Unveiling long-lasting and violent growth of galaxies with Herschel:
a puzzling uniformity of distant dusty galaxies

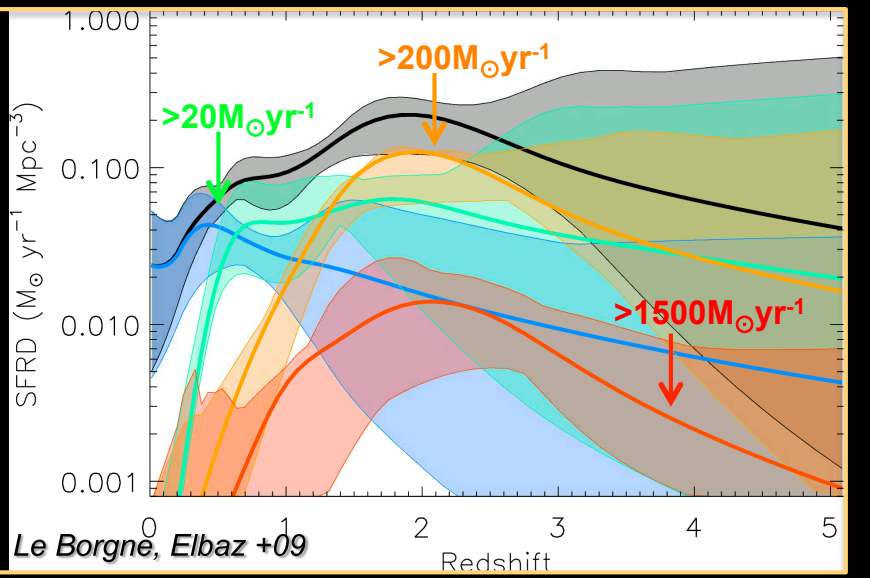
Elbaz, Hwang, Magnelli, Daddi, Aussel + PEP + HERMES consortia

• How and when did the bulk of present-day stars formed ?

→ short starbursts vs long duty cycle ...

→ mergers vs internal instabilities vs cold flows of intergalactic gas ...

→ cosmic SFR history vs cosmic stellar mass density ...

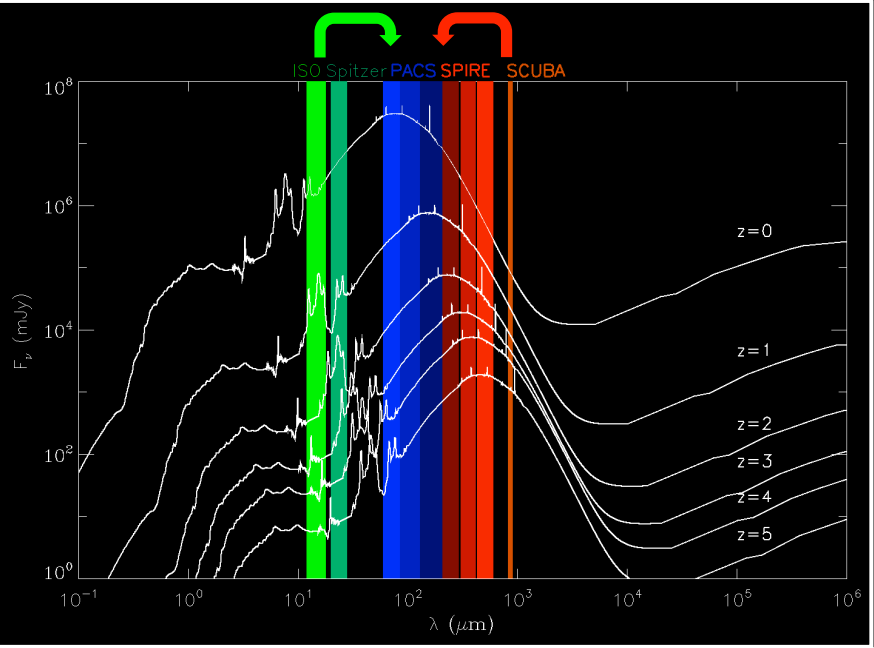


• Until now, bolometric luminosity extrapolated from mid-IR or sub-mm

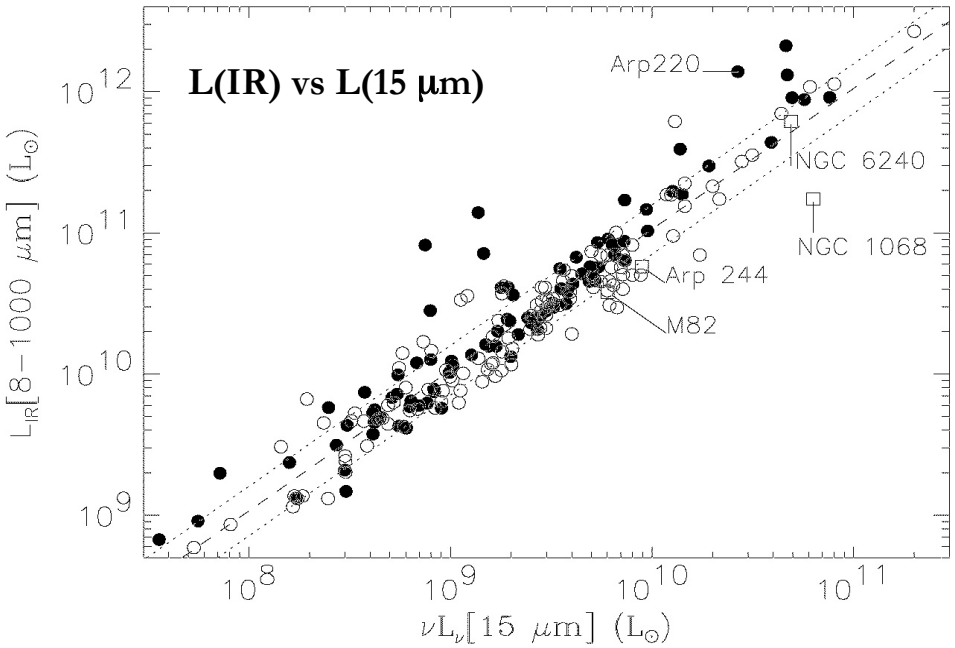
→ at z>0.7, cosmic SFR density dominated by LIRGs...

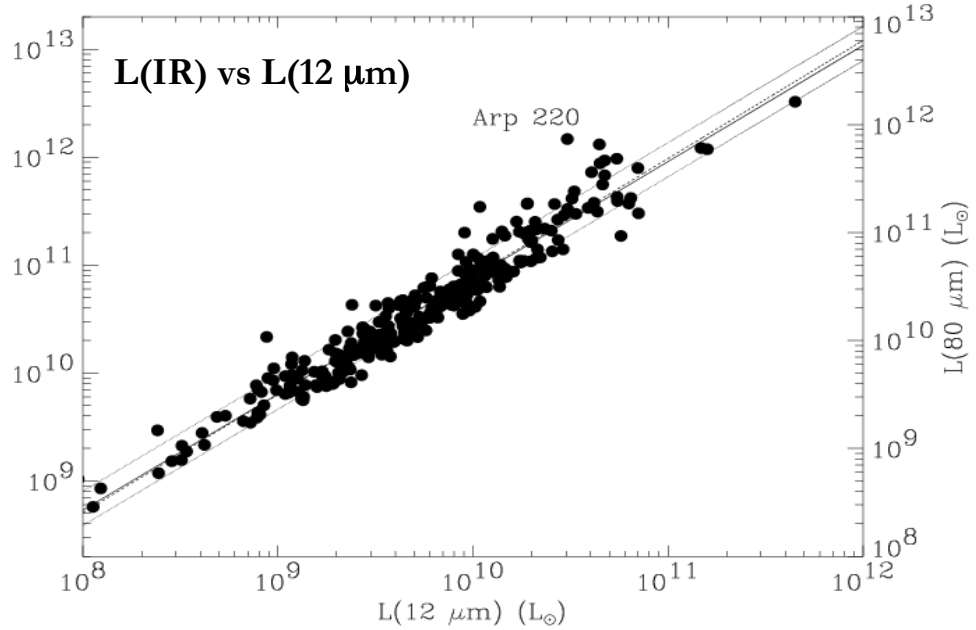
→ the role of major mergers has been questioned recently (morphology, SFR-M*)...

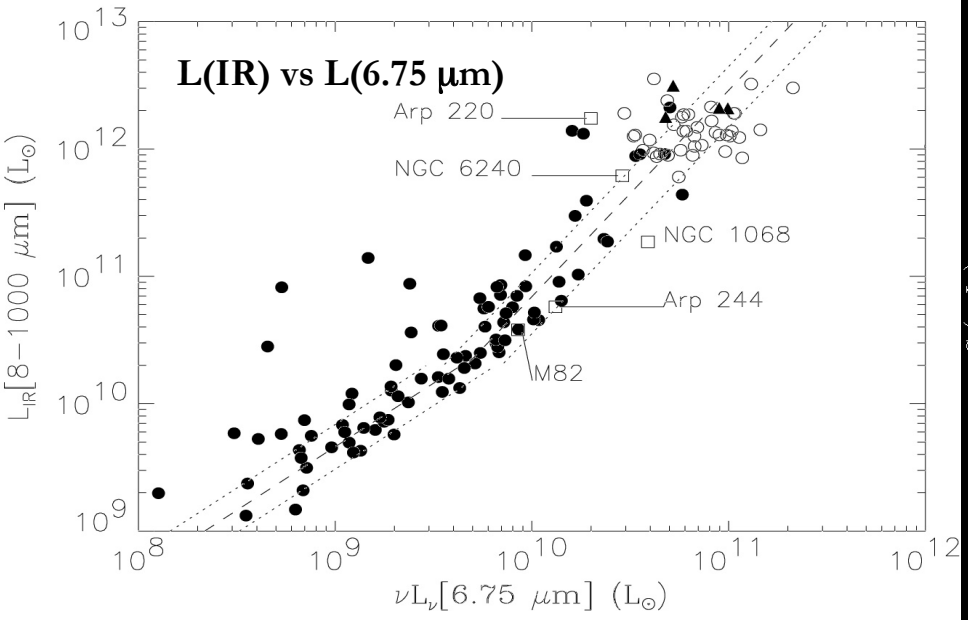
→ parallel growth of SMBH and stars...

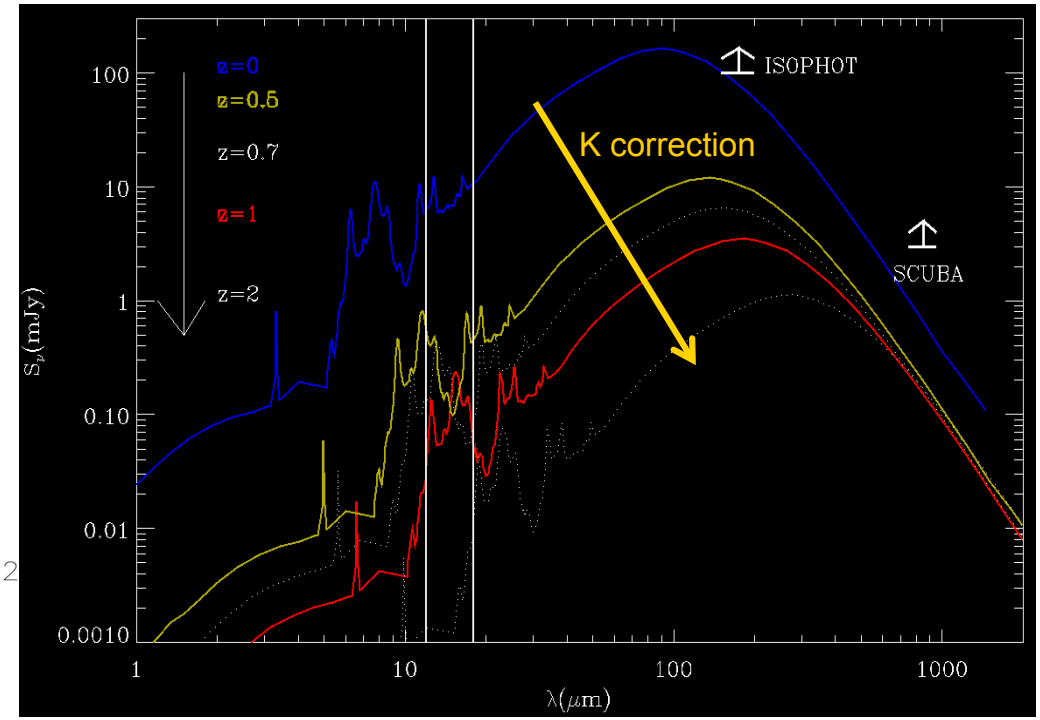


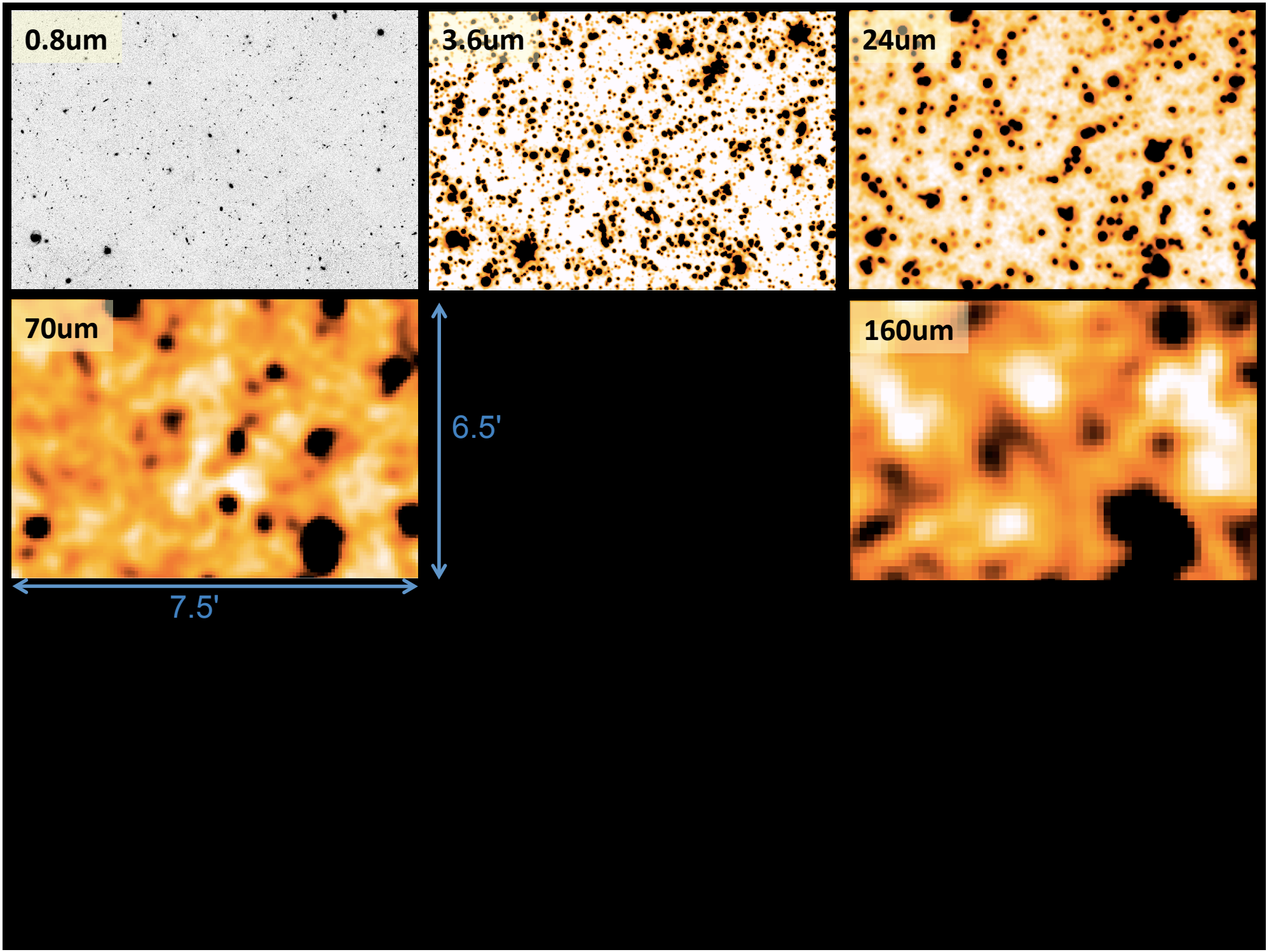
Before Herschel total IR luminosities were extrapolated from the mid-IR & submm

