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Metsähovi Radio Observatory
Annual Report 2000

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1 Introduction

The Metsähovi Radio Observatory, a separate research institute at the Helsinki University of Technology since May 1988, operates a 14 m diameter radio telescope at Metsähovi, Kylmälä, about 35 km west from the university campus. The institute also has premises in the Electrical Engineering Faculty building, Otakaari 5, Espoo. The main users of the station are the Helsinki University of Technology, the University of Helsinki, and the University of Turku. In the same area, near Metsähovi Radio Observatory, there are also the buildings of the Metsähovi Observatory (University of Helsinki; optical astronomy) and the Metsähovi Space Geodetic Station (Geodetic Institute; geodesy).

The Metsähovi Radio Observatory has been operational since 1974. The upgrading of the telescope was done during 1992−1994. The radome was replaced with a new one and new surface panels were installed. The surface accuracy of the present telescope is 0.1 mm (rms). The old analog servo system of the telescope was replaced by a new digital servo system in 1998−1999. Planning of new observing programmes was started in 1999.

The Metsähovi Radio Observatory is active in the following fields:

- Research in radio astronomy,
- Development of instruments needed in radio astronomy,
- Development of methods for radio astronomical measurements,
- Space research, and
- Education.

The activities at Metsähovi are concentrated on millimeter waves and microwaves. The used frequencies are $10 \cdots 120$ GHz, and the corresponding wavelengths $30 \cdots 2.5$ mm. The research in technology includes development of microwave receivers, development of receiving methods, development of data processing and development of antenna technology. The objects of radio astronomical research are: solar millimeter and microwave radiation, variable quasars, active galaxies, molecular line radiation, and very long baseline interferometry (VLBI). Metsähovi participates in the education at the Helsinki University of Technology by organizing courses and exercises for students, and graduate students can study for a licentiate's or doctor's degree at Metsähovi.

Around 20 scientists, engineers, or research assistants, and support personnel from the Helsinki University of Technology work at the institute. In addition about 10 students did radio astronomical observations under the guidance of Metsähovi staff. Five of the employees are paid by the Helsinki University of Technology, and the others are employed by research projects financed mainly by the Academy of Finland. The other users of the Metsähovi telescope are the radio astronomy group at the University of Helsinki, and the radio astronomy group at the University of Turku.

In 2000 the total expenditure of the Metsähovi Radio Observatory was about 4,63 million FIM, including salaries. This was financed by:

Helsinki University of Technology 43 %
Academy of Finland 40 %
Tekes 10 %
Others 7 %

2 Research Activities

In this chapter the main research activities at Metsähovi are introduced. Some of the project teams include also scientists working at other institutes. The contact person at Metsähovi is underlined in each project team list.

2.1 Radio Astronomical Instrumentation

Research Group at Metsähovi: Urpo, Engelberg, Karlamaa, Koistinen, Mujunen, Oinaskallio, Peltonen, Ritakari, Rönnberg

2.1.1 Planck 70 GHz Receiver

Project Team: Koistinen, Karlamaa, Peltonen, Rönnberg

The Planck demonstrator receiver has been measured in co-operation with Ylinen Electronics and Millilab. The demonstrator is basically similar to the continuous pseudo correlation 70 GHz receiver of the Planck satellite. A block diagram of the demonstrator receiver is shown in Figure 1.

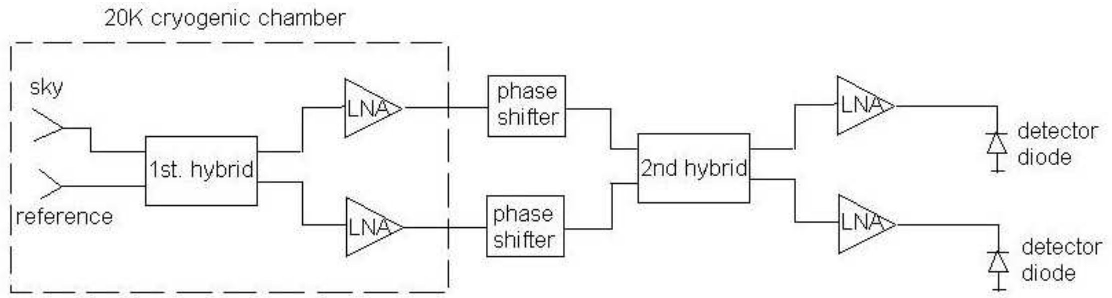

Figure 1: Block diagram of Planck demonstrator receiver.

The physical temperature of second hybrid and phase shifters is the main difference between the demonstrator and the final receiver. In the final receiver the phase shifters and the second hybrid will operate at 20 K physical temperature while in the demonstrator these parts are in room temperature. In the demonstrator also only one cryogenic (20 K) LNA (Low Noise Amplifier) was used when in the final version two cryogenic amplifiers will be used.

A cryogenic 20 dB directional coupler was used to measure the gain and the isolation of the demonstrator receiver. The directional coupler was connected between the sky load and the input of the first hybrid. Temperature variable loads were used as the sky and reference signals in the noise measurements. A room temperature horn antenna was also used in noise measurements when the noise behavior of the receiver in different physical temperature was studied. 80 K noise temperature was measured with temperature variable loads while the physical temperatures of the LNA were 26 K, Figure 2.

TRW's INP-HEMT amplifiers were used in the demonstrator measurement. The particular amplifiers were designed by Pekka Kangaslahti from Ylinen Electronics. On wafer measurements of the amplifiers were done at Millilab and the packaged amplifiers for the demonstrator receiver were measured at Ylinen Electronics with co-operation of Metsähovi Radio Observatory. Metsähovi Radio Observatory has done a great effort to get the demonstrator receiver work properly at 20 K temperature. The same receiver was measured at room temperature at Ylinen Electronics. The cryogenic measurements have

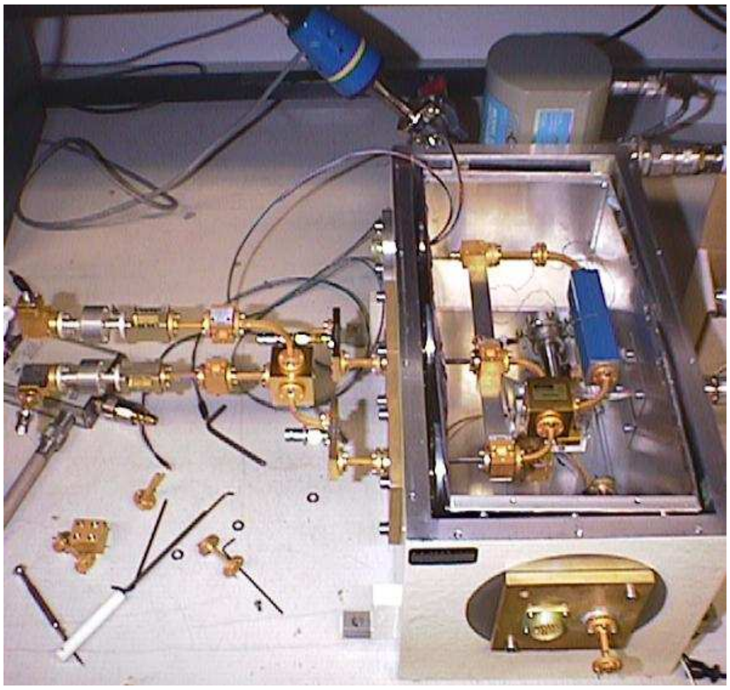

Figure 2: Planck demonstrator mounted in a cryogenic test chamber.

been done physically at Ylinen Electronics with equipment of Ylinen Electronics and Metsähovi Radio Observatory.

The measured results are promising compared to the requirements. The required isolations between the amplifier chains are 20 dB over the operating frequency band of 63−77 GHz. The required gain of the final front end module is about 40 dB. 20 dB isolation and more than 20 dB gain were measured with the demonstrator over the frequency band. Only one cryogenic amplifier per amplification chain was used in the measurement, so the gain would be around 40 dB with two cryogenic amplifiers. The next step in the Planck receiver development is the Elegant Bread Board (EBB) which will be ready for the measurements in near future. Nicholas Hughes designs the EBB at Ylinen Electronics.

Measurements with individually packaged amplifiers have been done parallel with the demonstrator measurements. The noise measurement system has been build at Ylinen Electronics with co-operation of Metsähovi Radio Observatory. Metsähovi made the cryogenic chamber for the measurement system of the individual amplifiers. Metsähovi made also all the noise measurements with the individual amplifier. Encouraging results have been measured with packaged amplifier. More accurate results will be measured in near future from new MMIC runs.

2.1.2 2 mm SIS Receiver

Project Team: Peltonen, Oinaskallio, Rönnberg, Sjöman, Urpo

Metsähovi Radio Observatory has received a 2 mm SIS VLBI receiver as a permanent loan from Instituto de RadioAstronomia Milimetrica (IRAM), Spain. This receiver has been already used successfully for VLBI measurements at IRAM for around 10 years. The receiver consists of a 3 K cryostat with a waveguide SIS mixer block (non-contacting backshort as a tuning element) and a corrugated feed horn, Figure 3.

The IF signal centered at 3.95 GHz with 500 MHz bandwidth is amplified with a HEMT preamplifier at 15 K ambient temperature. A motorized LO coupler of Mach Zender design is used to couple the

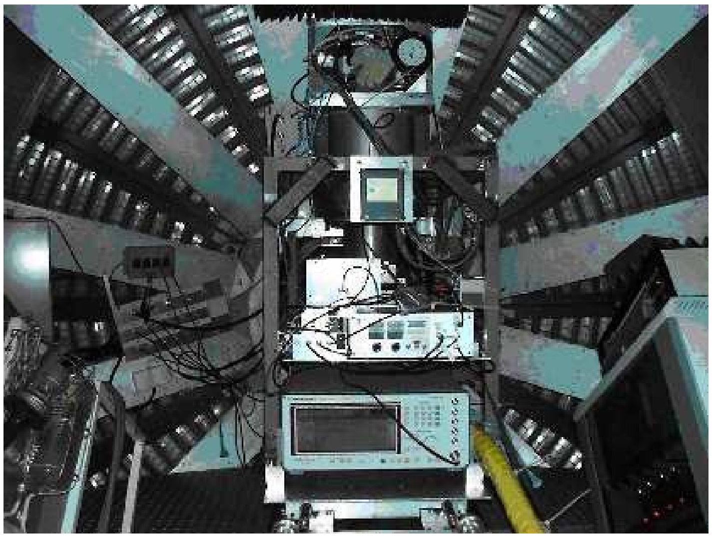

Figure 3: 2 mm receiver installed to the antenna of Metsähovi Radio Observatory.

required LO power into the mixer block, Figure 4.

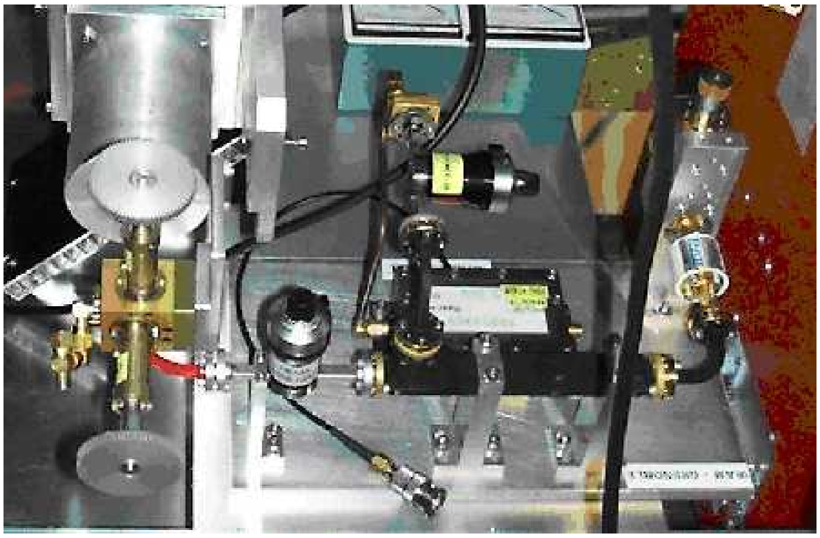

Figure 4: LO system mounted to the 2 mm receiver.

