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Metsähovi Radio Observatory
Annual Report 1998

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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 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.

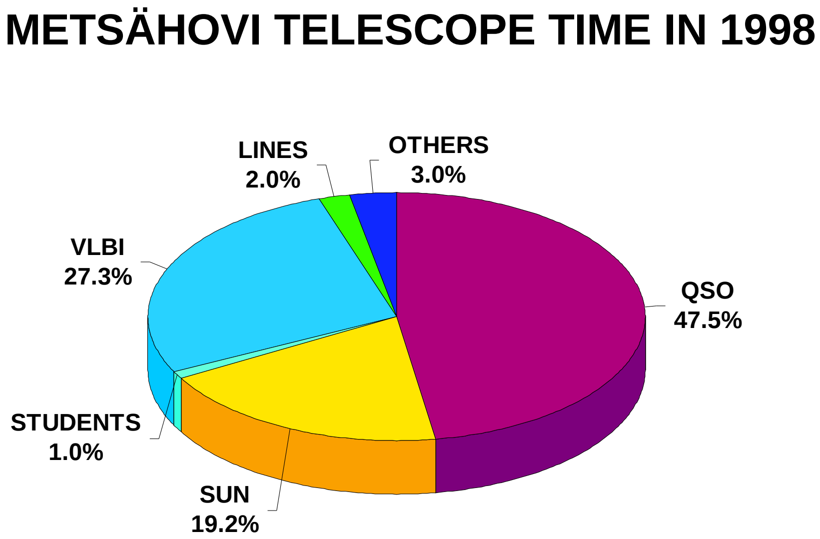

Figure 1: Metsähovi telescope time allocation in 1998.

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 1998 the total expenditure of the Metsähovi Radio Observatory was about 4.7 million FIM, including salaries. This was financed by:

Helsinki University of Technology 55 %
Academy of Finland 39 %
Others 6 %

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: <u>Urpo</u>, Engelberg, Karlamaa, Koistinen, Mujunen, Oinaskallio, Peltonen, Ritakari, Rönnberg, Tornikoski, Wiik

2.1.1 43 GHz VLBI Receiver

Project Team: <u>Koistinen</u>, Karlamaa, Peltonen, Rönnberg

In order to downconvert the 43 GHz signal to the 0.5-1.0 GHz VLBI band two consecutive mixing operations are used. In the first one local oscillator at 10-12 GHz followed by a frequency tripler is utilized to form a LO at 30-36 GHz. The second LO frequency is 7.5-8.0 GHz. For phase locking a frequency comb is generated for both of these YIG oscillators using commercial comb generators driven by a strong 100 MHz frequency standard. Unfortunately this comb falls within first IF-frequency band which is limited to 8-9 GHz by a microstrip band pass filter.

To prevent the leakage of these comb spikes to the final IF band two tunable waveguide narrowband cavity filters were designed and with these cavities the desired harmonic component is picked up and all other unwanted signals adequately suppressed.

For testing of the receiver we have selected the exact LO frequecies as follows: LO_1=11.62 GHz x 3 = 34.86 GHz and LO_2=7.62 GHz. Thus the signal frequency band will be from 42.98 to 43.48 GHz.

The phase locked loop consists of a digital phase comparator/prescaler (QualComm Q3236), a 2nd order type 2 loop filter and a V/I converter. The active loop filter was designed to provide at least 60° phase margin for the 100 kHz loop natural frequency. The damping factor (=0.707) was selected to achieve a fast locking time. An ultra-low noise operational amplifier (LT1028) was used to avoid excess noise due to the loop filter.

The measurement setup for the receiver stability is shown in Figure 2. The reference frequencies at 10.9 GHz and 1.1 GHz were derived from the atomic frequency standard with comb generators and filters to avoid any extra instabilities caused by exterior phase locked oscillators. The measurement setup is very sensitive to temperature fluctuations and it was therefore mounted at the same temperature stabilized enclosure as the receiver IF unit.

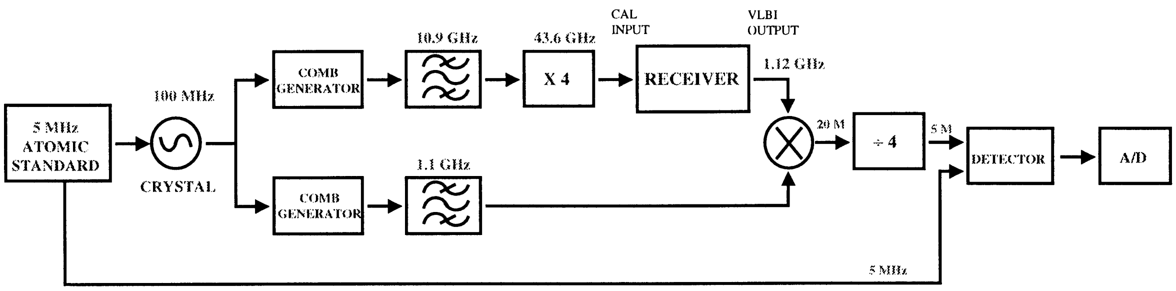

Figure 2: Measurement setup for the 43 GHz VLBI receiver stability.

The measured short term phase response of the receiver is shown in Figure 3a. The exterior temperature of the system is changed from 28°C to 5°C which induces a 3° phase shift in the measured response. The phase error over a 100 s measurement period stays within 1°. A sinusoidal jitter with a 20 min period is clearly detected in all measurements. This suggests a slow oscillation of the temperature stabilization of the IF and LO components and the control electronics. The peak-to-peak jitter is however only 2° with a 20 min period which gives a maximum contribution of 0.6° over any 100 s period of the measurement.

A long term trend measurement is presented in Figure 3b. The measurement showed better than 15° phase drift over a 60 hours period. The maximum phase change including both effects is 5° over 10 minutes and the corresponding phase error over a 100 s period is 1.5°. This can be treated as a worst case estimate because the telescope and the receiver are covered by a radome and only 5°C/h exterior temperature variations are expected.

The 11.62 GHz LO of the receiver was measured with a similar setup as in Figure 2. The LO was found to be very stable over a 10 min measurement period showing 1° short term variation and negligible long term drift. The 7.62 GHz LO is identical to the 11.62 GHz LO which indicates that the phase properties of the two oscillators are comparable.

According to measurements the temperature induced variations in the signal path components are the main contributors of phase deviations in the 43 GHz VLBI receiver. The local oscillators were found to have only marginal effect on the phase response of the receiver. The phase stability of the 43 GHz receiver at Metsähovi Radio Observatory meets the specifications for VLBI measurements.

2.1.2 A Correlation Receiver for Solar Research at 37 GHz

Project Team: Koistinen, Urpo, Rönnberg

The design and construction of a polarimetric receiver for solar research was completed during year 1998. The receiver is capable of detecting all four Stokes parameters by including a correlator unit to a two-channel receiver.

The RF unit of the receiver divides the incoming signal into two orthogonal polarizations. Options for both linear and circular polarizations are available. The center frequency of the receiver is 37 GHz and a 1 GHz bandwidth is used for both the intensity and correlator units. The intensities of the polarizations are measured with detectors. The noise temperature of the receiver is 425 K (DSB) for both channels.

The correlator consists of two identical active units. Two units are needed to detect the polarization angle of the incoming linear polarization and the portion of circular polarization of the total signal intensity. The correlator is based on microwave mixers which are used as cross-correlators. The advantage of mixers is a very wide RF bandwidth and a simple layout of the device.

Extensive tests for the correlators were made during 1998 including measurements of linearity, dynamic range, phase and amplitude response, and stability. According to measurements the dynamic range of the correlator is better than 40 dB. This is expected to be sufficient for solar measurements including the detection of strong solar flares where compression of the detecting elements is a risk because of the relatively high detected power levels.

The integration of the RF and correlation units of the solar receiver was completed in 1998. The temperature stabilization was tested to operate as planned. The antenna tests and the calibration procedure of the receiver are to be completed in 1999.

2.1.3 Maintenance and Upgrade of Receivers

Project Team: Peltonen, Oinaskallio, Rönnberg

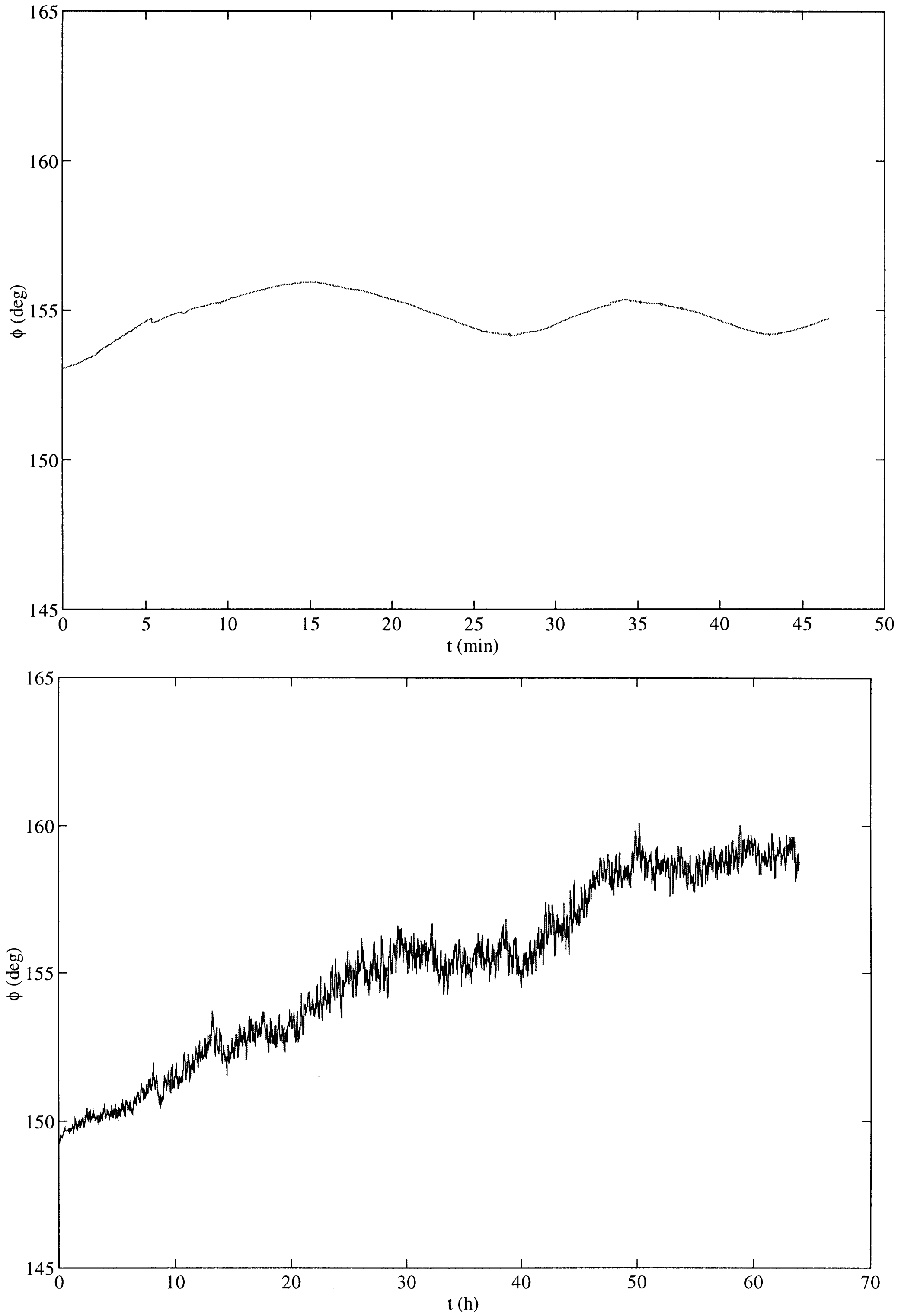

Figure 3: Short time stability (a) and long term stability (b) of the 43 GHz VLBI receiver.

The old 36.8 GHz receiver (mainly used for continuum observations but also usable for solar research) has been upgraded for better sensivity and more accurate temperature control of all millimeter wave and IF components. A new HEMT-preamplifier with gain of 25 dB and noise figure of 2.2 dB over

35.5 to 38 GHz was installed between the Dicke-switch and the old mixer/IF-preamplifier assembly. The IF-section contains three detected outputs i.e one for continuum observations, second for normal solar observations (quiet sun) and the third one with a logarithmic IF-amplifier for detection of solar flares.

The noise temperature of the new receiver measured in front of the A- and B-horns were 310 K and 270 K, respectively. The A-branch of the receiver contains before the Dicke-switch a thermal block and a remote controllable waveguide switch to choose between continuum or solar observations. The B-branch has a similar thermal block and a 30 dB directional coupler for calibration purposes.

All millimeterwave and IF-components (except horns) and also detectors followed by balanced amplifiers are mounted firmly on a temperature controlled mounting plate and installed into a box with thick temperature isolation sheets. Using Peltier elements the mounting plate can be heated or cooled with accuracy of 0.1°C thus the stability of the new receiver is much better than earlier.

2.1.4 EVN Mark IV R/W Upgrades (VIV)

Project Team: Ritakari, Myyry

Four European VLBI stations are going to upgrade their recording system from VLBA to Mark IV. Metsähovi will design and build the read/write electronics for the recorders, Figure 4.