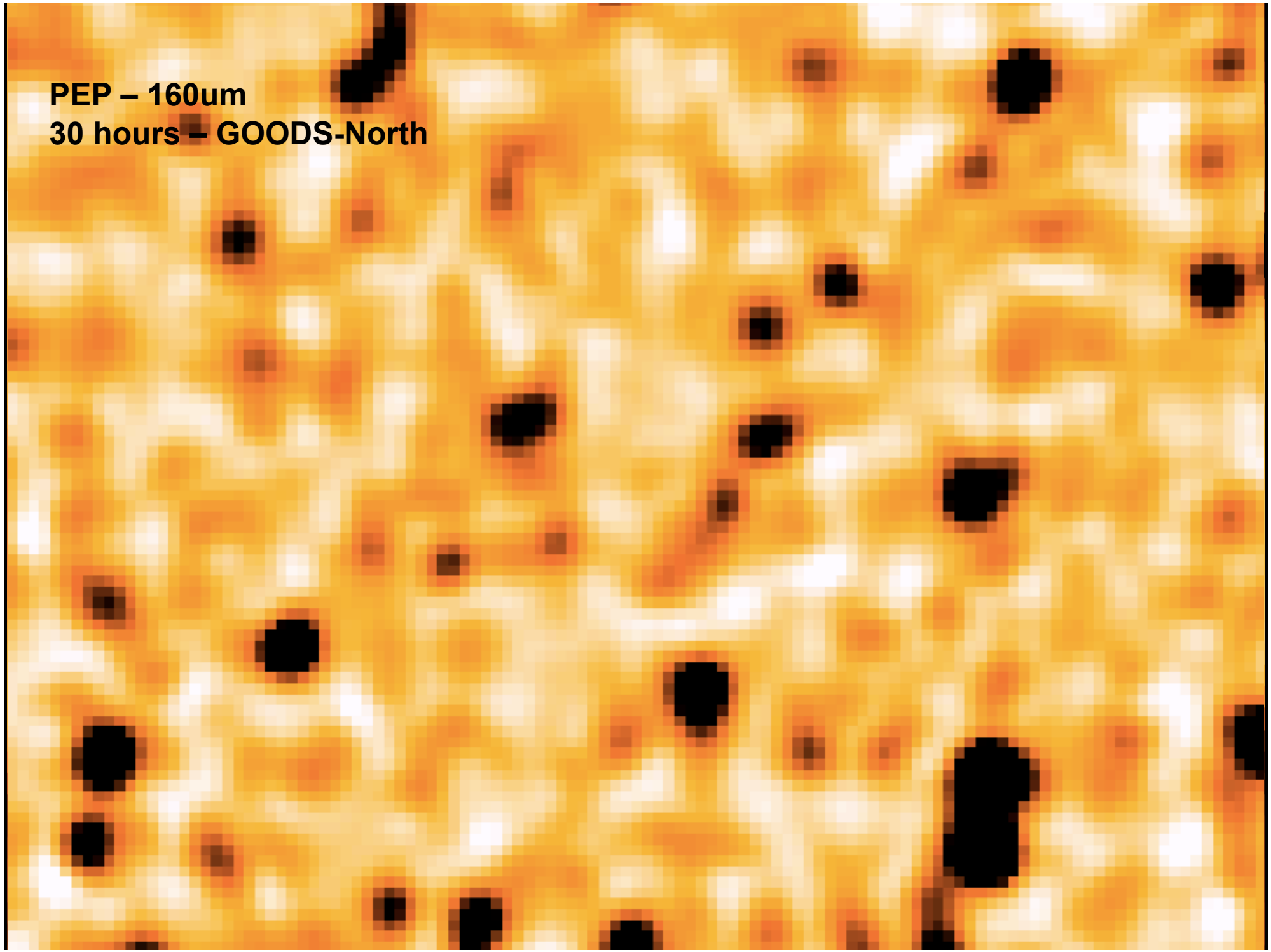


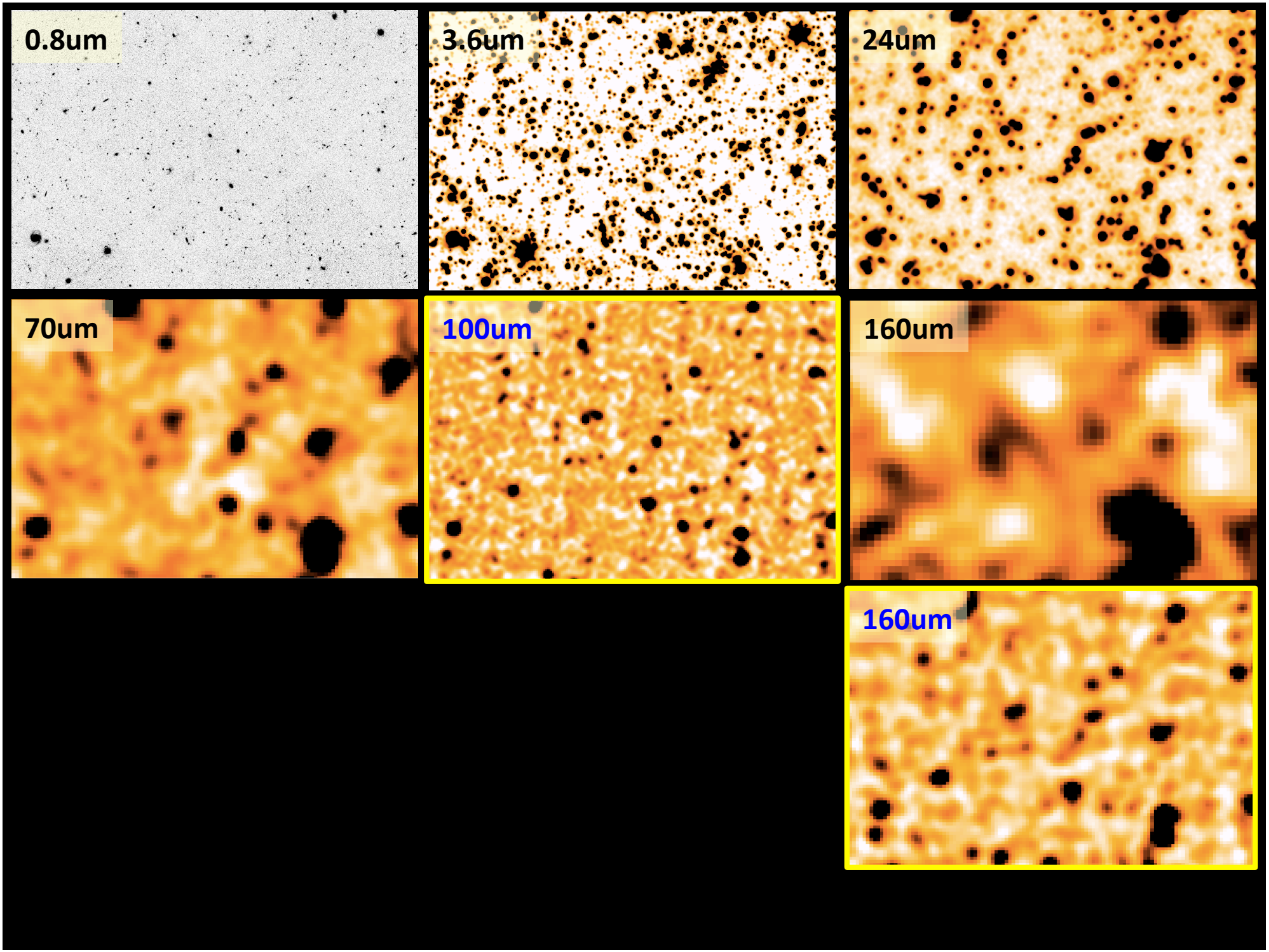


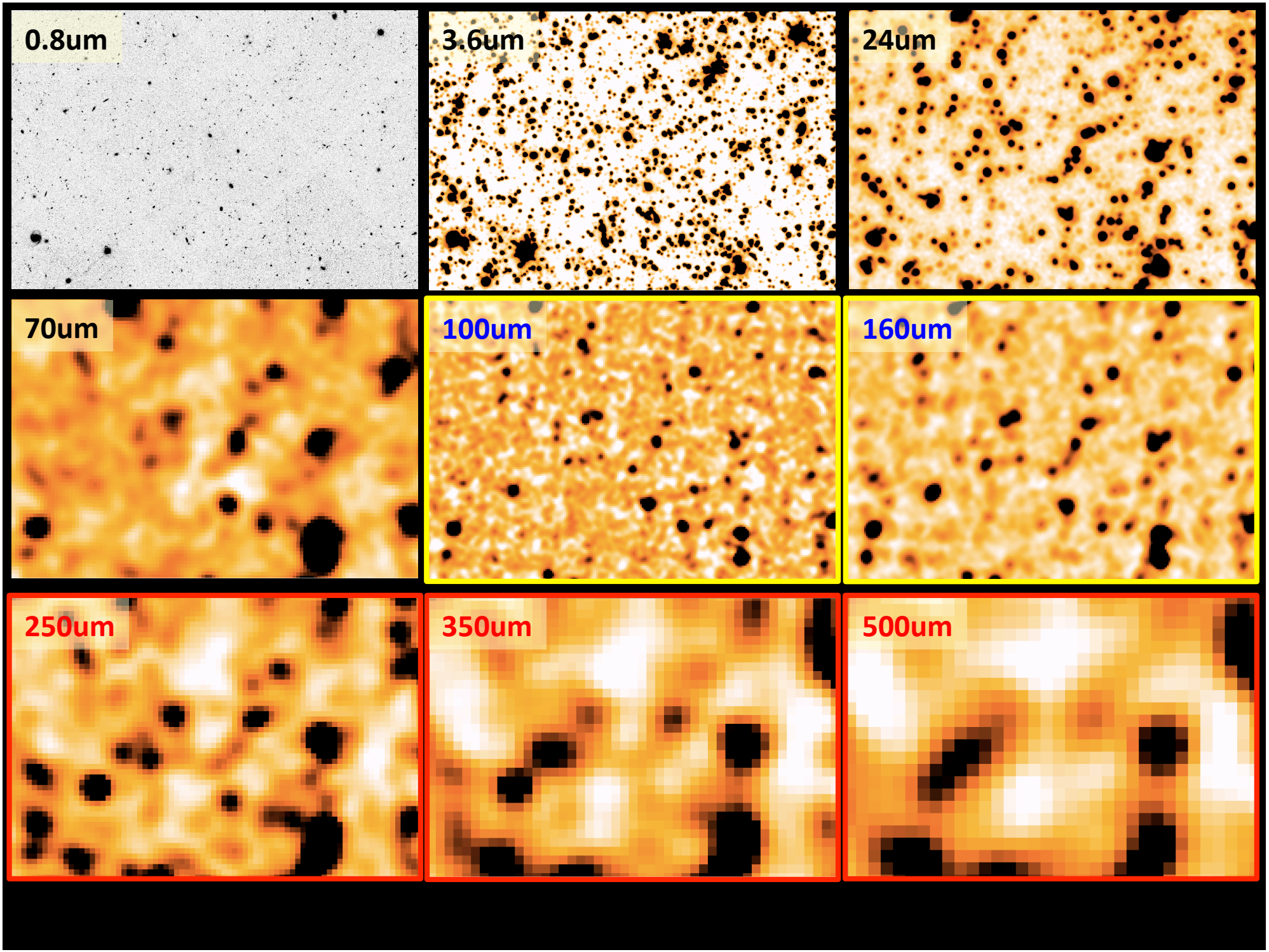





0.8um
3.6um
24um
70um
160um
6.5'
7.5'


