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SAFETY AT HIGH ALTITUDE; DEALING WITH THIN AIR AND REMOTENESS

Jacques Lassalle
Atacama Large Millimeter Array

Rodrigo Sandoval
Gemini Observatory

Content:

1. Introduction
2. The atmosphere around us
3. High altitude sickness and pathologies
4. Administrative controls
5. Preventive actions
6. ALMA Biomedical research case

1. Introduction

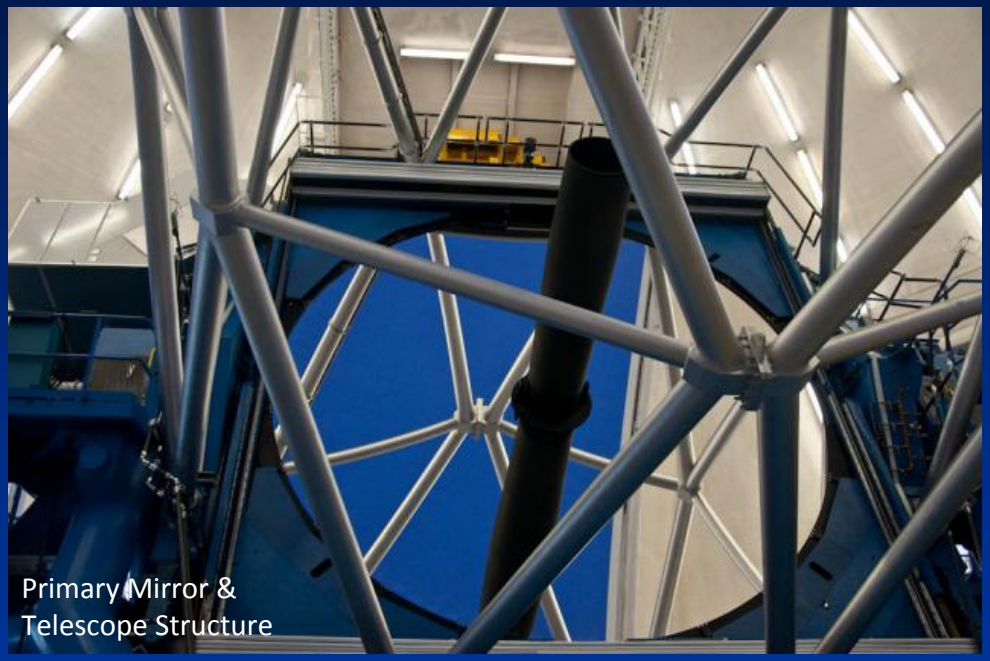
Chajnantor plateau –16500ft / 5050masl

Mauna Kea – 13824ft / 4213masl

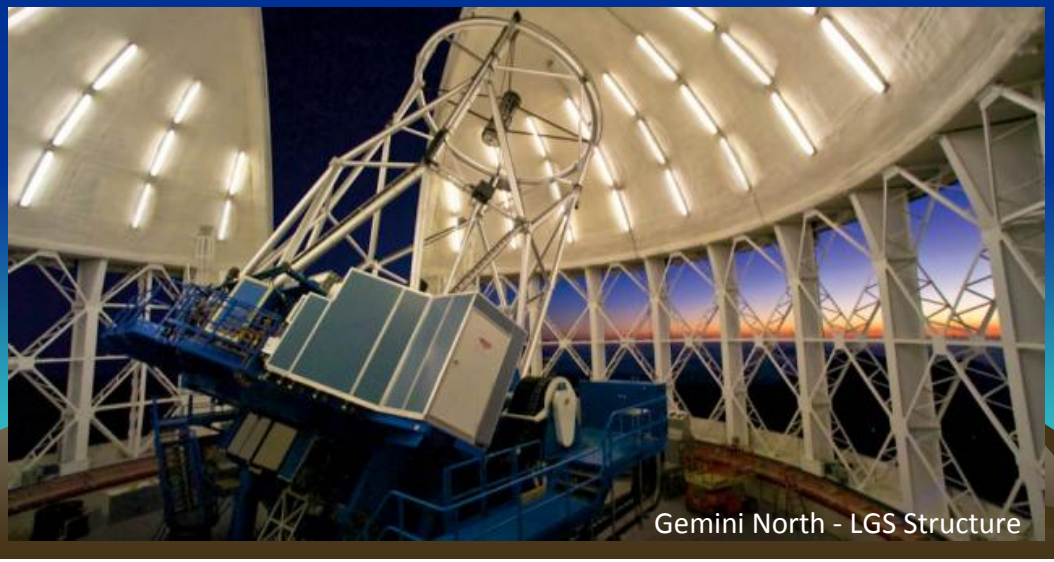
Enjoy the ride !

