Wide ASPECS: Bridging the gap between targeted observations and molecular deep fields

2017.1.00138.S

ABSTRACT

Molecular gas investigations in distant galaxies typically focus on sources that have been pre-selected based on various properties, in particular stellar mass, star formation, or IR luminosity. By construction, these galaxies typically populate the bright end of the main sequence of star-forming galaxies. An alternative approach consists of sensitive observations of deep fields, where molecular gas emission is blindly searched for without any pre-selection. Again by construction, this latter strategy picks fainter galaxies than the ones identified by targeted observations, but in a well-defined cosmological volume. Here we propose to bridge the gap between these two approaches. With a 23hr Band 3 scan we will extend the deep field approach to an unprecedentedly large area (52.5 arcmin2, quintupling the area of the ASPECS Large Program). This dataset will pin down the bright end of the CO luminosity function at high redshift, and put the galaxies pre-selected based on ancillary data into the broader context of the underlying population of molecular gas emitters. Additionally, we will place the first direct constraints on the large-scale clustering properties of CO-bright gaalxies.

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PI E-MAIL:	decarli@mpia.de			**PI INSTITUTE:**	Max-Planck-Institute for Astronomy
ESTIMATED 12M TIME:	**22.6 h**	**ESTIMATED ACA TIME:**	**0.0 h**	**ESTIMATED NON-STANDARD MODE TIME (12-M):**	**0.0 h**
CO-PI NAME(S): (Large & VLBI Proposals only)					
CO-INVESTIGATOR NAME(S):	Fabian Walter; Manuel Aravena; Chris carilli; Roberto Assef; Franz Bauer; Frank Bertoldi; Rychard Bouwens; Paulo Cortes; Pierre Cox; Elisabete da Cunha; Emanuele Daddi; Tanio Diaz-Santos; David Elbaz; Jorge Gonzalez; Rob Ivison; Pascal Oesch; Gergö Popping; Dominik Riechers; Rachel Somerville; Ian Smail; Mark Swinbank; Jeff Wagg; Axel Weiss; Paul van der Werf; Roland Bacon; Thierry Contini; Lutz Wisotzki; Hans-Walter Rix; Jacqueline Hodge; Olivier Le Fèvre				
DUPLICATE OBSERVATION JUSTIFICATION:					

REPRESENTATIVE SCIENCE GOALS (UP TO FIRST 30)

SCIENCE GOAL	POSITION	BAND	ANG.RES.(")	LAS.(")	ACA?	NON-STANDARD MODE
setup a	ICRS 03:32:30.0000, -27:48:15.000	3	1.000	2.000	N	N
setup b	ICRS 03:32:30.0000, -27:48:15.000	3	1.000	2.000	N	N
setup c	ICRS 03:32:30.0000, -27:48:15.000	3	1.000	2.000	N	N
Total # Science Goals : 3						

SCHEDULING TIME CONSTRAINTS	NONE	TIME ESTIMATES OVERRIDDEN ?	No

Wide ASPECS: Bridging the gap between targeted observations and molecular deep fields

The golden age of high–redshift molecular gas studies — The molecular phase of the interstellar medium (ISM) is the birthplace of stars, and thus it constitutes a key component in the life and evolution of galaxies. Nevertheless, observational constraints on the molecular gas content in galaxies throughout cosmic history are, still, limited to a relatively modest number of sources (see Carilli & Walter 2013). As the hydrogen molecule, H_2, is an inefficient radiator, ^{12}CO (hereafter, CO) is often preferred as a molecular gas tracer in distant galaxies. The lack of sensitivity of past observatories operating at mm-wavelength traditionally limited the detectability of CO at high redshift to the very tip of the iceberg of IR–bright sub-mm galaxies and quasar host galaxies. However, the bulk of cosmic star formation occurs in less extreme, "main sequence" galaxies (Noeske et al. 2007; Elbaz et al. 2007, 2011; Daddi et al. 2010a,b; Genzel et al. 2010; Wuyts et al. 2011; Whitaker et al. 2012). While prohibitive only a few years ago, CO observations in main sequence galaxies at $z > 1$ have now become feasible, with now a several dozens detections at $z > 1$.

The bulk of these detections came from "targeted" observations of galaxies that have been pre-selected based on their stellar mass (M_*) and star formation rate (SFR). The bright far–IR emission associated with dust–enshrouded star formation has often driven the pre-selection of the galaxies to observe in CO (e.g., Tacconi et al. 2010, 2013, 2017; Genzel et al. 2015), or even substituted CO as an alternative way to estimate molecular gas content, via appropriate dust-to-gas scaling (e.g., Magdis et al. 2011, 2012; Scoville et al. 2014, 2016, 2017; Groves et al. 2016; Berta et al. 2016). The FIR–driven selection typically picks CO–bright sources, that can be studied in large numbers (several hundreds, e.g., Scoville et al. 2017; Tacconi et al. 2017). These studies have been instrumental in shaping our understanding of the interplay between molecular gas content and various properties of the galaxies, such as SFR, M_*, specific SFR, depletion time, etc. On the other hand, by construction these targeted observations (in particular if the selection was aided by *Herschel* detections), typically focus on the bright end of the main sequence of galaxies. Vast gaseous reservoirs might be missed by the dust–driven selection, because of surface brightness / source confusion limitations, or because of the dust temperature–luminosity bias, which makes the warmer components of the dust emission much easier to detect compared to more diffuse and colder phases.