PEP – 160um
30 hours – GOODS-North

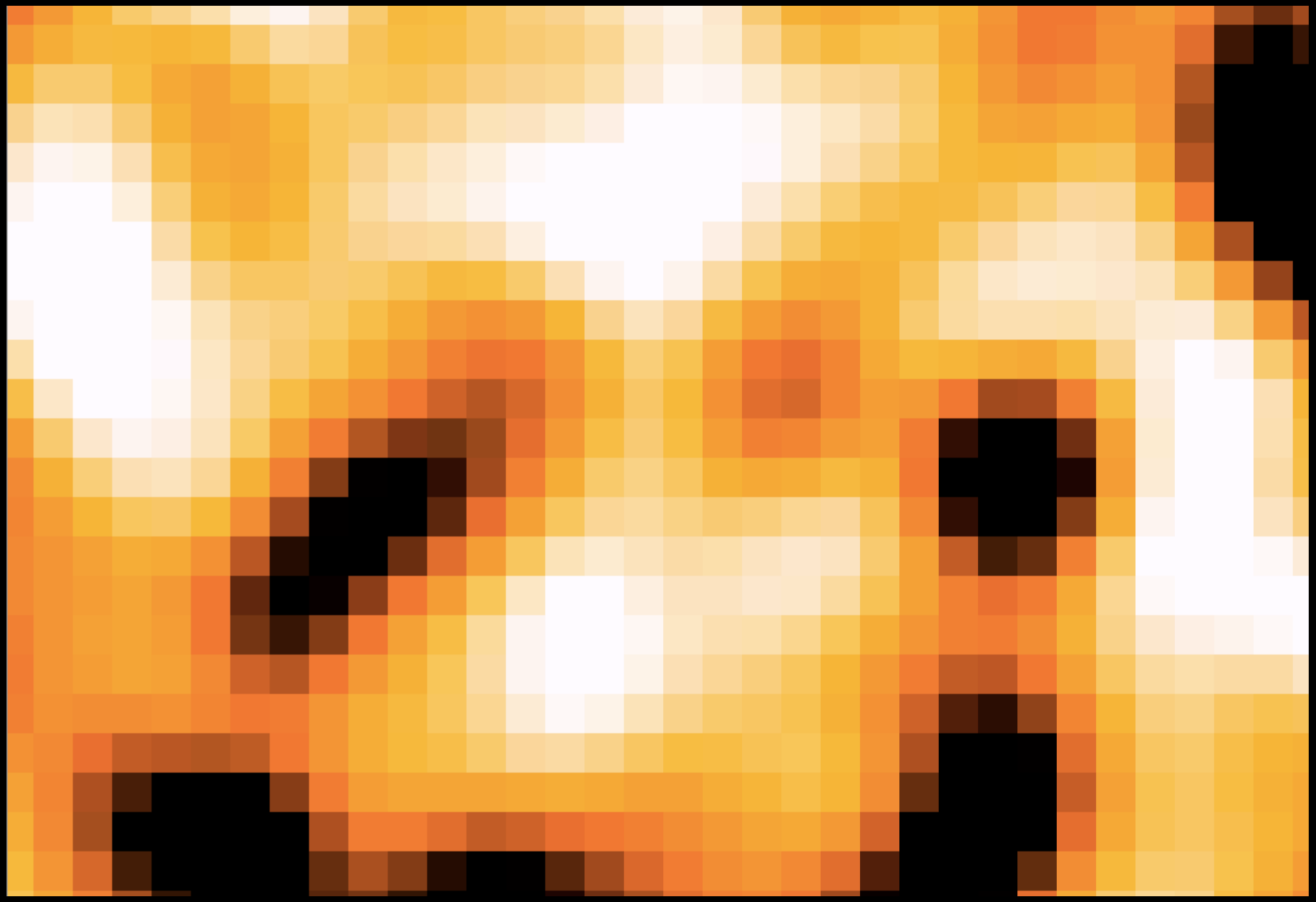

0.8um
3.6um
24um
70um
100um
160um
160um


0.8um
3.6um
24um
70um
100um
160um
250um
350um
500um

The power of multi-wavelength imaging against confusion

500um

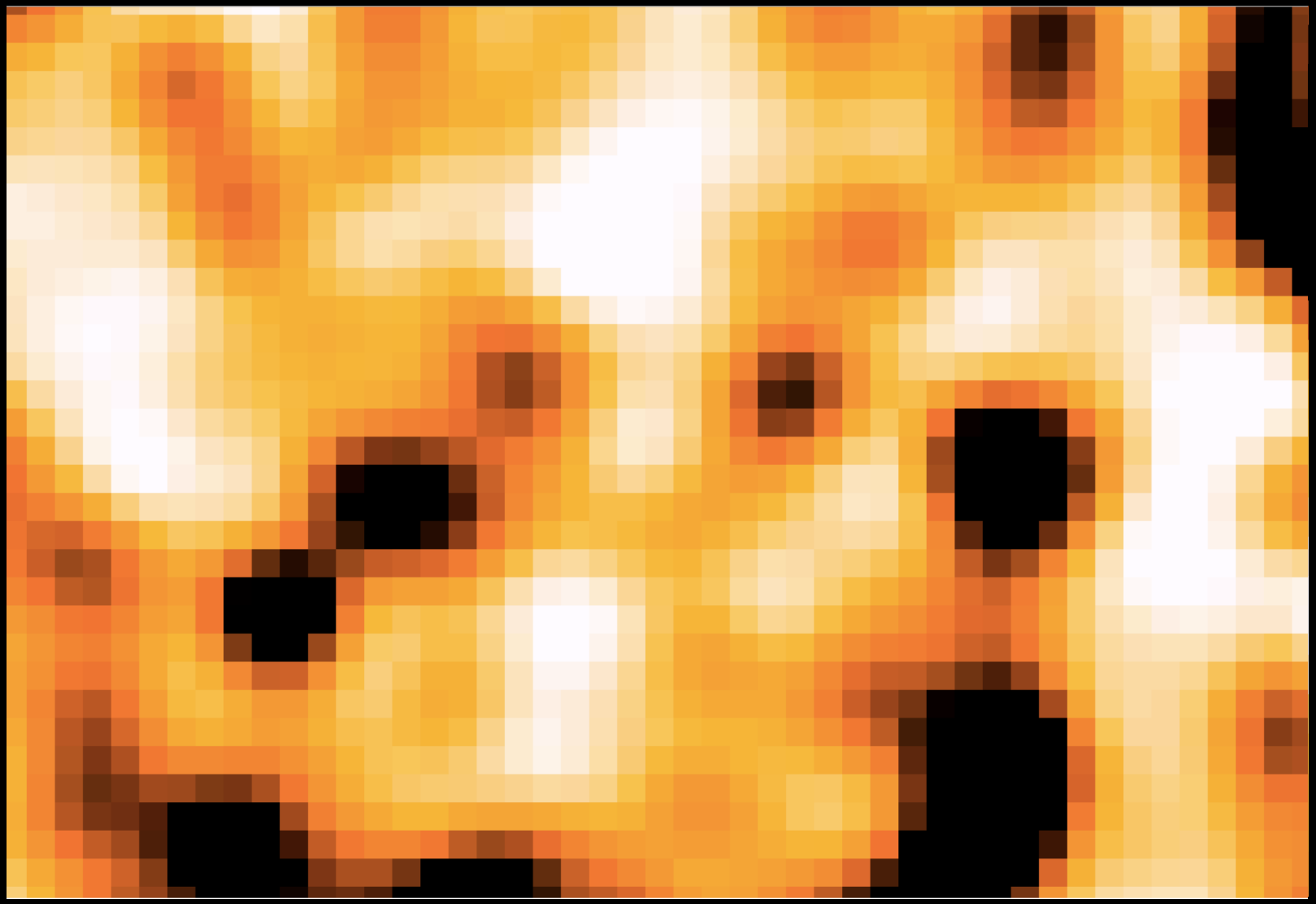
7.5' x 6.5' zoom on the GOODS-North field (10' x 15')



The power of multi-wavelength imaging against confusion

500um 350um

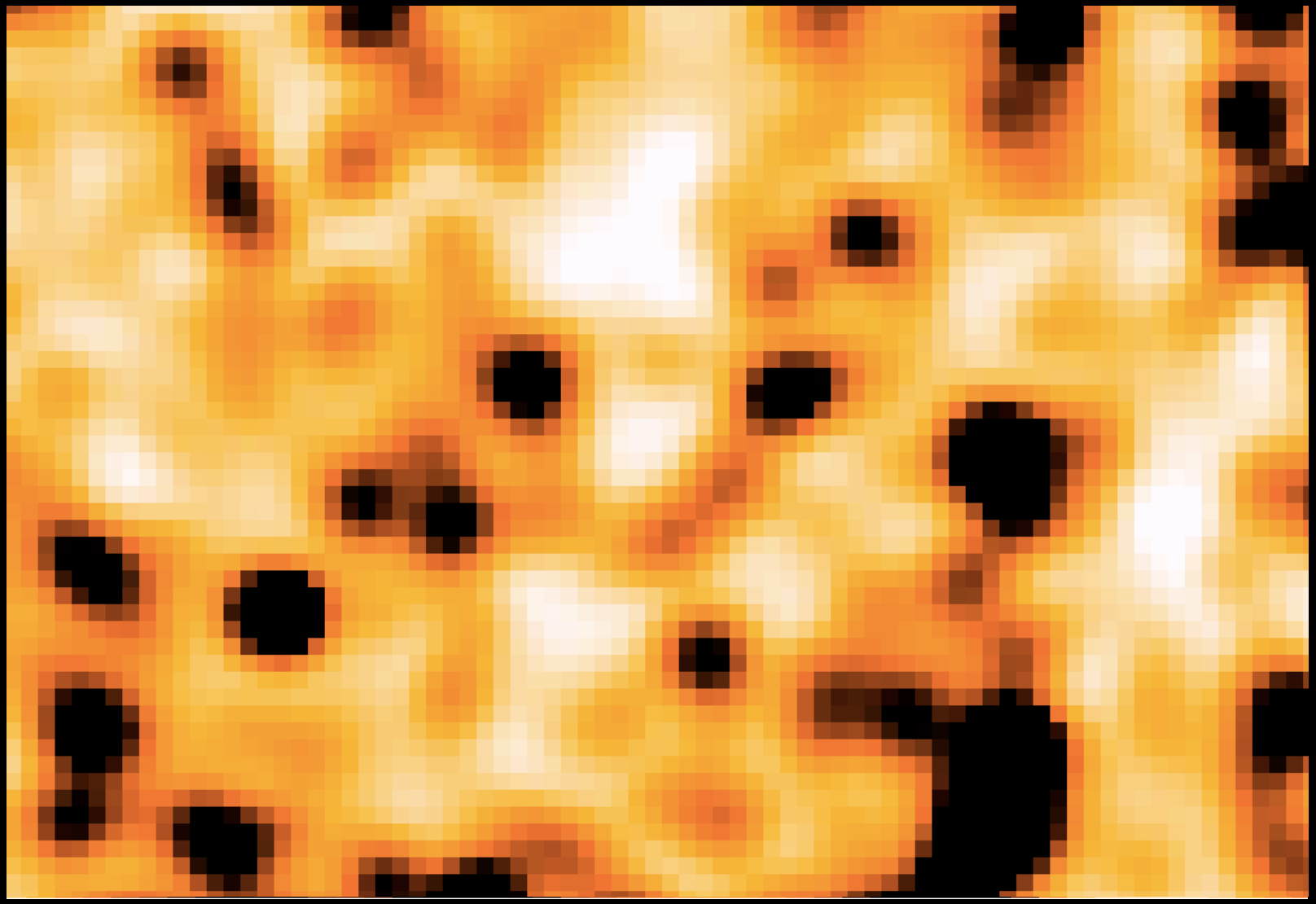
7.5' x 6.5' zoom on the GOODS-North field (10' x 15')



The power of multi-wavelength imaging against confusion

500um 350um 250um

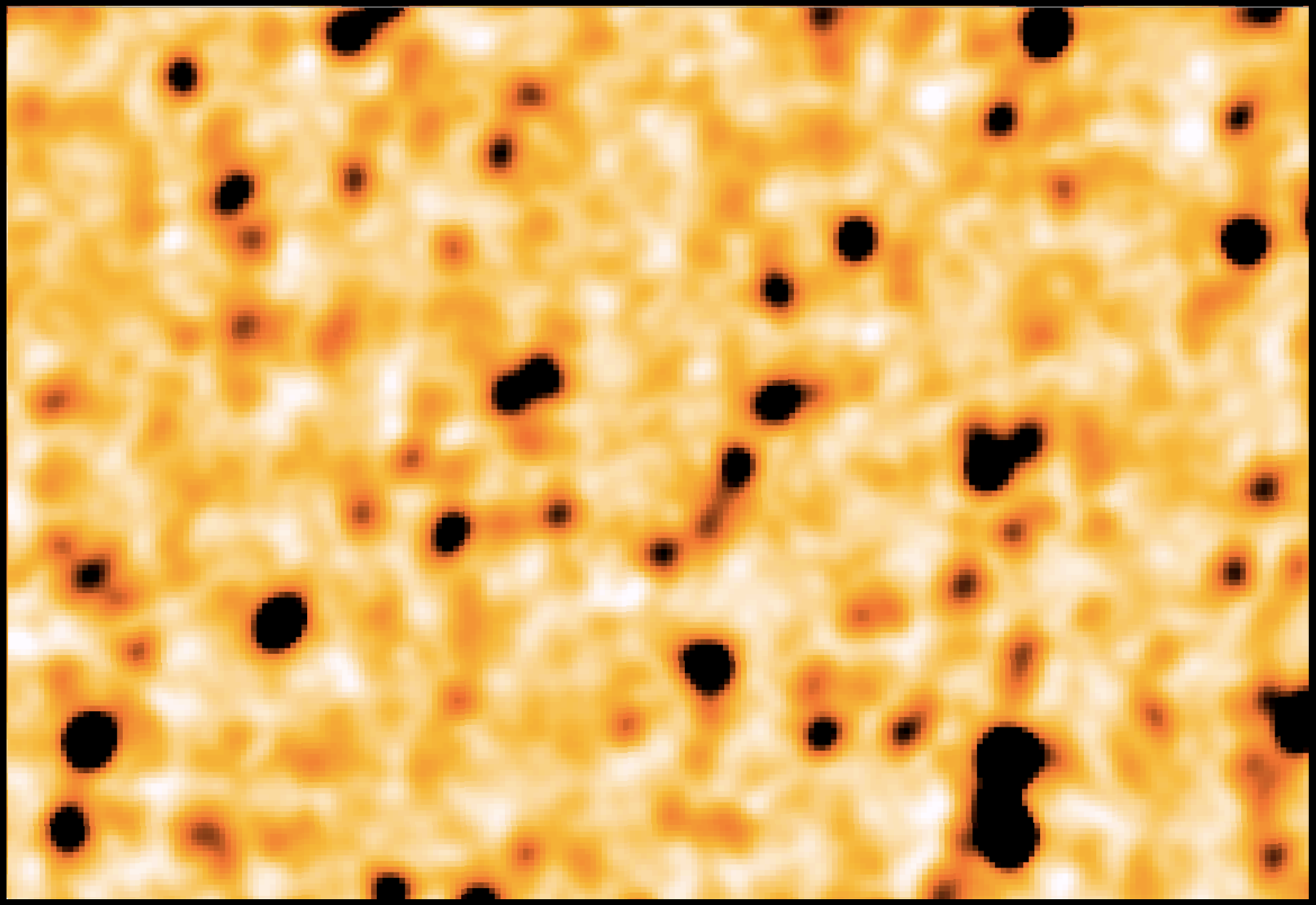
7.5' x 6.5' zoom on the GOODS-North field (10' x 15')



