Field Selection Criteria for the ACS Ultra Deep Field

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1. Selection Criteria

The basic criteria for selecting a field suitable for deep observations are:

- Low extinction and low cirrus. Unless otherwise stated, we require $E(B-V) \leq 0.02$ and adopt the maps by Schlegel et al. (1998, ApJ 500, 525). The Schlegel et al. (1998) map is based on 100 μm COBE/DIRBE and IRAS data. We use the low $E(B-V)$ constraint to capture also the low cirrus requirement.
- Low HI column density. Unless otherwise stated, we require $n_{HI} \leq 2 \times 10^{20}$ and adopt the map by Dickey and Lockman (1990, ARAA, 28, 215).
- Absence of known bright sources. Bright stars, galaxies, radiosources should not be present in, or near, the field so as not to alter the statistics nor create background.
- General convenience. Possibility of CVZ observations, accessibility by major facilities on the ground.
- Sufficiently large area. The area satisfying the above criteria should be large enough to enable wide field follow-up studies from the ground.

2. Implementation

The first step to search fields satisfying these criteria is to collect the required supporting data. For $E(B-V)$ we started out from the maps made available by Schlegel et al. (1998) in Lambert's coordinates, which we adopted as our working coordinate system. The $E(B-V)$ maps are shown in Figures 1 and 2 for the North and South Galactic caps, respectively.

Various catalogs in electronic form were used to select against other types of sources. Positions of bright stars were obtained from the PPM catalog by Roser and Bastian (1988, AAS, 74, 449) which includes 378,910 stars. Galaxies were obtained from the RC3 catalog (de Vaucouleurs et al. 1991), including a total of 23011 objects. Quasar positions were obtained from Version 10 of the Veron and Veron catalog (2001, AA 374, 92), including a total of 30119 objects. We selected radiosources from the First catalog (White et al. 1997, ApJ, 475, 479), which includes 549,707 sources and covers 5450 square degrees in the North Galactic cap and 610 square degrees in the South Galactic cap.

A mask for each hemisphere was created in order to exclude areas with known sources. The $E(B-V)$ and the HI column density maps were then searched at a resolution of about 4 arcmin^2 to identify areas with low extinction and low HI column density and not containing known sources. The list of all such areas was sorted in order of increasing extinction and scanned again in order to identify (grow) larger (square) fields.

The software we developed selects fields larger than some threshold value, allowing or avoiding known QSOs. The search is repeated also for additional requirements, namely for fields in the CVZ of HST, observable from both Hawaii and Paranal (i.e. within 50 degrees of zenith angle for both observatories, we will refer to these fields as "equatorial"), and outside the ecliptic (i.e. above 30 degrees of ecliptic latitude).

3. Automated Search Results

We are able to recover some of the fields selected for other surveys. If all criteria (except for the area one) are enforced, we can recover SDF, one of the DEEP fields, and EISDeep1. By relaxing the QSO avoidance criterion, one can recover also, e.g., HDFN, FORS-DF, Lockman, CDFS. In Table 1 we list a number of well studied survey fields listing their coordinates, and the values of $E(B-V)$ and of the HI column density n_{HI}. We give in boldface the name of those fields satisfying the extinction and HI column density requirements.

Requiring that each field be of at least 1200 arcmin^2 restricts the number of viable fields to 7/8 fields in the North (with/without QSO avoidance) and 9/13 fields in the South. Of these, 13/17 fields are observable both from Hawaii and from Paranal (with/without QSO avoidance). Of these "equatorial" fields, only 3 have an ecliptic latitude larger than 30 degrees. Close inspection reveals that none of these 3 fields is acceptable since they all contain clusters of galaxies.

The number of available fields increases rapidly if the minimum area constraint is relaxed. A summary of the results is given in Table 2.

We also find that it is very difficult to find fields satisfying our conditions and lying in the CVZ of HST. No CVZ field exists satisfying all constraints. In total, 7 fields can be found by relaxing the QSO avoidance criterion and the extinction and HI column density criteria to $E(B-V) \leq 0.03$ and $n_{HI} \leq 3 \times 10^{20}$. Alternatively, 27 CVZ fields are found if the minimum area requirement is reduced to 300 arcmin^2 (see also Table 2).

