A unique opportunity in Europe

to explore extended windows in the UV and IR spectrum for stellar and solar astronomers

HFSJG Historic Site Symposium

University of Bern
7 February 2019
Michel Grenon

Atmospheric properties at high altitudes

an ancient field of research at Geneva

H.-B. de Saussure by St-Ours (1796)

Relations

Pressure vs altitude (barometric law)
Temperature vs altitude (thermometric law)
precisely established by the J.-A. Deluc in 1760.

Confirmed for the full altitude range 300 - 4800 m
by H.-B. de Saussure in 1787.

High accuracy tables Absolute Hygrometry vs T and H%
(precipitable water) by Saussure in 1783.

Derived properties observed in altitude

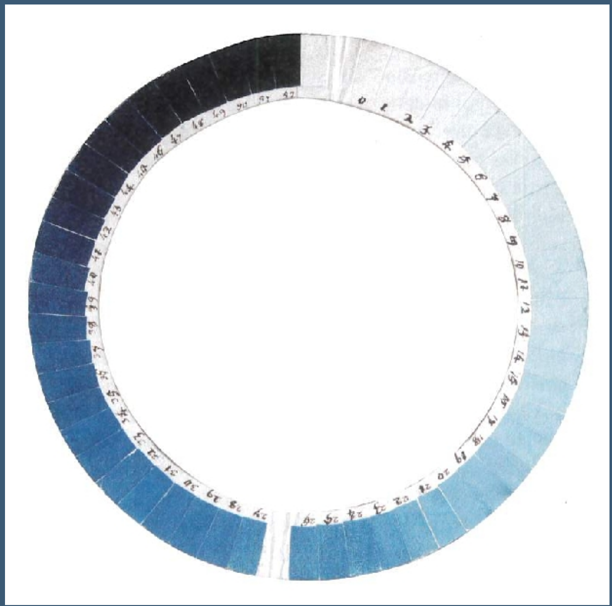
Sharp decrease of the scattered light above the haze layer
Sharp decrease of relative humidity above the haze layer
Daily temperature range decrease with altitude

Consequences

Decrease of stellar scintillation with altitude
Decrease of star image size
Increased visibilty of faint stars

The vertical structure of the atmosphere

an instrumental approach



The Saussure cyanometer with 52 steps of blue used during the second ascent of Mont Blanc in 1788.

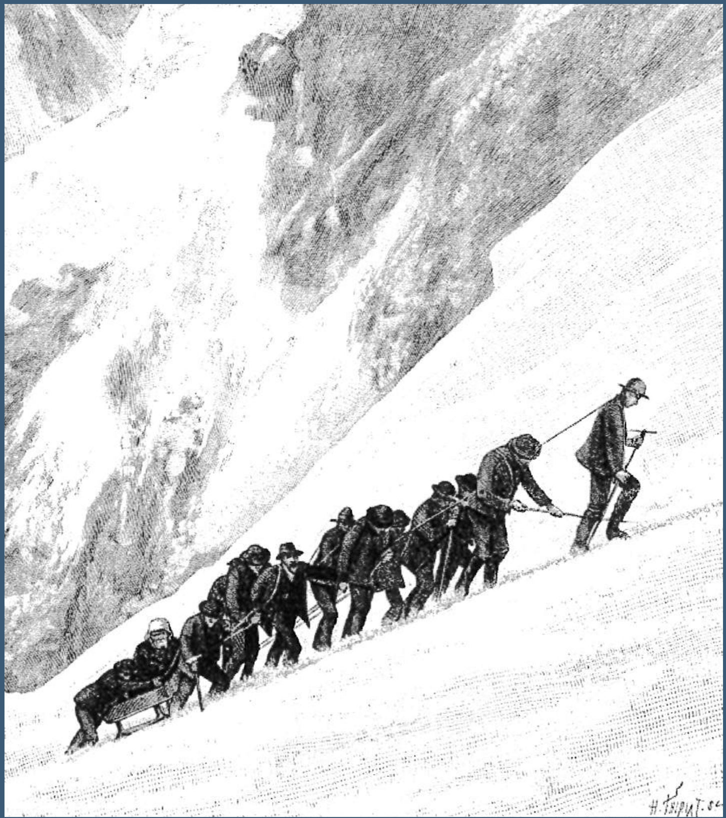
The whiteness increases with the number of molecules and dust particules on the line of sight.

The haze layer in Mont Blanc area under anticyclonic situation, similar to that observed during the second ascent of Mont Blanc.

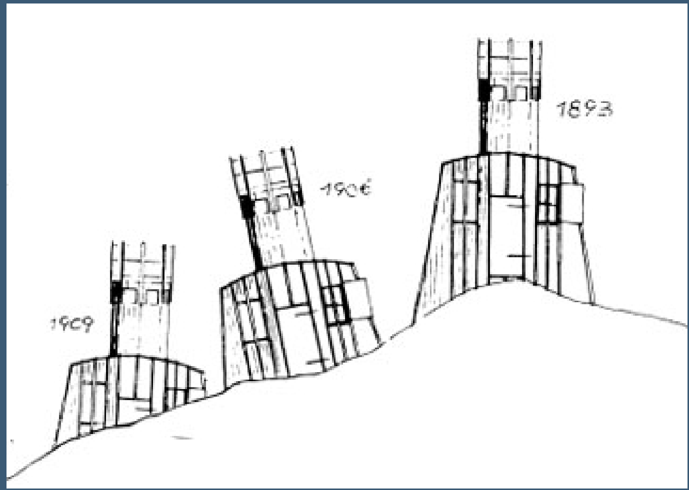
The haze layer (couche sale for Saussure) expands during the day. The dust and humidity sediment during the night. The air is dry and the transparency high above 2300-2500m the minimum altitude for an observatory

The Mont Blanc, an inaccessible ideal

until Janssen's Observatory near the top



The 1890 expedition to Mont Blanc, an ascent in a 12 men traction sledge for the Director J. Janssen.



Built inside the glacier, inaugurated in 1894 and abandonned in 1909, crushed by the ice.

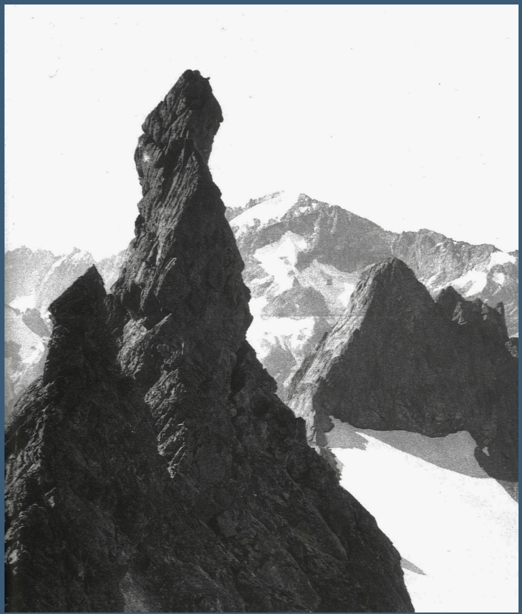
The precursor to the Junfraujoch station

Studies at 33 cm telescope, siderostat and spectrograph :

