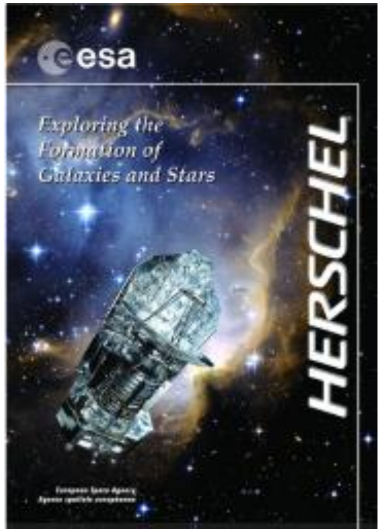
ASTROPHYSICAL
TERAHERTZ
LARGE
AREA
SURVEY



The Herschel-ATLAS:
Discovery and Properties of the Brightest 500 μm Galaxies in the Universe

Mattia Negrello (The Open University, UK)
on behalf of the H-ATLAS team

Why studying sub-mm **bright** galaxies?

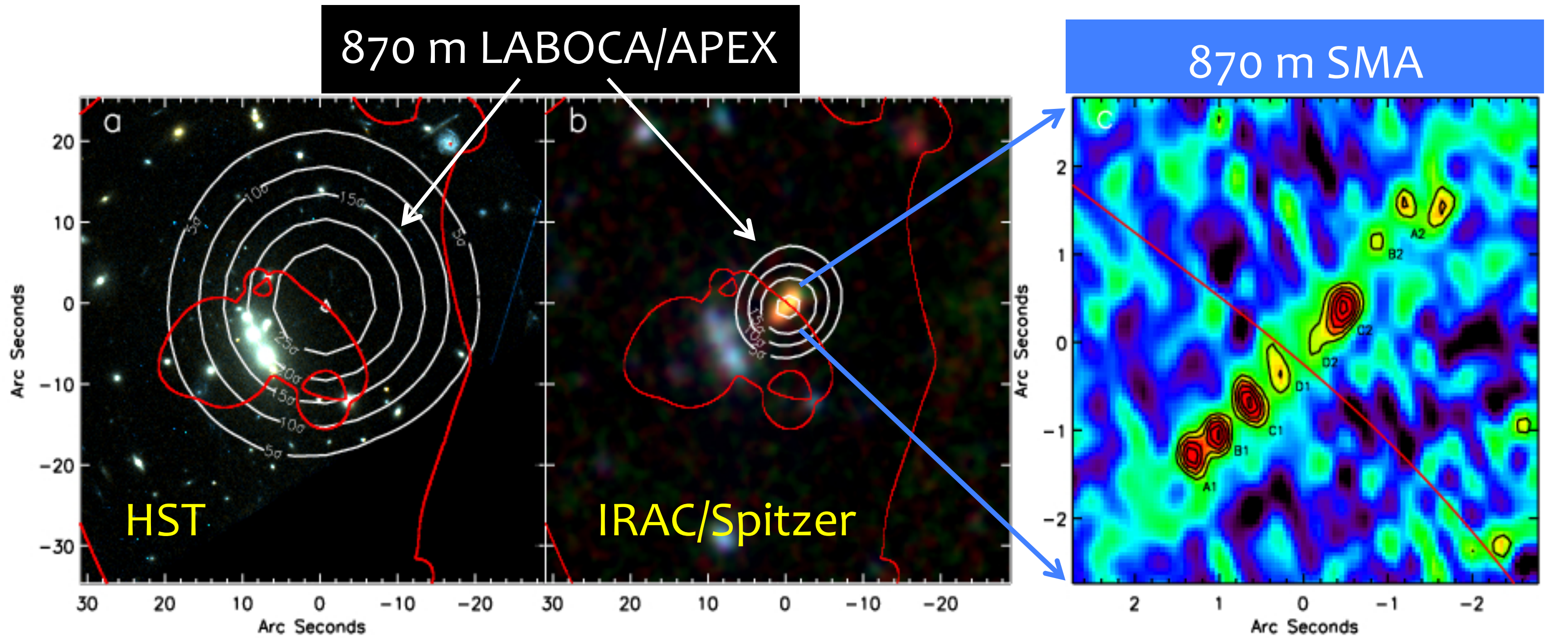
ASTROPHYSICAL
TERAHERTZ
LARGE
AREA
SURVEY

- constraints on galaxy formation/evolution models
- discovery of "extreme" (L_{IR}>~10^{14}) **HLIRGs**

WHY STUDYING SUB-MM **BRIGHT** GALAXIES?

What's the role of **gravitational lensing** ?

dust-obscured star-forming galaxy at **z=2.3**
lensed by a foreground **galaxy cluster** lens → **$S_{870\mu m}$=107 mJy !!**



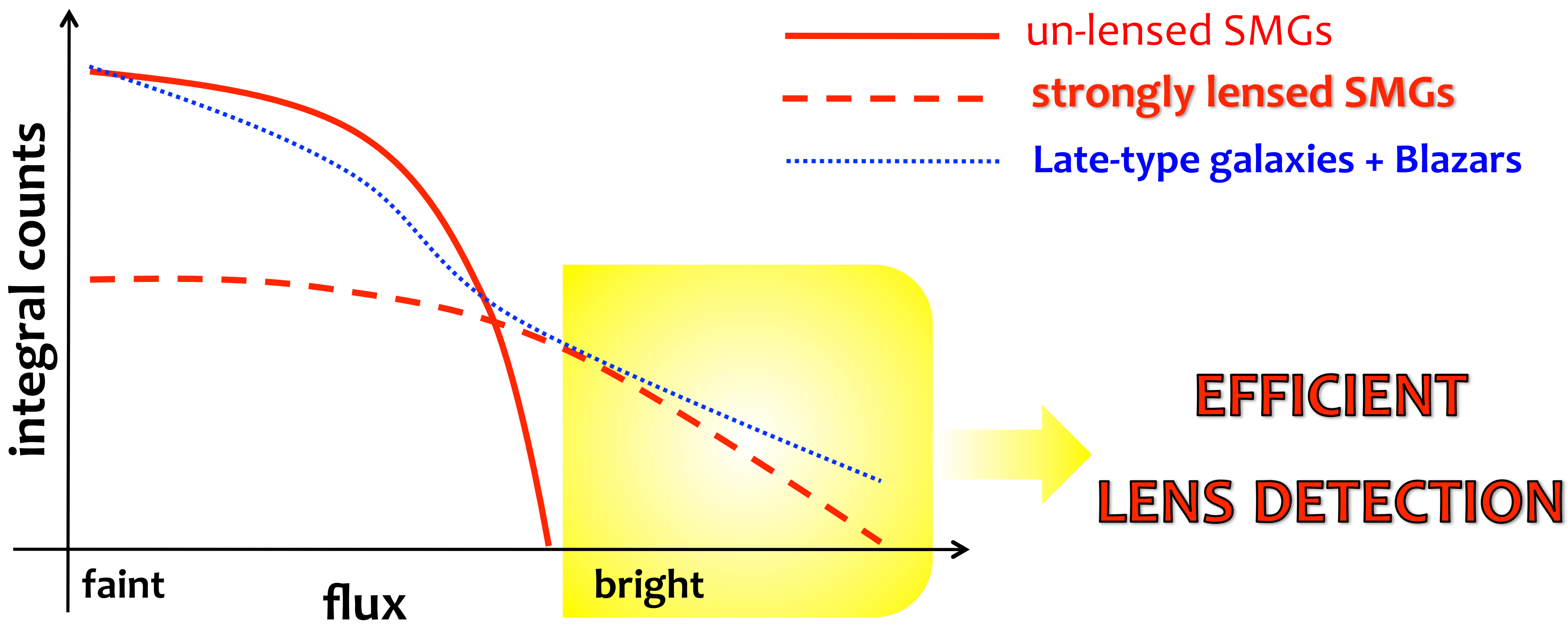
Swinbank et al., Nature (2010)

A LENSING SCIENCE CASE FOR H-ATLAS

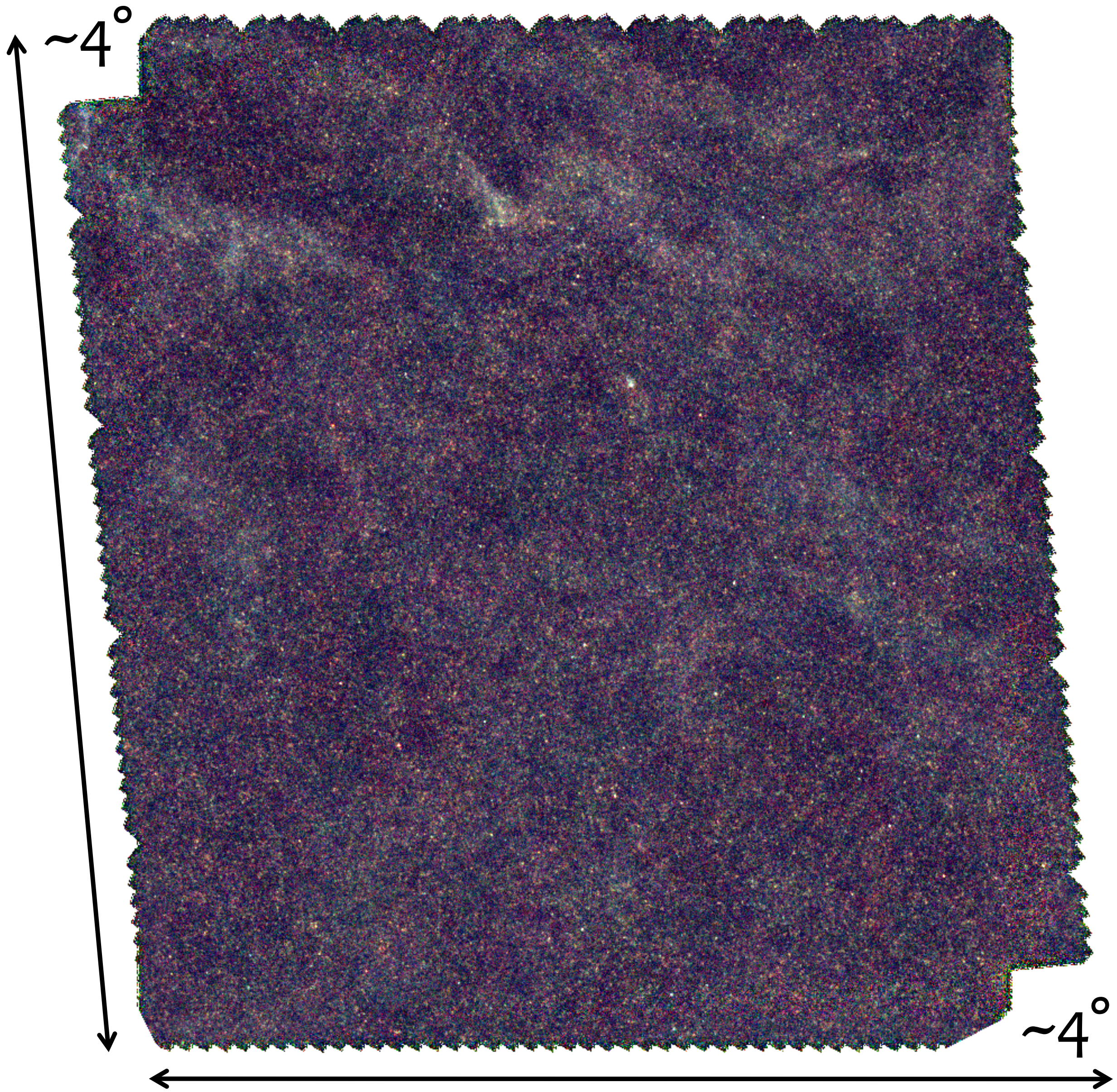
Sub-mm surveys are ideal for finding lenses