ft = feet / masl = meters above sea level

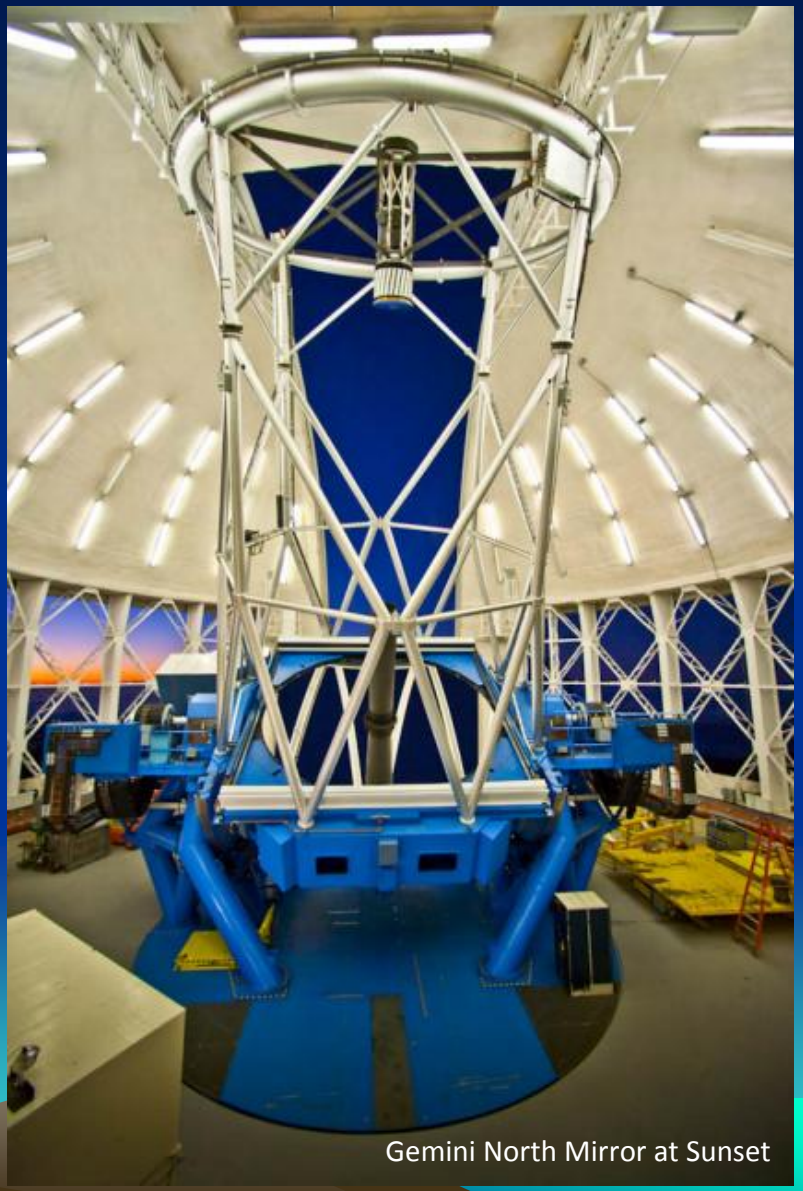
Gemini Telescope Interiors



Primary Mirror &
Telescope Structure



Gemini North - LGS Structure

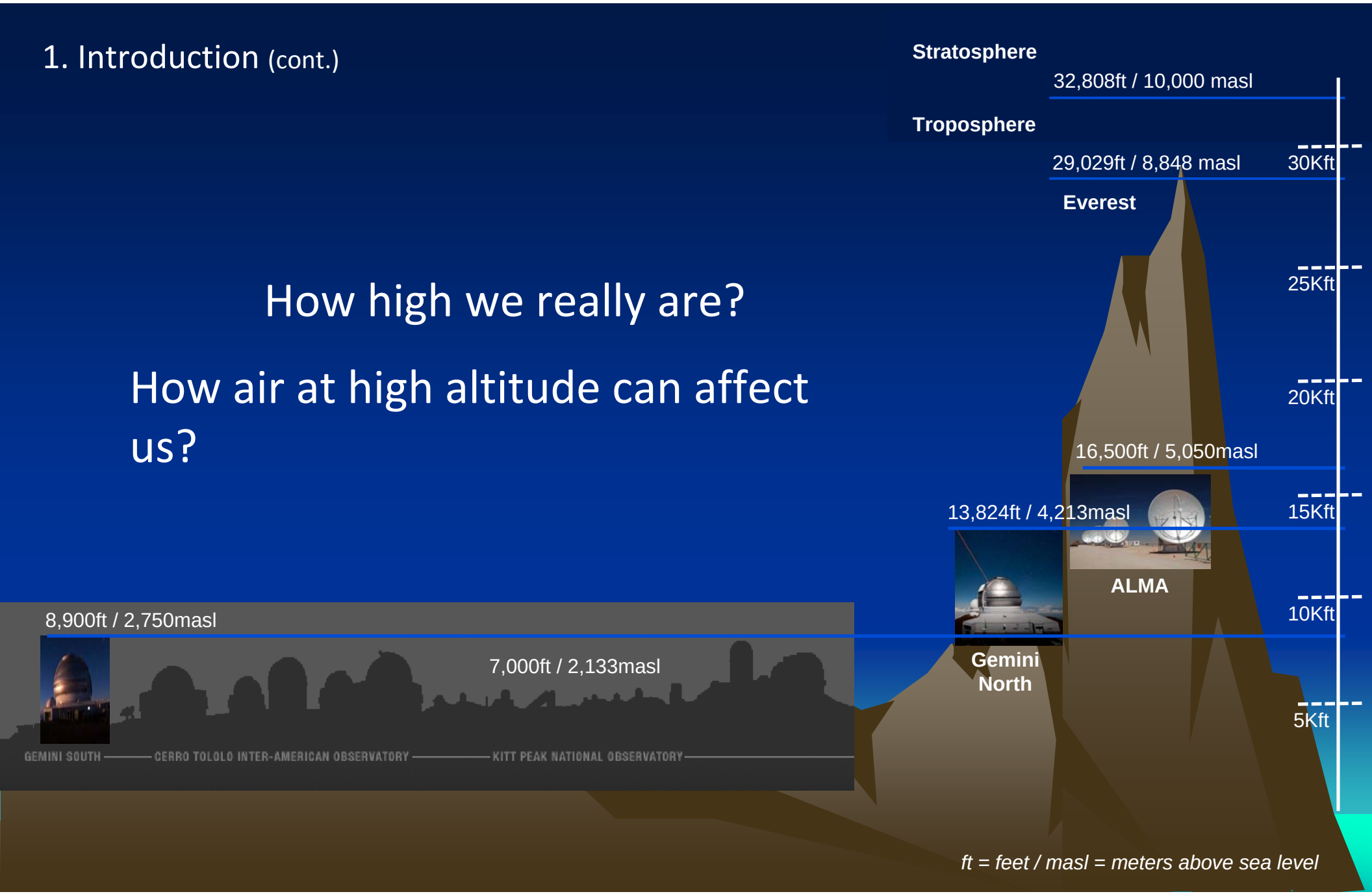


Gemini North Mirror at Sunset

1. Introduction (cont.)

How high we really are?

How air at high altitude can affect us?



