ARENA
Interferometry Working Group

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• Science support team
  – O. Absil (LAOG, Grenoble): modelization
  – E. di Folco (Geneva Obs.): observing strategies
  – C. Eiroa (UAM Madrid): input catalog
  – F. Vakili (Fizeau, Nice): instrumental concepts
Mandate
Group activity

+ Documents available
The long term perspective

- Complex imagery capability at sub-mas resolution
  - Think of an optical ALMA (or VLBA)...

- Full-sky coverage
  - Enabled by uniquely large isoplanetic patch on Antarctic plateau

- Profoundly impacts all domains of astrophysics

- A massive, complex machine (post-ELT?)
  - Kilometric optical / IR array
  - Many telescopes, delay lines
  - Dual field for faint objects
What does it take to characterize exo-earths?
Caveat: exozodiacal light!

Source: DARWIN CV proposal
Even in visible light...

Cash et al. 2008
So, why an exozodi explorer?

Exozodiacal characterization [...] is critical for future characterization of habitable Earth-size planets.

Exoplanets Forum report (2008), p. 46

To optimize the definition and mission profile of a future space mission dedicated to the spectroscopic characterization of habitable planets:

– Correctly dimension the duration of the mission
– Prioritize systems for which exozodi is not the dominant noise source

To understand the exozodi phenomenon as a boundary condition of planetary systems formation

Building a pathfinder retires risk well ahead of the project and has to be seen as a sound investment towards a 1.5B€ space mission.
Ground-based European Nulling Experiment

- **Context:**
  - Potential need identified by ESA
  - ESO/ESA collaboration
  - 2004/2005: phase A study
  - Concept: VLTI L band nuller instrument
  - Performance constrained by environment
  - Complex (estimated cost 20M€)
  - Must compete with other users for access to facility

Detectability of exozodis for the 259 GENIE sources
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Detectability of exozodis for the 259 GENIE sources

Graph showing 0.5% stellar diameter accuracy with targets, K-types, and F-types.

- targets: 259
- K-types: 161
- G-types: 60
- F-types: 31
- with ATs: 2

Graph showing detectable exozodi level in solar units.
Site performance comparison

8m – Paranal

2 x 1m – Dome C

Performance comparison
8m @ Paranal vs. 1m @ Dome C

Absil et al. 2007, A&A 475, 1185
Site performance comparison

8m – Paranal

2 x 1m – Dome C

2 x 0.4m – Space

Performance comparison
8m @ Paranal vs. 1m @ Dome C vs. 0.4m in space

PEGASE simulation
Defrère et al. A&A 490, 43
The ideal interferometric precursor looks like...

FKSI

Danchi et al.
What is needed for an optimized exozodi pathfinder

- Go to the best possible location
  - Antarctic plateau features low thermal background and large $r_0$, long $l_0$, above ground turbulence layer
- Build a dedicated facility
  - Full access to observing time
  - Optimize design at the system level
  - No compromise due to integration into existing infrastructure
- Integrate development, deployment, operations into the concept
  - Realistically emulate a space mission (minus the launch)

**The ALADDIN approach**

(*Antarctic L-band Astrophysics Discovery Demonstrator for Interferometric Nulling*)
The ground layer issue

Weather constraints (winter)
- 18m height => ~50% of down time in winter (seeing)
- Limitation: time frequency of good seeing periods

Graphs showing probability of being in free atmosphere and duration of continuous seeing period.
Strawman Design - Infrastructure

Claude Jamar
Contents

Principles
Instrumental parameters
From bottom to top:
  Interface with compressed snow
  Circular track
  Track and bogies
  Wheels and bogies
  Leveling
  General view of the bottom of the system
  Telescopes
  Nulling instrument
Instrumental parameters

Baselines: from 3 to 30m
Altitude above the snow level: 18m
Telescope diameters: 1m
Waveband: 3.1 – 4.1 µm (L-band)
Warm optics temperature >210K
Cryogenic temperature of the detectors: 100K
Fringe sensing: 2.0 – 2.4 µm (K band)
Tip-tilt sensing: 1.15 – 1.3 µm (J band)
The ground surface at Dome C is made of compressed snow with a density of a maximum of 800 kg/m³.

The structure will be deposited on the snow surface on 3 feet such as the Concordia station buildings themselves. The pressure accepted by the snow layer being 0.2 bar, the load shall be kept below 2 tons/m².

For a typical mass of the structure e.g. 120 tons, the total interface area shall therefore be 60 sq.m.

Each foot of 20 sq.m has to be adjusted to keep the track horizontal.
Circular track

An annular structure supporting a track which allows the azimuth motion

The diameter of the track has to be about 8m with flatness of about 1 mm/m. The track is about 4m above the snow level and lies on a cylindrical annulus structured to allow wind to pass through the structure and avoid the accumulation of snow.