Blain (1996), Perrotta et al. (2003), Negrello et al. (2007)

- **high redshift** → **high efficiency for lensing**
  Chapman et al. (2005)
- **steep counts** → **strong *magnification* bias**
  Coppin et al. (2006)



500 μm BRIGHTEST GALAXIES IN H-ATLAS SDP



H-ATLAS SDP field

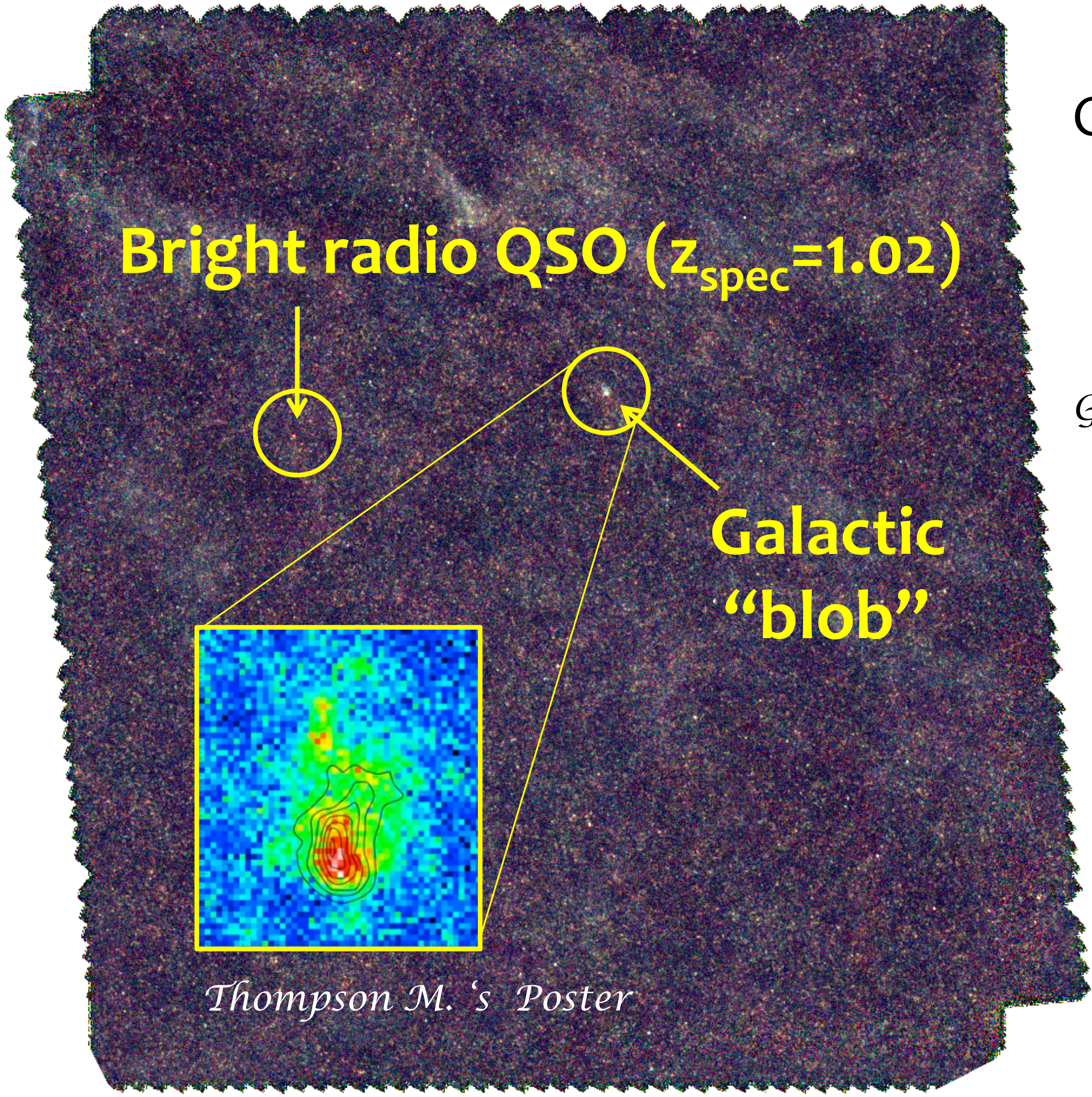
- ~ 14.4 deg^2
- ~ 7000 sources

see posters by E. Rigby, D. Smith

11 sources with

$S_{500\mu m}$ > 100 mJy

500 μm BRIGHTEST GALAXIES IN H-ATLAS SDP



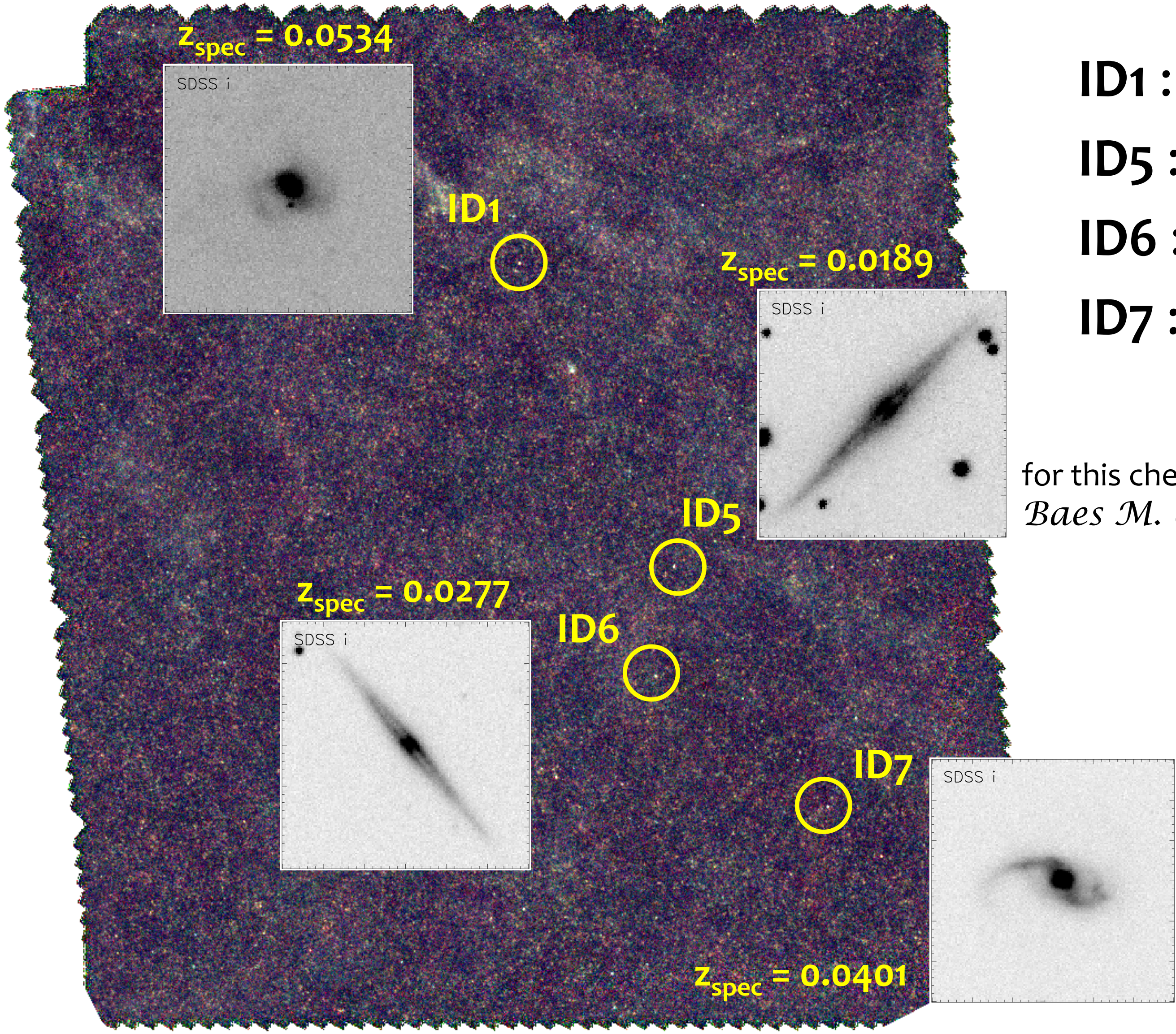
QSO: $S_{250\mu m}$ = 159.6 mJy
$S_{350\mu m}$ = 193.8 mJy
$S_{500\mu m}$ = 265.8 mJy !
$S_{1.4GHz}$ = 571.7 mJy

Gonzalez-Nuevo et al. Special Issue

prediction: **~0.1 deg^{-2}**

De Zotti et al. (2005)

