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Metsähovi Radio Observatory
Annual Report 1999

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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 $20 \cdots 120$ GHz, and the corresponding wavelengths $15 \cdots 2.5$ 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.

Distribution of the Metsähovi telescope time for different projects is illustrated in Figure 1. The share of service is high because in May 1999 started the final phase of the Metsähovi upgrade programme. Normal astronomical observations were halfed. All the cables to the telescope tower were replaced. The testing of the new digital servo system was started and procedures of new observing programmes were initiated.

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 1999 the total expenditure of the Metsähovi Radio Observatory was about 6.9 million FIM, including salaries. This was financed by:

Helsinki University of Technology 36 %
Academy of Finland 32 %
Tekes 19 %
Others 13 %

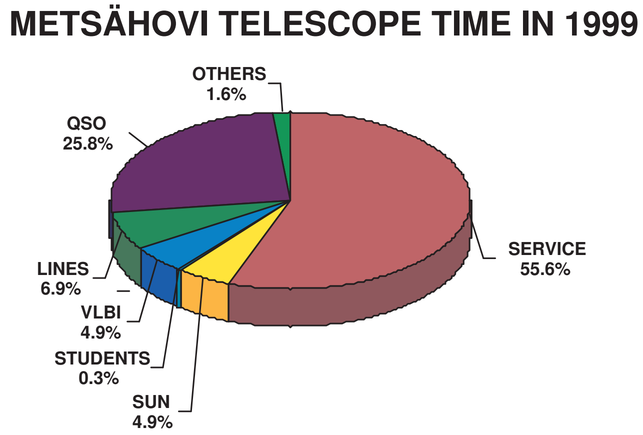

Figure 1: Metsähovi telescope time allocation in 1999.

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 43 GHz VLBI Receiver

Project Team: Koistinen, Karlamaa, Peltonen, Rönnberg

The new 43 GHz cryogenic VLBI receiver was successfully tested in VLBI session in March 1999.

2.1.2 A Correlation Receiver for Solar Research at 37 GHz

Project Team: Koistinen, Urpo, Rönnberg

The capability of the correlation receiver for the polarimetric measurements of the Sun was tested in 1999. The receiver should be capable of detecting all four Stokes parameters by including a correlator unit to a two-channel receiver.

The first antenna tests showed that the receiver is capable of measuring the Sun although no strong microwave bursts could be found. The dynamic range of the receiver is expected to be large enough for the detection of bursts 20 dB stronger than the quiet Sun. A weak polarization could be detected within active regions which suggests that also the polarization of the signal can be measured.

The final calibration procedure for the determination of the receiver Muller matrix is still investigated. At the moment there are no reliable means to produce strong polarized sources for the calibration and thus no corrections for the measurements can be made.

2.1.3 Planck Instrumentation

Project team: Koistinen, Urpo

Metsähovi participated in the Planck Cosmic Microwave Background Surveyor instrumentation team. The Finnish team designs, constructs and tests the 70 GHz HEMT receivers. The Planck Phase 0, "Critical Technology for Microwave Radiometers", consists of several InP MMIC process runs at Daimler-Chrysler. O. Koistinen has designed an ultra-wide band monolithic hybrid divider. The operating band of the hybrid is 20–100 GHz. Two designs with alternative port orders were accepted to the latest process run. Metsähovi was the prime contractor in Planck Phase 1a, "Evaluation of the TRW MMIC process and its upper frequency limits", Tekes contract 40162 / 99. Metsähovi and VTT contributed for the first TRW MMIC process run with a 3 stage LNA design. The LNA was designed for 18 dB gain and 2.4 dB noise figure.

2.1.4 EVN Mark IV R/W Upgrades (VIV)

Project Team: Ritakari, Myyry

In the past Metsähovi has produced read/write electronics upgrades for Mark IIIA VLBI (Very Long Baseline Interferometry) data acquisition systems for both European VLBI Network (EVN, 1995) and NASA Jet Propulsion Laboratory Deep Space Network (JPL DSN, 1997). These upgrades are required to convert the old Mark IIIA data acquisition terminals into next-generation Mark IV systems. (See Figure 2 for an illustration of upgrade components.)

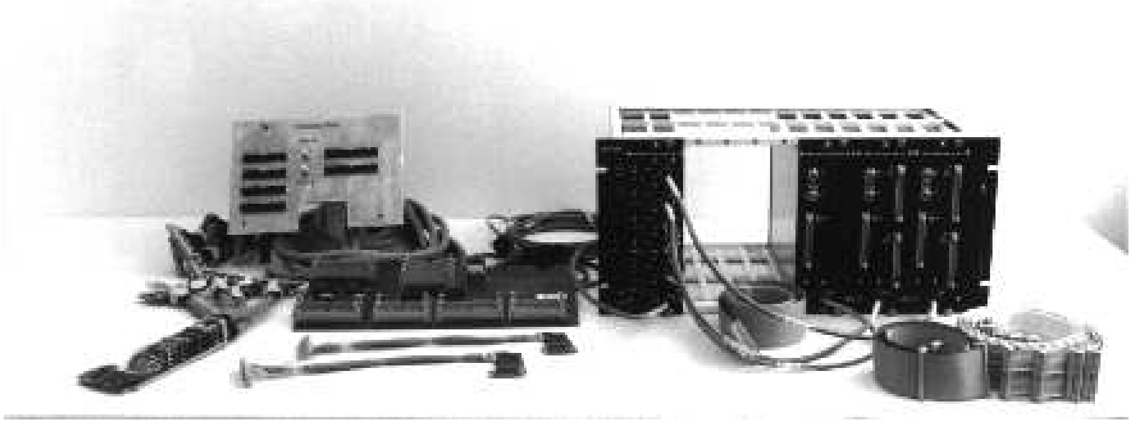

Figure 2: Mark IV R/W Upgrade Modules.

The expertise gained in the previous upgrades resulted in Metsähovi producing four VLBA4 electronics upgrade kits for the EVN in its "VLBA-to-Mark IV" (VIV) project. The goal of this project is to ensure that all EVN VLBI data acquisition systems (both Mark IIIA and VLBA systems) get upgraded to Mark IV performance level. The end result of an upgraded VLBA terminal is called "VLBA4".

The VLBA4 upgrade will quadruple the speed and double the capacity of the VLBA data acquisition terminal.

Metsähovi has received an order of two more VLBA4 upgrade kits and one is under negotiation.

2.1.5 Radio Spectrum Monitoring and Protection

Project Team: Engelberg, Mujunen, Oinaskallio, Rönnberg

The radio spectrum monitoring of interesting frequency bands continues normally, however for the most of 1999 it was stopped due to a problem in the antenna rotating system and due to a failure of the IFR spectrum analyzer.

The antenna rod was repaired in May and has worked since. The spectrum analyzer was shipped to United Kingdom for inspection of sudden noise level changes during the measurements. This took much longer than was expected - a total of six months i.e. from May until November 1999.

A new version of the radio spectrum monitoring daemon "`spektrd`" was written in October 1999. The program runs continuously collecting detailed RFI spectral information in UTC time-tagged ASCII files. It controls antenna rotation, spectrum analyzer settings, and archiving of the measured values. The system has been up since November 10^{th} 1999. 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.

After restarting the monitoring campaign in November, it was noticed that the GSM 1800 network is growing outside Helsinki area and a 1800 MHz base station signal can be measured at Metsähovi, although the signal level is 30 dB lower than the GSM 900 system signal.

2.1.6 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.

This year almost all of our Linux computers were upgraded from Debian/GNU/Linux (see the URL `http://www.debian.org`) version 2.0 to 2.1. 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 a 1.1 → 1.2 → 1.3 → 1.3.1 → 2.0 → 2.1 chain of upgrades.

IDL version 5.1 is still being used on "`kurp.hut.fi`" (2 floating licenses) and on two Linux computers dedicated to solar research. Version 5.2 was discovered to be incompatible with Debian/GNU/Linux and therefore its installation has been postponed; version 5.3 is waiting for to be tested for compatibility.

The "`15APR99`" release of AIPS VLBI data and image processing system was installed by visiting scientist Carl Gwinn (see section 5) at our university site.

For electronics development, PADS PowerLogic and PowerPCB 2.1 were used, together with Lattice/Vantis DesignDirect 1.1 CPLD development system.

2.1.7 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.

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" was put into full use in 1999. 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").

A common simple line format is being used. Each line of the text data files includes the UTC timestamp of the observation moment (with the precision of ten milliseconds), the name of the observed parameter, and the numeric value of it (see Figure 3). Other timestamped line formats can also be used, and the common background archiver daemon "arranger.pl" will continue to function normally to take care of fail-safe moving of archive data to the common "data.kurp.hut.fi" server.

```
2000022115467501     OutT     16.5
```

Figure 3: An example log line.

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".

Network timing protocol configuration was developed a little mainly due the new versions of "xntp" program. Recently the timing accuracy has reached the desired level, i.e. all the computers using "xntp" are within ± 0.1 second accuracy using same time in their clocks.

2.1.8 Data Monitoring

Project Team: Könönen, Mujunen, Vilenius

There are several different types of non-astronomical data which are observed and collected non-stop at Metsähovi Radio Observatory. The purpose of the data is to aid the observations and to help the maintenance and upgrading of the instruments.

At the present this kind of data is received from the two weather stations, a spectrum analyzer, an ADAM/NuDAM control/monitor network, and the EFOS-9 hydrogen maser. The data is saved in a the rack-mounted Linux PC "data.kurp.hut.fi" where main "/data" directory includes separate subdirectories for each data source. Daily files ("yyyymmdd.log") are saved to these subdirectories. These files consist of the UTC time stamped monitoring values.

There is a demand to view the data graphically, monitored values versus time. For that reason a CGI program was developed. The choices for a programming language and a plotting program (in the Linux computer environment of the Metsähovi Radio Observatory) were the Perl programming language and the Gnuplot plotting utility on account of their flexibility of handling text format data which includes time parameters and overall compatibility with each other, with system commands, and with HTML scripting.