4. The constraint of a minimum angle from the ecliptic

Low values of ecliptic latitute enhance the zodiacal background which is an important background contribution for imaging from space both from HST and from JWST. We can estimate this effect by using the version of the Good's IRAS model (1994, IRAS Sky Survey Atlas, Explanatory

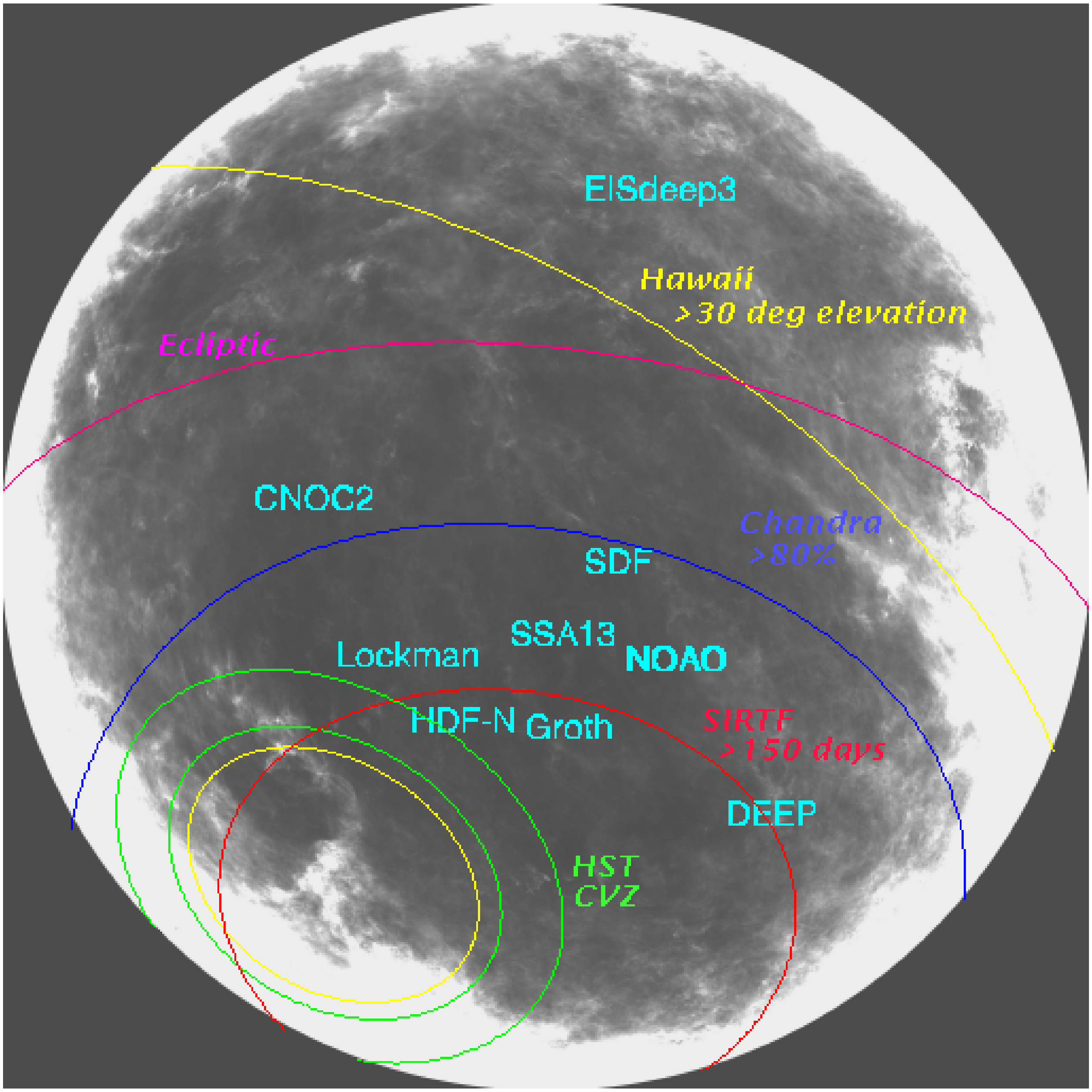

Fig. 1.— Map of E(B-V) for the North galactic cap in Lambert's coordinates. The yellow curves identify 30 degrees of elevation from Hawaii The green curves identify HST's CVZ. The magenta curve identifies the ecliptic. The blue and red curves identify the Chandra 80 % zone and the zone with more than 150 days per year of observability for SIRTF, respectively.