An alternative approach to search for molecular gas in high–z galaxies is based on molecular deep fields, i.e., sensitive spectral scans used to blindly search for CO emission without any pre-selection based on other wavelengths. This strategy follows the principles of highly–successful deep field photometric campaigns such as GOODS, COSMOS, and the Hubble Deep Fields (Williams et al. 1996; Giavalisco et al. 2004; Scoville et al. 2007; Beckwith et al. 2006). It offers a more direct census of the molecular gas in galaxies in well–defined cosmological volumes, and is therefore ideal in order to constrain the CO luminosity function in different cosmic epochs and the total budget of molecular gas in the universe (see, e.g., Walter et al. 2014, 2016; Decarli et al. 2014; 2016a,b). Our ASPECS Pilot program (2013.1.00146.S and 2013.1.00718.S, PIs: Walter & Aravena) and the subsequent ASPECS Large Program (2016.1.00324.L, PIs: Walter, Aravena, Carilli; one of the only 2 large programs approved to date for ALMA observations) have pioneered this line of research. Molecular deep field experiments so far have been designed to maximize the detection rate of galaxies close to the knee of the CO luminosity functions (LFs); this sets a compromise between depth and volume coverage that favours fainter sources than the ones typically studied in targeted observations.

The missing link: Wide ASPECS — In order to achieve a comprehensive and coherent understanding of the role of molecular gas in the evolution of galaxies, it is now mandatory that we bridge the gap between targeted observations and molecular deep fields. We propose to do so

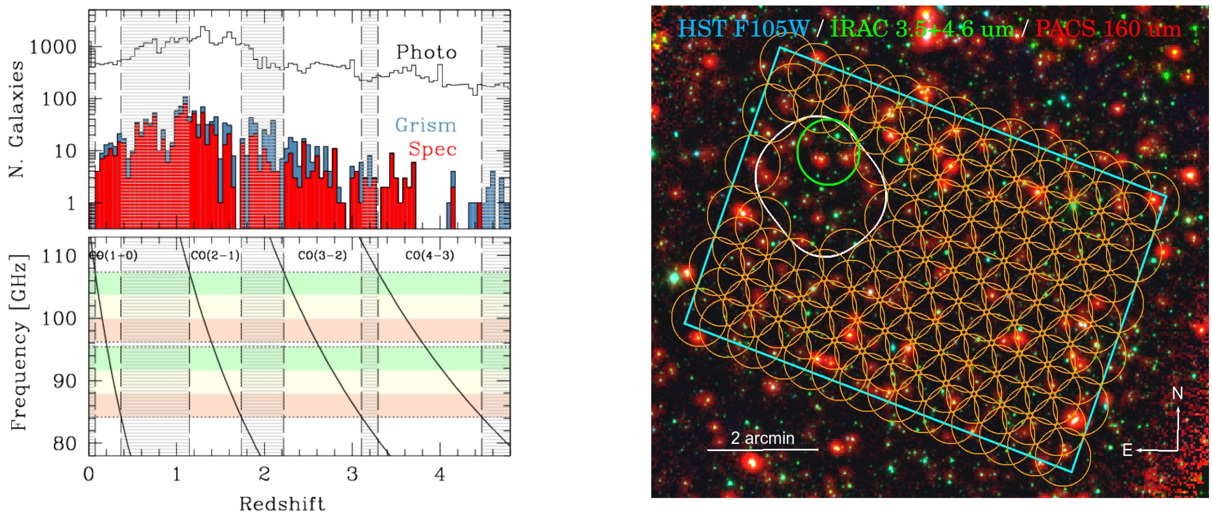
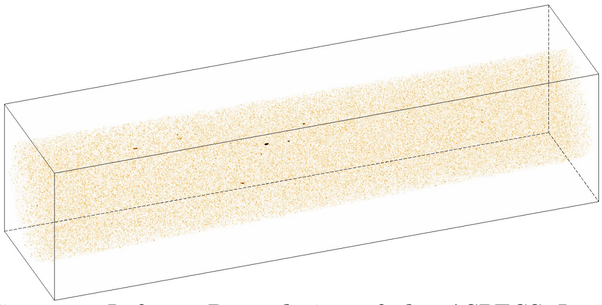


Figure 1: *Left* – Spectral and CO redshift coverage of the proposed observations, compared with the redshift distributions of galaxies in the field. With only 3 frequency settings (marked with green, yellow, and orange shading) in band 3 (thus, easily schedulable), we will be able to sample the bright end of the CO luminosity function at z~1.5 (at the peak of the galaxy formation) and almost continuously between z=2.2 and 4.4, thus encompassing thousands of galaxies (hundreds with already published spectroscopic redshifts). *Right* – Areal coverage of the proposed observations (orange circles) compared with the ASPECS pilot (green circle) and the ASPECS Large Program coverage (white contour). The 50% sensitivity area is marked in cyan. The proposed observations will encompass a grand total of 52.5 square arcmin, thus matching the area of the deepest CANDELS observations, where several bright Herschel sources are clearly visible. This "wedding cake" strategy has been extremely successful in extragalactic fields.