The power of multi-wavelength imaging against confusion

500um 350um 250um 160um

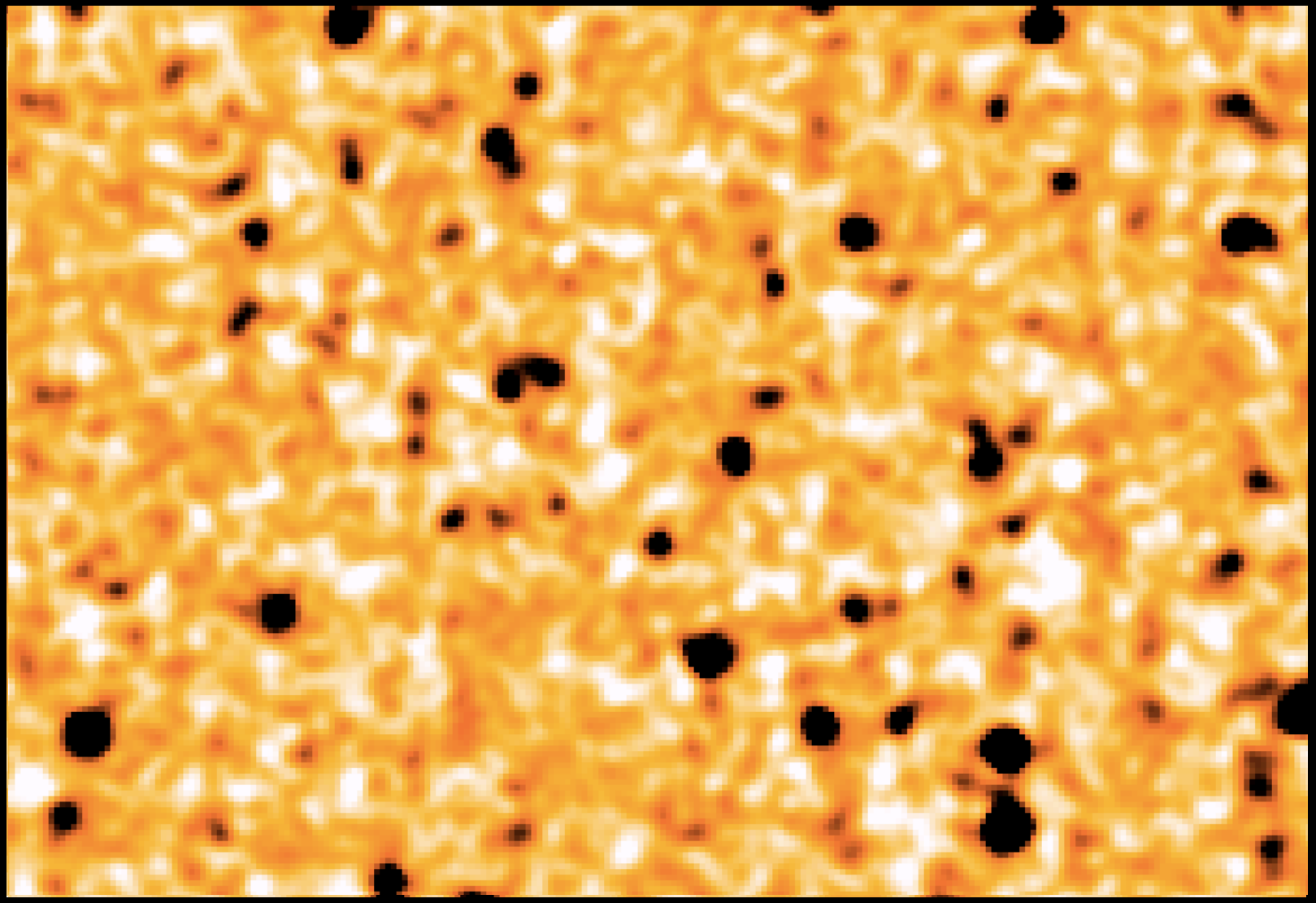
7.5' x 6.5' zoom on the GOODS-North field (10' x 15')



The power of multi-wavelength imaging against confusion

500um 350um 250um 160um 100um

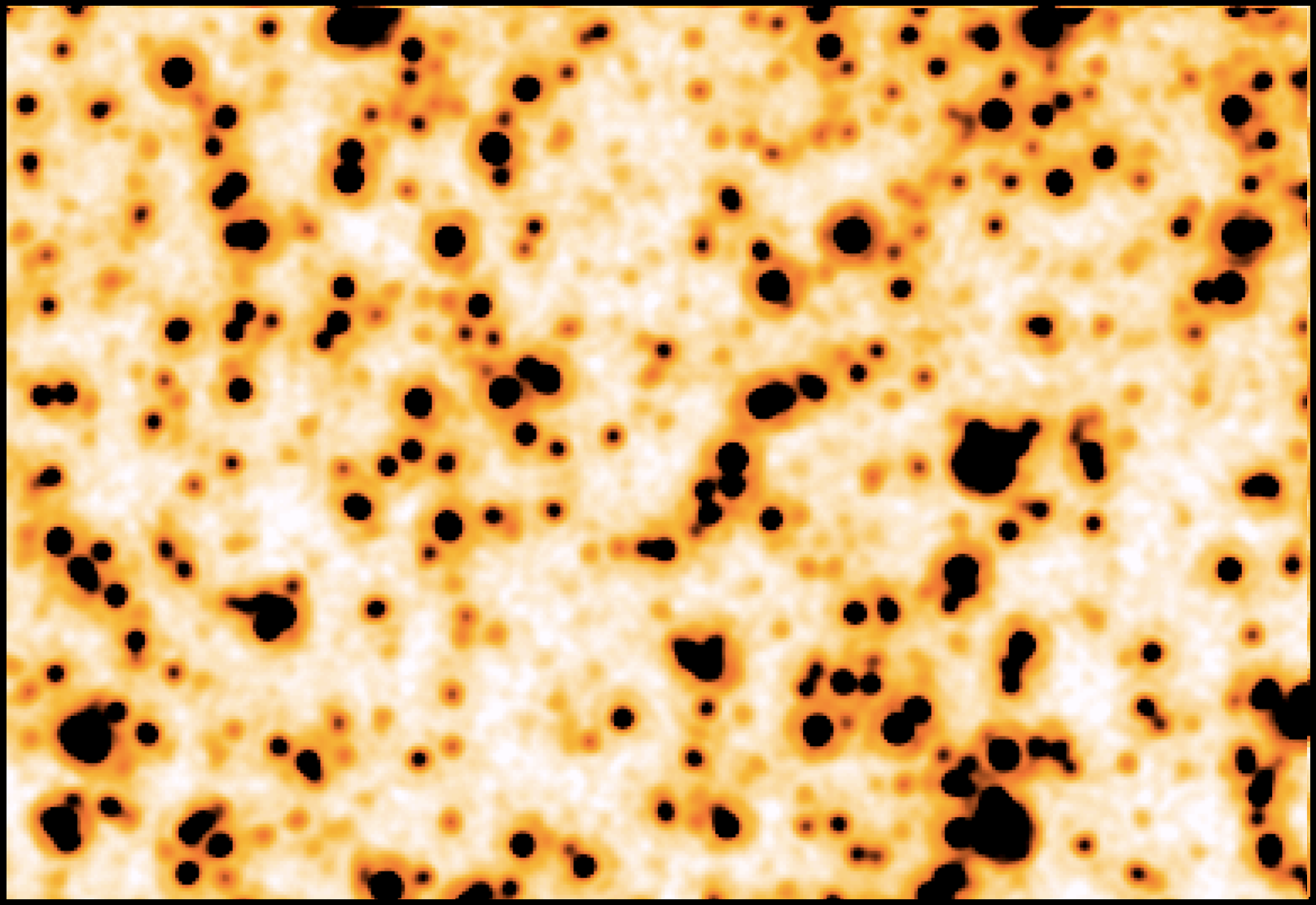
7.5' x 6.5' zoom on the GOODS-North field (10' x 15')



The power of multi-wavelength imaging against confusion

500um 350um 250um 160um 100um 24um

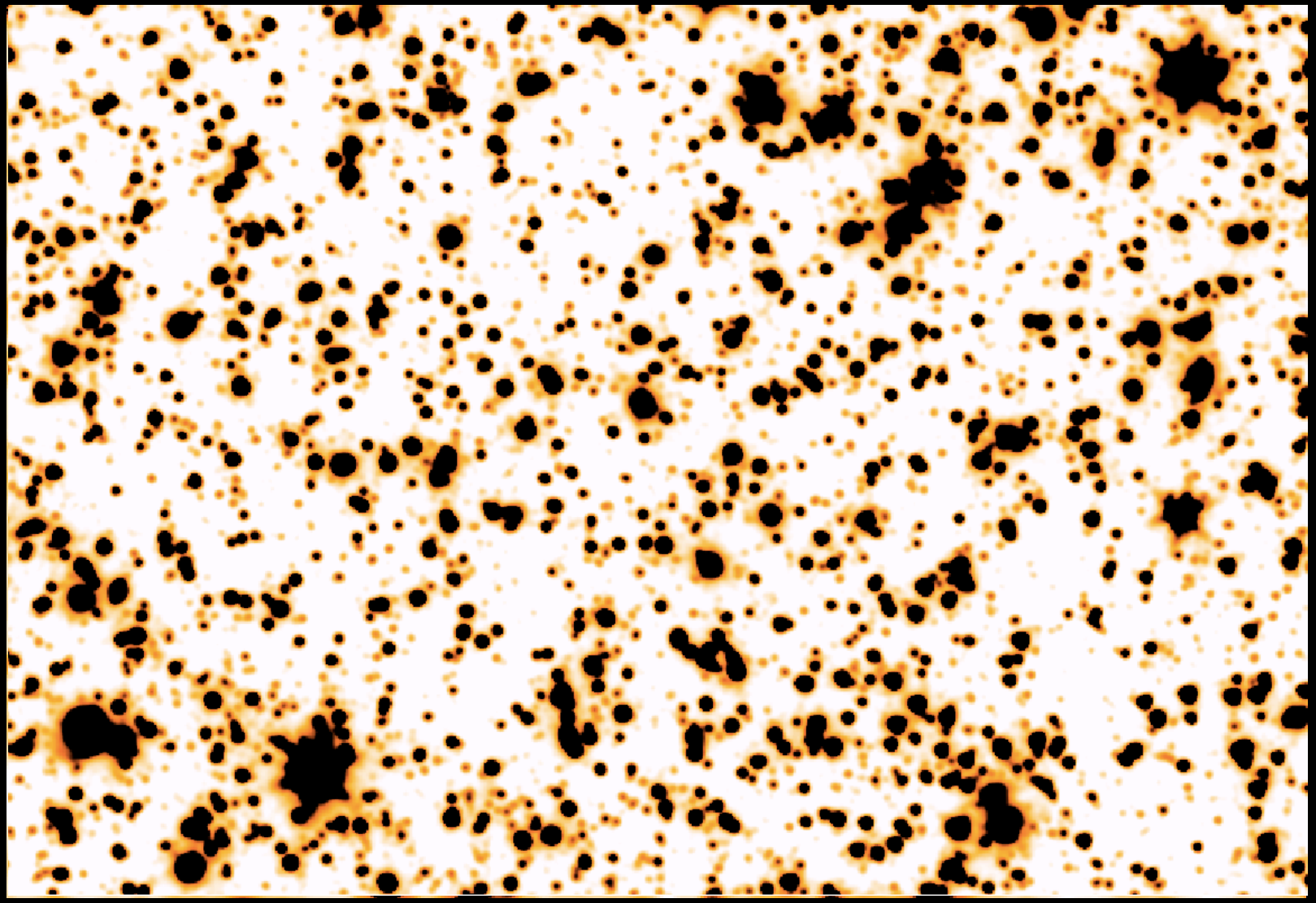
7.5' x 6.5' zoom on the GOODS-North field (10' x 15')



The power of multi-wavelength imaging against confusion

500um 350um 250um 160um 100um 24um 3.6um

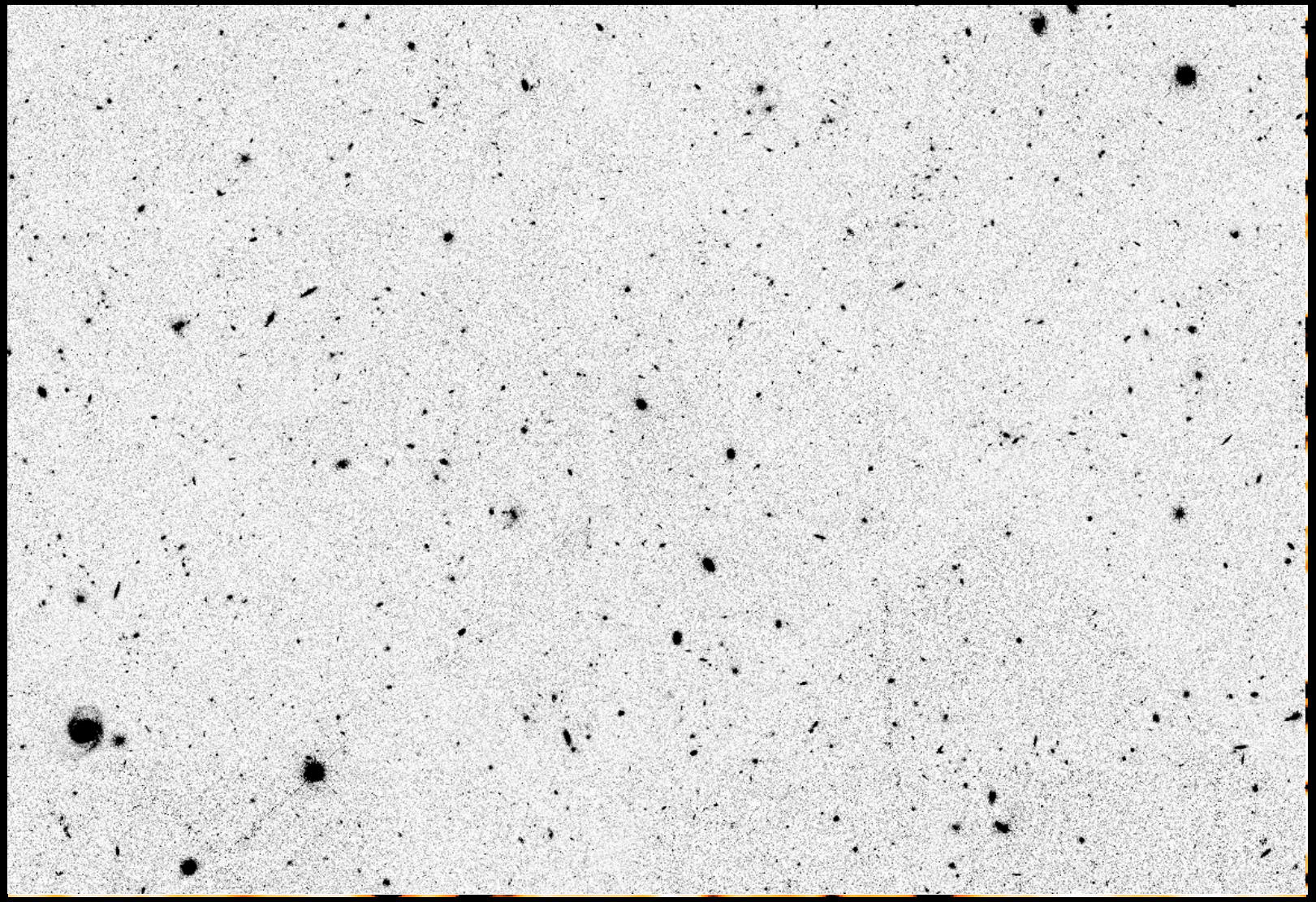
7.5' x 6.5' zoom on the GOODS-North field (10' x 15')