500 μm BRIGHTEST GALAXIES IN H-ATLAS SDP



ID1 : $S_{500\mu m}$ = 177 ± 28 mJy

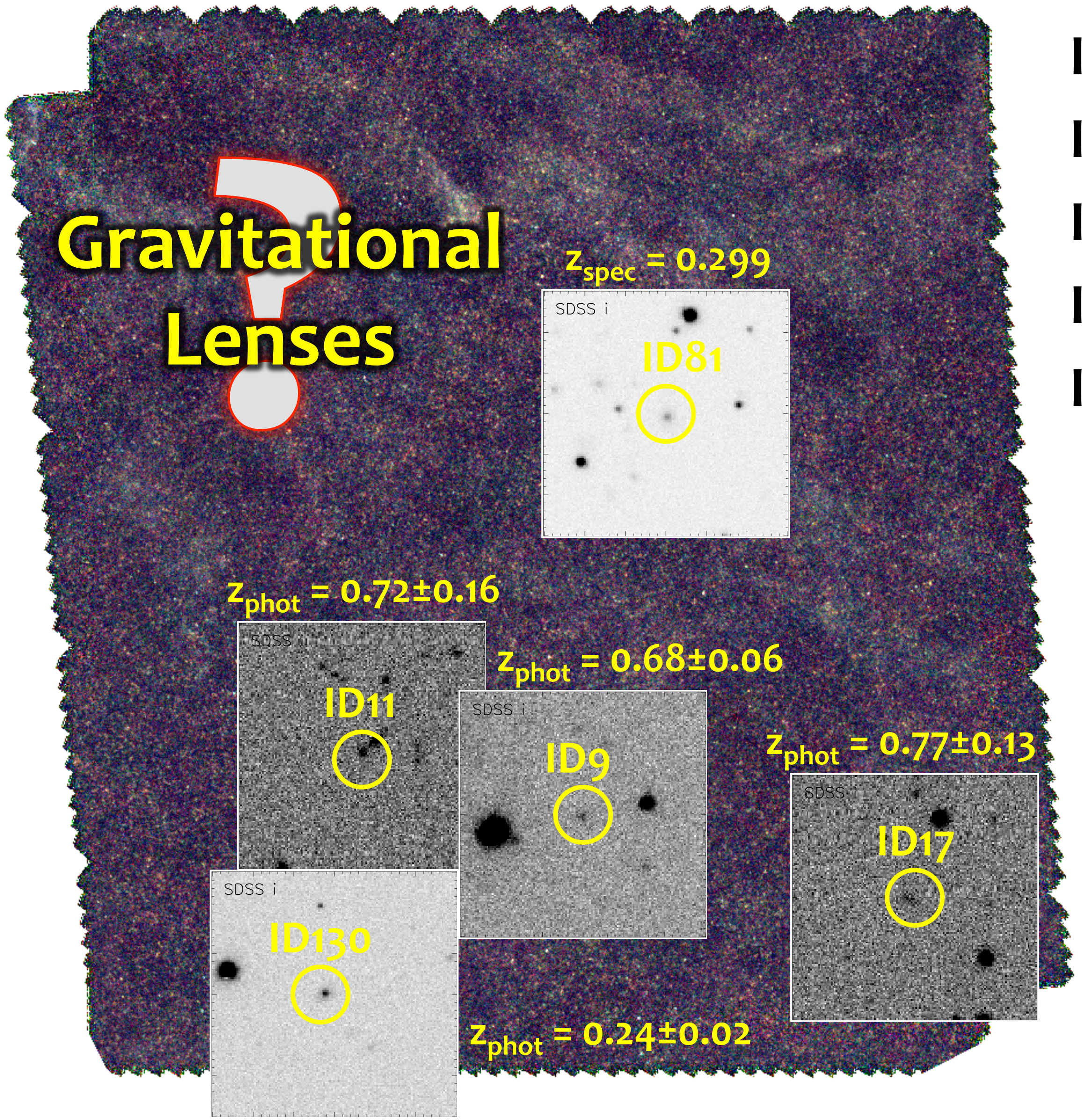
ID5 : $S_{500\mu m}$ = 122 ± 20 mJy

ID6 : $S_{500\mu m}$ = 112 ± 19 mJy

ID7 : $S_{500\mu m}$ = 104 ± 18 mJy

for this check
Baes M. et al. Special Issue

500 μm BRIGHTEST GALAXIES IN H-ATLAS SDP



ID9 : $S_{500\mu m}$ = 175 ± 28 mJy

ID11 : $S_{500\mu m}$ = 238 ± 37 mJy

ID17 : $S_{500\mu m}$ = 220 ± 34 mJy

ID81 : $S_{500\mu m}$ = 166 ± 27 mJy

ID130 : $S_{500\mu m}$ = 108 ± 18 mJy

optical counterparts

$z_{phot/spec} < 1.0$

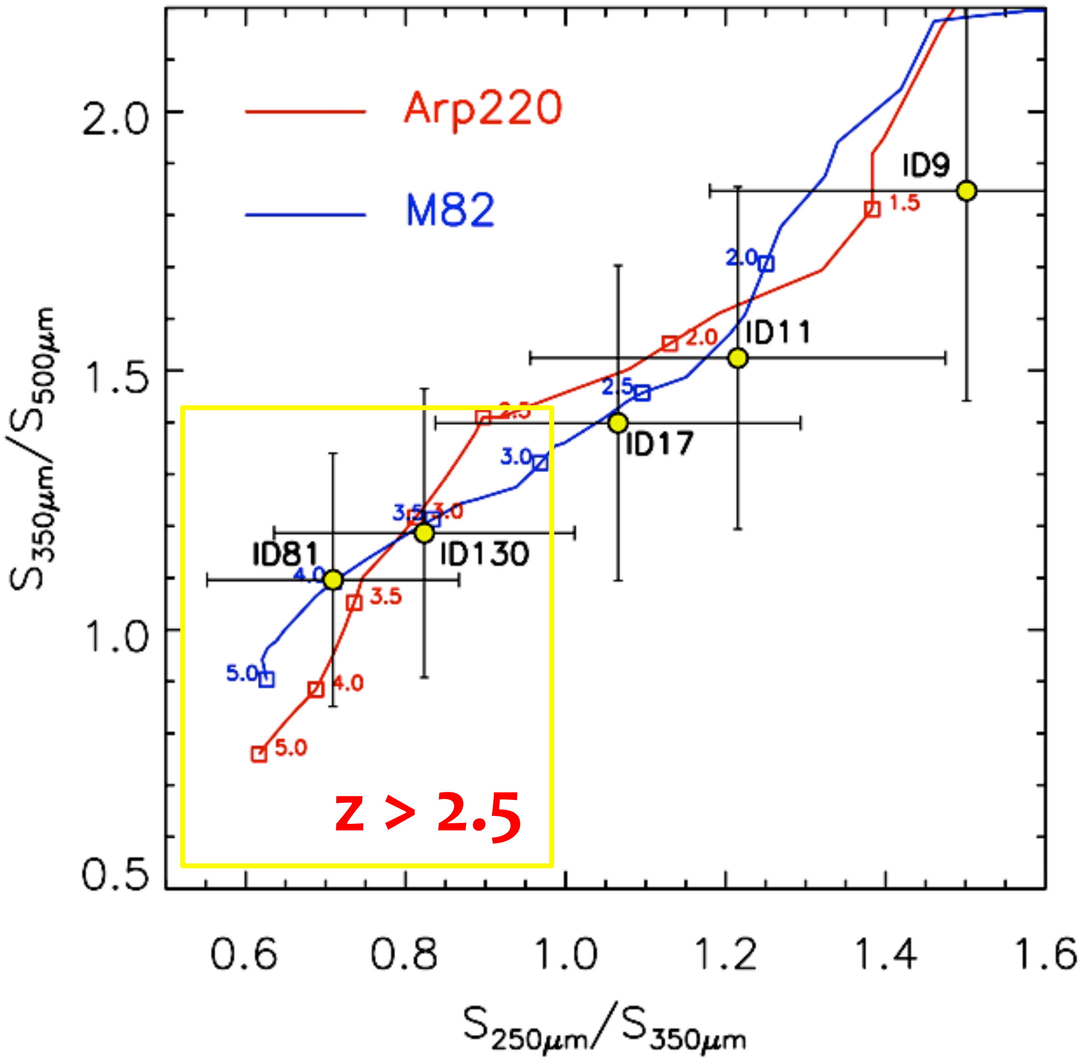
. . .

what about the sub-mm SED?

GRAVITATIONAL LENS CANDIDATES

ID81 - ID130:
UV/optical/near-IR SED
inconsistent with
sub-mm SED !

best lens candidates
for DDT follow-ups

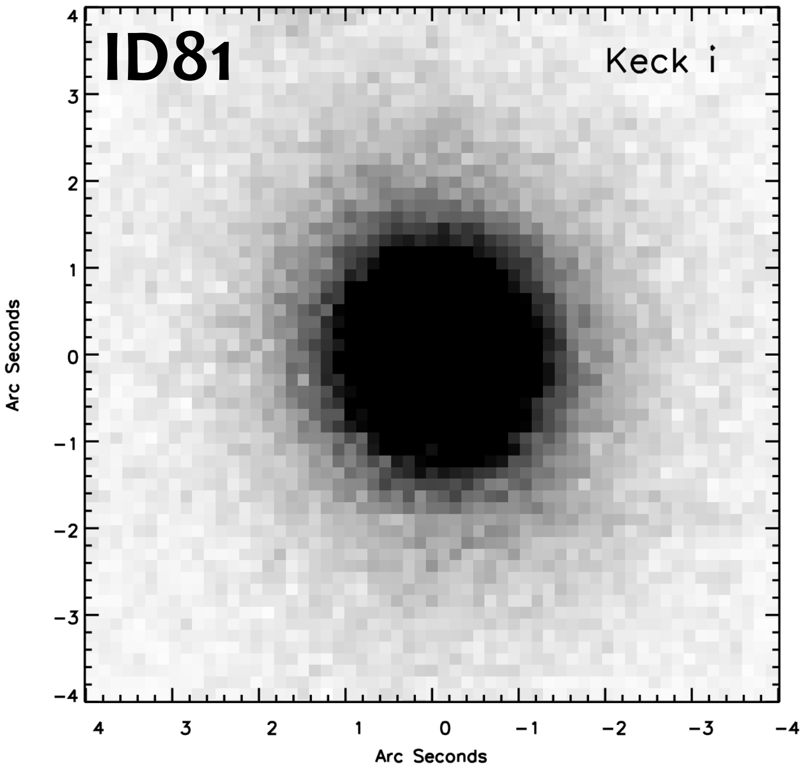


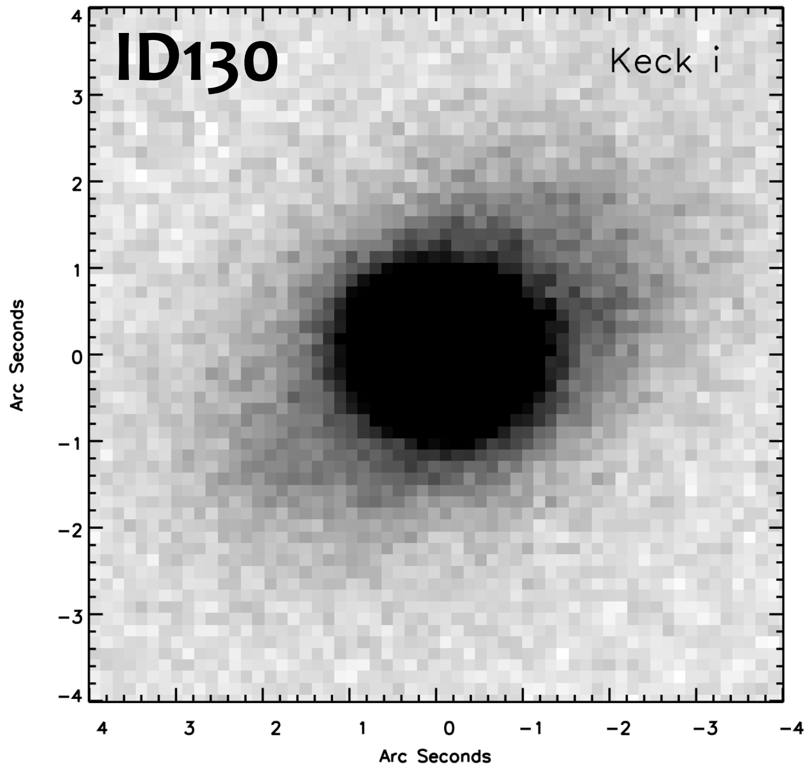
FOLLOW-UP PROPOSALS (A LOT!!)

