VISTA SCIENCE COMMITTEE

VSC99-06

Scientific issues concerning VISTA site choice

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Abstract: This report aims to summarise in a quantitative manner the scientific related issues that effect site choice. We include material that characterises the sites that are currently under consideration. Other issues relating to operational cost and logistics which can indirectly effect scientific output in a major manner are not considered. The report is not intended to be definitive at this stage and qualitative and quantitative input is welcomed.**Note this is still a draft and contains notes to the authors embedded in the text**

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1 Introduction

The choice of sites for VISTA is as important as the telescope design and we need to get it right. The issues are complex and we may have to weigh up issues like: is a site with median seeing of 0.5" and expensive operational costs or longer down time periods since we cannot get trained and motivated staff give us more Nobel prizes per buck that a site that has 0.6" seeing and higher data output. Similarly a site with higher wind speed or that is more gusty may have better seeing but this seeing may not be realised if the telescope structure resonates although tip-tilt may be a cure.

- See comments by Murdin is the ESPAS report
- see comments about local site costs in Magellan report

A useful source of material is http://www.eso.org/gen-fac/pubs/astclim/espas/espas_lib.html

2 Scientific related issues

The main site characteristics that impact on science are as follows:

- number of photometric nights
- seeing
- wind speed and direction
- relative humidity
- temperature

2.1 Number of photometric nights

Basically Chile is much better than Mauna Kea which is good news for planning and quality control in a photometric survey. Figure 4 in Sunzeff & Baldwin(1997) shows that whereas the median number of photometric nights per month is 60% at Tololo it is 50% at Mauna Kea.

2.2 Seeing

TBD

2.3 Wind speed and direction

TBD

2.4 Relative Humidity

TBD

2.5 Temperature

The ambient temperature can result in an appreciable cntribution to the sky background beyond 2microns and thus is only an important consideration for the K band and maybe narrow band observations at the red end of H. See section nn for further details.

Probably more importantly the rate of change of temperature at a site can have considerabel effect on the seeing since a rule of thumb is that a 2° C temperature difference between the primary and the dome air will add 1"(FWHM in quadrature) to the width of the focal plane image.(Persson, 1991).

3 The optical sky

In the absence of scattered moonlight and man-made pollution the optical sky at latitudes $<40^\circ$ is dominated by Zodiacal light and airglow(Benn and Ellison, 1999 and refs therein). The spectrum of the typical optical night sky is shown in Fig 1. It is worth noting that the SDSS Gunn g and r wavebands are chosen to avoid the OI lines at 5577 and 6302.

Good primers on optical sky brightness are; Benn & Ellison(1999), Walker(1999) and Garstang(1989a, 1989b).

The two most major issues for VISTA are light pollution as effecting Pachon and the effect of the solar cycle on the Airglow contribution. The peak to peak variations in B and V during the solar cycle is $\sim$0.5mags see Figure TBD from Krisciunas(1997). Interestingly the SDSS survey is starting when the sky is 0.3 mag brigher in V than at the solar minumum and the sky will get brighter as the SDSS survey continues, peaking in 2003. The issue of light pollution and Pachon is discussed later.

