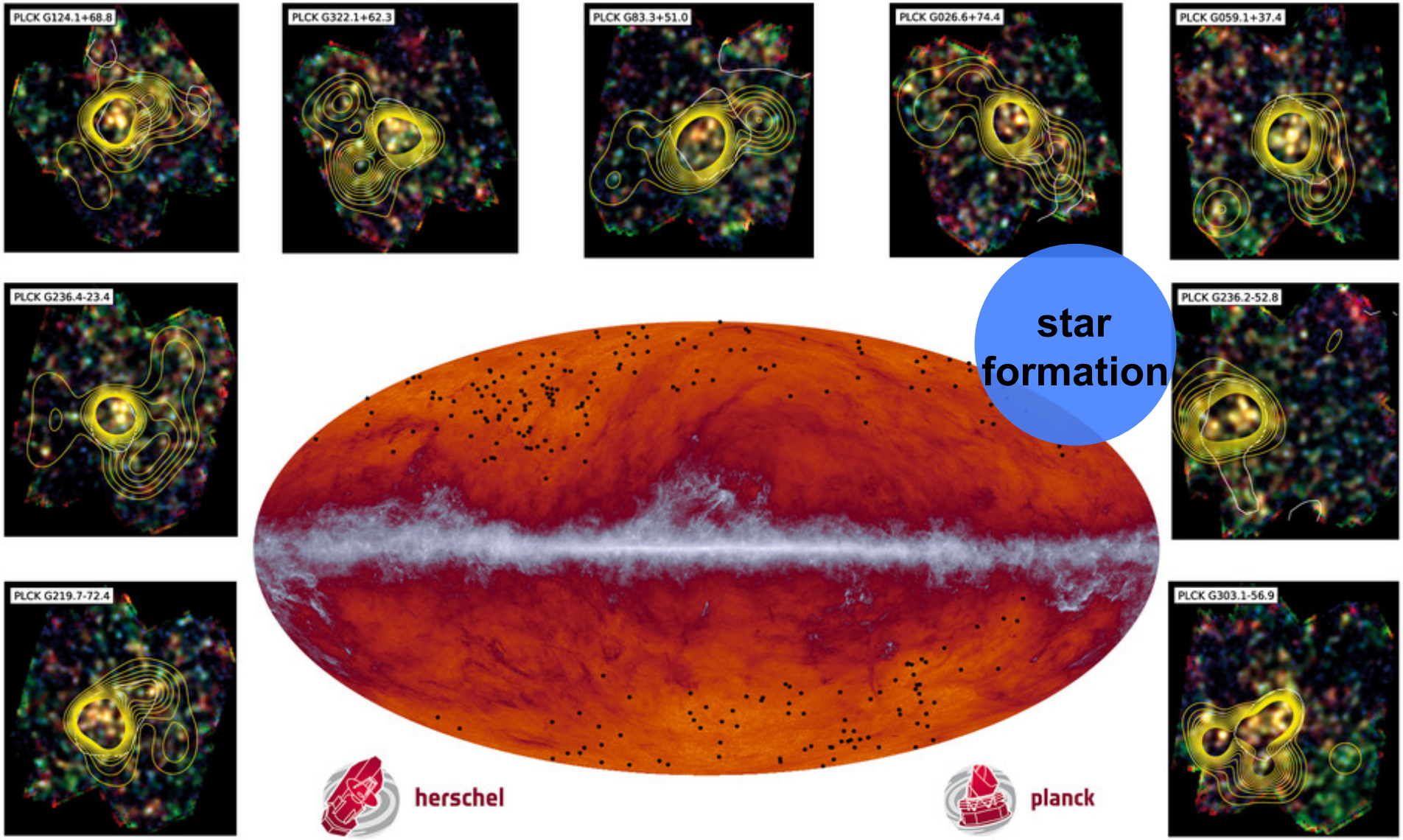



… and the CIB probes also high-z SFR

-> a novel method to search for high-z clusters in formation
(CIB > high SFR > massive high-z clusters)

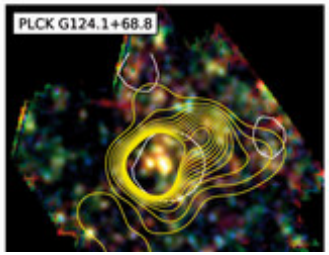
Planck 15 months
Planck Collaboration, 2013, 18

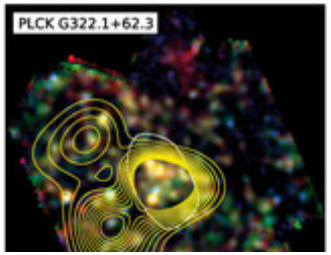
# 3 Herschel and Planck proto-cluster candidates

