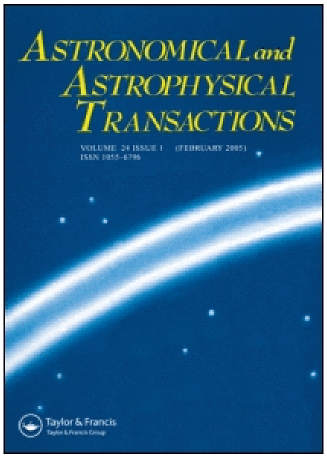

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RUSSIAN/FSU INTERESTS IN ANTARCTIC ASTRONOMY

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Russian/Former Soviet Union (FSU) specialists have great experience in the logistic support of scientific research, building, transportation etc. in extremal polar conditions. The Russian station Vostok is located in the area of Antarctica best suited for the International Astronomical Observatory to be built in Antarctica. Very low humidity of the surrounding atmosphere gives a chance for carrying out observations in submillimeter windows down to 200 μ. An example of the submillimeter interferometer is described. Ukrainian and Pulkovo astronomers have experience of realizing an astrometric observation from Arctica. They have worked out a proposal for astrometric observations from Antarctica. Observations in near UV spectral range may be carried out to perform ground-based ozone measurements. Long Polar nights are convenient for 24-hours monitoring of astronomical objects. Helioseismological observations are also proposed. Russian astronomers possess vast experience in site testings and suggest such testings in Antarctica. The engineers have developed the concept of an Antarctic observatory.

KEY WORDS Antarctic astronomy, submm observations, astrometric observations, astroclimatic measurements, astronomical site testing, Antarctic astronomical observatory

1 INTRODUCTION

The Project of International Antarctic Astronomical Observatory, which was approved by the Megascience forum held by Organization for Economic Co-operation and Development (OECD), is one of the important new projects and future concepts in Astronomy that require an advanced stage of international collaboration not only for reasons of economic circumstances but also for the advantage represented, in terms of coherence, by sharing ideas and teams across national boundaries.

The long term aim is the establishment of a broadly international scientific base at the highest point on the East Antarctic ice plateau, known as Dome A. In some important respects, this must be the best side for astronomy (and for some other scientific studies) on the Earth.

Russian scientists have great experience in Antarctic researches, logistic support and transportation of large-size constructions over Antarctica. From the point of view of IR/submillimeter astronomy the best place with existing logistic support is the Russian VOSTOK Station. The present situation in science demands special international cooperation in new large scientific projects (megascience projects in OECD terminology) (Praderie, 1993).

The following problems are interesting for Russian/FSU scientists in Antarctic Astronomy:

(1) Submillimeter photometry, spatial interferometry, down to the shortest wavelength $\lambda = 200\ \mu$ (Space Research Institute);

(2) astrometric observations (Nikolaev Observatory, Ukraine);

(3) solar observations, including helioseismology (IZMIRAN);

(4) ozone measurements [Rostov-on-Don University];

(5) 24-hours monitoring of variable stars and other objects (Sternberg Astronomical Institute: Moscow University);

(6) spectral lines in the Cosmic Microwave Background (MBG) radiation (Astro-Space Centre of P. N. Lebedev Physical Institute);

(7) Site-testing observations for selection of a site for Antarctic Astronomical Observatory (in optical, IR and submillimeter ranges) (Sternberg Astronomical Institute, Space Research Institute, Working Group of the Euro-Asian Astromical Society).

This continent, and especially its central parts possess unique climatic and meteorological characteristics. So we can see the future observatory at this site as: at first – the most transparent place on the Earth surface for IR and submillimeter astronomical observations; at second – alternative for space observation (at least at low prices); at third – an important step to Moon–Base creation.

2 VOSTOK STATION

VOSTOK Station is the Russian logistic high-latitude station which operates from 1957 up to the present (with the exception of 1993–1994 Antarctic winters).

Its location (see the map Figure 1) between Dome A and Dome C: the latitude −78 deg. 27 arc. min, the longitude 106 deg. 52 arc. min, the altitude 3488 meters, founded in 1957.

The Antarctic Astronomy Working Group of the Euro-Asian Astronomical Society (Former Soviet Astronomical Society) has processed meteorological and aerological data for the period of over 33 years (1958–1991) (Alexandrov *et al.*, 1992).

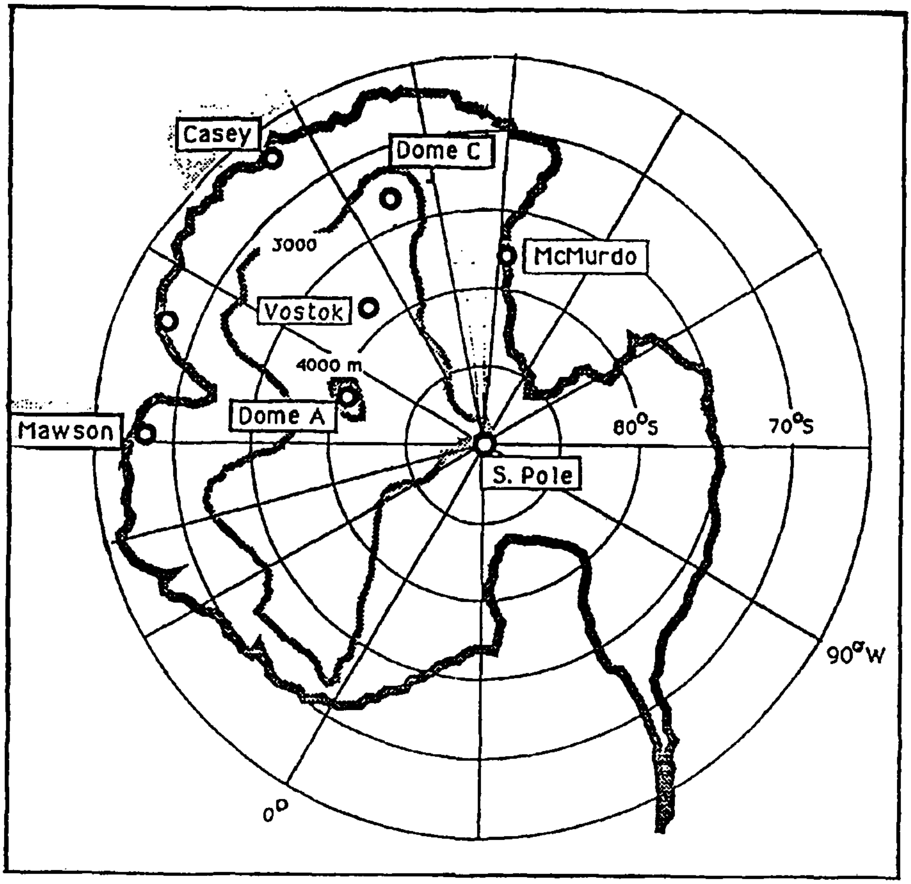


Figure 1 The sketch map of Antarctica showing the location of the sites being considered for astronomy on the high plateau (Dome A, Dome C, South Pole and Vostok).