- **IRAM/PdBI** : high resolution mm imaging
- **CARMA** : high resolution mm imaging
- **SMA** : very-extended + compact + sub-compact imaging at 870 μm
- **Keck** : imaging g & i bands
- **VLT** : NIR high-resolution imaging
- **SPIRE FTS + PACS** minipas
- **VLT** : NIR imaging
- **CSO/Z-spec** : CO lines
- **GBT/Zpectrometer** : CO lines
- **PdBI** : CO lines
- **SCUBA-2** : 450 & 850 μm
- **MAMBO** : 1.2 mm flux for all the 5 sources

GRAVITATIONAL LENS CANDIDATES ID81 – ID130

Keck imaging in **g** and **i** bands

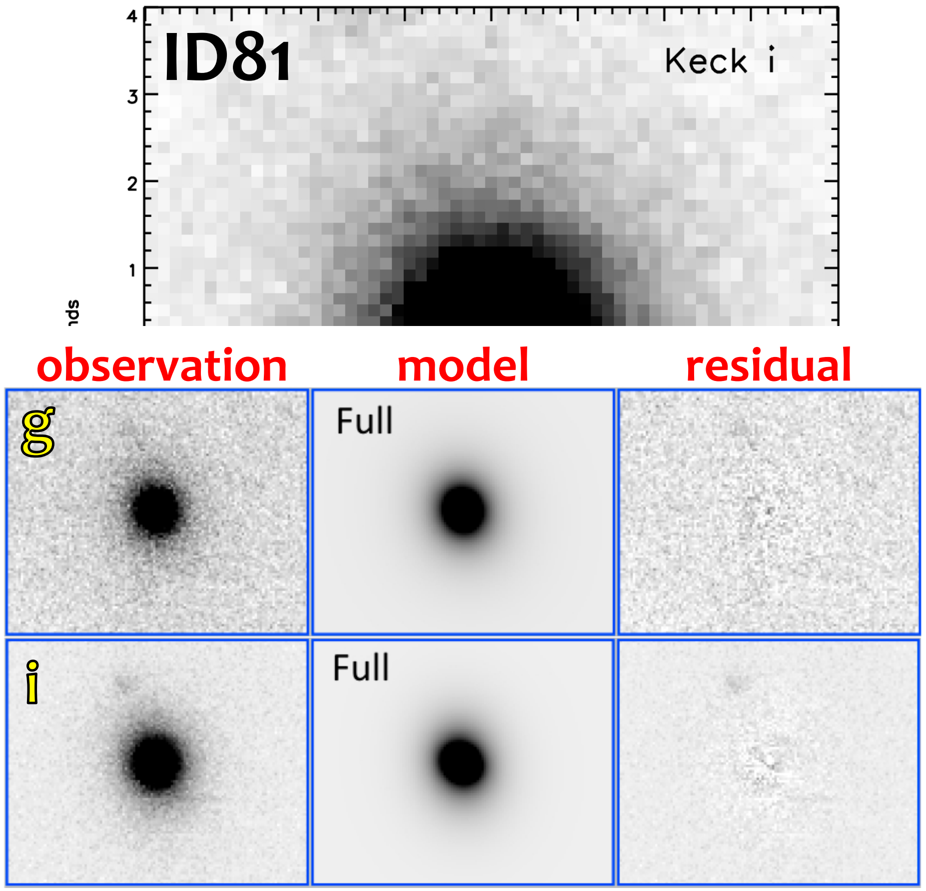


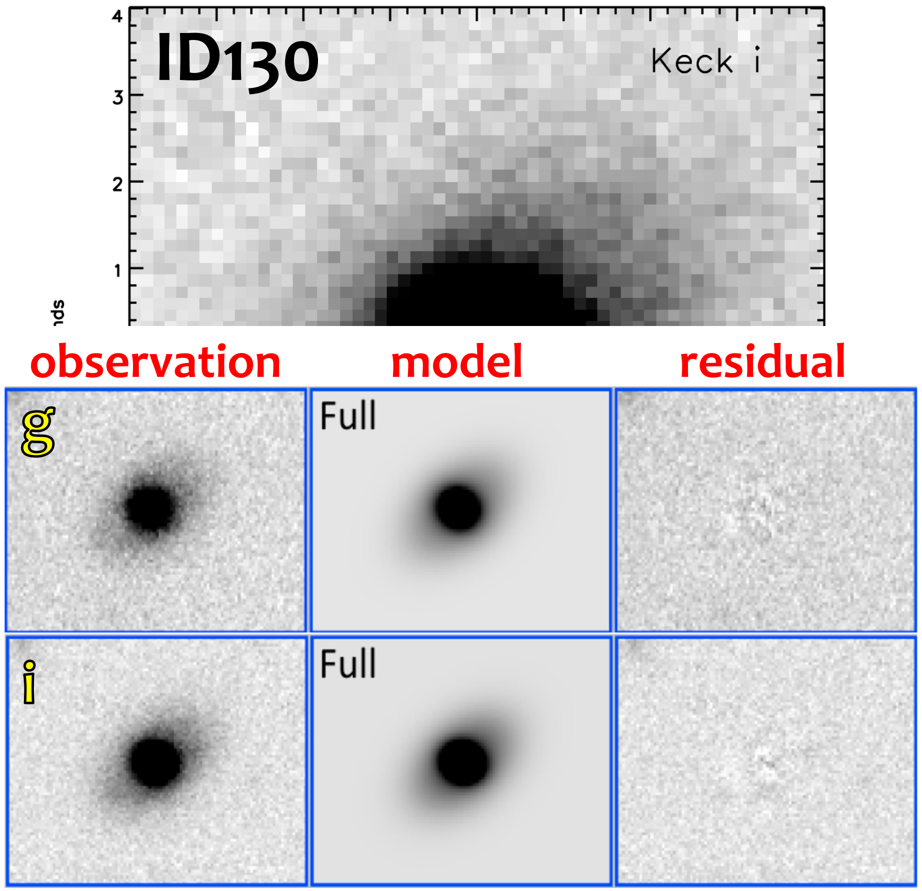


CREDITS: Betsy Barton, Jeff Cooke, Asantha Corray, Sam Kim

Gravitational Lens candidates ID81 – ID130

Keck imaging in **g** and **i** bands

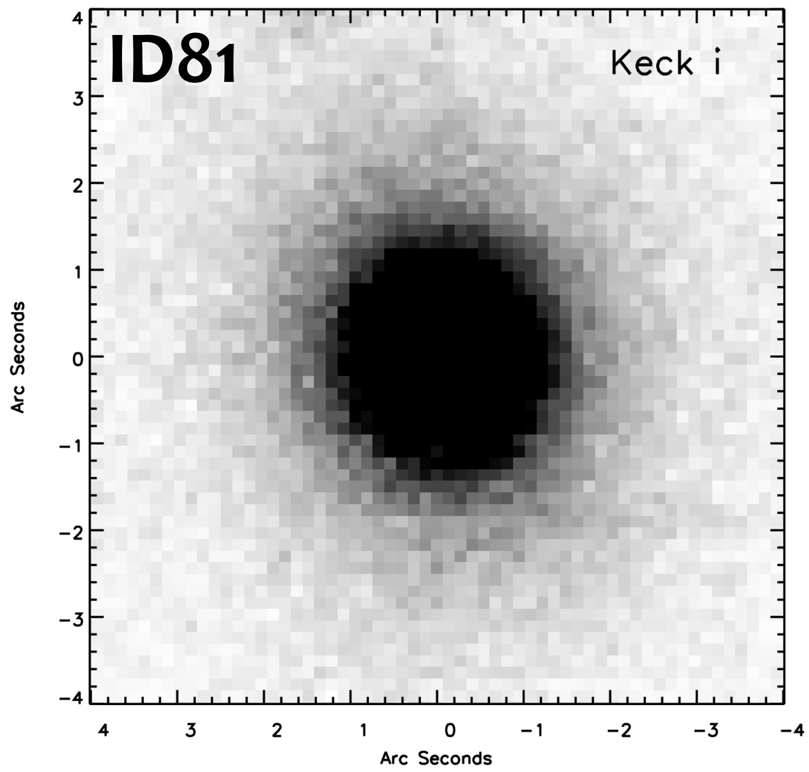


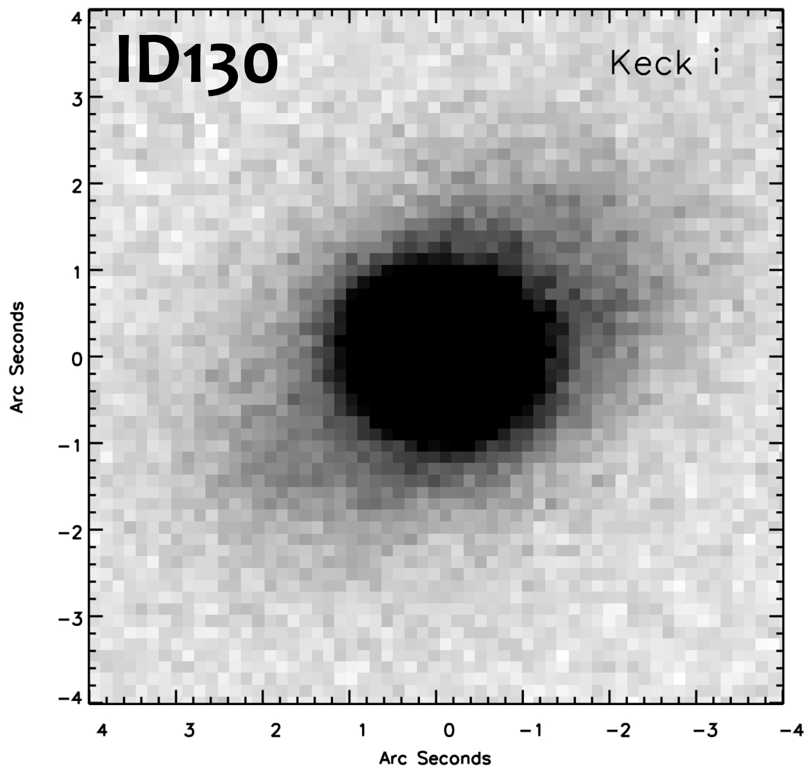


Credits: Rosalind Hopwood (OU), Sam Kim (Irvine U.)

GRAVITATIONAL LENS CANDIDATES ID81 – ID130

Keck imaging in **g** and **i** bands



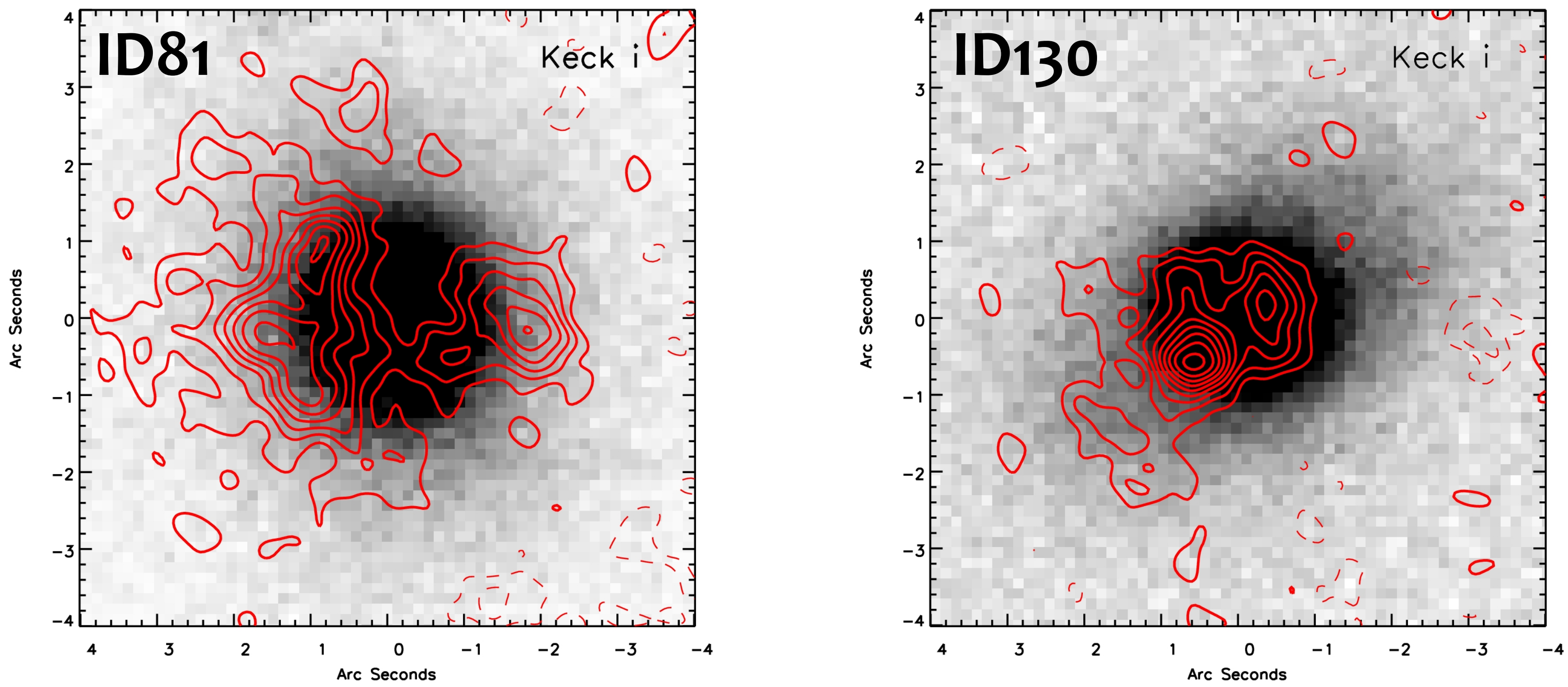


CREDITS: Betsy Barton, Jeff Cooke, Asantha Corray, Sam Kim

GRAVITATIONAL LENS CANDIDATES ID81 – ID130

Sub **M**illimeter **A**rray follow-up at **870 μm**

(*very-extended*, *sub-compact* and *compact* configurations)

