# NIKA2 Cosmology Legacy Survey

### Alexandre Beelen

(on behalf of the NIKA2 Collaboration)

### PIs: Guilaine Lagache (FR), Alexandre Beelen (FR), Nicolas Ponthieu (FR)

Cols: Rémi Adam (FR), H. Aussel (FR), Matthieu Bethermin (FR), Veronique Buat (FR), Frederic Boone (FR), Emanuele Daddi (FR), David Elbaz (FR), Daizhong Liu (DE), Francois-Xavier Desert (FR), Juan Macias-Perez (FR), Denis Burgarella (FR), Herve Dole (FR), Peter Ade (GB), Philippe Andre (FR), Alain Benoit (FR), Aurelien Bideaud (FR), Nicolas Billot (CH), O. Bourrion (FR), M. Calvo (FR), A. Catalano (FR), Grégoire Coiffard (IRAMF), S. Doyle (GB), J. Goupy (FR), Carsten Kramer (IRAMS), Samuel Leclercq (IRAMF), P. Mauskopf (GB), Frédéric Mayet (FR), A. Monfardini (FR), François Pajot (FR), Enzo Pascale (GB), Laurence Perotto (FR), Giampaolo Pisano (GB), Vincent Reveret (FR), Alessia Ritacco (FR), Louis Rodriguez (FR), Charles Romero (US), Florian Ruppin (US), Karl-Friedrich Schuster (IRAMF), Albrecht Sievers (IRAMS), Sebastien Triqueneaux (FR), C. Tucker (GB), Robert Zylka (IRAMF), Stephano Berta (IRAMF)



# Why Deep Field ?

## **Cosmic SFR History**

- UV based (Lilly et al 1996)
- ... IR based (ISO, Spitzer, Herschel,...)
- Peak  $\approx$  3.5 Gyr after the Big Bang
- Exponential decline
- Quantify the primordial role of dusty galaxies to star formation at z > 3.5
- ... find a Large number of high-z sources



Madau & Dickinson 2014

# Galaxy Formation & Evolution

## **Population Statistics**

- Number counts
- $\blacksquare$  +z : Luminosity functions
- Stacking
- Two points correlation function
- (Cross-) Power Spectra
- Galaxy Evolution Models



Franco et al. 2018; (Also see Maximilien's talk)

# Galaxy Formation & Evolution

## **Population Statistics**

- Number counts
- $\blacksquare$  +z : Luminosity functions
- Stacking
- Two points correlation function
- (Cross-) Power Spectra
- Galaxy Evolution Models



Wilkinson et al. 2017

## Physics of High-z Galaxies



Berta et al. 2013



## Physics of High-z Galaxies



J091828.6+514223, a lensed galaxy at z=5.25 (IRAM)

### Individual Sources

Panchomatic SEDs

 Far-IR / Radio relation see Ivan's talk
 SB vs AGN activity
 SFR, M<sub>dust</sub>, M<sub>\*</sub>, ...

 Probe into distant ISM

 Physical Condition
 Star Formation Laws

## Wide & Shallow

- Extreme sources
- Bright-end counts
- Missing bulk
- Stacking studies

## Narrow & Deep

- Standard sources
- Regular counts
- Most of sources
- Confusion

### **Caustic Lines**

- Faint-end sources
- Model dependent

### Interferometry

- Faint-end sources
- Cosmic variance
- Line Deep Field

Why (sub-) mm wave ?





Negative K-correction !

## Confusion





Elbaz et al. 2011

Ultimate observational limit (for single dish telescope)

## Dusty star formation at high redshift with millimeter Deep Fields

## NIKA2 Guaranteed Time

- Map SF at high-z in two of the most popular fields
- Detect hundreds of faint DSFG
- New windows on the faint and high-*z* dusty Universe.
- Large (>1200 @ 1mm) sample of mm-selected faint galaxies

## 300h

(N2CLS)

# N2CLS Objectives

## Typical DSFG $@z \ge 3$

- detect any  $L_{IR} > 1 \times 10^{12} L_{\odot}$
- SFR of MS galaxies @ z > 3
- Bulk of the DSFG
- MS vs SB