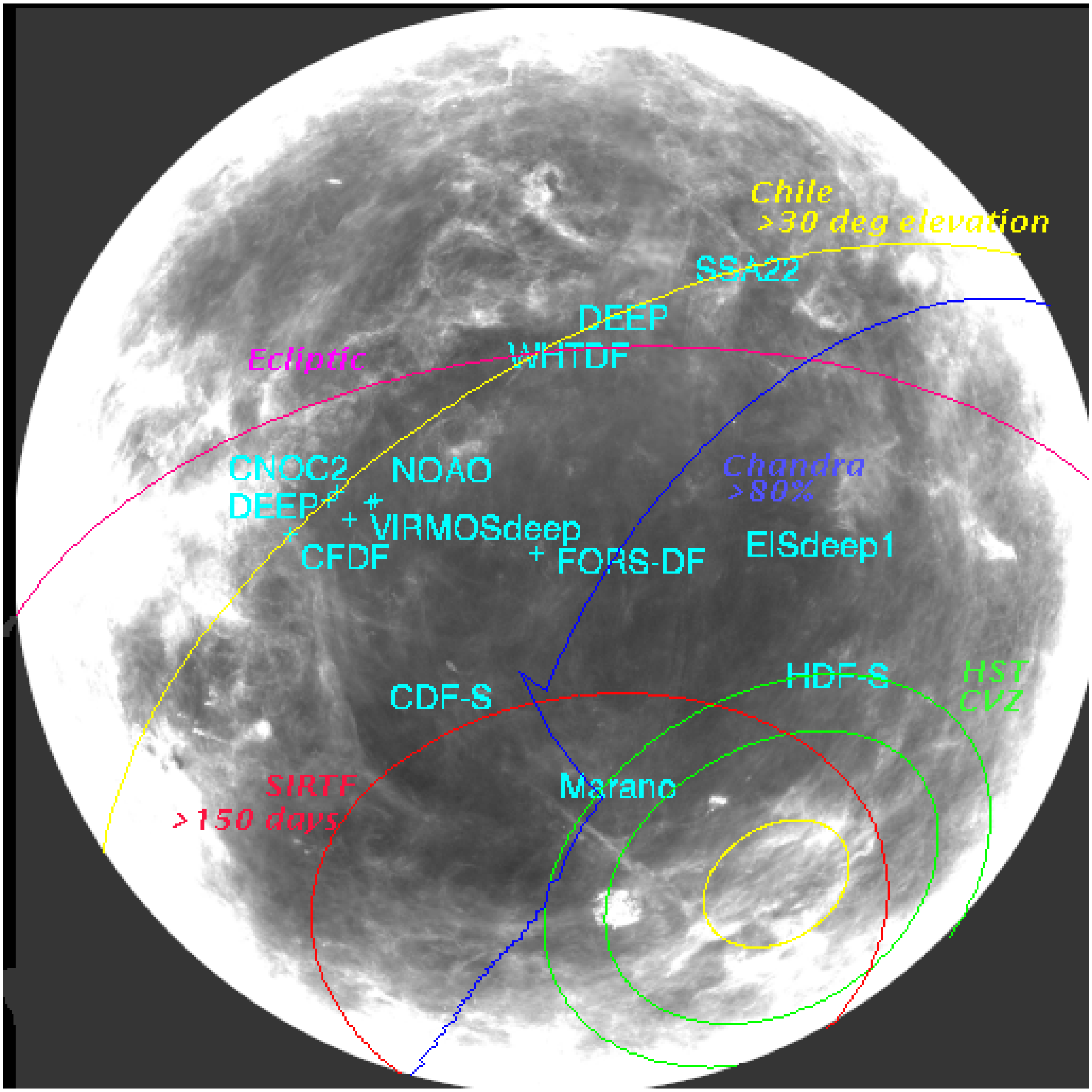

Fig. 2.— Map of E(B-V) for the South galactic cap in Lambert's coordinates. The yellow curves identify 30 degrees of elevation from Paranal. The green curves identify HST's CVZ. The magenta curve identifies the ecliptic. The blue and red curves identify the Chandra 80 % zone and the zone with more than 150 days per year of observability for SIRTF, respectively.

Table 1. Properties of known survey fields. None satisfies the 1200 arcmin^2 area criterion. The fields with name in boldface satisfy the extinction and HI column density criteria.

