EUROPEAN SOUTHERN OBSERVATORY

Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral
Europäische Organisation für astronomische Forschung in der südlichen Hemisphäre

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APPLICATION FOR OBSERVING TIME LARGE PROGRAMME PERIOD: **78A**

Important Notice:

By submitting this proposal, the PI takes full responsibility for the content of the proposal, in particular with regard to the names of COIs and the agreement to act according to the ESO policy and regulations, should observing time be granted

1. Title Category: **A–3**

The Chilean VST ISW DEEP RED SURVEY (ISW@VST)

2. Abstract / Total Time Requested

Total Amount of Time: Total Number of Semesters:

We propose a southern 5000 deg^2 deep survey of galaxies in the r band to detect the Integrated Sachs-Wolfe Effect with a signal to noise ratio 40% higher than any other survey so far (*e.g.* SDSS DR4) . The aim is to determine the equation of state of the universe by cross-correlating this galaxy map with high resolution CMB anisotropy maps from existing WMAP and future Planck observations. We show that we can reach a near-maximum S/N value of the ISW effect using a *single* broad-band (r) spatially-contiguous galaxy catalogue with a mean redshift $\langle z \rangle = 1.2$ at a particular scale of the sky (0.5 $\deg^2$). Morever, galaxy binning it is not required and therefore redshift information is not needed for all galaxies to compute the ISW effect. To cover the desired field, 64 nights in 4 years ($r_{AB} \lesssim 23.8$, 16 dark-grey 1.0 arcsec seeing nights per year) are required with VST. To maximize the output and open this survey to further science goals (ACT clusters, SZ effect, Red sequence galaxy clusters, LSBs, UCDs, Dwarf Galaxies, lenses) we will observe the same area as the approved VST ATLAS survey, which will provide de deep g band observations. The ISW results from this survey will surpass the results from SDSS, because of its depth, and be comparable to the results of the Dark Energy Survey, but 3 years earlier. This survey will be nade available to the community.

3.

Run	Period	Instrument	Time	Month	Moon	Seeing	Sky Trans.	Obs.Mode
A	79	OMEGACAM	40h	apr	d	$\leq 1.0''$	PHO	s
B	79	OMEGACAM	47.5h	sep	d	$\leq 1.0''$	PHO	s
C	80	OMEGACAM	32h	oct	d	$\leq 1.0''$	PHO	s
D	80	OMEGACAM	24h	nov	d	$\leq 1.0''$	PHO	s
E	81	OMEGACAM	40h	apr	d	$\leq 1.0''$	PHO	s
F	81	OMEGACAM	47.5h	sep	d	$\leq 1.0''$	PHO	s
G	82	OMEGACAM	40h	oct	d	$\leq 1.0''$	PHO	s
H	82	OMEGACAM	16h	nov	d	$\leq 1.0''$	PHO	s
I	83	OMEGACAM	40h	apr	d	$\leq 1.0''$	PHO	s
J	83	OMEGACAM	42.8h	sep	d	$\leq 1.0''$	PHO	s

4. Principal Investigator: L. Infante (P. Universidad Católica de Chile, RCH, linfante@astro.puc.cl)

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5. Description of the proposed programme

A) Scientific Rationale: Recent observations have established a new standard model of cosmology. With only five basic parameters (the age of the universe, the density of matter, the density of atoms, the amplitude of primordial fluctuations, and their scale dependence), this model fits both microwave background observations probing the physical conditions in the early universe and observations of the large-scale distribution of galaxies today (Spergel et al. 2003, Spergel et al. 2006).

While remarkably simple, the new standard cosmological model is also rather bizarre. It implies that protons, neutrons and electrons comprise only 4% of the energy density of the universe. Cosmologists believe that most of the mass in the universe is composed of weakly interacting subatomic particles ("the dark matter") which have never been directly detected. We also believe that all of the matter comprises only 26% of the total energy density of the universe, while the remainder is in some kind of energy associated with empty space ("the dark energy").

As the universe expands, light travels from the last scattering surface trespassing the matter structure along its path. Since this expansion is accelerated in some cosmics epochs, features are imprinted in the Cosmic Microwave Background (CMB) radiation, modifying its original gaussianity. This radiation as is observed is not isotropic (WMAP, Spergel et.al.,2006). Anisotropies are generated by several mechanisms along the radiation path. Among the best known are lensing, the Sunyaev-Zel'dovic (SZ) and the Integrated Sachs-Wolfe effect (ISW, Sachs & Wolfe, 1967). In this work, we propose to measure anisotropies generated by the ISW effect. The ISW effect arises as follows. As the Universe expands it weakens the gravitational potential wells associated with the clustering of galaxies. A photon traveling through such region gets an energy boost as it falls in the well, but because the well is shallower by the time the photon comes out it loses less energy than what it had gained. This will cause large scale anisotropies in the CMB. We will disentangle the lensing and SZ from ISW anisotropies and we will provide high signal to noise (S/N) value for Ω_λ and Ω_m.