- solar spectrum in UV, Visible and IR
- atmospheric ozone
- solar corona
- zodiacal light
- meteorology & physiology

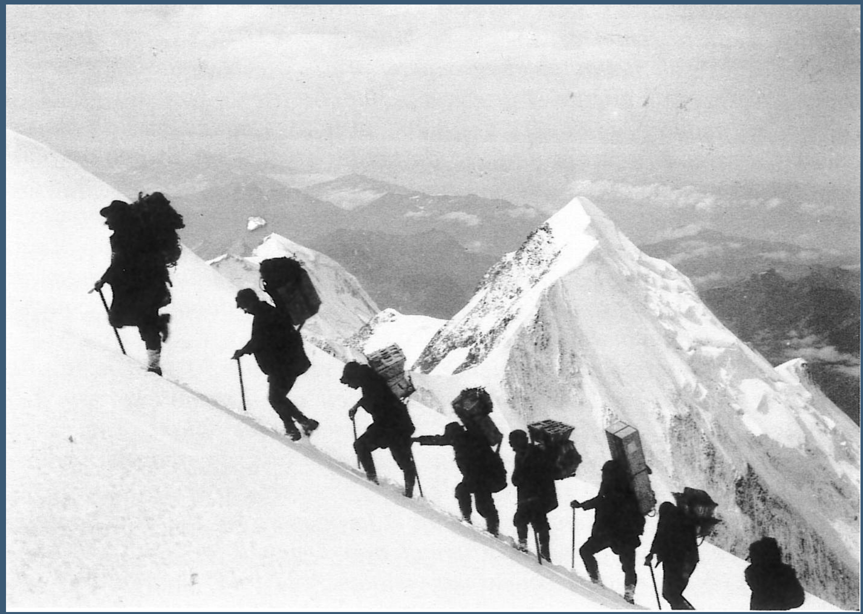
Daniel Challonge (1895-1975)

An early promoter of astronomy at high altitudes



An exceptional alpinist: first ascent of Pointe Chalonge 3357m (La Meije)

Born in Grenoble, a physicist, geophysicist and astrophysicist

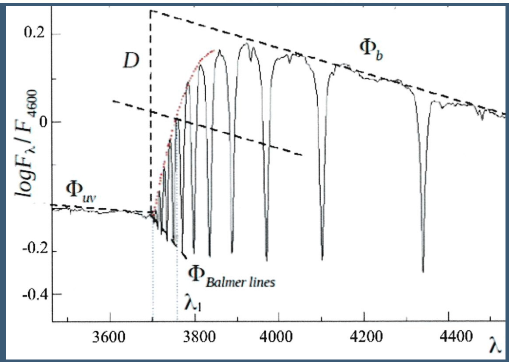


15 expeditions at Vallot Observatory (4362m) since 1923. In 1924, the 6th sherpa carries the spectrograph in the box named the "child coffin" at Chamonix.

Thesis on the atmospheric ozone in Paris. Researches on the Hydrogen atom and H- ion light absorption, applied to the classification of stars from near-UV and UV spectral features. Spectrographs transported at various sites as Vallot, Arosa, then at Jungfraujoch since 1928.

A revolution in stellar classification

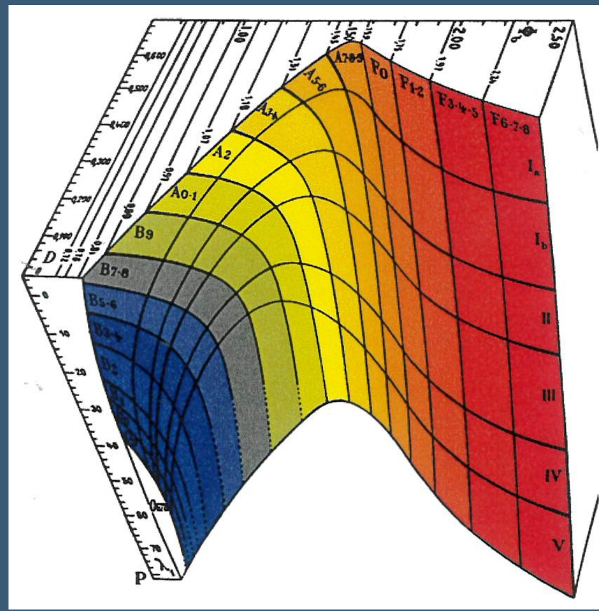
the two dimension system by Barbier & Chalonge



▲ Spectrum of a 10'000 °K star

◄ Energy distribution in log Flux, corrected for extinction and film sensitivity.

3 Parameters surface labelled in ► spectral type (T) and luminosity (g) V: dwarfs, III: giants, I: supergiants



Prior to Barbier & Chalonge

Whole Sky Survey with objective prism plates produced from 1918 to 1924. One dimension (T) spectral type for 225'000 stars produces at Harvard College.

Barbier & Chalonge method

Distinction between gravity and temperature effects

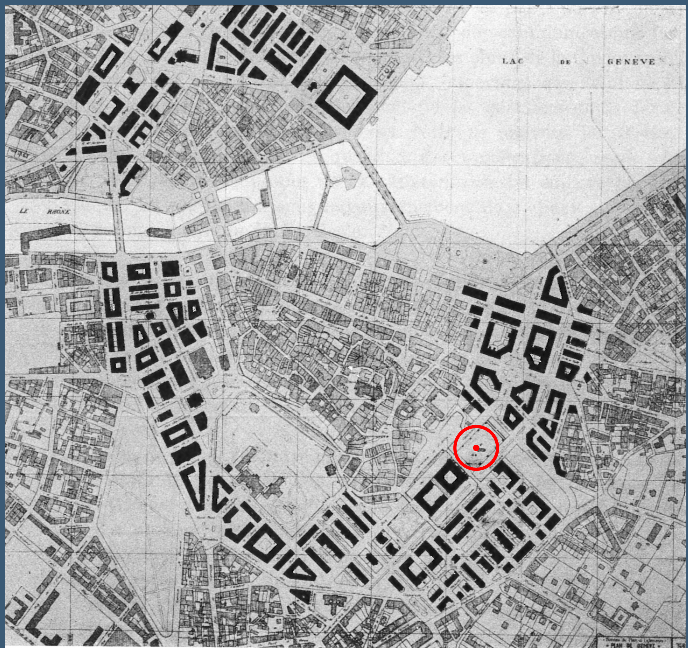
- Access to the stellar radius and absolute luminosity

with limitations

- Limited to stars with H lines present (Sun excluded)
- Young stars only (last 5 percent of Galaxy life)
- low sensitivity: very bright stars only

The Geneva Observatory in 1910

included in the city after the 1850's expansion



Circle: the old Observatory location

First (1772) and second (1829) Observatory built on the city walls with open horizon.