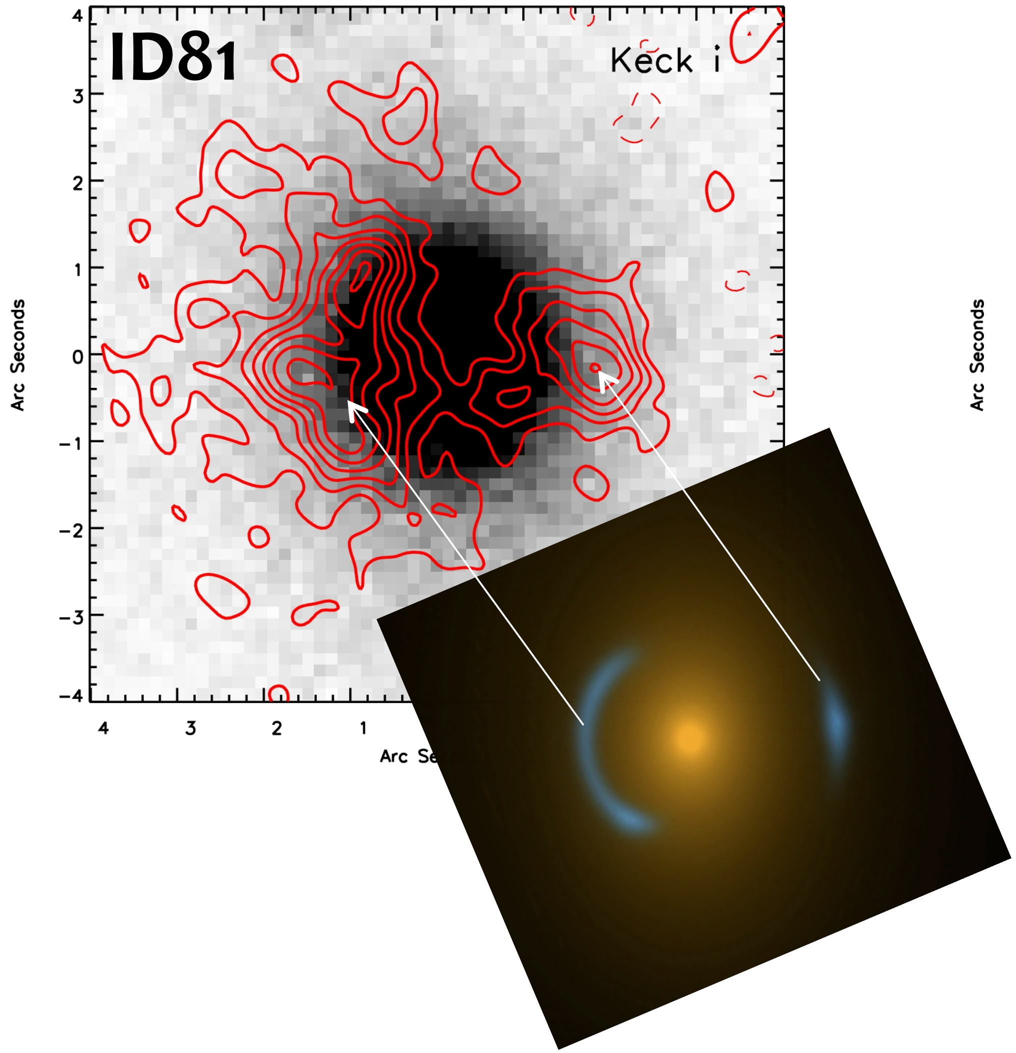


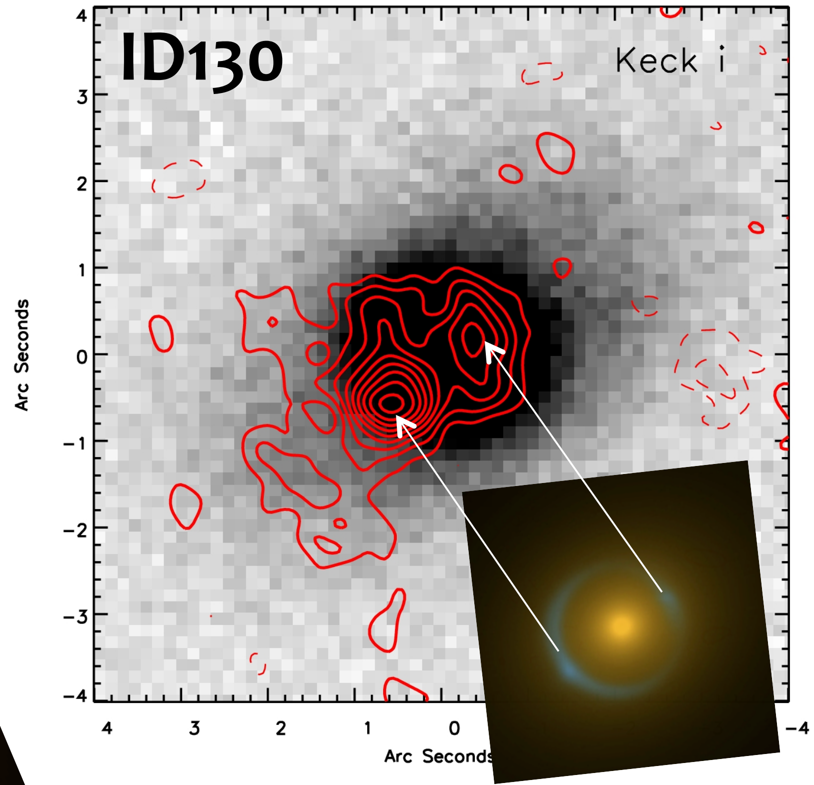
CREDITS: Mark Gurwell (CfA)

GRAVITATIONAL LENS CANDIDATES ID81 – ID130

Sub **M**illimeter **A**rray follow-up at **870 μm**

(*very-extended*, *sub-compact* and *compact* configurations)

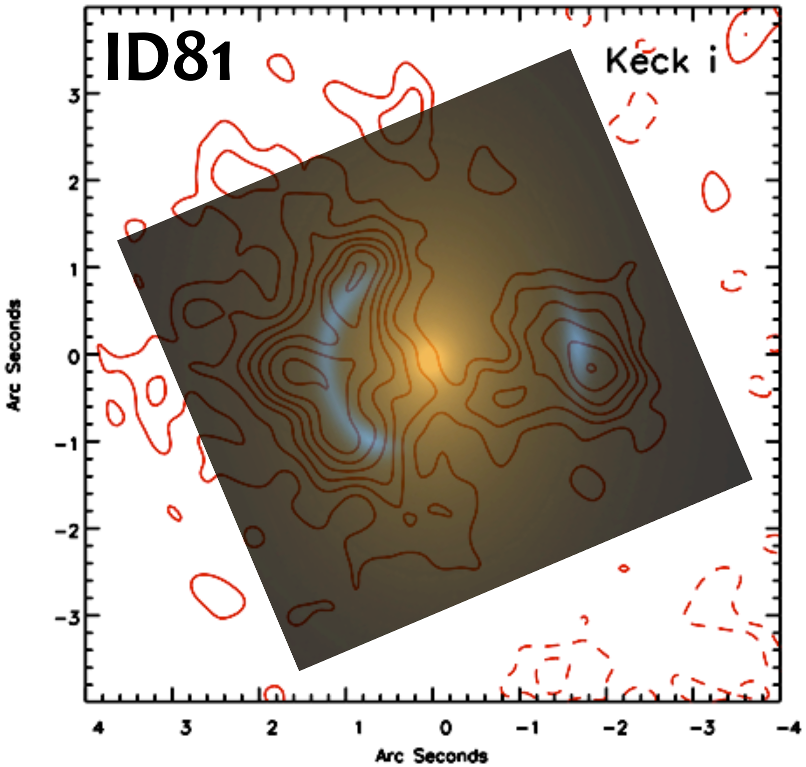


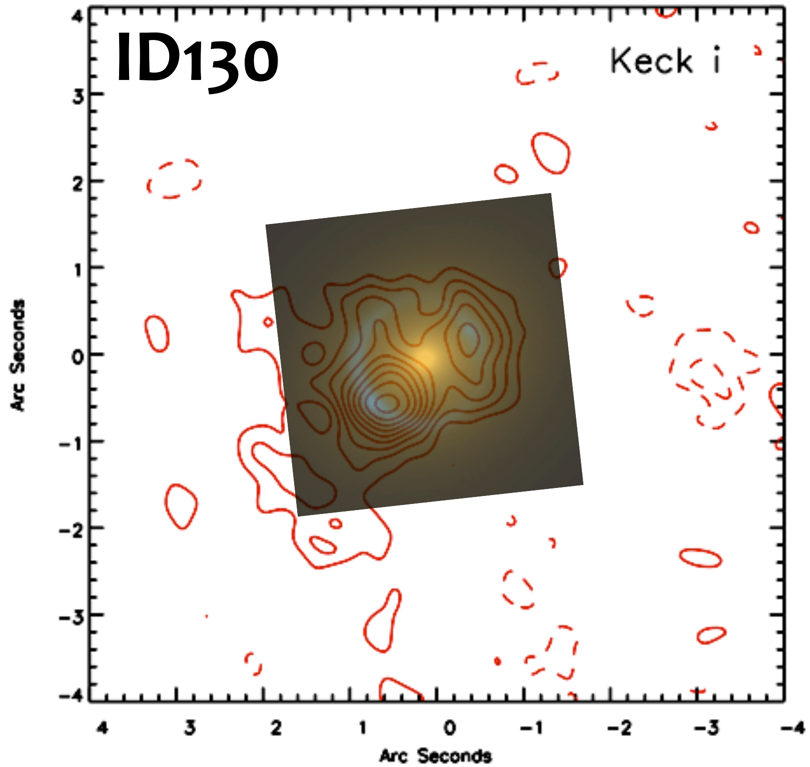


from http://www.slacs.org

Gravitational Lens candidates ID81 – ID130

Sub **M**illimeter **A**rray follow-up at **870 μm**
(*very-extended*, *sub-compact* and *compact* configurations)