The local oscillator power is derived from an InP Gunn oscillator (J.E.Carlstrom design) followed by a Schottky diode frequency doubler. For the signal (sky frequency) of 147.05 GHz the required Gunn oscillator frequency is 75.5 GHz when LSB operation is preferred. For the phase locking we use 16th harmonic of a Rohde Schwarz synthesizer giving reference frequency of 4.7125 GHz. With a second down converter we transfer the 3.7−4.2 GHz IF band to the standard VLBI band of 0.5−1.0 GHz using a Miteq phase locked 3.2 GHz cavity stabilized oscillator as a LO source.

First operational tests for the receiver were conducted with supervision help of Mr. Santiago Navarro and Dave L. John. The quasi-optical feed system (to convert the F/D ratio of 9.73 to 4.074) was designed by Mr. Kaj Wiik. This system consists of 3 plane mirrors and 2 elliptical mirrors together with rotating chopper beam-switch. Also a quarter wave polarizer from IRAM can be installed between elliptical mirrors, Figure 5.

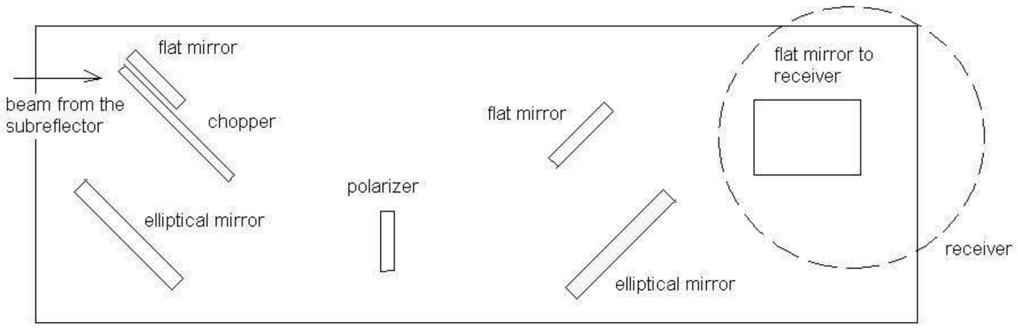

Figure 5: Quasi-optical mirrors in front of the 2 mm receiver.

For optimum performance the four main parameters of the receiver which should be optimized are mixer bias current, mixer backshort position, LO coupler and the pressure of liquid helium. With the optics in front of the receiver it is very easy and quick to measure the Y-factor of the system simply removing/replacing the hot load and liquid nitrogen load is kept in a fixed position. It was noticed that the receiver is very sensitive to the LO feed power level. For that reason the Gunn oscillator, harmonic mixer and tunable waveguide attenuator were installed in a temperature controlled enclosure. The measured noise performance of the system with optics (without polarizer) is shown in Figure 6.

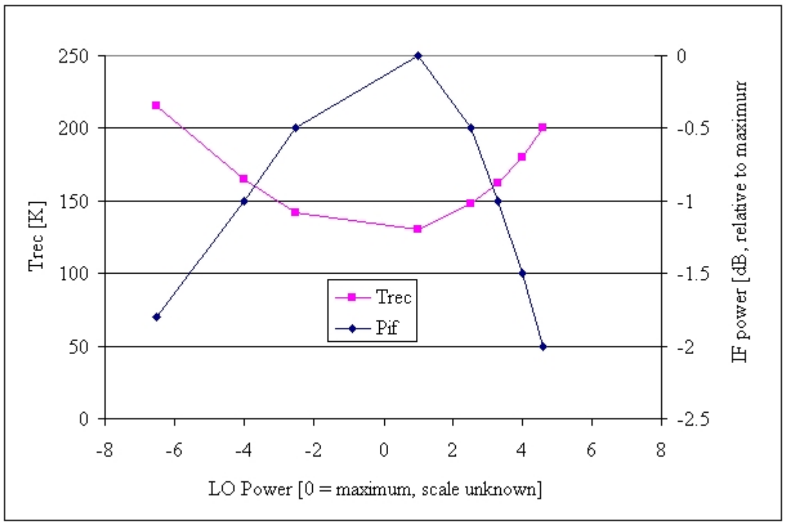

Figure 6: Noise temperature of the 2 mm SIS receiver as a function of LO feed.

It was found that the IF level peak with LO power is very tightly bound to the sensitivity of the receiver. Let us define the I-factor i.e. the relative IF level increase when first the LO power is turned off and then increased to reach the first IF maximum. If the I-factor is around 6 dB the noise temperature of the receiver is close to minimum. Due to this analogy between I- and Y-factors the sensitivity of the system can be roughly estimated (without cold load) measuring only the I-factor with 5.5−6 dB being acceptable values. For optimum noise temperature 130 K was measured with optics (with polarizer 145 K) and in front of the receiver feed horn 120 K noise temperature was recorded respectively.

2.1.3 Maintenance and Upgrades of Receivers

Project team: Koistinen, Urpo

A monolithic (MMIC) low noise amplifier (LNA) at 70 GHz was designed using HRL (Hughes Research Laboratory) Indium Phosphide (InP) process.

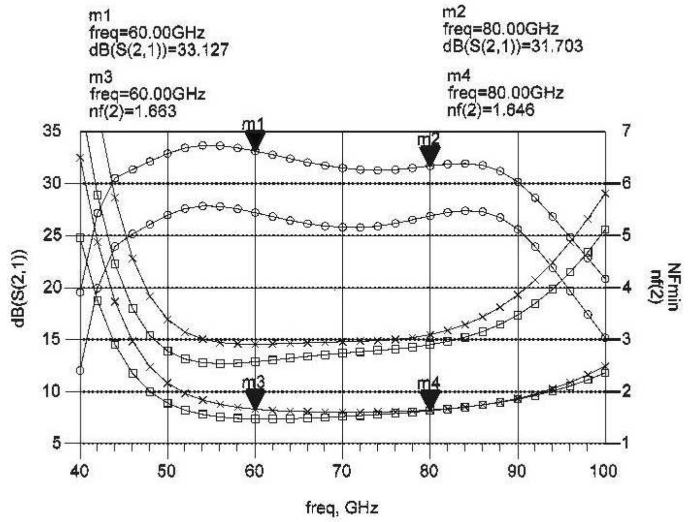

Figure 7: Gain and noise figure both with the adjusted (gm= 45 mS, Tds=4000 K) and the nominal foundry values (gm= 60 mS, Tds=1500 K).

The LNA is a 4-stage microstrip design, which provides 27 ± 1 dB gain and 3.0 ± 0.1 dB noise figure at 60−80 GHz frequency range with 2 × 25 μm HEMT active elements. The first two stages are optimized for the minimum noise. All stages are matched with reactive elements. An inductive feedback at the HEMT source is used to provide sufficient stability.

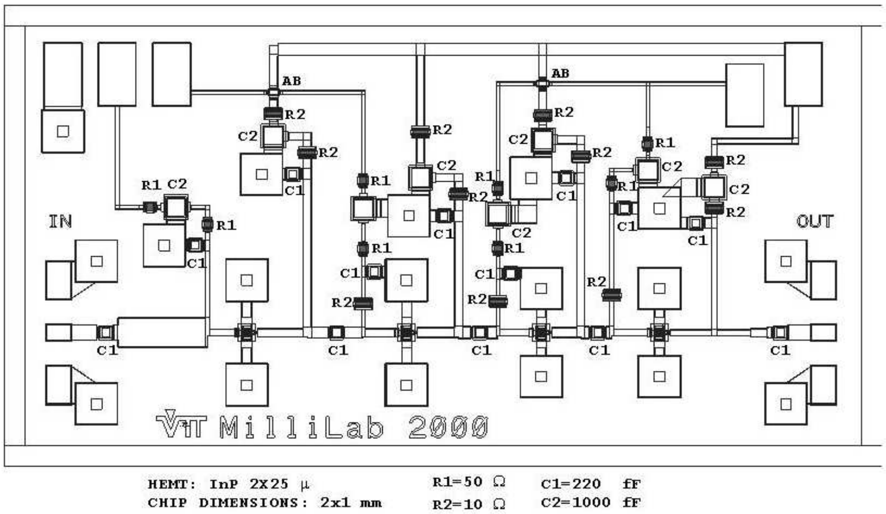

Figure 8: Layout of LNA.

The last two stages are optimized for high gain utilizing smaller source feedback. The reduced stability is compensated by inserting series resistors to the source bias lines close to the matching stages. The overall configuration provides a K factor of 20 or higher.

The design goal was to provide a considerably wider bandwidth than required to reduce the sensitivity to parameter variations. For instance the transconductance lies in the limits of 60 mS, reported by the foundry, and 45 mS which is the measured value at Millilab. The noise figure and gain of the LNA depend strongly on this parameter (see Figure 7 and 8), but due to the broadband design the shape of the curves remain the same.

A Magic-T type power dividing hybrid was designed for WR12 waveguide. The design is based on a higher frequency design by JPL. The hybrid is shown in Figure 9. The hybrid is designed for 70 GHz $\pm$ 7 GHz. The simulated return losses at all ports are less than -15 dB at this frequency range.

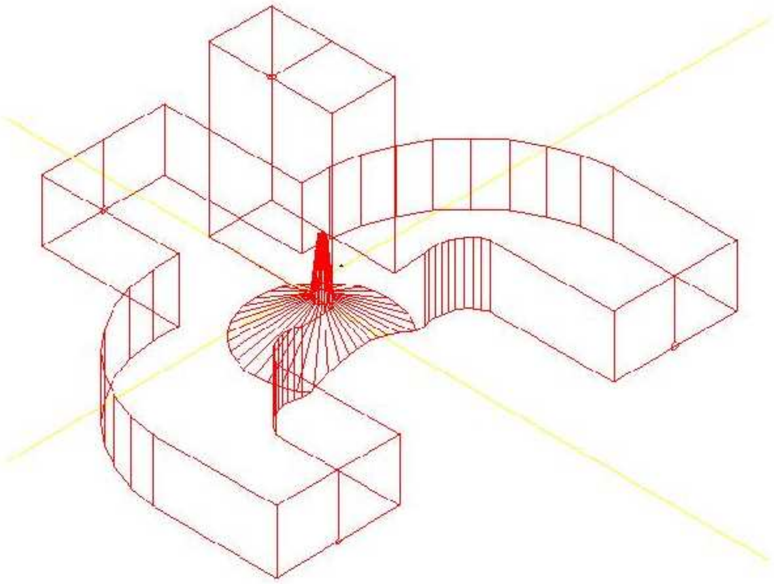

Figure 9: Magic T type waveguide hybrid.

The LO temperature stabilized box of 22 GHz VLBI receiver was re-wired to support additional ADAM/NuDAM remote monitoring channels (cryogenic temperatures and vacuum pressure). LO PLL locking problems were investigated and checks for both LO 5 MHz reference input and IF output power levels were done. With proper reference input level the LO keeps the lock reasonably well.

The RCP channel of the 43 GHz receiver is still out of order because of the damaged gate bonding of one of the HEMTs. The LCP channel of the 43 GHz receiver functions as do the 22 GHz and 86 GHz receivers.