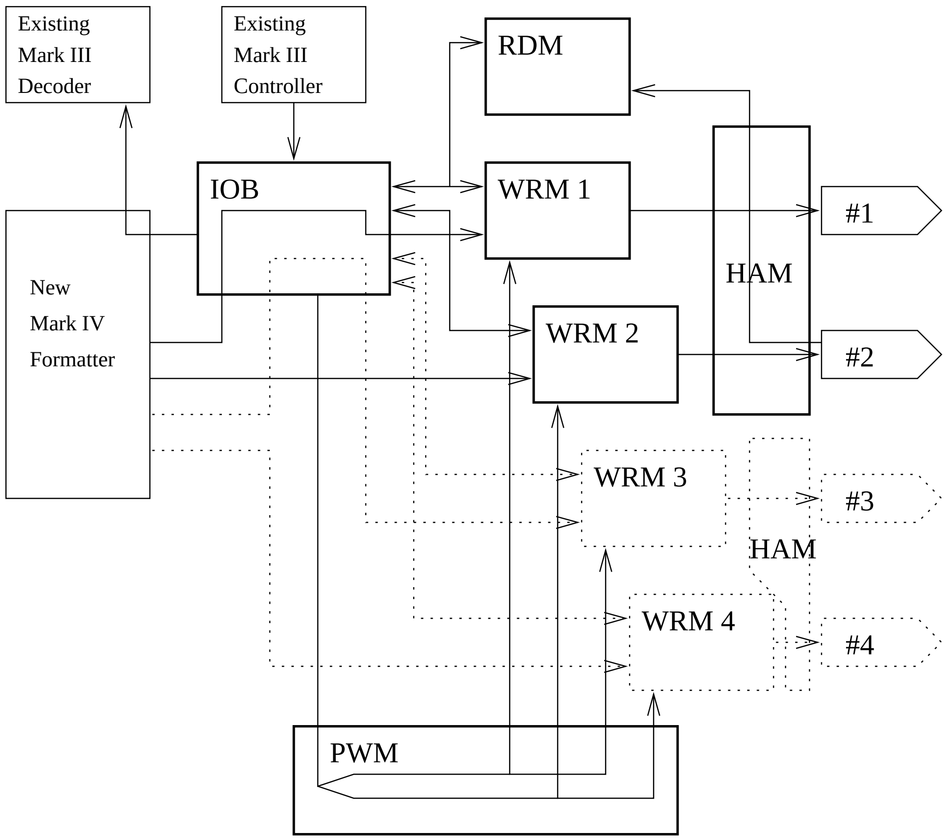

Figure 4: Mark IV R/W upgrade modules.

2.1.5 Radio Spectrum Monitoring and Protection

Project Team: Engelberg, Oinaskallio

Monitoring continues normally. The new monitoring software daemon, "`spektrd`" was written during autumn 1998. The band monitored is from 400 MHz up to 2 GHz. This is due to the IFs used at Metsähovi Radio Observatory. Spectrum is monitored from all directions with 60 degree intervals between directions, so in total 6 directions and 16 frequency bands with 100 MHz band are measured. A sample 100 MHz band is presented in Figure 5. The optimal way to change frequency bands and antenna direction is still under studies. The present antenna rod has to be replaced because of freezing effect interferes with the antenna rotating system.

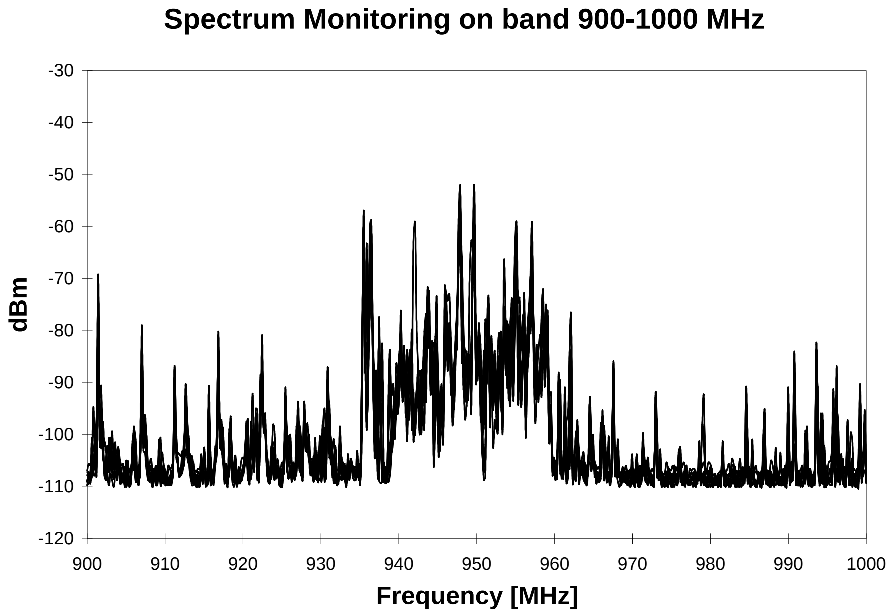

Figure 5: Frequency monitoring from 900 MHz to 1000 MHz. The increased signal level from 935 MHz to 960 MHz is due to the cellular telephones.

Administrative activities are increasing due to the forthcoming World Radio Conference (Year 2000 at Istanbul). Nationally several meetings took place at Telecommunications Administration Centre within two different working groups, UMTS (Universal Mobile Communications System) and WRC2000 (World Radio Conference).

International work was done through CRAF (ESF Committee on Radio Astronomy Frequencies) activities and administrative parties (ITU, ERC, ETSI, CEPT) documents and circular letters. CRAF became a sector member of ITU Radiocommunication Sector in spring 1998. Now the radio astronomy community has two organizations participating ITU-R activities, IUCAF and CRAF. As an European organization CRAF is mainly concerned issues related to Region 1 (Europe, Africa,...). CRAF main contribution to ITU-R is to provide input documents to ITU-R Study Groups and Working Parties and preparation for the WRC2000.

2.1.6 Computing Infrastructure

Project Team: Mujunen, Engelberg

A 2 Mbit/s dedicated leased line to university computing center provides Metsähovi its connection to the Internet. A stand-alone NAT LANB/290 IP router routes the TCP/IP network traffic between Metsähovi LAN and Internet WAN. Four 28.8k modems provide dial-in facilities for observatory personnel.

In spring 1998 Metsähovi became again a victim of an intruder ("hacker") attack. An unauthorized user managed to capture (using Ethernet listener software at university departmental 10Base2 network) a valid password on our computers and thus gained normal user access privileges. The main motive of this hacker seems to have been to get hold on as many user accounts and passwords as possible. Computers were planted with tainted versions of system software to collect and log additional passwords.

A similar attack occurred again in late summer 1998. No direct damage was caused by either of these incidents but certainly hundreds of man-hours were wasted in assessing the situation and repairing the damage. Since direct Internet access at Metsähovi observatory site was limited to one single Linux computer, "`kurp.hut.fi`", there was minimal damage to the internal network of Linux computers. All four Linux computers located at the university campus area had to be reinstalled two times, though.

This year all of our Linux computers were upgraded from a 1995-vintage Slackware distribution to Debian/GNU/Linux (see `http://www.debian.org`). 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 chain of upgrades.

IDL 5.0 was upgraded to 5.1 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.

The "`15APR97`" release of AIPS VLBI data and image processing system is still available at our university site. Upgrading to the latest AIPS has been postponed since user demand for AIPS has been relatively low.

2.1.7 Data Collection and Archival

Project Team: Mujunen, Engelberg

Metsähovi main NFS server "`/home`" disk space was increased from 9 GB to 32 GB using Linux built-in RAID0 disk array mechanism. At the same time the server computer was changed to a rack-mounted Pentium 233MHz/MMX Linux PC, connected to an array of Ultra-Wide SCSI hard disks. The hard disk array enclosure has two sets of four 9 GB hard disks, "`/home`" and "`/backup`". All user files can thus be backed up "on-line" using the Linux "`mirrordir`" utility in less than an hour. Saving "`/backup`" (instead of "`/home`") on DAT tape makes them also more consistent since "`/backup`" does not change during the DAT-"`tar`" procedure.

The necessary infrastructure for multiple concurrent software developers was taken into use in the form of "`/home/cvs`", a common CVS repository. CVS (Concurrent Versions System) keeps track of the evolution of source code and documentation files and allows multiple developers to 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 report "Using CVS at Metsähovi" (see section 3.4).

An additional "data warehouse" NFS server "`/data`" was created on "`data.kurp.hut.fi`" using a similar Linux RAID0 setup as what was used for "`/home`". Two 9 GB Ultra-Wide SCSI hard disks were combined for 18 GB 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 2.1.9). Environmental and auxiliary measurement information is collected by background daemons and archived in ASCII files, one 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 one tenth of millisecond), the name of the observed parameter, and the numeric value of it (see Figure 6). (The format of "`spektr`" spectrum analyzer data has no parameter names but instead 10 fixed parameters and 500 spectral points per one log line.)

```
1999022115467501    OutT    16.5
```

Figure 6: An example of common log line format.

A pair of Davis GroWeather (see "`http://www.davisnet.com`") weather stations acquired from a local systems integrator, Envia Oy, have performed satisfactorily. One station had to be replaced due to excessive damage caused by a summer thunderstorm. Additional optoisolators were added to both ends of external cabling to prevent this from recurring. (See Figure 7.)

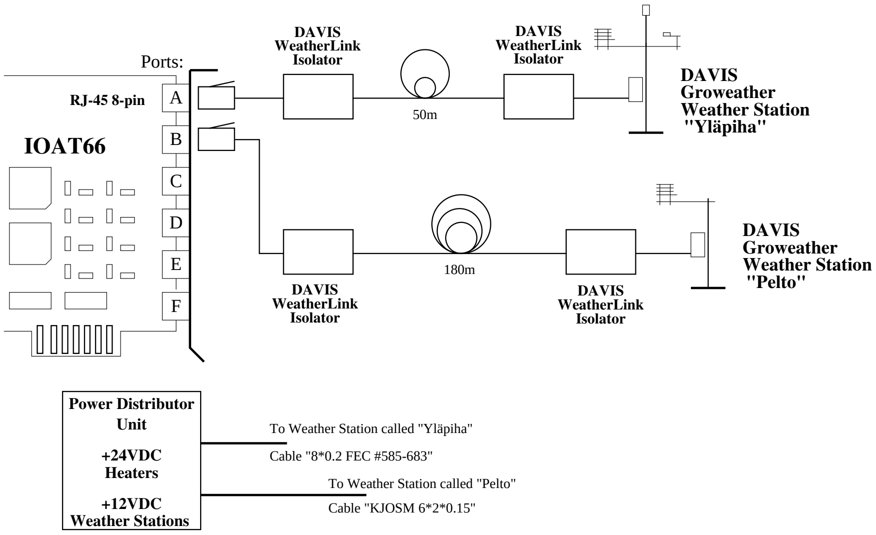

Figure 7: Cable connections between observatory and weather stations.

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.

Weather station data collection software "`weatherd`" was written. Software saves all data from stations in two different locations "`/data/weather/hi`" and "`/data/weather/lo`" based on the physical location of stations.

In 1998 the cabling of our ADAM/NuDAM monitor/control network was enhanced to cover most of the observatory site. (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 single twisted pair wiring. These modules allow contralized and coordinated monitoring and control of discrete adjust values spatially dispersed across the whole observatory site. A single Linux PC masters the RS485 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.

Hydrogen maser conditions was monitored with Toshiba laptop PC. It stored measured values to 1.44 Mb disks and then data was moved manually to WWW. A new Linux software daemon was written to take care of these things and at the same time measurement interval became shorter. The latest version of the software i.e. "`efos9d`" measures 34 monitoring channels and the maser frequency

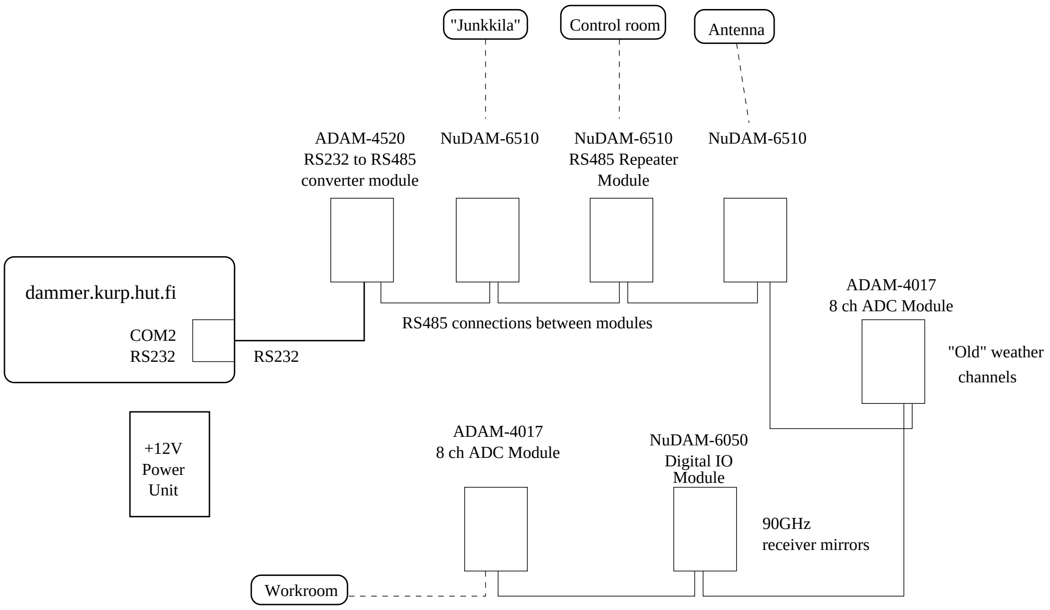

Figure 8: Block figure of "dammer" system.

value and saves them locally and afterwards these daily files are being moved to the main data archive located in "`data.kurp.hut.fi`".

The radio spectrum monitoring daemon "`spektrd`" was also written to comply with the data warehousing principles outlined in this section. "`spektrd`" runs continuously collecting detailed RFI spectral information in UTC time-tagged ASCII files. Analyzing and post-processing these raw data files requires further development.

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 as shown in Figure 9.