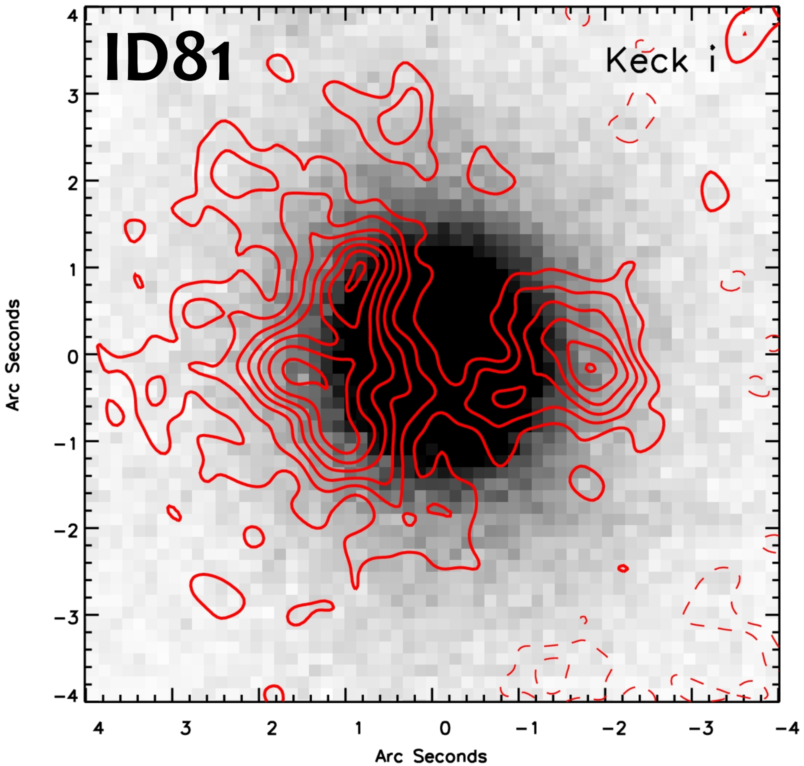


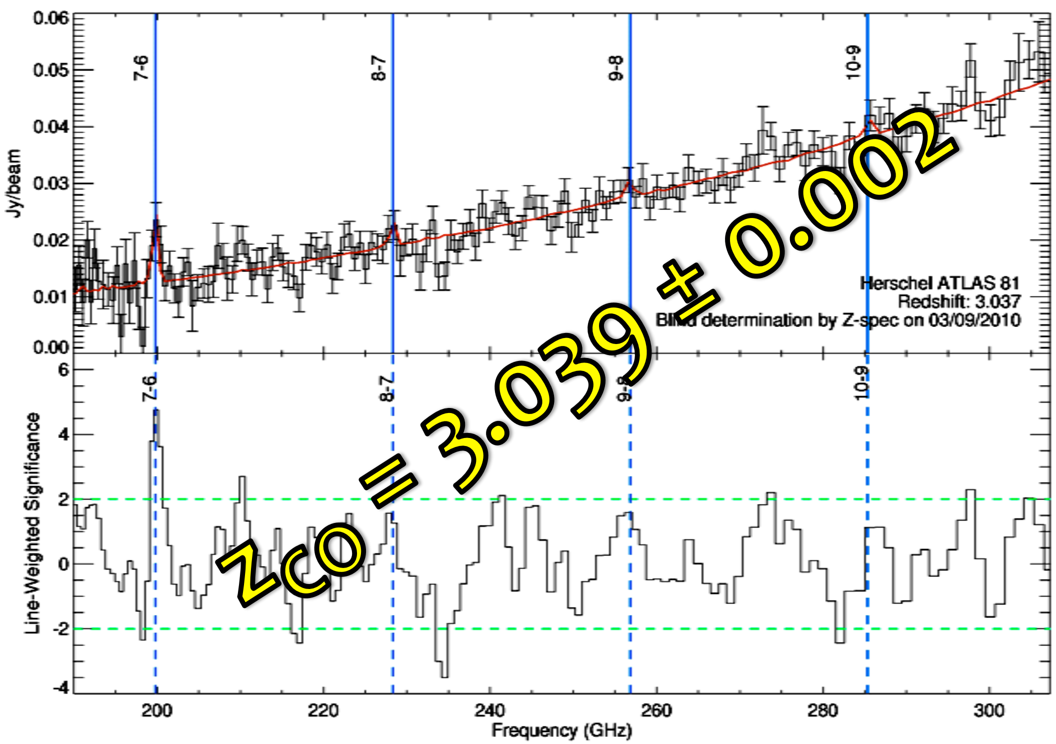


from http://www.slacs.org

GRAVITATIONAL LENS CANDIDATES ID81

CSO/Z-spec blind redshift determination for **ID81** (March 09 2010) from observations of the **CO ladder**

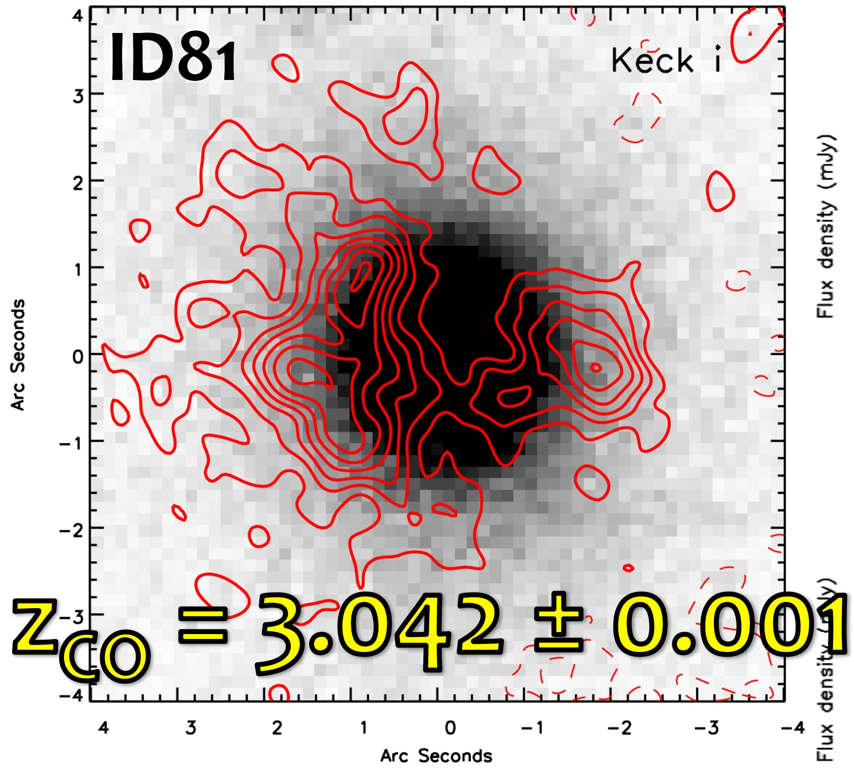


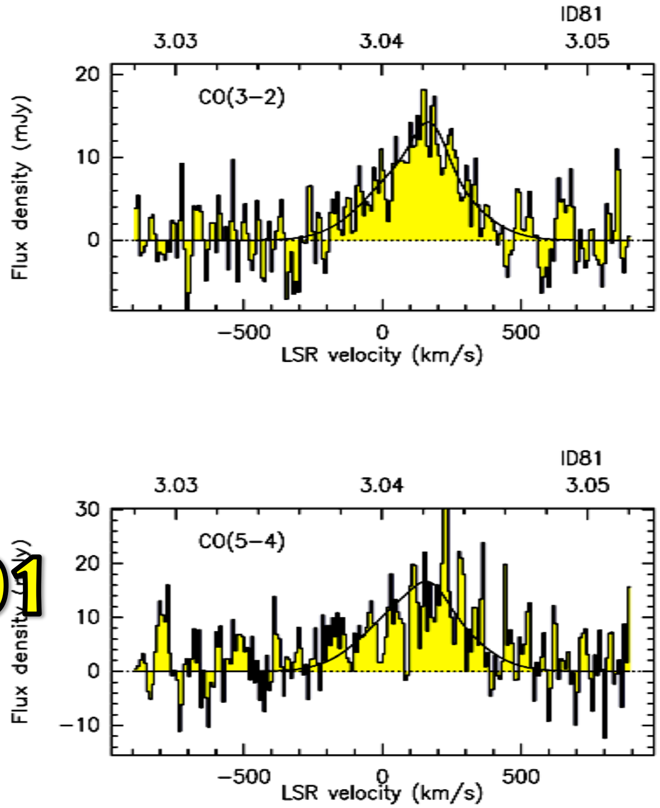


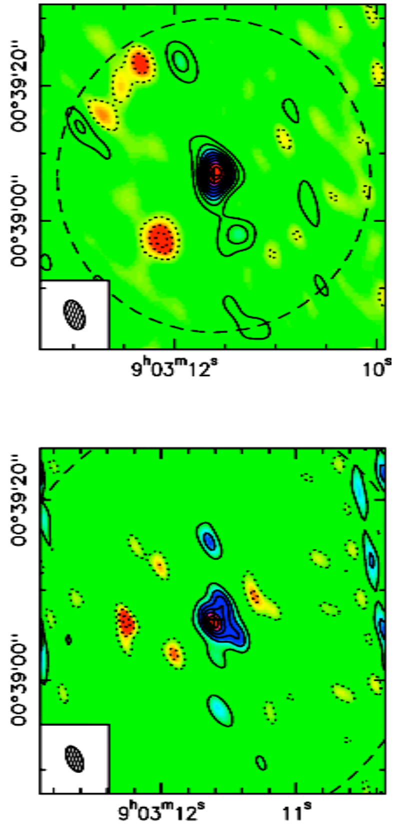
CREDITS: J. E. Aguirre, J. Bock, C. M. Bradford, L. Earle, J. Glenn, J. R. Kamenetzky, R. E. Lupu, P. Maloney, E. Murphy, H. Matsuhara, B. Naylor, H. T. Nguyen, K. S. Scott, J. Zmuidzinas

GRAVITATIONAL LENS CANDIDATES ID81

Redshift confirmed by **follow-ups** with the **PdB Interferometer** (March 23 2010) and **GBT/Zpectrometer** (March 25 2010)