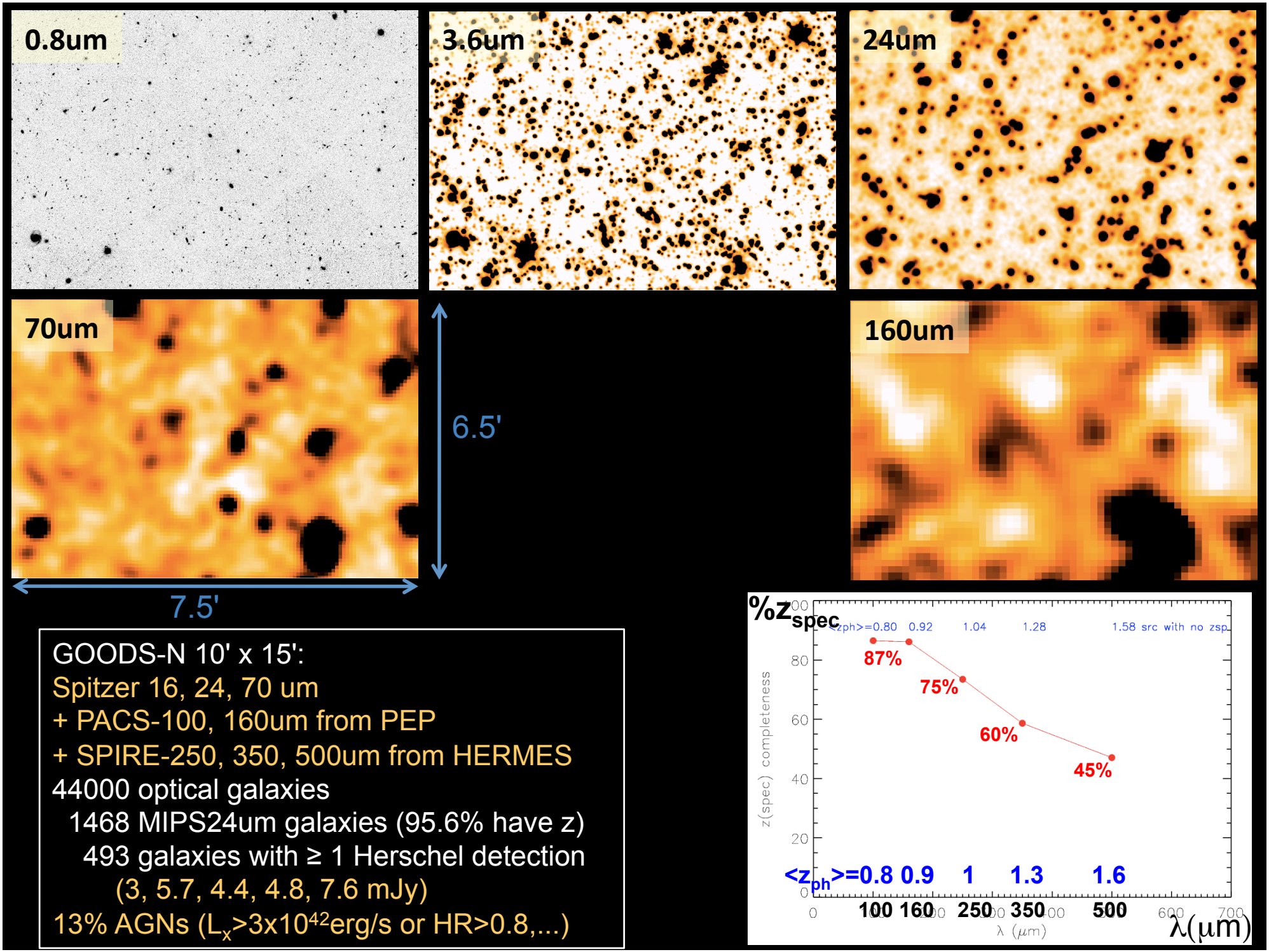


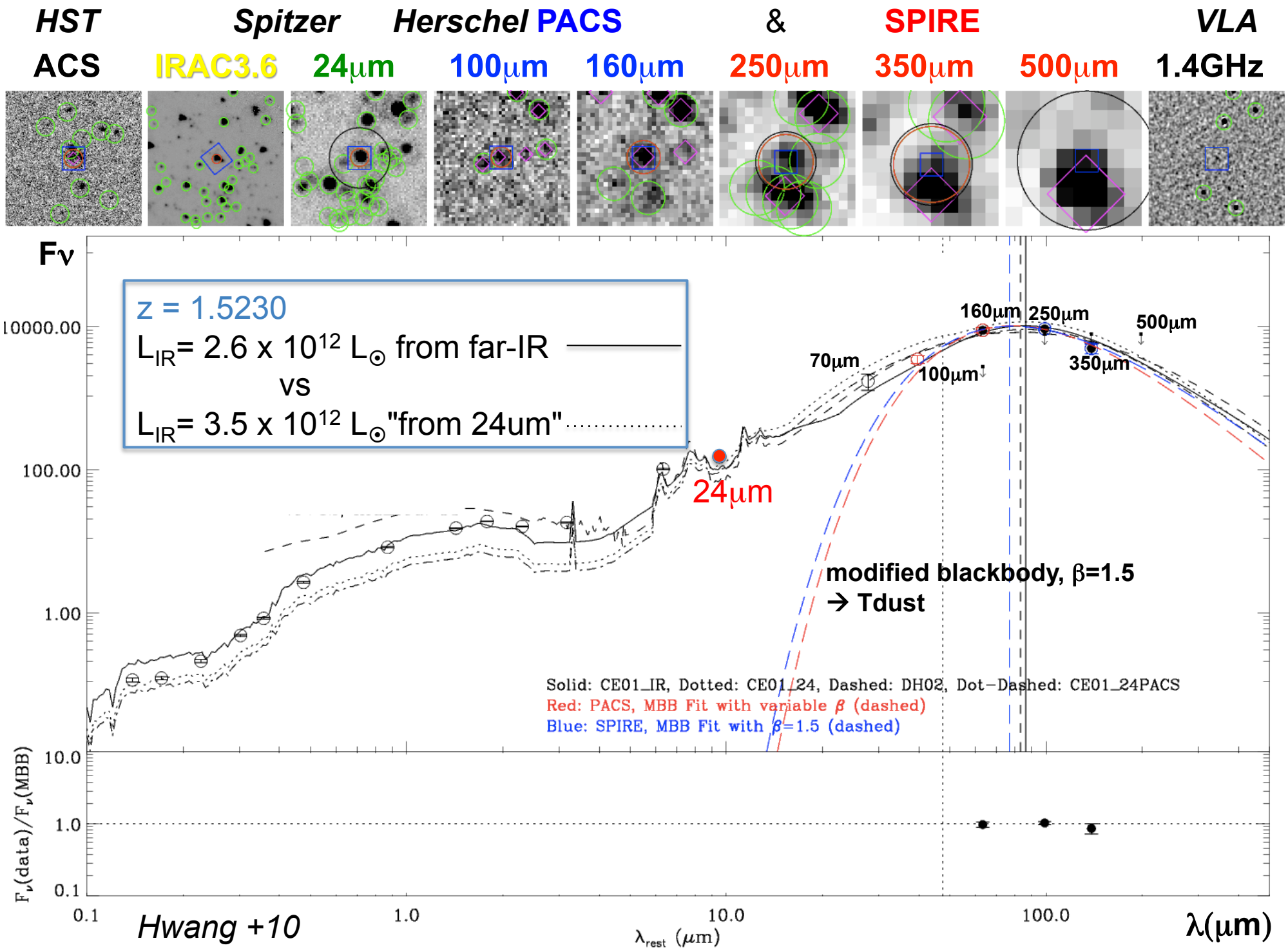
The power of multi-wavelength imaging against confusion

500um 350um 250um 160um 100um 24um 3.6um 0.8um

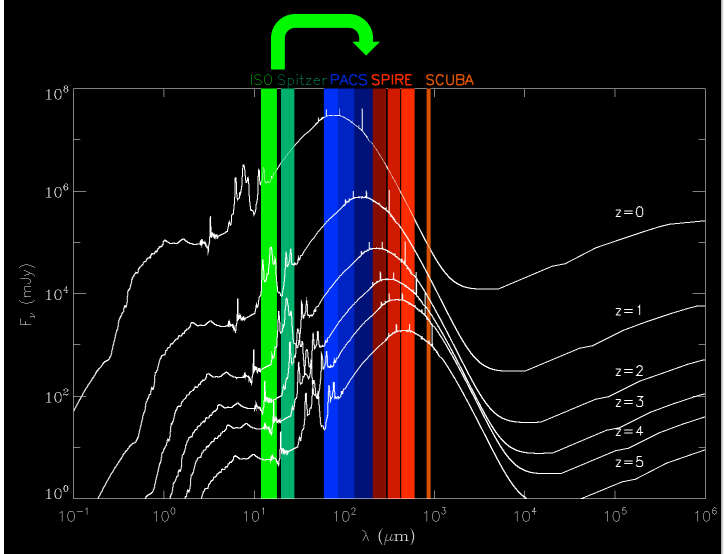
7.5' x 6.5' zoom on the GOODS-North field (10' x 15')

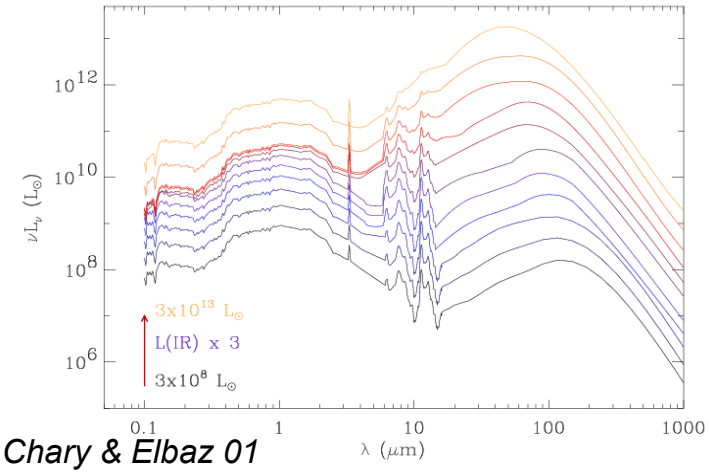



0.8um
3.6um
24um
70um
160um
6.5'
7.5'
GOODS-N 10' x 15':
Spitzer 16, 24, 70 um
+ PACS-100, 160um from PEP
+ SPIRE-250, 350, 500um from HERMES
44000 optical galaxies
1468 MIPS24um galaxies (95.6% have z)
493 galaxies with ≥ 1 Herschel detection
(3, 5.7, 4.4, 4.8, 7.6 mJy)
13% AGNs (Lx>3x10^42erg/s or HR>0.8,...)
%zspec
<zph>=0.80 0.92 1.04 1.28 1.58 src with no zsp
87%
75%
60%
45%
z(spec) completeness
<zph>=0.8 0.9 1 1.3 1.6
100 160 250 350 500
λ (μm)
λ(μm)