The VOSTOK is one of the most appropriate sites among the active ones at present in Antarctica (Table 1). Besides of an extreme dryness and very low temperatures the peculiarity of VOSTOK site is only a short warm period December–January and a prolonged cold one April–September (Figure 2).

The stable wind blowing mainly from south–west (70% of the time) is about 5 m/s (Figure 3). The variance during the day is about 1 m/s. Both low and high values are rare (4%). The maximum observed during 10 years 1958–1968 was 25 m/s and that over gusts 32 m/s.

The visual estimates of cloudness show more than half time of clear sky, i.e. 0–20 per cent of the sky area covered by clouds (Figure 4). One more peculiarity is the presence of a soft haze connected with the inversion layer. Stars and clouds are seen through that under-inversion haze but the signal lights on the ground are not seen through it from airplanes or helicopters.

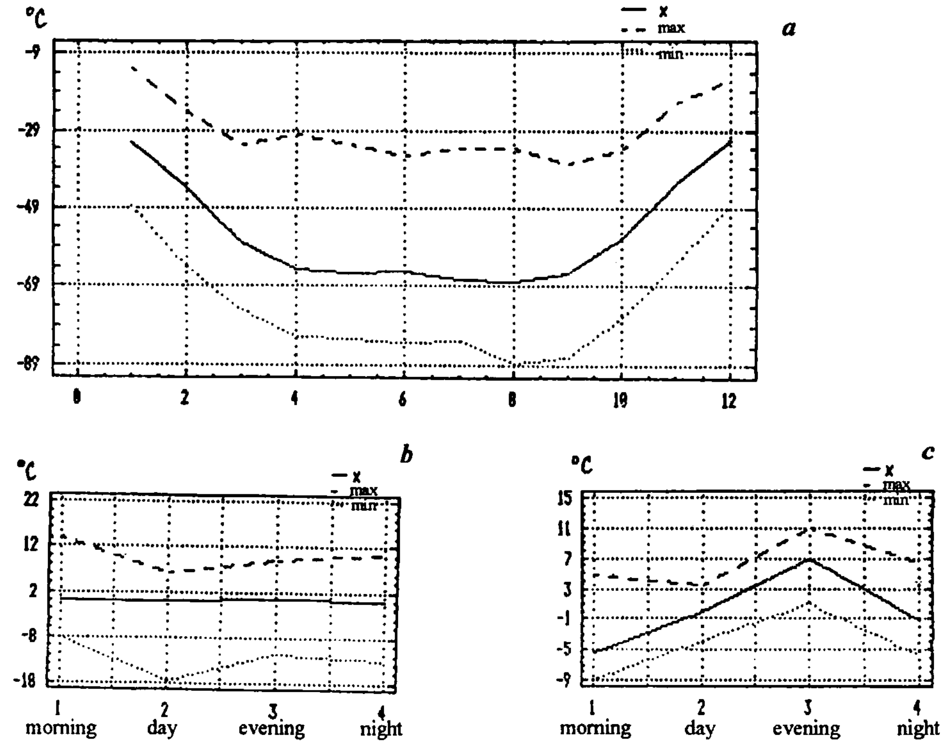


Figure 2 Annual behaviour of the temperature of the air (*a*) and the 24-hour changes of the temperature between the observational intervals in July (*b*) and January (*c*) (Alexsandrov *et al.*, 1992). On horizon axis: (*a*), number of month; (*b*), (*c*), parts of day in local time.

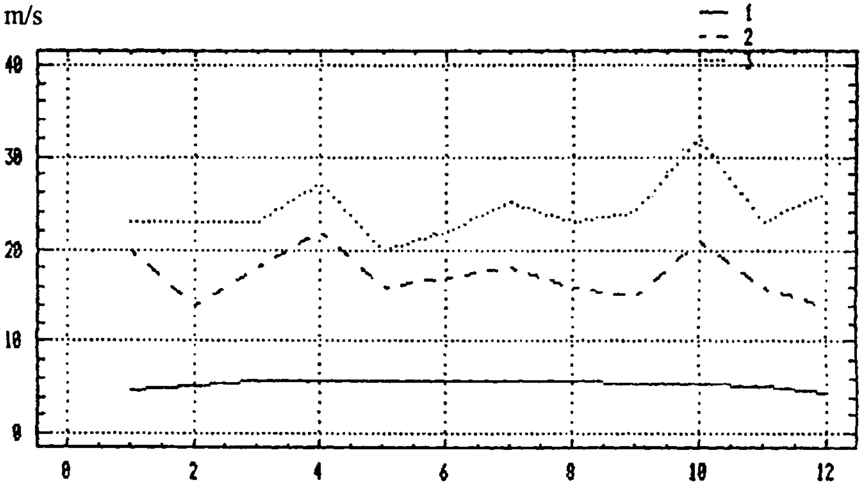


Figure 3 Annual behaviour of averaged monthly wind velocity (1), of maximal wind velocity according to the data acquired for the observational intervals (2) and of the maximal wind velocity guest (3) (Alexsandrov *et al.*, 1992).