via the Wide ASPECS survey: A wide–area molecular deep field, which will expand by a factor ~ 5 the areal coverage of the ASPECS Large Program, thus encompassing the entire deep part of CANDELS-GOODS South (Guo et al. 2013) in three of the 5 original frequency settings (see Fig. 1). The expanded volume coverage will allow us to detect bright CO emission associated with many of the galaxies typically selected in targeted observations, as well as in any other similarly CO–bright galaxy that would be missed by the pre–selection. One of our main goal is to constrain the bright end of the LF. The proposed observations will be significantly shallower than the ASPECS efforts profused so far ($\sim 3\times$ shallower, i.e., a factor ~ 10 faster in time). A simple comparison with the recently–delivered data from the 3mm part of the ASPECS Large Program suggests that at this decreased sensitivity, we will still be able to recover 3–4 of the brightest CO emitters identified in the ASPECS Large Program (see Fig. 2). By scaling to the larger areal coverage, we can expect to discover $\sim 15-20$ comparably bright CO emitters in the proposed observations, plus any other even brighter CO emitter that is simply too rare to fall into the volume probed so far – as expected, based on the many *Herschel* detections in the field (see Fig. 1). We stress that this "wedding cake" strategy (with various layers differently balancing areal coverage and depth) has been extremely successful in extragalactic surveys (as beautifully demonstrated by the complementarity of GOODS, CANDELS, and the HUDF). The main goals of Wide ASPECS are the following:

i- We will constrain the bright end of the CO LFs at $z \sim 1.4$, and $z = 2.2$–4.4 (see Figs. 1 and 3). We will test whether the observed CO LFs are more consistent with the expectations from semi-analytical models (e.g., Lagos et al. 2012; Popping et al. 2016) or with the significantly different empirical predictions based on the IR–continuum LFs from *Herschel* (e.g., Vallini et al. 2016). If our observations confirm the models predictions, this immediately means that there are flaws in the sensible conversions used to extrapolate CO from IR luminosities. Conversely, if our results confirm IR–based expectations, we will really confront semi-analytical models and put strong constraints on the efficiency with which gas is being stored/brought into galaxies. Furthermore, by crossmatching the CO bright ones to sub-mm galaxies we can constrain the contribution of sub-mm galaxies to the CO luminosity function.



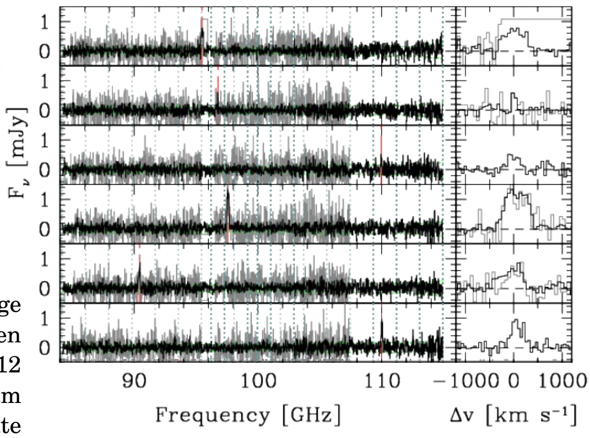


Figure 2: Left – 3D rendering of the ASPECS Large Program at 3mm. Some very bright lines are clearly seen in the rendering. Right – Spectra of 6 out of the 12 brightest CO detections from the ASPECS Large Program data recently delivered (black histograms). We simulate how these lines would look like in the proposed, shallower observations by artificially degrading the noise to match the level proposed here (grey histograms). We also take into account the actual frequency coverage (which avoids the high-frequency end of the original ASPECS spectral scan). We expect to retrieve 3-4 CO lines in this area. Given that the proposed areal coverage is ~5 larger, we expect that our Wide-ASPECS survey will result ~15-20 CO detections of comparable strength, and possibly 5-15 brighter (but rarer) lines if the *Herschel*-based predictions are valid (see Fig.3).

ii- We will search the cubes for additional CO–bright sources that are missed by classical selection techniques (based on IR–luminosity, SFR, M_*, optical/NIR colors, etc). This will allow us to place the results of targeted observations into a broader context of the underlying population of CO emitters.

iii- We will capitalize on the larger–than–ever sampled volume to constrain the clustering properties of CO emitters. In particular, we will be able to construct the 2–point correlation functions between, e.g., bright CO emitters and companion, color–selected galaxies at various mass / SFR cuts (see, e.g., Hickox et al. 2012; Garcia Vergara et al. 2017). This will enable the first direct measure ever of the clustering bias in CO emitters, thus constraining the typical halo mass in which they reside (see Fig. 4).