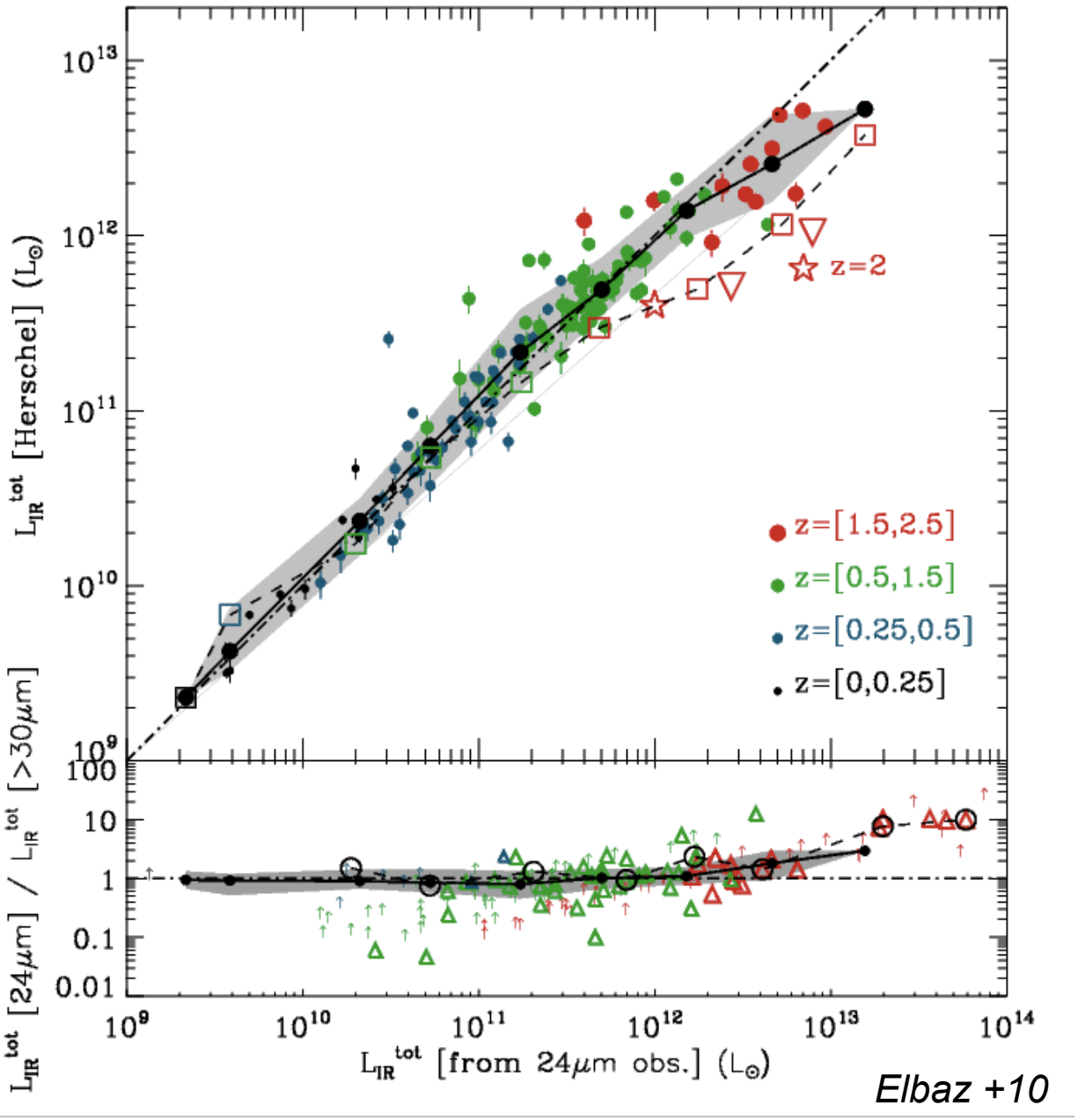

HST
ACS
Spitzer
IRAC3.6
24μm
Herschel PACS
100μm
160μm
&
SPIRE
250μm
350μm
500μm
VLA
1.4GHz
Fν
z = 1.5230
L_IR= 2.6 x 10^12 L⊙ from far-IR
vs
L_IR= 3.5 x 10^12 L⊙"from 24um"
70μm
100μm
160μm
250μm
350μm
500μm
24μm
modified blackbody, β=1.5
→ Tdust
Solid: CE01_IR, Dotted: CE01_24, Dashed: DH02, Dot-Dashed: CE01_24PACS
Red: PACS, MBB Fit with variable β (dashed)
Blue: SPIRE, MBB Fit with β=1.5 (dashed)
10000.00
100.00
1.00
10.0
1.0
0.1
Fν(data)/Fν(MBB)
0.1
1.0
10.0
100.0
λrest (μm)
λ(μm)
Hwang +10

A puzzling uniformity of distant dusty galaxies

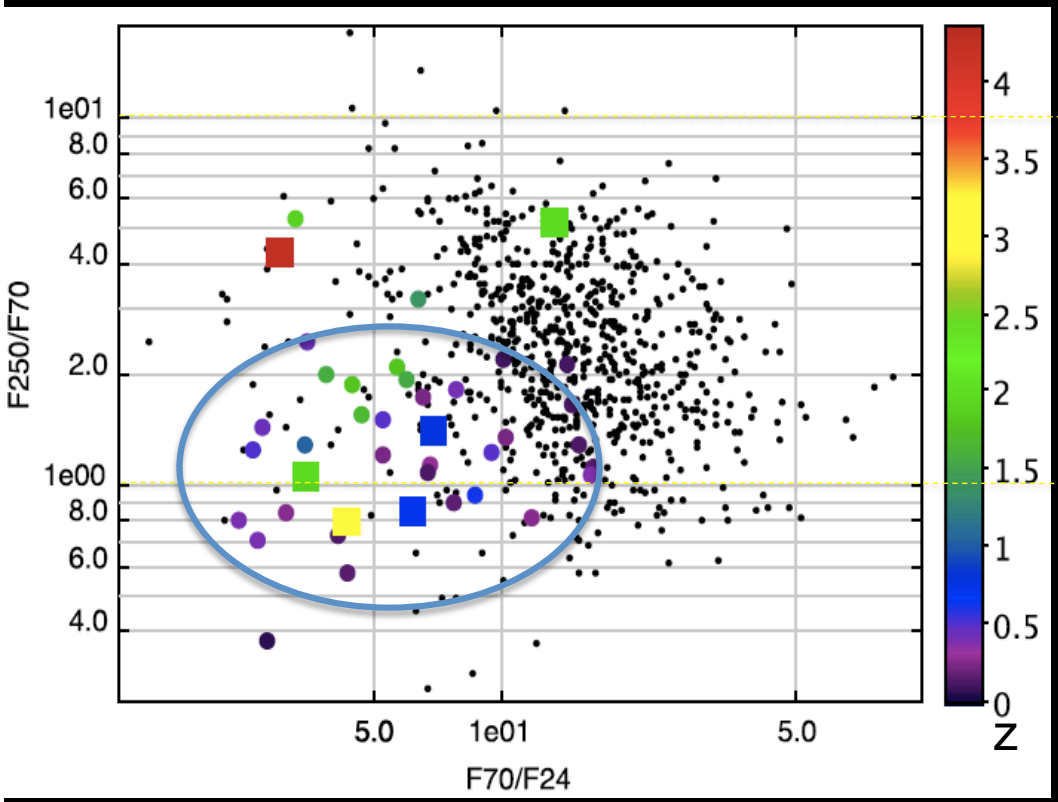




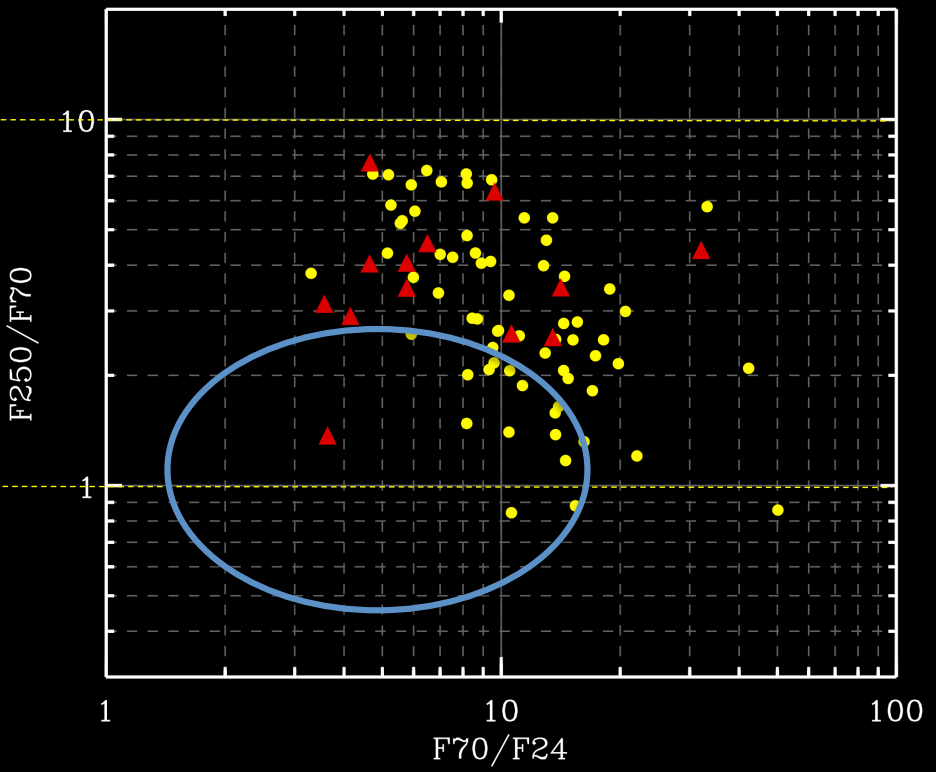
Chary & Elbaz 01



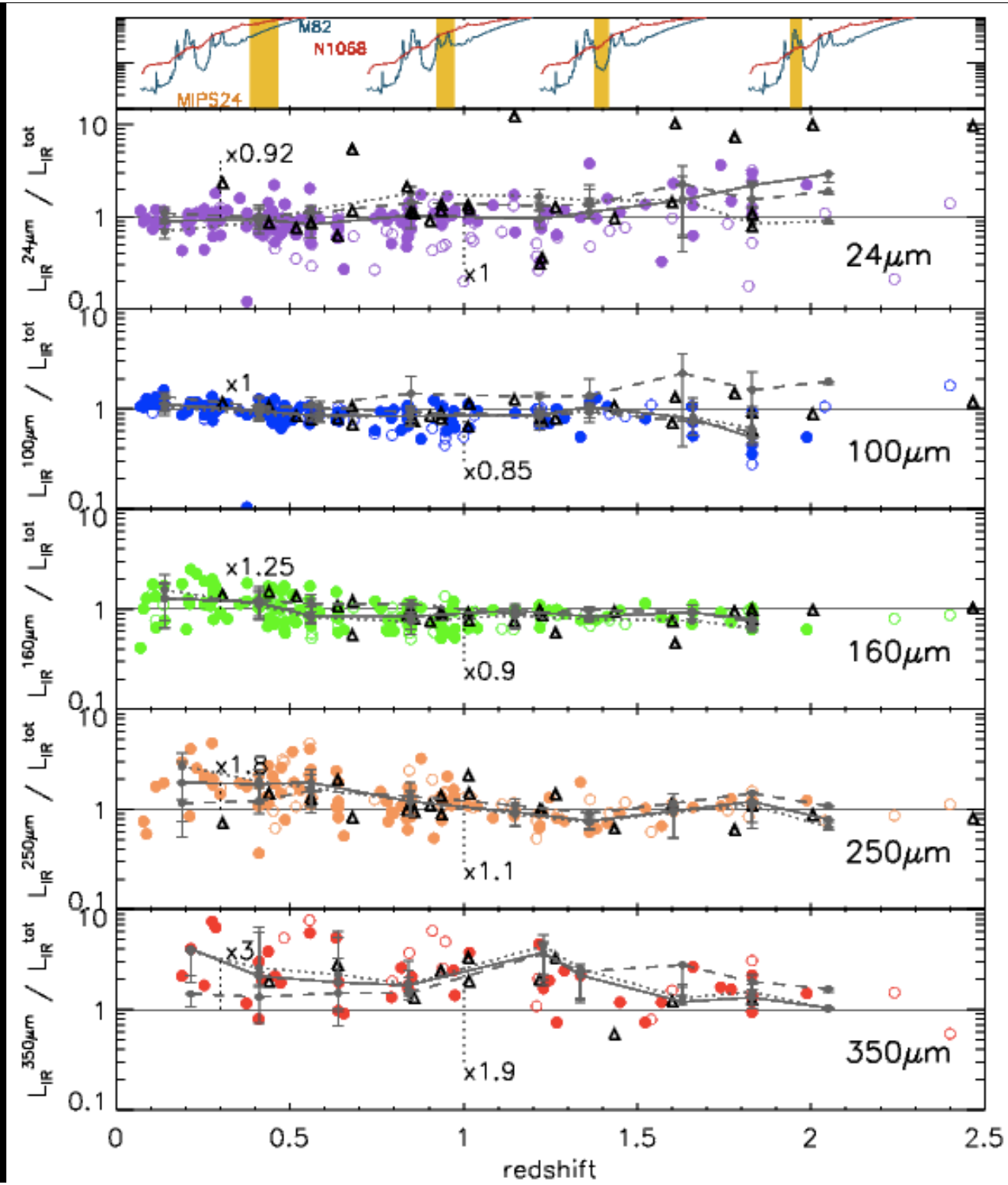
Elbaz +10



Hatziminaoglou et al. 2010
QUASARS in the Lockman – SWIRE & FLS fields
(Lx ~$10^{45\text{-}46}$ erg s^{-1})



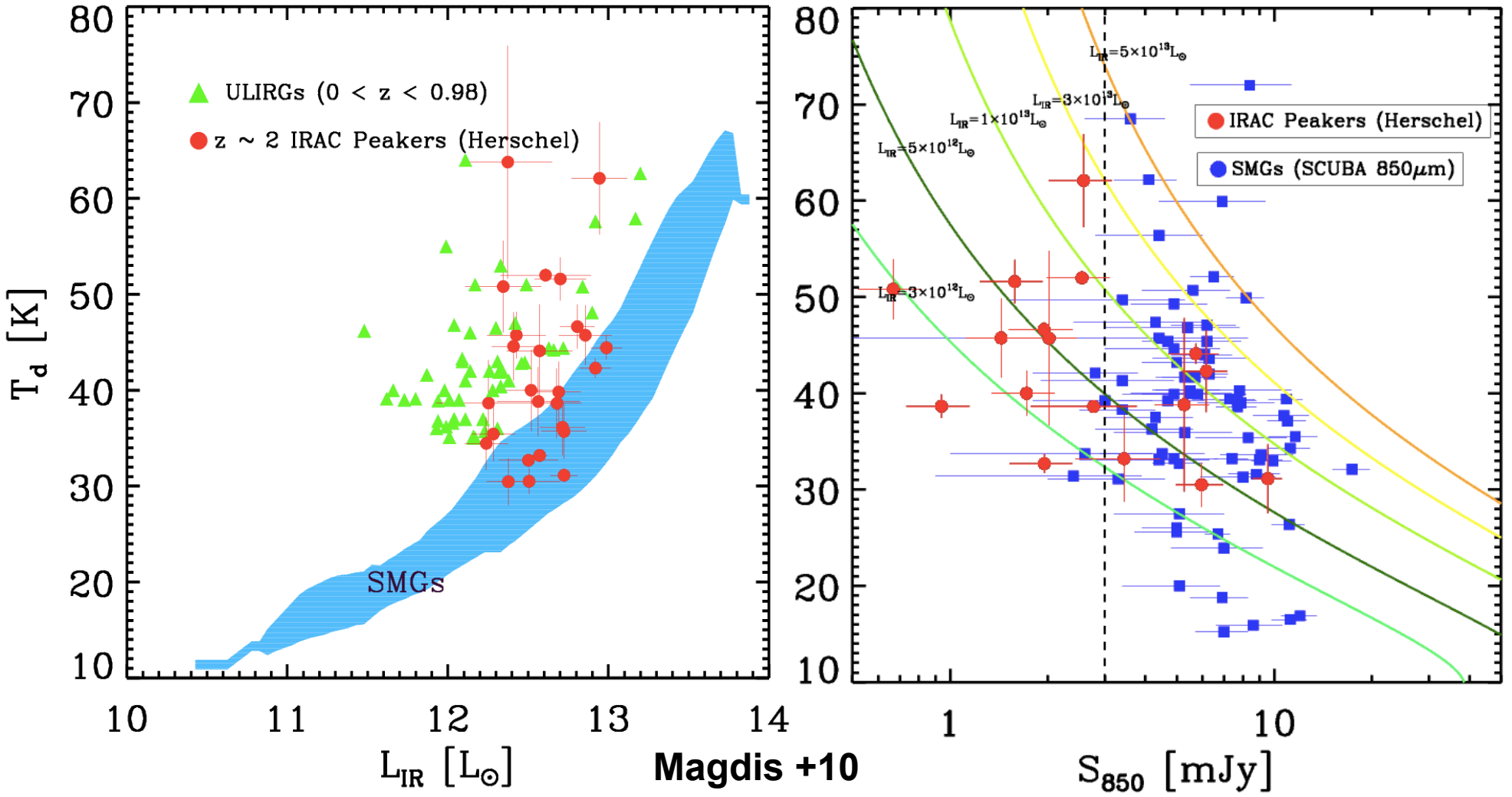
Lower luminosity AGNs in the
GOODS-North field
(Lx ~$10^{42\text{-}43}$ erg s^{-1})


M82
N1068
MIPS24
x0.92
x1
24μm
x1
x0.85
100μm
x1.25
x0.9
160μm
x1.8
x1.1
250μm
x3
x1.9
350μm
redshift

Herschel bridges the gap between local and distant ULIRGs...