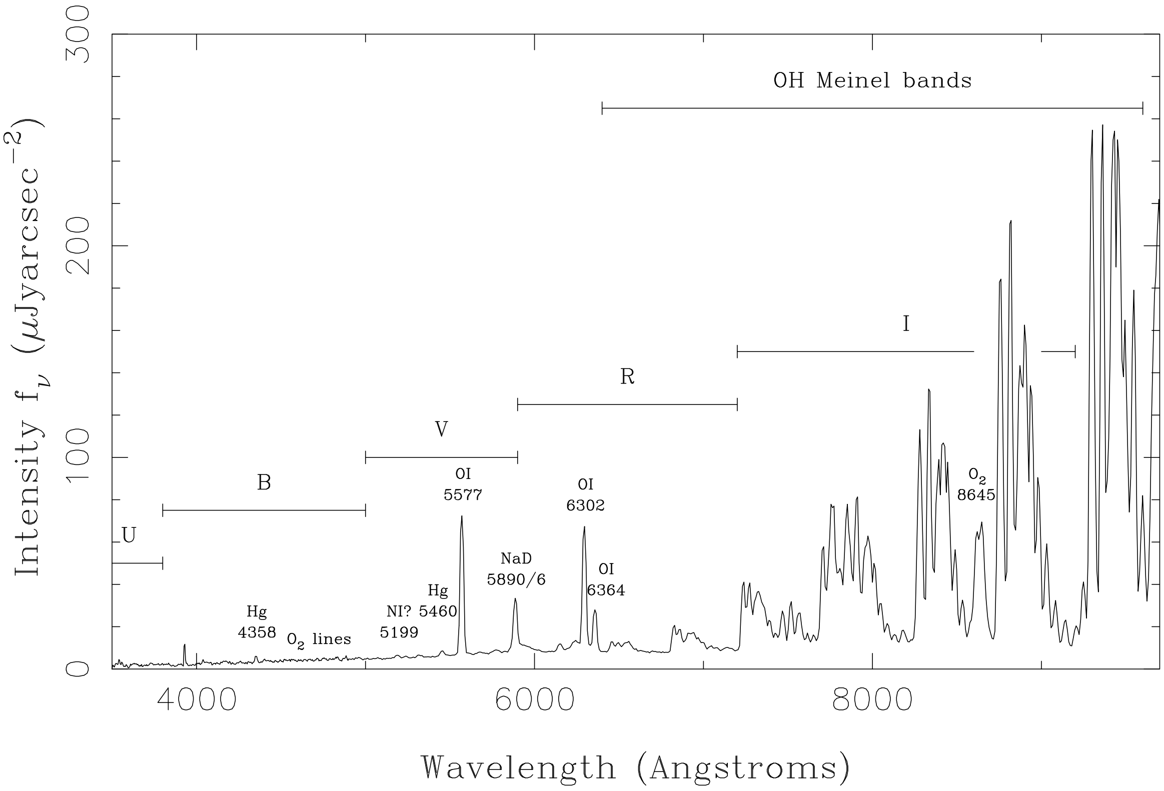

Figure 1: Typical spectrum of the La Palma sky on a moonless night, taken with the faint-object spectrograph of the William Herschel Telescope in March 1991. Most of the distinctive features of the night-sky spectrum are due to airglow. Airglow also contributes a pseudo-continuum in the blue from overlapping O_2 (forbidden Herzberg) bands (2600 - 3800 Å) and in the green from NO_2 bands (5000 - 6500 Å). The NaD emission at 5890/6 Å is partly from streetlighting, the mercury emission at 4358, 5461 Å wholly so. With the exception of the 8645-Å O_2 line, the features dominating the spectrum redward of 6500 Å are the Meinel rotation-vibration bands of OH. An atlas of the airglow 3100 - 10000 Å was presented by Broadfoot & Kendall (1968) (see also Ingham 1962). More recently, a low-resolution spectrum of the night sky was given by Louistisserand*et al* (1987) and high-resolution (0.2 Å) spectra of the wavelength range 5200 – 10600 Å were presented by Osterbrock *et al* (1996, 1997), and for $>$ 3100 Å by Vlasyuk & Spiridovna (1993). Spectra of the infrared airglow were presented by Ramsay *et al* (1992), Oliva & Origlia (1992) and Maihara *et al* (1993). The relative strengths of the lines do not reflect relative concentrations of the emitting species (NaD is bright in part because of the very short lifetime $\sim 10^{-8}$ sec of the high-energy state, so that many transitions are possible per unit time).

4 The near IR Sky

At λ >1μm background emission that limits astronomical observations is dominated by three emission processes.

- Rayleigh scattering of moonlight
- Intense airglow lines due to OH radicals(from altitudes of 88-100 km)
- Thermal emission from the astronomical instrument imaging system, the telescope and the atmosphere.

We now consider the contributions from these three processes.

4.1 Rayleigh scattering of moonlight

Two factors make scattered moonlight a minimal issue in infrared observations. First, the scattering mechanisms for light propagating through the atmosphere are highly wavelength dependent and tend to be much less efficient at longer wavelengths. Second, the intrinsic brightness of the sky is so much brighter in the infrared than it is at visible wavelengths, that the relative contribution from scattered moonlight to the total sky flux is relatively small. The exact brightness of the moonlit sky is a complex function of lunar phase, lunar altitude, target altitude, target-lunar angular separation, local extinction, and wavelength. Krisciunas and Schaefer (1991) list a series of equations in a model of scattered moonlight that can be used to estimate the sky brightness as a function of these parameters.