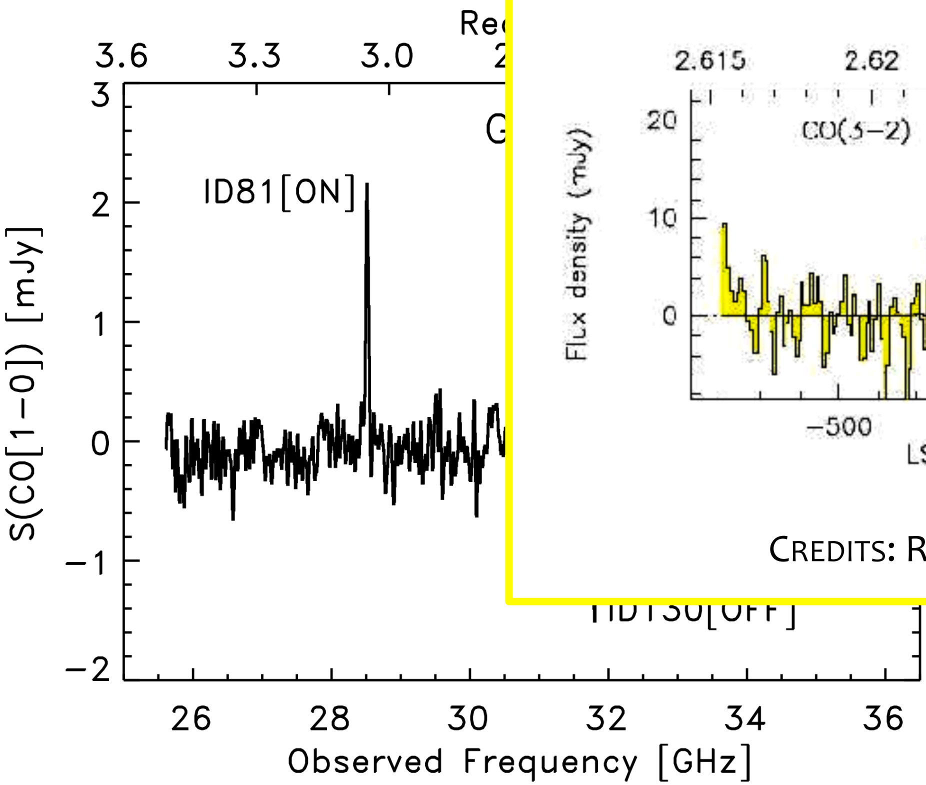




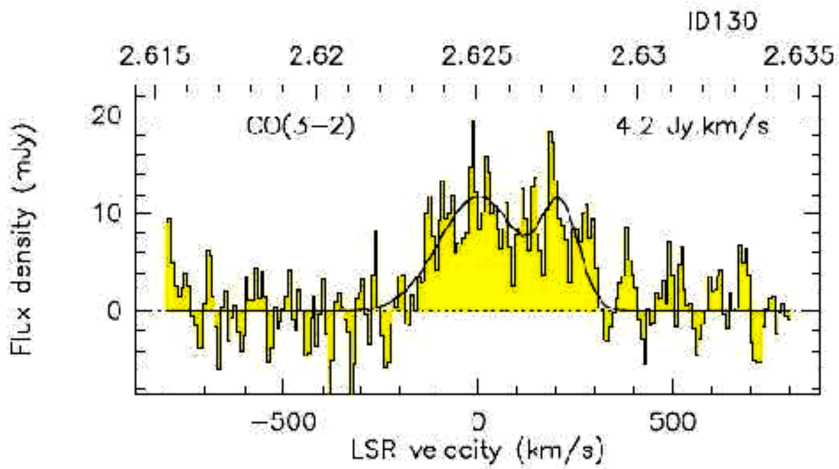
CREDITS: R. Neri, A. Omont, P. Cox, Beelen, Dannerbauer, F. Bertoldi

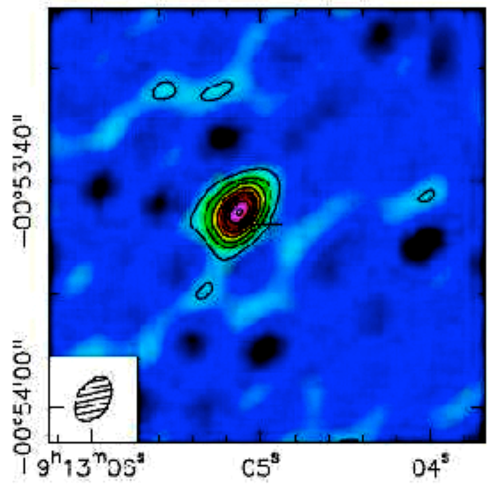
GRAVITATIONAL LENS CANDIDATES ID130

CO(1-0) redshift from GBT/Zpectrometer

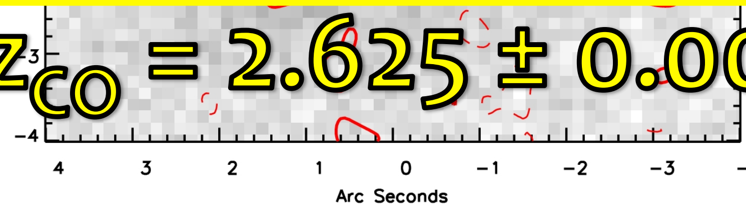


confirmed by **PdBI**





CREDITS: R. Neri, A. Omont, P. Cox, Beelen, Dannerbauer, F. Bertoldi

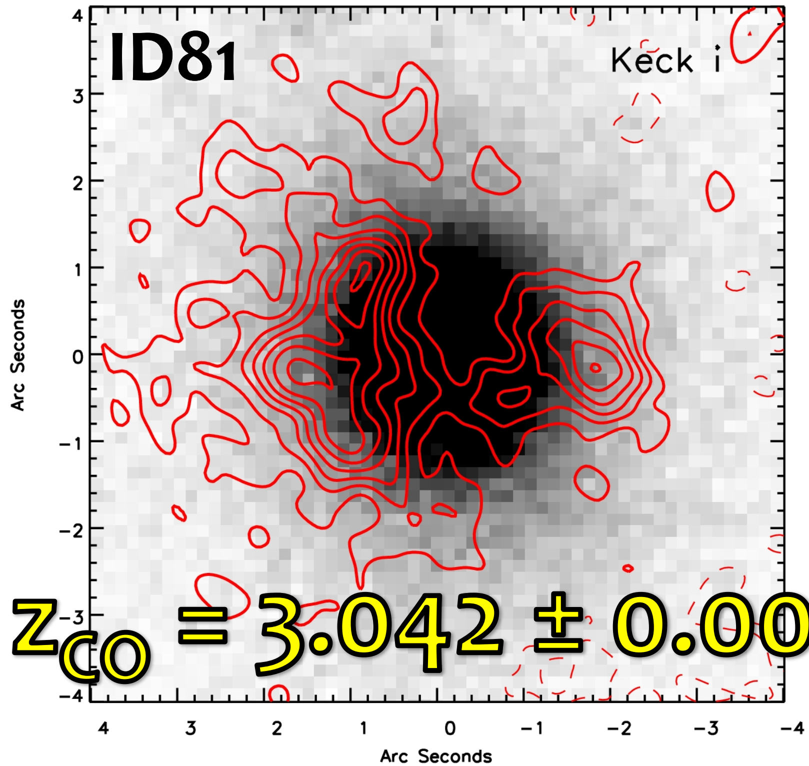


$z_{CO} = 2.625 \pm 0.001$

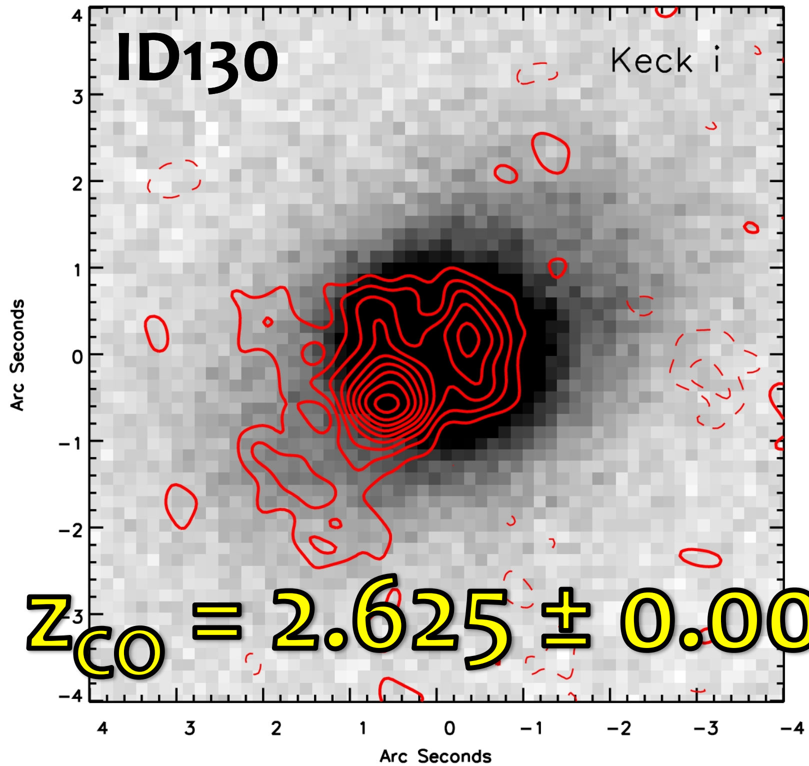
CREDITS: D. Frayer, A. Harris, A. Baker, R. Maddalena et al.

