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PolKa: A New Polarimeter for Millimeter and Submillimeter Bolometer Arrays

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Abstract. A new concept of polarimeter has been designed to be used together with the arrays of bolometers developed at the Max-Planck-Institut für Radioastronomie in Bonn. The new polarimeter has the unique characteristic of being tunable over a wide range of wavelengths and of producing a negligible absorption. It has been used at the Heinrich-Hertz telescope to measure the linear polarization of some quasars and of some extended sources inside our Galaxy. Some results are presented here. We detected polarization on the quasars 3C279 and 1633+382. On 3C279 we also detected polarization variability on a time scale of a week. We performed also maps of extended sources: the BN/KL complex in Orion OMC-1, a filament cloud in Orion OMC-3 and the massive star-forming region IRAS 05358+3543. The polarimeter has low spurious polarization and a high modulation efficiency and the tests at the telescope show that it is well suited to become a permanent facility.

1 Introduction

About fifteen years ago the first steps were taken toward submillimeter polarimetry, using single-pixel bolometric receivers. Starting with polarimetry at 100 μm (Werner et al. 1988; Novak et al. 1989) and 1100 μm (Clemens et al. 1990), between then and today the whole submillimeter range has been opened for polarimetry, (for now) culminating with the multiwavelength 300–2200 μm imaging polarimeter of the James-Clerk-Maxwell's Telescopes Submillimeter Common User Bolometer Array (SCUBA; Greaves et al. 2003). Linear polarization of submillimeter continuum radiation can be produced by optically thin synchrotron emission, dominant in extragalactic objects like radio galaxies and active galactic nuclei, or by the partial magnetic alignment of elongated dust grains, common in molecular clouds (see Hildebrand 1988). Since the bolometer signal is proportional to the dust column density, practically speaking, dense cloud portions, in particular such associated with star-forming regions and protostellar envelopes are promising targets. In both cases magnetic morphology can be deduced from the directions of polarization vectors, and polarimetry at millimeter and submillimeter wavelengths can be more precise than in the optical and radio regimes, where scattering and Faraday rotation, respectively, can dominate the polarized signal.

Multi-wavelength polarimetry is particularly desirable, since there exists a trend for decreasing polarization with increasing optical depth and, thus, decreasing wavelength (e.g. Schleuning et al. 1997). This is probably the result of collisional depolarization in the highest density environments, and thus provides a probe of these.

At submillimeter wavelengths the instabilities of the atmospheric transmission can be large, and ground-based polarimetric observations, requiring high accuracy and, thus, minutes to hours of integration time, necessitated by the weakness of the polarization signal (typically a few percent of the total, unpolarized, flux) are particularly challenging. In the last few years great steps have been taken in bolometer development and technology, and today we can make use of large arrays of detectors with hundreds of elements.

Here we present a new concept of polarimeter, named PolKa after the German *Polarimeter für Bolometer Kameras*, developed by the Bolometer Development Division of the Millimeter and Submillimeter Astronomy Group at Max-Planck-Institut für Radioastronomie (MPIfR). The work was started by the idea of creating a versatile instrument, capable of giving good results with any of the MPIfR bolometer arrays, at multiple wavelengths, and flexible enough to be installed at any of the telescopes where MPIfR bolometer arrays are in operation (for details about MPIfR bolometer arrays see Kreysa et al. 2002).

2 Instrument overview and observations

PolKa has many characteristics in common with other polarimeters for millimeter and submillimeter wavelengths. In some aspects, however, it is unique, such as the unusual solution of the reflection-type half-wave plate (hereafter RHWP, see Shinnaga et al. 1999) or the continuous spinning technique. In order to extract the polarized signal from the unpolarized foreground it is common to use the modulation/demodulation technique. Making use of a polarization modulator, usually a half-wave plate, the polarized component of the incoming radiation is modulated at a precise frequency. If the modulation acts only on the Q and U Stokes parameters of the radiation, its intensity will be unchanged. Since bolometers are incoherent detectors, they are not sensitive to the phase of the wave but only to its intensity. We need to insert, along the optical path, a linear polarizer in order to translate the modulation of the Stokes parameters into a modulation of the total intensity of the transmitted wave. For more details see Siringo (2003).

