A project for a **New Generation Infrared Sky Survey (NGISS)** with a **Polar Large Telescope (PLT)**

[Isabelle Vauglin, Maud Langlois (CRAL, Observatoire de Lyon, France), Gil Moretto (LIO/IPNL), Nicolas Epchtein (Lagrange)] for the PLT Consortium
Why do we need a new generation large scale (all-sky?) NIR survey?
Preparation, accompanying and following-up ELT IR key-programs

- 2MASS not deep enough, a 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, …)
Guidelines for a new broad band near IR survey

- Faster than VISTA @K by a factor > 10 or more
- Better angular resolution than VISTA (∼ 0.3 ” vs. 0.5”)
- Large Fields (comparable to VISTA’s). All sky (?)
- Repeated (time domain exploration) (LSST-style)
- Near thermal infrared (2.2 to 4.5 µm)
- Uninterrupted (day/night) observations beyond 3µm
- Possible imaging-spectroscopic mode in the 2.3-5 µm range?
- Provide lists of very faint exciting sources (transients, large z, candidate exoplanets…) for E-ELT, JWST… alerts
- Follow up large space surveys EUCLID, WFIRST
Top Science drivers that will take benefit from a NGISS

- **Distant Universe**
  - Early Universe: high redshift galaxies, probing epoch of reionization, Pop. III stars, H$_2$
  - SN-Ia in dusty galaxies (survey and light curve follow-up)

- **Extragalactic stellar populations**
  - Synoptic time monitoring of Magellanic Stellar populations (extension of VMC- deeper- $\lambda > 2.3 \, \mu m$)

- **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
Antarctica, an attractive site for infrared imaging survey
**ANTARCTIC PLATEAU DOME C**

**A MUST FOR ASTRONOMICAL OBSERVATIONS**

**HIGH ALTITUDE & CALM WINDS**
Dome C is at 3,202m and one of the least windy.

**CLEAR & STABLE SKIES**
The only turbulence at Dome C is close to the ground!

**LOW TEMPERATURES**
At -50°C to -90°C for Dome C, one of the coldest places on Earth

**DRY & CLEAN**
Low Precipitable Water Vapor (PWV) and Reduced Particulate Content

**TRANSPARENT, STABLE, COLD, DRY & CLEAN**
**LOW THERMAL BACKGROUND**
**LOW SKY BRIGHTNESS**

Sources: Andrew J. Monaghan (wind speed); Mark R. Swain and Hubert Gallée (turbulence); Australian Antarctic Division (temperature); Publications of the Astronomical Society of the Pacific; University of New South Wales
The Concordia station at Dome C (2011) operated by IPEV and PNRA (ENEA)

- Main buildings
- Astronomy area
- Site testing instruments (Concordiastro)
- IRAIT
- German Dome
- ASTEP
- cochise

- 75°06' South, 123°23' East
- Altitude 3220 m
- 1100 km inside the continent
Concordia DOME C SITE QUALITY at a GLANCE

WINTER:
Turbulent boundary layer = 23m
Above that seeing ~ 0.3"

<table>
<thead>
<tr>
<th></th>
<th>Seeing</th>
<th>Isop.</th>
<th>Coh. time</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIMM/GSM</td>
<td>0.4&quot;</td>
<td>4.1&quot;</td>
<td></td>
</tr>
<tr>
<td>SSS</td>
<td>0.3&quot;</td>
<td>6.9&quot;</td>
<td>10.2 ms</td>
</tr>
<tr>
<td>Balloons</td>
<td>0.4&quot;</td>
<td>2.7&quot;</td>
<td>6.8 ms</td>
</tr>
<tr>
<td>AASTINO 2004</td>
<td>0.3&quot;</td>
<td>5.7&quot;</td>
<td>7.9 ms</td>
</tr>
<tr>
<td>Simulations</td>
<td>0.3&quot;</td>
<td></td>
<td></td>
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</tbody>
</table>

Mauna Kea | 0.6" | 1.9" | 2.7 ms
Paranal   | 0.8" | 2.6" | 3.3 ms

SUMMER @ 8m:
seeing ~ 0.4"

Most appropriate spectral domain for NGISS

Better sky atmospheric transmission
First Astrophysical results obtained at Concordia: ASTEP (2011) IRAIT in 2013 (talk by M. Dolci)

WASP-19b Transit Lightcurve

from Abe et al., 2012, subm. A&A
ASTEP400 Results

- **Occulation ("secondary eclipse") of WASP-19b** (Abe et al., A&A 2013)
  - First ground-based observation of an occultation in this wavelength range (~R band)
  - 24 observing nights (May 2010), 14h/day

- **Planet candidates:**
  - 2010 & 2011 data fully processed (paper in preparation)
  - ongoing Radial Velocity (ANU, Australia – HARPS, Chile) and spectroscopic characterization.
  - Detection sensitivity: 1% up to R~16

- **ASTEP will not be operated in 2014**
  - Fix of hardware malfunction.
  - Summer campaign dedicated to fix software issues

- **Plans for 2015 and beyond:**
  - Propose an ASTEP+ version:
    - Instrument located @10m height (on top of a concrete pillar + wooden platform).
    - Possibility to add photometric filters(?)
    - Higher angular resolution: denser fields with better PSF stability (e.g. galactic center)
    - Collaboration with IRAIT for IR characterization of transits? (but field is very small)
Thence, road is free to devise bigger instruments and more ambitious projects

*vision 2010-2020*......
NGISS (2.5 m) performances
(from Epchtein et al. 2013, in preparation)