Gemini Telescope Exteriors

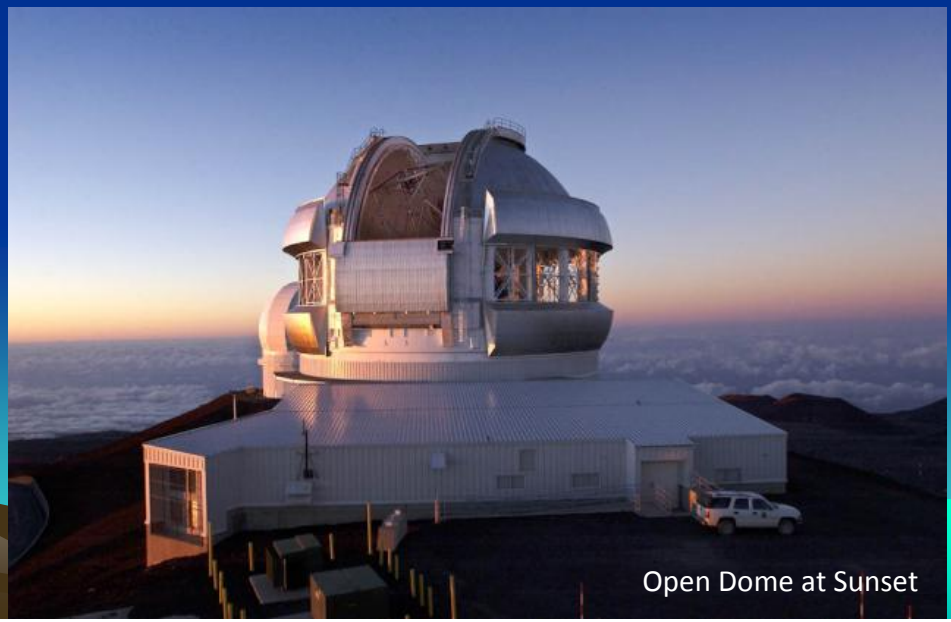
Safety at High Altitude;
dealing with thin air and remoteness

Gemini North Laser
Guide Star (LGS) System

Sunset From CFHT

Gemini North with star trails

Photo © Richard Wainscoat



Open Dome at Sunset

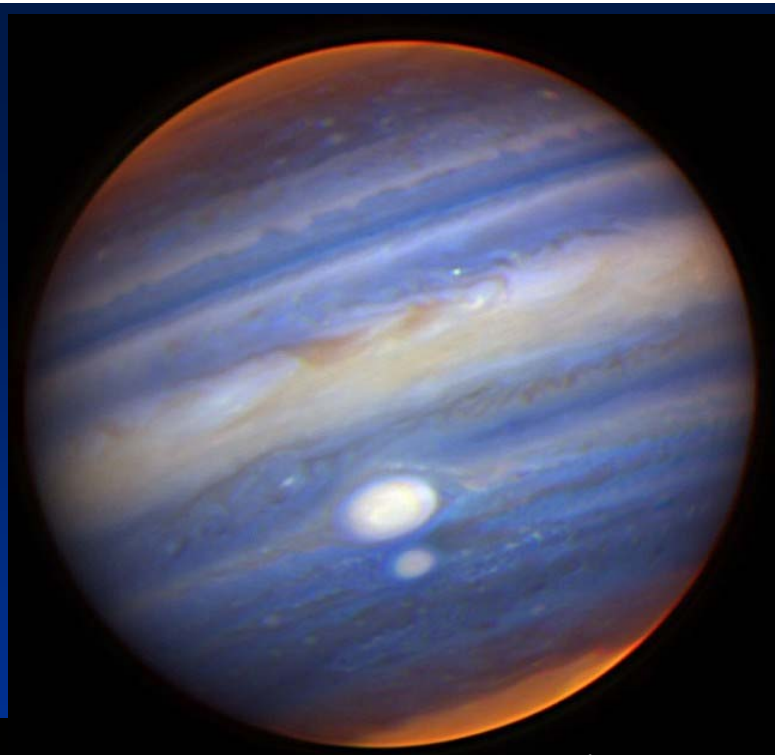
2. The atmosphere around us

• Miners (2k years ago) – when torch flickered and went out would become sick or die – first connection between air, combustion and life.
• Aristotle (300 BC) – "every body has weight, except fire, even air. It is proof that an inflated bladder weighs more than an empty one" – ***air was only the invisible, impalpable substance in which we all live.***
• Isaac Beeckman (1618) – "it happens that air in the manner of water, presses upon things and compresses them"- Physical properties of air were appreciated.
• Gaspar Berti (1638) – proved air had weight and a vacuum could exist – 1st primitive barometer.
• Evangelista Torricelli (1643) – ***1st mercury barometer***.
• Florin Perier (1648) – took 3 Torricellian barometers at top of the small mountain *Puy de Dome* and showed that atmospheric pressure decreased with increasing altitude – ***altimeter was born!***
• Lavoisier and Priestley (1976) – Isolated pure oxygen.

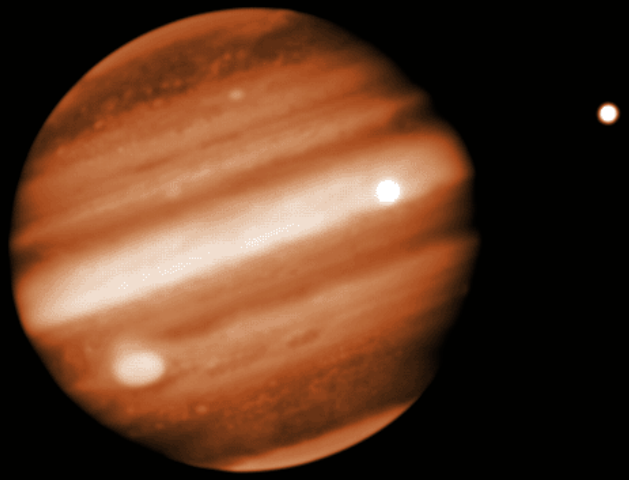
"Who can tell but that, in time, this pure air may become a fashionable article of luxury…"