Given the CMB temperature resolution achieved with modern microwave explorers such as WMAP (existing) and PLANCK (future), it is possible to cross correlate the local ($z \lesssim 1.2$) matter structure with the observed CMB structure. The cross correlation amplitude depends on the acceleration modulus which in turn depends on the dark energy (DE) density. Therefore, to unambiguously measure the signal, we propose a large, deep survey of galaxies. Below we show that $5000 deg^2$, in one band, down to $r \approx 23.8$, on 0.5 degrees scales and no redshift information provides the large scale data (i.e. galaxy map) to clearly measure the ISW signal.

The cross correlation analysis as shown in the following paragraphs has not been published so far. More details about the proposed survey, as well as of Value Added Projects, can be found in the project Redbook: http://www.astro.puc.cl/linfante/VST-ISW

Cross Correlation analysis The ISW effect dominates the cross correlation signal at an angular scale of $\theta \gtrsim 1$deg, while at lower angular scales the signal is dominated by the SZ effect. The cross correlation function of fields A and B, which we will call $\omega_{AB}(\theta)$, can be written in terms of the angular power spectrum multipoles, $C_{AB}(l)$, by expanding it on Legendre polynomials,

$$\omega_{AB}(\theta) \;=\; \sum_{l=0}^{\infty} \frac{(2l+1)}{4\pi}\, C_{AB}(l)\; P_l(\cos\theta),$$

where P_l is the Legendre polynomial of order l. It is possible to show that for small angles, or large l, (Afshordi et al. 2004, Cooray 2002)

$$C_{AB}(l) \;=\; \int_0^\infty \frac{dr}{r^2}\; P(k)\; W^A(k,r)\; W^B(k,r),$$

where $P(k)$ is the initial power spectrum of matter, k is given by $k \;=\; \frac{l+1/2}{r}$, and $W^X(k,r)$ is the window function of the field X. This approximation holds up to a good degree of accuracy for $l \geq 2$. According to Afshordi et. al. (2004), the error is 10% for $l = 2$ and falls like l^{-2}. It should be noted that for these estimations, we will use the initial matter power spectrum given by Bond & Efsthathiou (1984).

The window function of the anisotropy field generated by the ISW effect can be written as $W^{ISW}(r,k) \;=\; -3T_0\, \frac{\Omega_m}{k^2}\, \frac{H_0^2}{c^3}\, \frac{\partial F(z)}{\partial \tau}$, where T_0 is the mean temperature of the CMB, Ω_m is the matter density of the universe in units of the critical density, H_0 is Hubble's constant, c is the speed of light, τ is the conformal time ($dt = d\tau/(1+z)$) and $F(z)$ is the growth factor of the gravitational potential. An analytical expression for $\partial F/\partial\tau$ is given by Lahav (1991), which will be used for this calculation.

For the galaxy field, it is possible to show that $W^g \;=\; b_g\, \frac{H(z)}{c}\, D(z)\; n(z)$, where b_g is the bias factor, that we will assume to be 1 since the S/N estimations will not depend on this factor, $H(z)$ is the Hubble parameter as a function of redshift, $D(z)$ is the growth factor of the initial matter over densities in Fourier space, and $n(z)$ is the galaxy density distribution, which will depend directly on the characteristics of the observations.

Afshordi et. al. (2004) showed that the error on each multipole of the angular power spectrum is given by

$$\sigma^2_{C_{gT}} \;=\; \frac{1}{f_{sky}(2l+1)}\; \left\{ C^2_{gT}(l) + C_{TT}(l)\left[C_{gg}(l) + \frac{1}{\bar{N}} \right] \right\},$$

5. Description of the proposed programme (continued)

with $C_{TT}(l)$ being the multipoles of the temperature anisotropy field angular power spectrum, $C_{gg}(l)$ the ones of the galaxy field angular power spectrum and $C_{gT}(l)$ the ones of the cross power spectrum. $\bar{N}$ is the mean number of galaxies per steradian on the survey, the 'Shot Noise', and f_{sky} is the fraction of the sky used for the cross correlation. This can be propagated to the cross correlation function, so that

$$\sigma^2_{\omega_{gT}} \; = \; \sum_l \frac{(2l+1)}{f_{sky}(4\pi)^2} \; P_l^2(\cos\theta) \; \left\{ C^2_{gT}(l) + C_{TT}(l) \left[C_{gg}(l) + \frac{1}{\bar{N}} \right] \right\}.$$