The first allotment was the presentation of the weather station data and the EFOS-9 hydrogen maser data (programs "Weather" and "Efos9"). After that the code was generalized to enable also the handling of the spectrometer data which has a slightly different saving format ("multi-browsing" program "MB").

The present modification of the generalized "MB" program searches the "`/data`" directory for the text files which include the information of the data types and parameters. It then creates the Web inquiry forms which are based on this information. In the forms the user has a choice of data types, parameters, a time period and presentation of data. Available options are e.g. the number of parameters in one graph, the parameter axis, a plotting colour, etc. The resulting GIF files (see Figure 4) are shown on the screen and they are available via links.

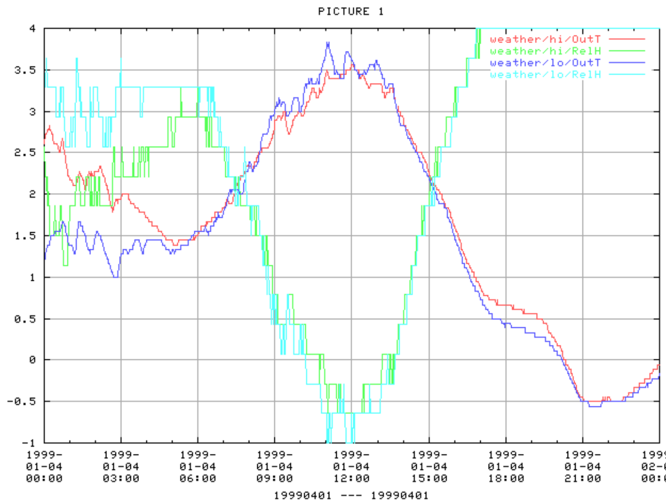

Figure 4: A set of graphs from "MB".

Another CGI script, "`latest.cgi`", makes it possible to easily create new HTML Web page templates which can contain references to latest data values available in standard "`yyyymmdd.log`" log files available on "`/data`". An initial Web page has been created which presents an illustration of Metsähovi radome and antenna together with embedded radome and antenna dish temperatures. It is anticipated that a varied collection of application-specific Web pages based on "`latest.cgi`" value substitutions will emerge in short time.

The CGI programs are available at the location "`http://kurp.hut.fi/local/`" which initially limits the access to the computers on-site at Metsähovi.

The potential extensions are the possibility to add the calibration offsets to the monitored "raw" data values and the possibility to average out the values. For this purpose, the determination of the most important weather offsets was performed and a report of this was made available in the laboratory report series (see section 3.4).

2.2 Antenna Control System Upgrade

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

Year 1999 resulted in significant progress in the "Phase 2" of our antenna control system upgrade. This was mainly because most project members were able to devote as much as 50% of their time to the antenna project.

The overall architecture of the observation system is presented in Figure 5. 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 5MHz 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.

To make it possible to implement a new digital servo system the same PC computer which receives RON806 encoder signals must drive the DC motors. This setup is presented in Figure 6.

Physically the servo PC and the motor control electronics reside in a compact rack enclosure in the antenna pedestal, in close proximity of the Az-El encoders. The maximum cable length from RON806 encoders to the IK121 PC ISA encoder interface board must not exceed 15 meters and this dictated the placement of the servo PC.

2.2.1 Dedicated Hardware

When the decision was made to continue using the same type of low-inertia DC brush motors for antenna movement as what was used before, a search was made to find a suitable commercial DC motor drive solution. One driver board from Maxon (Switzerland) was even tested and found inadequate for our 28VDC/8A motors. Thus it was decided to develop and build a computer-controllable PWM DC motor driver solution.

In autumn 1998 our "FET30" DC motor PWM FET driver board was developed to its third prototype stage. It was rigorously tested to ensure that we have achieved robustness against motor and software failures. In spring 1999 we continued to develop "PWMISA16", a PC ISA expansion board which allows PWM controlling up to five FET boards (four antenna movement motors and one shared subreflector motor drive). PWMISA16 also contains a 5MHz/1pps hardware clock counter which makes sub-second time available with 1μs resolution. A watchdog counter is provided, too, and a software failure to refresh it within 1.5 seconds causes the PWM outputs and enable relay outputs to be disabled.

To get information about the actual motor speeds digital quadrature tachometers (Heidenhain ERN420 10000 counts/revolution) were installed in each motor to replace the old analog generator-type voltage tachometers. Commercial quadrature encoder PC ISA boards were evaluated, as well as an integrated IC solution from HP (HCTL-2016). The cost of complex and large PC ISA boards was so high that we were able to develop a simple "QDRxxx" interface board at roughly the costs of one ready-made board. Our board is easier and cheaper to duplicate, thus we were able to use it in addition to motor tachometers also in the user interface manual "knobs" and also in the space weather system presented in section 2.7.5.

To make the antenna quick, easy, and familiar for existing users we decided to create a computer-simulated conventional control panel called "ANTBOX" with indicator LED lights, pushbuttons, and manual adjustment "knobs". The knobs were implemented using HP HEDS series panel-mounted quadrature encoders connected to our "QDR05R" interface board. This makes knob positions immediately available in numeric form to the `antcon` control Linux PC which can then simulate any manual

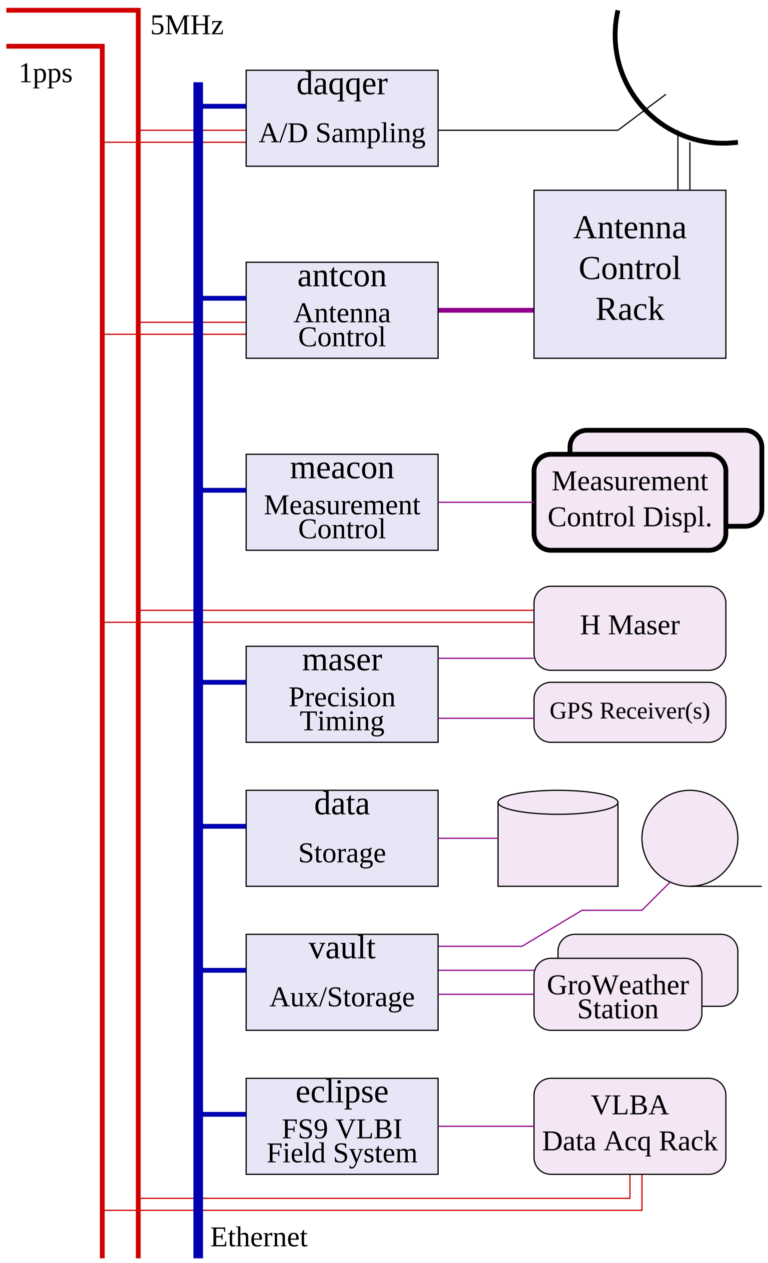

Figure 5: Distributed antenna control computers.

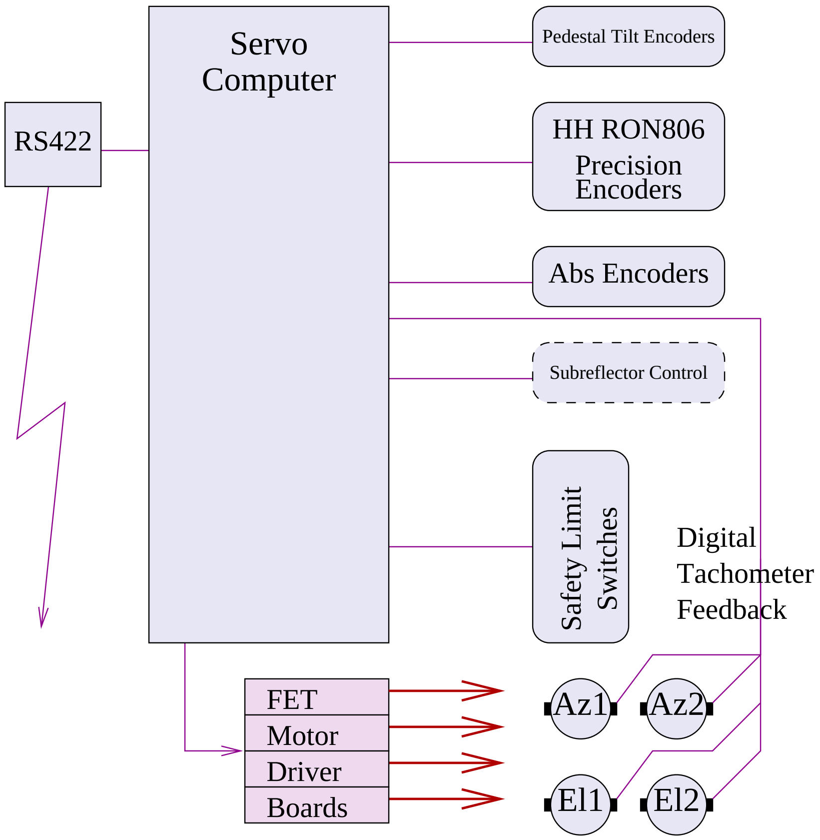

Figure 6: Embedded antenna servo rack in antenna pedestal.

changes/adjustments required such as adjusting manual offsets, moving the antenna at manual angular velocity etc.