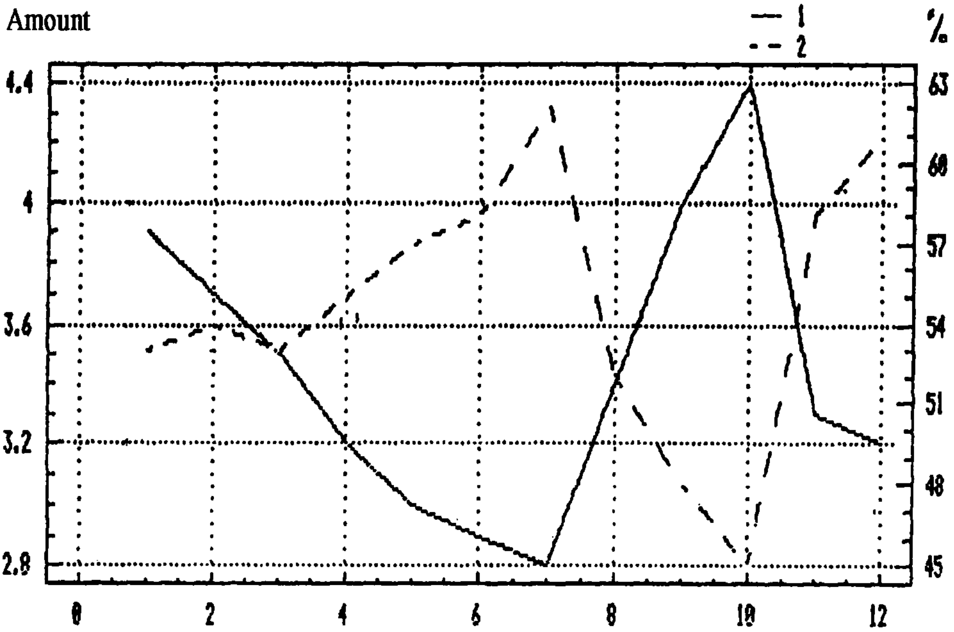


Figure 4 Annual behaviour of average monthly cloudiness (1) amount (are given in points, left scale; 1 point correspond 10 percent of covered sky) and clear sky reappearance (2) (right scale; in percent of sky with cloudiness less than 20 percent) (%) (Alexsandrov *et al.*, 1992).

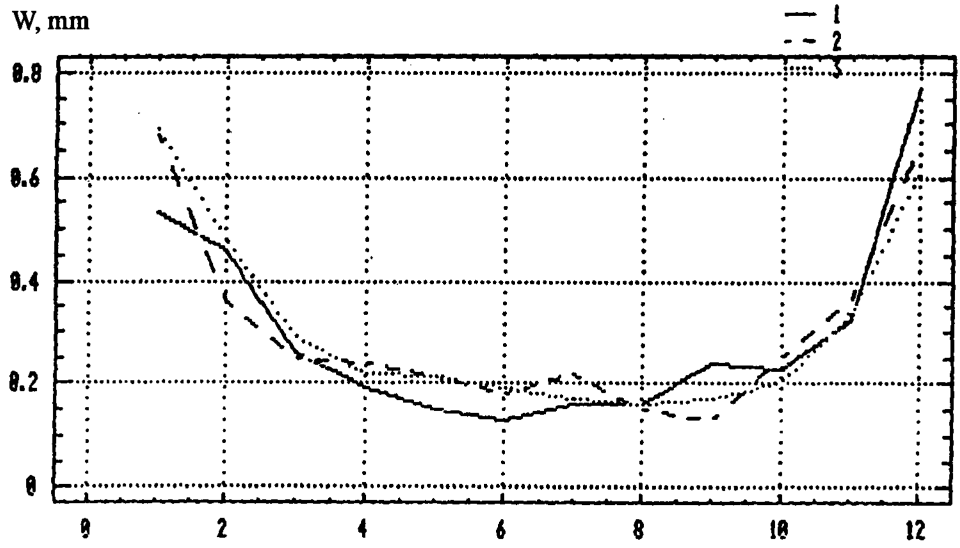


Figure 5 The precipitable water content in the atmosphere above the Vostok Station up to 300 gPa (30000 Pascal ≈ 0.3 atm.) altitude, mm. *1*, water abundance in the atmosphere in the interval ground 300 gPa in 1989; *2*, water abundance in the atmosphere in the interval ground 300 gPa in 1990; *3*, long-term value of water abundance for the period 1959–1989 (Alexsandrov *et al.*, 1992).

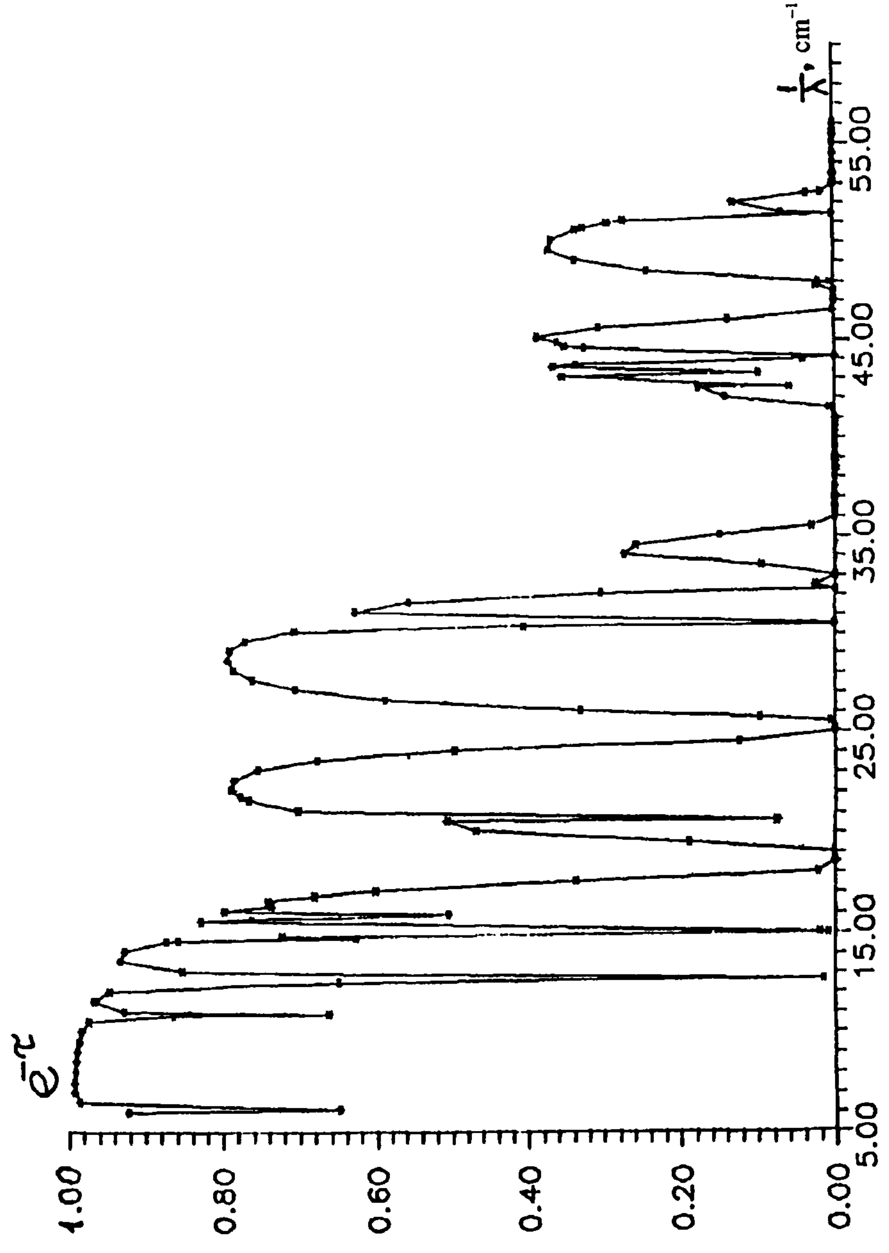


Figure 6 Spectral atmospheric transmission calculated for typical winter conditions at the Vostok Station (July, 1989) by Naumov and Zinitcheva (1993).