The horizontal position of the track is measured by inclinometers providing the information needed to actuate the motors of the feet.

The track of hardened steel material shall be made of pieces which can be accommodated in standard containers. It will be reassembled on the site.
Track and bogies

- The angle between the plane defined by the track and the horizontal plane is smaller than 10 arcmin (3 mm/m).
- The annular track is radially interfaced to a central bearing with a central annular encoding facility to define the position in azimuth of the superstructure.
- The general strategy of leveling is:
  - At very low frequency (once every day/week?) the level is got by the 3 main feet.
  - During the azimuthal rotation, the level is got with a bandwidth of few Hz by the active bogies.
- The vertical flexure between feet of the annular structure is compensated by the active bogies.
Telescopes

Each telescope is mounted on a trolley. The trolley is a transporter of the telescope, equipped with wheels; it circulates on a railway on top of the structure. One wheel of each trolley is equipped with an encoder. The system will be allowed to stop anywhere along the rails. Position of the trolley measured by a HP laser interferometer (inspired from MRO telescopes).
Telescopes

Errors on the absolute distance between the telescopes and on their stability have to be compensated by the tip-tilt system.

Trolleys are equipped with an enclosure which protects the optical system from weather, strong winds and snow falls. The enclosure could take the shape of a half cylinder similar to “far west wagon”.

(posed from MRO telescope)
General view
P. Bienvenu
T. Déchelette
Thalès
General Status

In progress:
- Design of the beam structure
- Design of telescope trolley and telescope
- Concordia-testing frost-repellant coatings

Could be made in 5 years after preliminary tests and K.O.

Electric consumption is not an issue (motors at very low speed, some sensors, actuators and detectors, small vacuum pump with limited duty cycle and cryocooler [500W])

Data flow is not a problem: the altitude of the telescopes doesn’t allow to work continuously

Mass should be kept below 120 tons
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ALADDIN instrument

Marc Barillot
Conceptual ALADDIN instrument

- Moderate volume
- Moderate power consumption
- Moderate data rate

- Intensity actuators
- Tip-Tilt Sensors
- OPD Sensor
- OPD Detector
- Science Detector
- Science Beam Combiner
- APS
ALADDIN-I Environmental issue

No human intervention on site
– Fully automatic / Remote controlled operation
– Human intervention limited to within Concordia station
  (final validations/adjustments before transport to site and integration).
– Regular roomspace only from Concordia (no Cl.100 clean rooms !)
– Extensive expertise of space industry in that matters

Environmental impact = that conventional equipment
– In operation, always inside cryostat
– Relevant complete validation in temperate site
Development issues

MAI² heritage
- Nulling level and stability demo.
- Unpolarised polychromatic source

PERSEE heritage
- Stability demo with perturbations
- Relevant / available for ALADDIN

• VLTI/GENIE Heritage
  - Existing preliminary design data package
  - GENIEsim software
  - Most of GENIE Team available
Conclusion

Realistic & reasonable nulling instrument thanks to Dome-C atmosphere and design

Antarctica Compatibility: like any other instrument

Strong heritage & experienced team

Ready for a Preliminary Design Study
Relevance for Space

Fully relevant precursor for Medium-class missions
– Ref. Pegase/FKSI
– 2-beam (Bracewell)
– MWIR
– Similar nulling/stability

Relevant development step for exo-Earth mission
– X-array based on 2 Bracewells
– Comparable operations
  • Control loops
  • Observations (calibration, programme)
  • Data processing
Cost issue

References
- Typical ROM-Cost of a nulling breadboard: ~1M€
- Typical ROM-cost of a spaceborne nulling instrument: 60M€

Comparison with a space instrument development costs
- No launch environment requirements
- No space environment requirements (thermal / radiations…)
- No multiyear reliability requirements
- No technology/process/components limitation (electronics/computing !)
- Virtually no mass/power/data rate constraints (even in Concordia !)
- No need for environment representative demos in the lab
Conclusions

The magic science case: detection and characterization of exo-zodis

ALADDIN is a technologically feasible project under Antarctic conditions

Phase A industrial study of a precursor interferometry mission is a must:

- benefits from existing synergies
- to get a realistic cost estimate
- better knowledge of interferometric conditions in Antarctica versus astronomical temperate sites
- relevance of building in the future a KOI

Measurements of $|0\rangle$, etc. are badly needed!
Conclusion

An “unavoidable” science case…
...for which Antarctica may provide an optimal answer
Certainly not a crazy idea
Builds on many synergies
Fits into “reasonable” Dome C logistics
...and probably not exclusive of other Dome C projects