We remark that goals *i* and *iii* capitalize on the well–defined cosmological volume offered by the deep field strategy. As a natural by–product of Wide ASPECS, we will also be able to significantly push the line sensitivity via stacking on sources with available spectroscopic redshifts; and we will obtain the first 3mm continuum image of the CANDELS–GOODS South field by collapsing our spectral scan along the frequency axis.

Survey outline — We propose to sample a wide area ($\sim 52.5\,\mathrm{arcmin}^2$ at $> 20\%$ of the peak sensitivity, $\sim 43\,\mathrm{arcmin}^2$ at $> 50\%$) with 3 different frequency settings. Observations will be in the easily–schedulable ALMA Band 3 (3mm), where the lowest J transitions of CO are observed (see Fig. 1). The frequency coverage aims at maximizing the observed volume of the universe without overlapping frequency settings. This provides CO redshift coverage at $z < 0.4$, at $z = 1.1 - 1.8$, and at $z = 2.2 - 4.4$, thus encompassing $\approx 17,000$ galaxies, of which hundreds have either a *HST* grism or long–slit spectroscopical redshift (see Fig. 1; this number will increase by an order of magnitude thanks to the VLT/MUSE GTO program which has already covered the entire targeted area). By cross-matching with optical/NIR counterparts, we will avoid any ambiguity in the line identification. The survey will cover an unparalleled volume of $\approx 550,000\,\mathrm{cMpc}^3$. The areal coverage will be achieved with a mosaic of 130 Nyquist–spaced pointings, thus yielding highly uniform sensitivity throughout the entire field. We will avoid the area already covered by the ASPECS Large Program, as the proposed observations will not improve on the unique depth of the available data on that region. Typical main sequence galaxies have CO peak flux densities as bright as 2–8 mJy, and line widths of 200–500 $\mathrm{km\,s^{-1}}$ (Tacconi et al. 2013, 2017). The implied CO luminosities match our predictions based on the SED fits of CANDELS data. We aim to detect a blindly–selected sample of similar CO

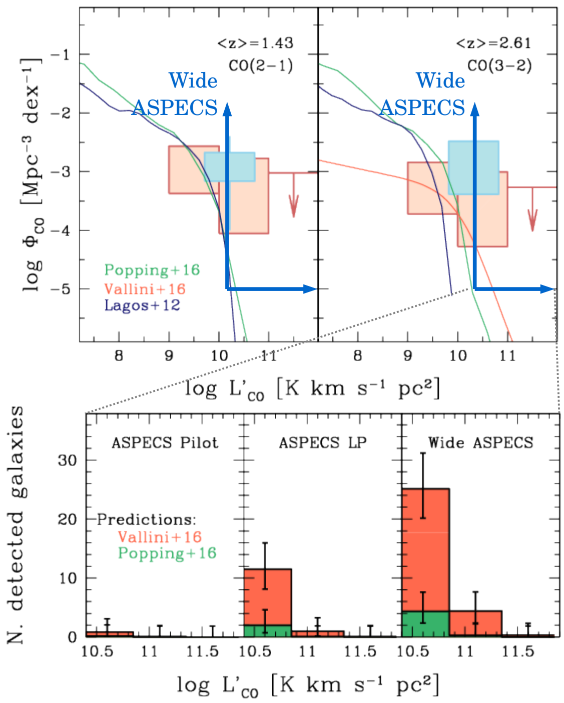


Figure 3: Upper panels: Constraints on the CO luminosity functions from the PdBI deep field (Walter et al. 2014) and from the ASPECS Pilot program (Decarli et al. 2016). The bright end of the luminosity function is highly uncertain, with orders-of-magnitude differences between semi-analytical models (Lagos et al 2012, Popping et al. 2016) and Herschel-based empirical derivations (Vallini et al. 2016). Bottom panels: The expected number of detections from the Popping+16 models (green) and the Vallini+16 empirical predictions (red), scaled to the volumes probed in the ASPECS Pilot, the ASPECS Large Program, and in the proposed Wide ASPECS. The ASPECS Large Program data, which we are currently analyzing, will be excellent in pinning down the shape of the CO LF close to the knee. In the spirit of the wedding-cake approach, we here request the areal coverage necessary to decisively pin down its bright end. The proposed observations will allow us to place IR-selected galaxies into a broader context of blindly-selected CO emitters.

emitters in our field. We therefore propose to reach a sensitivity of 0.66 mJy beam^{-1} per 100 km s^{-1} in all three frequency settings. This will allow us to securely detect (at $>5\sigma$) a 2 mJy, 300 km s^{-1} wide line in only 2–3 min of integration per pointing. This is a detection experiment, therefore any array configuration yielding a synthesized beam $> 1''$ (i.e., comparable with the typical angular size of galaxies at $z = 1-4$) is acceptable for our study. We note that the field of choice is the deepest part of the CANDELS coverage in GOODS-South, i.e., one of the best studied regions in the sky (including sensitive observations with *Chandra* as part of the Chandra Deep Field South; with *XMM*; with *Hubble*, spanning the whole optical/NIR regime; with *Spitzer*, *Herschel*, and *LABOCA*, sampling the entire dust SED). Abundant spectroscopic and *HST* grism information is already publicly available for hundreds of galaxies (see Fig. 1). Finally, a significant area of CANDELS will also be targeted by *JWST* GTO efforts.