Why Single scale measurements. Doing an analysis similar to the one used to predict the error on the cross correlation, is possible to show that the covariance between the measurements on two different angular scales, θ_1 and θ_2, can be estimated with the following expression

$$Cov(\theta_1, \theta_2) \; = \; \sum_l \frac{(2l+1)}{f_{sky}(4\pi)^2} \; P_l(\cos\theta_1) \; P_l(\cos\theta_2) \; \left\{ C^2_{gT}(l) + C_{TT}(l) \left[C_{gg}(l) + \frac{1}{\bar{N}} \right] \right\},$$

which, as expected, converges to the expression for the variance when $\theta_1 = \theta_2$. Unless one of the angular scales is very large, case on which the respective correlation signal will be very small, the covariance has a value similar to that of the variance. So, the overall signal to noise, considering all angular scales, will be extremely close to the maximum, since other angular scales will add a very little amount to it.

Signal to noise ratio. Hence, using the above formalism we can estimate the S/N of a certain measurement of the ISW cross correlation function at a certain angular scale.

We plan to map galaxies over approximately 5000 deg^2 of the southern sky in the r band. The left panel of Fig. 1 shows the expected redshift distribution for such a survey. The right panel of Fig. 1 shows its predicted cross correlation function S/N and also the one predicted for the DES and for the DR5 of the SDSS, assuming a Λ CDM cosmology ($\Omega_M = 0.3$,$\Omega_\lambda = 0.7$,$\Omega_k = 0$, $H_0 = 70$ and $w = -1$). The predicted S/N of this survey is indeed slightly higher than the one of the DES, and significantly higher by nearly 40% than the one of the DR5. No other projected or on-going survey will get closer to this.

The estimate of the S/N presented above does not consider the SZ effect. This will affect scales below $1deg$, including a little decrement on the peak S/N. For this reason we will focus on the scale of 1 degree even though it is slightly away from the peak S/N. In a few more years the South Pole telescope will measure this effect on the same region on which the DES is programmed. In principle it should be possible with this measurements to correct for this effect and recover the peak.

Why redshifts and multi-bands are not necessary As stated on the previous paragraphs, to detect the ISW effect we only need to detect galaxies, so multi-band observations will not yield an improvement in general. The only way multi band photometry could help us is by the use of photometric redshifts. If we divide our sample in various redshift slices, each slice would be independent of the others and have a smaller signal to noise than the maximum of the right panel of Fig. 1. The total signal to noise would be the addition in quadrature of all the individual ones, and one would expect a higher overall value. We test this for the proposed survey, assuming that we can use slices of 0.1 units of redshift up to a redshift of 2 for the cross correlation with negligible shot noise on the matter power spectrum. The top panel of Fig. 2 shows, with a dashed line, the overall added S/N, and it is, indeed, higher, even though just slightly, than the one obtained without the redshift slices. But in order to get such accurate photometric redshifts, we would need at least 4 photometric bands, which in practice would reduce by a factor of 4 the fraction of the sky covered by the survey. Fig. 2 (top panel) shows in a solid line the expected results considering only a fourth of the 5000 square degrees proposed. The S/N is roughly 0.5 times the maximum of Fig. 1. In conclusion, multi band observations will not yield a significant improvement to the measurement.

Optimum mean redshift and limiting magnitude. The ISW effect is driven by the accelerated expansion of the universe. Extremely distant galaxies are not affected at all by this accelerated expansion, so they will not produce anisotropies on the CMB. If our survey were to be extremely deep, the cross-correlation signal to noise will not be optimum, since distant galaxies will add noise to the measurement. Fig. 2 (bottom panel) shows the signal to noise as a function of the mean redshift of the survey at a scale of 0.5 deg. The maximum is for a mean redshift of ≈ 2 and the distribution is fairly flat around it. The mean redshift of the proposed survey is approximately 1.2 (see Fig. 1 for the redshift distribution), which will yield almost the maximum possible S/N. In Fig. 3 we show the average redshift of a sample of galaxies ($\langle z \rangle$) as a function of the magnitude limit, r_{lim}. Our estimates are based on a characteristic Schechter magnitude, M^*, consistent with recent estimates at $z \simeq 1$ (Gabasch et al., 2006). We show that adopting a magnitude limit of $r_{AB} = 23.8$ in the proposed survey, the mean redshift is $\langle z \rangle = 1.2$, which is optimum as shown in Fig. 2. Notice that these predictions are based on theoretical Omegacam performance, so even in the extreme case of overestimated the brightness of a M^* galaxy at $z = 1$ by 0.7 magnitudes, the proposed survey will still be able to provide a signal-to-noise similar than the one expected to be achieved by DES, but three years earlier.