Table 1. Average climatic conditions at the Vostok station during 1958–1991

Property	*Value*	
	Summer	*Winter*
Mean temperature, t° C	−31.9 December	−68.0 July
extreme monthly	−22.9	−80.9
extreme absolute	−13.3 January	−88.3 July
max mean 6 h change	−7.0 January (19-01 h GMT)	0.3 July (19-01 h GMT)
Pressure (mb)	635 December	621
Wind speed, m/s	4.6 January	5.8
Preciptitations, mm	0.6 December	0.38 June
Cloudness	0.39 January	0.28 June
Time of clear sky	0.53	0.62

Note. GMT – Greenwich Meridian Time.

Figure 5 shows the seasonal variation of the precipitable water obtained by integration of radio sounding balloon measurements over the pressure down to 300 millibar. The mean yearly value for more than 30 years 1958–1991 (the period recommended by World Meteorologic Organization as the most trustful) is 0.31 mm with very small rms 0.02 mm. About 20 per cent belongs to the inversion layer. The mean winter value for 7 month April–October is 0.19 mm thus approaching the aircraft 7.5 km value 0.14 mm in the middle northern latitudes.

Sholomitskii (1993a), Naumov and Zinitcheva (1993) shows a submillimeter transmission of water vapour calculated for the average humidity-height profile in July 1989 (Figure 6).

This calculations and comparative analysis of sites for IR and submillimeter observation (Sholomitsky 1993b) show that the VOSTOK station surpasess (in dryness) the South Pole as for atmospheric transmission estimates, nevetheless an experimental check is needed because of a poorly studied water-dimer contribution at low temperatures (Table 2).

Table 2. Comparision analysis of sites for IR and submm observations

Site	*Altitude, h (metres)*	*Precipitable water, W (mm)*	*Submm atmospheric transmition*	
			345 micron	*Reference*
Maun-Kea (Hawaii)	4200	1.2	32%	Morrison *et al.*, 1973
Shorbulak Obs (Eastern Pamirs)	4350	1.2 (0.3 min)	1–30% (at the "working angles")	Sholomitskii *et al.*, 1982 Kanaev *et al.*, 1983
South Pole	2900	0.4		Smith and Jackson, 1977
Vostok Station	3488			Burova *et al.*, 1986
summer		0.35	40%*	Alexandrov *et al.*, 1992
winter		0.19	80%*	Sholomitskii, 1993b

Note. *calculated values.

3 MAIN SCIENTIFIC GOALS SUBMILLIMETER OBSERVATION (Principial invistigator G. B. Sholomitskii, Space Research Institute)

Many astronomical objects particularly younger ones like protostars, protoplanetary nebulae, circumstellar disks and protogalaxies possess spectral maxima just nearby 200 μ and a lot of characteristic emission lines so both the traditional submm photometry/spectroscopy and spatial interferometry can be very productive at antarctic high transmission sites.

The following observations would become accessible at the VOSTOK station or higher-altitude sites:

(1) high quality photometry within "traditional" submm windows on a regular basis and winter-time measurements down to 200 μ;

(2) spectroscopy in CI 609 μ, HI 462 μ and 348 μ (H21α and H19α respectionally), NI 205 μ, CO 200 μ ($J = 13$–12) and other emission lines.

(3) interferometric studies of the thin structure of protostars, protoplanetary disks and other objects with the angular resolution down to a few arcseconds.

Previous photometric experience, includes: (1) submm observations of star formation regions and other objects at various telescopes of the former Soviet Union among them at 0.7 m - telescope of Pulkovo Observatory in Shorbulak, Eastern Pamirs (4350 meters), with low temperature bolometer system; (2) atmospheric transmission measurements by the Sun/Moon absorption with the Golay cell in the range 1–0.3 mm.

4 ASTROMETRIC OBSERVATIONS (Principial invistigator G. I. Pinigin, Nikolaev Observatory, Nikolaev, Ukraine; Pulkovo Observatory, St. Petersburg, Russia)

The astrometrists take interest in determining the positions of celestial bodies from the northern and southern high latitudes during polar nights. Under these conditions it is possible to observe stars during 24 hours and more with insignificant meteorogical variations, and results are independent of the Solar hour angle. A high position of celestial Pole over the horizon permits one to observe stars in two culminations along a very extended meridian arc. The observations during polar nights must also be free from systematic errors inevitable in other latitudes.

Previous experience. There were made the 70 polar night observations by the Nikolaev and Pulkovo Astronomical Observatories during 1974–1977 at the West Spitsbergen Island (Arctic Ocean, latitude = +78 degrees) for determination of accurate absolute positions FK4 Right Ascension System. Temperature variations during sideral night were $\Delta T < 1^\circ$ C.

First stage of the project of research from Antarctica is:

elaboration of methods of high latitude absolute observations, using:

(1) the new Nikolaev axial meridian circle [AMC];

(2) automatic control;

(3) CCD eyepice micrometer;

(4) accuracy ~ 0.01 arcsec.

The following steps are:

(1) elaboration of absolute methods of position determinations;

(2) making the accuracy analysis of expected results;

(3) formulation of the requirements for new facilities designing and construction in Antarctica;

(4) estimation of the influence of refraction errors in Antarctica.

5 HELIOSEISMOLOGY (Principal Investigator: Yu. D. Zhugzhda, IZMIRAN, Troitsk, Moscow Region)

It is necessary to provide continuous observations of own oscillation of the Sun surface (during two weeks permanently) to study the structure and dynamics of the internal stratum of the Sun. The best place for such an observation could be a high latitude observatory in Antarctica. Reasons to be in Antarctica: (1) 24-hours-a-day observations; (2) low systematic errors.

Previous experience. Some relioseismological observation were made, e. g.: (1) Fossa *et al.* (1989) (France): 120-hours permanent observations at the South Pole; (2) IZMIRAN (not in Polar regions Lebedev *et al.*, 1995).

6 OZONE MEASUREMENTS (Principal Investigator: V. V. Leushin, Rostov-on-Don University)

It is suggested to perform the monitoring of concentration of ozone in the Earth atmosphere by observing UV spectra of (λ 2900–3600Å – ozone molecular band) of stars during the night half-year and of the Sun during the polar day.