Field Name	RA (J2000)	Decl (J2000)	l	b	Ecl.Lat.	$E(B-V)$	n_{HI} ($\times 10^{-20}$)
WHTDF	0:19:59.50	0:04:20.0	106.1	-61.8	-1.9485	0.030	2.6900
WHTDF	0:22:33.30	0:20:57.0	107.6	-61.7	-1.9617	0.025	2.5613
FORS-DF	1:06:03.60	-25:45:46.0	191.1	-86.5	-30.0380	0.018	1.8800
NOAO	2:07:29.15	-4:44:08.2	165.3	-61.2	-16.5755	0.022	2.4473
NOAO	2:10:00.00	-4:30:00.0	166.0	-60.6	-16.5444	0.022	2.9199
CNOC2	2:23:00.00	0:00:00.0	165.7	-55.1	-13.4375	0.039	2.7125
DEEP	2:30:00.00	00:00:00.0	168.1	-54.0	-14.0161	0.022	2.5505
VIRMOSdeep	2:26:00.00	-4:30:00.0	172.0	-58.1	-17.9482	0.027	2.3767
CFDF	3:00:00.00	0:00:00.0	177.0	-48.9	-16.3572	0.096	7.2208
Marano	3:15:09.00	-55:13:57.0	270.2	-51.8	-67.5384	0.016	2.6910
CDF-S	3:32:30.00	-27:48:47.0	223.6	-54.4	-45.2118	0.008	0.7872
CNOC2	9:20:00.00	37:00:00.0	186.6	44.7	20.3266	0.011	1.5234
Lockman	10:52:43.00	57:28:48.0	149.3	53.1	45.3732	0.008	0.5684
EISdeep3	11:20:35.00	-21:42:00.0	276.4	36.5	-23.6886	0.045	4.1814
HDF-N	12:36:49.40	62:12:58.0	125.9	54.8	57.2971	0.012	1.4346
SSA13	13:12:21.40	42:41:21.0	109.0	73.9	45.4351	0.014	1.3752
SDF	13:24:21.38	27:29:23.0	37.6	82.7	33.3845	0.019	1.2060
Groth	14:16:00.00	52:10:00.0	96.3	60.4	59.4113	0.013	1.3000
NOAO	14:30:00.00	34:30:00.0	58.2	67.7	45.9519	0.012	1.0356
NOAO	14:32:05.72	34:16:47.5	57.4	67.3	45.9647	0.016	1.0091
DEEP	16:52:00.00	34:55:00.0	57.4	38.3	56.8681	0.016	1.7100
HDF-S	22:32:56.20	-60:30:02.7	328.3	-49.2	-46.5559	0.027	2.2200
SSA22	22:17:35.00	0:15:30.0	63.1	-44.0	10.1609	0.066	4.8500
EISdeep1	22:50:00.00	-40:12:59.0	357.5	-61.7	-30.0832	0.011	1.4700
DEEP	23:30:00.00	00:00:00.0	85.0	-56.7	2.9507	0.037	3.8460

Table 2. Number of candidate fields. "Equatorial" indicates fields that are observable from both Hawaii and Paranal with less than 50 degrees of zenith angle.

Field Type (area in arcmin^2)	$E(B-V)$	n_{HI} ($\times 10^{-20}$)	allow QSOs	allow QSOs ecl. lat. $>$ 30 deg.	avoid QSOs	avoid QSOs ecl. lat. $>$ 30 deg.
North 1200	0.02	2.0	8	0	7	0
South 1200	0.02	2.0	13	7	9	6
Equatorial 1200	0.02	2.0	17	3	13	3
CVZ 1200	0.02	2.0	0	0	0	0
North 1200	0.03	3.0	104	89	97	84
South 1200	0.03	3.0	27	16	19	13
Equatorial 1200	0.03	3.0	32	6	24	5
CVZ 1200	0.03	3.0	7	7	4	4
North 600	0.02	2.0	735	32	682	29
South 600	0.02	2.0	699	624	587	515
Equatorial 600	0.02	2.0	1084	306	966	241
CVZ 600	0.02	2.0	0	0	0	0
North 600	0.03	3.0	1771	497	1683	483
South 600	0.03	3.0	1559	1293	1378	1125
Equatorial 600	0.03	3.0	2117	579	1949	497
CVZ 600	0.03	3.0	46	46	40	40
North 300	0.02	2.0	1040	51	962	46
South 300	0.02	2.0	1484	1231	1166	963
Equatorial 300	0.02	2.0	1762	520	1511	372
CVZ 300	0.02	2.0	27	27	27	27
North 15	0.02	2.0	23735	2816	23628	2810
South 15	0.02	2.0	37530	30829	36363	30020
Equatorial 15	0.02	2.0	30304	6680	29669	6278
CVZ 15	0.02	2.0	915	915	914	914

supplement) presented in the WFC3 ISR 2002-02.