<table>
<thead>
<tr>
<th>Array type</th>
<th>HgCdTe HAWAII 4RG</th>
</tr>
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<tbody>
<tr>
<td>Array size</td>
<td>4k x 4k</td>
</tr>
<tr>
<td>FPA configuration</td>
<td>16 chips buttable end to end</td>
</tr>
<tr>
<td>Pixel size</td>
<td>10 ( \mu m )</td>
</tr>
<tr>
<td>Pixel scale</td>
<td>( \leq 0.15'' )</td>
</tr>
<tr>
<td>Final PSF FWHM</td>
<td>0.3''</td>
</tr>
<tr>
<td>Field of view of the camera</td>
<td>40' x 40'</td>
</tr>
<tr>
<td>Filter set (3 minimal)</td>
<td>( K_d, L_s, L' )</td>
</tr>
<tr>
<td>Possible additional filters</td>
<td>K, K_s, M', Grism, narrow bands</td>
</tr>
<tr>
<td>Read out time (typical)</td>
<td>5 sec</td>
</tr>
<tr>
<td>Integration time per frame (typical)</td>
<td>100 s</td>
</tr>
</tbody>
</table>

Table 2. Main characteristics of the NGISS infrared camera

<table>
<thead>
<tr>
<th>Band</th>
<th>( \lambda ) (( \mu m ))</th>
<th>( R ) (( \lambda/\Delta \lambda ))</th>
<th>FWHM (( '' ))</th>
<th>( m_{AB} ) mag.</th>
<th>( m_{AB} ) /arc(^2)</th>
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<tbody>
<tr>
<td>( K_d )</td>
<td>2.40</td>
<td>10</td>
<td>0.32</td>
<td>25.3</td>
<td>24.7</td>
</tr>
<tr>
<td>( L_s )</td>
<td>3.40</td>
<td>6</td>
<td>0.38</td>
<td>20.8</td>
<td>20.1</td>
</tr>
<tr>
<td>( L' )</td>
<td>3.76</td>
<td>5.8</td>
<td>0.40</td>
<td>21.2</td>
<td>20.8</td>
</tr>
<tr>
<td>M</td>
<td>4.66</td>
<td>19</td>
<td>0.46</td>
<td>19.6</td>
<td>19.4</td>
</tr>
</tbody>
</table>

Table 3. Expected sensitivity of the NGISS (5\( \sigma \), one hour exposure)
Telescope design

The off-axis telescope alternative
(2 to 4 m aperture)

G. Moretto (IPNL, Lyon)

see SPIE Amsterdam, July 2012
SCIENCE CASE COMPLIANCE:

- Exploration of the distant univers and nature of the dark matter
- Discovery of extrasolar planets
- Characterization of stellar populations

Science cases call for

1) the highest possible dynamic range for photometry
2) the highest angular resolution
3) a wide-field imaging
   in optical and thermal infrared

The only concept of telescope that could comply with science cases and capitalize such unique site Dome C performances is

A THREE-MIRROR OFF-AXIS TELESCOPE DESIGN

optimized for low scattered light

low emissivity

wide field of view
Two-Mirror (M2 + M3) Corrector optimized across a FLAT 1x1 Deg² FOV for wide-field surveys.

F/8 System
Plate Scale = 10.31 Arcsec/mm
1x1 Deg² ≈ 0.35m x 0.35m FOV

Off-axis design providing unprecedented low emissivity, high sensitivity and photometric and angular resolution dynamic range.
OPTICAL PERFORMANCE ACROSS FOV

- DL@550nm = CIRCLE DIA 0.111” and DL@1000nm = CIRCLE DIA 0.201” for a 2.5M Telescope;
- RMS DIAMETER ~ 85% Encircled Energy;
- FLAT FOV OF ≈ 0.35m x 0.35m.
POSSIBLE UPGRADE TO A 4M

Two-Mirror (M2 + M3) Corrector optimized across a wide FLAT 1x1 Deg\(^2\) FOV;

F/10 System
Plate Scale = 5.15 Arcsec/mm;

1x1 Deg\(^2\) ≈ 0.7m x 0.7m FOV;
WHY OFF-AXIS in ANTARCTICA?

A high dynamic range design to be performance compatible to the BEST ground astronomical site!

- A telescope design that reduces the sources of light scattering

- Low emissivity

- A tremendous advantage for studies of faint planets near bright stars and faint nebulosity surrounding young stars, where planets may be forming

- 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) has been submitted to the French ANR - Assessment study (Langlois et al. 2013) – but not selected.

The proposition included the construction of 0.5-0.7m winterized prototype

**Partners** are:

- **CNRS-INSU**: CRAL (Lyon); Lagrange (Nice)
- **CNRS-IN2P3** : IPNL (Lyon)
- **SAGEM-REOSC**

It will be proposed to H-2020 (HFIO – IfA)

**For H-2020, More EU partners**
Conclusions

- The new generation telescopes and space missions requires **new survey tools in the NIR**

- The IR **atmospheric conditions in Antarctica are optimal** to carry out in the best conditions a new generation deep NIR survey.

  In the best site, we need the best telescope → **an off-axis concept with GLAO delivering the highest possible photometric dynamic range and angular resolution and wide-field imaging capabilities in the near and thermal infrared**

- **Data pipeline is a huge burden** that requires expertise of specific institutes (such as STScI, IPAC, LSST, CC-IN2P3-Lyon…)

- No single lab or even country can manage and carry out such a project

  International collaboration is therefore mandatory (Europe, Australia, China, USA….)

  **We are open to collaborations with other partners**
Thank you for your attention!

and thanks to the staff of the Concordia station!