The LED indicator lights were also realized under full `antcon` computer control. A simple "LEDIM" control board allows up to 16 LEDs to be set to "off–dim–normal–bright". "LEDIM" also provides routing for "ANTBOX" pushbutton cabling.

A major design issue in the development of our new control system was that there should be no hardware or software single failure which could lead to antenna movement beyond its physical limits. A +24VDC chain of interlock switches is used and this voltage is used to power master relays on an "ANTREL4B" board. It drives the main contactors which are used to connect motor power supplies and motor wiring to the FET driver boards. The "ANTBOX" control panel includes also a "STOP" pushbutton to switch off the +24VDC interlock voltage—this results in main motor contactors to be deprived of their supply power and the antenna stops immediately.

As a remote site, Metsähovi often experiences power outages, especially during heavy snowfall in winter and during thunderstorms in summer. It was decided to adequately protect all antenna control system components with uninterruptible power supplies so that observing can continue for 15–20 minutes regardless the loss of power. For this purpose three 1600VA identical UPS units were installed, the first to protect antenna control, the second to protect receivers and data acquisition computers, and the third for the cryogenic compressor in antenna pedestal. Additional UPSes were already in place for data server computers, the VLBA DAR, and the H maser.

2.2.2 Cabling

All cabling between the antenna pedestal and the control room was dismantled and replaced with a new set of cables. Four thick RG214 cables are provided for receiver IF connections for up to two concurrent dual-polarization receivers. Twelve thin RG223 cables are intended for general-purpose analog interconnects such as total power etc. Two 24-pair instrumentation cables supplement the cabling.

Dedicated antenna control cables were reduced to only:

1. A bidirectional RS422 connection between "`antcon`" and "`antup1`".
2. A bidirectional audio connection for operator conversation between the control room and the antenna pedestal.
3. Safety interlock switch wiring to prevent antenna from moving if there are physical obstacles in its path.
4. UPS 230VAC power.

2.2.3 Computers

For the antenna pedestal servo rack presented in the above section 2.2 we needed a relatively compact PC with sufficient space for expansion boards. Three identical "`antup1/2/3`" PCs were acquired, the first for main antenna, the second as a spare, and the third for the space weather system (presented in section 2.7.5).

Several rack-mounted Linux PCs (see Table 1) for antenna control were acquired and mounted in our control rack.

Table 1: Antenna control Linux PCs.

Name	*Function*
`antcon`	Antenna pointing control.
`daqqer`	Analog data acquisition/sampling.
`meacon`	Observation control; ADAM/NuDAM, weather.
`data`	On-line data archive.

2.2.4 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 connection to the "lo" station was intermittent, however, and the Davis RS232 optoisolators seemed like to be the culprit. (See Figure 7.)

The optoisolators were replaced with isolated RS232/RS422 converters designed in-house. 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.

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

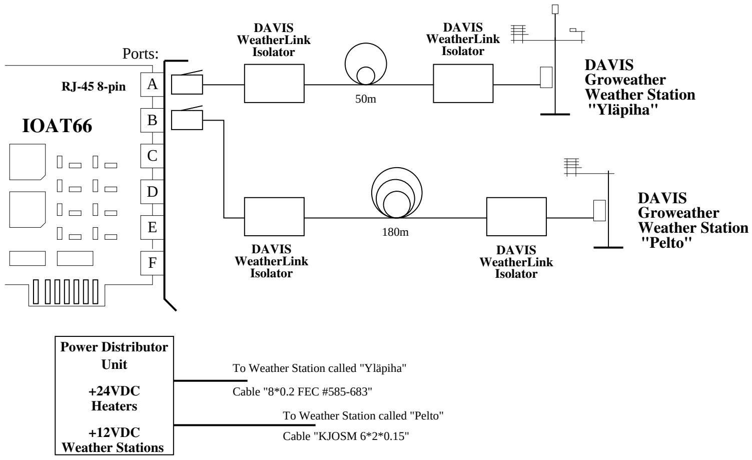

Figure 7: Cable connections between observatory and weather stations.

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.

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 2.1.8 makes it easy to generate customized weather plots using a Web-based end-user interface. Fundamental sensor calibration measurements were conducted by Esa Vilenius and the results are documented in a laboratory report HUT-KURP-17, 2000.

2.2.5 ADAM/NuDAM

In 1999 the central "hub" of our ADAM/NuDAM monitor/control network was re-built in a permanent rack enclosure. Twisted-pair from practically all areas of the observatory site terminate in this "ADAM/NuDAM Box". (See Figure 8.)

The network is based on commercially available ADAM/NuDAM A/D, D/A, and digital I/O modules which are connected together using a multidrop RS485 network implemented with single twisted pair wiring. These modules allow centralized and coordinated monitoring and control of discrete adjust values spatially dispersed across the whole observatory site. A single Linux PC masters the RS485 network bus while a TCP/IP server process running on it makes all ADAM/NuDAM modules equally accessible from any computer on the Metsähovi LAN using a simple, `telnet`-style protocol.

2.2.6 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 purchased and installed in "`daqqer`". 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.

The initial 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).

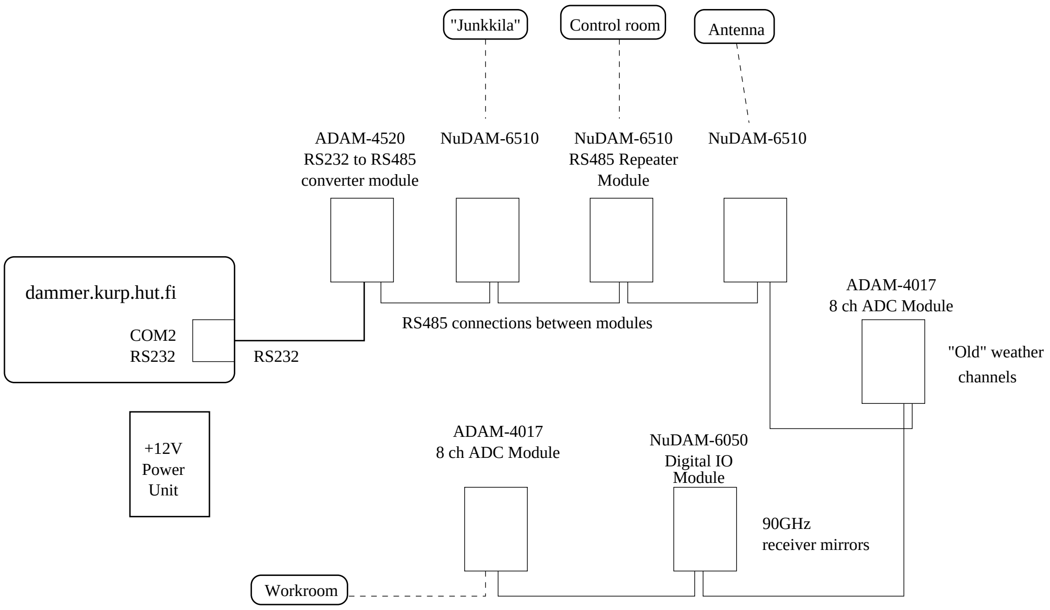

Figure 8: Block figure of the ADAM/NuDAM system.

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

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 monitoring of quasars at Metsähovi Radio Observatory continued in 1999 for the 19th year. Our main sample consists of 85 AGN (Active Galactic Nuclei), about equal number of BL Lac objects, HPQ's (high optical polarization quasars) and LPQ's (low optical polarization quasars). As the Metsähovi antenna was under maintenance from May to November, the total number of QSO observations was quite modest, only about 1900. The total number of observations since 1980 is now over 43000. All the observations during 1999 were at 22 and 37 GHz.

Altogether 11 persons took part in the QSO observations during 1999, most of them being students from the Turku University, whose salary was partly paid by Tuorla Observatory. Nearly 20% of the observations were done in automatic mode, mostly during the cold season, when dew is not expected on the radome. The observers were: Harri Teräsranta (HT), Anne Lähteenmäki (AL) and Merja Tornikoski (MT) from the Helsinki University of Technology, automatic observations (AU), Tuomas Niemelä (TN), Seppo Wiren (SW), Matti Koskimies (MK), Pertti Koivisto (PKo), Niko Varjonen (NV), Jani Achren (JA), Tuomas Savolainen (TS) and Markku Lainela (ML) from the Turku University and their share of the observations during 1999 is shown in Figure 9.

An example of our long term monitoring can be seen in Figure 10, the flux of the quasar OA 129 at 22 and 37 GHz since 1981.

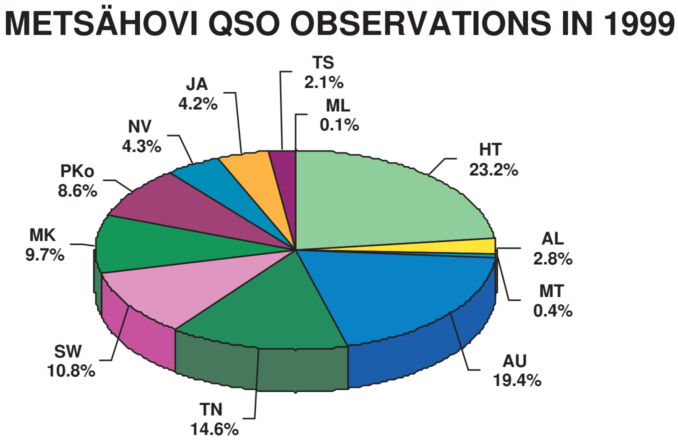

Figure 9: The observers share of the QSO observations during 1999.