Very high SFR for distant SMGs confirmed (Magnelli +10):
~ 560 (380) $M_{\odot}yr^{-1}$ for SMGs with S (850 μm) > 5 (2) mJy [Chabrier IMF]

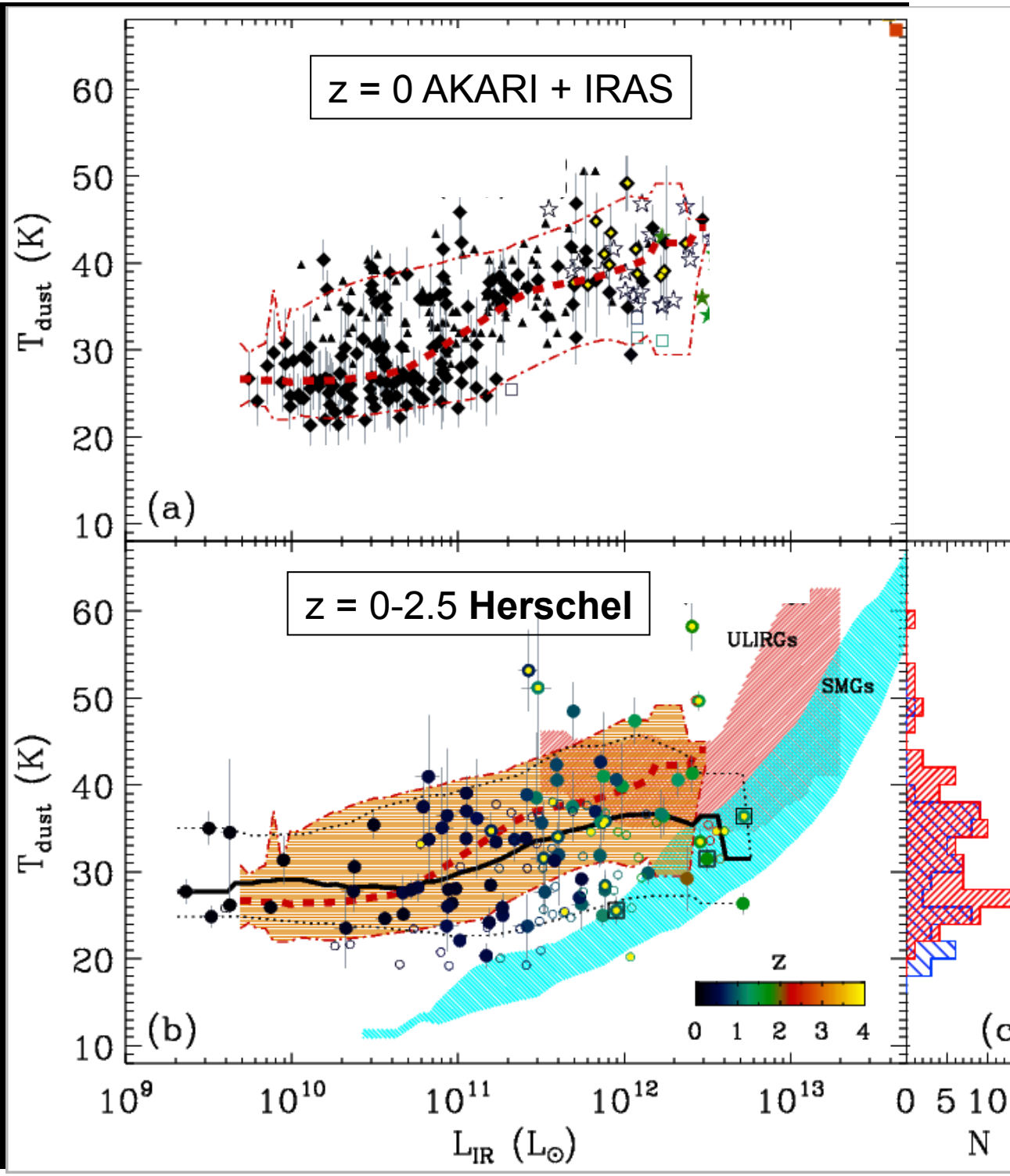
Magdis +10 (see poster #2.55 & Magnelli +10 *Thursday 12:40*, Chanial +10 P#1.63)



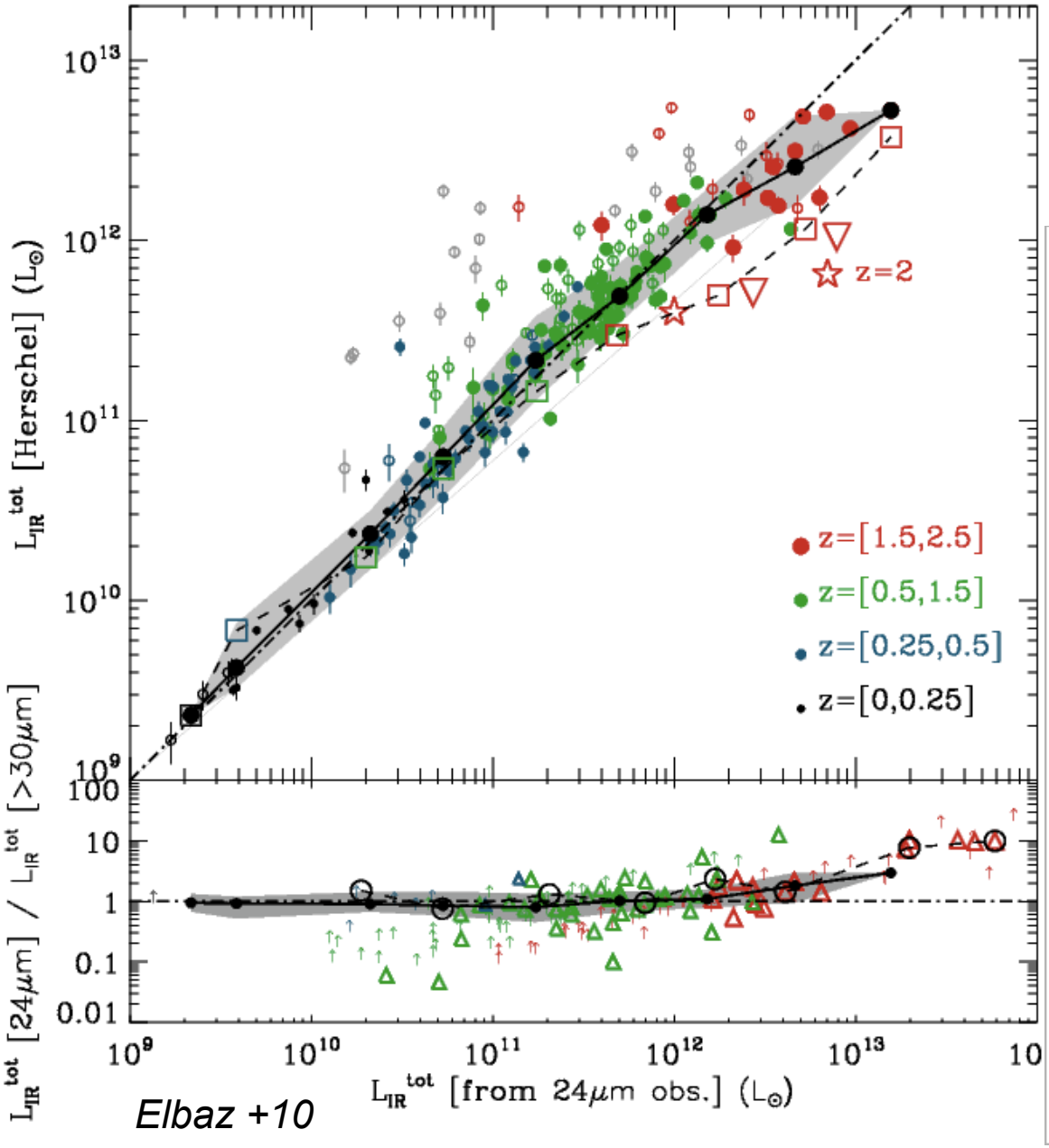
L_{IR} - T_{dust}

- marginal evolution of L_{IR}-T_{dust}
- mildly colder (U)LIRGs by ~2-5 K
- envelope extends to colder SMGs

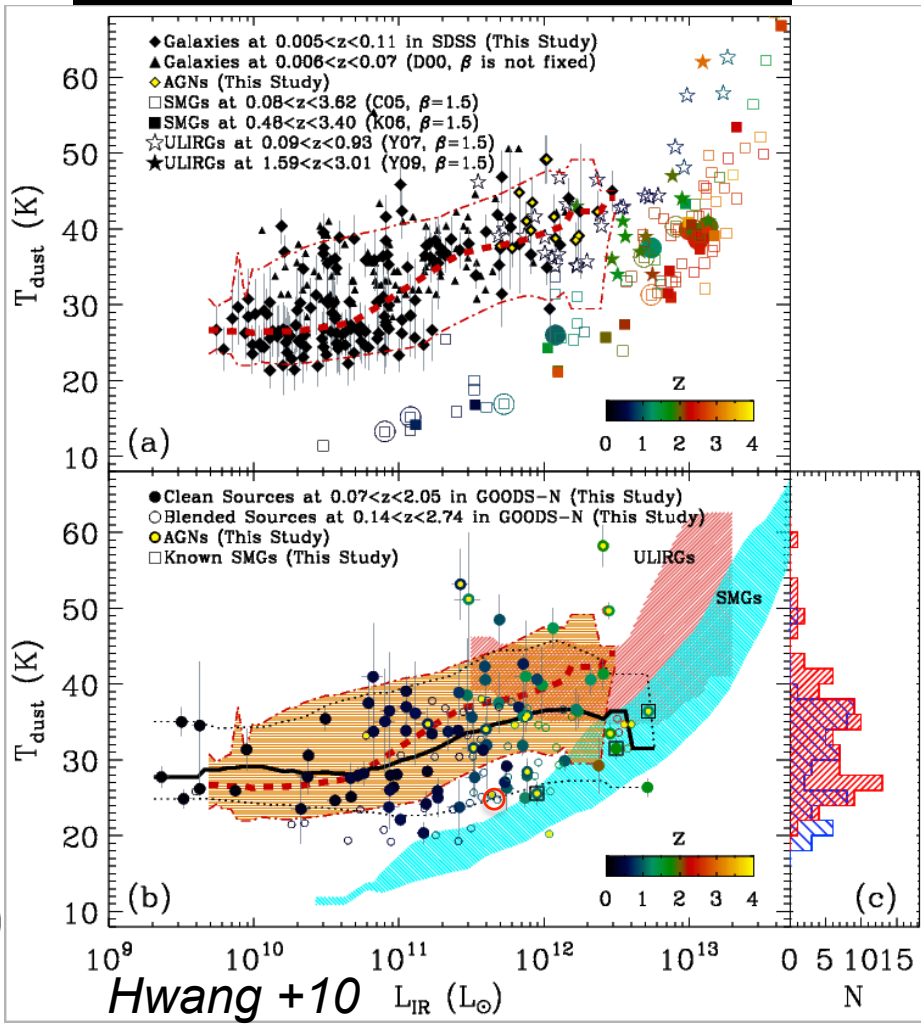
Hwang +10



"Local" vs "statistical" confusion



Elbaz +10



Hwang +10

Conclusions

1. Puzzling uniformity of MIR – FIR relation and Tdust with redshift !

2. Even more puzzling: AGNs follow a parallel behavior with MIR – FIR relation quite in agreement with SF galaxies ! Both activities take place together. Large % of AGNs with very high SFR at the same time.

3. The role of ULIRGs in cosmic SFR history has been overestimated in the past
   - → due to excess PAH/AGN emission on mid-IR side and cool Tdust on SMG side
   - → SFR can be overestimated by x10 at 850um depending on Tdust (25 – 55 K)
   - → need to see LIRGs at z>1.5... (GOODS-H)

4. Combining multi-λ allows to win against "statistical" confusion

Next step: pushing Herschel to its ultimate depth with GOODS – Herschel...