GRAVITATIONAL LENS CANDIDATES ID81 – ID130

CSO/Z-spec + GBT/Zpectrometer + PdBI → z_{CO}



$z_{CO} = 3.042 \pm 0.001$

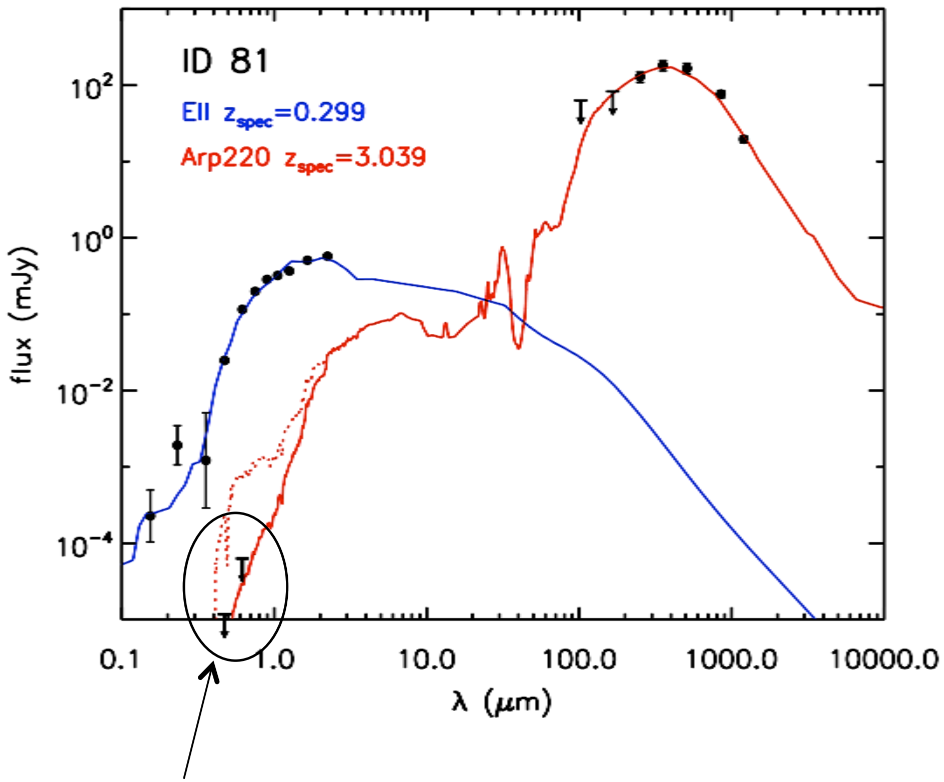


$z_{CO} = 2.625 \pm 0.001$

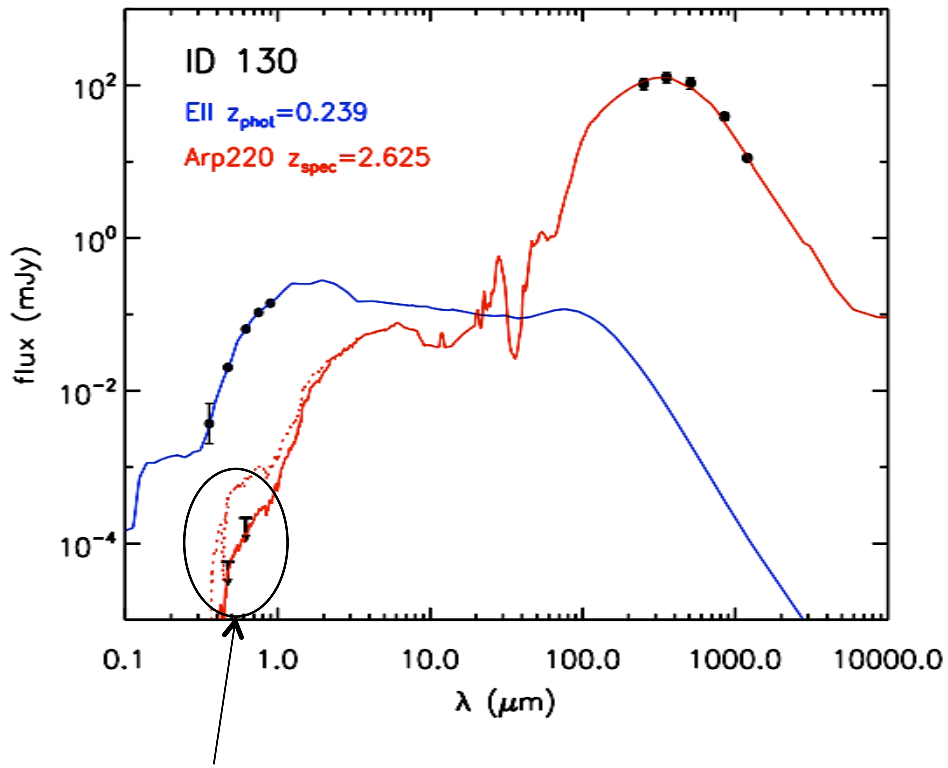
! STRONG GRAVITATIONAL LENS EVENTS !

GRAVITATIONAL LENSES ID81 – ID130

These systems are **missed in the optical** !



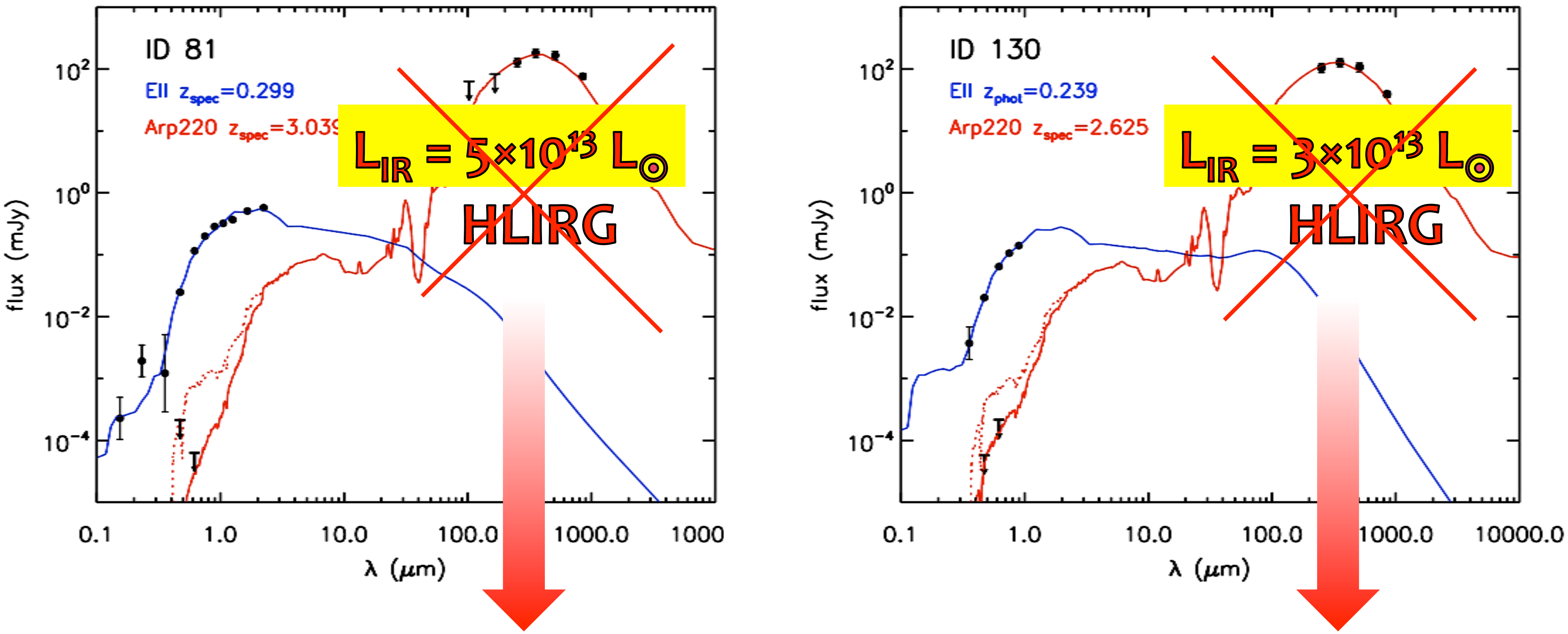
Keck 3σ upper limits



Keck 3σ upper limits

Gravitational Lenses ID81 – ID130

These systems are **missed in the optical** !

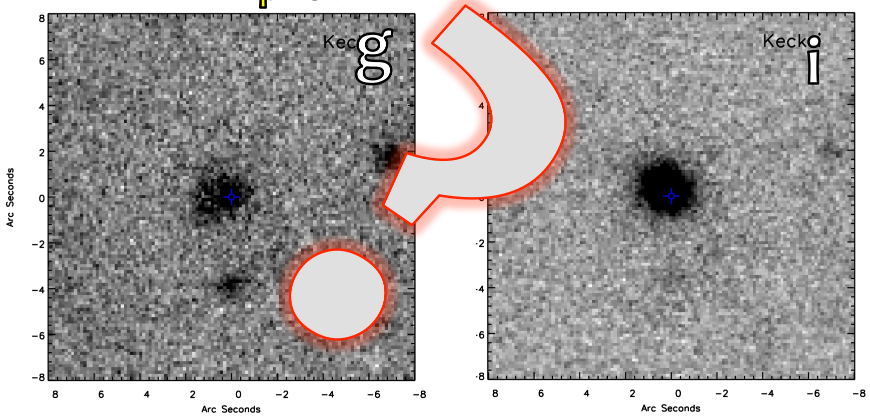


$L_{IR} < 10^{13} L_\odot$ **LIRGs/ULIRGs** $L_{IR} < 10^{13} L_\odot$

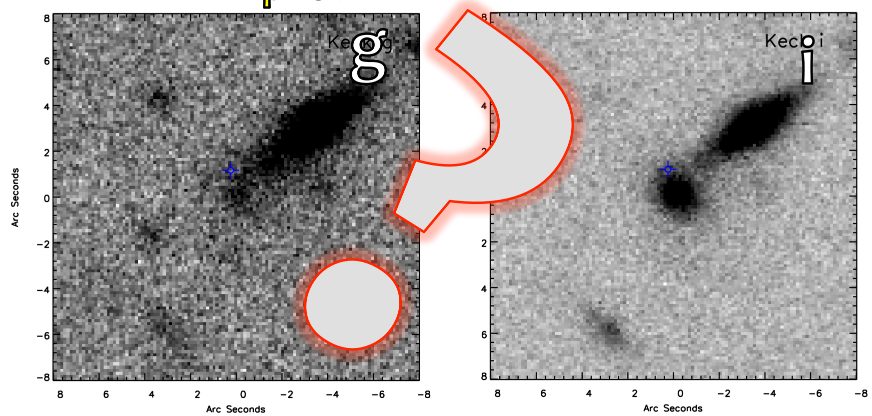
GRAVITATIONAL LENS CANDIDATES

Keck + MAMBO + Z-spec (ongoing…)

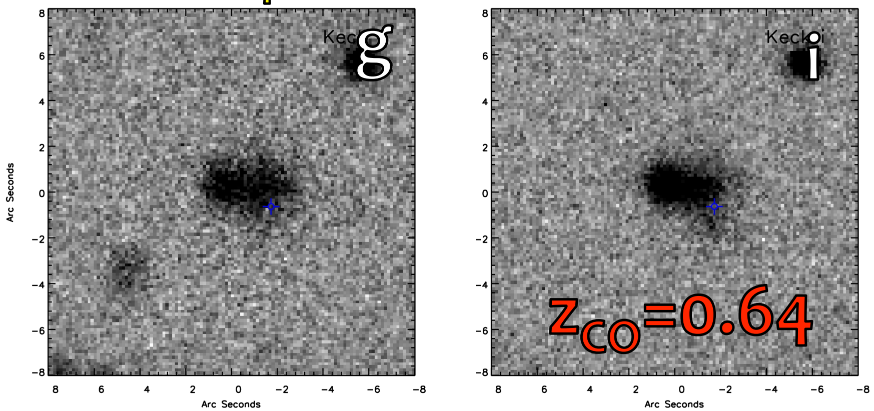
ID9 z_{phot}=0.68±0.06



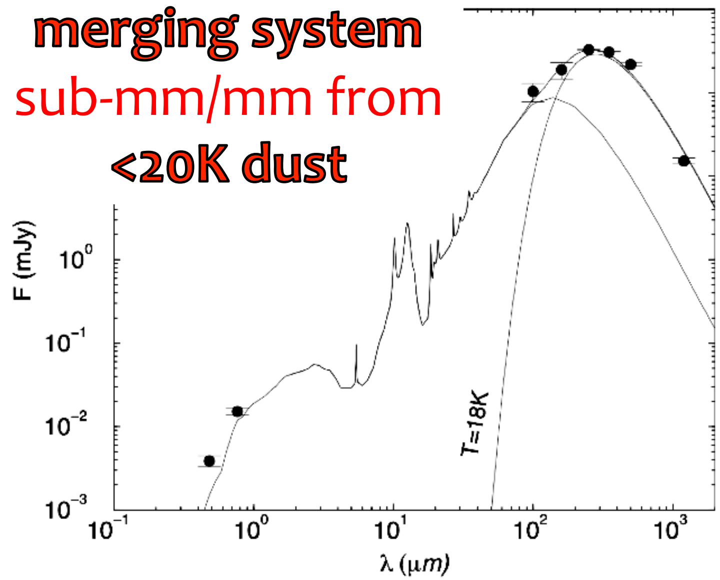
ID11 z_{phot}=0.72±0.16



ID17 z_{phot}=0.77±0.13



merging system
sub-mm/mm from
<20K dust



CONCLUSIONS

ASTROPHYSICAL
TERAHERTZ
LARGE
AREA
SURVEY

discovery of the **Sub-mm Brightest Galaxies**

STRONG GRAVITATIONAL LENS SYSTEMS

proof of concept
no serendipitous discovery

blind survey
no cluster field

galaxy-galaxy
lensing events

lenses **invisible**
in the **optical**

a **hundred** of
bright lenses
in full H-ATLAS

very high
lens selection
efficiency