Thus moonlight is not considered important even in J, as long as one observes >10deg^2 from the moon and is a smaller effect as one goes to longer wavelengths. Thin cirrus will increase the scattering of moonlight significantly in arbitrary parts of the sky so that IR observations may only be possible is the best conditions.

See Fig TBD reproduced from the CFHT Redeye manual.

See Fig TBD so see how the IR sky varies as a function of lunar angle.

4.2 Airglow emission

Figure nnn provided by Pat Roche show hows the spectral range 1.0 to 2.0 microns is dominated by intense OH lines. Thermal emission is negligible in even H.

Table nnn prepared by McMahon shows how the J and H sky brightnesses vary by $\sim$ 1 magnitude from site to site. In practice the H band sky can vary considerabley during a single night with factors of 3 not uncommon with the H sky geting darker as the night proceeds. Since the OH lines are created at altitudes of 80-100km the J and H sky brightnesses are probably the same at all the sites in Chile. A deatailed study of the nighly variations in J and H are available at the 2MASS WWW site.

4.3 Thermal Background

Assuming that the camera is properly baffled, the filters are properly blocked and that little out of beam thermal emission is reaching the detectors, the only broad band that is effected significantly is K.

Ashley at al(199n) show spectra over the 2.0 to 2.5micron range showing the sky background at the AAT (T=10 C) compared with the South Pole(T=-62 C). From this one can see quite dramatically how beyond 2.2 microns the sky background is dominated by thermal emission from the sky and telescope structure with values for the K sky background in th range 11-15.5 mag arcsec^{-2} commonplace.

Wainscoat and Cowie(1992) investigated how the effect of thermal emission can be reduced in the K band by altering the bandpass. By shifting the central wavelength to 2.1microns from the classical value of 2.2microns (see Figure TBD reproduced from Wainscoat & Cowie(1992)), the sky in K decreased by 0.9magnitudes. This band is commonly called K'. In addition the background in K' shows little variation with ambient temperature(see Fig 3b in Wainscoat & Cowie, 1999).

5 Characteristics of the observatory sites under consideration

Below we summarise the available material on sites under consideration. It is important to realize that some conditions eg seeing and wind can vary significantly within a specific site, so that site testing will still be required to determine the specific optimal location for VISTA.

1. Cerro Pachon(AURA)
2. Las Campanas(OCIW)
3. Paranal(ESO)
4. Cerro Tocco(Chile)

Needs a map to show the relative locations of the sites.

Table 1: Sites under consideration

Site	Operator	Latitude	Altitude (m)
Cerro Pachon	US-AURA	−30.1	2700
Paranal	ESO	−24.6	2600
Las Campanas	US-OCIW	−28.5	2400
Cerro Tocco	Chile	−25.0	5600

Table 2: Other sites for comparison

Site	Operator	Latitude	Altitude (m)
Cerro Tololo	US-AURA	−30.2	2200
LaSilla	ESO		
AAT	UK-Aust	−31.3	1150
Mauna Kea	U. of Hawaii	+19.8	4200
LaPalma	IAC-Spain	+28.2	2350

5.1 Cerro Pachon

Cerro Pachon is the location of Gemini South and is operated by AURA. It is also the site chosen for the SOAR consortium(????) for the constuction of a new 4m telescope. There have been two site surveys of Pachon. The first was carried out in 1964-66 by Babcock & Irwin in a series of reports published mainly as Carnegie Institute reports as part of a study to locate potential sites for a Southern Hemisphere 200inch telesocope. The second study was carried out by CTIO during the period 1988-92 in preparation for the Gemini Telescope Project. Thus Cerro Pachon has site characteristic data sampling over 30 years. The characteristics were summarised by Suntzeff & Baldwin(1997) as part of the SOAR consortium deliberations on site choice.