2.1 The reflection-type half-wave plate

The RHWP is mainly made of two parts: a wire-grid polarizer and a mirror. Tuning the distance t between the two parts (see Figure 1), depending on the working wavelength, it is possible to produce

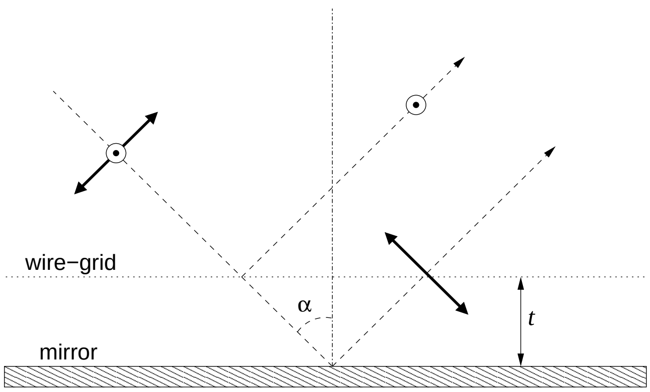

Fig. 1. Scheme of a reflection-type half-wave plate. The incident radiation is divided in two beams with orthogonal polarization states. The two emerging rays will have a phase shift proportional to t.

a phase shift between the two components of polarization, because one is reflected by the wires, the other one by the mirror, taking a longer path. The phase shift is given by the simple relation

$$\varphi(\lambda) = 2\pi \frac{t}{\lambda \cos \alpha} \tag{1}$$

where t is the distance between the polarizer and the mirror, α is the angle of incidence of the incoming radiation and λ is the operating wavelength. To have an HWP we assign $\varphi = \pi$ and the value of t for a central operating wavelength λ_0 is given by

$$t = \frac{1}{2} \lambda_0 \cos \alpha \tag{2}$$

The RHWP is mounted on an air bearing, which is driven by an integrated coaxial electric motor.

2.2 The analyzing system

We used two analyzers, mounted in a frame in front of the cryostat window, to easily switch between three different operating modes: 1) horizontal analyzer; 2) vertical analyzer; 3) no analyzer (empty slot) to be used for normal total power measurements. The analyzers are two identical wire-grid polarizers, with wires of 20 μm diameter, spaced at 50 μm. Before starting an observation, we selected the appropriate analyzer, or none for total power, by sliding the frame in front of the cryostat window.

2.3 Observations

PolKa was tested at the Heinrich-Hertz Telescope on Mt. Graham, Arizona, a 10 meter submillimeter telescope equipped with a 19-channel MPIfR bolometer array operating at 870 μm. In May 2001 we made a first test with a small RHWP; a second test with a full-size RHWP was made in January 2002. A typical observing session consisted of several steps. First of all, we had to perform the usual routine scans: a pointing on a strong point-like source, a focus, a second pointing and a skydip. Then, to retrieve the first three Stokes parameters, we needed to perform a total power scan to detect the flux of the source (Stokes parameter I) and a polarization scan (Stokes parameters Q and U). Before the beginning of the observations the RHWP was accurately tuned, in order to maximize the polarization modulation efficiency. To reduce the systematic effects and for a better removal of the spurious polarization, each polarization scan was repeated twice, one time using the horizontal analyzer and the second time using the vertical one. At the end of this sequence we performed another skydip. Polarization scans were performed following two different strategies: on-off, nodding the telescope on and off the source, in the case of point sources; on-the-fly maps in case of extended sources. In both cases we do not wobble the secondary mirror and the polarization of the incoming radiation is only modulated by the spinning RHWP.

2.4 Data acquisition

PolKa produces a polarization modulation acting on the Q and U Stokes parameters and the information about the first Stokes parameter (the total intensity I) is lost during polarization measurements. For this reason we needed to alternate between the total power data acquisition and polarization data acquisition. The telescope's total power backend was used for all the total power observing modes: pointing, focus, skydip and on-off and on-the-fly maps. The polarization backend acquired 23 signals (the bolometer signals plus reference signals used to demodulate the data) at a sampling rate of 512 S/s resulting in 32 points per polarization cycle, when the RHWP rotates at 4 Hz. The angular sampling interval is $2\overset{\circ}{.}8$ per point.

2.5 Data reduction and calibrations

New software was written by the authors to reduce data acquired in the polarization observing modes (for example, see the left plot in Figure 2). The data are demodulated by a synchronous demodulation algorithm. The polarization modulation efficiency was estimated in the laboratory to be $\sim 98\%$. The spurious polarization was estimated by observing the planets Mars and Saturn at different positions in the sky, assuming their emission being unpolarized. In all the cases the spurious polarization was below 0.7%. The polarized flux was calibrated by total power flux measurements of planets performed with the polarization backend. The polarization position angle was calibrated by using a local polarized target: these calibrations are therefore absolute and independent of sky sources. The calibration accuracy in the position angle is $0\overset{\circ}{.}8$.

3 Results

3.1 Polarization on-off (point sources)

We detected linear polarization in the two AGNs 3C279 and 1633+382.