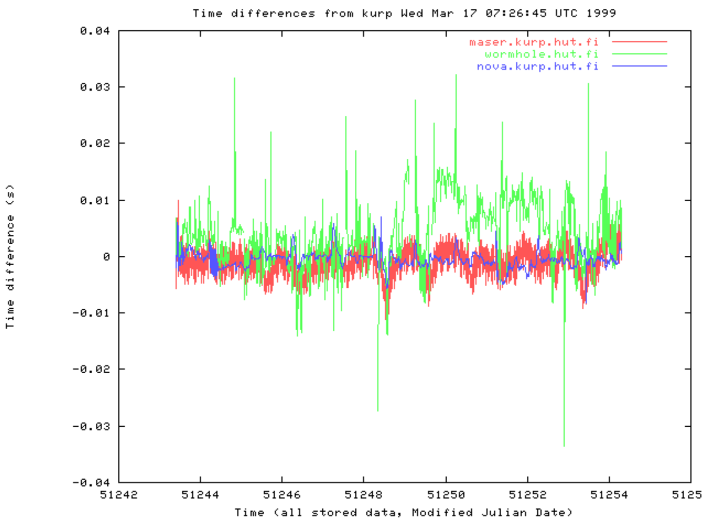

Figure 9: Computers in local network are using same time at subsecond level.

2.1.8 Data Browsing and Visualization

Project Team: Mujunen, Könönen (part-time since 1-Sep-1998)

There are several different types of non-astronomical data which are 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, and the EFOS-9 hydrogen maser at Metsähovi Radio Observatory. It is very probable that in the future there will be more data from several kinds of sources that can be and need to be collected in this way.

The main restriction to make up this kind of databases has been their uselessness, due to absence of suitable programs to visualize and manipulate the collected "raw" data. So far collected data has been visualized using a commercial spreadsheet (Excel) and there is a short Perl program (written by J. Engelberg and A. Mujunen) that demonstrates continuously the latest values of a few weather parameters affecting observations on one display located at the antenna control room.

The rack-mounted Linux PC "`data`" is used to save the data. At the moment the main "`/data`" directory has subdirectories "`efos9`", "`spektr`", "`weather/hi`" and "`weather/lo`".

The number of lines in one datafile may vary a lot (for example in the "`weather/hi`" directory the number of lines per file varies from two to approximately 115 000 lines). The variation has been due to changes in the time frequency of collecting data and possible functional disorders in the observing equipment. When the functioning is normal, the typical, collected numbers of lines per one individual datafile are approximately: "`efos9`" 50 000 lines, "`spektr`" 2000 lines, "`weather/hi`" and "`weather/lo`" 9000 lines. The number of parameters that are selected to be observed varies from approximately 15 of the "`weather`" files to 510 of the "`spektr`".

The easiest method to study the collected data is to present it graphically, observation time in the x-axis and the measured values in the y-axis.

One must be able to determine several selective options to the data presentation. The most obvious and the most important ones are:

- determining a certain time period
- choosing certain parameters

Also these features are important:

- drawing the value lines of several parameters into the same graph
- saving the selected parameter values into an ASCII text file for further data processing (using for example a spreadsheet)

Because all the employees at Metsähovi Radio Observatory have got the access to the WWW it is natural that a CGI program written in the Perl programming language was regarded as the most suitable choice. The favourable characteristics of the Perl are its text data manipulation capabilities as well as its "glue-like" nature which enables the required combination of the system commands, the plotting program commands and the HTML scripts into a one single program. The choice for a plotting program (in the the Linux computer environment of the Metsähovi Radio Observatory) was the "`gnuplot`" plotting utility because it is generally available and it can handle timestamp values.

The first allotment that is under the process of accomplishment is the presentation of weather data. The programmed subroutines are made as general as possible so that they could be used directly to program the presentation of "`efos9`" and "`spektr`" data, too.

The first and possibly the final version of the weather data presentation program will be available at the site "`http://kurp.hut.fi/local`". Initially this will limit the access to the computers on-site at Metsähovi.

2.1.9 Antenna Control System Upgrade

Project Team: Mujunen, Engelberg, Oinaskallio, Myyry

Other projects, most notably AMS, significantly drained resources from antenna upgrade during the first half of the year. In autumn our "FET30 DC" motor FET driver board was rigorously tested and developed to its third prototype stage. Testing has ensured us that we have achieved robustness against motor and software failures. We currently support both plain PWM and locked anti-phase drive capability on the same board—the latter delivers higher torque at slow tracking speeds.

The overall architecture of the upcoming observation system is presented in Figure 10. 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,the common station UTC 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 "`xntp`" Network Time Protocol software package.

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.
`vault`	Archive DAT, ADAM/NuDAM, weather.
`data`	On-line data archive.

The existing "single minicomputer" approach to making astronomical observations is illustrated in Figure 11. All timing and device control is performed by a monolithic control program running with pseudo-real-time requirements under VAX/VMS operating system.

Currently we are running a slightly upgraded variant of the VAX-based system. The differences are depicted in Figure 12. Both old Inductosyn encoders and old pointing error calculation electronics has been replaced with new Heidenhain RON806 optical encoders and an embedded PC. This arrangement has been in use since 1996 and it has given us the benefits of a 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.

Unfortunately the old (1970's) analog servo masks out much of the benefits of new encoders. It was designed to maintain tracking at the level of a few millidegrees only. To enable a new digital servo system to be implemented driving antenna DC motors must be moved to the same PC computer which already receives RON806 encoder signals. This setup is presented in Figure 13.

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`". An alpha prototype of a 5MHz synchronized 10 kHz sampling clock board has been built and tested using the DOS-based software of the A/D board, but a new time-synchronization board and corresponding Linux-based data acquisition software will be required before the board can become useful in astronomical measurements with the A/D converter.

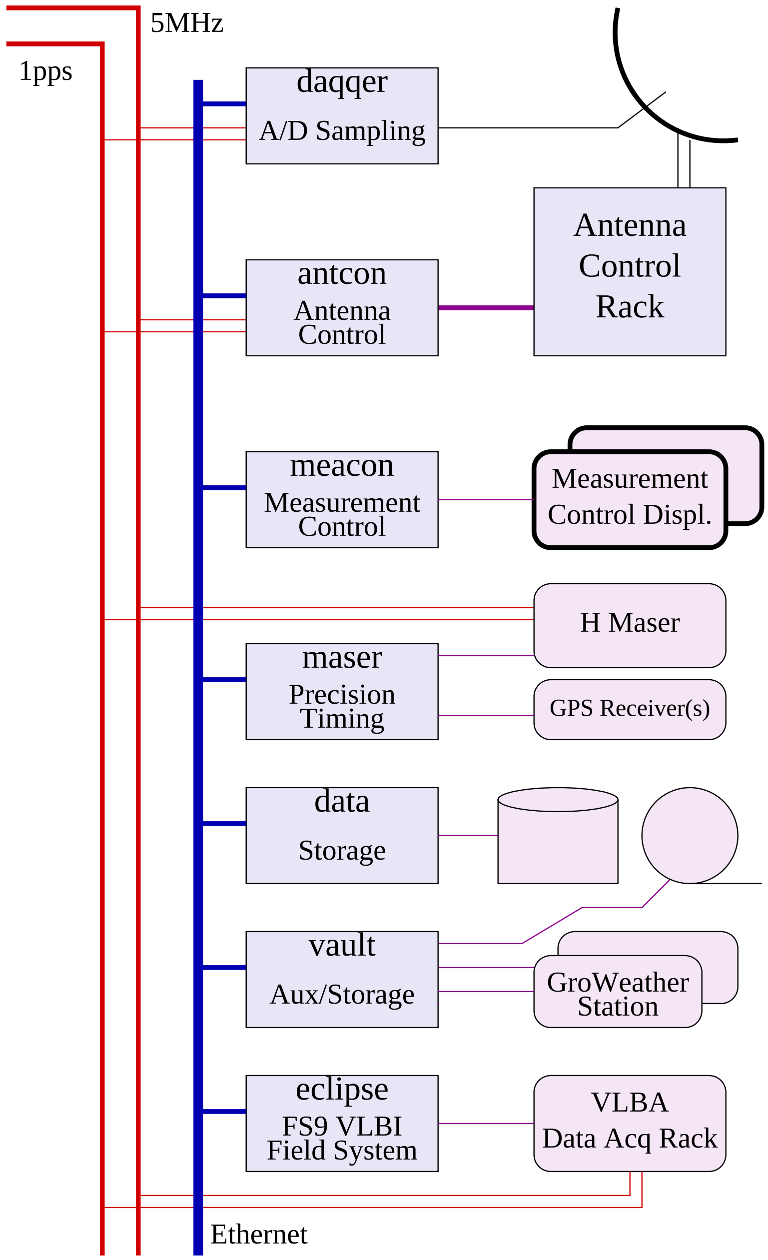

Figure 10: Distributed antenna control computers.

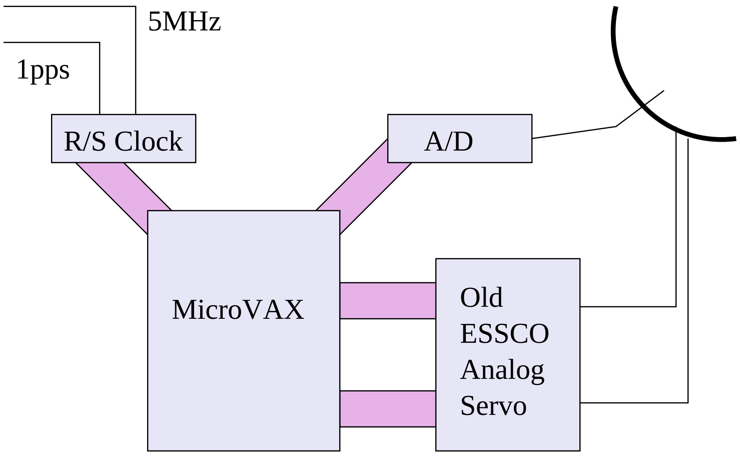

Figure 11: Existing single minicomputer-based antenna control.

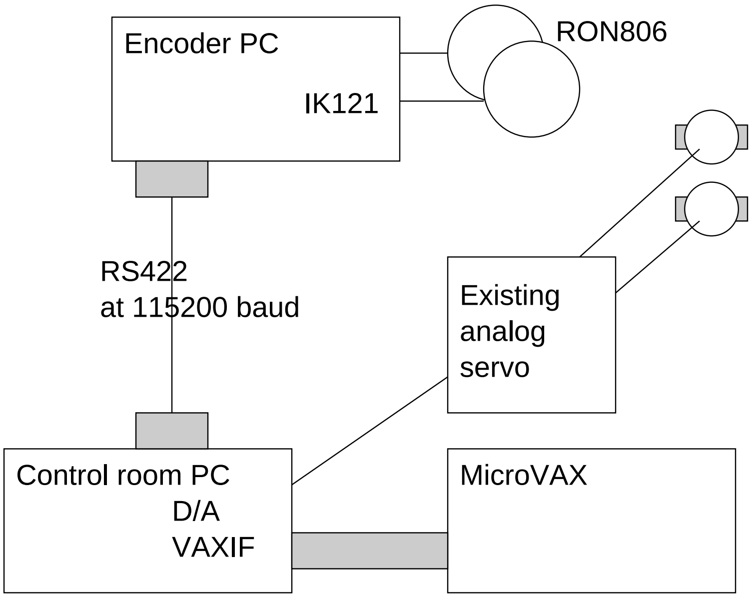

Figure 12: Intermediate encoder replacement solution.

2.2 Extragalactic Radio Sources

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

2.2.1 Monitoring of Quasars

Project Team: Teräsranta, Lähteenmäki, Tornikoski, Vilenius

The monitoring of quasars continued in 1998 for the 18th year. Our main sample consists of 85 AGN (Active Galactic Nuclei), about equal number of BL Lac objects, HPQs (high optical polarization quasars) and LPQs (low optical polarization quasars). The main task in our monitoring is still the temporal variations in QSO. The received light-curves can be used in testing source emission models together with other wavelength light-curves. Long historical light-curves also help to plan future

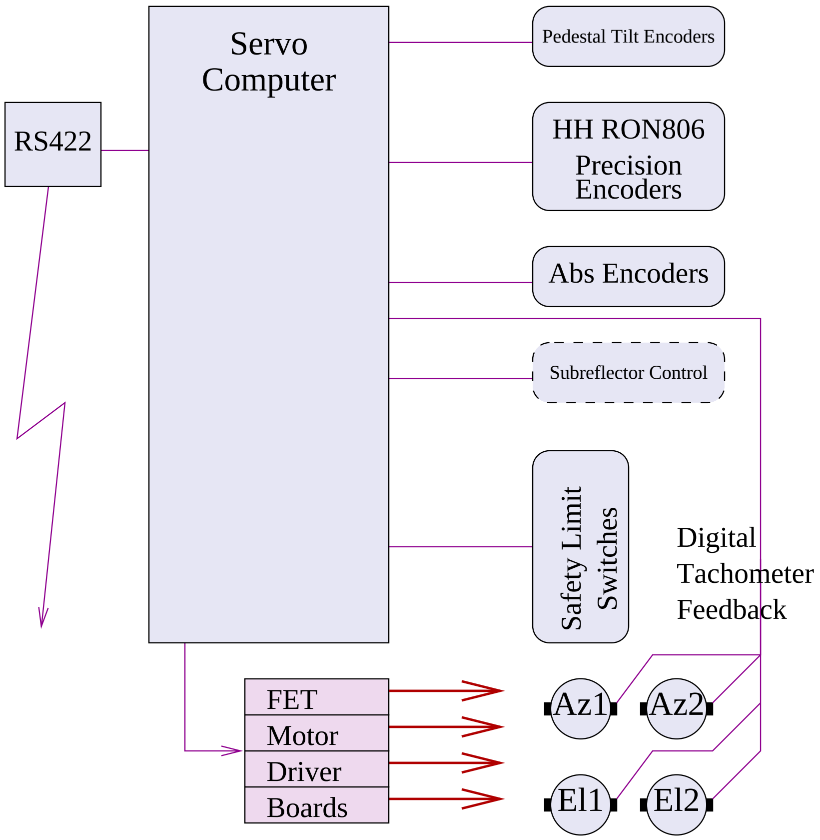

Figure 13: Embedded antenna servo rack in antenna tower.

observations with space borne instruments.