Comparison with Previous Studies Afshordi (2004) carried out predictions very similar to the ones presented in this proposal. The maximum possible S/N for a survey like the one proposed here can be calculated from his results to be ~ 2.7. This maximum, calculated in spherical harmonics space rather than in configuration space, considers redshift bins and all angular scales, is consistent with our $S/N = 2.2$ estimate. Previous measurements of the ISW have been carried out using different surveys. For example, Fosalba et al., (2003) used SDSS DR1 and APM data, Afshordi et al. (2004) used 2MASS and recently Cabre et al. (2004) used SDSS DR4 data. Compared to theoretical values, these results tend to have higher S/N by factors ~ 3, possibly due to contamination. For instance, Afshordi et al. (2004), obtained a 2.5-σ detection of this effect. However, if one considering galactic plane contamination the value goes down to a 1.7-σ. Fosalba et al. (2003) and Cabre et al., (2004) obtained a S/N of 3.3 and a 4.7 respectively, where the difference with this estimations mostly comes from the differences in the covariance estimations between different angular scales.

[**References:** Afshordi, N. 2004, PhRvD, 70, 083536; Bond, J.R. & Efstathiou, G. 1984, ApJ, 285L, 45; Cooray, A. 2002, Phys. Rev. D., 65, 103510; Lahav, O., Rees, M.J., Lilje, P.B. & Primack, J.R. 1991, MNRAS, 251, 128; Sachs, R.K. & Wolfe, A.M. 1967, ApJ, 147, 73; Spergel et al. 2003, ApJS, 148, 175; Spergel et al. 2006, ApJ, in press (astroph/0603449)] Cabre, A., Gaztañaga, E., Manera, M., Fosalba, P. & Castander, F., 2006, in press (astro-ph/0603690)

Value-Added Projects

1- The physics of galaxy clusters. We wish to use the excellent imaging qualities of VST, in combination with SZ observations from ACT, to constrain different physical models for energy injection and feedback in galaxy clusters.

2- Red Sequence Cluster Survey. The unprecedented large area and depth survey will allow us to detect about 20000 to 40000 clusters of galaxies up to $z \sim 1$ using the red-sequence cluster detection algorithm. This sample will allow cosmological and galaxy evolution studies up to half of the age of the universe.

3- Low Surface Brightness Galaxies. Given the combined area and depth sampled, an important by-product of this survey is the accurate census of low surface brightness galaxies (LSBs) in the nearby universe ($z \geq 0.08$). Considering the detection limit $r = 23.8$, a typical brightness profile of a LSB galaxy and the current number density of LSBs (Dalcanton et al. 1997, AJ, 114, 635)) we estimate that the number of nearby LSBs in 5000 deg^2 is ~ 22000, up to $\mu_B(0) \geq 25.8$ mag arcsec^{-2} (diameter ≥ 10 arcsec). This number will be useful to accurately determine, at last, the number density of LSBs as a function of the surface brightness, finally settling the problem of the apparent increase in the number density of LSBs to fainter surface brightnesses, establishing the contribution of LSBs to the baryonic matter in the local universe.

4- Local Census of Dwarf Galaxies. We intend to identify and characterize resolved low surface brightness and unresolved (ultra-)compact dwarf galaxies within a volume of 300 Mpc distance. Selection criteria are provided by the combination of the r-band data with the g-band data from the VST ATLAS survey. Special attention will be drawn to the frequency of ultra-compact dwarf galaxies as function of environment. This project will give us a local census of all kinds of dwarf galaxies and will show whether compact dwarf galaxies can make a significant contribution to the overall galaxy number budget.

5- Gravitational Lenses around Giant Elliptical Galaxies. The shape of an Einstein ring accurately determine the shape of the lens potential, breaking the degeneracies in the determination of the mass distributions inferred from observations. Assuming a rate of ring formation of one for every 600 sources (MGV survey), we infer that there should be 40 rings per square degree with $22 < g < 23$. The rings could be found using r band images to subtract the galaxy in g band, providing an homogeneous sample to study lens potential of distant galaxies.