SW horizon closed by the Museum of Art built in 1910

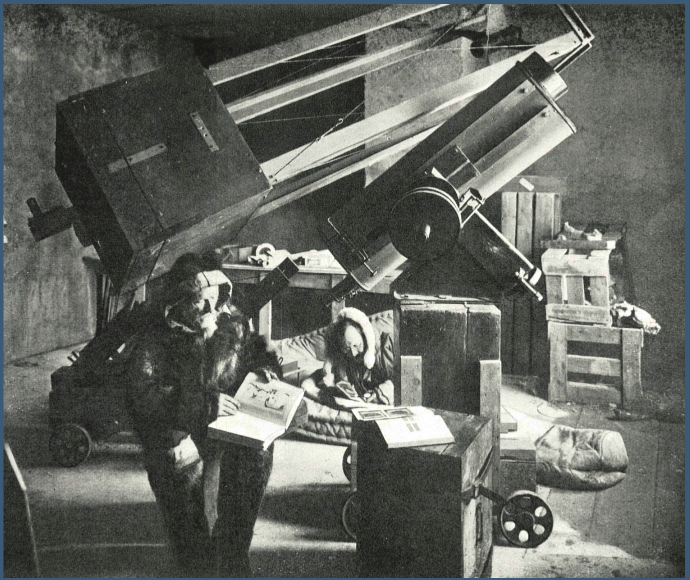
Prospecting for a new site for astrophysical activities

- around Geneva during 1910-1915 with a travelling telescope Check of stellar image quality with a photographic camera
- Jungfraujoch: an option after the 1912 railway inauguration

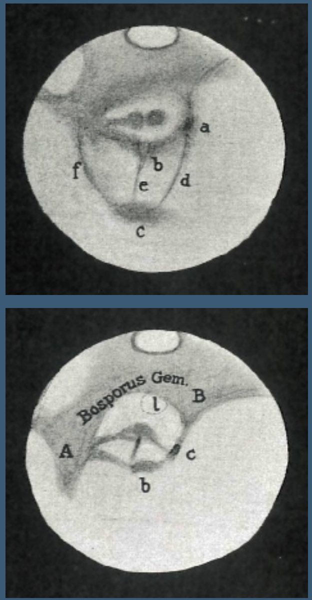
Search for an optimum site for stellar spectroscopy

The Mars opposition of 1924

site testing at Jungfraujoch astronomical station



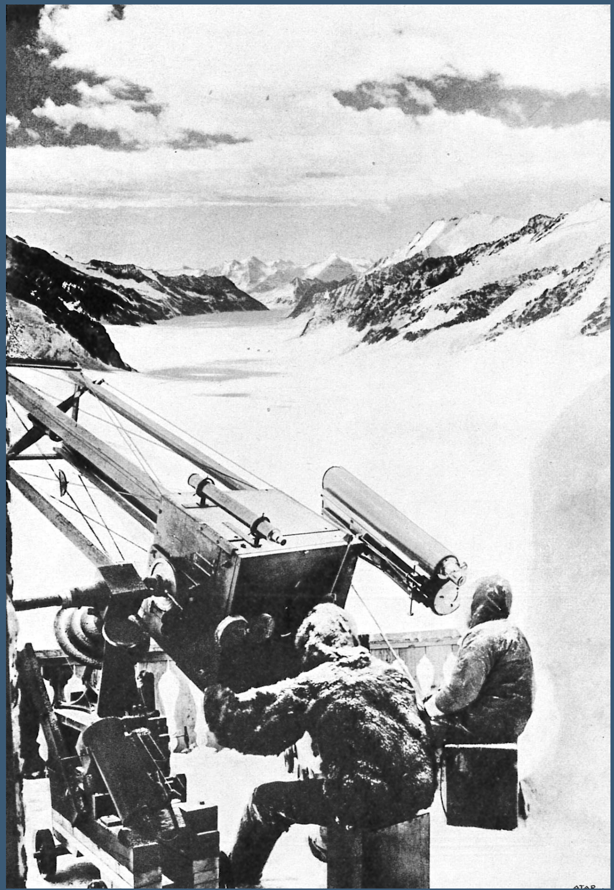
The instrument room, an annex to the Berghaus with 60 and 23 cm telescopes



Mars surface details as drawn by E. Schaer at 45 min intervall.

Bad weather period, few moments with stable images, Mars low above horizon

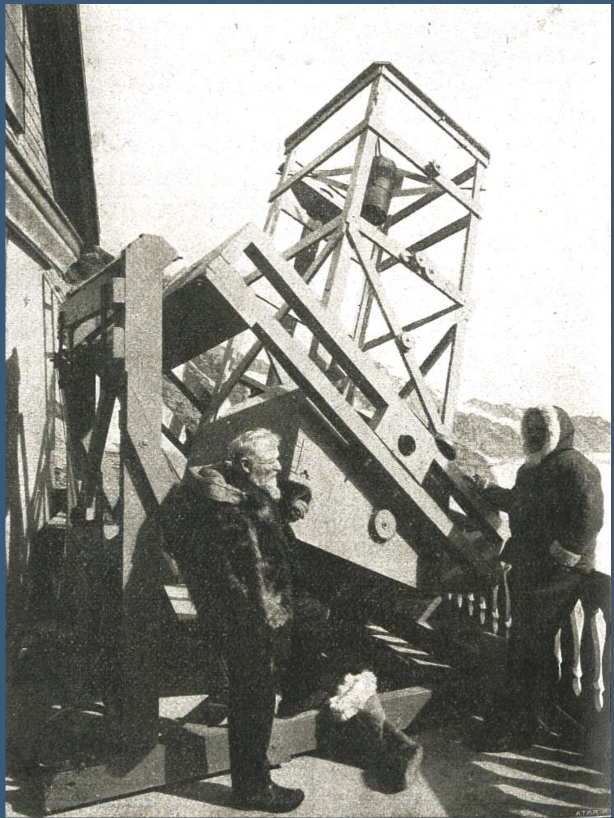
Inconclusive results on the site quality



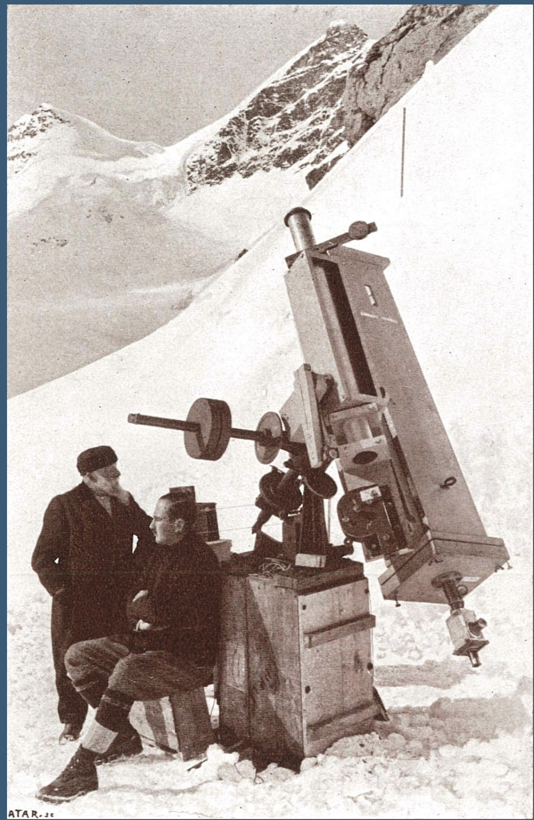
Open air observations at the terrace with flying snow falling on the necks

The 1926-27 expeditions

the final site selection



The 100cm Schaer refractor (wood+steel) at the Berghaus terrace in 1926



The 27cm refractor, at wind shadow, on the glacier, 25m below the Sphinx tunnel terrace