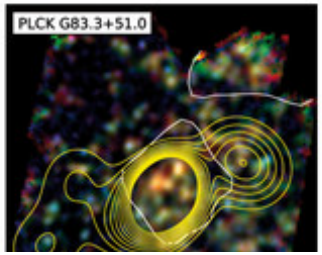


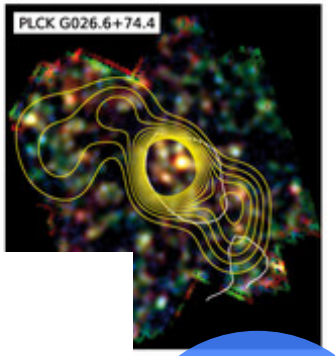

Planck Collab., 2015, Int XXVII, arXiv:1506.01962
Planck Collab., 2015, Int XXXIX, arXiv:1508.04171
Press Releases: ESA, NASA, INSU, A&A

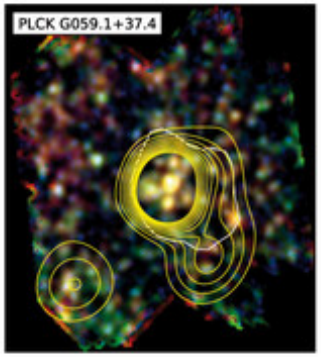
# 3 Herschel and Planck proto-cluster candidates