B) Immediate Objective: The main objective of this program is to produce a catalogue of southern objects over $5000 deg^2$ in the r band to determine with a very high accuracy, independent from existing methods (*e.g.* weak lensing, WMAP, Supernovae), the equation of state of the universe. This survey will be done in 4 years with the VST using 240 seconds exposure time in the r band. For this, 16 photometric nights per year of observing time with median seeing ($\lesssim 1$) are required. We have designed a plan to produce results earlier than any competing survey. The survey area will be the same as the approved ESO public survey VST ATLAS. Arrangements have been carried out so that we provide the deep r band observations and the VST ATLAS provide a deep 120 seconds g band survey. Having deep g and r bands in hand, a number of other programs are possible. In addition, negotiations are in progress to add IR J and H bands with VISTA. The finished product, in 2010, will be a deep (2 magnitudes deeper than SDSS) survey in four optical and infrared bands opened publicly to the astronomical community. Such survey will provide targets for the second generation VLT instruments and to the planned $25 - 100m$ class telescopes.

C) Telescope Justification: VST is designed for survey purposes. Due to its FOV and versatility, this telescope is the best altenative in the southern hemisphere to carry out the proposed survey. In any other telescope (*e.g.* Blanco, 2.2mESO) the number of nights required to cover 5000 deg^2 to $r = 23.8$ would be prohibitively large.

D) Observing Mode Justification (visitor or service): Service mode is the only option for this program.

5. Attachments (Figures)

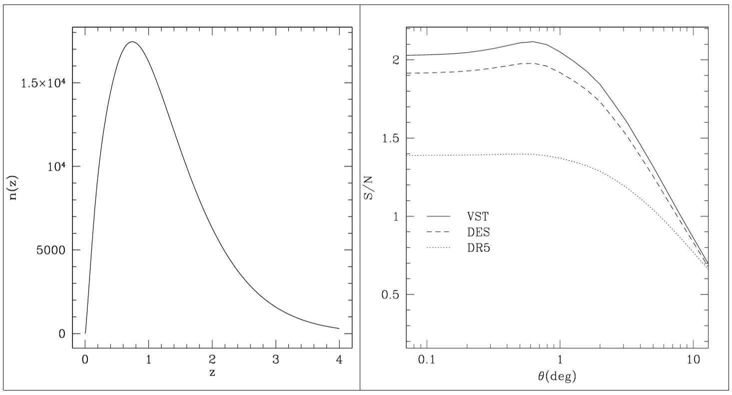

Fig. 1: Expected galaxy redshift distribution of the survey (left) and cross correlation S/N prediction for the proposed survey, DES and SDSS's DR5 (right). Note how the expected S/N is much higher than the one expected for the DR5. The expected S/N of the DES is of the same order but slightly lower. The redshift distribution is calculated assuming a Schechter Luminosity Function, $\Phi(M)$ (LF) for the galaxies corresponding to $M = -22.7$ and $\alpha = -1.33$. These parameters correspond to the r-Band $z = 1$ LF (Gabasch et al., 2006, A&A, 448, 101) estimated for FORS galaxies. The relation used to calculate the redshift distribution is $\frac{dn}{dz}(z) \propto \int_{M_{high}}^{M_{low}(z)} \Phi(M) dM \frac{dV}{dz}$,where we set the maximum galaxy luminosity at r-band $M_{high} = -25$ and the lower luminosity limit corresponds to the chosen magnitude limit, $m_{lim} = -23.8$, $M_{low}(z) = m_{lim} - 25 - 5\log(r(z))$. We assume $\Omega_m = 0.3$ and $\Omega_\Lambda = 0.7$ when calculating dV/dz and $r(z)$.

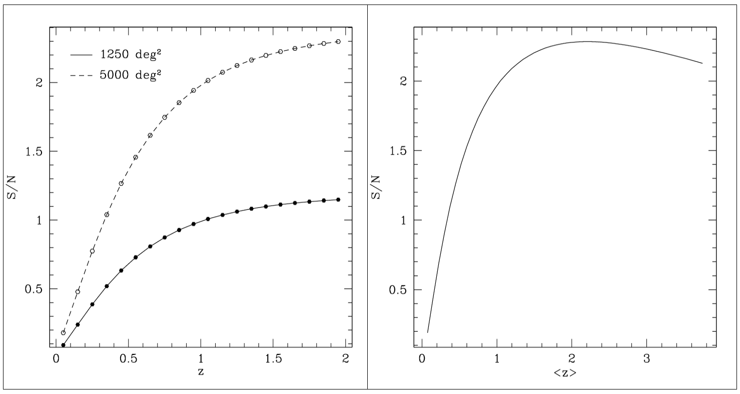

Fig. 2 **Top**: Accumulated S/N as a function of redshift, adding slices of 0.1 units of redshift with negligible shot noise up to redshift of 2. The dashed line assumes that the survey covers 5000 deg^2 while the solid line assumes it covers only a fourth part of that, what we would actually get with 4 bands imaging. **Bottom**: Maximum signal to noise of the correlation function as a function of the mean redshift of the survey. Our proposal considers a mean redshift of 1.2, yielding a S/N close to the peak value.