The prelaunch observations of foreground sources for the ESA Planck mission were started with observations at 22 GHz in the first stage. The removal of strong foreground sources from the Planck maps will increase its sensitivity, especially in the narrow field of view. The sources observed here in the first stage are limited to Northern part of the sky, declinations $0 - +75$ and flux density higher than 0.5 Jy at 1.4 GHz. The spectral index α between 1.4 and 4.85 GHz is another selection criteria, the sources are observed from the flat spectrum ones towards the steeper spectrum ones. In the end of the year 1999 the sources with α= -0.3 are nearly completed. The number of sources will increase as the spectral index gets smaller due to a larger fraction of ordinary radio galaxies. The α of ordinary radio galaxies can be considered constant in the radio-mm region, being around -0.7 and they are mostly nonvariable. Thus the effect of radio galaxies can be easily removed from the Planck maps. The sources with a flat spectrum up to higher frequencies (100 GHz) tend to be variable and also quite strong at higher frequencies, at least during the outburst stages. A small part of sources with a steep spectral index in the lower frequencies (1.4-4.85 GHz) are in reality flat spectrum sources and will show blazar type behaviour. Their steep spectral index at lower frequencies could be due to the surveys observations at the higher frequency (4.85 GHz) being in the relatively quiet phase, as the 1.4 GHz observation has been during a more active phase. A single epoch observation of our sample will still leave some flat spectrum sources undetected, as they might be in a low flux state during our observations. Thus 2-3 observations within 2-3 years should give a better estimate of the duty cycle. It must be noted, that our present rms error levels around 50 mJy with a typical 30 minute integration leave some of the sources undetected in their low stage. The new detected flat spectrum sources will be added to our observation sample. Some of the new sources in the sample have not yet an optical counterpart. Their identification has been started in co-operation with the Tuorla Observatory.

Although the launch of the Planck is still many years in future and the lower flux limits for the interfering sources at specific frequencies is not fixed, the early preparation can be justified by the flight of two important gamma-ray observatories before Planck, namely the Italian AGILE and NASA's GLAST. Both AGILE and GLAST will have a large field of view, in order of 2.5 sr for AGILE and even larger for GLAST. Together with planned long integration times (months) it will lead to many new gamma-ray sources to be detected. Also their duty cycle can be studied better than earlier. The close connection between gamma-ray emission and mm-radiation has been demonstrated in our previous works, but due to the poor temporal resolution in the gamma- ray data, the events can not yet be fully connected. All of the gamma-ray emitting AGN should also be flat spectrum radio sources and thus both AGILE and GLAST should complete our sample for the Planck mission.

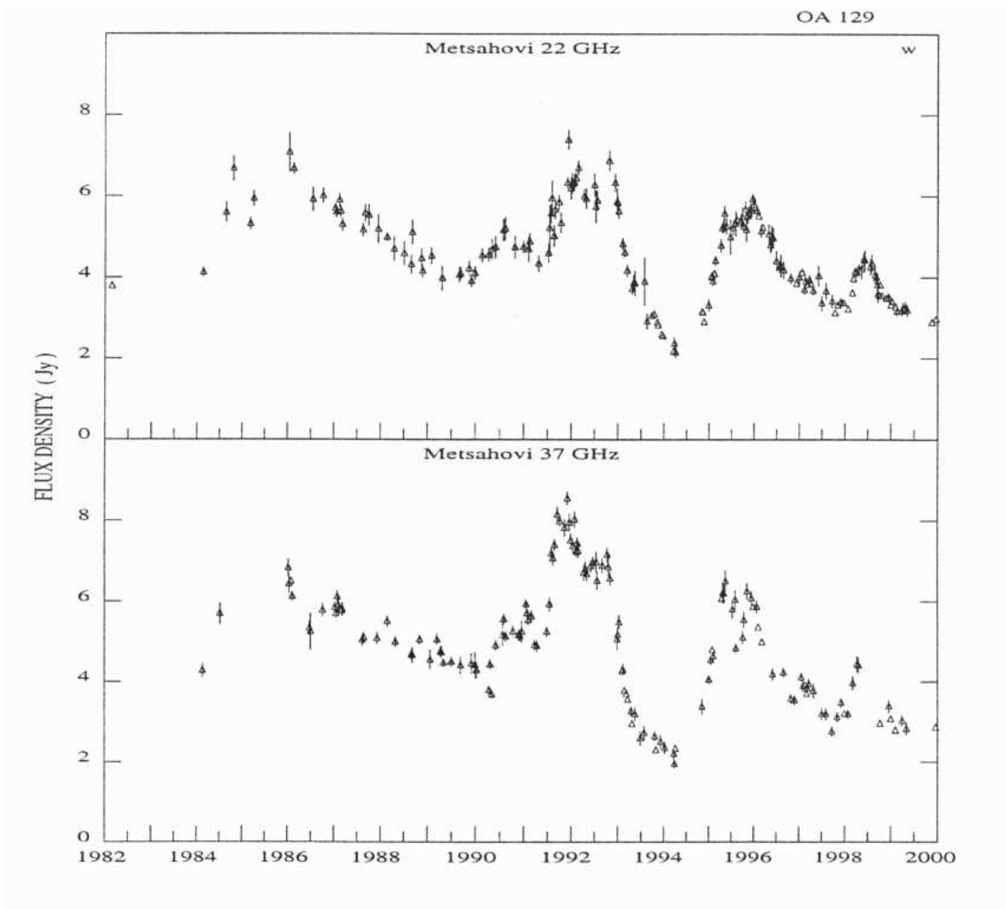

Figure 10: The flux density of the quasar OA 129 at 22 and 37 GHz since 1981.

2.3.2 SEST Observations

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

Our long-term high radio frequency (90 and 230 GHz) monitoring of AGNs with the SEST telescope was discontinued in 1998, but we still use the SEST for individual short observing projects related to our group's work on AGNs.

1. High-frequency spectra of faint radio sources and the extragalactic radio background.

This project is related to the Planck-foreground activities of the Metsähovi group. With our group's ground-based observations we aim to get a meaningful estimate of the contribution of extragalactic radio sources in the high radio frequency domain to the observed background as a prediction for the Planck mission. The SEST observations are essential to complement this study in order to extend the sample to the southern sky and to allow us to estimate the extragalactic foreground contribution from the high-frequency tail of the spectrum of radio sources.

Studying a full sample of extragalactic radio sources will give us a true estimate of the shape of the millimetre spectrum of these sources, including the fainter (at low radio frequencies) sources which are routinely excluded from flux-limited samples. It is worth noting that also non-detections (under good observing conditions) will offer us valuable information when estimating the contribution to the extragalactic background. Another goal, which is partly related to the goals of the Planck mission but also interesting *per se*, is the aim of finding sources with flat or inverted spectra in the GHz range.

In June 1999 we made our first SEST observations related to this project. The data are now being analyzed and will be published in 2000.

2. Gamma–ray loud and quiet southern AGNs

This project is connected to our earlier SEST studies of γ–ray sources and candidates.

The main goal of this study is to get a more thorough understanding of the relationship of the radio and γ–ray activity of AGNs. We aim to get a complete picture of the radio behaviour of a selected sample of southern sources, both γ–ray loud and quiet ones. We have monitored these sources with the SEST also earlier, and now that the EGRET lifetime is ending, we wanted to have our last look at these sources also at the SEST frequencies in order to have a full understanding of their radio states and the variability behaviour during the whole CGRO mission lifetime.

We will compare the radio properties of the γ–ray loud and quiet sources. Were the sources that were detected with the EGRET active also in the millimetre domain at that time? Were there times when they were in the EGRET field of view and not detected, and they were in a low radio state at that time? Are there any notable differences in the radio variability behaviour, amplitude and timescales, between the γ–ray loud and quiet AGNs?

This project was granted SEST observing time in October 1999, and the data are now being analyzed.

2.4 Planck-Related Science in Metsähovi

Project Team: Lähteenmäki, Teräsranta, Tornikoski, Urpo

The Planck satellite is one of European Space Agency ESA's main missions of the decade. It will measure the 3 K sky background radiation at several millimeter frequencies. This cosmic microwave background (CMB) radiation, observed from all directions in the sky, exhibits how the Universe looked shortly after the Big Bang. Examining the CMB at the high resolution and sensitivity of the Planck satellite will answer some of the fundamental questions about our Universe. The launch is scheduled for 2007 and the all-sky catalogs will be available in 2010.

The Planck satellite data can also be used for AGN science. The Low Frequency Instrument (LFI) data, in the range of 30 – 100 GHz, will comprise an enormous database of active galaxies and quasars. In fact, the Planck all-sky catalog of AGNs will be the most complete so far. This data can be used in traditional AGN research, e.g., in multifrequency spectral studies or in comparison with other frequencies.

However, the so interesting AGNs are a nuisance to the CMB measurements, and are regarded as mere foreground objects one should try hard to get rid of. This is why the Metsähovi radio telescope will be used in a search for sources whose spectra peaks at the LFI frequency range. The number, the strength, and the variability of these Gigahertz Peaked Spectrum (GPS) sources should be known in order to produce accurate CMB maps. The search for new GPS sources has already started in Metsähovi and at SEST, and simultaneous observations during the Planck satellite flight are being planned. The Metsähovi measurements will also be valuable when analysing the Planck all-sky AGN catalogs.

We have started a collaboration with the LFI Consortium foreground team, and there is an agreement on the exchange of data and on the scientific work contribution. The detailed concept of the foreground team, and its agenda, are expected to shape up during the year 2000. The Planck satellite project integrates naturally to the AGN project in Metsähovi, and provides new insights on the ongoing research as well as opens up entirely new possibilities both in science and in inter-observatory co-operation.

2.5 Observations with Other Facilities

Swedish–ESO Submillimetre Telescope (SEST), Chile:

21.–24.6. (46 hours) "High frequency spectra of faint radio sources, and the extragalactic radio background". P.I. M. Tornikoski, Co–Is H. Teräsranta, E. Valtaoja (Turku), M. Lainela (Turku), observer: M. Lainela.