Number of photometric night

The mean relative humidity of Pachon and Mauna Kea per month is 20-40and is indistiguishable between the two sites. From Fig 4 in SB97, the mean number of photometric nights on Mauna Kea is $\sim$45% and at Pachon(actually Tololo) is 60%. The worse months are in the in May, June, July in the Chilean winter where it drops to 40poorer number of photometric nights. The fraction of photometric nights during the Chilean Summer period of Dec-Mar is 70%+.

Seeing

The median seeing in Table 2 from SB97 is 0.50 with 25-75% quartiles of 0.39 to 0.64.

It would be nice if VISTA sampled the best 25would probably degrade to 0.5 when everthing is folded in.

- how was it measured
- what waveband
- seasonal issues

Wind

Wind Speed From Fig 12 in SB97, the mean wind speed at 12m height is 18mph with a 10-90% range of 0 to 35mph. Since wind is only a problem at the highest values, I also quote the 80% upper value of 25mph. There are strong seasonal variations with a median value of 21.7mph in the mid-Winter period of July-Aug-Sep and 10.1mph in the Summer period Dec-Feb.

Prevailing Wind Direction The wind rose shows that the wind almost always comes from the NNE as is in the case in other Chilean sites(Tololo, LaSilla, LasCapmanas). Based on experience (SB97) when the wind comes from other directions it is due to a weather front moving through and the seeing is often bad at these times. Wind direction is worth considering in scheduling and telescope design issues.

B99, has found that the wind direction at the SOAS site may have changed in recent years and may now be coming out if the NW ie almost a 90degree difference to older Gemini results.

Airflow issues

Baldwin(1999) looks at the issues of building height at the Soar site ay Pachon and found that:

- telescope must be greater than 0.6m higher than ground level so that ground level seeing effects are minimal and that the free-atmosphere limit is reached
- telescope should be placed as close as possible to the ridge edge as possible since turbulence effects rise as one moves away from the edge(see Fig 4 in B99).

Temperature

From Fig 10 in SB97, the mean temperature is 9C and 10–90% range is 2–14C. The mean hourly rate of change of nighttime temperature is -0.7 C/hr with a 10–90temperature change data includes around 10temperature rises during the night.

An important issue for VISTA will be the cost of ensuring that the telescope can track these temperature changes and that the telescope structure reach these temperatures quickly each night.

Water vapour

TBD

5.2 Las Campanas

LasCampanas is quite close to ESO and Tololo so that the general properties of the sites should be the same.

Number of photometric night

It should be the same as LaSilla/Pachon/Tololo

Seeing

From Table 2 in SB97 over the period 1988-89, the median seeing was 0.55 with 25-75% quartiles of 0.41 to 0.75. Persson reports that differences of 0.05 are common within the LCO site and could be due to the fact that the mean wind speed is variable across the site.

5.3 Paranal

Paranal is the site of the VLT and is the northern most of the sites under consideration at nnn km north of Santiago.

Number of photometric night

TBD

Seeing

TBD

Wind

Wind Speed

From Fig **??** the median night time wind speed for 1989-91 at an altitude of 10m above ground is 6.6m/s (14.8mph). This is higher than at LaSilla which is quoted as 4.6m/s(10.3mph).

Both LasCampanas and Pachon are widier than Paranal.

Prevailing Wind Direction

TBD

Airflow issues

TBD

Number of photometric nights

TBD

Seeing

From Table 2 in SB97 over the period 1988-89, the median seeing was 0.55 with 25-75% quartiles of 0.41 to 0.75. Persson reports that differences of 0.05 are common within the LCO site and could be due to the fact that the mean wind speed is variable across the site.

5.4 Cerro Tocco

This is a high altitude site in Chile near the proposed site for the millimtre array: ALMA. We have no data on Cerro Tocco but a summit near it has been surveyed by Cornell University. This data is located at: http://astrosun.tn.cornell.edu/atacama/datapage.html

The Cornell group have measured the seeing on the Chajnantor Plateau and on a small peak 200m above the plateau (called Cerro Chico) using a portable DIMM on loan from ESO.

They have found that the nedian seeing is 0.69". Interestingly, the Cornell group have compared seeing their Cerro Chico results with results for Paranal obtained during the same 17 nights and found a median seeing was 0.69 at Chico and 0.63 for Paranal.

6 Conclusions

TBD

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