The beam switcher of 87 GHz receiver was brought under remote ADAM/NuDAM control with the new antenna control system cabling and new ADAM/NuDAM central control box. This enables both single-beam observations (such as VLBI), beam switching (continuum), and calibration (hot–cold) observations to be made under computer control.

2.1.4 VLBI Instrumentation

Project Team: Ritakari, Mujunen, Oinaskallio

Extensive VLBA recorder recording quality tests were performed in April 2000 to investigate the reason for poor thin tape recording quality. Especially the recording quality of upper tracks was poor. This was most likely caused by thin/thick tape switching. There were long runs of thick tape in a CMVA session a little before the EVN thin tape session in February.

After extensive recorder tests no definitive cause could be found. Re-contouring the head with abrasive tape and high (40%) humidity has apparently (according to thin tape test at JIVE correlator) alleviated the problem. Currently we are running thin tape at a vacuum level of 6 inches and thick tape at 28(!) inches of water.

The new Mark IV formatter and associated VIV upgrade items were installed in October and used succesfully in November sessions. The electronics and mechanical mounts for the second head will be installed after a second fully functional headstack is available.

Jouko Ritakari and Ari Mujunen have written several papers on the impact of the fast Ethernet connections to the VLBI. These documents can be found at the following address:

- "`http://kurp-www.hut.fi/vlbi/instr/`".

An initial investigation of modern monolithic PLL/synthesizer chips was coducted as a possible replacement for VLBA BBC LO oscillators. National Semiconductor "PLLatinum" series chips seem promising but a suitable commercial VCO remains a problem with its 500−1000 MHz frequency range requirement.

Prototypes for a "Clodi" 1pps multi-channel simultaneous sampling clock difference counter have been built. The basic high-speed, low-skew 1pps rising edge detector/comparator has been designed and tested in prototype. Based on a 100 MHz CPLD design, the counter chips have also been tested in a two-channel prototype setup with an embedded alphanumeric display. A multi-channel prototype with computer LPT port interface is being developed.

2.1.5 EVN Mark IV R/W Upgrades

Project Team: Ritakari

Metsähovi has continued to provide Mark IV Read/Write electronics modules and upgrade kits. The supplemental kits of EVN VIV upgrade were provided. This upgrade updates an existing VLBA data acquisition terminal to Mark IV standards and increases data throughput from 256 Mbit/s to 512 Mbit/s and 1 Gbit/s.

Three upgrade kits were sent to Jodrell Bank (Cambridge VLBA DAR), IRAM (Pico Veleta), and OAN (Yebes).

2.1.6 Radio Spectrum Monitoring

Project Team: Engelberg, Mujunen, Oinaskallio, Rönnberg

The radio spectrum monitoring daemon "`spektrd`" has been running continuously since November 1999. Detailed RFI spectral information is collected in the frequency band from 400 MHz to 2 GHz in UTC time-tagged ASCII files. Currently the database contains 1.8 GB of raw data.

"`spektrd`" controls antenna rotation, spectrum analyzer settings, and archiving of the measured values. Analyzing and post-processing these raw data files requires further development. Interesting development is on-going at NFRA (Netherlands) where a set of RFI detection and visualization software packages is being developed as a part of an EU project.

The most severe sources of interference at Metsähovi are GSM mobile phone base stations in the frequency range 890−960 MHz. This coincides with the IF bands used to transmit signals from receivers in telescope to control room. During the year 2000 the GSM 1800 network continued to grow outside Helsinki area and a relatively strong 1800 MHz base station signal can be measured at Metsähovi.

2.1.7 Computing Infrastructure

Project Team: Mujunen, Engelberg

Metsähovi observatory site is connected to the Internet using a 2 Mbit/s dedicated leased line to university computing center. A stand-alone NAT LANB/290 IP router routes TCP/IP network traffic between Metsähovi LAN and Internet WAN. Four 28.8k modems provide dial-in facilities for observatory personnel although the availability of free-of-charge Internet modem service providers has mostly rendered in-house modems obsolete.

A Tektronix Phaser 740 color printer was installed in addition to the existing HP LaserJet 5M black and white printers.

An increasing number of PC fans and power supplies failed and had to be replaced. Small CPU fans seem to be especially vulnerable to failures after only 2−3 years of use. A batch of new ATX power supply units was purchased to allow quick in-house swaps of failed PSUs.

Many of our Linux computers were upgraded from Debian/GNU/Linux (`http://www.debian.org`) version 2.1 to 2.2. The Debian "`dselect/dpkg`" mechanism offers continuous upgradability package-by-package without the need to reinstall the operating system from scratch. It seems to work surprisingly well, since we have had a couple of computers undergo an uninterrupted chain of upgrades (from 1.1 → 1.2 → 1.3 → 1.3.1 → 2.0 → 2.1 → 2.2).

IDL version 5.4 was installed on "`kurp.hut.fi`" (2 floating licenses) and on two Linux computers dedicated to solar research. The incompatibility issues with Debian/GNU/Linux of versions 5.2 and 5.3 have been resolved and an upgrade from 5.1 was possible. Version 5.4 drops support for GIF graphic output.

For electronics development, PADS PowerLogic and PowerPCB 2.1 were used, together with Lattice/Vantis DesignDirect 1.1 and ispDesignEXPERT CPLD development systems. Evaluation of Xilinx Foundation v2.1i VHDL tools for FPGA development was started.

2.1.8 Data Collecting and Archival

Project Team: Mujunen, Engelberg

Metsähovi main NFS server "`/home`" continues to be the same 32 GB four-disk RAID0 disk array which was installed in 1998. The hard disk array enclosure has two sets of four 9GB hard disks, "`/home`" and "`/backup`". All user files can thus be backed up "on-line" using the Linux "`mirrordir`" command in less than an hour. This process was automated by using a "`cron`" job to execute mirroring daily at 18:30 local time.

This division of available hard disks into "backup" and "hot" disks proved its usefulness in 2000 when one of the 9GB disks failed. The failure was in "backup" set, so it was enough to shut down the automatic backup procedure while waiting for the replacement disk. If the failure had been in the "hot" set, "`/backup`" would have been re-mounted as "`/home`" for immediate backup data availability.

Backing up "`/backup`" (instead of "`/home`" directly) on DAT makes tape backups more consistent since "`/backup`" does not change during the DAT-"`tar`" procedure. It also provides a snapshot of yesterday's files which allows us to recover from, for instance, accidental user file deletions and similar mishaps.

The necessary infrastructure for multiple concurrent software developers in the form of "`/home/cvs`", a common CVS repository, has been found extremely useful. CVS (Concurrent Versions System) keeps track of the evolution of source code and documentation files and allows multiple developers have private "sandbox" development copies of the same set of files. Later changes can be merged back to the common repository version of each file. CVS conventions at Metsähovi are documented in a laboratory report "Using CVS at Metsähovi".

The additional "data warehouse" NFS server "`/data`" created on "`data.kurp.hut.fi`" continues its full operation. The server uses a similar Linux RAID0 setup as what was used for "`/home`". Two 9GB Ultra-Wide SCSI hard disks were combined for 18GB of total "`/data`" disk space and another two disks make up on-line "`/backup`".

"`/data`" is reserved for continuous log and data file storage for different components of Metsähovi observation system (see section 2.2). Environmental and auxiliary measurement information is collected by background daemons and archived in ASCII files, one file per each UTC day ("`yyyymmdd.log`").

Hydrogen maser conditions were monitored with a Linux software daemon "`efos9d`". The latest version of the software measures 34 monitoring channels and the maser frequency value and saves them locally and afterwards these daily files are being moved to the main data archive located in "`data.kurp.hut.fi`".

Weather station software and RFI spectral monitoring software continue their autonomous operations as is explained in their respective sections.

2.1.9 Data Monitoring

Project Team: Könönen, Mujunen, Vilenius

There are several different types of data which are observed and collected non-stop at Metsähovi Radio Observatory. The data sources vary; for example, there are two weather stations in Metsähovi, a spectrum analyzer to measure radio interference, the EFOS-9 hydrogen maser which is the frequency reference of the observatory and an ADAM/NuDAM control/monitor network which is used amongst other things to observe the state of astronomical receivers and to collect the data from two meter solar radiometer.

Most often the purpose of the data is to aid the observations and to help the maintenance and upgrading of the instruments. So there is a demand to view the data graphically, monitored values versus time. For that reason two CGI programs have been developed. These are "MB" and "Latest", both written in Perl programming language. They are available at the site "`http://kurp.hut.fi/local/`" which initially limits the access to the computers on-site at Metsähovi.

The "Multi-browsing" program "MB" allows user to freely choose data types, parameters, a time period, and presentation of data. The results of an inquiry are plotted to files both in Postscript and GIF formats and shown on the browser.

The "Latest" script inserts the latest monitored values into template HTML text. One can also format the output of the data. The script has been used for example to make an HTML page for observers. The automatically updating page shows the latest weather and antenna temperature values printed on the visualizing picture of the observatory.

The flexibility of the programs results from the feature that they automatically make new data types available if only the data is archived into the "`data`" machine and a "`mb_txt`" file describing the data parameters exists in the same directory where the data files are.

2.1.10 Solar Monitoring Telescope

Project Team: Mujunen, Puhakka, Sjöman

The project to design and build up a small size receiver for Sun measurements started already in the beginning of the year 1999. The final aim is to participate in the space weather research by monitoring long term variations and short term bursts during daytime when the Sun is visible at Metsähovi. The main concept is to introduce rather light and simplified construction compared to typical radio telescopes. This is implemented by using a standard commercial satellite dish and microwave receiver

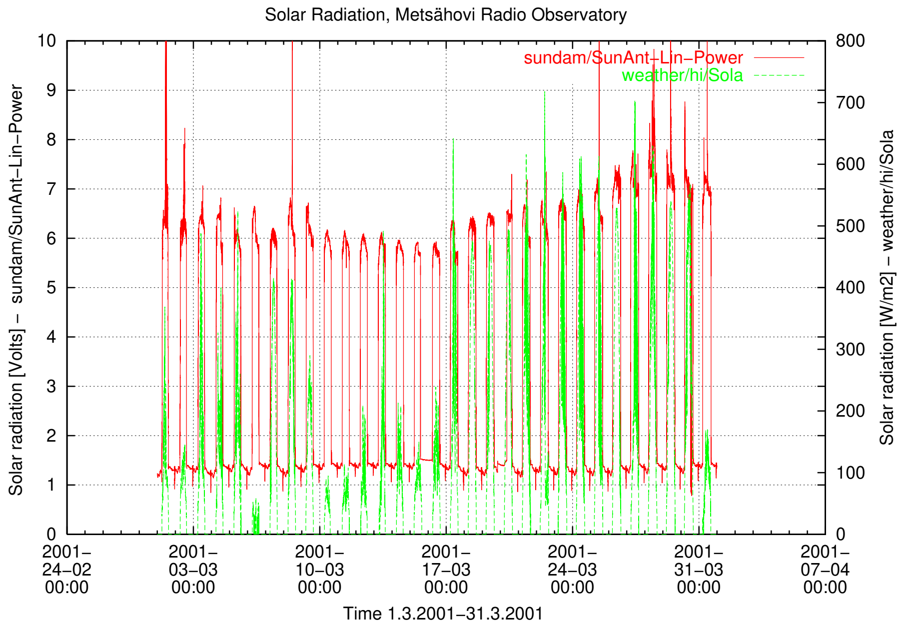

Figure 10: A MB plot of the solar radiation values within a time period of one month. One can easily see that the solar radiation detector of the weather station is more sensitive to clouds than the two meter solar radiometer. The state of activity in Sun shows in occasional peaks.