Solar System

Saturn & Titan

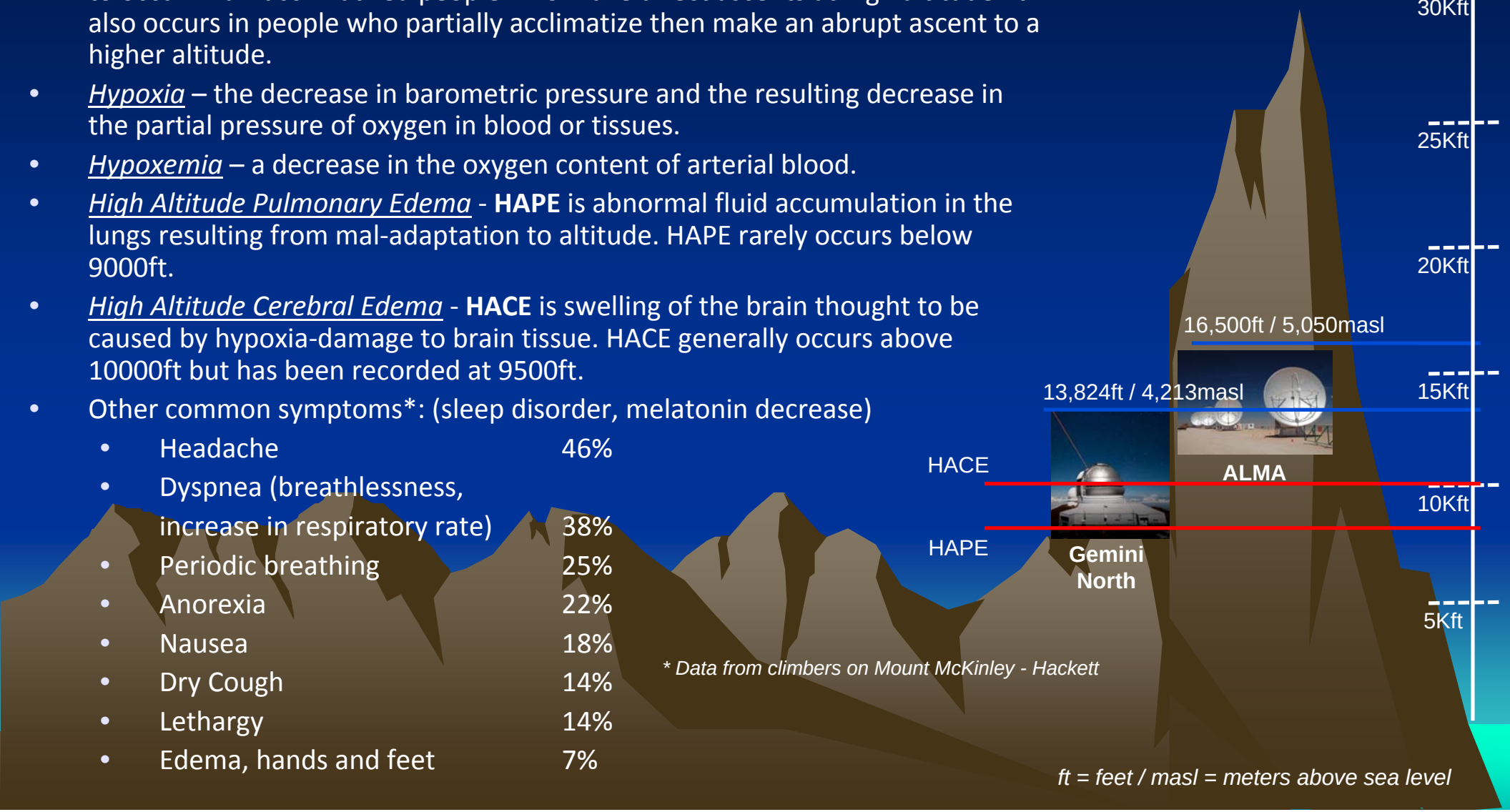


Jupiter's Red Spots



3. High Altitude Sickness and Pathologies

- *Acute Mountain Sickness* - AMS is a term applied to a group of symptoms likely to occur in un-acclimatized people who make direct ascents at high altitude. It also occurs in people who partially acclimatize then make an abrupt ascent to a higher altitude.
- *Hypoxia* – the decrease in barometric pressure and the resulting decrease in the partial pressure of oxygen in blood or tissues.
- *Hypoxemia* – a decrease in the oxygen content of arterial blood.
- *High Altitude Pulmonary Edema* - **HAPE** is abnormal fluid accumulation in the lungs resulting from mal-adaptation to altitude. HAPE rarely occurs below 9000ft.
- *High Altitude Cerebral Edema* - **HACE** is swelling of the brain thought to be caused by hypoxia-damage to brain tissue. HACE generally occurs above 10000ft but has been recorded at 9500ft.
- Other common symptoms*: (sleep disorder, melatonin decrease)
  - Headache 46%
  - Dyspnea (breathlessness, increase in respiratory rate) 38%
  - Periodic breathing 25%
  - Anorexia 22%
  - Nausea 18%
  - Dry Cough 14%
  - Lethargy 14%
  - Edema, hands and feet 7%



** Data from climbers on Mount McKinley - Hackett*

ft = feet / masl = meters above sea level

Nebulae, Cluster & Star Formation

NGC 3582 - The Heart of a Stellar Nursery

Orion Bullets

Chinese Dragon NGC 6559

4. Administrative Controls

High Altitude Medical Exam	
High altitude risk information	
Physical recommendations before ascending	
Waiver and release	
Cold Weather Gear	
Acclimatization	
Use of oxygen	
Escort (2 man rule)	
2 hours max at the high site (visitors only)	X
OSF paramedic screening	X

Galaxies & Distant Universe

Galactic Waltz NGC 1532-31

Stephan's Quintet

Twin Galaxies NGC 5426-27

5. Preventive actions

Physical condition check
Medical contraindications
Acclimatization
Hydration
Oxygen
Sun radiation
Emergency procedures

- 3 lts/min of O2 application increases O2 hemoglobin saturation: After one minute the improvement appears
- After one minute of oxygen application (3 lts/min) the heart rate decreases significantly, particularly in subjects with tachycardia.
- After 10 minutes of oxygen application (3 lts/min), hypoxia symptoms practically disappear.
- After 15 minutes of oxygen application (3 lts/min) the worker is prepared to gradually return to his tasks.
- Among analgesics provided at Chajnantor, a one-time doses of 500mg of Paracetamol and 400 mg of Ibuprophene showed the best results…

Before Ascending:

- Spend one night at approximately ~ 9000ft (e.g. Calama, St Pedro de Atacama or OSF) before ascending in order to help acclimatize.
- Limit outside work hours at high site. Do not drive after long stay
- You must not be suffering from any acute respiratory infection.
- Eat a light breakfast and start early in the morning.
- ALMA provisions water to the staff.
- Drink abundant water (not less than 3 L daily) without carbonation, or gas, during the trip
- Natural fruit juice is recommended.
- Hydration should be self controlled by urine observation. Urine being nearly colorless indicates appropriate hydration.