GOODS-Herschel

The Great Observatories Origins Deep Survey : far infrared imaging with Herschel

Dave Alexander, Durham University, UK
Bruno Altieri, ESAC, ESA
Herve Aussel, CEA / Saclay
Mark Brodwin, NOAO
Veronique Buat, OAMP, Marseille, France
Denis Burgarella, OAMP, Marseille, France
Daniela Calzetti, University of Massachussetts, USA
Catherine Cesarsky, ESO
Stephane Charlot, IAP, Paris, France
Vassilis Charmandaris, Dept. of Physics, Univ. of Crete
Ranga–Ram Chary, Spitzer Science Center, USA
Emanuele Daddi, SAp, CEA/Saclay, France
Mark Dickinson, NOAO, USA
Herve Dole, IAS, Orsay, France
Peter Eisenhardt, JPL/Caltech, USA
Henry C. Ferguson, STSci, USA
Natascha Forster Schreiber, MPE, Garching, Germany
Dave Frayer, IPAC, Caltech, USA
Rene Gastaud, CEA / Saclay
Mauro Giavalisco, University of Massachussetts, USA
Roberto Gilli, INAF, Bologna, Italy
Minh Huynh, Spitzer Science Center, USA
Rob Ivison, ROE, UK
Damien Le Borgne, SAp, CEA/Saclay, France
Emeric Le Floc'h, University of Hawaii, USA
Dieter Lutz, MPE, Garching, Germany
Benjamin Magnelli, SAp, CEA/Saclay, France
Glenn Morrison, U. Hawaii/IfA, USA
Eric J. Murphy, IPAC, CalTech, USA
Casey Papovich, Texas, A&M University
Alexandra Pope, NOAA, USA
Paola Popesso, MPE, Garching, Germany
Naveen Reddy, NOAO, USA
Douglas Scott, University of British Columbia, Canada
Christian Surace, LAM, Marseille, France
Harry Teplitz, Spitzer Science Centre, USA
Ivan Valtchanov, ESAC, ESA
Min S. Yun, University of Massachussetts, USA
Grant Wilson, University of Massachussetts, USA

David Elbaz (CEA Saclay)

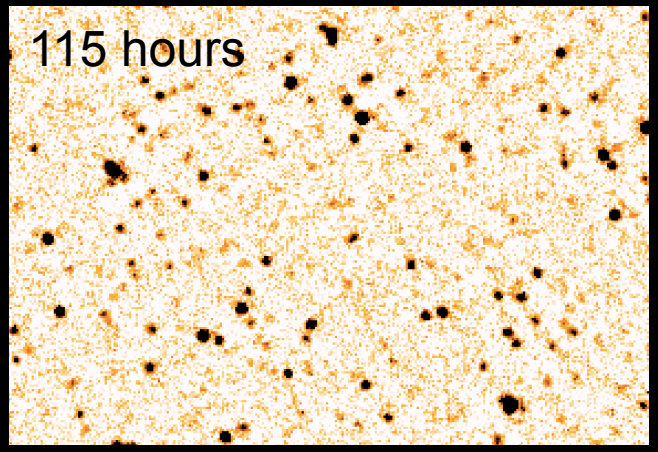
Collaborators (39 +...):

France, USA, Germany, UK, Greece, Italy, Canada, ESO, ESA

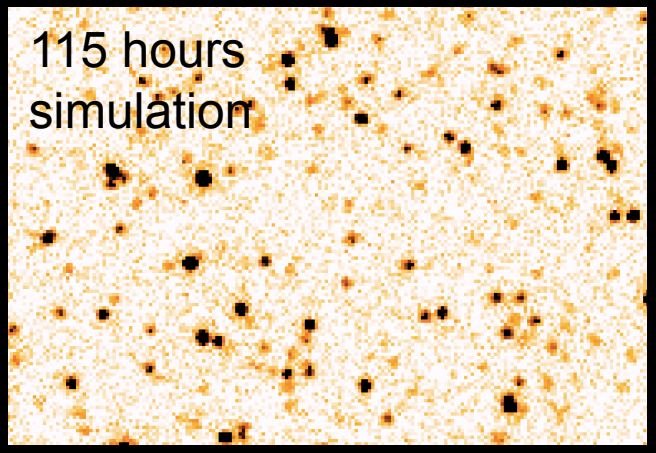
362.6 hours (100μm & 160μm PACS, including 31 h SPIRE)

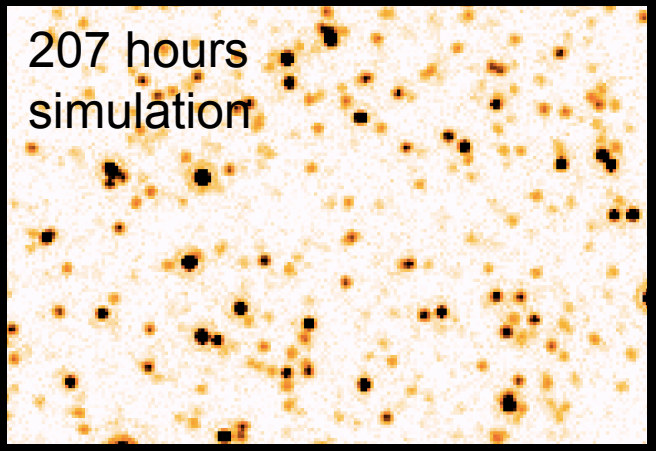
GOODS: from PEP to GOODS-Herschel the "ultra-deep" Universe...

GOODS South – 100um

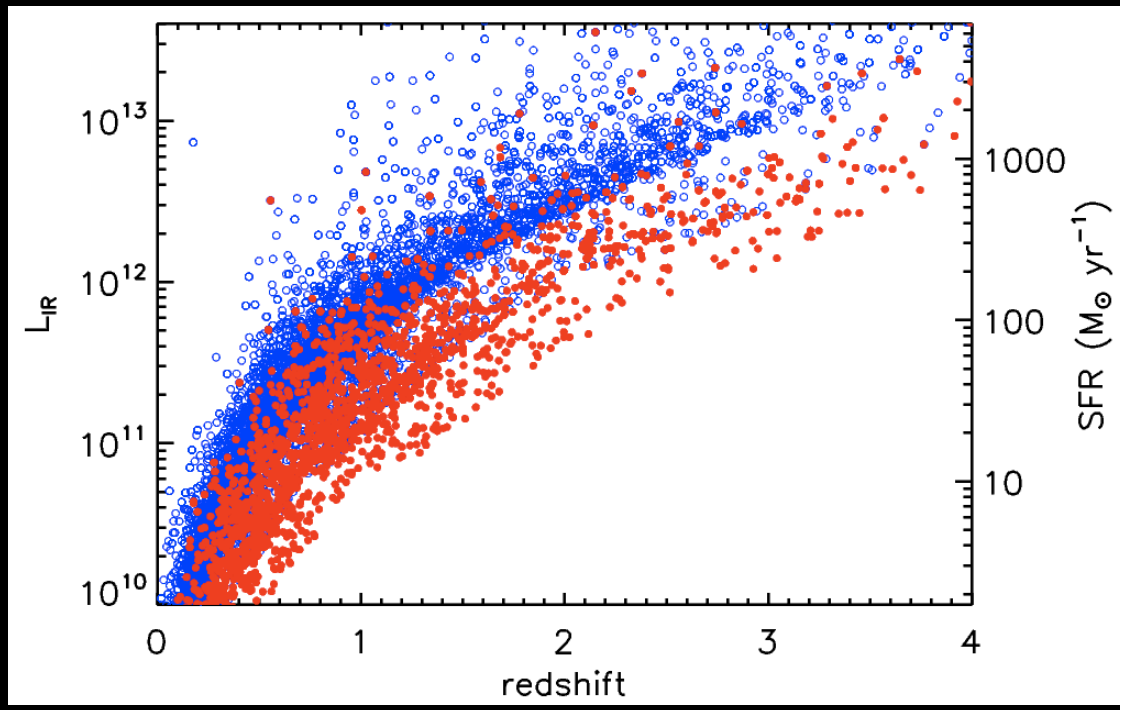


PEP





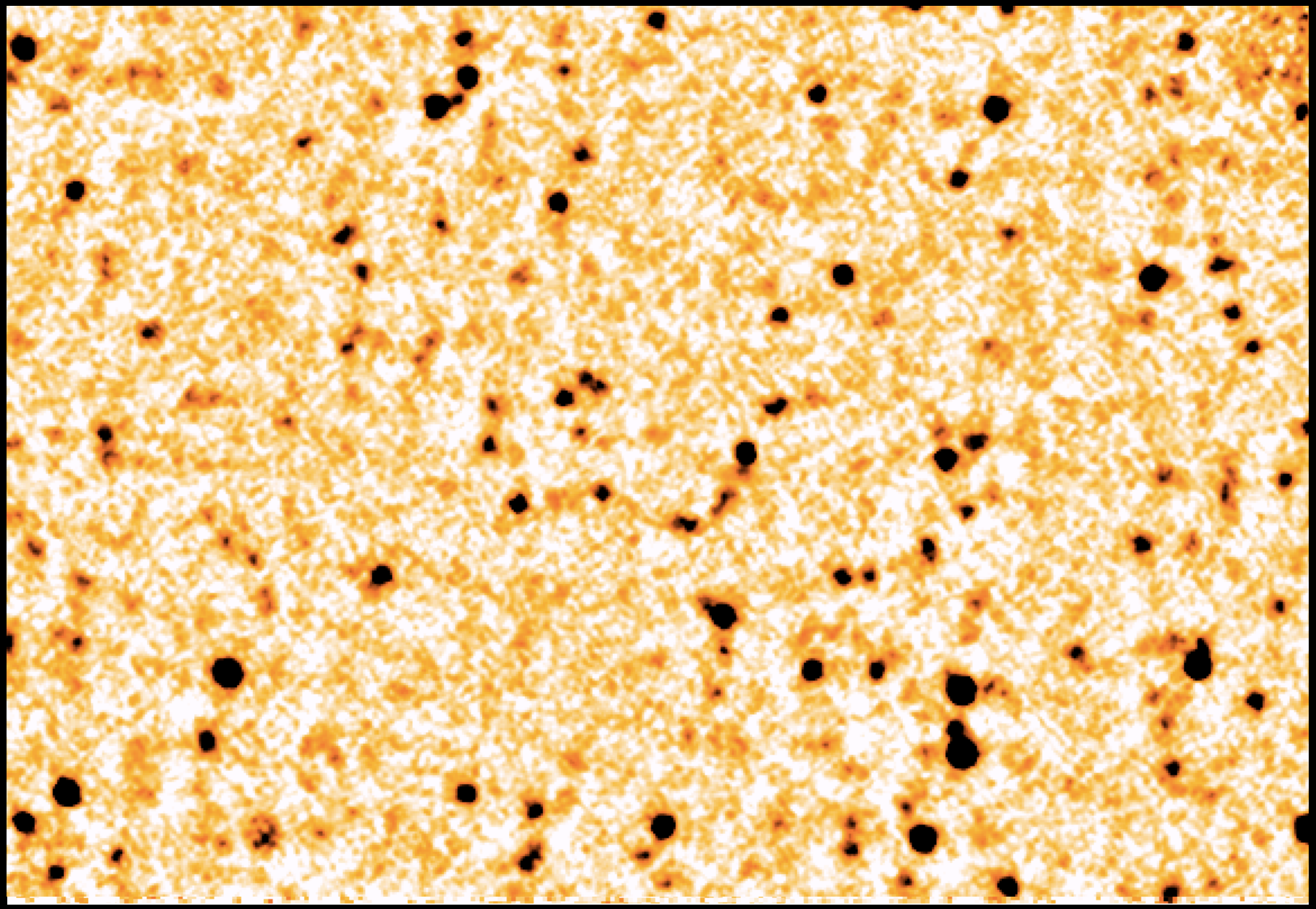
GOODS-Herschel
Simulation



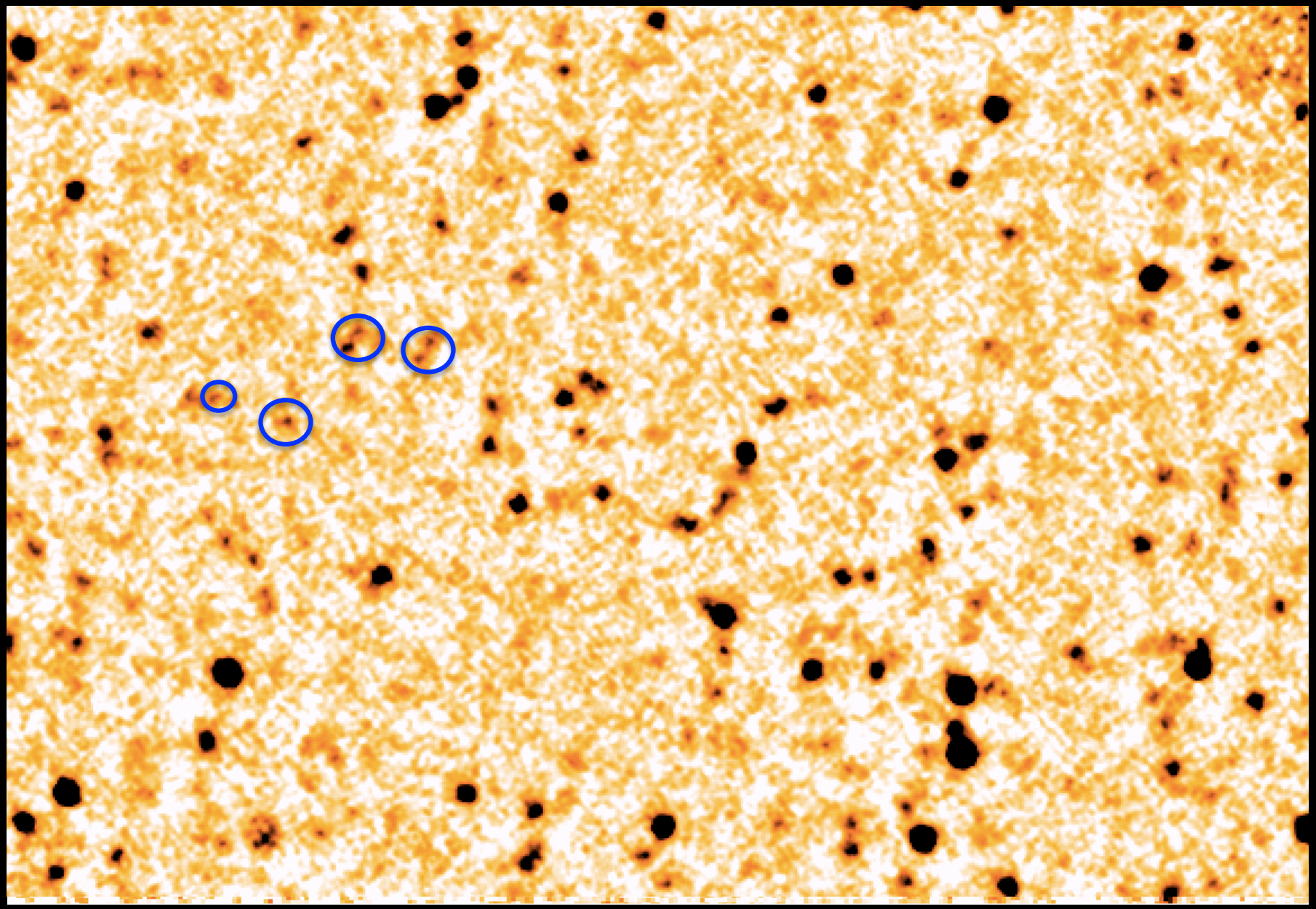
GOODS - Herschel

- Extension to normal galaxies
- (U)LIRGs from z=0.5 – 4
- Heavily obscured AGNs

GOODS – North : PEP (30 h) → GOODS – Herschel (70 h, 57%)



GOODS – North 160um : PEP (30 h) → GOODS – Herschel (70 h, 57%)



Merging vs secular evolution

- cosmological simulations → cold flows
- role of mergers ?
- puzzling uniformity of distant dusty galaxies: SEDs, SFR – M*, AGN

HORIZON project (R.Teyssier et al.)
MareNostrum simulation