Bonev *et al.* (1992) proposed to use a spectrograph with small expeditionary reflector of mirror diameter of up to 20 cm. The spectral resolution of up to 0.1Å permits a considerable increase in measurements of the ozone abundance along the full height of Earth atmosphere (distribution via altitude) in different directions. They plan to reach an accuracy up to 0.1–1%. The continuous atmospheric ozone monitoring by a ground-based astrophysical method would permit one to solve the problem of the ozone layer thinning and the ozone abundance variations dependence from man-generated factors and general physical-chemical changes in the Earth atmospere. The usage of a broad spectral range permits one to raise the reliability of the results. By comparing the UV range data obtained by ground-based device with the results of space-based and radio range measurements, gives chance of eleboration of a mutual calibration of the results.

7 24-HOURS MONITORING OF VARIABLE STARS AND OTHER OBJECTS (Principal Investigator: A. M. Cherepashchuk, Sternberg Astronomical Institute, Moscow)

Investigations of many X-ray binary systems and variable stars of different kinds need a continuous monitoring of their optical variability on the characteristic timescale from 1 sec to a couple of years. Such a programme allows one to investigate mechanism of rapid and long-term variability of X-ray binary systems, which is of great interest for understanding precession effects similar to those in SS433 object and 294 d variability of Cyg X-1.

In the USSR and Russia for last two decades the optical monitoring of nonstationary objects has been carried out by 22 observatories. A very high extension of Russia along the longtitude (10^h) allow one to realize an efficient optical monitoring on small telescopes of the former USSR republics – Georgia, Armenia, Ukraine, etc. At present the programme is supported by Russian Science Ministry. Investigations of X-ray binaries, cataclysmic variables, active Galactic nuclei are now in progress, which could be much improved thanks to a long clear night period in Antarctica.

8 SITE-TESTING OBSERVATIONS TO SELECT A PLACE FOR THE INTERNATIONAL ANTARCTIC ASTRONOMICAL OBSERVATORY (in optical, IR and submillimeter ranges) (Principial Investigators: P. V. Sheglov, Sternberg Astronomical Institute and K. R. Kir'yakov working group for Antarctic Astronomy of Euro-Asian Astromical Society)

A good site testing in the visual range gives the limiting atmosperic point sprad function (PSF) for a given site, the number of nights with a given quality of image, the speckle time and the isoplanatic angle. All these quantities are essential to chose a good site for a new observatory and to operate a telescope on existing sites without loss of efficiency.

The polar seeing monitor (PSM) developed in 1976 at the Sternberg Astronomical Institute of Moscow State University, is a portable photoelectric device having no fibre elements giving additional noise, and measuring the atmospheric motion of the Polar star without loss of time, like raster devices. So, its S/N ratio is close to the theoretical one (atmospheric FWHM's can be measured down to 0.3 arcsec). The Sternberg PSM is fitted with an internal optical calibration device. The sites studied by the PSM differ drastifically in quantity of excellent images (Figure 7). To be sure of the absence of notable systematic errors, the Sternberg PSM was

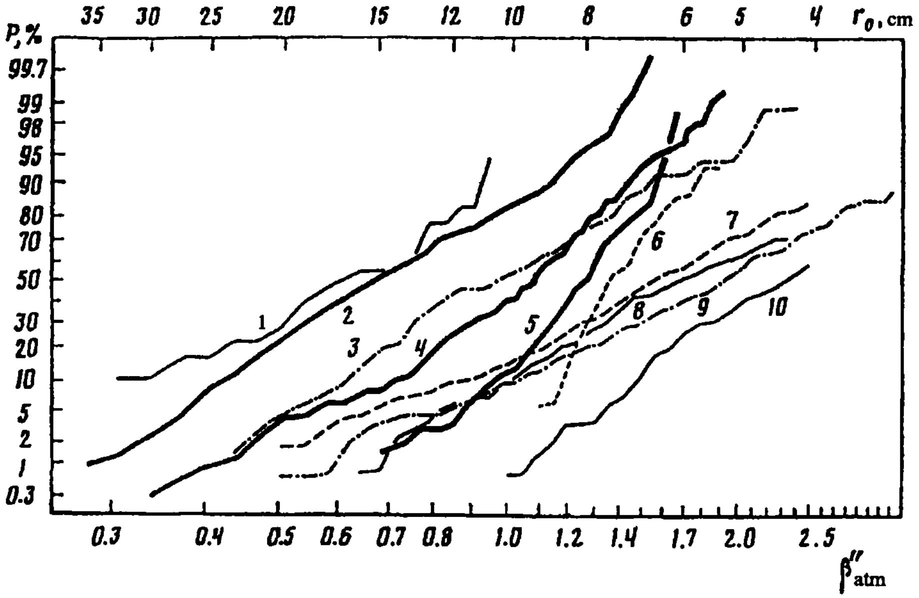


Figure 7 Cumulative FWHM curves for different mountain sites on the territory of the FSU. The percentage (p, %) of excellent seeing (say, $\beta_{atm} < 0.5''$ FWHM) can change more than 10 times from site to site, P being the percentage of image better than given. 2, Mt. Sanglok; 4, Mt. Maidanak; 5, Crimean Observatory; 7, the 6-m telescope site; 10, Fesenkov Astrophys. Inst.; Tian-Shan near Alma-Ata (Sheglov and Gur'yanov, 1991). r_0 is diffractional radius.

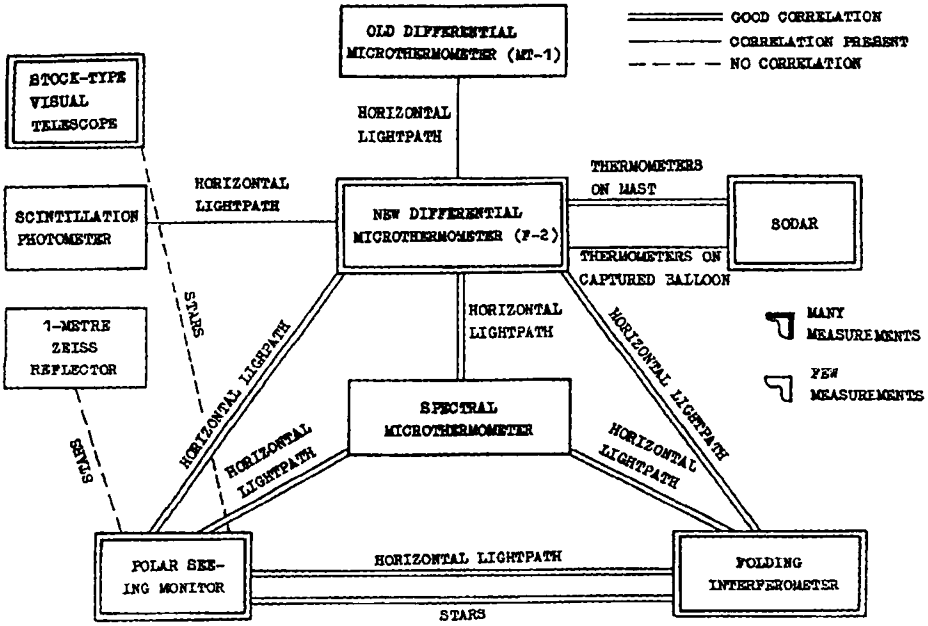


Figure 8 Intercalibration of the PSM versus many optical and thermometric devices used in site testing made from 1981 to 1990.