The site requirements

- open horizon to E, S and W
- protected against W and NW winds
- foreground with minimum warming during day and cooling during night

The site testing results

- perfect images obtained on the glacier
- minimum absorption by H2O in the solar spectrum
- impossibility to operate a 1-m class telescope in a windy open air site
- no space on top of the Sphinx

1928: a difficult choice

the "Alleingang" temptation

The Jungraujoch neighbourhood was already tested by the Geneva team

- a 1-m telescope already the property of the Observatory
- a second 60 cm telescope to be received in January 1929
- a sufficient funding expected

Therefore the Geneva 1928 proposal :

Two distinct and independant scientific Institutes at Junfraujoch

1) Institut international de recherches scientifiques

   (physics, biology, physiology, geophysics, meteorology, etc)

2) Observatoire astronomique

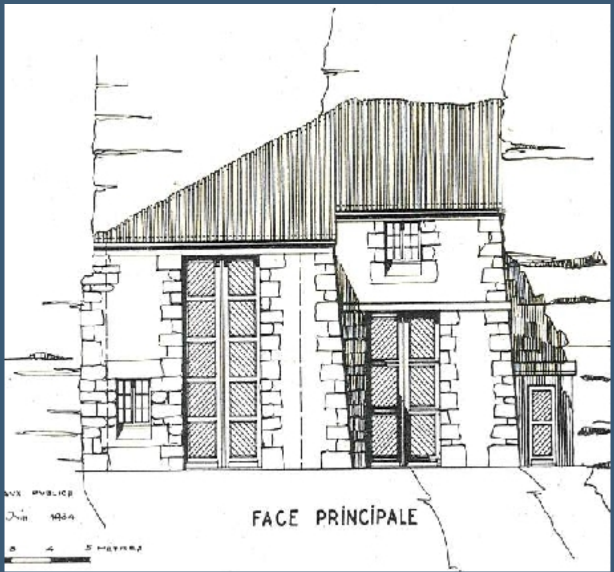
   full property of Geneva Observatory, as a branch of Geneva Observatory

This choice, and that of the observing site, soon appear to lead to a disaster

1929 beginning of works at Jungfraujoch and of the World Great Depression
1932 Banque de Genève went into bankruptcy
1934-38 abolitions of posts at the Observatory with loss of qualified manpower

The "ideal" site

an hermitage nested in the Sphinx cliff



The main facade with two doors for the way in/out on rails of the telescopes

Structure similar to the Berghaus :

- building excavated in the rock with rooms for the instruments and small room for the observers
- terrace for open air observations

The astronomical station in Summer 1933

The incredible choice

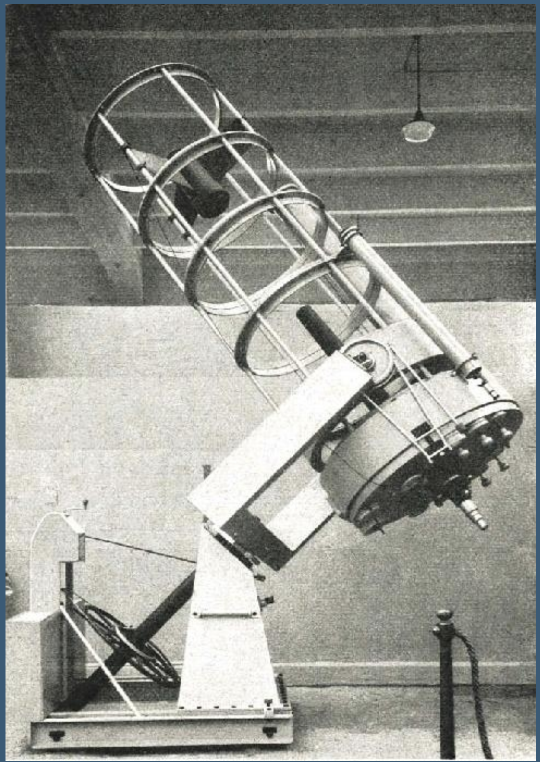
to abandon the visibility to half of the Northern Sky in favour of the Equatorial and Southern Sky, as seen from the Junfraujoch under poor seeing conditions was aberrant.

Circumpolar stars not visible from the Geneva station !

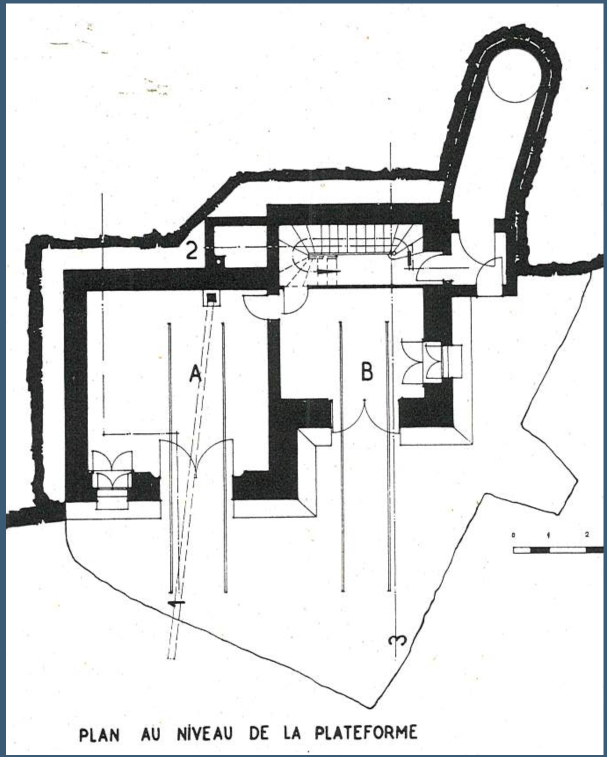
JUNGFRAUJOCH: EXTENDED UV AND IR WINDOWS FOR ASTRONOMY

The Geneva astronomical station

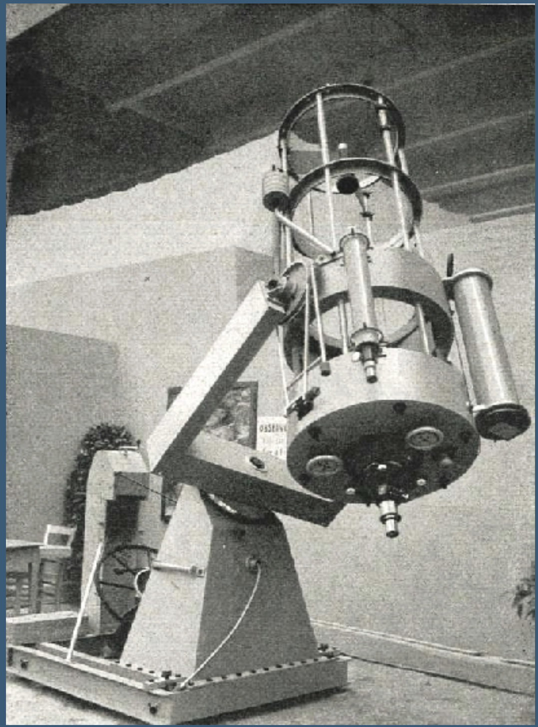
from the dream to the nightmare



The 100 cm telescope



The terrace floor with access tunnel and the rails for the telescopes motion



The 60 cm telescope

Large volumes of ice formed between the building and the rock and inside the access chimney.