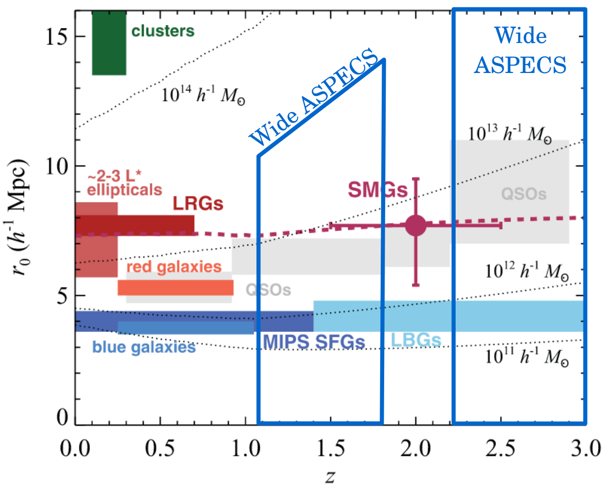


Figure 4: Scale length of large scale clustering for various astronomical objects, as a function of redshift. Thanks to its unprecedented areal coverage, Wide ASPECS will enable, for the first time, the measure r_0 (and therefore establish the halo mass) of CO emitters, via a 2-point correlation function analysis against other classes of galaxies. Figure adapted from Hickox et al. (2012).

REFERENCES: Beckwith et al. 2006, AJ, 132, 1729 • Berta et al. 2016, A&A, 587A, 73 • Carilli & Walter 2013, ARA&A, 51, 105 • Daddi et al. 2010a, ApJ, 713, 686; 2010b, ApJ, 714, L118 • Decarli et al. 2014, ApJ, 782, 78; 2016a, ApJ, 833, 69; 2016b, ApJ, 833, 70 • Elbaz et al. 2007, A&A, 468, 33; 2011, A&A, 533, 119 • Genzel et al. 2010, MNRAS, 407, 2091; 2015, ApJ, 800, 20 • Giavalisco et al.~2004, ApJ, 600, L93 • Groves et al.~2015, ApJ, 799, 96 •Magdis et al. 2011, ApJ, 740, L15; 2012, ApJ, 758, L9 • Noeske et al. 2007, ApJ, 660, L43 • Popping et al. 2016, MNRAS, 461, 93 • Scoville et al. 2007, ApJS, 172, 38; 2014, ApJ, 783, 84; 2016, ApJ, 820, 83; 2017, ApJ, 837, 150 • Tacconi et al. 2010, Nature, 463, 781; 2013, ApJ, 768, 74; 2017 (arXiv:1702.01140) • Vallini et al. 2016, MNRAS, 456, L40 • Walter et al. 2014, ApJ, 782, 79; 2016, ApJ, 833, 67 • Whitaker et al. 2012, ApJ, 754, L29 • Williams et al., 1996, AJ, 112, 1335 • Wuyts et al. 2011, ApJ, 738, 106

2017.1.00138.S

SG : 1 of 3 setup a Band 3

Large mosaic (>100 pointings) in the lowest frequency setup in the scan at 3mm.

Science Goal Parameters

Ang.Res.	LAS	Requested RMS	RMS Bandwidth	Rep.Freq.	Cont. RMS	Cont. Bandwidth	Poln.Prod.	Non-standard mode
1.0000"	2.0"	1.025 mJy, 172.8 mK	100 km/s, 28.4 MHz	85.142261 GHz	59.615 µJy, 10.1 mK	7.500 GHz	XX,YY	No

Use of 12m Array (43 antennas)

t_total(all configs)	t_science(C43-4)	t_total()	Imaged area	#12m pointing	12m Mosaic spacing	HPBW	t_per_point	Data Vol	Avg. Data Rate
7.5 h	4.1 h	0.0 h	22.8 "	130	offset	68.4 "	127.0 s	385.0 GB	14.5 MB/s

Use of ACA 7m Array (10 antennas) and TP Array

t_total(ACA)	t_total(7m)	t_total(TP)	Imaged area	#7m pointing	7m Mosaic spacing	HPBW	t_per_point	Data Vol	Avg. Data Rate

Spectral Setup : Spectral Line

BB	Center Freq Rest GHz	spw name	Eff #Ch p.p.	Bandwidth	Resolution	Vel. Bandwidth	Vel. Res.	Res. El. per FWHM
1	85.142261	setup A0	3840	1875.00 MHz	1.129 MHz	6602.4 km/s	3.975 km/s	75
2	87.017366	setup A1	3840	1875.00 MHz	1.129 MHz	6460.1 km/s	3.890 km/s	77
3	97.142932	setup A2	3840	1875.00 MHz	1.129 MHz	5786.8 km/s	3.484 km/s	86
4	99.018037	setup A3	3840	1875.00 MHz	1128.906 kHz	5677.2 km/s	3.418 km/s	88

1 Target

No.	Target	Ra,Dec (ICRS)	V,def,frame --OR--z
1	1-CANDELS_-_GO...	03:32:30, -27:48:15	0.00 km/s,lsrk,RADIO