The 37 GHz receiver dating back from 1986 was upgraded during the summer of 1998. The receiver was equipped with a sensitive front end amplifier and Peltier-elements were applied to the temperature control system. The system temperature of the 37 GHz receiver is now around 300K DSB at ambient temperature, instead of the earlier 500K. This improvement will allow us to shorten integration times and also observe weaker sources.

The number of individual observations during 1998 was about 4280, 10% more than during the previous year. The yearly QSO observations since 1979 are shown in Figure 14.

Altogether 14 persons took part in the QSO observations during 1998, most of them being students from the Turku University. About 12% of the observations were done in automatic mode, mostly during the cold season, when dew is not expected on the radome. The observers and their share of the observations during 1998 is shown in Table 2.

An example of our long term monitoring can be seen in Figure 15, the flux of the quasar 0528+134 at 22 and 37 GHz since 1988.

Besides our own long term monitoring, we participated in several multifrequency campaigns including astronomical space borne instruments like RXTE, ASCA and EGRET. The most intesive campaigns being with the sources 0836+710, Mark 421, Mark 501 and III ZW 2.

Towards the end of the year we started a new project to support the Planck mission. This satellite of ESA will be launched in the year 2007. The Planck mission is to study the anisotropies of the 3 K background radiation at mm and submm frequencies. To get the full advantage of the fine resolution

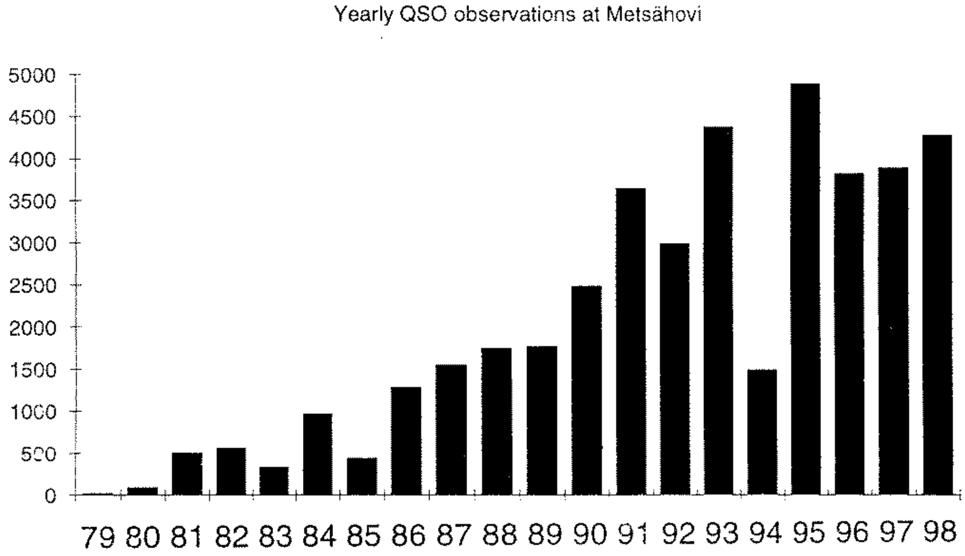

Figure 14: Yearly QSO observations with the Metsähovi Radio Telescope.

Table 2: QSO observations at Metsähovi during 1998.

Observations during 1998

Observer	**part of observations**	**University**
H. Teräsranta	29%	TKK
M. Tornikoski	3%	TKK
E. Vilenius	1%	TKK
A. Lähteenmäki	1%	TKK
N. Varjonen	12%	TY
T. Niemelä	9%	TY
M. Koskimies	8%	TY
J. Achren	7%	TY
P. Koivula	5%	TY
S. Wiren	4%	TY
M. Lainela	2%	TY
P. Keinänen	1%	TY
P. Könönen	5%	HY
J. Pesonen	1%	HY
AUTO	12%	TKK

of the Planck instrument, strong contaminating foreground objects, like quasars should be removed from the maps.

We first try to estimate how common are sources which are relatively weak (flux density below 0.5 Jy) at lower frequencies, 1.4 and 5 GHz, but reach 1-3 Jy levels at mm-bands at least during an outburst phase. Such a source is III ZW 2, whose fluxes at 1.4 and 4.85 GHz were 300 mJy and 435 mJy in the Green Bank and GB6 cataloques, but has reached 3 Jy at 22 and 37 GHz in our monitoring. Such high peaking sources are hard to find, as solely the GB6 5 GHz cataloque contains over 50000 sources with a limiting flux of 18 mJy. The number of sources with the flux over 200 mJy at 4.85 GHz in the GB6 cataloque is over 3200, more than we could expect to observe during one calender year at 22 and 37 GHz, even if we used all our antenna time to this project. Thus tight selection criterias are needed to find the most propable high peaking sources from those 3200.

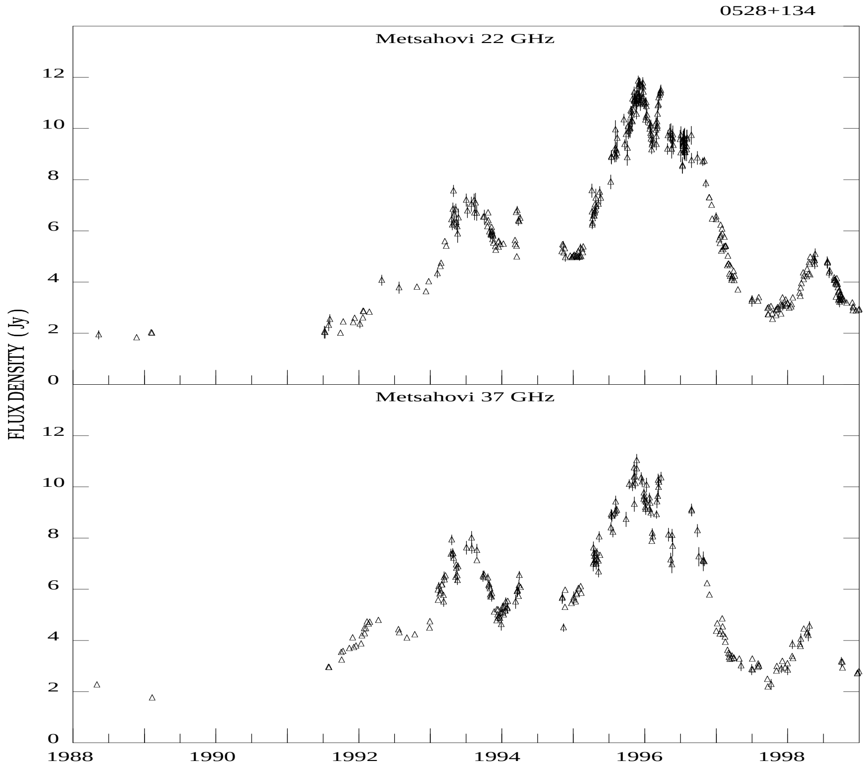

Figure 15: The flux density of the quasar 0528+134 from 1988 at 22 and 37 GHz.

2.2.2 SEST Observations

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

High radio frequency (90 to 230 GHz) monitoring of Active Galactic Nuclei (AGN) with the Swedish–ESO Submillimetre Telescope (SEST) in Chile were continued until February 1998. For the subsequent observing periods the SEST Programme Committee granted us no AGN oberving time. This marked the end of the very succesful high radio frequency AGN monitoring project which had been going on since 1987, and the data from which are being widely used for scientific studies by both the Metsähovi and Turku scientists as well as our numerous collaborators.

During our February 1998 SEST observing run we were using the SEST telescope for the following two observing projects:

1. High radio frequency ground support for VSOP observations of AGN. This project was started as a support for the VSOP project, where the new powerful tool of space–VLBI technology is being used for studying the structure and physics of AGN. Even though the 22 GHz receiver onboard the VSOP satellite (or, HALCA) turned out to be defective and most of the 22 GHz observing programs were cancelled, the SEST support for the low frequency programs was seen to be vital especially for the southern sources.

2. Long term monitoring of active galactic nuclei. This was an on-going project continued from the previous years. The objective of this project was to frequently monitor a relatively small sample of bright and variable sources in order to get well-sampled high frequency time series for the selected sources, as well as to get good multifrequency coverage for some of the most interesting nearly-equatorial AGN.

The message about the discontinuation of our SEST AGN projects was received with feelings of grief and disbelief, and even though the Metsähovi scientists will continue to use the SEST for various other individual observing projects, our AGN data base of SEST observations ends at this epoch.

Because the Metsähovi scientists were already committed to several multifrequency collaboration projects for 1998 (involving several satellites and numerous ground-based observatories), some of the projects were transferred from our group to our collaborator and SEST staff member Dr. Rantakyrö, who also managed to complete data sets for some of our most interesting sources for which we needed data in 1998 (e.g. PKS 2255−282 and CTA 102, section 2.2.3 for more information).

2.2.3 AGN Science

Project Team: Tornikoski, Lähteenmäki, Valtaoja (Turku)

Radio-optical correlations. We have contiued to study the correlation of the radio and optical flux curves and especially the possible simultaneity of radio-optical outbursts in order to better understand the outburst mechanisms at both frequency domains. In 1998 we collected long time series of radio and optical data for the source CTA 102, in which optical outbursts both with and without simultaneous radio counterparts have been observed. Preliminary results were presented in an international conference, and a more in-depth analysis of the data is currently in process.

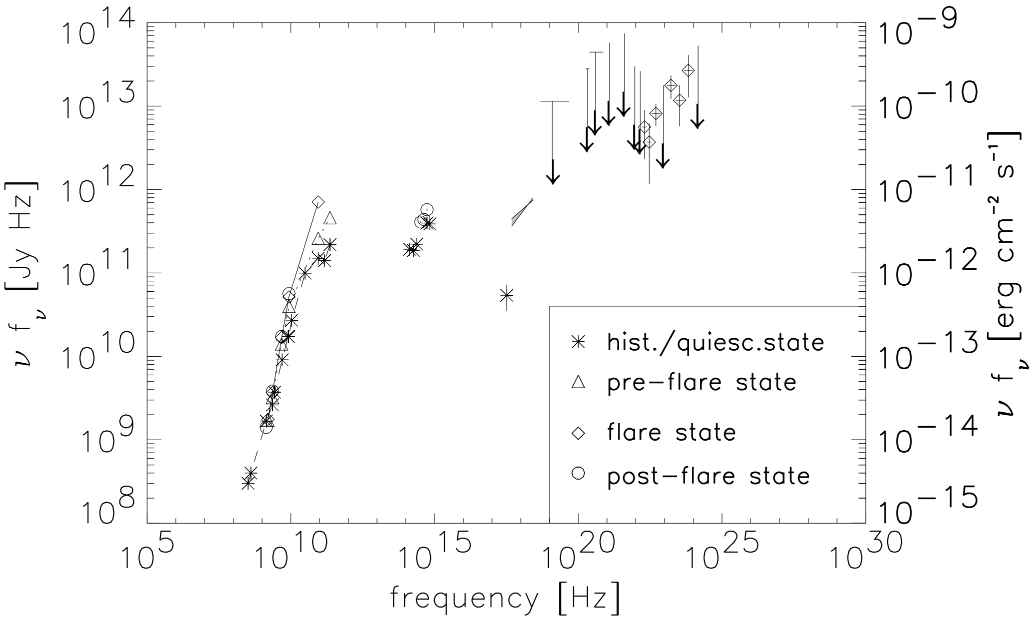

Figure 16: Spectral energy distribution of PKS 2255−282 in different activity states. The symbols for data points are as defined in the legend, and the downward pointing arrows denote upper limit values during the flare state.

Multiwavelength observations of PKS 2255−282. PKS 2255−282 has been one of the standard targets of our high radio frequency SEST AGN monitoring programme since 1988, even though it has earlier been classified by us as one of the low priority sources (i.e. not observed very frequently). In 1997 we observed a major millimetre-wave outburst from PKS 2255−282 (flux density at 90 GHz exceeding 10 Jy) and initiated a campaign for multifrequency radio monitoring and VLBI imaging of the source. In January 1998 the EGRET instrument onboard the CGRO detected a bright high energy γ–ray outburst from its direction. Thus we had the unique opportunity to monitor the source in detail at various radio frequencies already before the detection of the γ–ray outburst. We also initiated multiwavelength followup observations (X–ray, mm and cm radio wavelengths, and optical). The discontinuation of our SEST projects severely hindered the millimetre follow-up observations, but we were lucky to get some high radio frequency data points observed by a friendly SEST staff member. Thus we were able to study the spectral shape of this source before, during and after the γ–ray flare (Fig. 16) and derive physical parameters based on the observed multiwavelength data. The paper based on the results of this project was submitted in 1998.

Radio behaviour of EGRET detected sources. One of the interesting questions related to the gamma-ray behaviour of AGN is why some sources have been detected with EGRET, while others, with similar radio properties, have not been detected. With our collaborators we have compiled multi-frequency radio observations of a number of sources, in an effort to confirm previously reported correlations between activity at radio wavelenghts and EGRET detections, and to investigate whether the non-EGRET-detected sources were in radio- and gamma-ray-quiet phases during this period.