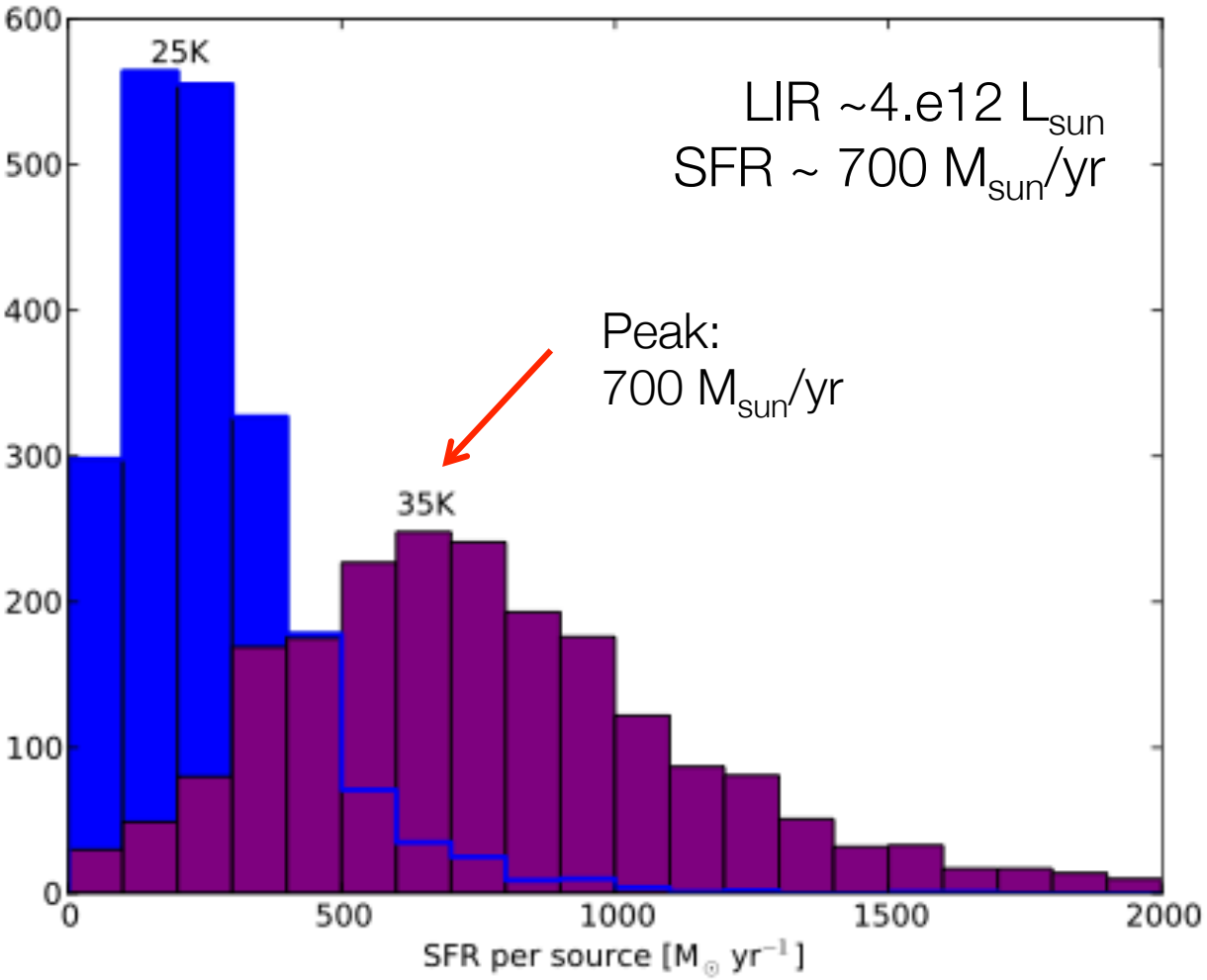


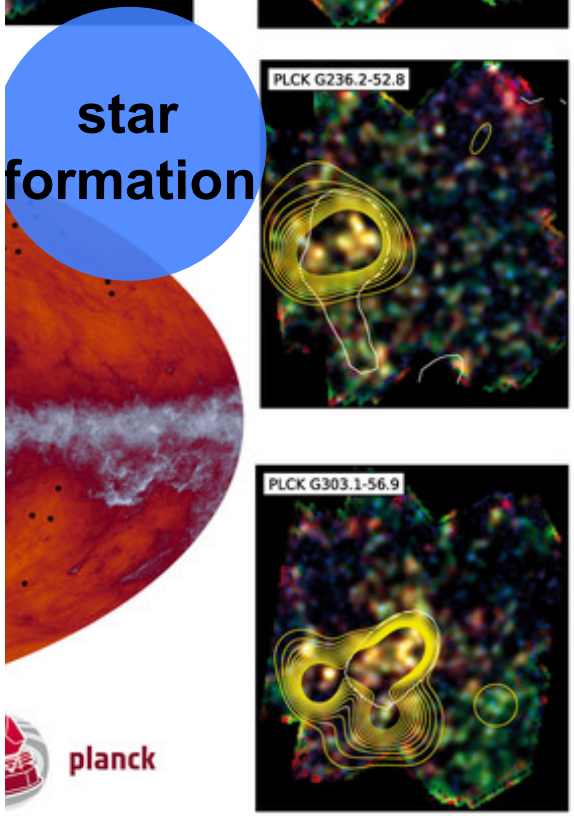



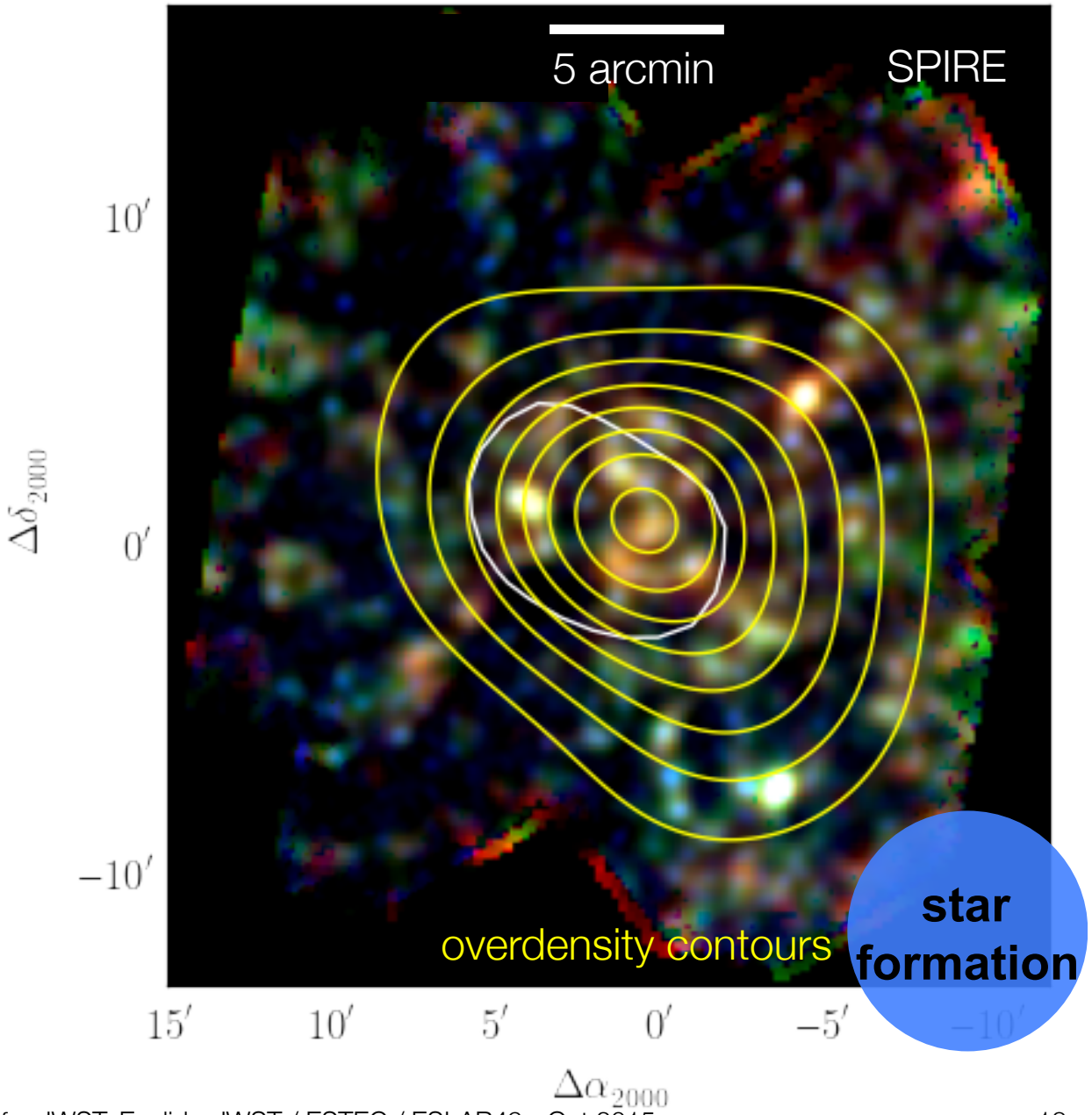