Expected Source Properties

	Peak Flux	SNR	Pol.	Pol. SNR	Linewidth	RMS (over 1/3 linewidth)	linewidth / bandwidth used for sensitivity
Line	2.00 mJy	2.1	0.0%	0.0	300 km/s	968.77 µJy, 163.4 mK	3.00
Continuum	0.00 uJy	0.0	0.0%	0.0			

Dynamic range (cont flux/line rms): N/A

1 Tuning

Tuning	Target	Rep. Freq. Sky GHz	RMS (Rep. Freq.)	RMS Achieved
1	1	85.142261	968.77 µJy, 163.4 mK	965.40 uJy - 991.57 uJy

Sensitivity Comments

Note that one or more of the S/N estimates are < 3. Please double-check the RMS and/or line fluxes entered and/or address the issue below.

Justification for requested RMS and resulting S/N (and for spectral lines the bandwidth selected) for the sensitivity calculation.

We aim at detecting at high significance a 2 mJy line with a width of 300 km/s (i.e., among the faintest PHIBSS galaxies). We therefore require a S/N=3 over 100 km/s (yielding a S/N~5.2 over the entire line width). This implies that our target rms is 0.66 mJy/beam per 100 km/s bins. Because we use a customized pointing pattern (that avoids the area already covered in the ASPECS Large Program, and that provides Nyquist sampling at the higher frequency setting, and super-Nyquist for the others), the AOT does not account for the overlaps between our pointings. Therefore, the required rms is scaled up to include the contribution from the neighboring pointings. This is computed as follows: at the center of a given pointing, the sensitivity of the neighboring pointings will be exp(-0.5*(0.51093*2.35)**2)=0.4849. By combining all the seven pointings, the S/N will therefore improve by a factor 1./sqrt(1 + 6*0.4849**2)=0.644. Therefore, our target rms can be relaxed down to 0.66 mJy/beam / 0.644=1.02 mJy/beam. We do not expect any significant continuum emission in our sources.

Justification of the chosen angular resolution and largest angular scale for the source(s) in this Science Goal.

This is a detection experiment. We aim at maximizing the S/N, therefore compact array configurations are preferred. The typical size of the targeted galaxies is ~1", and certainly not exceeding 2". In band 3, configuration C43-4 provides us with 1" resolution. Any more compact configuration (C43-1,2,3) is equally fit for our program.We aim at detecting at high significance a 2 mJy line with a width of 300 km/s (i.e., among the faintest PHIBSS galaxies). We therefore require a S/N=3 over 100 km/s (yielding a S/N~5.2 over the entire line width). This implies that our target rms is 0.66 mJy/beam per 100 km/s bins. Because we use a customized pointing pattern (that avoids the area already covered in the ASPECS Large Program, and that provides Nyquist sampling at the higher frequency setting, and super-Nyquist for the others), the AOT does not account for the overlaps between our pointings. Therefore, the required rms is scaled up to include the contribution from the neighboring pointings. This is computed as follows: at the center of a given pointing, the sensitivity of the 6 neighboring pointings will be exp(-0.5*(0.51093*2.35)**2)=0.4849. By combining all the seven pointings, the S/N will therefore improve by a factor 1./sqrt(1 + 6*0.4849**2)=0.644. Therefore, our target rms can be relaxed down to 0.66 mJy/beam / 0.644=1.02 mJy/beam. We do not expect any significant continuum emission in our sources.

Justification of the correlator set-up with particular reference to the number of spectral resolution elements per line width.

In order to maximize the spectral coverage (and therefore the volume of universe sampled in our study) we need to maximize the instantaneous bandwidth (1.875 GHz per SPW). The targeted lines have typical widths of a few hundred km/s, so the coarser sampling (resulting in ~130 km/s wide channels) is too coarse for our purspose. We therefore opt for the second coarser option, which yields a native channel of ~2 km/s. We will rebin at correlator level (by a factor 2x) in order to minimize the data rate.

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SG : 2 of 3 setup b Band 3

Large mosaic (>100 pointings) in the intermediate frequency setup in the scan at 3mm.

Science Goal Parameters

Ang.Res.	LAS	Requested RMS	RMS Bandwidth	Rep.Freq.	Cont. RMS	Cont. Bandwidth	Poln.Prod.	Non-standard mode
1.0000"	2.0"	1.025 mJy, 158.6 mK	95.787 km/s, 28.4 MHz	88.887500 GHz	59.418 µJy, 9.2 mK	7.500 GHz	XX,YY	No

Use of 12m Array (43 antennas)

t_total(all configs)	t_science(C43-4)	t_total()	Imaged area	#12m pointing	12m Mosaic spacing	HPBW	t_per_point	Data Vol	Avg. Data Rate
7.5 h	4.1 h	0.0 h	21.8 "	130	offset	65.5 "	127.0 s	385.0 GB	14.5 MB/s

Use of ACA 7m Array (10 antennas) and TP Array

t_total(ACA)	t_total(7m)	t_total(TP)	Imaged area	#7m pointing	7m Mosaic spacing	HPBW	t_per_point	Data Vol	Avg. Data Rate

