A NEW GENERATION INFRARED SKY SURVEY for the E-ELT era

(an assessment study)

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RATIONALE: A new era for optical/IR astronomy will begin by the end of this decade with JWST, LSST, EUCLID and 30/40 m class ground based telescopes such as the **E-ELT**. Giant instruments providing gains in sensitivity of several orders of magnitudes will require **new large scale surveys (such as LSST)** that will accompany their missions and key-programs to single out and follow-up new sources. Renewed *canonic* documents such as **digitized catalogues and maps** will be required. In the infrared range, projects are currently proposed to supersede 2MASS by a factor ~1000 in sensitivity and ~3 in angular resolution, such as SASIR in the Northern Sky. We propose here a **New Generation Infrared Sky Survey (NGISS)** that could benefit from **the Polar atmospheric conditions (**e.g., at the French Italian Antarctic station **Concordia)** to optimize the performances and to **extend the spectral covera**ge **beyond 2.3 µm**. The Antarctic Plateau offers very low sky brightness throughout the near-and mid-infrared range. A modest 2.5 telescope would have a sensitivity in K comparable to that of a 10 m ground-based telescope at Paranal. To fully benefit from the polar advantages, **an off-axis** telescope concept is proposed.

Why a New Generation Infrared Sky Survey ?

Preparing, accompanying and following-up ELT IR key-programs

- 2MASS not deep enough, NGISS should supersede VISTA (sky coverage, sensitivity, angular resolution, spectral range)
- NGISS coverage: 5 to 15 000 square degrees (Southern Sky)
- High sensitivity: gain ~ 1000 with respect to 2MASS at K
- High contrast → off-axis telescope proposed (*see below*)
- High angular resolution **: 0.3''** or better (thanks to site + GLAO)
- Extend spectral coverage **beyond 2.3 µm** (in particular the K_{dark} and L windows); bridging ground/space surveys (WISE, Spitzer, ...)

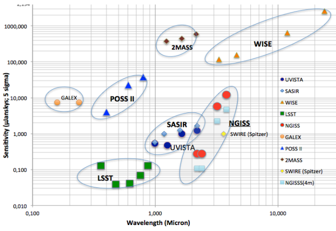
Goals, deliverables, status

- Largest possible sky coverage at $K_{A\text{-}B}$ ~ 25
- Provide new documents (catalogs, maps, data bases) matching the E-ELT requirements.
- Pipeline (LSST- CC IN2P3)
- VO access compliance
- **Explore time domain (*like* LSST)**
- Follow-up transient sources discovered by explorer missions (e.g., EUCLID)
- Status: assessment study (ANR, *Horizon 2020*)

name	Wave lengths	Sky coverage	Angular resolution @ K	Point source limiting magnitude @ $K_{A\text{-}B}$ (5sigma)
TMSS (IRC)	IK	North + extension	5 arcminutes	3.5
2MASS	JHK	All-sky	1 arcsec	15.5
DeNIS	IJK	80% southern sky	1 arcsec	13.5
IRAS	12-100 µm	Almost all sky	10 arcmin (*at 10 µm*)	NA
VISTA (Viking)	YIJHK	1500 deg ^{2}	0.5 arcsec	21
UltraVISTA	YIKHK	0.7 deg^2	0.5 arcsec	23.7
SASIR	YJHK	All-sky	0.5 arcsec	23.4
WISE	3.6 -25 µm	All-sky (except gal. Plane)	6.1 arcsec	18.5 (@ 3.6µm)
NGISS (2.5m)	K K_d L_s L'	Large areas up to 15 000 deg^2	0.3 arcsec	25
NGISS (4 m)	**K K_d L_s L'**	Large areas up to 15 000 deg^2	**0.2 arcsec (?)**	**26.5**
E-ELT	K_s	A few deg^2	0.1 arcsec	>30?