Collab., 2015, Int XXVII, arXiv:1506.01962
Collab., 2015, Int XXXIX, arXiv:1508.04171
Press Releases: ESA, NASA, INSU, A&A

# the case of one field: Herschel & Spitzer

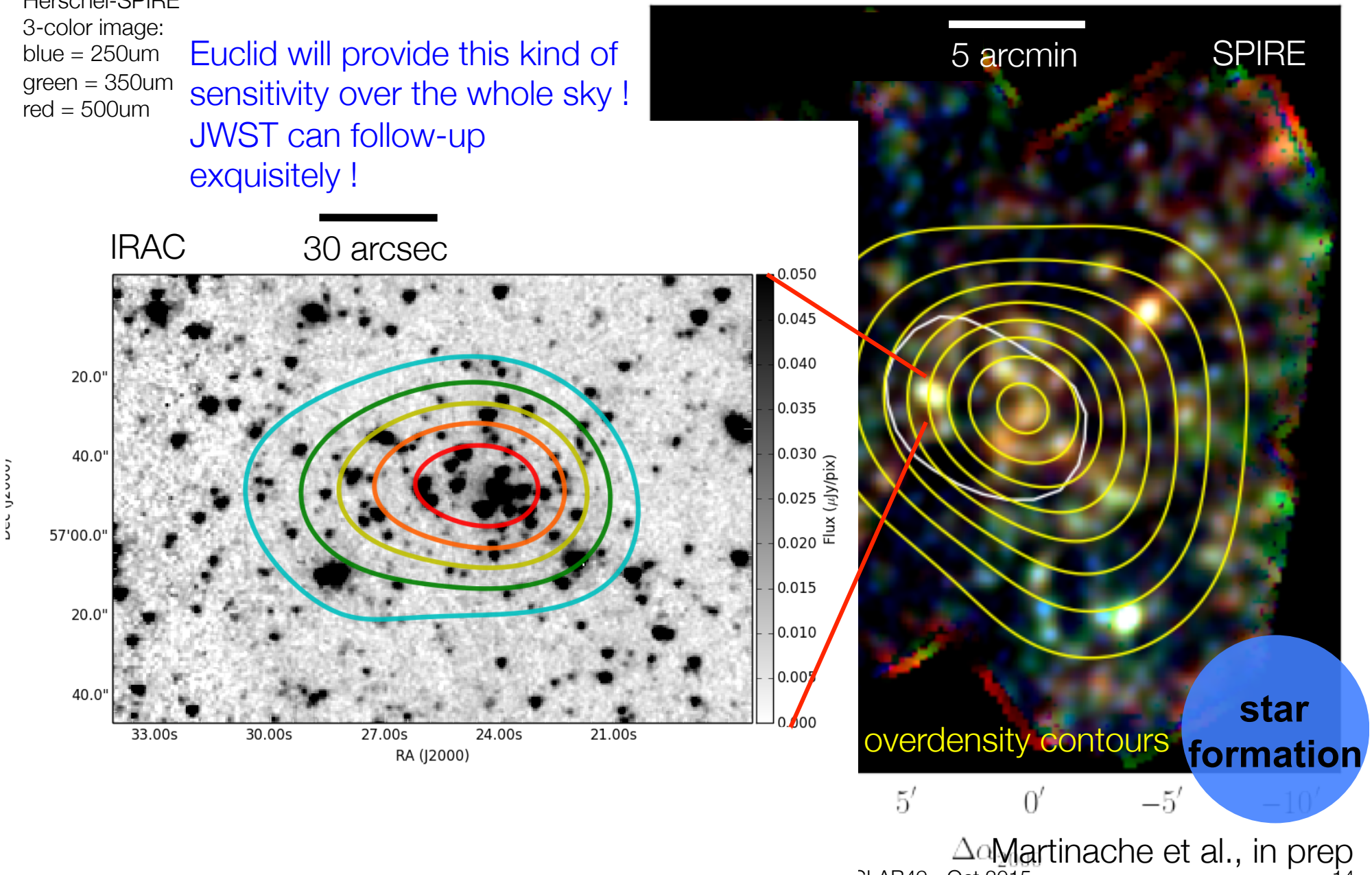
Herschel-SPIRE
3-color image:
blue = 250um
green = 350um
red = 500um