Safety at High Altitude;
dealing with thin air and remoteness

ALMA

OPERATION SUPPORT FACILITIES

OSF site -9500ft

ALMA

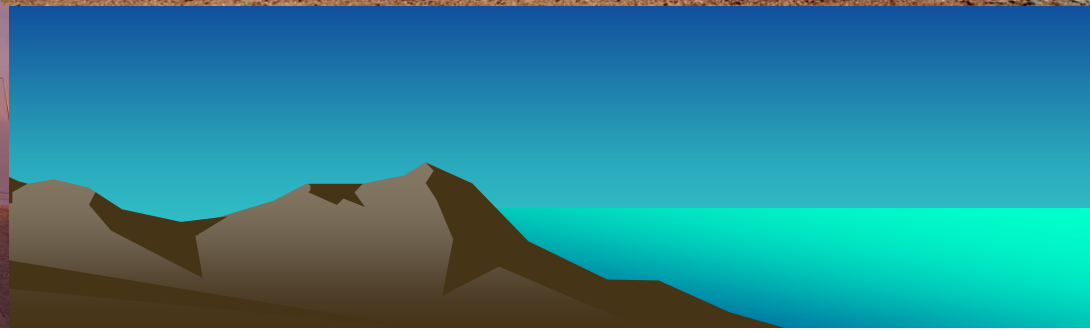
- The Atacama Large Millimeter, Sub Millimeter Array (ALMA), one of the largest ground-based astronomy projects of the next decade, is a major new facility for world astronomy and the principal objective is the installations of the 66 antennas.
- ALMA is located on the high-altitude Llano de Chajnantor (16500ft), east of the village of San Pedro de Atacama in Chile.
- The ALMA project is a partnership between Europe, North America and Japan in Cooperation with the Republic of Chile.

ATACAMA DESERT NEAR SAN PEDRO

Safety at High Altitude;
dealing with thin air and remoteness

ARRAY OPERATION SITE – 5050M ~16500FT

OPERATION SUPPORT FACILITIES (OSF)



Extreme environments characteristics

- Oxygen, air dryness, thin air and remoteness , solar radiation, temperatures, and psychological reactions to these items.
- The most important challenge to the well being of workers performing work at the ALMA High Site is the relative lack of oxygen.
- To some extent, all workers will suffer physiological and metabolic changes that diminish the capability to perform both physically and mentally.
- These physiological & metabolic changes also contribute to risk of severe high altitude related diseases. Considering the nature of construction, this increases the chance of having accidents.
- Trauma at altitude is difficult to manage due to the environmental challenges that high altitude offers for medical rescue.

ARRAY OPERATION SITE

Safety at High Altitude;
dealing with thin air and remoteness

ARRAY OPERATION SITE - AOS/TB

Safety at High Altitude;
dealing with thin air and remoteness

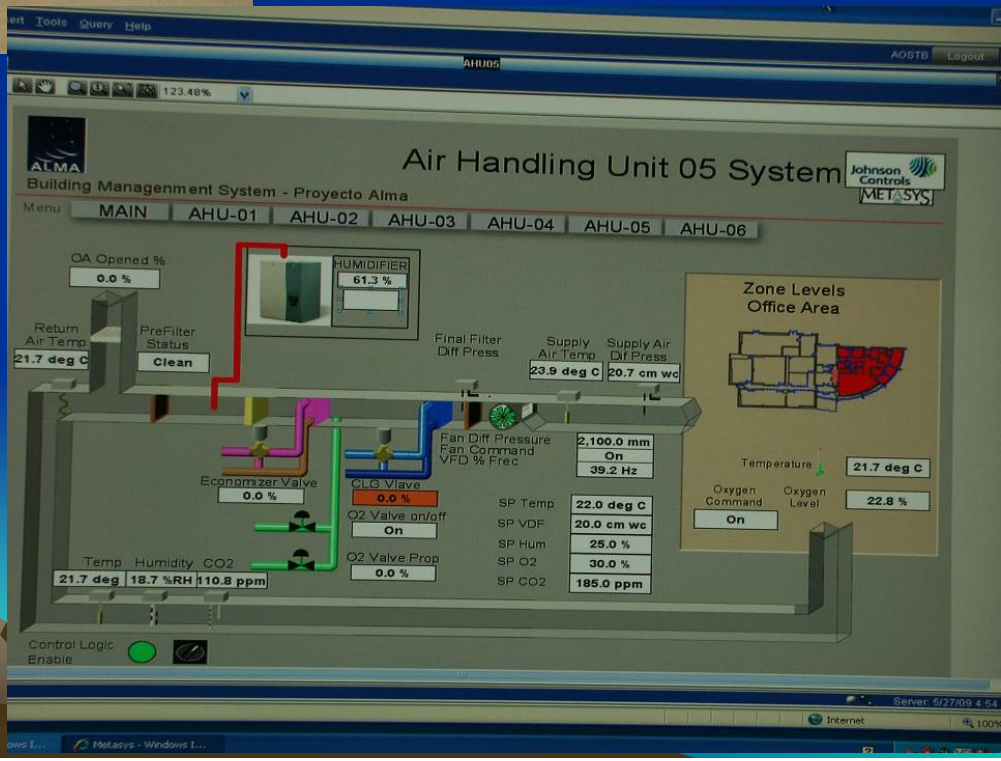
Oxygen Use at Chajnantor

Aerosol O2

2 types oxymeters
NONINO (black)
and HEAL FORCE

415 L Type D
248 L Type C
815 mL Can

O2 bottles/ regulator



Antenna move – (16500ft)

All human work, including own
- maintenance
- reparation and
- operation

requires energy in form of adenosintriphosphate (ATP)

To produce ATP,
oxygen is required

The lack of oxygen in relation to ATP demands = hypoxia and oxidative stress

The lack of ATP in relation to work related ATP demands = fatigue.

Hypoxia, thus implicates fatigue

- At high altitude Free radicals, derivative of O2, which are produced by hypoxia condition, are highly damaging lipid, protein and nucleic effects. In order to maintain a good balance and prevent an excess of free radicals, the antioxidant capacity of the body has to be reinforced by supplementing vitamin E, C and possibly Melatonin.
- Melatonin increases at night in order to guaranty the sleep and decreases by day to allow alertness, which depends on blue light.
- However blue light decrease at high altitude. Alternative source of blue light is needed.