Top Science drivers that will take benefit from a NGISS

- **Distant Universe**
  - ✓ Early Universe: high redshift galaxies, probing epoch of reionization; cosmic distance scale, Pop. III stars
  - ✓ Type Ia Sne in dusty galaxies (survey and light curve follow-up)
- **Extragalactic stellar populations**
  - ✓ Synoptic time monitoring of Magellanic Stellar populations (extension of VMC- deeper- λ>2.3)
- **Low mass stars, exoplanets and small bodies of the Solar System**
  - ✓ Stellar: extreme brown dwarfs/free floating planets (field and SFR)
  - ✓ Small bodies of the Solar system (complementary to LSST)



The expected sensitivity of NGISS compared to other surveys

NGISS (2.5 m) performances

(from Epchtein *et al.* 2013, in preparation)

Array type	HgCdTe HAWAII 4RG
Array size	4k × 4k
FPA configuration	16 chips buttable end to end
Pixel size	10 µm
Pixel scale	≤ 0.15''
Final PSF FWHM	0.3''
Field of view of the camera	40' × 40'
Filter set (3 minimal)	K_d, L_s, L'
Possible additional filters	K, K_s, M', Grism, narrow bands
Read out time (typical)	5 sec
Integration time per frame (typical)	100 s

Table 2. Main characteristics of the NGISS infrared camera

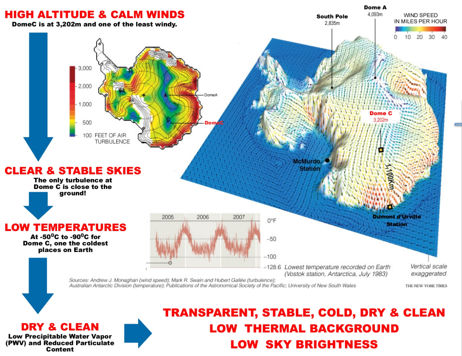
Band	λ (µm)	R ($\lambda/\Delta\lambda$)	FWHM ('')	m_{AB} mag.	m_{AB} /arc^2
K_d	2.40	10	0.32	25.3	24.7
L_s	3.40	6	0.38	20.8	20.1
L'	3.76	5.8	0.40	21.2	20.8
M	4.66	19	0.46	19.6	19.4

Table 3. Expected sensitivity of the NGISS (5σ, one hour exposure)

	PLT	LSST
Image exposure time	30s	30s (2 × 15s)
FOV (sq. deg.)	0.5	10
Sky coverage (sq. deg.)	5 000	20 000
Coverage time	4 × 24 hours	3 nights
Raw pixel data per 24 h period	0.5 to 1 Tb	15 Tb
Yearly archive rate	100 to 200 Tb	5.6 Pb
Number of visits per year (*indicative for PLT*)	25 @ K_d/ 90 @ L', M	100
Number of filters (baseline, mini, goal)	4, 3, 6	5, 3, 6
Image quality (average, maxi, goal) (arcsec)	0.40, 0.45, 0.35	0.56, 0.59, 0.53

Table 4. NGISS and LSST observing strategies and data flows.

Antarctica, an attractive site for future infrared imaging surveys



- **Great seeing and atmospheric stability**
- **Great IR transmission**
- **Low IR thermal background**

PRECIPITABLE WATER VAPOUR (PWV): Monthly average range from 0.72(+/-0.20)mm in December to 0.26(+/-0.1)mm in March/April period. Observations in the 200µm window opens at a transmission level about 20% during 25% of the time. Low PWV means higher transmission in the NIR and MIR windows and an extended wavelength coverage. The K_{dark} window is optimal. The L_{short} (3.2-3.6µm) window opens, allowing **day-time (and twilight) observations.**

SKY BRIGHTNESS (IR): At wavelength above 2.3µm, the dominant factor is the temperature of the atmosphere (-50°C to -90°C). The full K window becomes fully exploitable (not just K_{short}). **Fainter OH airglow emission.**

TEMPERATURE AND WIND PROFILES: Quasi-periodic ground temperature oscillation during summer and winter months. Winter dT/dt up to 30°C/week. Summer dT/dt > 10°C/hour.

Wind speed are low (*Aristidi et al., 2005, A&A 430, 739*).

Ground layer wind profile do not show any strong diurnal variation. Very appropriate **to GLAO correction.**

Concordia DOME C SITE QUALITY at a GLANCE

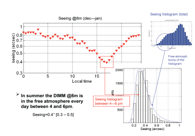
WINTER: Turbulent boundary layer = 23m
Above that seeing ~ 0.''36

SUMMER @ 8m seeing ~ 0.''40

	Seeing	Isop.	Coh. time
DIMM/GSM	**0.4 ''**	**4.1 ''**	
SSS	**0.3 ''**	**6.9 ''**	**10.2 ms**
Balloons	**0.4 ''**	**2.7 ''**	**6.8 ms**
AASTINO 2004[1]	***0.3 ''***	***5.7 ''***	***7.9 ms***
Simulations[2]	0.3 ''		

@ground	Seeing	Isop.	Coh. time
Mauna Kea	0.6 ''	1.9 ''	2.7 ms
Paranal	0.8 ''	2.6 ''	3.3 ms