6.–11.10. (37 hours) "Gamma-ray loud and quiet southern AGN", P.I. M. Tornikoski, Co–Is H. Teräsranta, E. Valtaoja (Turku), M. Lainela (Turku), observer: M. Lainela.

VLBA: 18.5. (3.5 hours) "The bursting gamma ray source, PKS 2255−282", P.I. S. Tingay, Co–Is M. Tornikoski et al.

"Monitoring extremely variable spiral III ZW 2", P.I. H. Falcke, Co-I H. Teräsranta. Observations with the VLA during: 8.1, 22.2, 23.3, 23.4, 13.5, 22.6, 7.7, 1.8, 28.8, 20.9, 18.10, 11.11 and 5.12 1999.

2.6 VLBI Research

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

2.6.1 EVN

Project Team: Urpo, Engelberg, Karlamaa, Mujunen

Metsähovi participated in two EVN 22 GHz sessions in February and in March with success. 22 GHz receiver has worked without problems. In March 1999 Metsähovi participated for the first time in an international VLBI session at 43 GHz. The array consisted of all VLBA antennas, phased Y (13 antennas), Effelsberg, Metsähovi, Onsala, Yebes and Medicina. Metsähovi produced again fringes. Metsähovi participated in this session of interesting bit of science and the results will be published in Nature. The 43 GHz receiver noise temperature is around 65 K. The RCP channel is still out of order because gate bonding of one of the HEMTs is damaged. We don't know yet how to repair it. 86 GHz receiver is available and operational.

Kaj Wiik has moved to Tuorla Observatory, Turku, and he is not actively participating Metsähovi VLBI group activities. His main interest is in CMVA. PhD student Mika Perttula has left from the Metsähovi VLBI group, he is currently working at Finnish Telia.

Compressor cover was built to protect the compressor during winter. It has worked fine, no problems even at temperatures less than −25 C.

2.6.2 CMVA, Coordinated Millimetre VLBI Array

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

Metsähovi participated in one CMVA session in 1999 with success.

2.6.3 Space VLBI

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

Metsähovi continued to participate in the space VLBI projects HALCA (Japan) and Radioastron (Russia). In 1999 there were no 22 GHz sessions with HALCA but scientists from Metsähovi were members of several accepted HALCA science projects at lower frequencies. The progress of Radioastron was slow in 1999 but Metsähovi continued as a member of RISC (Radioastron International Science Committee).

2.6.4 FS Support

Project Team: Mujunen

Since 1995 Metsähovi has participated in and contributed to the development of the Field System, software used to control VLBI Data Acquisition Racks during VLBI observations. Currently we participate in a three-year European Community Contract FMGE-CT98-0101 program for enhancing EVN together with five European institutes. Our efforts concentrate on enhancing the FS software to support evolving observational techniques being developed in this EU program.

In 1998 the third generation of the FS adaptation of the Linux operating system was created, called "FS Linux 3", based on Debian/GNU/Linux 2.0r5. In February 1999 it was presented in EVN TOG meeting (Noto, Catania, Italy) and CD-R disks were distributed. In 1999 an increasing number of stations migrated to using FS Linux 3.

A considerable level of Linux support via email was given to collaborators at NASA GSFC geodesy VLBI project, Ed Himwich and Nancy Vandenberg. This included about 170 emails sent in 1999, in addition to email support sent directly to stations.

The European FS FTP archives at Metsähovi ("`ftp://kurp-ftp.hut.fi/pub/fs*`") are the primary source of FS Linux files and they also act as the primary means for EVN stations to access mirrored FS files from "`ftp://gemini.gsfc.nasa.gov`".

2.7 Solar Research

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

2.7.1 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 in the Web, at **http://www.hut.fi/~spo/idl.html**, with guidebooks both in English and in Finnish.

2.7.2 Solar Polar Features at mm-Waves

Project Team: Pohjolainen (Observatoire de Paris, France), Portier-Fozzani (LAS-CNRS, Marseille, France), Riehokainen (Turku), Valtaoja (Turku)

Metsähovi radio maps at 87 GHz (3.5 mm) from 1996-1997 have been analysed and compared with nearly-simultaneous SOHO/EIT and YOHKOH/SXT images. Emphasis was given to comparing polar radio brightenings with features seen in EUV, but also many radio depressions and their EUV and SXT counterparts were analysed. The radio enhancements were found to correlate with bright points, polar plumes or plume bases, and EUV bright diffuse structures. No uniform brightness was found inside the coronal holes: the holes appeared generally as radio dark, with local brightenings inside them. The visibility of radio bright coronal holes seemed also to depend on how much of the polar area was exposed, due to the variation of the B_0-angle. The analysis and results are presented in Pohjolainen et al. (A&AS, in press).

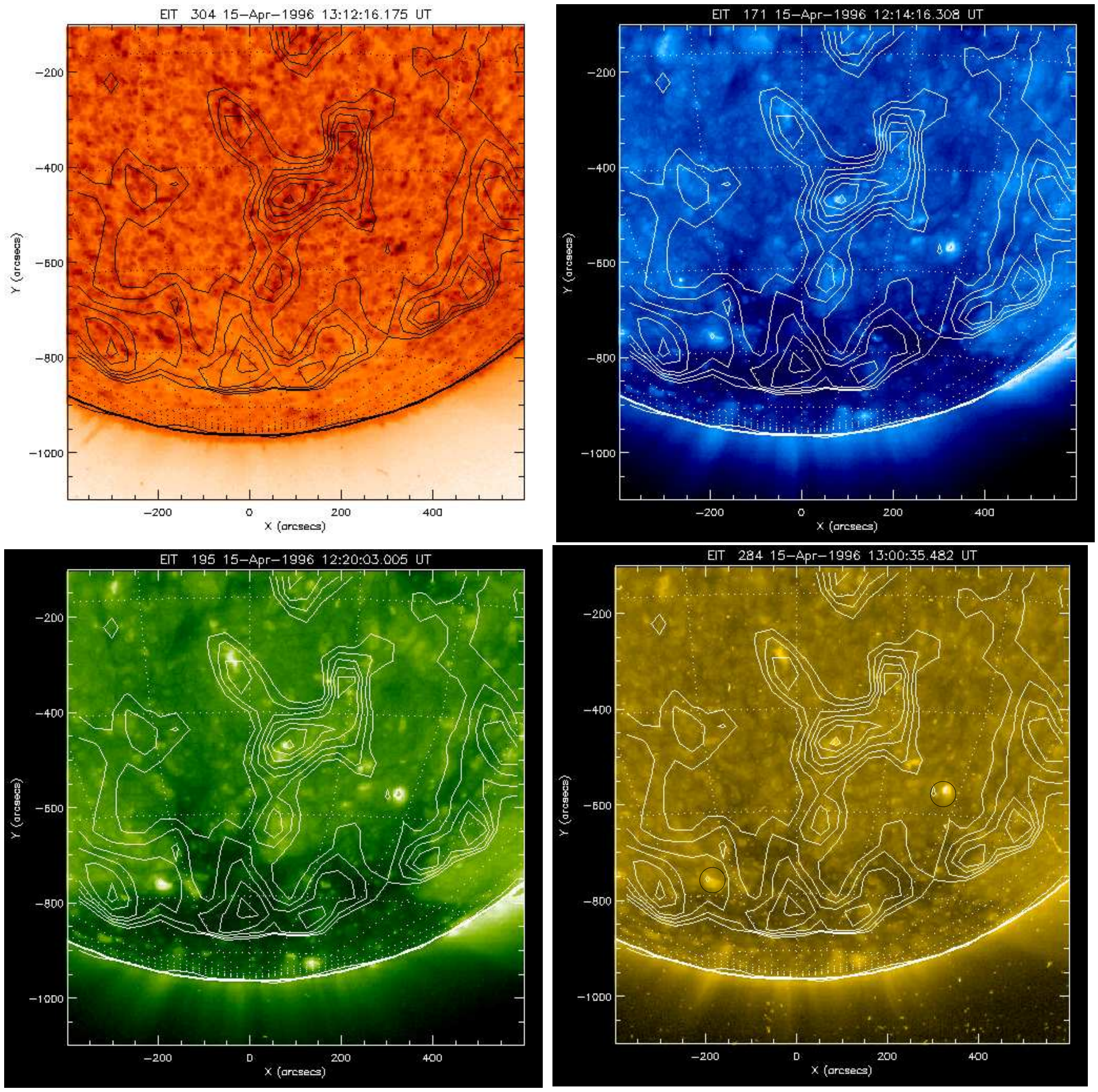

Figure 11: SOHO/EIT images on April 15, 1996: He II (304 Å, T = 80000 K, reversed colours) at 13:12 UT (top left), Fe IX/X (171 Å, T = 1.3 MK) at 12:14 UT (top right), Fe XII (195 Å, T = 1.6 MK) at 12:20 UT (bottom left), and Fe XV (284 Å, T = 2.0 MK) at 13:00 UT (bottom right). Superimposed are some selected radio contour lines (white), that show emission above the quiet Sun level (7200 K) at 3.5 mm wavelength at 12:05-12:13 UT. The black circles in the Fe XV image (bottom right) show the positions of EUV and X-ray bright points. The circles represent the radio resolution, i.e., a beam size of 60 arcsec. Radio enhancements are seen over the coronal hole and diffuse emission regions, while the EUV bright points only have very faint radio signatures.

A similar analysis was done using the Metsähovi 3.5 mm radio data and TRACE EUV and UV data from 1998 (Pohjolainen et al., 1999, ESA SP-448). The results were similar to the EIT–Metsähovi comparison, only now the resolution in EUV was much better and smaller features could be recognized. Many EUV bright points – some of them were also seen in UV – were found to correlate with locations of enhanced radio emission. This suggests that some of the radio brightenings are formed very low in the solar atmosphere. Also local radio brightenings inside coronal holes were observed, with no obvious reason for the enhanced millimetric emission.