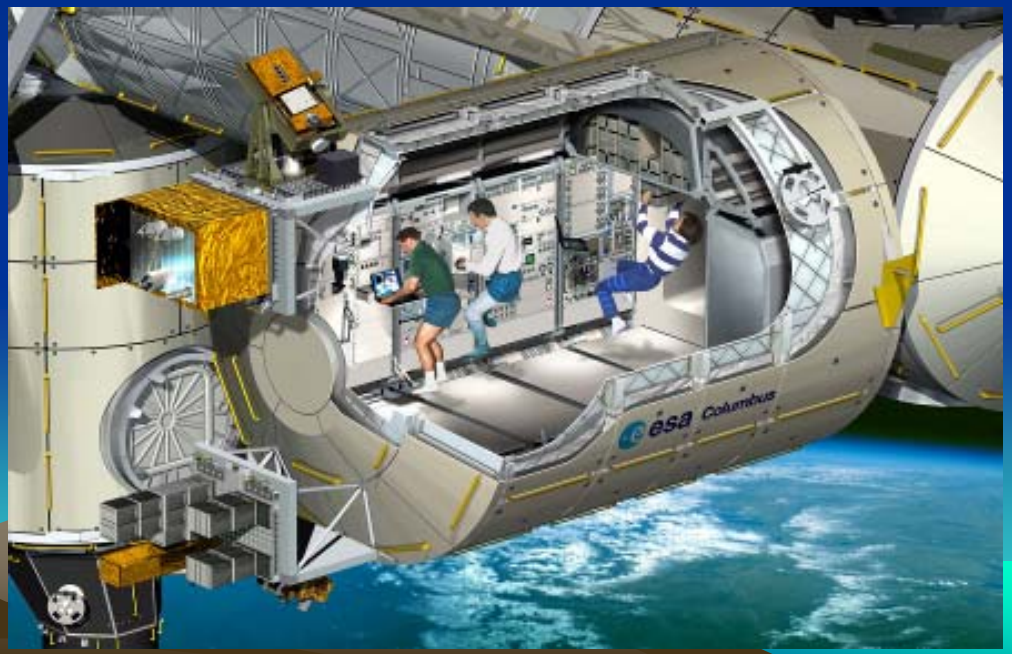
BIOMEDICAL RESEARCH

- Dr Claus Behn in charge of “Physiology & Biophysics program at UC, is the PI of a biomedical research funded by FONDECYT (National organism for promoting Science and Technology in Chile.

- The program consist in a continuous and systematic survey of objective biomedical data in subjects working at HA, to allow developing a data base, as a solid background for further decisions in the permanent process of improving human health and performance in subjects working under that condition.

BIOMEDICAL RESEARCH

Health, safety and work performance at high altitude (HA) can be optimized on the basis of objective biomedical data obtained *in situ*. For adequate handling of acute problems, as well as, for prevention of possible complications in the long term, specific information on human tolerance to local conditions is needed. Relevant biomedical data can nowadays be obtained *in situ*, without affecting usual activities, even in Space.

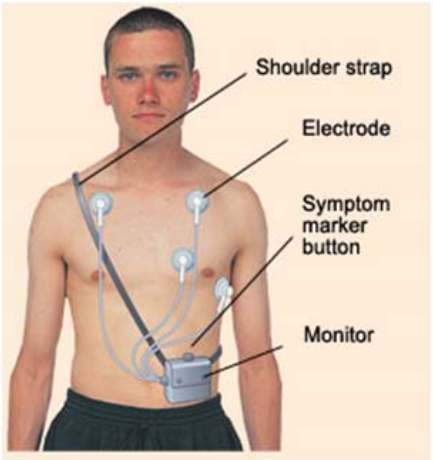


OBJECTIVE OF THE PROJECT

- **The present project proposes** to study whether high altitude (HA) effects on human wellbeing and work performance may involve circadian rhythm disruption (A **circadian** rhythm is a roughly 24-hour cycle), as potentially induced by hypoxia, oxidative stress and lack of blue light discrimination. New perspectives could thereby emerge in order to optimize HA as a safer and, therefore, also as a more productive environment.

BIOMEDICAL RESEARCH

- **Antennas Transporters drivers and auxiliary personnel will non-invasively be monitored** during work and rest for a total period of four years.



BIOMEDICAL RESEARCH

- **Data collection** to be realized under above conditions refers to

a) **Circadian rhythm evaluation**: 24-h locomotors activity by actigraphy; 24-h continuous core temperature recording by either ingestible radio capsules and/or a newly developed thermo-helmet; 24-h heart and respiratory rate and rhythm variability by Holter recording (ambulatory electrocardiography device);

b) **Metabolism and redox state evaluation**: basal breath-by-breath oxygen consumption, 3x/"test" journey; exhaled breath condensate analysis including lipid peroxidation products, biomarkers and hormones 3x/"test" journey); brain and digital oximetry, 3x/"test"journey,

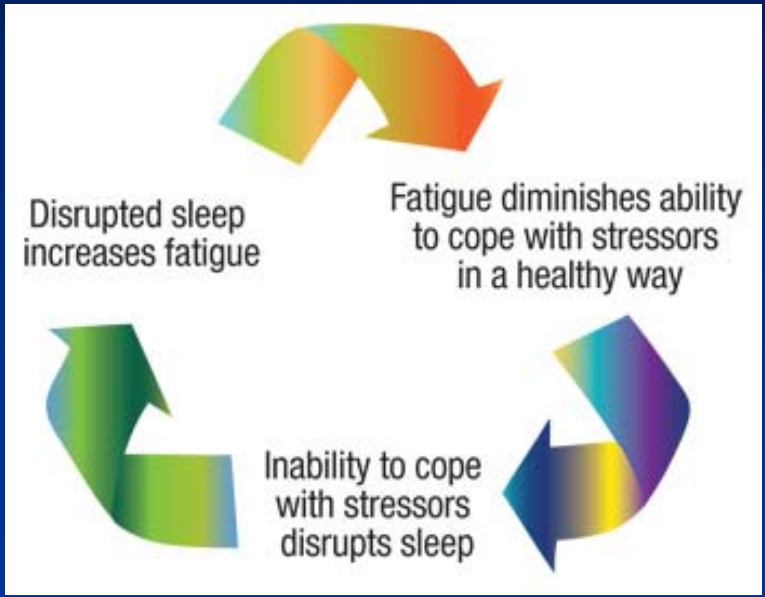
BIOMEDICAL RESEARCH

- **Work performance relevant parameters:** 5-h drivers seat actigraphy;
- 5-h electro/oculogram (eye blink rate); color vision test and pupillary reaction to light, 3x/"test" journey; psychophysical evaluation, 3x/"test" journey
- **On a total of 120 "test" journeys**,
- **All techniques considered for application in the present project are non-invasive** and harmless, but rendering records of high informative contents.
- Effects of any change of environmental conditions (i.e. blue light, oxygen, melatonin etc.) on biological clock function and thereby on sleep-wake cycle can be tested on the basis of objective data obtained individually at the proper workplace.
- Does sojourning between sea level and an altitude of 3,000 m asl affects the sleep-wake cycle by altering endogenous biological rhythm synchronization?