### Complete view SFRD @high-z

- Mostly UV @ z > 3.5
- Need for (sub-)mm surveys
- N2CLS > 3× deeper than S2CLS in GOODS-North

### Clustering of DSFG @z > 2

- > 700 sources in COSMOS
- 2 pts correlation function
- DM Halo & Galaxy properties
- Evolving LSS(z)

### Confusion, Counts & CIB

- CIB mean level at 1.2 & 2mm
- Resolve > 30 and 20% of CIB
- Best estimate of the confusion level

# N2CLS Fields

## GOODS-N Narrow & Deep

- 100 hrs
- 160 Sq. Arcmin (CANDELS)
- At the confusion,

 $\sigma_{1.2mm} =$  0.10 - 0.13 mJy/beam,

 $\sigma_{2.0\rm{mm}} =$  0.06 - 0.08 mJy/beam

- 32 % (23%) of CIB
- 237 DSFGs @ 1.2mm
   12 @ z > 5



# N2CLS Fields



## COSMOS Wider & Shallower

- 200 hrs
- 1350 Sq. Arcmin
- Match S2CLS 850 microns sensitivity
  - $\sigma_{1.2\text{mm}} =$
  - 0.19 0.56 mJy/beam,
  - $\sigma_{2.0\text{mm}} =$
  - 0.11 0.32 mJy/beam
- 5 x larger, 2 x deeper than actual 1.2mm surveys
- 1133 DSFGs @ 1.2mm
   76 @ z > 5

# **GOODS NORTH**

### 266 Scans - 33 / 100 hours on source

- ≈ 160 arcmin<sup>2</sup>
   scans in RA/DEC orientation
- IMCM method (cf. N. Ponthieu's talk)
- gaussian noise almost white



# **GOODS NORTH**



- preliminary analysis
- 17 sources already with very high confidence
- nominal behavior so far



# **GOODS NORTH**

### 266 Scans - 33 / 100 hours on source



- $\blacksquare$   $\approx$  1400 arcmin<sup>2</sup>
- scans in RA/DEC orientation
- longer scans, more challenging
- IMCM (cf. N. Ponthieu's talk)
- gaussian noise almost almost white





COSMOS



## **Redshift Identification**

- > 1000 sources detected
- Large ancillary database w. photo-z and/or spectro-z
- Identification of the high-z candidates
- Towards a complete sample identification & Luminosity Functions of DSFG @ z > 3

### Follow-up observations

## NOEMA & ALMA

- Multiplicity of bright sources
- Redshift search & position accuracy
- ISM studies

## NIKA Blind Survey SV

- 6.5 hours on GOODS-N
- Small fields around a  $z \approx 6$  candidate
- Super-deblending method (Liu et al. 2017)
- 1*σ* = 0.6(0.2) mJy
- 3 SNR > 3.5 detection
  - Dusty MS galaxy (AzGN10, ID12646)



# **Case Studies**

## NIKA Blind Survey SV

- 6.5 hours on GOODS-N
- Small fields around a  $z \approx 6$  candidate
- Super-deblending method (Liu et al. 2017)
- **1** $\sigma$  = 0.6(0.2) mJy
- 3 SNR > 3.5 detection
  - Dusty MS galaxy (AzGN10, ID12646)





#### Best model for id12646 at z = 3.8. Reduced $\chi^2$ =0.48

### ID12646

- After many proposal...
- 1h+19h on source w. NOEMA
- 9σ @ 1.17mm cont.
- 12σ @ 2.7mm cont.
- candidate z ~ 3.8 DSFG



#### Best model for id12646 at z = 3.8. Reduced $\chi^2$ =0.48

### ID12646

- After many proposal...
- 1h+19h on source w. NOEMA
- 9σ @ 1.17mm cont.
- 12σ @ 2.7mm cont.
- candidate  $z \sim 3.8$  DSFG

### Deblending and SED templates can be tricky

Ponthieu et al. in prep

## Case Studies cont.

## NIKA2 SV HLS J0918+5142

- z = 5.2 lensed DSFG (Combes et al. 2012)
- See Nicolas's talk
- Few ancillary data Herschel...

Two candidates at  $z \approx 7$  !!!