At large sun angles the difference between 10 degrees and 30 degrees from the ecliptic is neglible. However, once the sun angle decreases this difference becomes important. As an example, for a sun angle of 120 degrees, the background in the J and H bands at 10 degrees from the ecliptic is 30 per cent higher than the minimum zodiacal background, while it is 20 per cent higher than the minimum value at both 30 and 45 degrees. At a sun angle of 90 degrees, the background at 10 degrees from the ecliptic reaches a factor two over the minimum, while it increases only to 60 and 50 per cent, respectively, for 30 and 45 degrees from the ecliptic. Thus, a high ecliptic angle increases visibility at low background levels.

This effect will be particularly important for JWST since the telescope architecture forces it to observe far from the anti-sun, so that sun angles in the range 90 to 120 degrees are representative.

Here, we have discussed mostly the reflected sunlight component of the zodiacal background but clearly the thermal component is also important for Far IR observations.

5. Screening the fields

The fields listed in Table 2 have been selected by software. The final field selection needs to be verified by making sure that additional disqualifing objects, not listed in the catalogs used for the automated search, are absent. Examples of such objects are bright stars not present in the PPM, clusters of galaxies, or radiosources not listed in the Veron or First catalogs. This additional search can be done by using NED. In Table 3, we list our best, verified, fields and those of the standard fields that satisfy the extinction and hydrogen column density criteria (see also Figure 3).

The table does not include any “equatorial field” in the Northern hemisphere. This is mostly due to the requirement of a minimum ecliptic latitude of 30 degrees. Northern fields visible from both Paranal and Hawaii are available but only at an ecliptic latitude of about 10 degrees.

Table 3. List of verified fields.

Field Name	RA (J2000)	Decl (J2000)	l	b	Ecl.Lat.	$E(B-V)$	n_{HI} ($\times 10^{-20}$)	Notes
FORS-DF	1:06:03.60	-25:45:46.0	191.1	-86.5	-30.03	0.018	1.88	Eq.
CDF-S	3:32:30.00	-27:48:47.0	223.6	-54.4	-45.21	0.008	0.79	Eq.
CNOC2	9:20:00.00	37:00:00.0	186.6	44.7	20.32	0.011	1.52	
Lockman	10:52:43.00	57:28:48.0	149.3	53.1	45.37	0.008	0.57	
HDF-N	12:36:49.40	62:12:58.0	125.9	54.8	57.29	0.012	1.43	CVZ
SSA13	13:12:21.40	42:41:21.0	109.0	73.9	45.43	0.014	1.38	
SDF	13:24:21.38	27:29:23.0	37.6	82.7	33.38	0.019	1.21	
Groth	14:16:00.00	52:10:00.0	96.3	60.4	59.41	0.013	1.30	
NOAO	14:30:00.00	34:30:00.0	58.2	67.7	45.95	0.012	1.04	
NOAO	14:32:05.72	34:16:47.5	57.4	67.3	45.96	0.016	1.01	
DEEP	16:52:00.00	34:55:00.0	57.4	38.3	56.86	0.016	1.71	
EISdeep1	22:50:00.00	-40:12:59.0	357.5	-61.7	-30.08	0.011	1.47	
	0:37:25.00	-61:56:02.0	305.8	-55.1	-57.14	0.013	1.72	CVZ, 300
	0:13:49.00	-63:55:05.0	309.7	-52.7	-56.57	0.017	1.49	CVZ, 300
	3:29:00.00	-26:54:43.0	221.8	-55.1	-44.09	0.010	0.89	Eq., 600
	3:33:25.00	-27:13:17.0	222.6	-54.1	-44.71	0.010	0.96	Eq., 600
	3:52:39.00	-29:47:24.0	227.8	-50.3	-48.51	0.010	0.95	Eq., 600
	3:53:15.00	-27:50:39.0	224.8	-49.9	-46.70	0.009	0.98	Eq., 600
	3:54:10.00	-29:37:24.0	227.6	-50.0	-48.46	0.009	0.97	Eq., 600
	4:38:15.00	-61:01:26.0	271.3	-39.5	-79.48	0.016	1.79	CVZ, 300
	4:38:24.00	-59:32:55.0	269.4	-39.8	-78.49	0.024	2.16	CVZ, 1200
	8:28:23.00	64:59:49.0	150.8	34.6	44.22	0.022	2.90	CVZ, 1200
	10:23:46.00	63:52:45.0	145.4	46.3	48.80	0.024	2.88	CVZ, 1200