  This is to be investigated by a non-invasive follow up of actigraphic, electrocardiographic and oculographic parameters, as well as vision diagnostics, both at work and during rest.
- **The impact HA may have on body time Sleep-wake cycle alterations and their possible relation with biological rhythm desynchronization**

BIOMEDICAL RESEARCH

Somnolence during work and insomnia during rest constitute main complaints of lowlanders when exposed to high altitude (West, 2004; Mortola, 2007).



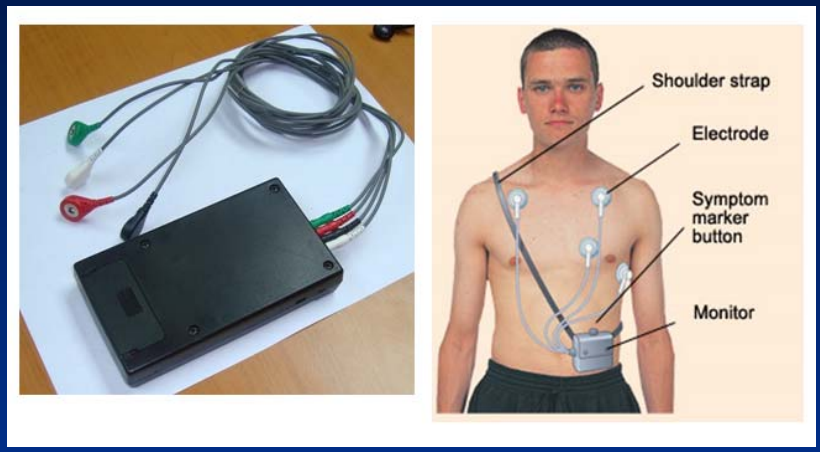
The vicious, self-sustaining cycle of sleep disturbances and fatigue
Sleep quantity and quality during the resting period has therefore, to be given the uttermost attention.

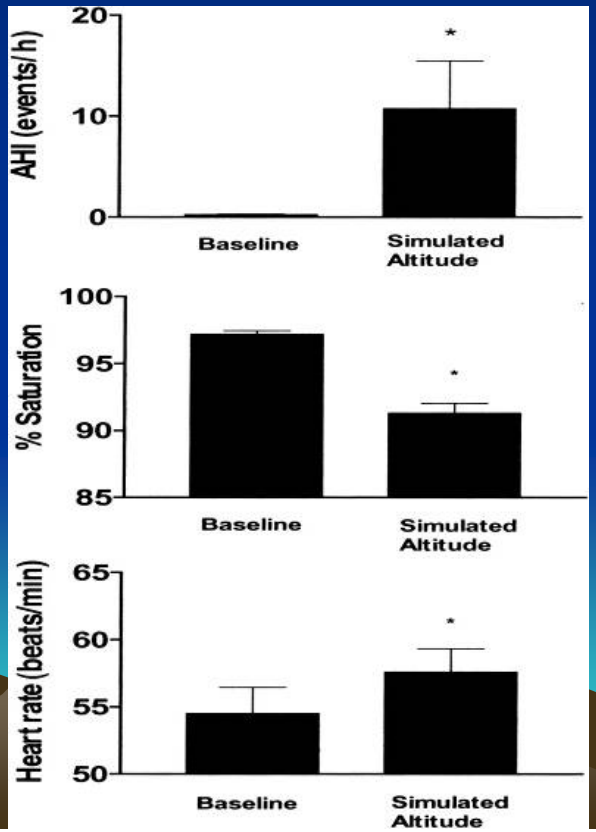
Individual susceptibility to sleep disturbances at HA can non-invasively be detected by actigraphy i.e. application of accelerometers

BIOMEDICAL RESEARCH

- **Portable electrocardiography (Holter method)**

Continuous monitoring of heart rate (HR) and heart Rate variability (HRV) will be done by applying Holter electro-cardiographic devices.

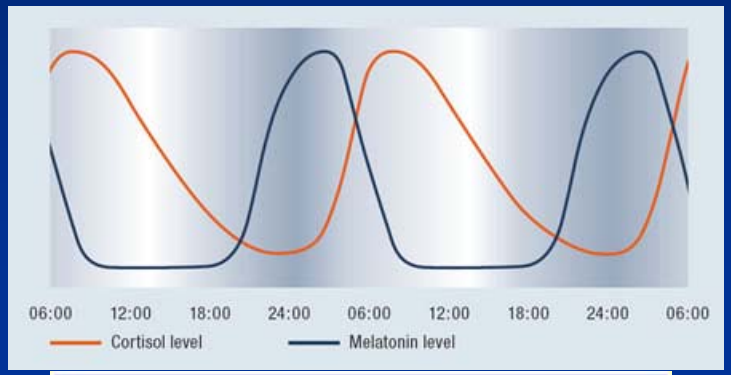




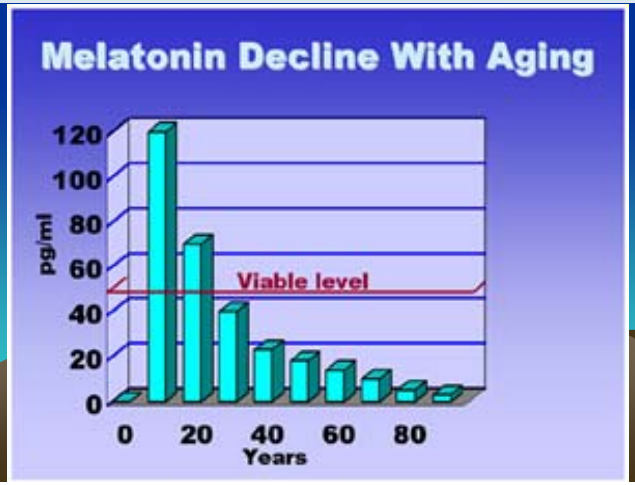
- **(AHI) Hypopnea/apnea episodes** (irregular respiration) potentially affecting sleep quantity and quality occur in young healthy men already at an altitude of 2,650 m asl (Kinsman et al., 2002)
- **hemoglobin desaturation and heart rate increase in men exposed to a simulated altitude of 2,650 m asl**

BIOMEDICAL RESEARCH

- **Respiratory and, thus, sleep disturbances** have opportunely to be detected
- Sleep alterations at HA can further be envisioned on the basis of endocrine sleep control.
- **Biological clock alignment implicates a role of the pineal hormone melatonin** (Arendt, 2006) the latter hormone preparing the body for sleep.
- **Epiphyseal melatonin secretion** increases in the dark and is suppressed by light in opposition to Cortisol cycling.