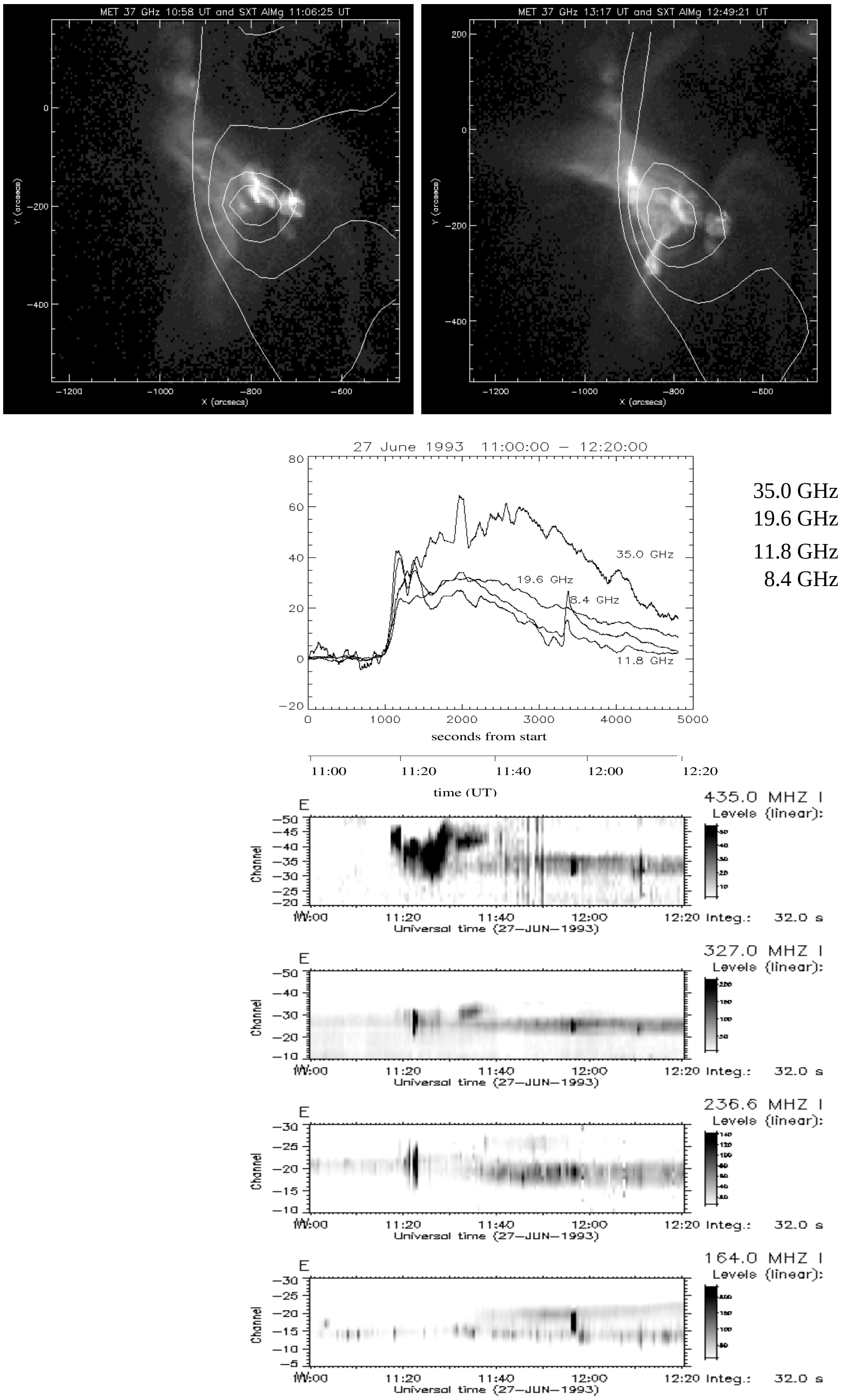

Figure 12: Metsähovi 37 GHz radio contours superimposed on the YOHKOH/SXT images before (top left) and after (top right) the flare on June 27, 1993. Bern data at 35.0, 19.6, 11.8, and 8.4 GHz, integrated over 60 s (middle). Nancay Radioheliograph East-West scans at 435, 327, 237, and 164 MHz (bottom). The plotted time interval is 11:00–12:20 UT on June 27, 1993.

2.7.3 Multi-wavelength Analysis of Energetic Solar Flares

Project Team Pohjolainen, Vilmer (Observatoire de Paris, France), Khan (ISAS, Japan & Mullard Space Science Lab., UK), Magun (Bern, Switzerland)

Analysis of selected solar events producing soft and hard X-ray emission, as well as low and high frequency radio emission, has been started. The purpose is to study the link between flares and the onset of coronal mass ejections. YOHKOH satellite data have been analysed to determine the emission sites, temperatures, and emission measures of the flaring plasma. Low frequency data from the Nancay radioheliograph (150-450 MHz) have been used to infer the signature of low energy non-thermal electrons. The analysis of the events on May 2, 1998 (Pohjolainen et al., 1999, ESA SP-448) and June 27, 1993 (Pohjolainen et al., 1999, Proc. HESSI Workshop) have already been started.

Future analysis and other events will include data from the Nobeyama Radioheliograph (17 and 34 GHz) and the CGRO BATSE experiment (hard X-rays).

2.7.4 High Latitude Active Regions

Project Team: Urpo, Riehokainen (Turku), Valtaoja (Turku)

Solar radio radiation mass measured at Metsähovi show localized regions of enhanced mm-wave emission at low, 0-45 degrees, and at high 50-90 degrees, solar latitudes. Both spatial and temporal distribution of these active regions have been studied. Typically the high latitude sources are in the maps 100-400 K hotter than the quiet Sun but the actual brightness of these sources can be at least 1000 K if the size of the emission is much smaller than the beam of our telescope. The high latitude mm-wave sources correlate with the cycle of polar faculae which is in antiphase with the 12 year sun-spot cycle.

2.7.5 Space Weather Monitoring

Project Team: Urpo, Puhakka, Oinaskallio

Metsähovi has started a project to predict space weather by monitoring solar radio bursts connected to solar energy and particle releases. If the solar energy release is big enough it produces disturbances in the ionosphere and magnetosphere of the Earth.

Antenna construction consist of 1.8-m diameter reflector with 10 GHz microwave receiver. The beam of the antenna will cover the whole disk of the Sun. As a stand for these components there is an old stand of optical telescope and it is being modified now for this new purpose. Small 1.8-m reflector is sufficiently accurate for measurements because the total intensity of the Sun is the only information in which we are interested. Due to slow tracking speeds we have to use very accurate speed reducers and position encoders. Also mechanical assembling have to be very accurate and tight. Turning of the antenna will be done with two small DC-motor-tacometer-combinations which are controlled with pulse width modulation -card. This made it possible to use partially same electrical parts and software as in the main telescope.

During year 1999 most of heavy mechanical parts of the antenna have been done ready for final assembling. Designing and production of control and RF electronics and also software engineering continued to next year. Aim is to get first data plots during summer 2000.

2.7.6 INTAS

Project Team: Urpo, Bogod (Pulkovo), Krüger (Potsdam), Pohjolainen, Stepanov (Pulkovo), Zaitsev (Nizhny Novgorod)

This research is based on the INTAS grant INTAS-RFBR-95-316 "Coronal Physics from Observations at Centimer and Millimeter Wavelengths" were S. Urpo is the coordinator.

Microwave tomography of solar atmosphere. Method of tomography of the solar atmosphere based on the broadband spectral radio observations with high spatial resolution was proposed. Solution of radiation transfer equation in magnetized thermal plasma is applied for the magnetic field measurements. The method was used to the search of solar chromosphere and corona during numerous observations at 3 mm-wavelength (Metsähovi), at 1.6-32 cm wavelengths (RATAN-600), and at 17 mm-wavelength (Nobeyama). Optical data from solar magnethographs and space mission data were also used. Proposed method opens new possibilities for the study of coronal heating, energy storage and release in different regions of solar atmosphere.

Magnetic field structure in coronal holes on the Sun. First measurements of the magnetic field strength in a coronal hole in low coronal levels have been made on the base of the spectral-polarization solar observations at microwaves (2-30 cm) with high spatial and spectral resolution using the RATAN-600. Circular polarized radio emission associated with the isolated equatorial coronal hole has been measured during two solar rotations (CPM - 12.10.1996 and 9.11.1996) at wavelengths longer than 8 cm. The measured polarization degree turned out to be between 0.2

Peculiarities of wave conversion in stellar coronae. It was shown that due to high plasma temperature ($10^7 - 10^8$ K) in the coronae of UV Ceti and RS CVn type stars the effectiveness of conversion of Langmuir waves into electromagnetic ones is one-two orders more compared to the solar corona conditions. This is due to the larger conversion length as compared with "cold" solar corona. The plasma turbulence level in the case of loss-cone instability of magnetically trapped high-energy electrons in stellar coronal loops is determined. Therewith the brightness temperature of second harmonic plasma radiation can reach 10^{14} K for spontaneous conversion and 10^{16} K for induced conversion.

Dynamics of energy release in a current-carrying coronal loop. Pulsating and explosive time profiles of mm-wave solar bursts observed at Metsähovi in terms of the energy release in single current-carrying loop are explained. It was suppose that the electric current in a loop is driven by the photosphere convective flows. The flare occurs due to the flute instability providing the penetration of partially ionized chromosphere plasma into the current channel of a loop and consequently the loop resistance grows by many orders of magnitude. The feedback of the deviation of the loop magnetic field on the energy release rate was taken into account. Two regimes of energy release are studied: (i) Pulsating energy release in rarefied current loop with plasma beta $\beta \ll 1$; (ii) Explosive energy release in a loop with the gradient of gas pressure of about Ampere force. We have shown that using two mentioned regimes and its combination one can explain different time behavior of the flares, for example, several quasi-periodic pulses, and pulsations with increasing amplitude at pre-flash phase followed by explosive enhancement of the emission at flash phase.