No lift before 1938. September 1939 inauguration cancelled because of start of W.War II. Project abandonned after 10 years of expensive efforts (telescopes still buried in ice in 1957)

In contrast, the fast development

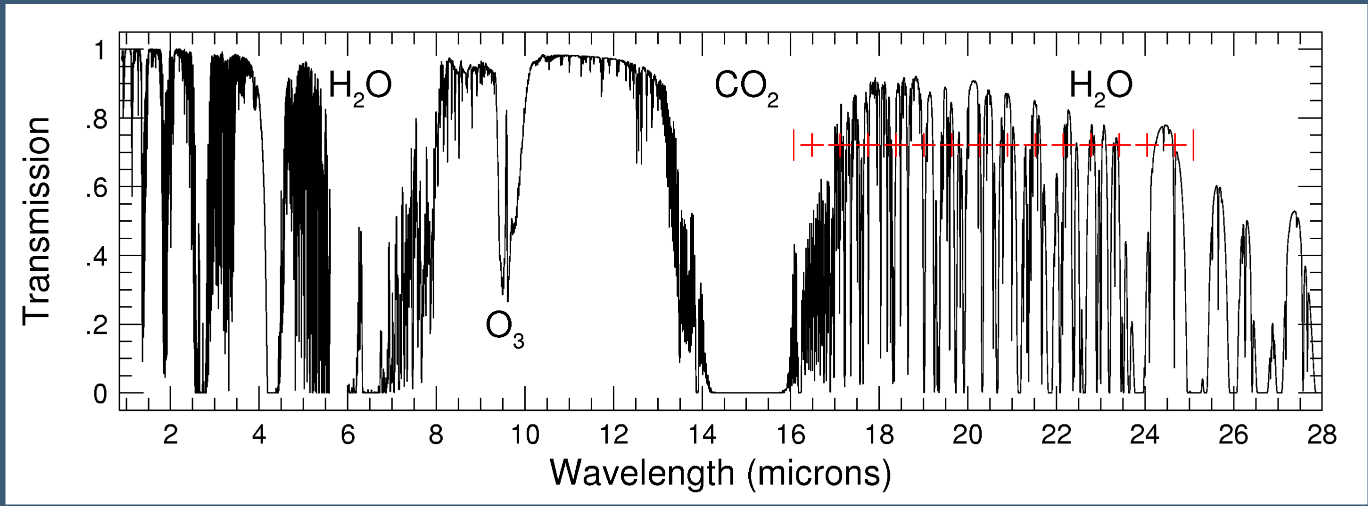
of the Scientific Station and Sphinx Observatory

A tight schedule

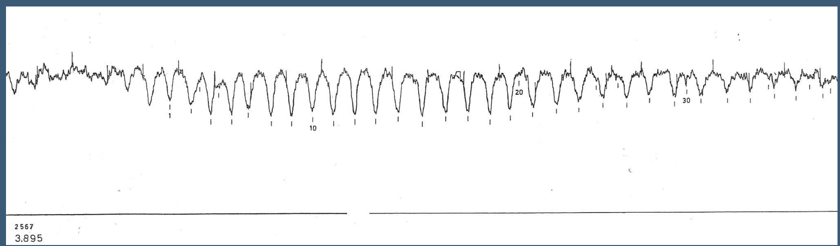
1930-31	Construction and Inauguration of the Scientific Station
1934-36	Observations of UV & O3 by Challonge at the old Scientific Station A synthesis on stellar spectra between 310-460 nm for 47 stars
1936-37	Construction and inauguration of the Observatory at Sphinx A shelter with mobile roof installed on top of Sphinx, gift of France
1939-45	World War II
1946	New observations by Barbier & Chalonge for a quantitative stellar classification, the BCD system
1951	First astronomical dome at Sphinx, 4.5m diameter, gift of UNESCO Beginning of Belgian nearly permanent activities at Jungfraujoch (Liège Institut d'Astrophysique and Observatoire royal at Uccle) First Belgian Solar IR spectrograph at Sphinx Observatory "The solar spectrum from 2.8 to 23.7 microns" published in 1957
1956	An additionnal story to the Sphinx Observatory
1957-58	Installation of the large solar spectrograph at Sphinx (Migeotte, Delbouille, Neven et Roland)

The 1957 Liège IR solar spectrum

a spectral range extended to 16-23.7 microns



Spectra obtained in windows not saturated by H2O + CO2 bands [2.8-5.5] [6.9-14.2] & [15.8-23.7]



The nitrous oxide N2O band around 3900 nm

Less than 110 solar atomic lines, outside the CO lines. The other 3100 lines are telluric, produced in our atmosphere by H2O, HDO, CO2, CH4, N2O and O3.

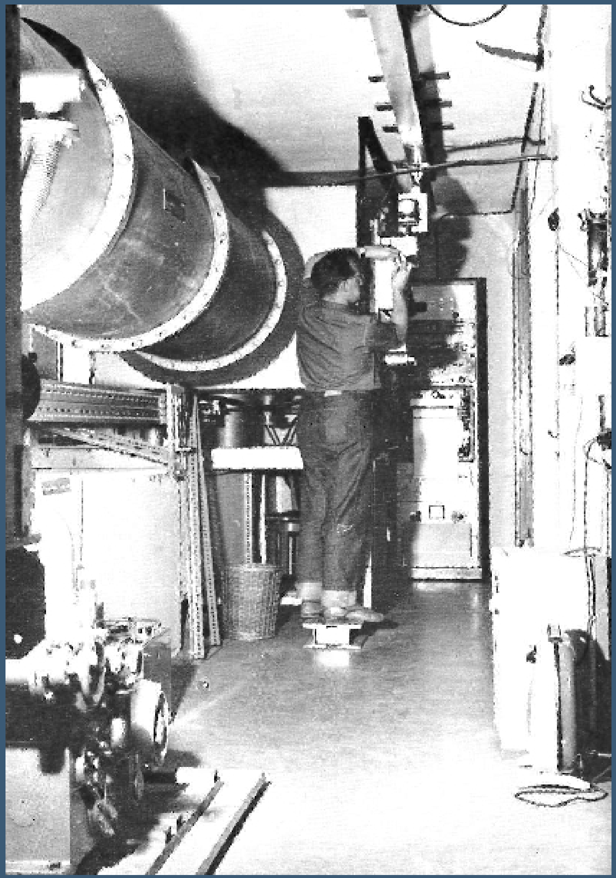
This atlas: a precious reference for the Earth's atmosphere composition for the Epoch 1950

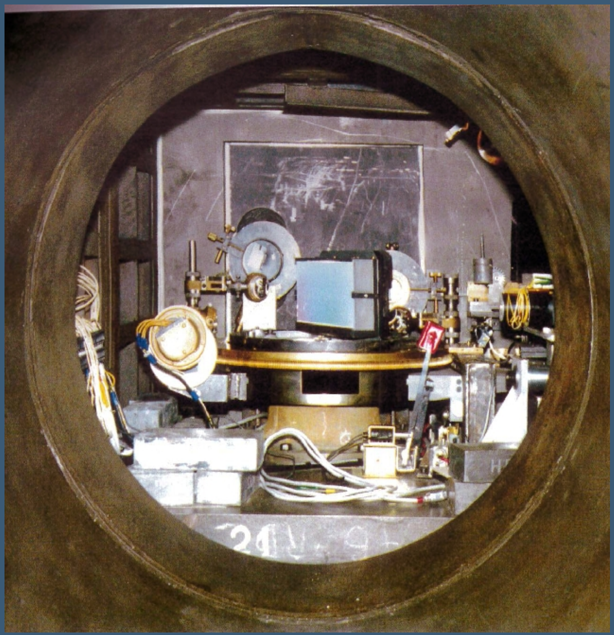
Le Grand spectromètre solaire

a new era in solar spectroscopy at Jungfraujoch

Since 1958, the new Great solar spectrometer occupies a full laboratory at Sphinx. A coelostat, automatically guided, maintains the image of the Sun center on the spectrometer entrance slit.