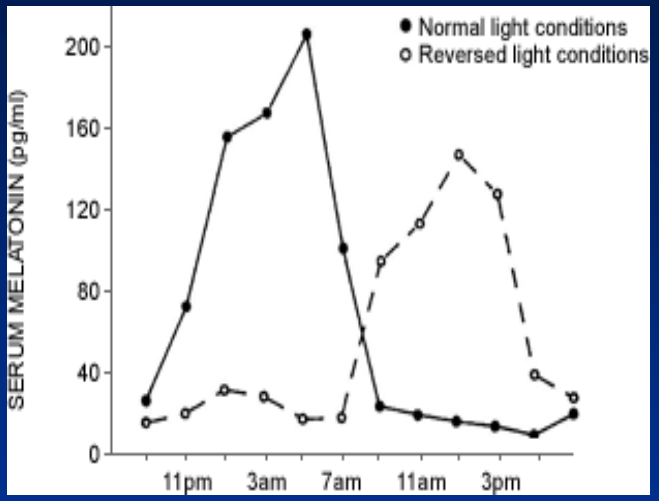


Light-dark related cycling of melatonin and cortisol
At HA, melatonin secretion appears to be altered (Kaur et al., 2002; Frisch et al., 2004). Nocturnal melatonin secretion decreases (and insomnia increases) with age and increases with lack of light during the waking period (Reiter et al., 2002).



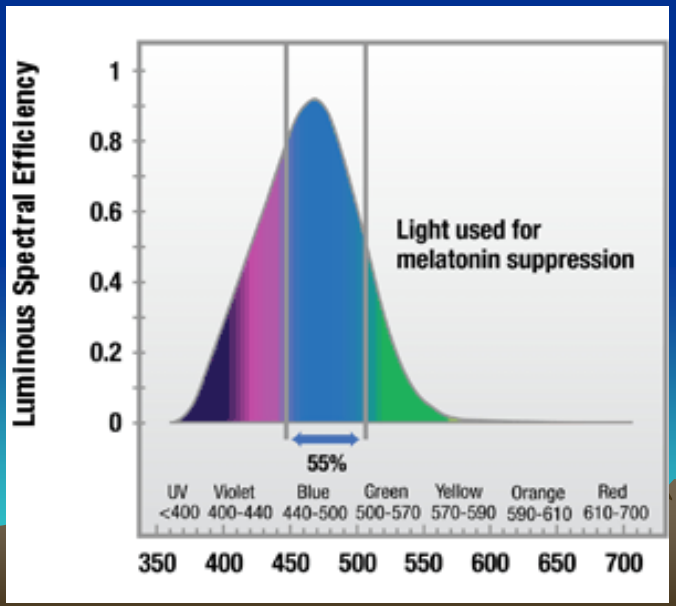
Melatonin declining with aging

BIOMEDICAL RESEARCH



Melatonin levels as appearing inversely related to alertness (Arendt 2002)

Melatonin secretion can be suppressed during nocturnal work by adequate lightning, a rebound effect being observed in that case during the following rest period, potentially thus favoring sleep quantity and quality during the latter



- Melatonin secretion is mainly suppressed by blue-light (Brainard et al., 2001a; Brainard et al., 2001b).
- Reduction of melatonin secretion during the work improves sleep quantity and quality for the resting period if the latter is carefully prevented from any blue light impact.
- Additionally, melatonin supplementation during the resting period can be considered in order to adequate circadian rhythms for health and safety.
- Melatonin is also considered to represent a natural antioxidant (Susa et al., 1997).
- Specifically the shorter wavelengths of the visible spectrum (blue light) may be involved in suppressing melatonin secretion (Hoang et al., 2008).
- Blue light sources (e.g. Litebook), is easy to be applied even in driver cabins

BIOMEDICAL RESEARCH

Oculography Pilot fatigue

- A decreased blinking amplitude corresponds with an increased number of errors (Morris TL, MillerJC, 1996, *Biol. Psychol.* 42, 343-60).
- The degree of mental fatigue will be evaluated by continuous evaluation of ocular movements as recorded by reflectance of infrared light as used by the Optalert® system (Michael et al., 2008)

- HA-related defect in blue axis discrimination at HA may alter non-visual brain responses to light, among them some cognitive functions, as well as circadian rhythm control.
- Activation of the melanopsin photoreceptor system by blue-light (480 ± 20 nm) is supposed to mediate non-image forming photo-reception, related to pupillary constriction and circadian rhythm control.
- Defects in blue-light discrimination (perception) at HA, thus, could be *related* to circadian rhythm alterations under the latter condition. Blue-light discrimination will be tested in the present case by a computer-assisted version of the Mollon-Reffin Minimalist test itus)

BIOMEDICAL RESEARCH

- **Pupillary light responsiveness** will be tested 3x/"test"journey by computer-assisted video pupillometry.
- **Circadian changes of melatonin levels** Saliva, urine, and/or exhaled breath condensate (EBC) will be sampled at appropriate time.
- **Exhaled breath condensate (EBC)** For evaluation of oxidative stress and some hormonal and metabolic parameters will be analysed.
- **Core temperature** 24-h recordings will be realized by using Ingestible Core Temperature Capsules and /or the Thermo-helmet recently developed by Pr.Gunga.
- **Basal breath-by-breath oxygen consumption**
- **Brain and finger oximetry** will be realized

Quasar & Deep Galaxy Field

Questions ?

Thank you and be safe !