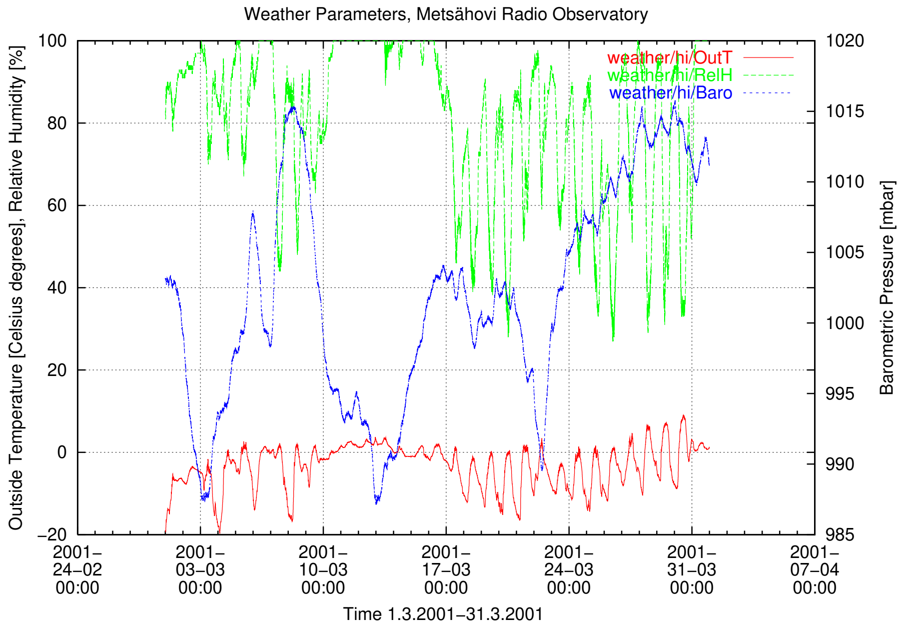

Figure 11: The values of most important weather parameters during the same time period as in plot above.

with a pass band around 12 GHz. With a dish diameter of 1.8 meters the beam is wide enough to observe simultaneously the total power over the whole surface of the Sun hemisphere.

Outdoor part of the telescope consists essentially of few meters high pedestal for the dish, equipped with DC-motors and required encoders for servo system. Main electronics for servo system and signal

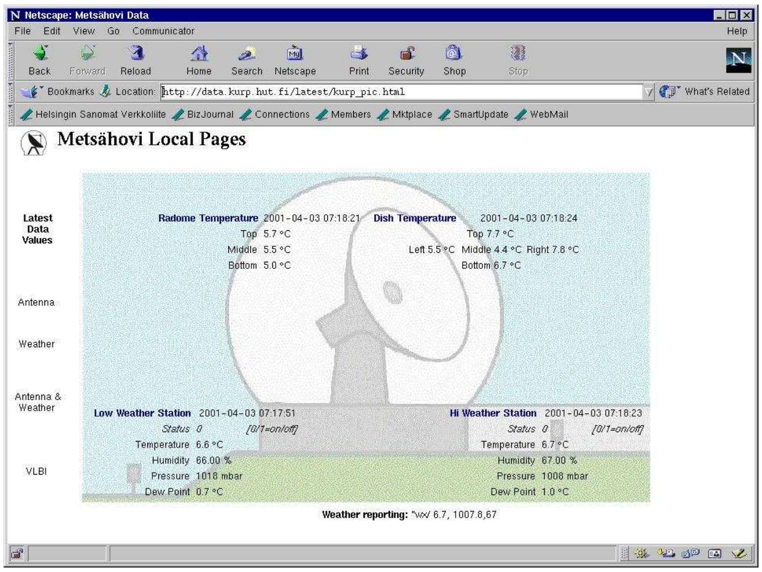

Figure 12: The Latest script is used to monitor the weather and antenna temperature values.

Figure 13: Sun antenna.

processing including self designed hardware and two computers are fitted into one rack inside the control room. A new design for SSI interface main encoders was developed and an existing QDR interface from main antenna control system was reused for motor tachometers.

The whole mechanical and electrical construction was completed first time during the summer 2000. After that, different kinds of tests were made and finally, a preliminary continuous monitoring program started to run. Developing the system is still going on and some modifications are made during the autumn 2000.

The first measurement period in autumn 2000 proofs that this type of telescope is capable of tracking the Sun rather accurately and various bursts with different amplitudes were observed. Scientific research for space weather will be started as soon as possible. In any case, best results will be gained after all final modifications and adjustments have been completed.

Figure 14: Sun antenna control rack.

2.2 Antenna Control System Upgrade

Project Team: Mujunen, Engelberg, Myyry, Oinaskallio, Rönnberg

The overall architecture of the observation system is presented in Figure 15. The main objective is to offload observation/measurement tasks across multiple industry-standard PCs running the freely available Linux operating system. To attain high time accuracy common station time is distributed with 5 MHz and 1pps signals to all participating computers. Hardware clock counters are used to make precise common sub-second time easily available in all PC Linux software, and higher-level common UTC time is distributed from GPS monitoring subsystem using the "`xntp`" Network Time Protocol software package.

Heidenhain RON806 optical encoders have been in use as the main Az-El axis encoders since 1996 and they have given us the benefit of a (at least) tenfold improvement in encoder accuracy when compared to old Inductosyns. RON806s exhibit very little periodic/geometric distortions and they deliver noise-free and repeatable sub-millidegree accuracy. Much of this accuracy can also be attributed to careful mechanical fitting and alignment of the encoders; also the Heidenhain-supplied IK121 PC ISA encoder interface board provides excellent results when it interpolates the 11μA sinusoidal current signals for 1024-fold resolution improvement over the optical 36000 lines per revolution grating line count.

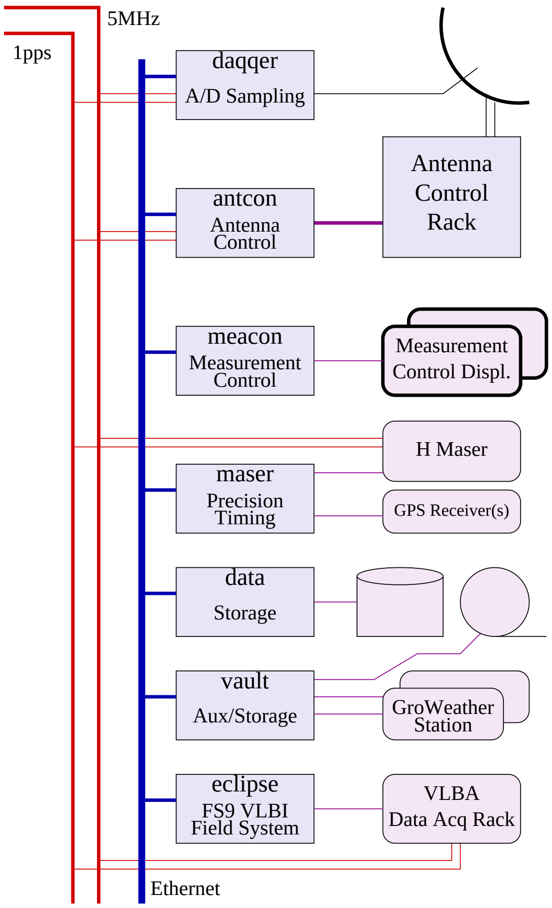

Figure 15: Distributed antenna control computers.

2.2.1 Antenna Control

A dual-process antenna control server, "`antcon/antcli`" was created. The processes run in parallel sharing a SHM segment. This architecture effectively separates network communication (TCP server process "`antcli`") from antenna control and thus enhances the robustness of "`antcon`.

Antenna control software utilizes USNO Novas C Library version 2.0 which enables it to track the Sun, the Moon, all planets, and extragalactic sources with J2000 coordinates. Older 1950 epoch coordinates are supported in compatibility mode. Planet tracking uses JPL DE405 ephemeris data for accurate planet, Sun, and Moon positions. Strict GPS-based UTC timing is "fine-adjusted" with current and predicted IERS timing data available at "`ftp://maia.usno.navy.mil/ser7`". This enables correct handling of UTC leap seconds.

Support for line observations in form of line frequency Doppler shift calculations was added along with tests of AOS spectral line software by Helsinki University group.

2.2.2 Data Acquisition (A/D)

For analog data acquisition a Datel PCI-416M 4-channel 200 kHz simultaneous sampling 16-bit A/D converter board was used in "`daqqer`" Linux PC. A Linux device driver "`pci416.o`" for the board was written and verified to be able to continuously stream in samples from all four channels at a sampling rate of 10ksps, for a total data aggregation rate of 80kB/s.

There have been problems with PCI-416M board locking up the whole PCI bus at random. Initially a software problem in "`pci416.o`" was suspected, but finally the supplier of the board, Datel, acknowledged that boards with AMCC "S5933QB" chips are vulnerable to PCI timing problems and that the chip should be replaced into a "S5933QE". This swap is scheduled for 2001.

The second prototype version of "BEclock" back-end clock generator box was built. It includes 5kHz active sampling filters for four differential input channels and a 1pps triggerable 10kHz sampling clock (synchronized to 5MHz H maser reference for absolute time tagging). A/D clock start is synchronized to station 1pps signal. 25 Hz Dicke switching control signals are being generated in-sync with sampling clock.

The "BEClock" box also includes a digital 5 MHz/1pps phase digitizer which samples and displays the timing difference of rising edges of 1pps and 5 MHz signals. The rising edges must be kept non-simultaneous to avoid problems in equipment relying on these signals.

Linux-based data acquisition software "`daqcon/daqcli`" was built to utilize the time synchronization provided by "BEclock". All further integration (beyond fixed 10kHz sampling) and handling of beam switching is done in "`daqcon`" software.

First prototypes of new total power differential instrumentation amplifiers were built and tested. These tests verified that to support high gains required by continuum observations a general total power level offset adjustment must be implemented, preferably under remote computer control.

2.2.3 Weather Stations

A pair of Davis GroWeather (see "`http://www.davisnet.com`") weather stations acquired from a local systems integrator, Envia Oy, have performed satisfactorily. The more completely equipped "upper" weather station is depicted in Figure 16.

Figure 16: The upper weather station.

Both GroWeather stations feature temperature, barometric pressure, and relative humidity sensors. The first station is located near the telescope and radome, and the second one is a bit farther away and about 10 meters lower in altitude. It acts both as a backup of the first station, as a "second opinion", and also hopefully as an "early warning" system, as mist and dew seem to appear first in the low-altitude “valley” area. The “hi” station includes additional solar radiation, wind speed and direction, and rain gauge sensors which were omitted in the “lo” station.

Isolated RS232/RS422 converters were designed in-house to provide a reliable way to connect stations to `meacon` Linux computer. RS232 is not reliable with long cable runs (50/180m in this case) whereas RS422 works reliably up to 1000m and more of twisted-pair cable. Our converter combines complete electrical isolation (including power supply and ground) together with standard RS422 drivers with surge suppression, thus forming a robust interface for outdoor cabling.

Weather station data collection software “`weatherd`” was put into full use after completion and installation of the isolated RS232/RS422 interface adapters. Software saves all data from stations in two different locations “`/data/weather/hi`” and “`/data/weather/lo`” based on the physical location of stations. The “MB” software presented in section 2.1.9 makes it easy to generate customized weather plots using a Web-based end-user interface.