5. Attachments (Figures)

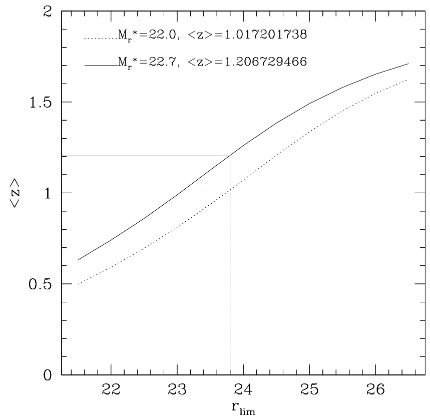

Fig. 3 Average redshift of a sample of galaxies ($\langle z \rangle$) as a function of the r band magnitude limit, r_{lim}. Black solid line corresponds to a characteristic Schechter magnitude, M^*, consistent with recent estimates at $z \simeq 1$ (Gabasch et al., 2006), and black dotted line shows the results for a different, lower value of M^*. The gray horizontal lines indicate the average redshifts corresponding to the adopted magnitude limit of $r_{AB} = 23.8$ in the proposed survey, which is $\langle z \rangle = 1.2$ for the measured value of M^*, and only diminishes to $\langle z \rangle = 1.0$ when introducing a lower characteristic luminosity.lower characteristic luminosity.

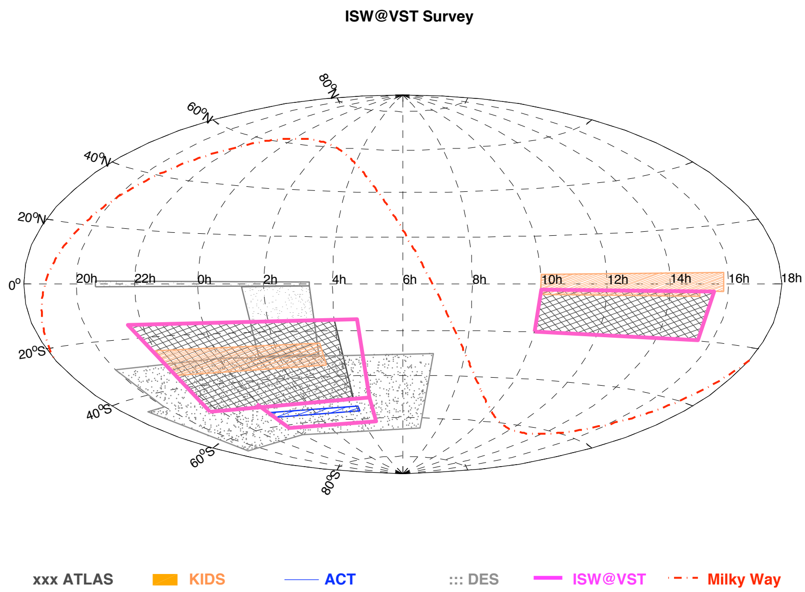

Fig. 4 An "aitoff" representation of the survey boundaries. Other survey boundaries are also shown.The survey area and layout are shown. We will survey the VST ATLAS area (4500 deg^2) plus a contiguous 500 deg^2 field wich overlaps with the planned Atacama Cosmology Telescope (ACT) strip. In this way we maximize year coverage and overlap with other surveys. Surveys that map different areas of the sky are completly independent for measuring the cross correlation signal of the ISW effect. This means that the detection of the ISW effect with this survey will not only have a higher S/N than for any other projected survey, but will also be complementary with them.

6. Experience of the applicants with telescopes, instruments and data reduction

The PI and most of the CoIs have years of observing and data reduction experience. Most of us have been part of research groups carrying out extensive optical and IR surveys.