Spectral Setup : Spectral Line

BB	Center Freq Rest GHz	spw name	Eff #Ch p.p.	Bandwidth	Resolution	Vel. Bandwidth	Vel. Res.	Res. El. per FWHM
1	88.887500	setup B0	3840	1875.00 MHz	1.129 MHz	6324.2 km/s	3.808 km/s	79
2	90.762500	setup B1	3840	1875.00 MHz	1.129 MHz	6193.6 km/s	3.729 km/s	80
3	100.887500	setup B2	3840	1875.00 MHz	1.129 MHz	5572.0 km/s	3.355 km/s	89
4	102.762500	setup B3	3840	1875.00 MHz	1128.906 kHz	5470.3 km/s	3.294 km/s	91

1 Target

No.	Target	Ra,Dec (ICRS)	V,def,frame --OR--z
1	1-CANDELS_-_GO...	03:32:30, -27:48:15	0.00 km/s,lsrk,RADIO

Expected Source Properties

	Peak Flux	SNR	Pol.	Pol. SNR	Linewidth	RMS (over 1/3 linewidth)	linewidth / bandwidth used for sensitivity
Line	2.00 mJy	2.1	0.0%	0.0	300 km/s	945.01 µJy, 146.2 mK	3.13
Continuum	0.00 uJy	0.0	0.0%	0.0			

Dynamic range (cont flux/line rms): N/A

1 Tuning

Tuning	Target	Rep. Freq. Sky GHz	RMS (Rep. Freq.)	RMS Achieved
1	1	88.887500	965.57 µJy, 149.4 mK	965.57 uJy - 1.01 mJy

Sensitivity Comments

Note that one or more of the S/N estimates are < 3. Please double-check the RMS and/or line fluxes entered and/or address the issue below.

Justification for requested RMS and resulting S/N (and for spectral lines the bandwidth selected) for the sensitivity calculation.

We aim at detecting at high significance a 2 mJy line with a width of 300 km/s (i.e., among the faintest PHIBSS galaxies). We therefore require a S/N=3 over 100 km/s (yielding a S/N~5.2 over the entire line width). This implies that our target rms is 0.66 mJy/beam per 100 km/s bins. Because we use a customized pointing pattern (that avoids the area already covered in the ASPECS Large Program, and that provides Nyquist sampling at the higher frequency setting, and super-Nyquist for the others), the AOT does not account for the overlaps between our pointings. Therefore, the required rms is scaled up to include the contribution from the neighboring pointings. This is computed as follows: at the center of a given pointing, the sensitivity of the neighboring pointings will be exp(-0.5*(0.51093*2.35)**2)=0.4849. By combining all the seven pointings, the S/N will therefore improve by a factor 1./sqrt(1 + 6*0.4849**2)=0.644. Therefore, our target rms can be relaxed down to 0.66 mJy/beam / 0.644=1.02 mJy/beam. We do not expect any significant continuum emission in our sources.

Justification of the chosen angular resolution and largest angular scale for the source(s) in this Science Goal.

This is a detection experiment. We aim at maximizing the S/N, therefore compact array configurations are preferred. The typical size of the targeted galaxies is ~1", and certainly not exceeding 2". In band 3, configuration C43-4 provides us with 1" resolution. Any more compact configuration (C43-1,2,3) is equally fit for our program.We aim at detecting at high significance a 2 mJy line with a width of 300 km/s (i.e., among the faintest PHIBSS galaxies). We therefore require a S/N=3 over 100 km/s (yielding a S/N~5.2 over the entire line width). This implies that our target rms is 0.66 mJy/beam per 100 km/s bins. Because we use a customized pointing pattern (that avoids the area already covered in the ASPECS Large Program, and that provides Nyquist sampling at the higher frequency setting, and super-Nyquist for the others), the AOT does not account for the overlaps between our pointings. Therefore, the required rms is scaled up to include the contribution from the neighboring pointings. This is computed as follows: at the center of a given pointing, the sensitivity of the 6 neighboring pointings will be exp(-0.5*(0.51093*2.35)**2)=0.4849. By combining all the seven pointings, the S/N will therefore improve by a factor 1./sqrt(1 + 6*0.4849**2)=0.644. Therefore, our target rms can be relaxed down to 0.66 mJy/beam / 0.644=1.02 mJy/beam. We do not expect any significant continuum emission in our sources.

Justification of the correlator set-up with particular reference to the number of spectral resolution elements per line width.

In order to maximize the spectral coverage (and therefore the volume of universe sampled in our study) we need to maximize the instantaneous bandwidth (1.875 GHz per SPW). The targeted lines have typical widths of a few hundred km/s, so the coarser sampling (resulting in ~130 km/s wide channels) is too coarse for our purspose. We therefore opt for the second coarser option, which yields a native channel of ~2 km/s. We will rebin at correlator level (by a factor 2x) in order to minimize the data rate.

2017.1.00138.S

SG : 3 of 3 setup c Band 3

Large mosaic (>100 pointings) in the highest frequency setup in the scan at 3mm.