# 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 !

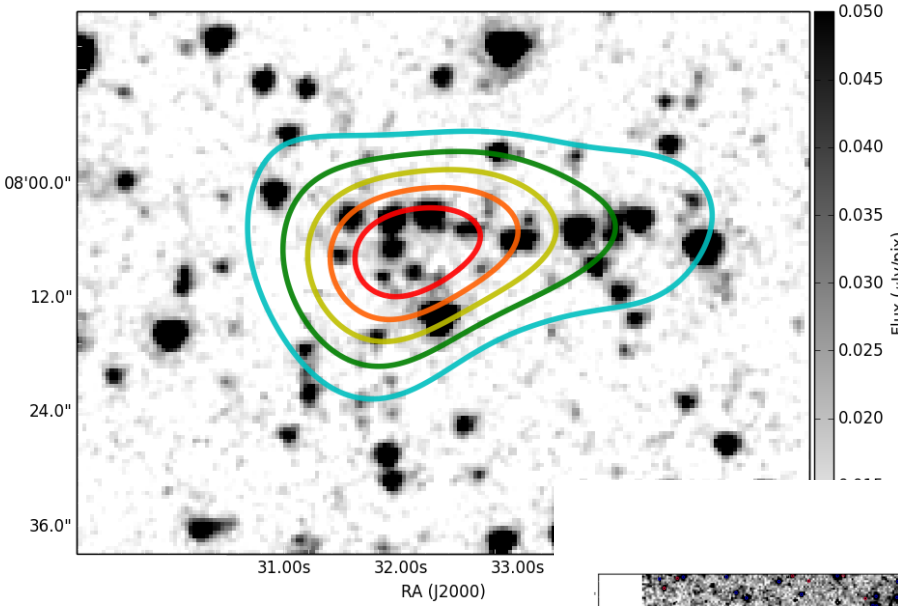



Martinache et al., in prep

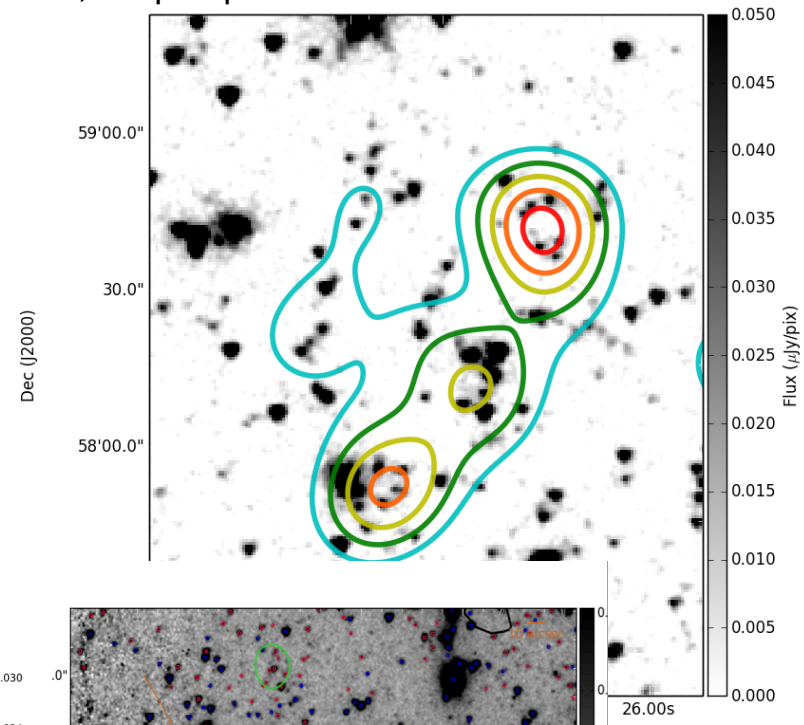
# many more Spitzer examples of Planck src