The coelostat on the upper terrace





▲ The grating mounted on a rotating support at the tube extremity

◄ The spectrosopic laboratory at Sphinx.

The major results

from the Grand spectromètre solaire

A series of photometric atlases covering the whole range of wavelengths from the UV-B limit to the Visible, near IR and Infrared, with impressive lists of line wavelengths, identifications, atomic or molecular, and origin : solar or telluric.

1963 in near IR : Photometric Atlas of the solar spectrum from λ 7498 - 12016 Å
by L. Delbouille & G. Roland

1970 followed by : Ibid. A Table of Measures and Identifications, 450 pp
by J. W. Swensson & W. S. Benedict and L. Delbouille & G. Roland

From 1964 on, improvement of spectrometer (reduction of light scattering, fast scanning to reduce scintillation effects, and near vacuum to reduce the turbulence inside the instrument). Project to rescan the whole range 3000 to 10000 Å.

1973 a revised : Photometric Atlas solar spectrum from λ 3000 to λ 10000
by L. Delbouille G. Roland and L. Neven.

An upgrade of the Minnaert et al. Atlas from 3612 Å to 8771 Å, measured at Mount Wilson (USA) and Utrecht, used by all astrophysicists since 1940.

Improved chemical abundances of all elements (Fe, Ni, Mg, Ti, Zr ..) in the solar photosphere.

All determinations of stellar abundances are relative to the Solar or meteoritic abundances reached 4.56 Ga ago through the various nucleosynthetic processes.

The Geneva astronomers

back to Jungfraujoch in 1960

Installation of 40 cm telescope by the Geneva Observatory, on M. Golay initiative, with the goal to perform stellar multicolour photometry on Galactic targets.

Multicolor photometry advantages over photography

Use of photomultiplier detectors

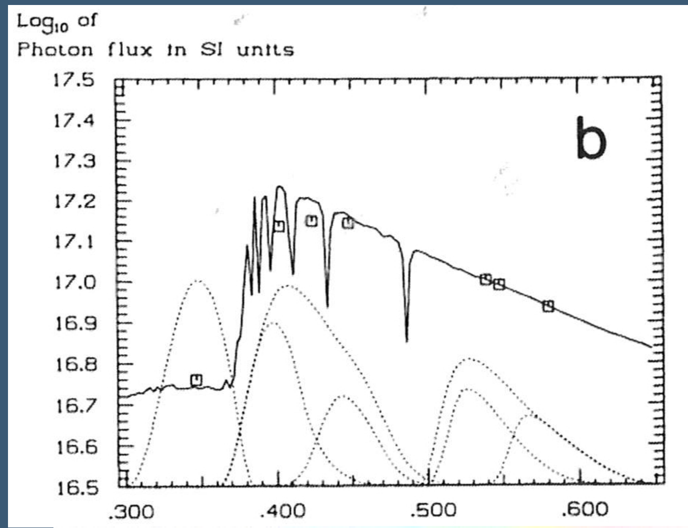
- with linear response over extended intensity range

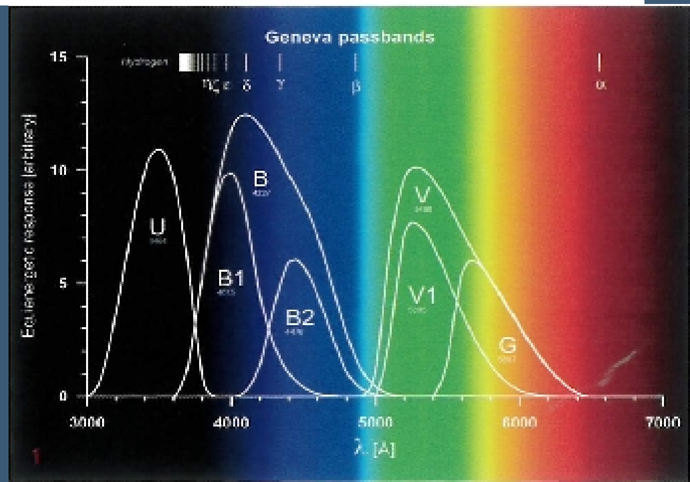
Broad to intermediate bands

- stellar flux integrated over broad spectral range
- Geneva sytem: 5 intermediate bands of 400 nm width at 1/2 transmission
- faint stars observable down to mV 10.5 at 40 cm tel.

Johnson (1953) Broad band system UBVRIJKL provides an overall energy distribution but no access to astrophysical quantities as gravity or metal-abundances.

Access possible through intermediate bands, well located on spectral features





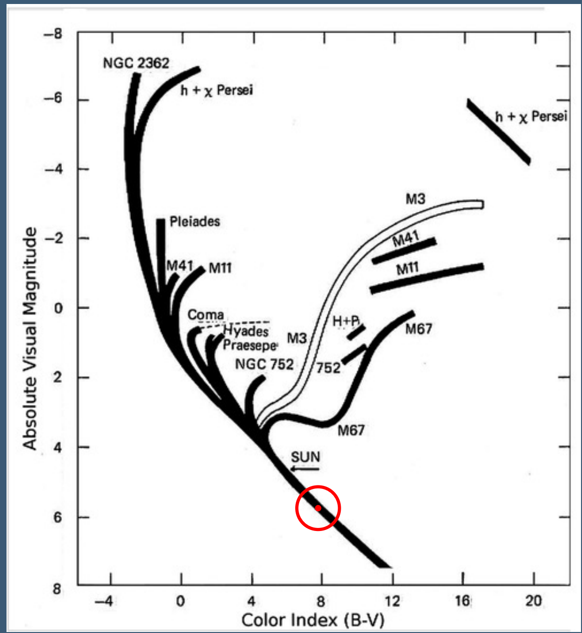
Vega spectrum with observed intensities □
Name and colours of Geneva filters ▸

Golay system: extension of the Chalonge spectrophotometry

The first programme

open clusters and representative field stars

The M44 open cluster, Praesepe, born in Cambrian time, 625 My ago.



Composite HR diagram (luminosity vs colour (Teff) of nearby open clusters of various ages.

The M45 open cluster, Pleiades, born during the Cretaceous, 100 My ago.