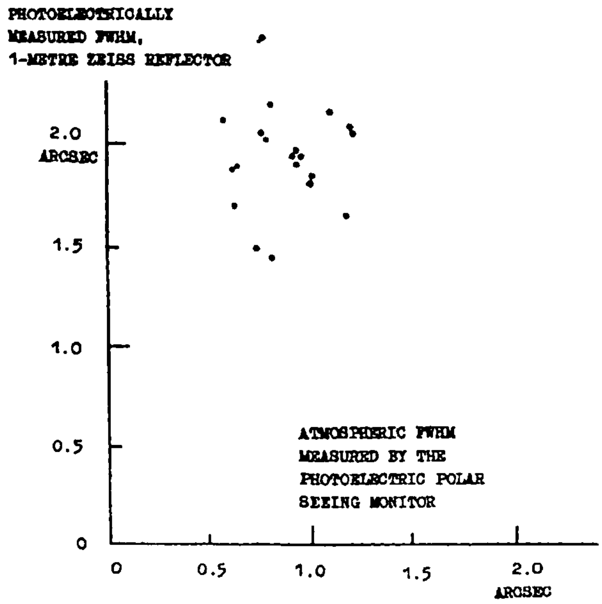


Figure 9 The PSM values do not correlate with the photoelectric FWHM ones measured with a 1-metre Carl Zeiss Iena Ritchey-Chretien reflector with a closed tube mounted at a height of 15 m, being about 1 arcsec better (Mt. Sanglok, Tajikistan). Seeing goes bad by telescope construction (Gur'yanov *et al.*, 1985).

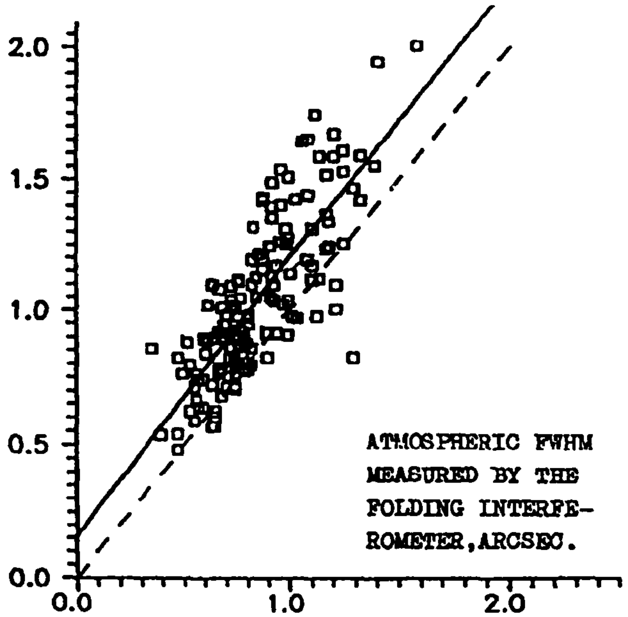


Figure 10 Good correlation of PSM readings (ordinate axis, in arcsec) is observed against a folding interferometer measuring the atmospheric FWHM using not stellar images motion, but interference, Gur'yanov *et al.* (1992).

carefully calibrated against many site testing optical and thermometric devices and telescopes (Figures 8, 9, 10). It became clear that visual methods (Kitt Pick National Observatory, 6-m telescope Observatory (SAO RAN) and Observatory La Silla) must be discarded and that some of the existing telescopes FWHM depends on their own quality, resulting from their centreing and heat generation instead of atmospheric turbulence (Sheglov, 1995). Some suspicion on large systematic errors of Differential Image Motion Monitor (DIMM)-type device exist.

It is possible to use an optical hygrometer for site-testing in IR-range. This device is a two-channel photometer, one of the channels is a reference one (out of the absorption line, $\lambda = 0.870\ \mu$) and another is a measurer (in the absorption line, $\lambda = 0.980$ micron). Previous observations by a similar device were carried out 1989–1990 at the VOSTOK station (Kir'yakov, 1990).

An aluminium compact portable telescope/photometer with Golay-cell could be applied for site-testing in submm range. It will be deployed at the South Pole station or Vostok station during the austral winter. Previous similar observation were carried out 1980 at the Shorbulak site in the Eastern Pamirs (Sholomitskii, 1993b).

9 THE CONCEPT OF THE INTERNATIONAL ANTARCTIC OBSERVATORY

(Principal Investigator: Yu. V. Baranov, working group for Antarctic Astronomy of Euro-Asian Astronomical Society)

The Euro-Asian Astronomical Society Working Group on Antarctic Astronomy has formed a team of the leading engineers from different institutions capable to construct a station for logistic support of the Antarctic Astronomical Observatory. The group of engineers is very experienced in making engineering constructions under extermal living conditions acquired in the former Soviet Union. The group has prepared a zero-stage project of the Station (Baranov *et al.*, 1996).

One of the important factors is geographical position and the corresponding climatic conditions. One of the best places for observatory is Dome A with the approximate coordinates: 82 southhern latitude and 72 eastern longitude. The altitude above the sea level is 4200 m. The barometric altitude is about 4700 m. The observatory is supposed to work both during the polar day and night. Because of the station being very remote and due to exterme climatic conditions, visits to the station in order to change and to servie the equidment, to supply materials and to change the crew are possible only 2 months a year. Thus the future station is somewhat average between an ordinary ground-based observatory and a space station. The supposed number of a permanent station personnel is 6 people.