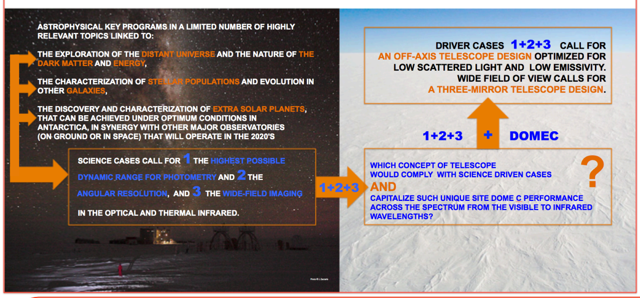
[1]Lawrence et al 2004
[2]Lascaux et al 2011



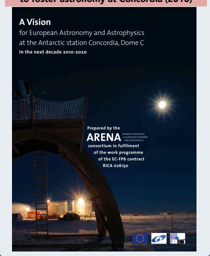
Aristidi et al. 2009, A&A 499, 955.

Telescopes already in operation at Concordia:
ASTEP400: planetary transits (40 cm)
IRAIT: infrared telescope (80 cm)

SCIENCE CASES COMPLIANCE:

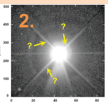


The European roadmap ARENA (FP6) to foster astronomy at Concordia (2010)

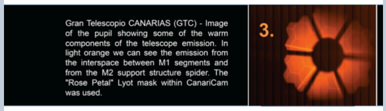


An OFF-AXIS TELESCOPE
To minimize thermal emission and diffraction

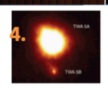
1. Off-axis telescopes can have far superior constrast because there are no obstructions in the beam such as secondary and tertiary mirrors supports. This limits the diffraction as well as scattered light from obstructions.
2. Off-axis telescopes allow to observe an important part of the universe where current concentric telescopes are blind because of scattered light.



3. Off-axis telescopes reduce the sources of self thermal emissivity. A MUST for infrared astronomy!



4. Off-axis telescopes can have a tremendous advantage for studies of faint planets near bright stars and faint nebulosity surrounding young stars, where planets may be forming;

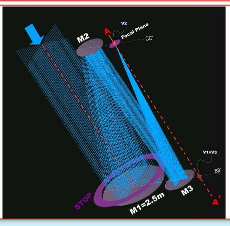


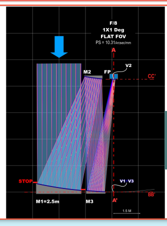
5. Off-axis telescopes turn out a natural-filled-aperture: no azimuthal PSF structure, no missing or interpolated wavefront errors: a natural advantages for interferometry and adaptive optics performance!!

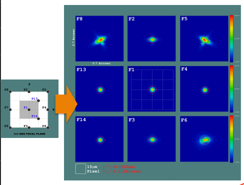
The proposed concept of off-axis mirror for a 2.5 m NGISS (*Moretto et al., 2012, SPIE vol. 8444)*. Assessment study (*Langlois et al.* 2013, submitted to the French ANR + H-2020 *).*

Partners are:

- **CNRS-INSU**: CRAL (Lyon); Lagrange (Nice)
- **CNRS-IN2P3** : IPNL (Lyon)
- **SAGEM-REOSC**
- **More EU partners for H 2020**







Project: a 4-year Assessment Study

- **Collect science requests from E-ELT, EUCLID, JWST... keyprograms**
- Monitor **sky background emission at** Concordia @ 2-**4 µm, using IRAIT**
- Design, build and test a ~40 cm **off-axis mirror prototype**
- Design **GLAO** device compliant with atmospheric turbulence properties
- Design adequat **pipeline** architecture (huge data flow from remote site)
- **Goal**: Design final telescope → **to be operational in the early 20's (E-ELT)**

• **Summary**: **A New Generation Infrared Sky Survey is proposed for the next decade offering performances matching the requests of the new extremely large telescopes such as the E-ELT in order to prepare and follow-up their programmes. This will require the coverage of thousands of square degrees at K ~ 25 or better, with an angular resolution of ~ 300 mas and time domain exploration. In the Southern hemisphere a NGISS using a relatively modest aperture telescope (2.5 to 4 m) set up on the Antarctic Plateau looks particularly attractive. Moreover, an off-axis optical combination is preferred to fully benefit from the exceptional atmospheric properties of the site and to explore the 2.3-4 µm windows in optimal thermal emission conditions.**