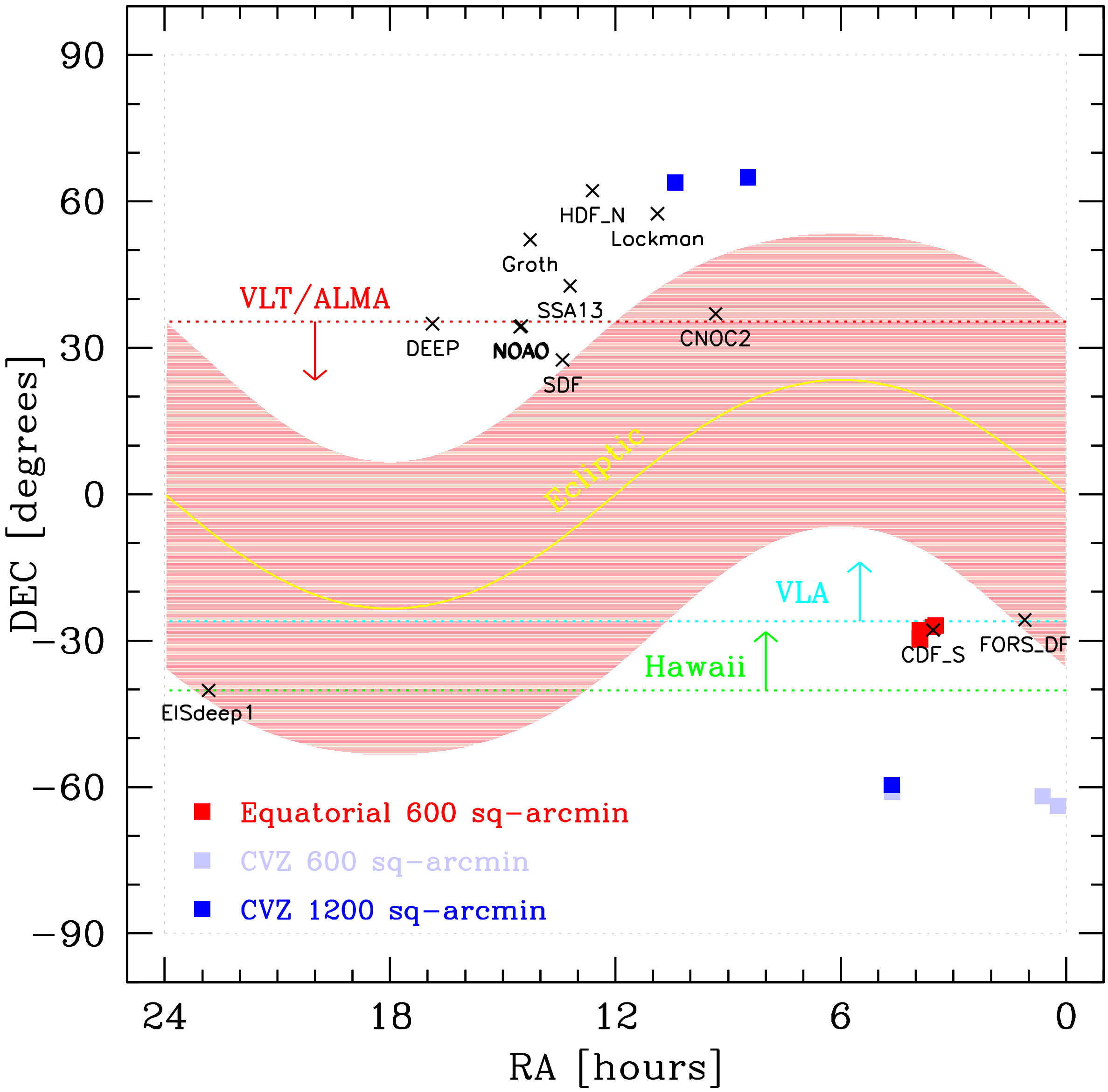

Fig. 3.— Location of the standard survey fields satisfying our extinction and column density constraints and of our best verified fields. We identify also the areas within 60 degrees of zenith angle from the VLA (cyan), Hawaii (green), and Paranal (VLT/Alma, red). The pink band identifies and exclusion zone within 30 degrees of ecliptic latitude. Note that the "equatorial" 600 arcmin^2 fields are close to the CDF-S.