The 1960-63 programme consists of

- sample of field stars of all types and luminosities for astrophysical calibration.
- nearby stars with known trigonometric distance, to define the distances to open clusters.
- members of nearby clusters to expand the luminosity-T relation to more massive stars

Photometric observations
at Jungfraujoch 1960-1963

Acquisition at the 40cm telescope, equipped with a P2 photometer built at Geneva.

Stars observed through circular diaphragms as small as possible to optimize the ratio beteween the star and background light (size adapted to the image quality).

Feb 1960 to March 1963: 65 usable nights or 17 percent of all nights spent at Jungfraujoch.

The P2 photometer attached to the 40 cm telescope main focus.

A very slow acquisition rate

- inaccurate pointing system
- poor guiding (recentering every 3-4 minutes)
- long integration time to average the scintillation
- 15 filter measurements of star and background.

Rate : 3 stars/hour

The 1963 first Photometric Catalogue

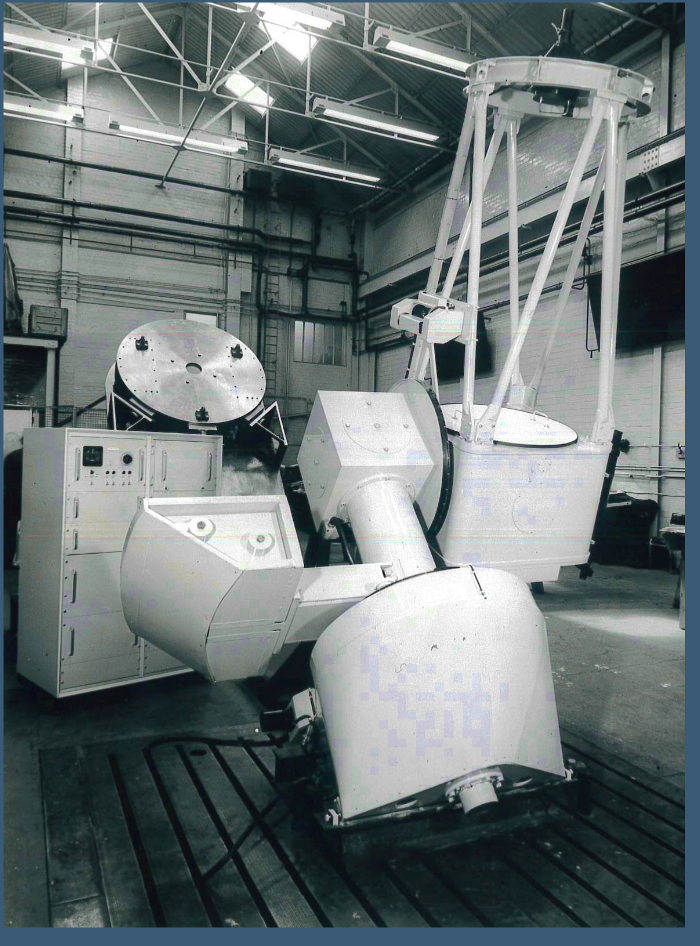
232 stars observed 4 times (on average)
110 stars observed once

But sufficient to

- check the method to estimate the atmospheric extinction
- reach an accuracy better than 1 percent on fluxes
- establish a set of Standard Stars of various colours, demonstrated to be non-variable.

The need of modern instrument

the 30 inch reflecting telescope



The 76 cm telescope during the final assembly phase at Grubb Parsons factory (UK) in 1967

A robust, compact, multifunctional refractor

- Cassegrain system (main focus) may host

- light instrument (e.g. photographic camera)
- Photometer
- Spectrometer
- any Special equipment

- Coudé system

- daytime : solar observations

Main progress

- improved star tracking
- increased luminosity: factor 2 on star maximum distances
- reduced scintillation (shorter integration times)

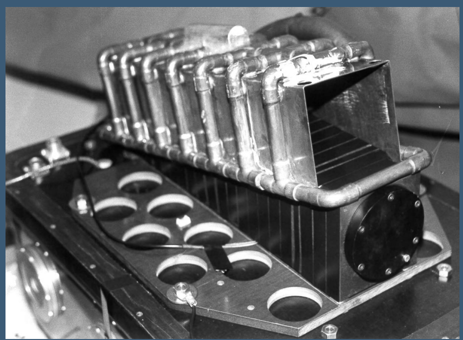
Some inconvenients

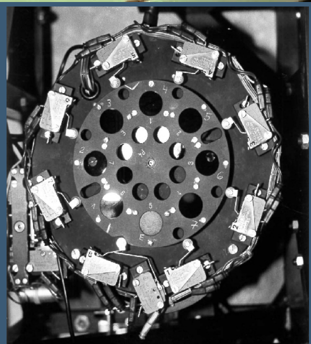
- inaccurate manual pointing (hour angle, not right ascension)
- short footed telescope:
  observer at floor on his back to point at zenith !

Instrument funded by Belgium, France and Switzerland NSF's

P3 an upgraded photometer

for more accurate measurements at the 30"





The P3 internal structure: upper part with the optics, the diaphragm and filter wheels; lower part with the photomultiplier and its cooling system

P3 + 30" telescope, a performing combination ?

Improved

- mechanics and optics.
- thermal control of the photomultiplier and filters

A large number of observing runs by various groups:

- Geneva Observatory
- Lausanne Institute of Astronomy
- Institut of Astronomy KU Leuven
- Institut d'Astrophysique, Paris
- Bureau des Longitudes, Paris
- Palais de la Découverte Paris, etc

Most measurements processed at Geneva

670 useful nights between Oct 79 and Nov 98 (end of stellar photometry at Joch) at the rythm of 20*/night

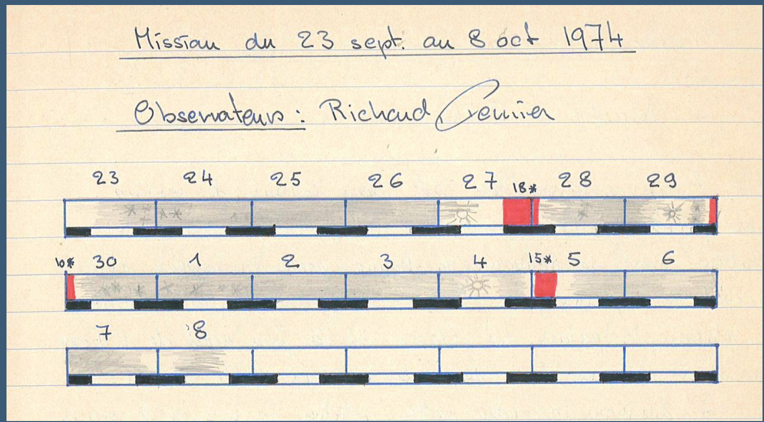
Rythm too slow to plan any large observationnal programme

Photometric observations

limited by local meteorological phenomena

Photometric weather conditions:

Total absence of clouds in all directions during several consecutive hours



Typical diagram of sky condtions at Junfraujoch by desperate observers, with one partial night and two half nights during a 15 days mission

The transit of wet air masses over the Alps barrier may produce local fog or lenticulars clouds at higher altitudes, long fog periods and enhanced snowfalls. With fresh snow and wind, flying snow imposes to close the dome.