2.3 Extragalactic Radio Sources

Research Group at Metsähovi: Urpo, Karlamaa, Lähteenmäki, Teräsranta, Tornikoski

2.3.1 Monitoring of Quasars

Project Team: Teräsranta, Lähteenmäki, Tornikoski

The quasar monitoring with the Metsähovi antenna reached its 20 year mark during the year 2000. Observations of the main list with some 85 sources were continued through the year, though the sampling at 37 GHz suffered from the problems with that specific receiver. During the year 2000 about 2750 individual quasar observations were done. About half of those were done in an automated mode. The observers in order of number of observations were: H. Teräsranta, J. Virtanen, P. Koivisto, T. Niemelä, J. Hänninen, J. Torppa, M. Koskimies, M. Tornikoski, S. Wiren and A. Lähteenmäki and their share from the total observations ranged from over 30% to under 0.2%. The observers come from University of Turku (6), Helsinki University of Technology (3) and Helsinki University (1). In Figure 17 is shown the flux density of the Seyfert Galaxy 3C 120 from 1981 to the end of 2000 at 37 GHz as observed at Metsähovi.

The first phase of the search for new flat spectrum sources was completed and the source list was updated. From the year 2001 the source list consists of sources with a flux higher than 0.5 Jy at 22 GHz on average, spectral index higher or equal to -0.4 between 4.8 and 22 GHz, source declination between 0 and $+75$ degrees and distance from the galactic plane more than 20 degrees. Some additional sources, mostly Northern gamma-ray detected sources are still in the source list, even they don’t satisfy all those 4 items mentioned above. The new sample should be observed with a monthly sampling for all sources at both 22 and 37 GHz. The main objective for the new sample is to study the duty cycle of the sources which are most probably detected by the next generation gamma-ray observatories AGILE and GLAST. As all the gamma-ray detected AGN have also flat spectrum up to millimeter frequencies, this sample with additions from the gamma-ray observatories detections, would hold in it the strongest foreground source s for the cosmic background explorer PLANCK. The successful running of this monitoring project would require most of the observing time of the Metsähovi radio telescope during the next years.

Co-operation with several research groups continued also during this year.

2.3.2 AGN Science

Project Team: Tornikoski, Lähteenmäki, Jussila, Johansson, Valtaoja (Turku), Lainela (Turku)

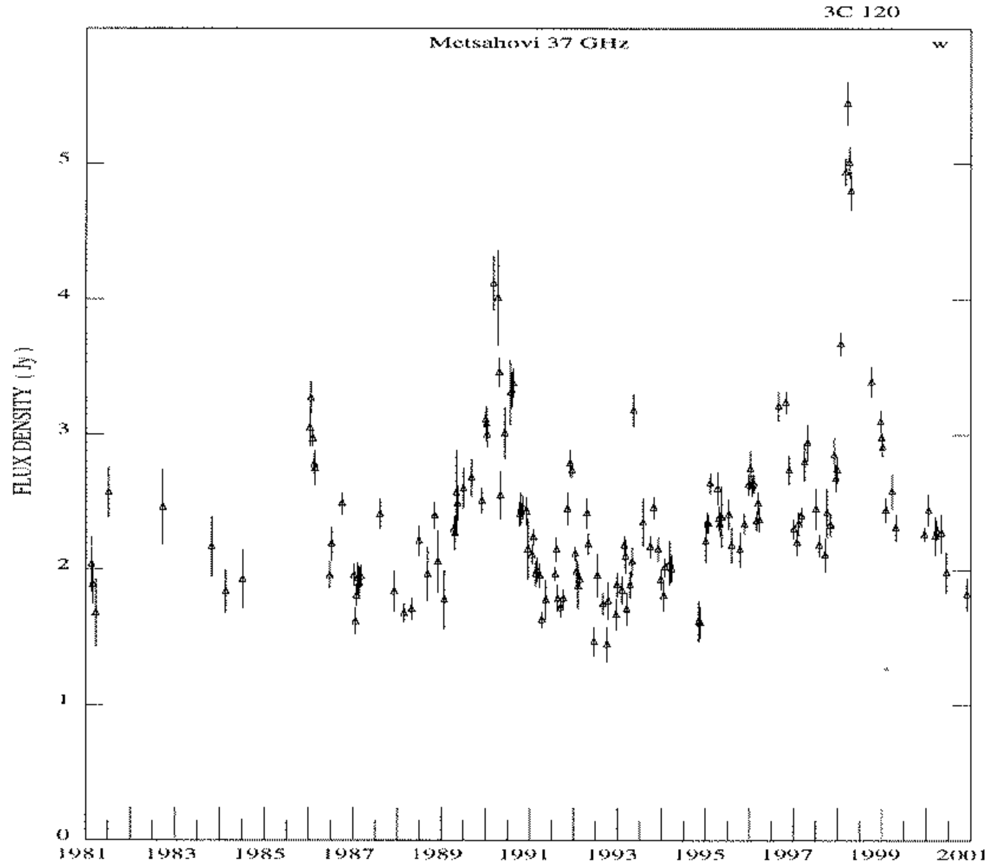

Figure 17: The flux density of the galaxy 3C 120 at 37 GHz since 1981.

Southern extragalactic radio sources

We have complemented our study of the complete sample of Southern BL Lacertae objects and quasars originally presented in Tornikoski et al. 1993, AJ 105, 1680. The new SEST data set includes 230 GHz data for all of these sources and numerous additional 90 GHz measurements, which enabled us to study the high radio-frequency spectra and variability of these sources in detail.

Many of the sources have flat spectra up to 90 GHz, but even at 230 GHz they remain bright enough to be detected at > 100 mJy flux levels, many of them considerably brighter than that. When we construct an average spectrum using the spectral shape from the sample sources, we find that sources as faint as 350 mJy at 2.3 GHz should be detected at 230 GHz with the current SEST setup, indicating that a large number of sources fainter at the lower frequencies that get excluded from the "complete" samples should be easily detectable in the millimeter domain. Many of these sources probably exhibit interesting high radio frequency variability behavior and studying them more closely could offer us new information about the millimeter tail of the radio spectrum.

We have analyzed the millimeter-domain variability of our sample sources, finding that with random data sampling, only 1/5 of the observations at 90 GHz and 1/10 at 230 GHz detect BLOs and HPQs in the flaring state. The variability behaviour should be taken into account when estimating the source behavior based on only few data points, likely to have been observed during the intermediate or quiescent state.

The results of this study were published in Tornikoski et al. 2000, AJ 1739, 2278.

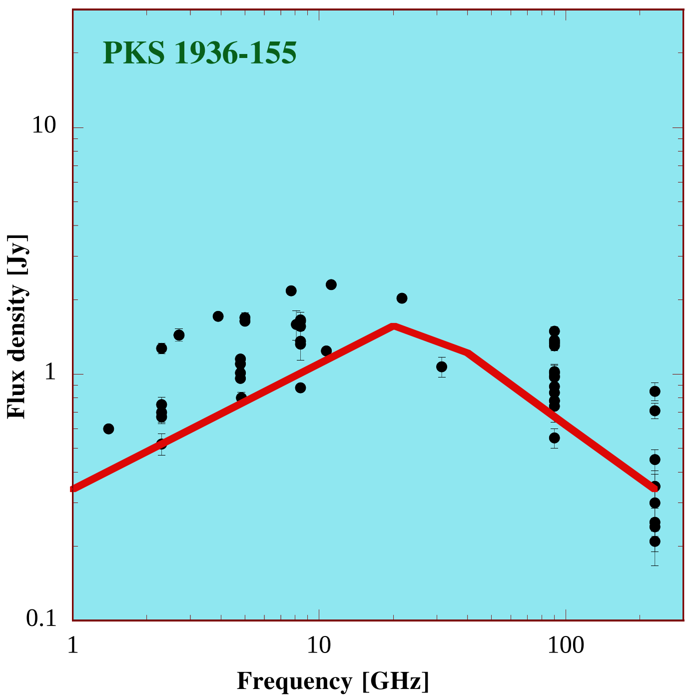

Figure 18: A new gigahertz-peaked spectrum (GPS) source PKS1936−155 was identified by our group (Tornikoski et al. 2000, Astronomical Journal 120, 2278). The data points presented in the figure were mainly observed by our group and our collaborators over a time span of 8 years. The red solid line shows the shape of the canonical GPS spectrum given by de Vries et al. (Astronomy and Astrophysics 321, 105, 1997). PKS1936−155 has a spectral shape of a typical GPS source, but the peak frequency is exceptionally high, ca. 20 GHz, whereas "ordinary" GPS sources have peak frequencies just slightly above 1 GHz. The long term monitoring of this source shows that it is a highly variable source across the whole radio spectrum. Even though GPS sources have been considered to be among the least variable extragalactic sources, we suggest that this kind of variability is typical for the quasar-type high peaking GPS sources.

New GPS candidates

When analysing our complete sample of southern sources, we identified two new candidates for Gigahertz Peaked Spectrum (GPS) sources. These two sources are PKS 1936−155 and PKS 2008−159, both peaking at unusually high frequencies, ca. 10−20 GHz in the observer's frame (See Figure 18).

The radio continuum spectra of these two sources were published in Tornikoski et al. 2000, AJ 1739, 2278. In this paper we also suggest that probably many more GPS sources with extreme peak-frequencies exist, but they are easily ignored because their low-frequency data points may have been taken during a flaring state of their variability cycle, indicating flatter spectra than the typical inverted spectra of the canonical GPS sources, and especially because they are not being systematically searched for at the high radio frequencies.

We continued our search for new GPS source candidates by carefully examining our full SEST data base, ~100 sources with at least one data point at 90 GHz and/or 230 GHz with $S/N \geq 4$, almost all of which are quasars or BL Lacertae objects. We identified 12 quasar-type sources with convex spectra resembling those of the GPS sources and peaking at high frequencies. 6/12, i.e. 50%, of the sources have their spectral turnover at $\nu_T \geq 10$ GHz in the observer's frame, which makes them unusually high-peaked sources. We also presented 8 additional sources with inverted spectra in the GHz region but either with too little data to make conclusive statement about their true spectral shape or with spectral shapes, though at least somewhat inverted, not strictly adhering to the generic GPS shape.

The spectra of the new GPS source candidates and other sources with inverted spectra will be published in Tornikoski et al., AJ, in press.

Variability of known GPS sources

Among the sources in our complete sample of Southern sources (see above) there were two bona fide GPS sources that exhibited radio variability behaviour similar to the average sources in our sample, and also similar to our two newly identified GPS sources. We wanted to study the variability of also other known GPS sources, and we found the variability of the known quasar-type GPS sources observed by our group to be strong. Thus the often quoted statement that GPS sources would belong to the least variable class of compact extragalactic radio sources seems to be incorrect at least for these quasar-type GPS sources.

On the other hand, the strong variability of flat-spectrum radio sources may also lead to misidentifications. We have shown 6 cases where the densely sampled radio spectrum of the sources quoted as GPS sources in the literature is in conflict with the generally accepted definition of a GPS source spectrum. If the sources are observed only few times, it is easy to misidentify a variable flat-spectrum radio source as a GPS source if the source has been in an active state during the observation.

The results about the variability of bona fide GPS sources will be published in AJ together with the new GPS identifications.

Radio properties of BL Lacertae objects

During the summer 2000 a research on BL Lacertae objects was conducted. The aim of the research was to compile "complete" samples of different classes of BL Lacs by collected data from various databases. Four samples were made representing 1) all known BL Lacs, 2) the radio-selected BL Lacs (RBL), 3) the X-ray-selected BL Lacs (XBL) and 4) the Intermediate BL Lacs (IBL). For 75 radioloud BL Lacs radio data were found from the Metsähovi summary data file. For these objects logarithmic frequency vs. flux density plots were made. In addition to the power-plots linear variation-plots were made at different frequencies. The radio-selected BL Lacs were analysed in greater detail. Spectral index plots, variability plots and redshift plots were made and the properties of some of the interesting objects were collected from the literature. The results were published in the Bachelor's thesis of P. Johansson (Helsinki University, 2000)

The long term goal of the research is to understand how the new classes of BL Lacs behave at high radio frequencies, especially at the Planck satellite's frequency range. The various samples of the BL Lacs will be observed using the Metsähovi and SEST telescopes from 2001 onwards.