Electric parameters of coronal loops on the Sun and the stars. Electric parameters of magnetic loops in solar and stellar atmospheres based on an equivalent LRC-circuit analog and on the data on pulsations of flare emission are determined. Electric current is driven by the converging flows of the photosphere matter. Analysis of mm-wave solar flare bursts gives the currents $I \approx 6 \times 10^{10} - 1.4 \times 10^{12}$ A, the resistance $R \approx 10^{-4} - 10^{-2}$ Ohm, the inductance $L \approx 1 - 10$ H, and the capacitance $C \approx 0.1$ F. For the coronal loops on red dwarfs and close binaries $I \approx 10^{13} - 10^{14}$ A, and $R \approx 0.01 - 1$ Ohm.

2.8 HRDL for Alpha Magnetic Spectrometer (AMS)

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

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

Metsähovi is participating in the Alpha Magnetic Spectrometer (AMS)—a collaboration with CERN, NASA, and other institutes.

Metsähovi is responsible for designing and operating the High Rate Data Link (HRDL) subsystem of AMS and acquiring the data produced by the spectrometer.

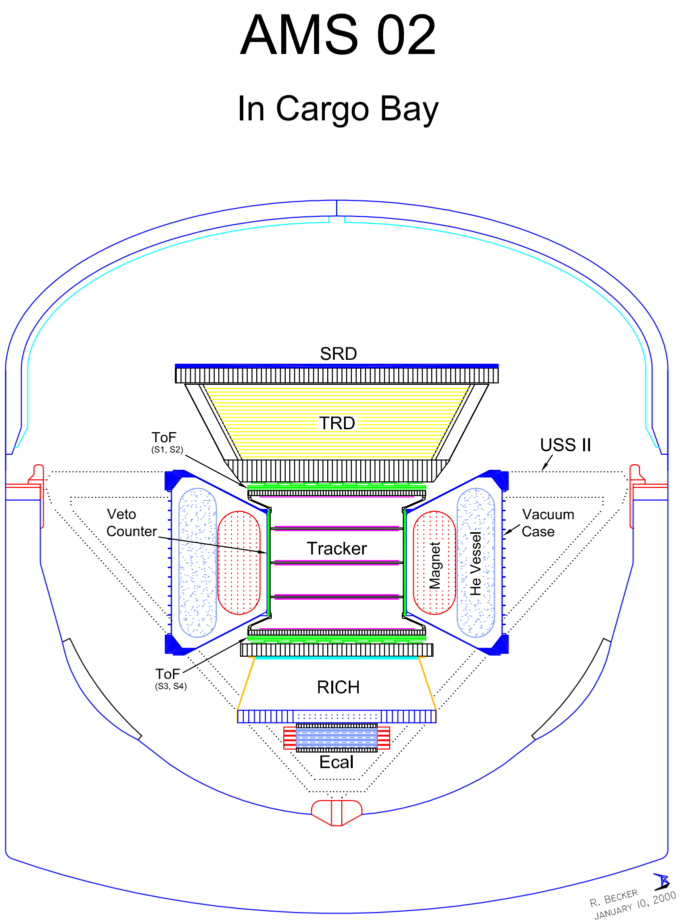

Figure 13: AMS-02 in Shuttle Cargo Bay. (Illustration courtesy of Dr. R. Becker, MIT.)

The first version of AMS was tested in the space shuttle Discovery during flight STS-91 in June 1998 in a 51.7 degree orbit at altitudes between 320 and 390 km. Metsähovi personnel worked in three shifts in the NASA Mission Control Center, Houston, during the 10-day flight.

The detector was successfully tested and a total of 2.86×10^6 helium nuclei were observed in the rigidity range of 1 to 140 GV. 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. (See the first publication of the AMS collaboration listed in section 3.1.)

AMS-02 (see Figure 13), the second and improved version of AMS will be transferred to the International Space Station on the shuttle flight UF-4 in the year 2003. The second version will be based on a superconductive cryomagnet which will considerably improve its capability to detect even the slightest amount of antihelium nuclei. Numerous other improvements on sensors and data acquisition will also be included.

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 massive star-forming region W49 N. Water maser observations commonly show dramatic variations in flux density as 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 W49 N. 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 field with respect to the line of sight. The crucial observation is the measurement of the nonthermal velocity fluctuation of the line peak during maser outbursts. These velocity fluctuations are produced by Alfvenic pressure, which is substantially increased in the sudden compressions associated with shocks. Thus they trace the Alfven velocity, and together with the preshock density, the preshock field strength. The fact that Alfvenic wave fluctuations are oriented pærpendicular to the field lines enabled us to estimate the inclination angle of the mean field from the observed dispersion of the line velocity fluctuations. The postshock field strengths are determined from space/shock velocities of the maser features (measured by VLBI).

One uniquely powerful outburst feature in our W49 N data, referred to as the "big flare feature", showed also the narrowest linewidth. Our data indicate that the space velocity of this feature lies in the plane of sky, whereas preshock and postshock magnetic fields are directed nearly along the line of sight (i.e., this feature originated from a perpendicular shock). Consequently, Alfvenic wave fluctuations along the line of sight, and linewidth, are minimal, and a very high aspect ratio is achieved. Furthermore, the big flare feature stands out through its low space velocity, higher 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 line at 119 GHz and 487 GHz. The 119 GHz receiver of ODIN has been built by the Radio Laboratory of Helsinki University of Technology. The Finnish participation is financially supported by Tekes.

The scientific preparatory work of the ODIN astronomy group has been split into 17 project teams, of which Liljeström and J. Black form the lead scientist pair of two teams: Photon Dominated Regions and High-latitude Clouds. 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.

Much effort has been put to the preparatory work required from the team leaders since autumn 1995. The ODIN satellite will be launched in late 2000.

3 Publications

3.1 International Journals

1 Raiteri, C.M., Villata, M., Tosti, G., Fiorucci, M., Ghisellini, G., Takalo, L.O., Sillanpää, A., Valtaoja, E., Teräsranta, H., Tornikoski, M., Aller, M.F., Aller, H.D., De Francesco, G., Heinämäki, P., Katajainen, S., Lanteri, L., Nilsson, K., Pursimo, T., Rizzi, N., Sobrito, G.: Optical and radio behaviour of the blazar S4 0954+65. *Astronomy and Astrophysics*, Vol. 352, pp. 19-31, 1999.

2 Lähteenmäki, A., Valtaoja, E., Wiik, K.: Total flux density variations in extragalactic radio sources. II. Determining the limiting brightness temperature for synchrotron sources. *Astrophysical Journal*, Vol. 511, No 1, pp. 112-117, 1999.

3 Brajša, R., Ruždjak, V., Vršnak, B., Wöhl, H., Pohjolainen, S., Urpo, S.: An estimate of microwave low brightness temperature regions' heights obtained measuring their rotation velocity. *Solar Physics*, Vol. 184, pp. 281-296, 1999.

4 Falcke, H., Bower, G.C., Lobanov, A.R., Krichbaum, T.P., Patnaik, A.R., Aller, M.F., Aller, H.D., Teräsranta, H., Wright, M.C.H., Sandell, G.: A major radio outburst in III Zw 2 with an extremely inverted, millimeter-peaked spectrum. *Astrophysical Journal*, Vol. 514. pp. L17-L20, 1999.

5 Türler, M., Paltani, S., Courvoisier, T.J-L., Aller, M.F., Aller, H.D., Blecha, A., Puchet, P., Lainela, M., McHardy, I.M., Robson, E.I., Stevens, J.A., Teräsranta, H., Tornikoski, M., Ulrich, M-H., Wamsteker, W.: 30 years of multi-wavelength observations of 3C 273. *Astronomy and Astrophysics Supplement series*, Vol. 134, pp. 89-101, 1999.

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33 Pohjolainen, S., Khan, J.I., Vilmer, N.: A multiwavelength study of active region evolution and flare onset preceding a CME event. EPS Meeting on Solar Physics, September 1999 (poster presentation), *ESA SP-448*, 6 p., in press, 1999.

34 Pohjolainen, S., Riehokainen, A., Valtaoja E.: Polar radio sources observed in UV and EUV. EPS Meeting on Solar Physics, September 1999 (poster presentation), *ESA SP-448*, 6 p. in press, 1999.

35 Pohjolainen, S., Portier-Fozzani, F., and Ragaigne, D.: Radio bright structures near the solar poles at millimeter wavelengths. Proc. of Nobeyama Symposium, NRO Report, 6 p., in press, 1999.

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3.3 National Conferences

1 Karlamaa, K.: First International VLBI measurement at 43 GHz at Metsähovi Radio Observatory. URSI/IEEE XXIV Convention on Radio Science, University of Turku, October 4-5, 1999, *Tuorla Observatory Reports Informo No 181*, editors: E. Valtaoja, K. Wiik, pp. 42-43, 1999.

2 Tornikoski, M.: Citius, Altius, Fortius... A look at the modern radio astronomy. URSI/IEEE XXIV Convention on Radio Science, University of Turku, October 4-5, 1999, *Tuorla Observatory Reports Informo No 181*, editors: E. Valtaoja, K. Wiik, pp. 100-101, 1999.

3 Liljeström, T.: Single-dish and VLBI linewidths of water masers in W49N. URSI/IEEE XXIV Convention on Radio Science, University of Turku, October 4-5, 1999, *Tuorla Observatory Reports Informo No 181*, editors: E. Valtaoja, K. Wiik, pp. 50-51, 1999.

4 Sillanpää, A., Lähteenmäki, A., Pursimo, T., Takalo, L., Petry, D., Böttcher, M., Connaughton, V., Raiteri, C.M., Sobrito, G., Villata, M., Teräsranta, H., Tosti, G., Schröder, F.: Multiwavelength observations of the BL Lac Object MKN 501 during the 1997 high state. URSI/IEEE XXIV Convention on Radio Science, University of Turku, October 4-5, 1999, *Tuorla Observatory Reports Informo No 181*, editors: E. Valtaoja, K. Wiik, pp. 94-95, 1999.

3.4 Laboratory Reports

1 Lähteenmäki, A., Valtaoja, E.: Total flux density variations in extragalactic radio sources. III. Doppler boosting factors, Lorenz factors and viewing angles for active galactic nuclei. *Metsähovi Publications on Radio Science HUT-MET-28*, 23. p, 1999.