The housing laboratory block includes:

(1) life support system;

(2) energy supplying system;

(3) control system;

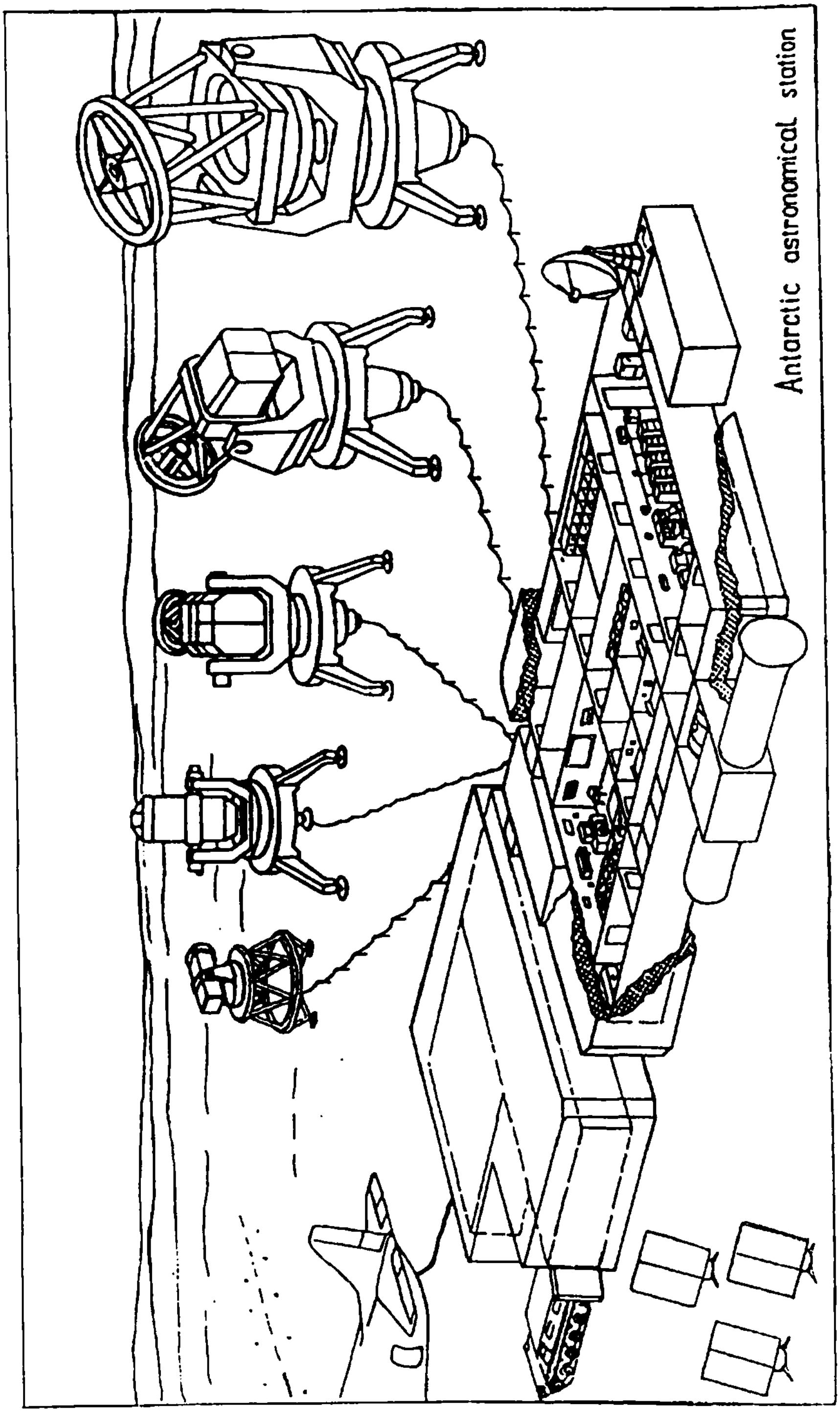


Figure 11 Antarctic astronomical station (Baranov *et al.*, 1996).

(4) radio communication system;

(5) a complete set of instrumentation and tools;

(6) a complete set of spares;

(7) a complete set of testing and measuring apparatus.

The supposed outlook of the station is presented in Figure 11.

The main characteristics of the life support system of the Antarctic observatory are presented in Table 3.

Table 3. A Main Characteristics of the Life Support System (Baranov *et al.*, 1996)

1. Constant personnel	6 persons
2. Guest personnel	10 persons
3. Time of autonomous existence	12 months
4. Existence time in emergency conditions	3 months
5. Atmospheric parameters inside the station:	
5.1 Temperature	22...27 C
5.2 Relative air humidity	30...70 %
5.3 Pressure:	
full	53...59 kPa
oxigen	16 kPa
carbon dioxide	0.06 kPa
6. Electric power consumption:	
6.1 In routine conditions:	
average	5.5 kW
maximal	10 kW
7. Average domestic water consumption	
in routine conditions	75 kg p.d.
in emergency conditions	40 kg p.d.
8. Drinking water consumption	15 kg p.d.
9. Food supply per year	4400 kg
10. Absorbents supply per year	200 kg

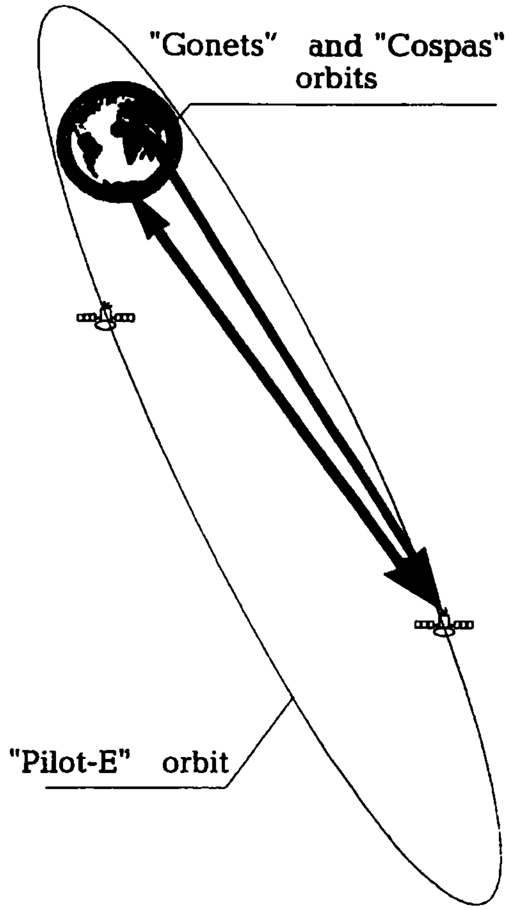
The radio communication system should provide communication with international scientific centres:

(1) to receive scientific tasks and working programmes for the station;

(2) to transmit scientific results, data and the data concerning technological condition of equipment etc. to international astronomical centres.