The Gornergrat an attractive site

for the 2-m Swiss National Telescope ?

In 1967, start of site testing at Gornergrat, an optimum site to for the 2-m Swiss National Telescope and a French 3.5 m telescope for observations in UV, IR and Millimetric wavelengths.

The 40cm tel and the small dome from the Joch installed on the South Hotel tower. Photometric observations by Geneva Team started in Summer 1969

In 1975, installation of the 1m Marly telescope from Lyon Observatory for IR tests, rapidely stopped because of excessive humidity for IR astronomy. Geneva photometry until January 1983.

Partially disappointing results wrt Joch

- more frequent touristic nice weather, but no less cirrus
- southern flank of Gornergrat overheated during daytime :
  excessive turbulence and humidity brought up by convection

In 13 years at Gornergrat: 478 nights with 11489* measured (mean rate 24*/night, instead of 20*/night at Joch).

Adhesion to ESO preferred to a National telescope at Gornergrat

Complementary data collection

at Haute-Provence (OHP) and La Silla Observatories

OHP 650m, 100 cm Geneva telescope

from 1964 to 77: 1082 nights with P4 : 14280*, 13*/n
variable extinction

ESO La Silla, 2400m, Geneva telescopes

from 1975: P4 at 40 cm Swiss : 30.4*/n
from 1980: P7 at 70 cm Swiss : 72.0*/n

P7 at the 70 cm

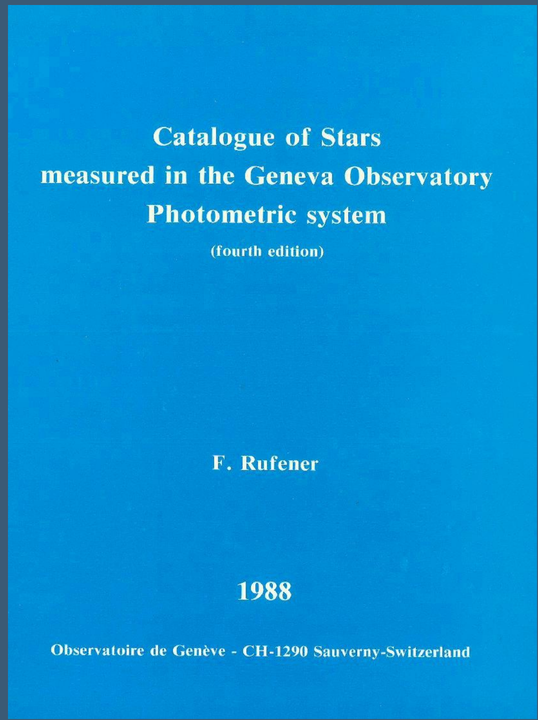
Major improvements thanks to :

- automatic telescope pointing
- two channel photometer (Star+Background) & (Background)
- photon counting technique
- automatic data storage, etc

Higher number of photometric nights:

230 nights/year instead of 60 in the Alps.

In 1988, prior to the HIPPARCOS launch : Catalogue of stars measured in the Geneva Photometric system: 200´000 measurements of 29'400*, obtained from 1960 to Summer 1987 :



Jungfraujoch	5.3 %
Gornergrat	5.6 %
Haute-Provence	8.9 %
La Silla	79.4 %

30 years later: the GAIA Era

all scientific goals of the sixties achieved from space

The most ambitious space mission in the history of Astronomy

Launch on Dec 19, 2013, still running. Second Data release April 2018:

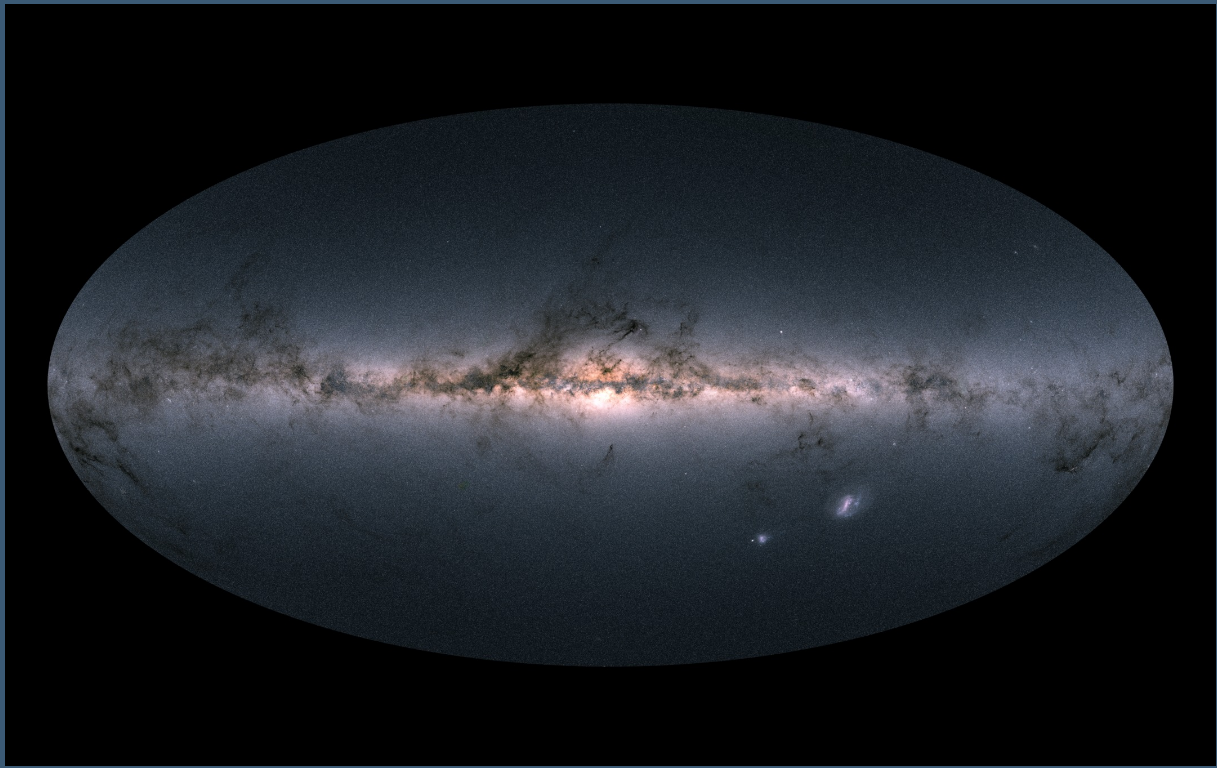
target position	1’692’910’130
parallaxes (distances)	1’331’909’730
surface temperature	161’500’000
radius and luminosity	76’956’780
Colour excess E(b-v)	87’733’700
Radial velocity	7’224’630

All stars survey down to mag 21

Missing parameters after Gaia : radial velocities for O,B,A type stars.

60 years only after the first measurements at Jungfraujoch

Low cost : 1 EUR/star



Not an image, but a plot of all sources, showing the Galaxy disc and bulge, the dark filamentous interstellar matter, and the satellite galaxies the Small and Large Magellanic Clouds.

**For the Swiss astronomical community
an adventure permitted by the deep
involvement
of the pioneers as Chalonge, Migeotte, Golay
and the founders of the scientific station
at Jungfraujoch**