Multifrequency studies. Even though multifrequency campaigns to study an individual interesting source across the electromagnetic spectrum usually take a considerable coordination effort and often bring only little merit to the numerous observers involved in the campaign, these campaigns continue to be very essential in understanding the physics of AGN. Also, the flexible scheduling of the Metsähovi telescope as well as our freedom to reorganize our SEST observing list on demand has enabled us to participate in the campaigns relatively easily. In 1998 the results of several multifrequency campaigns were published.

Radio jet parameters of AGNs. The decompositions of radio flares in extragalactic radio sources, performed a year ago, were applied to the calculation of reliable Doppler boosting factors, viewing angles and Lorentz factors for a sample of active galactic nuclei AGNs. A reliable determination of these parameters is a key step in studying the origins of the physical processes in the compact emission regions of AGNs. The relativistic outflow in an AGN can be defined by the speed of the jet flow (the Lorentz factor) and the viewing angle. These can be calculated if the apparent superluminal speed and the Doppler boosting factor of the jet are measured. The superluminal speeds can be derived directly from VLBI monitoring. The Doppler factors were estimated from total flux density radio flares which are associated with new VLBI components emerging from the AGN core. This new method is more accurate and reliable than the traditional methods and can be used for modelling of AGNs, for example, testing the unification models. A typical radio-loud quasar has Doppler and Lorentz factors of ~ 10 and a viewing angle of $< 5°$. A typical BL Lac object has Doppler and Lorentz factors of ~ 5 and a viewing angle of $< 10°$. The quasars are clearly different from BL Lac objects. The radio galaxies in our sample typically have Doppler and Lorentz factors of ~ 2 and viewing angle of $< 50°$. We find clearly different Doppler factors for high polarization quasars (HPQ) and low polarization quasars (LPQ). However, the difference between the two groups of quasars is not very clear when looking at the Lorentz factors or the viewing angles alone. It seems that a combination of a more rapid flow speed and a smaller viewing angle produces a HPQ or a LPQ —not merely the viewing angle, as in basic unification. The numerical results are shown in Figure 17. The comparison of EGRET gamma-ray data and Metsähovi radio data of BL Lac objects (BLOs) confirmed that most of them never reach high enough Doppler factors to be detected in gamma-rays. The BLOs are actually less variable than previously thought and they also are generally less variable than either HPQs or LPQs.

2.3 Observations with Other Facilities

Swedish–ESO Submillimetre Telescope (SEST), Chile. Observing time on February 13–15 (36 hours). P.I. M. Tornikoski, Co–Is E. Valtaoja, H. Teräsranta and M. Lainela, and P.I. E. Valtaoja, Co–Is M. Tornikoski and H. Teräsranta.

Nordic Optical Telescope (NOT), La Palma, Canary Islands. Observing time April 1–5 and December 11–14. P.I. E. Valtaoja, Co–I M. Tornikoski.

HALCA. March 1st and 6th, June 6th and 10th. P.I. S. Tingay, Co–I M. Tornikoski et al.

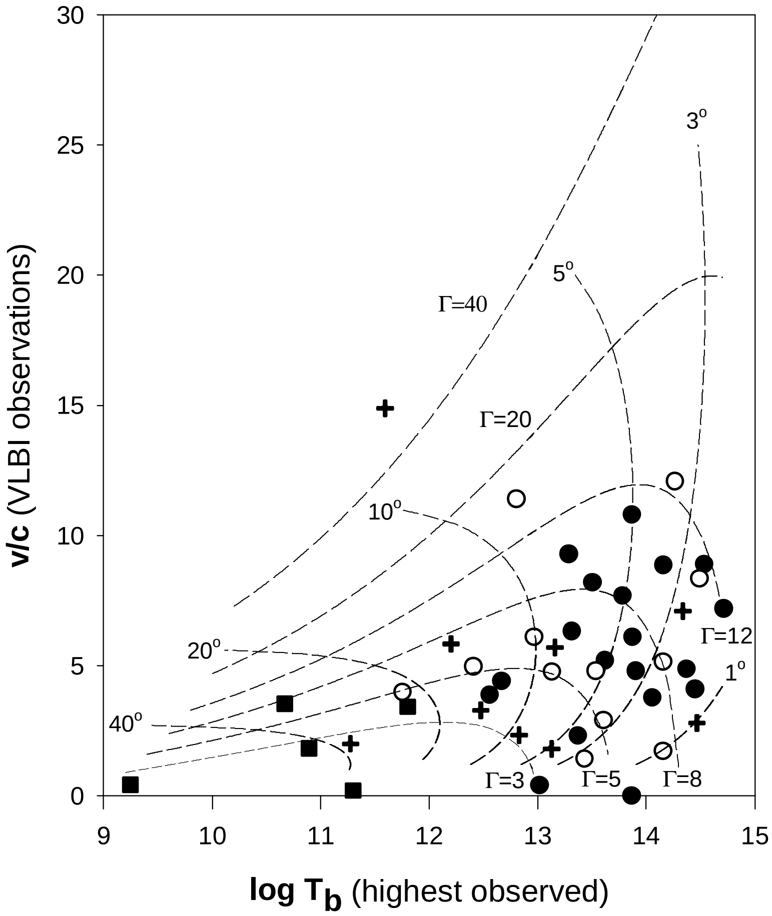

Figure 17: The Lorentz factors γ_{var} and the viewing angles θ_{var} and their dependence on the observable quantities (the superluminal speed $\frac{v}{c}$ and the highest observed variability brightness temperature $T_{b,var}$). Filled circles, HPQs; open circles, LPQs; crosses, BLOs; filled squares, radio galaxies.

HALCA. June 19th. P.I. P. Edwards, Co–I M. Tornikoski et al.

HALCA. July 25th and 27th. P.I. L. Kedziora-Chudczer, Co–I M. Tornikoski et al.

VLBA. Observing time June 24th, 8h. P.I. F. Rantakyrö, Co–Is E. Valtaoja, M. Tornikoski, K. Wiik.

2.4 VLBI Research

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

2.4.1 EVN

Project Team: Wiik, Engelberg, Karlamaa, Mujunen

The first correlation fringes at 7 mm were detected to Metsähovi in the February 1998 test with Effelsberg telescope. The strength and coherence of the signal were good. After this test Metsähovi was ready to participate fully in the upcoming 7 mm EVN sessions. Many thanks to the MPIfR team and especially to Dave Graham for their help and efforts.

The 43 GHz receiver noise temperature is around 100 K and SEFD is about 4500 Jy. The receiver is dual polarisation (L+R) with two NRAO HEMT amplifiers. Unfortunately just before the fringe test it was found that the HEMT amplifier of the RCP channel was not working. Later microscope revealed that the gate bonding of one of the HEMTs was damaged.

Some of the BBC's in our VLBA rack are not working, mainly due to VCO problems. A problem with a recorder which caused thick tape to run at low of vacuum and that jumbled the tape during unload was solved by adjusting the vacuum column sensors.

Metsähovi participated in the two EVN 22 GHz sessions in February and in March with nominal success.

2.4.2 CMVA, Coordinated Millimetre VLBI Array

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

Metsähovi observed all four CMVA sessions in 1998 (February, April, May, and November).

The ongoing program to improve Metsähovi mm-VLBI capability continued by developing a postprocessing program for NASA Field System pointing observations. It enables to use dual band differential radiometry to minimize the effects of the changing atmospheric emission, Figure 18.

The gain and constant noise power offset are determined by fitting a radiometer model to the two different channels. The bandwidth of the channels can be different and usually the reference channel is as wide as possible (16 MHz) and the signal channel width is matched to the spectral line.

The good rejection of atmospheric noise changes enabled us to measure accurately the change of the focal length of the telescope as a function of the elevation angle, Figure 19. If focal length could be adjusted automatically, according to Figure 20, this dependence could be compensated which would lead to greater overall efficiency at higher frequencies.

2.4.3 Space VLBI

Project Team: Wiik, Leppänen (Nokia), Liljeström, Lähteenmäki, Teräsranta, Tornikoski, Valtaoja (Turku)

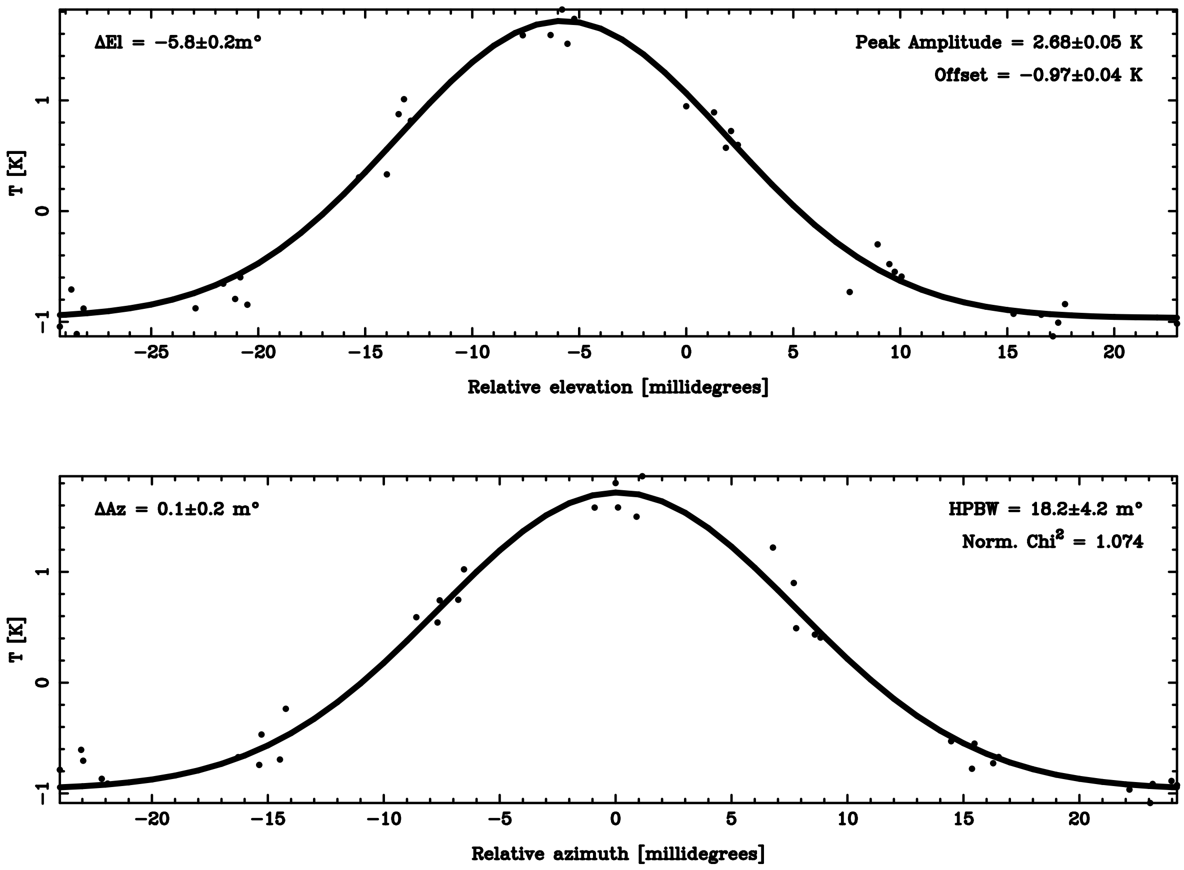

Figure 18: A typical display of five 7-point scans in azimuth and elevation with the two channel differential radiometry. Virtually all atmospheric emission is compensated and the residual noise is at thermal level. The observation was performed at 86 GHz using a SiO maser spectral line source.

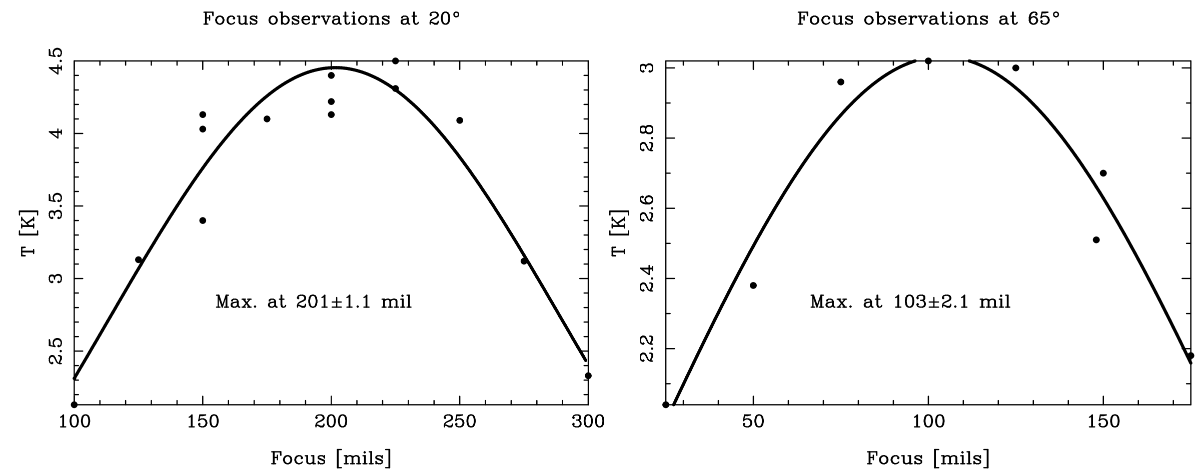

Figure 19: SiO maser line antenna temperature at different focal length settings at two telescope elevations.