2 Zaitsev, V.V., Urpo, S., Stepanov, A.V.: Dynamics of energy release in single flare loop. *Metsähovi Publications on Radio Science HUT-MET-29* 16 p., 1999.

3 Zaitsev, V.V., Urpo, S., Stepanov, A.V.: Radiation signatures of solar energy release at mm-wavelengths: advanced circuit model. *Metsähovi Publications on Radio Science HUT-MET-30*, 15 p., 1999.

4 Urpo, S., Mujunen, A. (editors): Metsähovi Radio Observatory Annual Report 1998. *Metsähovi Reports HUT-KURP-15*, 43 p., 1999.

5 Lähteenmäki, A.: Total flux density variations in extragalactic radio sources: Observations and analysis. *Metsähovi Publications on Radio Science HUT-MET-31*, 33 p, 1999.

3.5 Other Publications

1 Bogod, V., Garaimov, V., Grebinskij, A., Urpo, S., Fu, Q.J., Zhang, H.: Pre- and post-flare evolution of AR 8038 on 9-14 May 1998 with Metsähovi-RATAN-600 spectral microwave observations. *Bulletin of Special Astrophysical Observatory* 47, 5 p., 1999.

2 Arajärvi, M., Ahola, K., Mattila, K., Pellinen, R., Valtonen, M., Hermunen, H., Mursula, K., Tornikoski, M., Vihma-Kaurinkoski, M.: Tähtitieteen suurhankkeet - Työryhmän muistio. *Opetusministeriön työryhmien muistioita*, 8:1999, 108 p., 1999.

3 Urpo, S.: Radioliikenteemme havaittavuus lähitähdille. *Tähdet ja Avaruus* 4/99, p. 48, 1999.

4 Grassl, H., Rasool, S.I., Urpo, S.: Scientific Audit of the Space Applications Institute. *Joint Research Centre, Scientific Audit*, 1999.

5 Grebinskij, A., Bogod, V., Gelfreikh, G., Shibasaki, K., Urpo, S., Pohjolainen, S.: Chromospheric magnetic field measurements by a microwave free-free emission polarization, theory and observations. *JOSO Annual Report '98*, in press, 1999.

6 Brajša, R., Ruždjak, V., Vršnak, B., Wöhl, H., Pohjolainen, S., Urpo, S.: An analysis of the solar rotation velocity determined tracing microwave features and an estimate on their heights. *JOSO Annual Report*, in press, 1999.

4 Visits to Foreign Institutes

Post doc researcher, Observatoire de Paris, Meudon, France, from 1.10.1998, S. Pohjolainen

5 Visiting Scientists

Dr Alexander Stepanov (Pulkovo Observatory, St Petersburg, Russia), visit at Metsähovi, 3-6.5.1999, 20.10.-2.11.1999.

Prof. Alan Marscher, Boston University, USA, 13-17.6.1999, opponent in A. Lähteenmäki's dissertation.

Dr Valery Zaitsev (Institute of Applied Physics, Russian Academy of Science, Nizhny Novgorod, Russia), visit at Metsähovi 20.10.-2.11.1999.

Dr Igor Zinchenko (Russian Academy of Science, Institute of Applied Physics, Russia), visit at Metsähovi, 10-23.6.1999.

Dr Alexey Stepanov (Pulkovo Observatory, St Petersburg, Russia), visit at Metsähovi 24-27.1999.

Professor Carl Gwinn (University of California, Santa Barbara), visit at Metsähovi 3-7.9.1999.

6 Thesis

Thesis for the degree of Doctor of Technology

Anne Lähteenmäki: Total flux density variations in extragalactic radio sources: observations and analysis.

Evaluation of the manuscript of P. Piironen intended to doctor thesis, S. Urpo

7 Teaching

Spring 1999: weekly seminars of the post-graduate course on space technology: Satellite Astronomy. S. Urpo, M. Tornikoski.

Laboratory exercise for Space Technology students, Helsinki University of Technology, March 1999, A. Lähteenmäki.

Lecture about radio astronomy and the Metsähovi research projects to a group of the VTT chemical technology unit, 20.5., M. Tornikoski

Lecture about radio astronomy and the Metsähovi research projects to the amateur astronomy club Pollux, 22.11., M. Tornikoski

General Metsähovi-tour and short lecture about the research projects to several high school classes and other groups, M. Tornikoski, H. Teräsranta, S. Urpo, P. Könönen, A. Lähteenmäki

8 Other Activities

8.1 Participation in Boards and Committees

European Science Foundation Committee on Radio Astronomy Frequencies (CRAF) Board Member, J. Engelberg

Member of the Finnish working group on large scale facilities for astronomy / Ministry of Education, 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

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

COSPAR, Finnish National Representative 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, S. Urpo

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, National Representative of Commission J, Radio Astronomy S. Urpo

URSI, Finnish National Committee, vice member S. Urpo

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

International Academy of Astronautics, Sub-Committee on Small Satellites for Countries Emerging in Space Technology, member S. Urpo

Planck LFI Consortium Funding Committee, member S. Urpo

8.2 International Meetings and Talks

Planck/First Payload Meeting, 11.1.1999, ESA, Paris, France, S. Urpo

CEPT FM PT34 12-13.1.1999, Telecommunications Administration Centre(TAC), Helsinki, Finland, J. Engelberg

CEPT FM PT33 11-14.2.1999, ERO Office, Copenhagen, Denmark, J. Engelberg

ESA/SPC Meeting, 16-17.2.1999, Paris, France, S. Urpo

Planck LFI Consortium Meeting, 25-28.3.1999, Firenze, Italy, S. Urpo,

EVN/TOG Meeting, 26-30.3.1999, Catania, Italy, A. Mujunen, J. Ritakari

27$^{\mathrm{th}}$ CRAF meeting 10-14.4.1999, Torun, Poland, J. Engelberg

EVN Directors Meeting, 23-24.4.1999, Bordeaux, France, S. Urpo

ESA/SPC Meeting, 19-20.5.1999, Bern, Switzerland, S. Urpo

OJ-94 annual meeting 1999, Torino, Italy, 19-21 May 1999, **talk**: Harri Teräsranta: New prospects in radio monitoring.

EVN Directors Meeting, 22.6.1999, Frankfurt, Germany, S. Urpo

VIII Russian-Finnish Symposium on Radio Astronomy, Central Astronomical Observatory at Pulkovo, St. Petersburg, 28.6.-3.7.99, J. Engelberg, P. Könönen, T. Liljeström, A. Mujunen, S. Urpo.

Type III Connections Meeting, 8-13.7.1999, Ika, Croatia, S. Urpo

Scientific Audit of the Space Applications Institute of JRC, 27-30.7.1999, Ispra, Italy, S. Urpo

28$^{\mathrm{th}}$ CRAF meeting 4-8.9.1999, Cambridge, United Kingdom, J. Engelberg

Fifth Compton Symposium on Gamma-Ray Astronomy and Astrophysics, 14 – 21.9.1999, Portsmouth, New Hampshire, USA, A. Lähteenmäki, H. Teräsranta, M. Tornikoski. **Poster** A. Lähteenmäki, E. Valtaoja, M. Tornikoski: "The radio/gamma-ray connection in AGNs", **Poster** M. Tornikoski, A. Lähteenmäki: "Millimeter wave behaviour of EGRET-detected and non-EGRET-detected AGNs". **Poster** Bloom S D, Wehrle A E, Balonek T J, Teräsranta H, Tornikoski M, Aller M F, Aller H D, Tosti G, Takalo L, Thompson D J: "Analysis of the Ground Based Data for 3C279: 1990–1999"

ESA/SPC Capri-type Meeting, 22-23.9.1999, Naples, Italy, S. Urpo

EVN/TOG Meeting, 1-3.10.1999, Hoogeveen, The Netherlands, A. Mujunen, K. Karlamaa, J. Ritakari

Conference on Science with the Atacama Large Millimeter Array (ALMA), Washington, D.C., 6-8.10.1999, **poster**: "Inversion of Water Maser Observations to Shock Physics", T. Liljeström.

Planck LFI Consortium meeting, 6 – 11.10.1999, Capri, Italy, A. Lähteenmäki, H. Teräsranta , S. Urpo. **Talk** Harri Teräsranta: Observations of the foreground sources at 22 and 37 GHz.

AMS Technical Interchange Meeting 16-23.10.1999, NASA Johnson Space Center, Houston, USA, J. Engelberg

2$^{\mathrm{nd}}$ CRAF Workshop 27-31.10.1999,Max-Planck Institut für Radioastronomie, Bonn, Germany, J. Engelberg

ESA/SPC Meeting, 9-10.11.1999, Paris, France, S. Urpo

CEPT PT3 30.11.-3.12.1999, TAC, Helsinki, J. Engelberg

8.3 National Meetings and Talks

URSI/IEEE XXIV Convention on Radio Science, 4.–5.10., Turku, Finland. **Invited talk 5.10.1999** Tornikoski M.: "Citius, Altius, Fortius... A Look at the Modern Radio Astronomy"

URSI XXIV Convention on Radio Science, Turku 4-5.10.1999, **talk** Tarja Liljeström: "Single-dish and VLBI linewidths of water masers in W49 N".

Radio Administration Advisory Group/WRC2000 Preparation Group, Telehallintokeskus, Helsinki 29.3.1999, J. Engelberg

Radio Administration Advisory Group/WRC2000 Preparation Group, Telehallintokeskus, Helsinki 31.8.1999, J. Engelberg

8.4 Public Relations

Interview by Tekniikan Maailma 20.1.1999, S. Urpo.

Radio EXTREM 25.1.1999 (SETI), S. Urpo, M. Tornikoski.

Finnish TV 1 teaching programme on physics, first presentation in October 1999, replays in November 1999, S. Urpo.

9 Personnel in 1999

Permanent Positions funded by the Helsinki University of Technology

Urpo, Seppo, Prof., Dr.Tech.	Director of the institute, Docent	Seppo.Urpo@hut.fi
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Vilenius, Esa, student	Research aid	

Metsähovi Advisory Committee

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