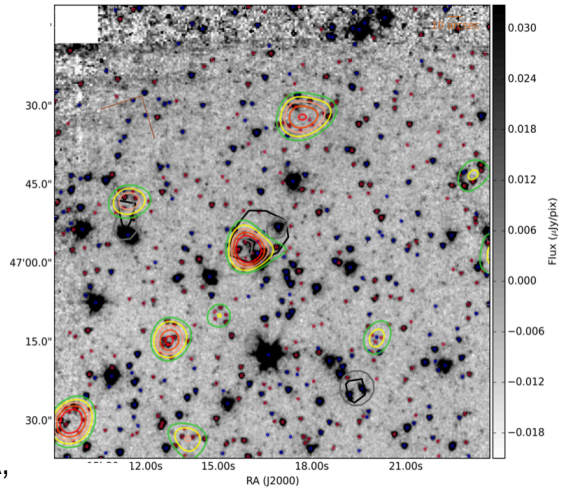
Martinache et al., in prep

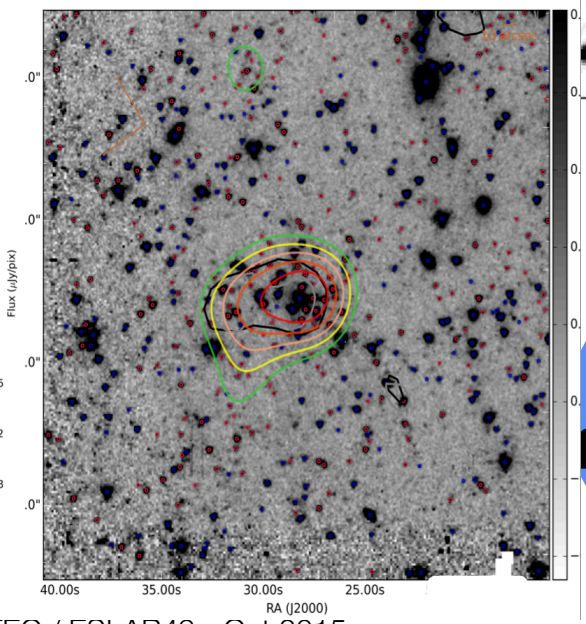
IRAC




IRAC



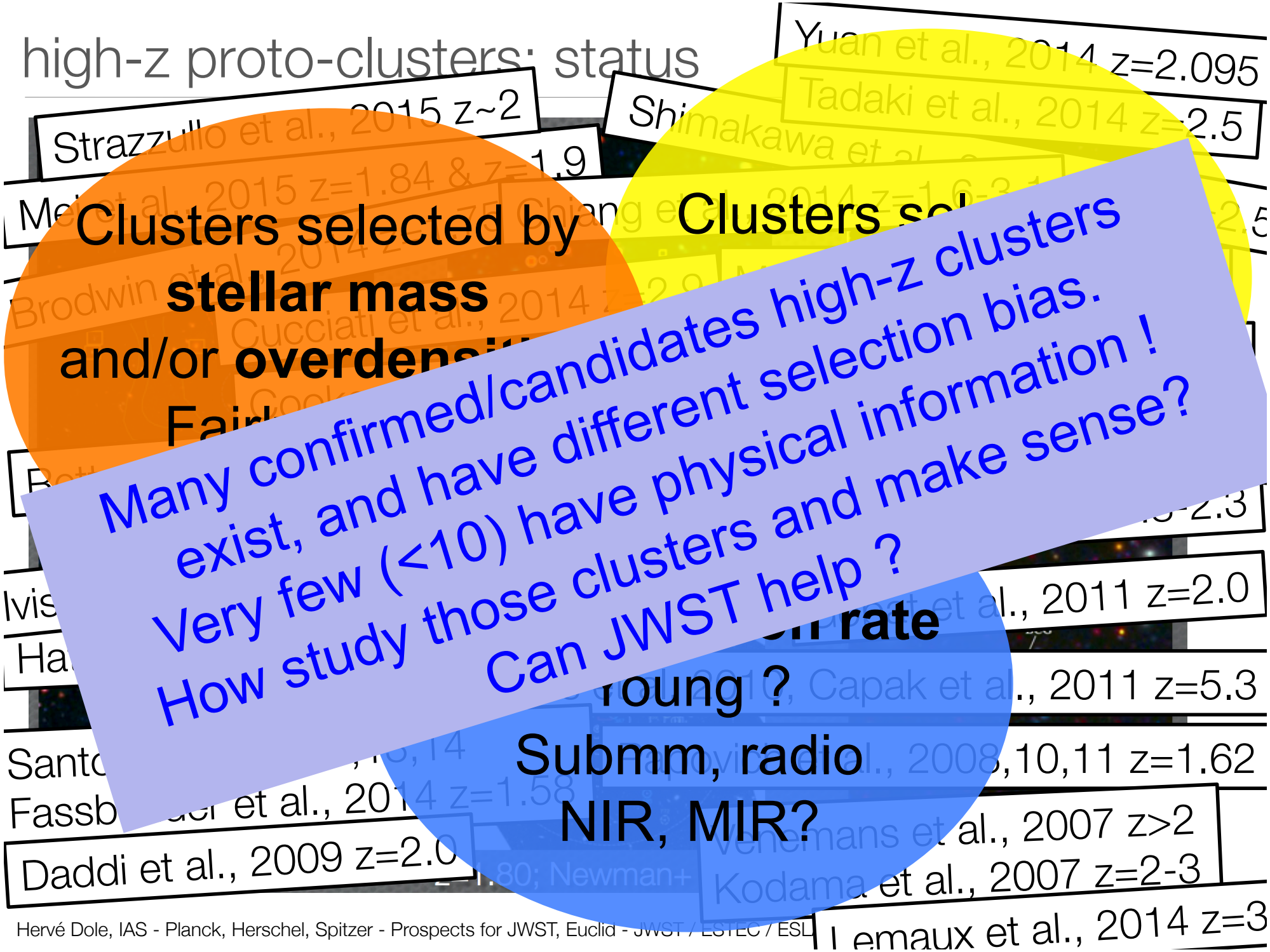



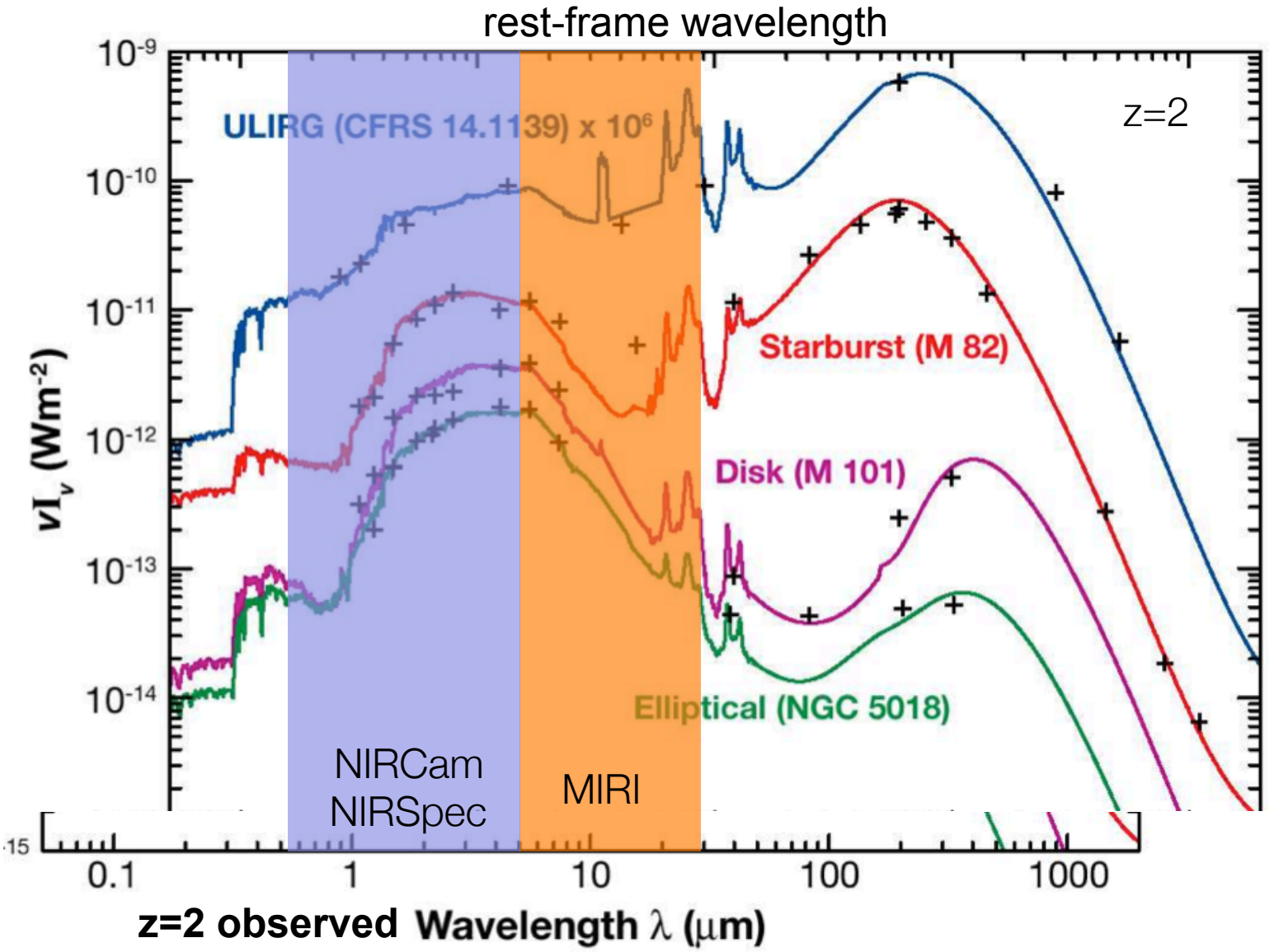

**star formation**

See also Flores-Cacho et al., 2015, A&A,

# high-z proto-clusters: status



# NIR+MIR: a key range for z>1 structures



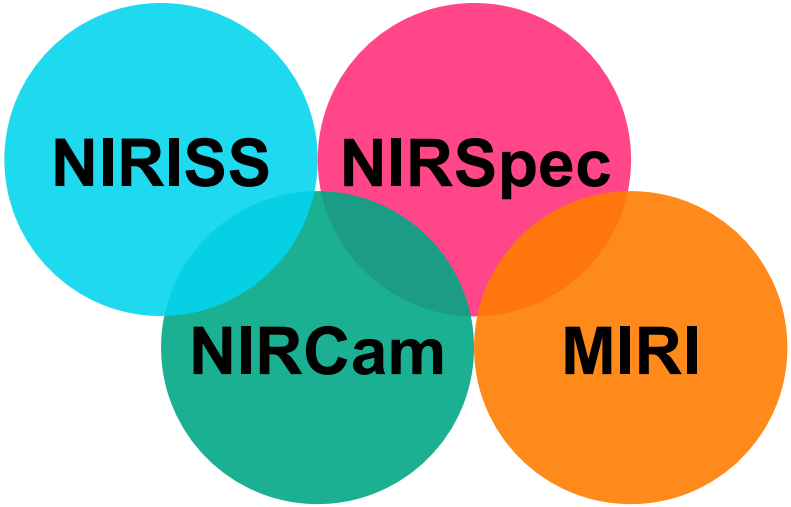

In the redshift range
~1 < z < ~4
MIRI probes
unique spectral
features,
even at low spectral
Resolution

AGN vs SF
H2

Lagache, Dole, Puget, 2005, ARAA
from Galliano 2004

# A coherent JWST GO on high-z clusters ?

- 450 high-z (proto-)clusters: about 150 clusters of each class at z>~2


- Science goals: cluster formation / bias baryons vs DM / star formation/ AGN in dense environements w/ z
- census of cluster formation
- DM-baryons links, and gas dynamics
- NIR+MIR lines
  - Galaxies and cluster dynamics w/ galaxies and gas
  - Mass, (z), SF vs AGN, energetics

- NIR and MIR spectroscopy
  - Slitless NIRISS+NIRCam
  - or NIRSpec MOS
  - and MIRI IFU
  - + preimaging

# 5. summary & concl.: high-z (proto-)clusters

- High-z (proto-)clusters are exciting
  - Cosmology, LSS
  - Galaxy evolution
  - e.g. Planck/Herschel
- Many samples of z>2 cluster exist
  - confirmed or candidates
  - targets are already identified
  - or to be identified: open discovery space
- Different & complementary selections
- Coordination for a high-z cluster JWST proposal
  - NIR+MIR spectroscopy + imaging
  - 450 clusters (150 each) allowing stacking and statistical analysis
  - Census of z>2 galaxy cluster formation, the gas in densest environments and halos
  - and 3 clusters for an ERS proposal
  - Synergies w/ Euclid & ground (e.g. SPT) adding new clusters