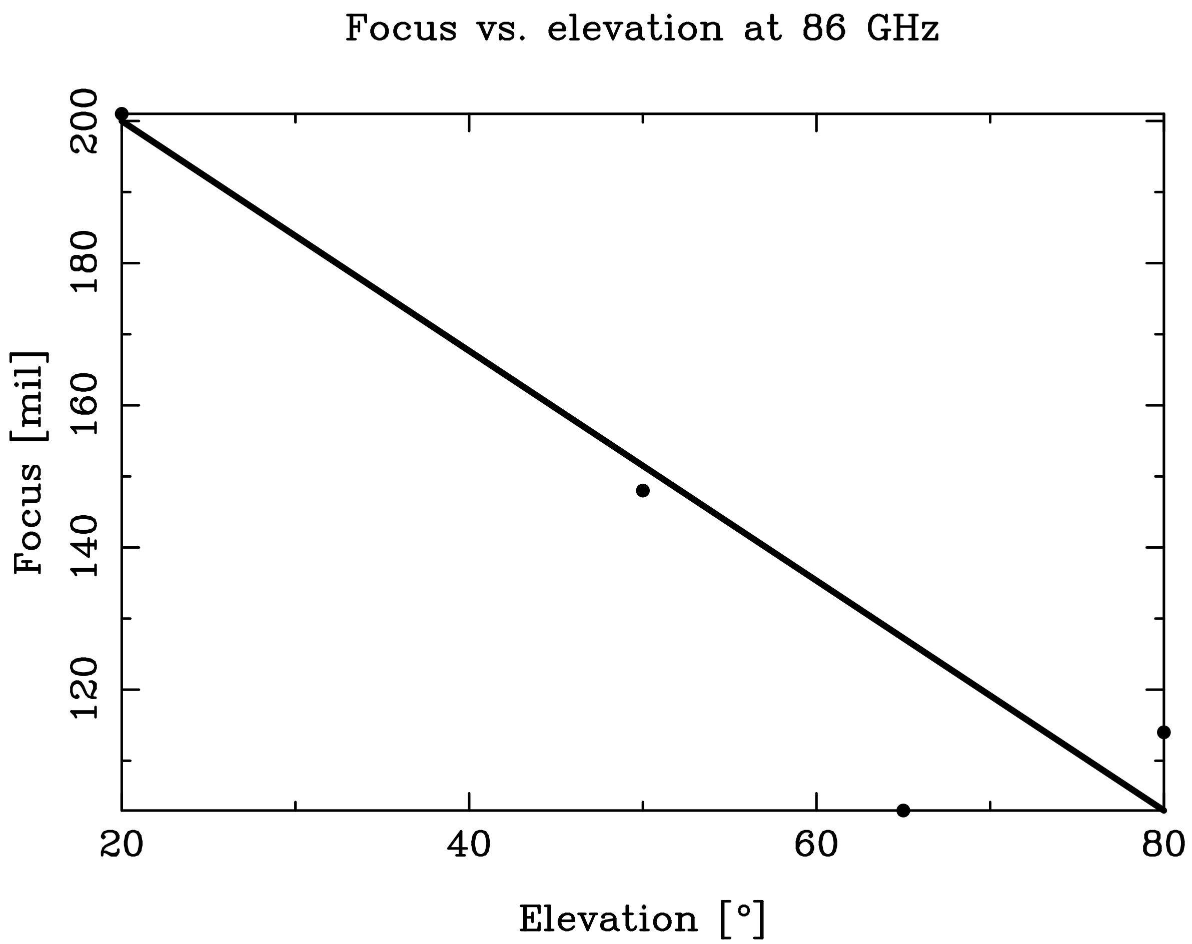

Figure 20: Focal length dependence of elevation angle at 86 GHz.

Metsähovi took part in testing of the Space VLBI telescope HALCA in March 1998. The tests led to the detection of first 22 GHz fringes between satellite and earth based telescopes in early April 1998. In the first tests HALCA antenna was not pointed properly to the desired source (bursting water maser in Orion-KL). When pointing was corrected, first fringes were found between HALCA and VLBA telescopes.

2.4.4 Astronomical Masers

Project Team: Liljeström, Leppänen (Nokia), Wiik

The study on the linear polarization of W51 M was finished (Leppänen, Liljeström, & Diamond, ApJ 1998). These first 22 GHz polarimetric spectral line images, obtained with VLBA, showed that high-resolution (0.2 milliarcsecond) polarization observations of water masers provide a powerful tool for studying shocked and dense star-forming regions. It also showed that, if large scale polarization structures are present, magnetic field strengths can be determined from proper motion and linear polarization data.

2.4.5 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". It is based on Debian/GNU/Linux 2.0r5 and it features Linux kernel 2.0.34—this was required to support emerging new PC hardware and to enhance FS compatibility in networked Linux environments. 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 270 emails sent in 1998.

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/pub/fs*`".

2.5 Solar Research

Research Group at Metsähovi: Urpo, Heikkilä, Koistinen, Perttula, Pohjolainen, Ragaigne,

2.5.1 Solar Observing Campaigns

Project Team: Pohjolainen, Heikkilä, Perttula, Ragaigne, Tornikoski, Urpo

The new Solar Cycle 23 is now producing more and more active regions and flares. The mean rise time for a solar cycle is around 4 years, so the next solar activity maximum is expected to occur around 1999-2002. At Metsähovi, the solar observations were mostly done at 87 GHz (3 mm) during 1998, and a long observing run (25 days) was organized in June-July. The observing times and solar radio maps – one per day – are available in the Web, at **http://kurp-www.hut.fi/sun/observations/**.

2.5.2 Solar Data Analysis

Project Team: Pohjolainen, Heikkilä, Perttula, Urpo

The study of solar flares has continued in cooperation with several research groups and observatories, using the data recorded during the previous solar activity Cycle 22. The Metsähovi radio data have been studied, e.g., in comparison with soft X-ray data (GOES satellites) and hard X-ray data (Compton-GRO BATSE instrument). Besides flares and active regions, also coronal holes have been studied in microwaves and soft X-rays using the instruments onboard the Japanese satellite Yohkoh. This is a common project with scientists from Metsähovi, National Astronomical Observatory in Japan, Hvar Observatory, and Kiepenheuer Institut für Sonnenphysik.

The analysis of solar radio maps can now be done using an 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.

2.5.3 Solar Polar Features at Mm-Waves

Project Team: Pohjolainen, Portier-Fozzani (LAS-CNRS, Marseille, France), Ragaigne, Heikkilä

Solar mm-wave maps show a variety of features near the solar poles. To analyse these features, a selection of radio maps at 87 GHz (3 mm), from 1996-1997, were studied and compared with nearly-simultaneous SOHO/EIT images. Emphasis was given to comparing polar radio brightenings with features seen in EUV, but also many radio depressions were analysed. The preliminary analysis of the radio data was mainly done by D. Ragaigne, as part of her training for a Master's Degree (Université de Paris Sud, France), and was presented at the CESRA conference in Espoo (Finland), in June 1998.

Some radio enhancements were found to have polar plume bases, but in most cases the radio brightenings corresponded to EUV bright diffuse sources, coronal holes, mini-coronal holes, or a mixture of these features. In many of the locations classified as mixed features a mini-coronal hole was present. The results indicate that coronal hole radio brightenings are present also at high frequencies, but not all coronal holes are radio bright at 3 mm. The analysed radio depressions corresponded well with less dense regions – coronal holes and mini-coronal holes – in the EIT images. However, only a few of the many low density regions seen in EUV were seen as depressions in radio. These results were presented at the Nobeyama Symposium (Japan), in October 1998. An example of an EIT map with superimposed radio brightenings is presented in Figure 21.

2.5.4 Multi-wavelength Analysis of Energetic Solar Flares

Project Team: Pohjolainen (at Meudon since Oct. 1, 1998), Vilmer (Observatoire de Paris at Meudon, France), Khan (ISAS, Japan)

Analysis of selected solar events producing soft and hard X-ray emission, as well as low and high frequency radio emission, was 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. Future analysis of other events will also include high frequency radio data from Metsähovi (87 GHz) and Nobeyama (17 and 34 GHz).

An example of this work is presented in Figure 22. A coronal mass ejection was observed by SOHO/LASCO on May 2, 1998, after 14:06 UT. There were two active regions present that day, in the north-east and south-west parts of the solar hemisphere, and activity was observed from both of them, at different times. Low frequency radio emission (Nancay) was observed at the same time as a flare occurred in the south western active region, starting around 13:34:50 UT. The radio sources first formed an

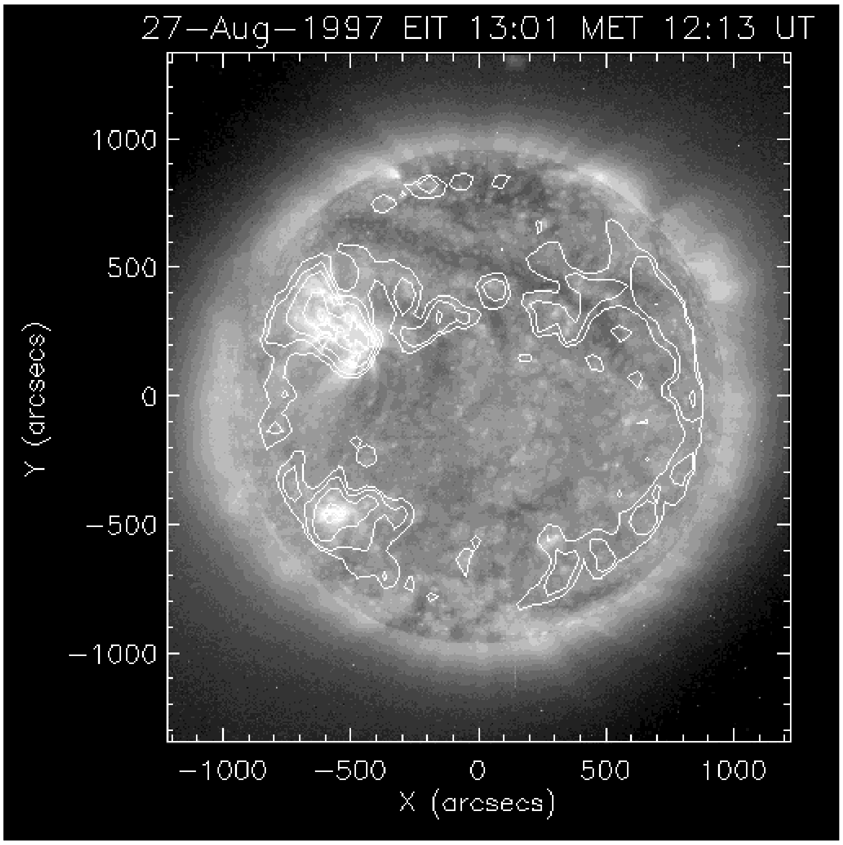

Figure 21: Solar polar sources seen in the Metsähovi 87 GHz map, observed at 12:13-12:21 UT (white contours), superimposed on the SOHO EIT Fe IX/X image at 13:31 UT, on August 27, 1997.

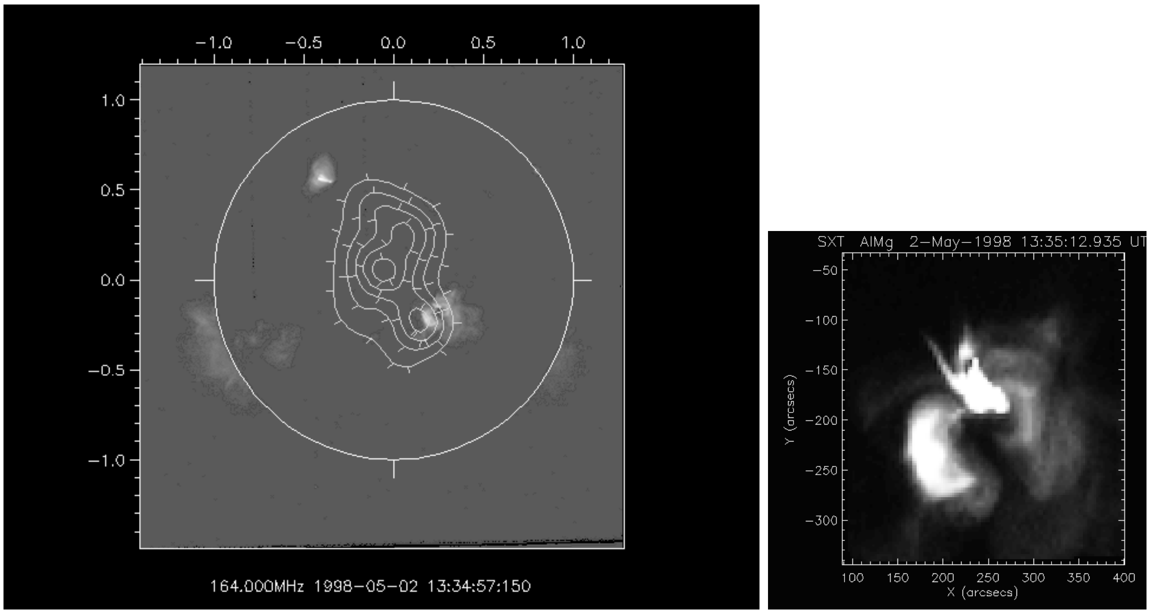

Figure 22: **Left**: Yohkoh SXT full disk image from May 2, 1998 at 13:31 UT, with the Nancay 164 MHz sources at 13:34:57 UT superimposed. **Right**: The flaring southern active region, recorded by Yohkoh at 13:35 UT.

arch-like structure between the two active regions, Figure 22, left side image, but after a few minutes the direction of the radio sources seemed to move towards north-west. In the image from the flare site, Figure 22, right side, two jet-like structures can be seen pointing to north east and north.

2.5.5 Organization of the CESRA'98 Workshop

Local Organizing Committee: Pohjolainen (Chair), Fagerström (HUT/Espoo Visitor and Convention Bureau), Hurtta, Urpo

The Community of European Solar Radio Astronomers (CESRA) organizes a series of workshops on investigations of the solar atmosphere using radio and other observations. These workshops are intended to bring together different communities of observers and theoreticians in order to discuss current problems of the structure and dynamics of the solar atmosphere, its impact on, and relationship with the heliosphere. Although special emphasis is given to radio diagnostics, the workshop topics are of interest to a large community of plasma astrophysicists.