Science Goal Parameters

Ang.Res.	LAS	Requested RMS	RMS Bandwidth	Rep.Freq.	Cont. RMS	Cont. Bandwidth	Poln.Prod.	Non-standard mode
1.0000"	2.0"	1.025 mJy, 146 mK	91.909 km/s, 28.4 MHz	92.637500 GHz	59.71 µJy, 8.5 mK	7.500 GHz	XX,YY	No

Use of 12m Array (43 antennas)

t_total(all configs)	t_science(C43-4)	t_total()	Imaged area	#12m pointing	12m Mosaic spacing	HPBW	t_per_point	Data Vol	Avg. Data Rate
7.5 h	4.1 h	0.0 h	21.0 "	130	offset	62.9 "	127.0 s	385.0 GB	14.5 MB/s

Use of ACA 7m Array (10 antennas) and TP Array

t_total(ACA)	t_total(7m)	t_total(TP)	Imaged area	#7m pointing	7m Mosaic spacing	HPBW	t_per_point	Data Vol	Avg. Data Rate

Spectral Setup : Spectral Line

BB	Center Freq Rest GHz	spw name	Eff #Ch p.p.	Bandwidth	Resolution	Vel. Bandwidth	Vel. Res.	Res. El. per FWHM
1	92.637500	setup C0	3840	1875.00 MHz	1.129 MHz	6068.2 km/s	3.654 km/s	82
2	94.512500	setup C1	3840	1875.00 MHz	1.129 MHz	5947.8 km/s	3.581 km/s	84
3	104.637500	setup C2	3840	1875.00 MHz	1.129 MHz	5372.3 km/s	3.235 km/s	93
4	106.512500	setup C3	3840	1875.00 MHz	1128.906 kHz	5277.7 km/s	3.178 km/s	94

1 Target

No.	Target	Ra,Dec (ICRS)	V,def,frame --OR--z
1	1-CANDELS_-_GO...	03:32:30, -27:48:15	0.00 km/s,lsrk,RADIO

Expected Source Properties

	Peak Flux	SNR	Pol.	Pol. SNR	Linewidth	RMS (over 1/3 linewidth)	linewidth / bandwidth used for sensitivity
Line	2.00 mJy	2.2	0.0%	0.0	300 km/s	930.22 µJy, 132.5 mK	3.26
Continuum	0.00 uJy	0.0	0.0%	0.0			

Dynamic range (cont flux/line rms): N/A

1 Tuning

Tuning	Target	Rep. Freq. Sky GHz	RMS (Rep. Freq.)	RMS Achieved
1	1	92.637500	970.3 µJy, 138.2 mK	970.30 uJy - 1.05 mJy

Sensitivity Comments

Note that one or more of the S/N estimates are < 3. Please double-check the RMS and/or line fluxes entered and/or address the issue below.

Justification for requested RMS and resulting S/N (and for spectral lines the bandwidth selected) for the sensitivity calculation.

We aim at detecting at high significance a 2 mJy line with a width of 300 km/s (i.e., among the faintest PHIBSS galaxies). We therefore require a S/N=3 over 100 km/s (yielding a S/N~5.2 over the entire line width). This implies that our target rms is 0.66 mJy/beam per 100 km/s bins. Because we use a customized pointing pattern (that avoids the area already covered in the ASPECS Large Program, and that provides Nyquist sampling at the higher frequency setting, and super-Nyquist for the others), the AOT does not account for the overlaps between our pointings. Therefore, the required rms is scaled up to include the contribution from the neighboring pointings. This is computed as follows: at the center of a given pointing, the sensitivity of the neighboring pointings will be exp(-0.5*(0.51093*2.35)**2)=0.4849. By combining all the seven pointings, the S/N will therefore improve by a factor 1./sqrt(1 + 6*0.4849**2)=0.644. Therefore, our target rms can be relaxed down to 0.66 mJy/beam / 0.644=1.02 mJy/beam. We do not expect any significant continuum emission in our sources.

Justification of the chosen angular resolution and largest angular scale for the source(s) in this Science Goal.

This is a detection experiment. We aim at maximizing the S/N, therefore compact array configurations are preferred. The typical size of the targeted galaxies is ~1", and certainly not exceeding 2". In band 3, configuration C43-4 provides us with 1" resolution. Any more compact configuration (C43-1,2,3) is equally fit for our program. The pointing pattern to is Nyquist sampled in the highest frequency setting, and super-Nyquist in the lower frequency setups. The pointing pattern is customized in order to avoid the area already covered by the ASPECS Large Program (see Fig.1).

Justification of the correlator set-up with particular reference to the number of spectral resolution elements per line width.

In order to maximize the spectral coverage (and therefore the volume of universe sampled in our study) we need to maximize the instantaneous bandwidth (1.875 GHz per SPW). The targeted lines have typical widths of a few hundred km/s, so the coarser sampling (resulting in ~130 km/s wide channels) is too coarse for our purspose. We therefore opt for the second coarser option, which yields a native channel of ~2 km/s. We will rebin at correlator level (by a factor 2x) in order to minimize the data rate.