7. Resources available to the team, such as: computing facilities, research assistants, etc.

We have reached an agreement with the VST ATLAS and VISTA teams to use their data management system. What follows are the VST ATLAS plans adapted to the current survey. For a detailed description, please refer to the VST ATLAS proposal and references herewith. In short, the current survey and the VST ATLAS will use the VISTA Data Flow System (VDFS; Emerson et al. 2004, eds. P.J. Quinn & A. Bridger, Proc. SPIE, vol. 5493, 401 - Irwin et al. 2004, eds. P.J. Quinn & A. Bridger, Proc. SPIE, vol. 5493, 411 - Hambly et al. 2004, eds. P.J. Quinn & A. Bridger, Proc. SPIE, vol. 5493, 423) for all aspects of data management, including: pipeline processing and management; delivery of agreed data products; production of a purpose-built VO compliant science archive with advanced data mining services which will be duplicated at PUC. Standardized data products produced by VDFS will be delivered to the community, with a copy remaining at the point of origin (in the Science Archive run by WFAU in Edinburgh) and PUC. The VDFS is sufficiently flexible as to be applicable to any imaging survey project requiring an end-to-end (instrument to end-user) data management system. The data flow system will be produced by the current VDFS team, who will be responsible for the main data products and for delivering data products to agreed specification to the ESO Science Archive. The VDFS pipeline will be used for all processing. This includes the following processing steps: instrumental signature removal - bias, non-linearity, dark, flat, fringe, cross-talk, persistence; sky background tracking and adjustment during image stacking and mosaicing; combining frames; consistent internal photometric calibration to put observations on a uniform internal system; standard catalogue generation including astrometric, photometric and morphological shape descriptors and derived Data Quality Control(DQC) information, all with appropriate error estimates; accurate WCS astrometric calibration stored in FITS headers; nightly photometric calibration; propagation of error arrays; nightly average extinction measurements in relevant pass bands.

Sufficient resources for new processing, analysis and archival hardware will be provided by Fondap II in the next 5 years, starting in 2007. A postdoctoral fellow, a research assistant and a computer analyst will be hired to work for this program, based at PUC.

8. Special remarks:

This survey will be carried out in collaboration with the VST ATLAS survey. The VST ATLAS will survey in three years 4500 deg^2 in five band passes, u, g, r, i, z. The proposed plan is to use Chilean VST time to make the deep r-band (240secs) observations and increase the ATLAS exposure time in another band, possibly, g, from 60 to 120secs. The combined ISW@VST and VST-ATLAS surveys offer the unprecedented opportunity to develop collaborative projects on two deep band passes over 4500 deg^2. If approved, this project will be a Centre for Astrophysics Key Project, funded by Fondap, Conicyt, Chile. The PI of this proposal is the PI of the Fondap "Birth and evolution of Structures in the Universe" area. The current Fondap program will be evaluated during 2006. We are confident that the funding for the new Centre for Astrophysics program will be extended for 5 more years. This survey will be made available to the community.

9. Justification of requested observing time and lunar phase

Lunar Phase Justification: In order to reach a photometric signal to noise ratio of 10 in the r band for a $r_{AB} = 23.8$ object we need a lunar illumination less than 50%, which is ~ 7 nights before or after new moon.

Time Justification: (including seeing overhead) As shown above, the ISW cross correlation signal to noise ratio is maximized with a catalogue whose mean redshift is 1.2. As show in Fig. 4 using the VST this mean redshift is achieved with a limiting magnitude of $r_{AB} = 23.8$. We used the VOCET exposure time calculator to estimate that 240secs exposure time per exposure to reach a a S/N ratio of 10. Now we estimate the total time required to survey $5000deg^2$ in the r band to the above depth. We assume the following: no binning (0.21×0.21pixels; 52secs of overheads per exposure (Valentijn, priv. comm.); 10% overlap per pointing which implies an effective area per pointing of $0.78deg^2$; 9hrs per night between astronomical twilights (average of 8hrs per night Oct-Mar and 10hrs Apr-Sep); Dark time; 240secs in r results in $9.6deg^2$ per hour. Therefore, to cover $5000deg^2$ we need 58 nights in four years. Time allocation should be $< |7|$ nights from new moon. We shall need to allow 10% more for calibration observations, implying that the total number of nights that will be needed to cover $5000deg^2$ is 64 dark to grey nights; 16 nights per year.

Calibration Request: Standard Calibration

Convert to a normal programme? No

10. Report on the use of ESO facilities during the last 2 years

In the last three observing periods the PI has had visitor time at the VLT ISAAC to do low resolution spectroscopy of $z \gtrsim 6.5$ galaxies. Our candidates are z band dropout resolved objects selected close to clusters of galaxies using HST/ACS and Magellan IR data. So far we have observed more than 10 candidates. No emission lines have been found and, therefore, none of them have been confirmed as $z > 6.5$ galaxies.