The previous workshops in this series have been held in Caputh near Potsdam (Germany) in May 1994, on Coronal Magnetic Energy Releases, and in Nouan-le-Fuzelier (France) in June 1996, on Coronal Physics from Radio and Space Observations. These gave a summary of present knowledge and key questions on topics such as dynamics of the quiet sun and coronal heating, shock waves and coronal mass ejections, energy release processes and particle beams in the solar corona and in the interplanetary medium. These subjects are related to space missions such as SOHO, YOHKOH, ULYSSES and WIND.

The 1998 workshop on **Coronal Explosive Events** was continuing this series. The meeting was held at Siikaranta, in the city of Espoo in Finland, on June 9-13, 1998. The workshop layed emphasis on the different spatial scales of coronal restructuring and energy release, ranging from the apparently quiet corona to CMEs. It consisted of invited reviews and talks, contributions in the form of posters, and working group discussions. The meeting was attended by 81 participants from 19 countries, of which 25 were young researchers funded by European Community grants.

The sponsoring institutions of the meeting were: Academy of Finland, City of Espoo, Community of European Solar Radio Astronomers (CESRA), EU's Human Capital and Mobility Programme (Euroconference), European Physical Society (EPS), Helsinki University of Technology (HUT), Metsähovi Radio Observatory, and Observatory of University of Helsinki.

More information on the meeting (**http://www.hut.fi/~spo/cesra98.html**) and CESRA (**http://www.astro.phys.ethz.ch/rapp/cesra/cesra_home.html** is available in the Web.

2.5.6 High Latitude Active Regions

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

Full-disk solar maps at 36.8 GHz show localized regions of enhanced mm-wave emission at low, 0 - 45 degrees, and at high, 50 degrees or more, solar latitudes. Both spatial and temporal distribution of these active regions have been studied. The activity of the low latitude sources follows the 12 years cycle of sunspot activity. The high latitude radiation enhancements correlates with the polar faculae cycle. Typically in our measurements these sources are 100-400 K hotter than the quiet Sun. However, we have some evidence that these sources are much smaller than our telescope beam size so that the actual brightness of these sources is at least 1000 K or more. Physically, the high latitude sources could be connected to density and temperature enhancements, related polar phenomena which have comparable lifetimes.

2.5.7 INTAS

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

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

Plasma radiation from solar and stellar coronae. The plasma radiation mechanism driven by the loss-cone instability of magnetically trapped high-energy electrons under conditions of 'warm' background plasma and intermediate magnetic field was proposed. Such a conditions can realize, for instance, in the flaring loops on the Sun and in the coronal magnetic loops of active stars. Growth rates of plasma waves near the upper hybrid frequency are calculated numerically. These electrostatic waves are the fastest-growing mode in X-ray emitting stellar coronae as compared to the whistlers and electromagnetic waves near electron cyclotron harmonics. The calculations of the radiation pattern of the second harmonic plasma emission arising due to the coalescence of upper hybrid waves have shown that the x-mode radiation prevails over the o-mode in a source. Nevertheless due to the strong gyroabsorption of the x-mode on the warm background plasma the resulting emission is polarized in the ordinary sence. This can explain flaring and quiescent radio emission from dMe and RS CVn stars polarized sometimes in the o-mode. Moreover the calculations of the angle dependence of optical depths for gyroabsorption at the third, fourth, and fifth harmonics indicate that there are actually no escape windows for the electron cyclotron maser emission.

Magnetic fields in coronal holes on the Sun. Results of coronal holes observations at microwaves performed with the RATAN-600 on the descending phase of sunspot cycle No 22 and during the period of current minimum of the solar activity cycle (1992-1996) were analysed. The observations were made simultaneously at 27-40 wavelengths in the range of 1.8-31.6 cm at RATAN-600 upgraded by the panoramic spectral analizer. Maximum spatial resolution of RATAN-600 was 17"x13' and the sensivity for the circular polarization (Stokes parameter V) was 0.03%. The last value is exclusive in the solar radio astronomy. Due to this we performed the first measurements of the magnetic field in the coronal holes. Based on the RATAN-600 observations and the thermal bremsstrahlung formulas we obtained the magnetic field of 2-3 G.

On the origin of radio emission from AE Aquarii. The interpretation of the radio spectrum of cataclysmic variable AE Aqr was proposed based on the optically thin synchrotron radiation of relativistic electrons. It is supposed that these electrons are quasi-monoenergetic and trapped in the magnetic field of the plasmoids outflowing from the magnetosphere of the compact star. The source variability is explained in terms of the variation of the rate of plasmoid generation due to the interaction between the primary's magnetosphere and the accretion disk.

2.6 HRDL for Alpha Magnetic Spectrometer (AMS)

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

Project Team at Metsähovi: Ritakari, Engelberg, Karlamaa, Mujunen, Tornikoski, Wiik

Metsähovi Radio observatory is participating in the Alpha Magnetic Spectrometer (AMS) program that is building a particle physics detector for the International Space Station (ISS).

The purpose of the AMS project is to study the following phenomena:

- The origin and structure of "dark matter", which is believed to make up 90% of the universe
- The presence or absence of antimatter in distant galaxies
- The origin and composition of cosmic rays.

The AMS project is multinational, the AMS detector has been constructed by an international team of physicists and engineers from 37 universities and research institutes located in Switzerland, France, Russia, China, Taiwan, Italy, Germany Spain, Portugal, Romania, Finland, and the United States.

The responsibility of Metsähovi Radio Observatory in the AMS project is to develop the high rate data link for the transfer of scientific data.

AMS has been built in accordance with strict space qualification standards and safety parameters required by NASA. Along with the international support of the experiment, the project represents a major joint effort by the U.S. Department of Energy and the National Aeronautics and Space Administration. The final integration took place in NASA Kennedy Space Center in Cape Canaveral, Florida, Figure 23.

The AMS detector was successfully tested in June 1998 on space flight STS-91. (Space shuttle Discovery's flight to MIR space station). During the flight the Metsähovi team worked ten days in three shifts in NASA Mission Control Center in Houston, Figure 24.

In January 2002, NASA has scheduled the shuttle Atlantis, STS-120, to deliver AMS to the International Space Station (ISS) where it will be deployed for a three year mission.

2.7 Radio Spectroscopy

Research Group: Liljeström, Wiik

Project team: Liljeström

Figure 23: M. Tornikoski and K. Karlamaa in MPPF building at NASA KSC.

Figure 24: M. Tornikoski and A. Mujunen in AMS Payload Operations Command Center in Mission Control Center building at NASA JSC.

2.7.1 Water Masers

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

Long-term water maser outburst observations of the massive star-forming region W49 N have been obtained with the Metsähovi radio telescope. A fruitful collaboration with prof. Gwinn (University of California Santa Barbara) opened the possibility to combine this Metsähovi H_2O database with simultaneously obtained multi-epoch VLBI data of W49 N. This enabled to observationally fix all free parameters in the comprehensive shock and maser models of Hollenbach, McKee, and Elitzur (1989) yielding some 20 shock and maser parameters, among others the kinetic temperature, pre- and postshock densities, column density, water abundance, Alfven velocity as well as the pre- and postshock magnetic field strengths. Also the observationally more hidden parameters of astrophysical interest were revealed. This new diagnostic astrophysical method was intensively worked out during 1998.

2.7.2 Preparatory Work for the Submillimetre Wave Satellite Odin

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 different astrophysical objects 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 T. 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) Exotic Chemistry.

Much effort has been put by the lead scientists to the preparatory work during autumn 1995 - December 1998. The ODIN satellite will be launched in December 1999.

2.7.3 Star Formation

The study of the shocked HH 135/136 complex around the newly born star IRAS 11101-5829 was finished. This study was a collaboration with K. Ogura (PI, Tokyo, Japan), M. Nakano (Oita Univ., Japan), and K. Sugitani (Nagoya Univ., Japan). The 220 and 230 GHz CO and 13CO data, obtained with SEST, enabled to investigate the cloud core and the molecular outflow associated with the highly shocked optical outflow from the embedded very young star. We found that the density peak of the cloud core is displaced from the power source of the outflow. This was interpreted as following from a radiative implosion triggered by the strong UV radition field at the SW edge of the cloud core (optically revealed as a bright-rimmed cloud).

In order to explain the complicated velocity structure reported by Ogura et al. for the shocked optical outflow, traced by the forbidden lines SII and NII, a model was constructed in which the jetlike outflow is collisionally deflected by the cloud core.

3 Publications

3.1 International Journals

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3.4 Laboratory Reports

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3 Mujunen A., Perttula M., Engelberg J.: Using CVS at Metsähovi; *Metsähovi Reports HUT-KURP-14*, 1998.

3.5 Other Publications

1 Engelberg, J., Hansen, H., Huhtala, M., Isotalo, T., Jokela, P., Koho, K., Kohtala, A., Kumpumäki, T., Lehikoinen, P., Leino, A., Länsman, P., Mattila, O., Mecklin, J., Mentula, M., Ojanen, P., Partanen, K., Pasanen, M., Pikkarainen, K., Rasilainen, H., Ruismäki, R., Ruohomaa, S., Savojoki, J-P., Tikkanen, M., Vainikainen, P., Varsila, T., Vepsäläinen, P., Wikström, T.: UMTS frequencies and operating licences in Finland; *The report of national UMTS working group*, 30th November 1998.

2 Ahola, K., Lahtinen, J., Urpo, S. (Editors): Space Research in Finland 1996-1997; *COSPAR Finnish National Committee and TEKES Technology Development Centre Finland*, 54 p, Helsinki, 1998.

3 Pedersen, H., Fynbo, J., Valtaoja, E., Tornikoski, M., Clasen, J., Palazzi, E.: GRB980329 R & I-band observations; *GCN GRB observation report, GCN Circular Nr 52*, 1998.

4 Urpo, S., Lahtinen, J.: COSPAR kokoontui Nagoyassa; 32nd COSPAR Scientific Assembly, July 12-19, 1998, Nagoya, Japan, *Avaruusuutiset, 4/98*, p 13, 1998.

5 Ragaigne, D.: Observations of the Sun in Radio waves and Analysis of data; 33 p, 1998.

4 Visits to Foreign Institutes

Main Astronomical Observatory, Pulkovo, Russia, 24-28.3.1998, S. Urpo, M. Perttula, J. Heikkilä.

SAO, Southern Astronomical Observatory, Pulkovo, Russia, 26.3.1998, S. Urpo, M. Perttula, J. Heikkilä.

IAP, Institute of Applied Astronomy, St. Petersburg, Russia, 25.3.1998, S. Urpo, M. Perttula, J. Heikkilä.

RT-32, Svetloe, Russia, 25.3.1998, S. Urpo, M. Perttula, J. Heikkilä.

Joffe Institute, St. Petersburg, Russia, 26.3.1998, S. Urpo, M. Perttula, J. Heikkilä.

Neuchatel Observatory, Neuchatel, Switzerland, 22-23.2.1998, S. Urpo.

AMS High Rate Data Link Rack and DCU Installation, NASA, Kennedy Space Center, USA, 11-18.1.1998, J. Engelberg, A. Mujunen.

AMS HRDL Rack H1 setup, Zürich, Switzerland, 24-27.1.1998, E. Oinaskallio.

AMS Integration Test, NASA, Kennedy Space Center, USA, 1-10.2.1998, J. Engelberg, J. Ritakari.

AMS Integration Test, NASA, Kennedy Space Center, USA, 26.2-7.3.1998, J. Ritakari.

AMS HRDL Support, Flight Operations Review and Paper Simulation, NASA Kennedy Space Center, Johnson Space Center, USA, 17.2.-2.3.1998, J. Engelberg, A. Mujunen.

AMS, HRDL Support Flight Operations Review and Paper Simulation, NASA, Kennedy Space Center, USA, 17.2.-25.2.1998, M. Tornikoski, K. Karlamaa.

AMS CITE Interface Verification Test and End-to-End Test, NASA Johnson Space Center, Houston, USA, 15-26.3.1998, J. Engelberg, A. Mujunen.

AMS CITE Interface Verification Test and End-to-End Test, NASA Kennedy Space Center, 19-25.3.1998, K. Wiik.

AMS STS-91 Joint Integrated Simulation, AMS Stand-Alone Tests, AMS STS-91 Final Flight Configuration, NASA Johnson Space Center, Kennedy Space Center, Johnson Space Center, USA, 30.3.-21.4.1998, J. Engelberg, A. Mujunen.

AMS, JIS TEST, NASA, Johnson Space Center, USA, 7-14.5.1998, K. Karlamaa, M. Tornikoski, J. Ritakari, K. Wiik.

AMS PAD Interface Verification Test and PAD End-to-End Test, NASA Johnson Space Center, Houston, Kennedy Space Center, USA, 17-25.5.1998, J. Engelberg, A. Mujunen.

STS-91 AMS Shuttle flight ground support, deintegration after mission, NASA Johnson Space Center, Kennedy Space Center, USA, 30.5-20.6.1998, J. Engelberg, A. Mujunen.

AMS, STS91 Payload Support, ASA, Johnson Space Center, USA, 30.5.-15.6.1998, K. Karlamaa, J. Ritakari, M. Tornikoski, K. Wiik.

EVN Technical Operations Group, Gothenburg, Sweden, 26-28.6.1998, J. Engelberg, A. Mujunen.

AMS High Rate Rack deintegration, NASA Kennedy Space Center, USA, 1-6.7.1998, J. Engelberg, A. Mujunen.

AMS Post Flight Test Setup, ETH-Zentrum, Zürich, Switzerland, 10-11.8.1998, J. Engelberg, A. Mujunen.