High-frequency radio observations of fainter southern sources

There have been several studies of "complete" samples of radio sources, each selected using different criteria, leading to the inclusion of different objects. When selecting good candidates for high radio-frequency observations, it is generally assumed that the radio spectra peak at low frequencies and get very steep in the millimeter range. Thus, only sources exceeding a certain flux limit (e.g., $S > 1$ Jy at 5 GHz) and showing a flat spectrum at the low frequencies often end up being monitored in the millimeter domain. Also, the selection is often based on only one-epoch observations at the low frequency range. Thus there is a risk that a large number of interesting sources, especially the ones that are relatively faint but show strong variability in the millimeter domain, are excluded from the high radio-frequency studies.

We have studied at SEST a sample of sources fainter in the low-frequency domain to see whether the radio to millimeter to submillimeter spectral indices of the faint flat-spectrum sources are within the range found for the brighter flat-spectrum sources. Our initial results indicated that the fainter sources tend to have steeper than expected high-frequency spectra. The results will be published in 2001.

Possible identifications for Southern EGRET sources

In 2000 we had two sessions of SEST observations during which we made 90 GHz observations of a sample of AGNs that we had chosen for possible candidates of some of the unidentified EGRET sources. These observations will be reduced and the results published in 2001.

2.4 Planck Science

Project Team: Lähteenmäki, Teräsranta, Tornikoski, Urpo, Valtaoja (Turku)

The Planck satellite will measure the cosmic microwave background (CMB) radiation of the entire sky in order to reveal the ultimate secrets of our Universe. Apart from that, it will measure all other radio sources in the sky, including active galactic nuclei (AGNs). The satellite launch is scheduled for 2007 but scientific preparations are already under way in various forms. Researchers from Metsähovi are working on Planck core science program proposals as well as the preparatory science behind them, both theoretical and observational. Lots of prelaunch information on AGNs is required to ensure good-quality CMB maps for cosmologists, and observations for this purpose have been planned and executed.

Year 2000 brought along active and enthusiastic preparation of the Planck core science program. It was decided in the LFI Consortium meeting in Saariselkä, Finland, in February that the second Consortium meeting of the year, held in Manchester, UK, in October would be dedicated to science. It was essential to configure the core science program well in advance of the First General Planck meeting at ESTEC, scheduled for early 2001, which would review the science efforts of both LFI and HFI. In Saariselkä teams were assembled for each science area to ensure that all topics and details would be included and properly considered.

Figure 19: 1:4 scale model of Planck satellite at ESTEC (photo M. Tornikoski).

The team concerned with extragalactic radio sources was further divided into eight specific science areas. Metsähovi was a member of five of these areas, and leading two (Variability, BL Lacs and flat-spectrum quasars). The leaders of each science area collected ideas from the entire extragalactic radio source team and submitted “proto-proposals”, based on the ideas, to the team leaders. A.

Lähteenmäki was requested to review the proposals concerning blazars, BL Lac and QSO science in the LFI Consortium meeting in Manchester. Based on the discussions and reviews in Manchester, the number of actual core science abstracts of the extragalactic point source team for the ESTEC meeting was reduced to four (Phenomenology of radio sources, Extreme GPS and other strongly inverted-spectrum radio sources, Astrophysics of quasars and BL Lac objects, Statistical properties). A. Lähteenmäki was chosen to prepare the Astrophysics of quasars and BL Lac objects abstract. A significant contribution aiding the preparation of the three other abstracts was also given. All abstracts were eventually submitted to Planck LFI PI, and would be presented at the ESTEC General Planck meeting in 2001.

The Astrophysics of quasars and BL Lac objects abstract included 6 separate areas of interest: physical models (to study the structure and physics of radio sources, unifying models etc.), BL Lac objects (see "Radio properties of BL Lacertae objects" in 2.3.2), fainter flat-spectrum active galactic nuclei (see "High-frequency radio observations of fainter southern sources" in 2.3.2), variability (to study the variability phenomenon of AGNs at different scales), follow-up satellite and ground based observations (to supplement Planck observations during and after the mission), and quicklook (to get real-time AGN data from Planck).

Encouraged by the strong Finnish science involvement in Planck (cosmology and foreground science), an application for funding from the Academy of Finland and National Technology Agency research programme for space research (ANTARES) was submitted, in collaboration with teams from Millilab, University of Helsinki and University of Turku. The projects selected for funding will be announced in spring 2001.

2.5 Observations with Other Facilities

Swedish–ESO Submillimetre Telescope (SEST), Chile:

29.–30.4. (16 hours) "Unidentified Southern EGRET Sources", P.I. M. Tornikoski, observer: M. Lainela.

17.–18.8. (16 hours) "Unidentified Southern EGRET Sources", P.I. M. Tornikoski, observer: A. Lähteenmäki.

VLA:

"III ZW 2, a superluminal jet in a spiral galaxy", P.I. H. Falcke, CO–I H. Teräsranta. Monthly observations with the VLA during the year 2000.

4.7. (8.5 hours) "High brightness temperature source PKS 1921−293", P.I. P. Edwards, Co–I M. Tornikoski et al.

VLBA: 5.7. (8 hours) "High brightness temperature source PKS 1921−293", P.I. P. Edwards, Co–I M. Tornikoski et al.

VSOP:

"Gamma–ray loud and quiet AGN with VSOP at 5 GHz", P.I. S. Tingay, Co–I M. Tornikoski et al., 5 GHz VSOP observations on 22.5., 5.6., 28.6. and 1.7.

"The high brightness temperature source PKS 1921−293", P.I. P. Edwards, Co–I M. Tornikoski et al., 5 GHz VSOP observations on 5.7.2000.

2.6 VLBI Research

Research Group at Metsähovi: Urpo, Karlamaa, Liljeström, Mujunen

There have been negotiations with Finnish Geodetic Institute for starting geodetic VLBI observations possibly in 2002. The equipment requirements include a new receiver and a new secondary mirror, full number of BBCs (in addition to currently functional 8) and a renewed phase calibration system which needs to include the cable delay calibrator. New VLBA baseband converters have been ordered from Signatron.

The FS was updated three times within a year, the present version is 9.4.18.

The antenna control system VLBI software has been operational since the beginning of year 2000 and it is completely independent from the old MicroVAX-based system.

The small VLBI operation support group is heavily involved in other non-VLBI projects and there have been changes in the personnel. Manpower problems caused that one CMVA session in October had to be cancelled.

2.6.1 EVN

Project Team: Urpo, Engelberg, Karlamaa, Mujunen

In 2000 Metsähovi participated in two VLBA+EVN joint sessions at 22 GHz in February and in November. The 22 GHz sessions were thin tape observations which suffered from poor recording quality. One of the reasons may have been improper pre-contouring of the recorder head after thick tape sessions. Also there were BBC problems during the February sessions and in November the H maser instabilities caused some troubles. The reason for the maser instabilities was the failure of the maser room air conditioning system.

2.6.2 CMVA, Coordinated Millimetre VLBI Array

Project Team: Urpo, Engelberg, Karlamaa, Valtaoja (Turku), Wiik (Turku)

Metsähovi participated in one 86 GHz session in April 2000 with successful results.

2.6.3 Space VLBI

Project Team: Urpo, Liljeström, Tornikoski, Valtaoja (Turku), Wiik (Turku)

M. Tornikoski was a Co–investigator in two HALCA proposals observed during 2000.

2.6.4 FS Support

Project Team: Mujunen

Metsähovi participates an EU RTD project FMGE-CT98.0101 "Enhancing the European VLBI Network of Radio Telescopes". Our contribution concentrated on providing technical support to EVN stations in deploying "FS Linux 3" in their Field System computers. Ari Mujunen cooperated with Ed Himwich (NASA/GSFC) in this process. A new version of the FS software was released, the latest being 9.4.18. This version supports the newest VLBI data acquisition rack variants, both Mark IV and VLBA4.

The project plan is to provide EVN stations Field System support so that existing VLBI projects can be run effectively and so that new emerging VLBI techniques will be enabled in the FS observations system. The technical prerequisites for adopting new FS software (that is, the adoption of "FS Linux 3") have been accomplished by the project. "FS Linux 3" has been widely adopted at EVN observatories.

The password-protected FTP area for FS software distribution is available at both Metsähovi Radio

Observatory and NASA Goddard Space Flight Center. 40 institutions world-wide have requested a password to get access to FS software and user accounts for them have been created. Automatic mirroring setup was created to ensure that both FTP servers have the same contents. "FS Linux 3" software is mirrored from Metsähovi to GSFC and "FS" software is mirrored from GSFC to Metsähovi.

Technical tutorials on FS Linux 3 daily use and system administration were prepared and presented in an international conference "First IVS Technical Operations Workshop" at MIT Haystack Observatory in March 2001.

Technical advancements in computer hardware necessitate the development of next-generation "FS Linux 4" package for FS use. Distribution archives and documentation for "FS Linux 4" are planned to be completed within year 2001.

The latest FS 9.4.18 version was installed in Metsähovi in the end of year 2000.

A problem with overheating CRU SCSI disk cartridges was resolved at Metsähovi by installing an external cooling fan to the cartridge.

2.7 Solar Research

Research Group at Metsähovi: Urpo, Koistinen, Pohjolainen, Phan

2.7.1 Solar Observing Campaigns

Project Team: Urpo

Solar observations continued at Metsähovi in 2000. Receivers working at 37 GHz and 87 GHz were used. Number of observing days was 43. More than 100 solar radiation maps were measured and active regions were tracked for about 100 hours in order to detect energy burst and releases at radio waves. Only few events were detected. Analysis of measured data continued in international cooperation.

2.7.2 Solar Data Analysis

Project Team: Pohjolainen, Urpo

Metsähovi solar radio maps can be analysed using the IDL-based software developed by S. Pohjolainen. The latest version is available on the Web, at "`http://www.hut.fi/~spo/idl.html`", with guidebooks both in English and in Finnish.

2.7.3 Solar Polar Features at mm-Waves

Project Team: Pohjolainen (Observatoire de Paris, France), Portier-Fozzani (LAS-CNRS, Marseille, France), Riehokainen, Valtaoja (Tuorla Observatory, Finland), Urpo

Metsähovi radio maps at 87 GHz (3.5 mm) from 1996-1998 have been analysed and compared with nearly-simultaneous SOHO/EIT, TRACE, and YOHKOH/SXT images. Emphasis was given to comparing polar radio brightenings with features seen in EUV, but also radio depressions and their counterparts—like coronal holes—were analysed. The high latitude radio enhancements were found to correlate with bright points, polar plume bases, and bright diffuse structures seen in EUV. No uniform brightness (or darkness) was found inside coronal holes: the holes appeared generally as radio dark but with local brightenings inside them. The observed radio features were later verified by calculations, using temperatures and densities derived from EUV and soft X-ray observations. Significant limb brightening at 87 GHz was also detected in the Metsähovi solar maps for the first time.