11. Applicant's publications related to the subject of this application during the last 2 years

Spergel D. N., Verde L., Peiris H. V., Komatsu E., Nolta M. R., Bennett C. L., Halpern M., Hinshaw G., Jarosik N., Kogut A., Limon M., Meyer S. S., Page L., Tucker G. S., Weiland J. L., Wollack E., Wright E. L., 2003, ApJS, 148, 175 ,First-Year Wilkinson Microwave Anisotropy Probe (WMAP) Observations: Determination of Cosmological Parameters

Spergel et al., 2006, ApJ, in press (astroph/0603449)

Jimenez, R., Verde, L., Treu, T., Stern, D., 2003. ApJ, 593, 622-629. Constraints on the Equation of State of Dark Energy and the Hubble Constant from Stellar Ages and the Cosmic Microwave Background.

Verde, L., Jimenez, R., Kamionkowski, M., Matarrese, S., 2001., MNRAS, 325, 412-418. Tests for primordial non-Gaussianity.

Broadhurst, T., and 41 colleagues, 2005, ApJ, 621, 53-88, Strong-Lensing Analysis of A1689 from Deep Advanced Camera Images.

Miley, G. K., and 37 colleagues 2004, Nature 427, 47-50. A large population of 'Lyman-break' galaxies in a protocluster at redshift z 4.1.

Galaz, G., Dalcanton, J. J., Infante, L., Treister, E., 2002. AJ 124, 1360-1379. Properties of Low Surface Brightness Galaxies and Normal Spirals in the Near-Infrared.

Infante, L., and 15 colleagues 2002, ApJ 567, 155-162. The Angular Clustering of Galaxy Pairs.

12. List of targets proposed in this programme

Run	Target/Field	α(J2000)	δ(J2000)	ToT	Mag.	Diam.	Additional info	Reference star
A	R1-A	12 45 00.0	-17 54 00	40	23.8		RA 10h00:15h30, Dec -15.7:-20.1	
B	R2-B	01 15 00.0	-17 12 00	47.5	23.8		RA 21h30:4h40, Dec -15:-19.4	
C	R2-C	01 15 00.0	-20 16 48	32	23.8		RA 21h30:4h40, Dec -19.4:-21.16	
D	R3-D	2 16 00.0	-55 16 48	24	23.8		RA 23h52:4h40, Dec -52.64:-57.92	
E	R1-E	12 45 00.0	-13 30 00	40	23.8		RA 10h00:15h30, Dec -11.3:-15.7	
F	R2-F	01 15 00.0	-23 21 36	47.5	23.8		RA 21h30:4h40, Dec -21.16:-25.56	
G	R2-G	01 15 00.0	-27 19 12	40	23.8		RA 21h30:4h40, Dec -25.56:-29.08	
H	R3-H	2 16 00.0	-51 28 12	16	23.8		RA 23h52:4h40, Dec -50:-52.94	
I	R1-I	12 45 00.0	-9 32 24	40	23.8		RA 10h00:15h30, Dec -7.78:-11.3	
J	R2-J	01 15 00.0	-31 16 48	42.75	23.8		RA 21h30:4h40, Dec -29.08:-33.48	

Target Notes: The current ESO macro does not allow targets past period 83. Our proposal considers observation up to period 85. Enclosed are the target K,L,M,N and O for periods 83 (K and L), 84 (M and N) and 85 (O).

Run α(J2000) δ(J2000) Add.info
K 01 15 00.0 -35 40 48 RA 21h30:4h40, Dec -33.48:-37.88
L 2 16 00.0 -60 7 12 RA 23h52:4h40, Dec -57.92:-62.32
M 12 45 00.0 -5 8 24 RA 10h00:15h30, Dec -2.5:-7.78
N 01 15 00.0 -40 57 36 RA 21h30:4h40, Dec -37.88:-44.04
O 01 15 00.0 -47 07 12 RA 21h30:4h40, Dec -44.04:-50.2

12b. ESO Archive - Are the data requested by this proposal in the ESO Archive (http://archive.eso.org)? If yes, explain why the need for new data.

No

13. Scheduling requirements

14. Instrument configuration

Period	Instrument	Run ID	Parameter	Value or list
79	OMEGACAM	A	IMG	r
79	OMEGACAM	B	IMG	r
80	OMEGACAM	C	IMG	r
80	OMEGACAM	D	IMG	r
81	OMEGACAM	E	IMG	r
81	OMEGACAM	F	IMG	r
82	OMEGACAM	G	IMG	r
82	OMEGACAM	H	IMG	r
83	OMEGACAM	I	IMG	r
83	OMEGACAM	J	IMG	r