### Ponthieu et al. in prep

## Case Studies cont.

## NIKA2 SV HLS J0918+5142

- z = 5.2 lensed DSFG (Combes et al. 2012)
- See Nicolas's talk
- Few ancillary data Herschel...

Two candidates at  $z \approx 7$  !!!



## Case Studies cont.

### Ponthieu et al. in prep



## NOEMA Redshift search

- 2 settings, 16hours total
- 1 clear line SNR > 7 !
- Ambiguous z solution
- Hunt the CO(7-6) line !



## Case Studies cont.

### Ponthieu et al. in prep



## NOEMA Redshift search

- 2 settings, 16hours total
- 1 clear line SNR > 7 !
- Ambiguous z solution
- Hunt the CO(7-6) line !
- Clear detection ! ``



## Case Studies cont.

### Ponthieu et al. in prep



## NOEMA Redshift search

- 2 settings, 16hours total
- 1 clear line SNR > 7 !
- Ambiguous z solution
- Hunt the CO(7-6) line !
- Clear detection ! ``



# Wrapping-up ?

### Lesson Learned

- Deblending and/or photo-z can be surprising
- Potentially a new, missed, population of DSFG with (very) cold dust

## **NOEMA** Synergies

- Bright sources multiplicity
- Positional accuracy
- Redshift searches
- Continuum studies (3mm)
- Lines studies

Also see Charlène's talk

Expect New Large Follow-Up on N2CLS Sources !

# Synergies with other LP

## NIKA2 LPSZ

- Strong complementarity
- Point source contamination
- Ancillary datasets
- SED fitting & Removal
- Hunting highly lensed DSFGs !









# NikaMap



- Read IDL pipeline products
- Easy plotting
- Match filtering
- Bootstrap & Jackknife analysis
- Power spectrum estimation
- Point sources detection & photometry

# NIKA2 Cosmology Database

## Features

- Retrieve meta data
- Download data
- Follow observations progress

NIKA2 Cosmology Legacy Survey Home MiniTapas Reduce About Sign Up Sign In								
	Summary							
	Source Name	Observed scans	Available scans	Usable scans	Usable Time	Files size		
	DeepField1	149	0	0	None	553.3 MB		
	GOODSNORTH	296	266	266	1 day, 8:59.59	62.2 GB		
	HLS091828	177	169	169	10:49:47	18.7 GB		
	COSMOS	181	134	134	1 day, 6:40.55	69.1 GB		
	G2	205	204	204	19:59:51	33.8 GB		
	Total	1008	773	773	3 days, 22:30:32	184.3 GB		



surce List



# NIKA2 Cosmology Database

### Features

- Retrieve meta data
- Download data
- Follow observations progress
- Reduce data IDL pipeline Many methods

NIKA2 Cosmology Legacy Survey Home MiniTapas Reduce About Sign Up Sign In

#### Summary

Source Name	Reduced scans	Usable scans	Files size
GOODSNORTH	2072	2059	95.1 GB
COSMOS	416	416	135.0 GB
HL5091828	1843	1848	59.1 GB
G2	2214	2169	70.8 GB
Total	6550	6492	359.9 GB

All syn revisions, all methods

#### **Reduction status**

19364	20750					
Decor Method			62	HLS091828	GOODSNORTH	COSMOS
ATM_AND_ALL_BOX			997	164	227	8
ATM_AND	ATM_AND_ALL_BOX_ITER			277	165	52
ATM_CON	ATM_COMMON_MODE_BOX			228	163	52
ATM_CON	ATM_COMMON_MODE_ONE_BLOCK			278	165	<b>1</b> 2
ATM_COMMON_MODE_ONE_BLOCK_ITER		237	52	197	358	
ATM_DER	IV_ONE_BO	ж	220	82	203	564
COMMON	_MODE_BO	xc		238	163	203
COMMON	_MODE_0	WE_BLOCK	368	228	203	82
	_	-				

aced Scan List Parameters List Weather plots Diagnostic plots Diagnostic plots per an

# NIKA2 Cosmology Database

### Features

- Retrieve meta data
- Download data
- Follow observations progress
- Reduce data IDL pipeline Many methods

## Quality Assessments

NIKA2 Cosmology Legacy Survey Home MiniTapas Reduce About Sign Up Sign In



Go back