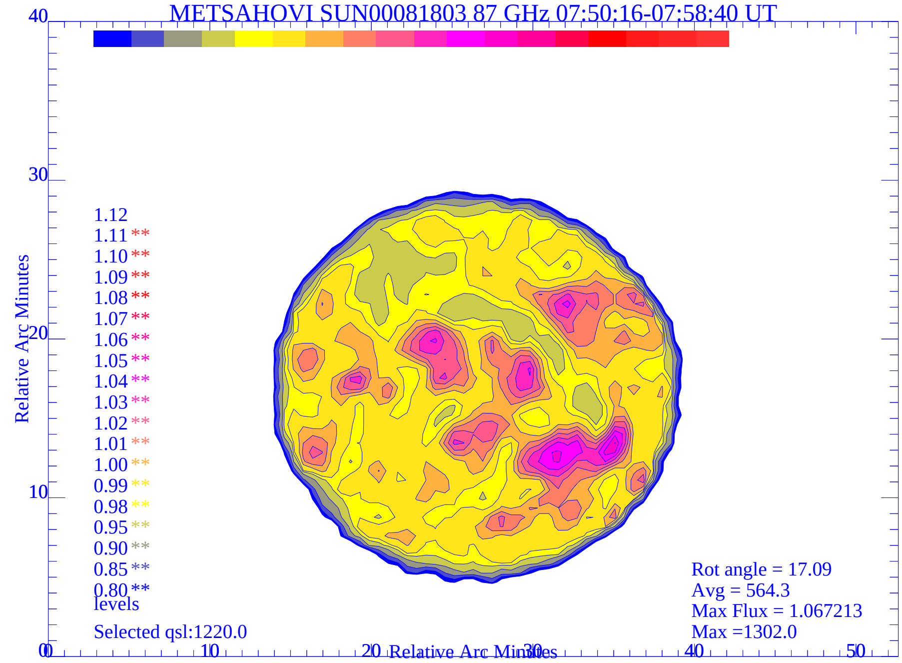

Figure 20: Solar map measured at Metsähovi on August 18, 2000. Frequency was 87 GHz (wavelength 3 mm). North is on top. Several active regions can be seen (red coloured areas) and a prominent coronal hole extends from the solar limb to the equator (green coloured structure).

2.7.4 Space Weather Monitoring at 12 GHz

Project Team: Urpo, Puhakka, Oinaskallio

A new radio telescope system with an 1.8 meter diameter dish was constructed. It is used to continuous monitoring of solar radiation at 12 GHz. The beamwidth of the telescope is so wide that whole solar disk is covered. All solar radio events starting from intensities of a few Solar Flux Units will be detected. Experimental operation started in August 2000 and continued to the end of the year. About 30 strong events were measured in addition to numerous small events.

2.8 HRDL for Alpha Magnetic Spectrometer (AMS)

Research Group Heads: Urpo, Ting (Massachusetts), Torsti (Turku)

Project Team at Metsähovi: Ritakari, Engelberg, Mujunen, Urpo

The Alpha Magnetic Spectrometer (AMS) was flown on the space shuttle Discovery during flight STS-91 in June 1998 in a 51.7 degree orbit at altitudes between 320 and 390 km. During the flight the Metsähovi team worked ten days in three shifts in NASA Mission Control Center in Houston. The detector was successfully tested and a total of 2.86×10^6 helium nuclei were observed in the rigidity range 1 to 140 GeV. No antihelium nuclei were detected at any rigidity. An upper limit on the flux ratio of antihelium to helium of $< 1.1 \times 10^{-6}$ is obtained.

AMS publications can be found on-line at "`http://hpl3tri1.cern.ch/AMS/Publications/`".

A project is underway to build the successor of AMS, AMS-02. It will be based on a superconductive cryomagnet which will considerably improve its capability to detect even the slightest amount of antihelium nuclei. In May 2003 NASA has scheduled a shuttle flight to deliver AMS-02 to the International

Space Station (ISS) where it will be deployed for a three-year mission. Experiment integration will start in ETH Zurich in the beginning of 2002, and Metsähovi has been asked to take the responsibility to collect all scientific data coming through the improved version of the HRDL data link. Additionally we have been asked if we would like to be involved in designing and building AMS ICE, "Internal Computing Equipment" which would be located on-board on the ISS in an ISPR (International Standard Payload Rack). This shows a high-level endorsement of Metsähovi's abilities to realize demanding scientific data acquisition systems. For this we have been able to leverage many technologies learned during building the astronomical VLBA data acquisition system.

2.9 Radio Spectroscopy

Research Group: Liljeström, Urpo

2.9.1 Water Masers

Project Team: Liljeström, Gwinn (Univ. of California)

The 22 GHz water maser is the brightest spectral line in the radio universe and highlights shocked star forming regions, dense circumstellar shells around evolved stars as well as circumnuclear disks around massive black holes of active galactic nuclei.

The Metsähovi radio telescope has been used for long-term water maser observations of the most powerful maser source in our Galaxy, W49N. Water maser observations commonly show dramatic variations in flux density as a function of time. Such short-lived (typically some 2 months), dramatic increases in flux density are termed as "outbursts". Combining the Metsähovi 22 GHz database of some 150 maser outbursts of W49 N (Liljeström 2000) with simultaneous VLBI data of Gwinn (University of California Santa Barbara), notably obtained with the same velocity resolution, Liljeström and Gwinn (2000) were able to fix the free parameters in the shock model of Hollenbach and McKee (1979, 1989) and the maser model of Elitzur, Hollenbach and McKee (1989). This enabled a straightforward determination of some 20 physical parameters of W49N. We checked the validity of these models with independent measurements and found a very good agreement between predictions and observations.

The most important characteristic of the novel diagnostic method of Liljeström and Gwinn (2000) is its capability to determine both preshock and postshock magnetic field strengths as well as the inclination angle of the mean magnetic field with respect to the line of sight. The preshock field strenght is determined from the jump condition of strong shocks and is observationally based on the observed preshock density and rms value of the observed line velocity fluctuations of maser features during outbursts. In order to determine the postshock field strength, the preshock density and space/shock velocities of the maser features (measured by VLBI) must be observationally known. The observed nonthermal line velocity fluctuations of maser features are caused by Alfvenic wave pressure, which is substantially increased in the sudden compressions associated with shocks. The fact that Alfven wave fluctuations are oriented perpendicular to the field lines enabled us to estimate the inclination angle of the mean field from the observed dispersion of the line velocity fluctuations.

One uniquely powerful outburst feature in our W49N data, referred to as the "big flare feature", showed also the narrowest linewidth. Our data indicated that the space velocity of this feature was directed along the plane of sky, whereas preshock and postshock magnetic fields were directed nearly along the line of sight. Consequently, Alfvenic wave fluctuations along the line of sight, and linewidth, were minimal, and a very high aspect ratio was achieved. This big flare feature of W49N stood out through its low space velocity, higher kinetic temperature (480 K), and larger preshock magnetic field strength (8.2 mG). These are naturally explained, if the big flare feature was located closer to the shock front than the other masers in W49 N.

2.9.2 Spectroscopic Space Research with the Submillimetre Wave Satellite Odin

Project Team: Liljeström

ODIN is a Swedish satellite project with international participation from Canada, Finland and France. The most important spectral lines to be observed in a variety of astrophysical environments are the H_2O line at 557 GHz and the O_2 lines at 119 GHz and 487 GHz. The measurements of ODIN will reveal how common the chemical conditions for life are in the universe. The ODIN satellite will be launched in February 2001.

The scientific preparatory work of the ODIN astronomy group has been split into 17 project teams, of which Liljeström and J. Black are the lead scientist pair of two teams: (1) photon dominated regions and (2) high-latitude clouds. In addition, Liljeström has a co-investigator status in the following ODIN teams: (1) Galactic centre, (2) giant molecular clouds, (3) star forming regions, (4) shocks and outflows, and (5) absorption lines.

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11 Riehokainen, A., Urpo, S., Valtaoja, E., Makarov, V.I., Makarova, V.V., Tlatov, A.G.: Millimeter-radio, SOHO/EIT 171Å features and the polar faculae in the polar zones of the Sun. *Sun at Maximum Activity and Solar-Stellar Analogy,* GAO RAN, Pulkovo, St. Petersburg, 17-22.9.2000, p. 94, 2000.

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3.3 National Conferences

1 Urpo, S.: Avaruustutkimuslaitostyöryhmä. *Report 2/2000, Observatory, University of Helsinki,* VIII Suomen Avaruustutkijoiden COSPAR-Kokous, Helsinki-Tukholma-Helsinki 25-27.9.2000, p. 11, 2000.

2 Ritakari, J.: Alpha magnetic spectrometer 02-tiedonkeruuta. *Report 2/2000, Observatory, University of Helsinki,* VIII Suomen Avaruustutkijoiden COSPAR-Kokous, Helsinki-Tukholma-Helsinki 25-27.9.2000, p. 14, 2000.

3 Tuovinen, J., Karttaavi, T., Lahdes, M., Varis, J., Hughes, N., Kangaslahti, P., LeCong, T., Jukkala, P., Koistinen, O., Urpo, S.: Planck-luotaimella kuva maailmankaikkeudesta sen nuoruusvuosilta. *Report 2/2000, Observatory, University of Helsinki,* VIII Suomen Avaruustutkijoiden COSPAR-Kokous, Helsinki-Tukholma-Helsinki 25-27.9.2000, p. 24, 2000.

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5 Lähteenmäki, A.: Planck-satelliitti ja ekstragalaktiset radiolähteet. *Report 2/2000, Observatory, University of Helsinki,* VIII Suomen Avaruustutkijoiden COSPAR-Kokous, Helsinki-Tukholma-Helsinki 25-27.9.2000, p. 26, 2000.

6 Tornikoski, M: GPS-tyyppiset ekstragalaktiset radiolähteet ja Planck-tiede. *Report 2/2000, Observatory, University of Helsinki,* VIII Suomen Avaruustutkijoiden COSPAR-Kokous, Helsinki-Tukholma-Helsinki 25-27.9.2000, p. 27, 2000.

7 Eskelinen, P., Sjöman, P.: A short performance evaluation of the Metsähovi clock arrangement for VLBI measurements. *Abstracts of the URSI XXV National Convention on Radio Science Reports 2000:5, Ilmatieteen laitos,* Helsinki 21-22.9.2000, A. Viljanen, R. Pirjola, T.J. Tuomi (editors), pp. 60-61, 2000.

3.4 Laboratory Reports

1 Engelberg, J., Mujunen, A., Oinaskallio, E.: Radio Spectrum Monitoring System - spektrd. *Metsähovi Reports HUT-KURP-16,* 8 p., 2000.

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4 Urpo, S., Mujunen, A. (editors): Metsähovi Radio Observatory Annual Report 1999. *Metsähovi Reports HUT-KURP-19,* 35 p., 2000.

5 Engelberg, J., Mujunen, A.: EFOS monitoring system - efosd. *Metsähovi Reports HUT-KURP-20,* 7 p., 2000.

6 Könönen, P.: "Efos9@Metsähovi" - Efos 9 hydrogen maser monitoring system at Metsähovi. *Metsähovi Reports HUT-KURP-21,* 14 p. 2000.

7 Zaitsev, V.V., Kislyakov, A.G., Urpo, S., Stepanov, A.V., Shkelev, E.I.: The Wigner-Ville analysis of solar microwave emission. *Metsähovi Publications on Radio Science HUT-MET-32,* 19 p. 2000.

3.5 Other Publications

1 Urpo, S., Arajärvi, M., Herland, E-A., Joensuu, A., Nyberg, M., Pulkkinen, T., Vihma-Kaurinkoski, M., Lahtinen, J.: Avaruustutkimuslaitostyöryhmän muistio. *Opetusministeriön työryhmien muistioita,* 24:2000, 29 p., 2000.

4 Visits to Foreign Institutes

Post doc researcher, Observatoire de Paris, Meudon, 1.1. - 31.7.2000, S. Pohjolainen.