AMS HRDL PC Maintenance, ETH-Zentrum, Zürich, Switzerland, 21-23.8.1998, J. Engelberg, A. Mujunen.

Collaboration on water masers, University of California, Santa Barbara, USA, 6-27.7.1998, T. Liljeström.

Post doc researcher, Observatoire de Paris, Meudon, France, 1-6.9.1998, 16-21.9.1998, from 1.10.1998, S. Pohjolainen

Work on Yohkoh satellite data, ISAS, Sagamihara Kanagawa, Japan, 30.10-3.11.1998, S. Pohjolainen.

Observations with the Nordic Optical Telescope, La Palma, Canary Islands, 31.3-7.4.1998 and 8.-15.12.1998 M. Tornikoski.

5 Visiting Scientists

F. Portier-Fozzani (Equipe SOHO/EIT, Laboratoire d'Astronomie Spatiale, LAS-CNRS, Marseille, France), working visit at Metsähovi on 6-7.6.1998.

Dr K. Jiricka (Astronomical Institute, Ondrejov, Czech Republic) visit at Metsähovi 18.5-8.6.1998.

Dr A.V. Stepanov (Pulkovo Observatory, St Petersburg, Russia), visit at Metsähovi 16-25.11.1998.

Dr V.V. Zaitsev (Institute of Applied Physics, Russian Academy of Science, Nizhny Novgorod, Russia), visit at Metsähovi 16-25.11.1998.

80 participants of the CESRA'98 Workshop visited Metsähovi on 11.6.1998.

6 Teaching

The primary school of Nöykkiö, Espoo, spring 1998: lectures on astronomy and space science by S. Pohjolainen.

Metsähovi Radio Observatory, summer 1998, S. Pohjolainen: supervisor for the summer trainee.

Space Technology, Helsinki Univ. of Technology, 1998, S. Pohjolainen: supervisor for a special laboratory work.

Lecture about antimatter and the Alpha Magnetic Spectrometer to the amateur astronomy club Lohjan Ursa, January 28, 1998, M. Tornikoski.

Lecture about radio astronomy and the Metsähovi research projects to the amateur astronomy club Pollux, during their excursion to Metsähovi, October 5, 1998, M. Tornikoski.

Radioastronomy, an undergraduate course at the Helsinki University of Technology, September - December 1998. Teacher M. Tornikoski, assistant A. Lähteenmäki.

Laboratory exercise for space technology students, Helsinki University of Technology, April 1998 and October 1998, A. Lähteenmäki.

Lecture about the AMS project at the research seminar of space technology/HUT , October 16, 1998, M. Tornikoski, A. Mujunen, J. Ritakari.

Metsähovi Radio Observatory was visited in 1998 by following high school classes: Askolan lukio, Porkkalan lukio, Haukilahden lukio, Espoonlahden lukio, and Nummelan lukio.

The fifth grade of the primary school of Veikkola visited Metsähovi in November 1998.

Students of the Electrical Department of Helsinki University of Technology visited Metsähovi in November 1998.

7 Other Activities

7.1 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.

AAS, American Astronomical Society, member S. Urpo

AMS, Tekes Guiding Group, member S. Urpo

CESRA, member of the Scientific Organizing Committee S. Urpo

CESRA, member of the LOC of the Meeting June 9-13.1998 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

COSPAR, General Assembly, Nagoya, Japan, 12-19.7.1998, S. Urpo

COSPAR, Council Meetings 12.7.1998 and 19.7.1998, S. Urpo

EAS, European Astronomical Society, founding member S. Urpo

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

ESA SPC, Paris, France, 16-17.2.1998, S. Urpo

ESA SPC, Paris, France, 28-29.5.1998, S. Urpo

ESA SPC, 1st FIRST/PLANCK Payload Meeting, Paris, France, 16-17.2.1998, S. Urpo

ESA SPC, 2nd FIRST/PLANCK Payload Meeting, Paris, France, 16-17.2.1998, S. Urpo

ESA SPC, Paris, France, 2-3.11.1998, 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

OECD Mega Science Forum, Working Group on Radio Astronomy, member S. Urpo

OECD Mega Science Forum, Working Group on Radio Astronomy, Washington DC, USA, 1-2.6.1998, S. Urpo

RISC, Radioastron International Science Committee, member S. Urpo

RISC, Neuchatel, Switzerland, 23-24.2.1998, 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

7.2 International Meetings and Talks

Interstellar Turbulence -Conference, Puebla, Mexico, 12-16.1.1998, **invited talk**: "Water masers tracing alfvenic turbulence and magnetic fields in W51 and W49", T. Liljeström.

ODIN Workshop, Helsinki, 26-28.5.1998, **two invited talks**: "Status of the ODIN PDR Programme"; "Status of the ODIN HLC Programme", T. Liljeström.

Protostars and Planets IV, Santa Barbara, USA, 6-11.7.1998, **poster**: "The Pseudodisk and Hydromagnetic Accretion Shock around Z Cma", T. Liljeström.

Institute of Applied Astronomy, St. Petersburg, Russia, 25.3.1998, **invited lecture**: "Research and Results at Metsähovi Radio Observatory", S. Urpo.

SAO, Southern Astronomical Observatory, Pulkovo, Russia, 26.3.1998, **invited lecture**: "Solar Polar Activity", S. Urpo

Joffe Institute, St. Petersburg, Russia, 27.3.1998, **invited lecture**: "Satellite and Other Research at Metsähovi Radio Observatory", S. Urpo

ESA Workshop on Millimetre Wave Technology and Applications, Espoo, Finland, 27 29.5.1998, **talk**: "Phase Stability of a 43 GHz VLBI Receiver" O. Koistinen, J. Peltonen, S. Urpo.

ESA Workshop on Millimetre Wave Technology and Applications, Espoo, Finland, 27-29.5.1998, **session chairman**: S. Urpo.

Séminaires de l'Observatoire de la Côte d'Azur, Nice, France, April 15, 1998, **talk**: "Emission mechanisms in solar flares at millimetre wavelengths", S. Pohjolainen.

European VLBI Network (EVN) Directors' Meeting, Bologna, Italy, April 17, 1998, participation by S. Pohjolainen.

CESRA Workshop on Coronal Explosive Events, Espoo, Finland, June 9-13, 1998, **posters** J. Heikkilä (1), S. Pohjolainen (5), D. Ragaigne (1), and S. Urpo (4), see publications list for titles. Other participants A. Lähteenmäki, M. Perttula. Local Organizing Committee S. Pohjolainen (chair), S. Hurtta (secretary), S. Urpo (member). Scientific Organizing Committee S. Urpo (member). EU Contract ERBCHECCT940179 contact person S. Pohjolainen, Editor of Conference publication S. Pohjolainen.

NRAO Sixth Summer School in Synthesis Imaging. Socorro, New Mexico, USA, June 17-23, 1998, participation in the course: K. Karlamaa, M. Perttula, and S. Pohjolainen.

JIVE Correlator Inauguration Meeting, Dwingeloo, Netherlands, Oct. 22, 1998, participation by S. Pohjolainen.

Nobeyama Symposium on Solar Physics with Radio Observations, Kiyosato, Japan, October 27-30, 1998, **talk**: "Radio bright structures near the solar poles at millimeter wavelengths", S. Pohjolainen.

BL Lac Phenomenon, Turku, Finland, 22 –26.6.1998, **talks** A. Lähteenmäki: "Comparison of radio and EGRET gamma-ray properties between BL Lacs and other AGN"; H. Teräsranta: "Long term continuum monitoring of AGN with the Metsähovi and SEST telescopes", **posters** A.Lähteenmäki: "New evidence for the shocked jet model"; H. Teräsranta: "Detection of a strong flare in the BL Lacertae object 0235+164 at 1-230 GHz 1997-1998"; M. Tornikoski: "Multifrequency behaviour of PKS 2255-282" and "Simultaneous radio/optical outburst in CTA 102'.

EVN TWG Meeting, Alacala de Henares, Spain, 17-21.1.1998, K. Karlamaa, K. Wiik.

VLBI Operations Workshop, Boston, USA, 10-14.5.1998, K. Karlamaa, K. Wiik.

Arise Workshop, Green Bank, USA, 16-23.8.1998, K. Wiik.

EVN TOG, Onsala Space Observatory, Göteborg, Sweden, 26-28.6.1998, J. Engelberg, A. Mujunen.

7.3 National Meetings and Talks

National UMTS (Universal Mobile Telecommunications Systems) Working Group 2nd Meeting, Telehallintokeskus, Helsinki 9.1.1998, J. Engelberg.

National UMTS Working Group 7th Meeting, Telehallintokeskus, Helsinki 20.8.1998, J. Engelberg.

National UMTS Working Group 8th Meeting, Haikon kartano, Porvoo 29.9.1998, J. Engelberg.

Metsähovi Research Seminar, 3.9.1998, **talk**: "Enhanced temperature regions in the polar zones of the Sun", S. Urpo.

Laboratory of Space Technology, Helsinki University of Technology, 20.10.1998, **lecture**: "Research at Metsähovi Radio Observatory", S. Urpo.

Metsähovi Research Seminar, 6.11.1998, **talks**: "Gamma-ray bursts GRB980329", "Multi-wavelength observations of PKS 2255-282", M. Tornikoski.

Metsähovi Research Seminar, 25.11.1998, **talks** by A. Stepanov, Pulkovo, and V. Zaitsev, Nizhny Novgorod.

Helsinki University Observatory Colloquium, 14.12.1998, **talk**: "LSA/MMA, the technology and science possibilities of possible Finnish participation", S. Urpo.

Metsähovi Review Meeting, 30.9 - 1.10.1998, Tallinn, Estonia, J. Engelsberg, J. Heikkilä. S. Hurtta, K. Karlamaa, O. Koistinen, P. Könönen, A. Lähteenmäki, M. Myyry, E. Oinaskallio, M. Perttula, J. Ritakari, M. Tornikoski, S. Urpo.

Meeting of Finnish COSPAR Researchers, 14-15.9.1998, Kiljavanranta, **talks and posters** J. Engelberg: "AMS HRDL Rack Performance Before and During STS-91 Mission",A. Mujunen: " AMS High Rate Data Link Software Architecture" O. Koistinen, M. Perttula, K. Karlamaa, J. Peltonen, K. Wiik, S. Urpo.

The First Millennial Tuorla-Metsähovi Symposium, Tuorla Observatory, March 6, 1998, **talk** S. Pohjolainen :" Solar research and ongoing projects at Metsähovi", J. Engelberg, J. Heikkilä, S. Hurtta, A. Mujunen, E. Oinaskallio, M. Perttula, H. Rönnberg, M. Tornikoski, K. Wiik.

Seminar on High-Energy Astrophysics at the University of Helsinki, introduction on Sept. 23, 1998 by S. Pohjolainen "Discussion on practical issues connected to a job in a foreign country".

Artjärvi Telecommunications Society Microwave Days, Viestikallio, Artjärvi, Sept. 26, 1998 **talk**: "Sun, Radio, Earth, and Us (in Finnish)", S. Pohjolainen.

Radio Administration Advisory Group/WRC2000 Preparation Group, Telehallintokeskus, Helsinki, 8.10.1998, J. Engelberg

7.4 Public Relations

MTV 3 (Finnish Commercial TV Channel), 31.3.1998, News about Halca and related Metsähovi measurements, S. Urpo.

TV reportage about Metsähovi activities to be used in a documentary about Finnish forestry and to be distributed in Germany, 25.8.1998, S. Urpo.

8 Personnel in 1998

Permanent Positions funded by the Helsinki University of Technology

Urpo, Seppo, Prof., Dr.Tech. docent	Director of the institute, on leave of absence as senior researcher for the Academy of Finland (Aug 1, 1997 - Jul 31, 1998)	Seppo.Urpo@hut.fi
Engelberg, Jan, Eng.	Operations engineer	Jan.Engelberg@hut.fi
Hurtta, Solveig, Ms.	Secretary	Solveig.Hurtta@hut.fi
Oinaskallio, Erkki, Mr.	Technician	Erkki.Oinaskallio@hut.fi
Peltonen, Juhani, Dr.Tech.	Laboratory engineer	jussi@kurp.hut.fi

Scientific and Technical Staff Funded by Research Contracts

Heikkilä, Juho, student	Research aid, part time	Juho.Heikkila@hut.fi
Karlamaa, Kirsi, student	Research aid	Kirsi.Karlamaa@hut.fi
Koistinen, Olli, Lic.Tech.	Researcher	Olli.Koistinen@hut.fi
Könönen, Prisse, student	Research aid from September 1, 1998	prisse@kurp.hut.fi
Liljeström, Tarja, Lic.Phil.	Researcher June 1 - August 31, 1998	Tarja.Liljestrom.hut.fi
Lähteenmäki, Anne, M.Sc.	Researcher	alien@kurp.hut.fi
Mujunen, Ari, Dipl.Eng.	Researcher	Ari.Mujunen@hut.fi
Myyry, Mika, Mr.	Mechanic	Mika.Myyry@hut.fi
Perttula, Mika, Dipl.Eng.	Researcher until November 15, 1998	
Pohjolainen, Silja, Dr.Phil.	Researcher, acting director of the institute (Aug 1, 1997 - Jul 31, 1998)	Silja.Pohjolainen@hut.fi
Ragaigne, Delphine	Summer trainee May 1 - July 31, 1998	
Ritakari, Jouko, Dipl.Eng.	Researcher, part time	jr@kurp.hut.fi
Rönnberg, Henry, Mr.	Mechanic	
Teräsranta, Harri, Dr.Tech.	Researcher	hte@kurp.hut.fi
Tornikoski, Merja, Dr.Tech.	Researcher Docent of space technology and radio astronomy since June 1998	Merja.Tornikoski@hut.fi
Wiik, Kaj, Dipl.Eng.	Researcher	Kaj.Wiik@iki.fi

Metsähovi Advisory Committee

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