The radio communication system should transmit urgent information in the case of emergency at the station.

Since the station is to be placed near the pole, it becomes problematic to use the system of geostationary satellites for radio communication. It is supposed to use "Pilot-E" system with a highly-elliptic orbit and with an apogee in the southern hemisphere for transmitting large volumes of information. The possibility of using quasigeostationary orbit sattellites may be investigated.



TECHNICAL PARAMETERS OF THE SATELLITE COMMUNICATION SYSTEM OF THE IAAS

"Pilot-E" system

Number of satellites: 2.

Transmitting information:

massives of digital information, TV and broadcasting, telephone, telex, facsimile.

Data transmission rate: 60 Mbit/s.

Session time: 2x8 hours.

"Gonets" system

Number of satellites: 36.

Transmitting information:

digital telephone, data transmission, telex, facsimile.

Data transmission rate: 64 kbit/s.

The mean waiting time for a communication session under the probability 0.8: < 20 min.

"Cospas" system

Transmitting information:

urgent signals.

Figure 12 Technical parameters of the satellite communication system of the International Antarctic Astronomical Station (IAAS).

As an auxilliary system it is suggested to use the "GONETS" system which can work both as a retransmitter and as an electronic mail facility. The "COSPAS" system should be placed on the station for emergency signal transmission. The main characteristics of radio communication system are presented in Figure 12.

The composition of the complete set of scientific equipment must meet a set of scientific tasks accomplished by the station. The set scientific tasks is defined by the IAU Resolutions.

10 SUBMM INTERFEROMETER FOR ANTARCTIC OBSERVATORY (a draft of the Russian project at zero phase. Principal Investigator: G. B. Sholominskii, Space Research Institute and working group for Antarctic Astronomy of Euro-Asian Astronomical Society)

The main goal of this project is to show principial technological capability to make ground based observations at $\lambda = 200$ micron with angular resolution of the largest submm telescope (< 5–$10''$) near the spectral maxima of compact objects.

The shape of the variable-base interferometer is shown in Figure 13.

The interferometer comprises three telescopes connected with each other by common apparatus room. The foundation of the interferometer are piles dug in ice. There are precision rails between supporting landing. All of the telescopes have their own mounting and can scan in two axes. The vertical axis have inclination 8 degree. The central telescope is immovable, but two others can move in discrete positions.

The apparatus unit is power construction and have three floors. There are system of compensation of the optical length on the first floor, optical devices for leading up and leading out on the second floor, and telescope-commutator, scaners, lasers etc. on the third floor.

Some of main technical characteristics are:

(1) size of mirrors = 0.6–1.5 metre;

(2) variable distance (base) from 6 to 15–30 metres;

(3) material for mirrors is silicon carbide (SiC);

(4) temperature range for work from +20° C to −90° C.

This variable-base option proposed by Zacharenkov *et al.* (1994), have a low optical efficiency because of a large number of reflecteing mirrors. It could be proposed the option of fixed base-line interferometers on the steerable rigid girder. Several pairs of telescopes displaced symmetrycally do not need path difference compensating systems as the symmetry can be attained without active regulation.

In this projects optical schemes, system of registrated of images, constructions of interferometer and other problems are elaborated.

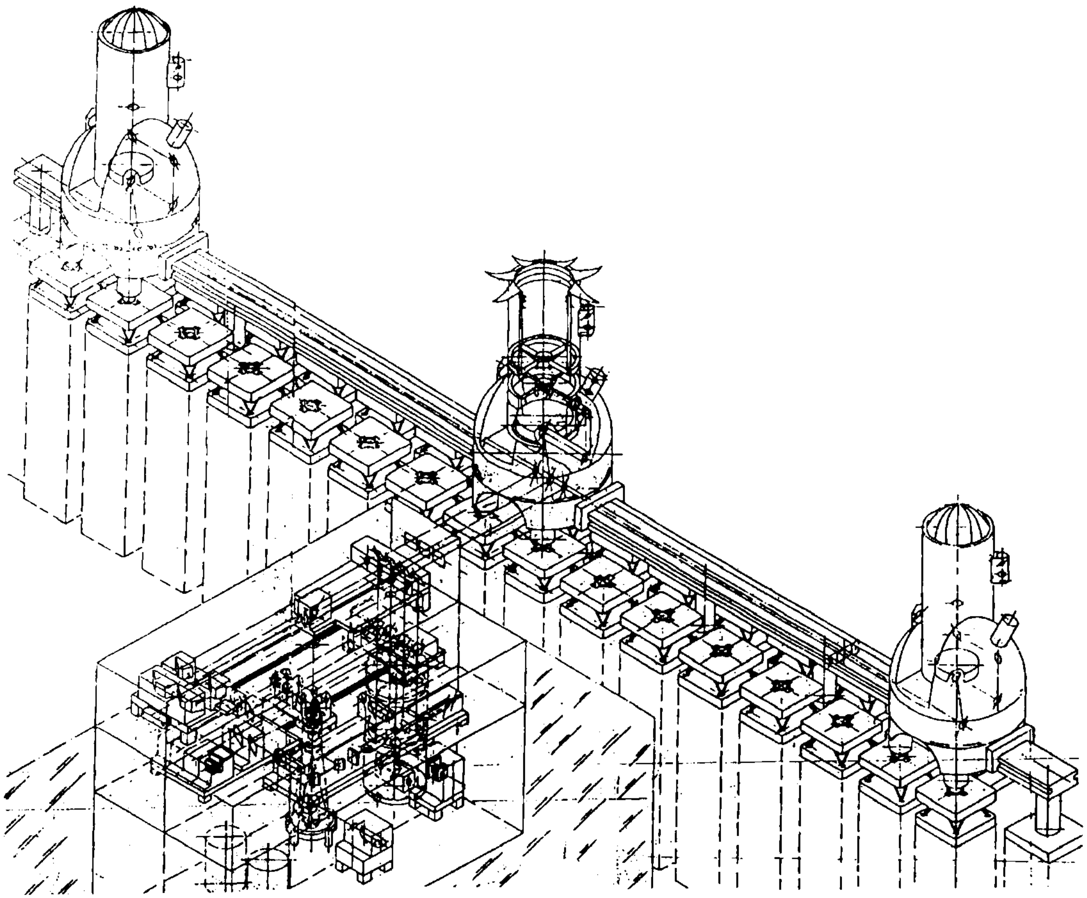


Figure 13 Submm interferometer for Antarctic observations (Zacharenkov *et al.*, 1993).

Acknowledgements

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