Visit to the Ventspils International Radio Astronomy Center (VIRAC), Latvia, 18.3.2000, M. Tornikoski.

Invited participant in the ITP program on Astrophysical Turbulence, organized by the Institute for Theoretical Physics (ITP), University of California Santa Barbara, 10.4-14.5.2000. The visit was financed by ITP and National Science Foundation (USA), T. Liljeström.

Planck collaboration, 23–28.5.2000, Osservatorio Astronomico, Padova, Italy, A. Lähteenmäki.

Observations with the SEST, 13 –21.8.2000, SEST/ESO, La Silla, Chile, A. Lähteenmäki.

Visit to Jodrell Bank Observatory, UK, 19–21.10., A. Lähteenmäki, M. Tornikoski.

5 Visiting Scientists

Dr. Phil Edwards, ISAS, Japan, Dr. R. Spencer, Jodrell Bank, UK, Dr. P. Colomer, Yebes, Spain, Dr. A. Baudry, Bordeaux Observatory, France, Dr. H. Bucher, NFRA, The Netherlands and Dr. R. Booth, Onsala Space Observatory, Sweden visited Metsähovi 9.5.2000.

Dr. G. DeZotti, University of Padova, Italy, visit to Metsähovi 23.2.2000. (Tornikoski)

Prof. A. Stepanov, Pulkovo Observatory, St Petersburg, Russia and prof. V. Zaitsev and prof. A. Kislyakov, Nizhny Novgorod State University, Russia, visited Metsähovi 28.9-7.10.2000.

Mr. Santiago Navarro, IRAM, Spain visited Metsähovi 3-7.10.2000.

Mr. David John, IRAM, Spain visited Metsähovi 7-12.11.2000.

6 Thesis

Thesis for Bachelor of Astronomy at Helsinki University: "Radio properties of BL Lacertae objects", P. Johansson, work supervised by M. Tornikoski.

7 Teaching

Laboratory exercise for Space technology students, Helsinki University of Technology, April 2000, A. Lähteenmäki, M. Tornikoski

Autumn 2000: weekly lectures of the course Radio Astronomy at Helsinki University of Technology, M. Tornikoski and A. Lähteenmäki.

Lecture about radio astronomy, Metsähovi research and the Planck project to the amateur astronomy club Pollux 27.11.2000, M. Tornikoski.

M. Tornikoski supervised two summer students, Peter Johansson and Ilona Jussila. Mr. Johansson wrote a bachelor's thesis in connection to his work in the AGN group.

General Metsähovi tours and short talks about radio astronomical research to several high school classes and other groups of visitors, P. Könönen, M. Tornikoski, S. Urpo, E. Oinaskallio.

8 Other Activities

Preliminary examiner of the Doctoral Thesis of Tapio Pursimo, University of Turku, M. Tornikoski.

Referee for Astronomy and Astrophysics, A. Lähteenmäki, M. Tornikoski, T. Liljeström.

Referee for The Astrophysical Journal, T. Liljeström.

Referee for Solar Physics, S. Urpo.

8.1 Participation in Boards and Committees

Board member of the Finnish Astronomical Society, 2000-2001, M. Tornikoski.

Finland's delegate to the Scientific Comission J (Radio Astronomy) of the International Union of Radio Science (URSI), 2000-2002, M. Tornikoski.

Member of the scientific organizing committee of the 2001 Nordic Baltic Summer School in Radio Astronomy: "Radio Universe", 2000-2001, M. Tornikoski.

Member of the programme committee of Antares = Academy of Finland and National Technology Agency Research Programme for Space Research, M. Tornikoski.

Chairman of the Finnish working group on space research institute/Ministry of Education, S. Urpo.

AAS, American Astronomical Society, member S. Urpo.

AMS, Tekes Guiding Group, member S. Urpo.

Planck, Tekes Steering Group, member, S. Urpo.

COSPAR, Committee on Space Research, Finnish National Committee, member, S. Urpo.

COSPAR, Commission E2, Solar Physics, member S. Urpo.

EAS, European Astronomical Society, founding member S. Urpo.

ESA, European Space Agency, SPC Science Programme Committee delegate S. Urpo.

EVN, European VLBI Network Board of Directors, member S. Urpo.

EVN, European VLBI Network, Technical Operations Group, (TOG), FS subgroup chairman, A. Mujunen.

Finnish Space Committee, permanent adviser S. Urpo.

Hvar Observatory Bulletin, Board of Editors S. Urpo.

IAG, associate member S. Urpo.

IAU, Finnish National Committee, member S.Urpo.

INTAS Project INTAS-RFBR-95-316, coordinator S. Urpo.

RISC, Radioastron International Science Committee, member S. Urpo.

Tuorla Observatory, member of the Board S. Urpo.

URSI, Finnish National Committee, vice member S. Urpo.

Working Group for Finnish-Russian Cooperation in Space Field, member S. Urpo.

Planck LFI Consortium meeting, LOC member, S. Urpo.

8.2 International Meetings and Talks

ESA/SPC Meeting, 21-22.2.2000, Paris, France, S. Urpo.

Symposium of the Planck LFI consortium, Saariselkä, 25-26.2.2000, A. Lähteenmäki, H. Teräsranta, M. Tornikoski. Talk: AGNs in the mm/submm region: the Metsähovi contribution, A. Lähteenmäki

Planning meeting of the Nordic-Baltic summer school in radio astronomy 2001, 17-20.3.2000, Riga and Ventspils, Latvia, M. Tornikoski.

EVN Directors Meeting 8-9.5.2000, Espoo, Finland, S. Urpo, A. Mujunen, J. Ritakari.

ESA/SPC Meeting, 5-6.6.2000, Paris, France, S. Urpo.

5th European VLBI Network Symposium, Chalmers Technical University, 29.6. - 1.7.2000, P. Könönen.

Conference on Astrophysical Turbulence, 8-12.5.2000, organized by ITP, University of California Santa Barbara. Contributed Conference talk: "Anisotropic Line Velocity Variations during Water Maser Outbursts", T. Liljeström.

The Synthesis Imaging Summer School, 20-27.6.2000 in Socorro, New Mexico, USA, organized by NRAO, T. Liljeström.

ODIN Astronomy Group Meeting in Paris, 14-16.9.2000. Two invited talks: "ODIN programme on photon dominated regions" and "ODIN programme on high-latitude clouds", T. Liljeström.

51st International Astronautical Congress, as a participant of ESA Student Outreach Program 2-6.10.2000, Rio de Janeiro, Brazil, V. Saarinen.

ESA/SPC Meeting, 11-12.10.2000, Paris, France, S. Urpo

Symposium of the Planck LFI consortium, Jodrell Bank, Manchester, United Kingdom, 18-22.10.2000, A. Lähteenmäki, M. Tornikoski. Talk: Planck core science topics: Blazars, BL Lac and QSO science, A. Lähteenmäki.

EVN Directors Meeting, 30.11-4.12.2000, Madrid, Spain, S. Urpo

8.3 National Meetings and Talks

Tornikoski, M.: "Southern flat spectrum radio sources and new GPS identifications", meeting of the Finnish Astronomical Society held in Helsinki, Finland, 26.5.2000.

VIII Finnish COSPAR meeting, 25 – 27.9.2000, Helsinki-Stockholm-Helsinki, Finland, S. Urpo, O. Koistinen, A. Lähteenmäki, M. Tornikoski, J. Ritakari
Talk: Planck-satelliitti ja ekstragalaktiset radiolähteet, A. Lähteenmäki
Talk "Gigahertz Peaked Spectrum Radio Sources and Planck Science" (in Finnish), M. Tornikoski.
Chairman to the sessions "Extragalactic astronomy" and "Planck", M. Tornikoski.

Metsähovi Review Meeting, 15-16.12.2000, Tallinn, Estonia, M. Hirvonen, S. Hurtta, I. Jussila, P. Könönen, A. Lähteenmäki, E. Oinaskallio, J. Ritakari, P. Sjöman, M. Tornikoski, S. Urpo,

9 Public Relations

Radio program Radiaattori, 19.4. 9:00, replay 18:00. Interview about the recently discovered high-redshift (z=5.82) quasar and its implication to cosmology and AGN research, M. Tornikoski.

Interview by Helsingin Sanomat, 7.10.2000, S. Urpo.

Interview by Radio 1, 1.11.2000, S. Urpo.

Professional assistance for translating the film "Contact" to Finnish, broadcasted on MTV3 network on 13.11.2000, M. Tornikoski.

10 Personnel in 2000

Permanent Positions funded by the Helsinki University of Technology

Urpo, Seppo, Prof., Dr.Tech.	Director of the institute, Docent	Seppo.Urpo@hut.fi
Engelberg, Jan, Eng.	Operations engineer, until 29.2.	
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Puhakka, Pekka, student	Research aid, part time 1.1-30.4. full time 1.5-31.7.	
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Saarinen, Ville, student	Research aid, full time 23.5-31.8. part time 24.3-22.5., 1.10-31.12	vss@kurp.hut.fi
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Metsähovi Advisory Committee

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Somervuo, Pekka, Dr.Tech.
Tanskanen, Pekka, Prof.
Tiuri, Martti, Prof.emer., M.P. (Chair)
Valtonen, Mauri, Prof.
Urpo, Seppo, Prof. (Secretary)

HELSINKI UNIVERSITY OF TECHNOLOGY, METSÄHOVI RADIO RESEARCH STATION REPORT SERIES A

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METSÄHOVI PUBLICATIONS ON RADIO SCIENCE

HUT-MET-27 Silja Pohjolainen (ed.): CESRA Workshop on Coronal Explosive Events. 1998.

HUT-MET-28 Anne Lähteenmäki, Esko Valtaoja: Total flux density variations in extragalactic radio sources. III. Doppler boosting factors, Lorentz factors and viewing angles for active galactic nuclei. 1999.

HUT-MET-29 V.V. Zaitsev, S. Urpo, A.V. Stepanov: Dynamics of energy release in single flare loop. 1999.

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HUT-MET-31 Anne Lähteenmäki: Total flux density variations extragalactic radio sources: observations and analysis. 1999.

HUT-MET-32 V.V. Zaitsev, A.G. Kislyakov, S. Urpo, A.V. Stepanov, E.I. Shkelev: The Wigner-Ville Analysis of Solar Microwave Emission, 2000.

METSÄHOVI REPORTS

HUT-KURP-13 Silja Pohjolainen (ed.): Metsähovi Radio Observatory Annual Report 1997. 1998.

HUT-KURP-14 Ari Mujunen, Mika Perttula, Jan Engelberg: Using CVS at Metsähovi. 1998.

HUT-KURP-15 S. Urpo, A. Mujunen (eds.): Metsähovi Radio Observatory, Annual Report 1998. 1999.

HUT-KURP-16 J. Engelberg, A. Mujunen, E. Oinaskallio: Radio Spectrum Monitoring System – spektrd. 2000.

HUT-KURP-17 Esa Vilenius, Prisse Könönen: Calibration of the "GroWeather" weather stations at Metsähovi. 2000.

HUT-KURP-18 Prisse Könönen: "Weather@Metsähovi" – weather monitoring system at Metsähovi. 2000.

HUT-KURP-19 S. Urpo, A. Mujunen (eds.): Metsähovi Radio Observatory, Annual Report 1999. 2000.

HUT-KURP-20 J. Engelberg, A. Mujunen: EFOS Monitoring System – efosd. 2000.

HUT-KURP-21 P. Könönen: "Efos9@Metsähovi" – Efos 9 Hydrogen Maser Monitoring System at Metsähovi. 2000.

HUT-KURP-22 S. Urpo, A. Mujunen (eds.): Metsähovi Radio Observatory, Annual Report 2000. 2001.

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