3C279

During our second telescope run we measured a total (I) flux density of about 14 Jy, stable within the errors during our week of observations. We also performed 7 polarization scans per analyzer

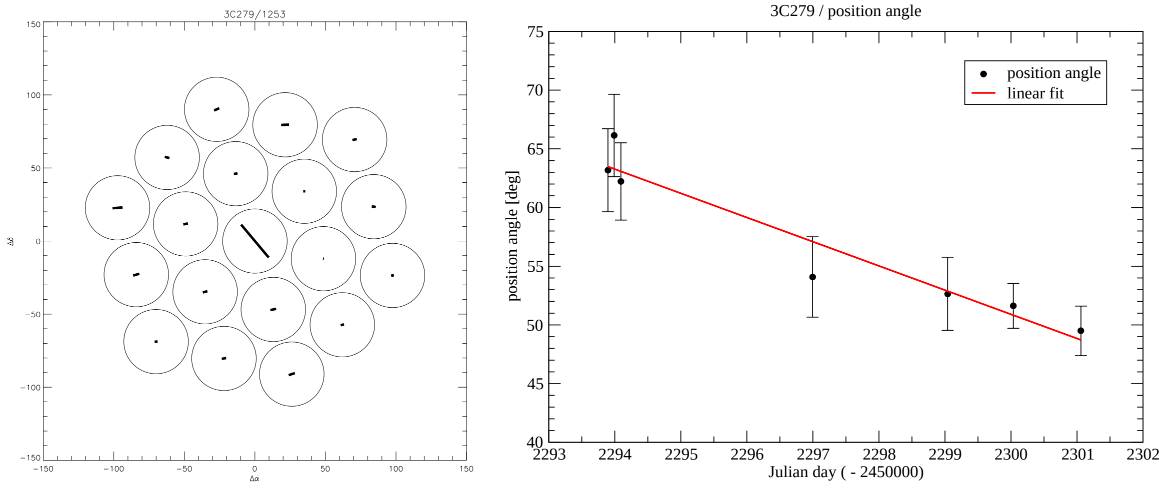

Fig. 2. *Left:* Example of polarization on-off data reduction: the configuration of the array on the sky is shown together with the measured polarization vectors of each channel. The central channel shows the detection on 3C279 (2002 January 26, 13:17 UT). *Right:* Polarization position angle of 3C279 in the 7 days of observations. The variation is $\sim 14°$. The linear fit gives a correlation coefficient of 0.97.

configuration. The mean value of the polarization degree, averaged over the week, is $p = 5.9\% \pm 0.3\%$ after 160 minutes of integration time. However, more interesting than the polarization degree was the behaviour of the position angle of 3C279 for which we detected variability over a time scale of one week. It is well known that the position angle of the polarized radiation emitted by the core of 3C279 varies with time (see Homan et al. 2002; Taylor 1998, 2000). In Figure 2 the right plot shows the position angle of 3C279 during the 7 days of our PolKa observations.

1633+382

The 1633+382 observations are noisier than those of 3C279, because the source is weaker. The observed polarization degree, after 80 minutes of integration time, is $p = 4.6\% \pm 0.5\%$. In this source there is no appreciable variation of the position angle. The observed value is $\chi = 45\overset{\circ}{.}2 \pm 9\overset{\circ}{.}8$ in good agreement with the VLBI measurements at 5 GHz published by Cawthorne et al. (1993).

3.2 On-the-fly maps (extended sources)

The strong flux and the possibility of comparing our results with previous observations made Orion OMC-1 our favourite target. We made also maps of a filament cloud in Orion OMC-3 and of IRAS 05358+3543, which are not presented here.

Orion OMC-1

The map shown in Figure 3 is the result of 12 scans performed during our 2002 telescope campaign. Each scan covers $360'' \times 360''$ and required a little more than 30 minutes, resulting in a total integration time of ≈ 6 hours. Figure 3 shows the deduced magnetic field (polarization vectors rotated by 90°). The information shown in the map is manifold. In the background is a total power map of OMC-1. On top of it, polarization vectors are drawn with a resolution of $10''$ per vector. The polarization degree is proportional to the length of the vectors. In the top right corner the size of a 5% vector is shown for reference. The position angle is indicated by the direction of the vectors, and it is referred to the equator and increases from east to west. The quality of the detection is represented by the width of the vectors (see the top right corner for a scale). The map shows only detections that are better than 1σ. The total power threshold in this map is fixed to 4 Jy, 2.4% of the peak. Where the total flux is above this threshold, and no vector is drawn, no meaningful polarization signal was detected. The

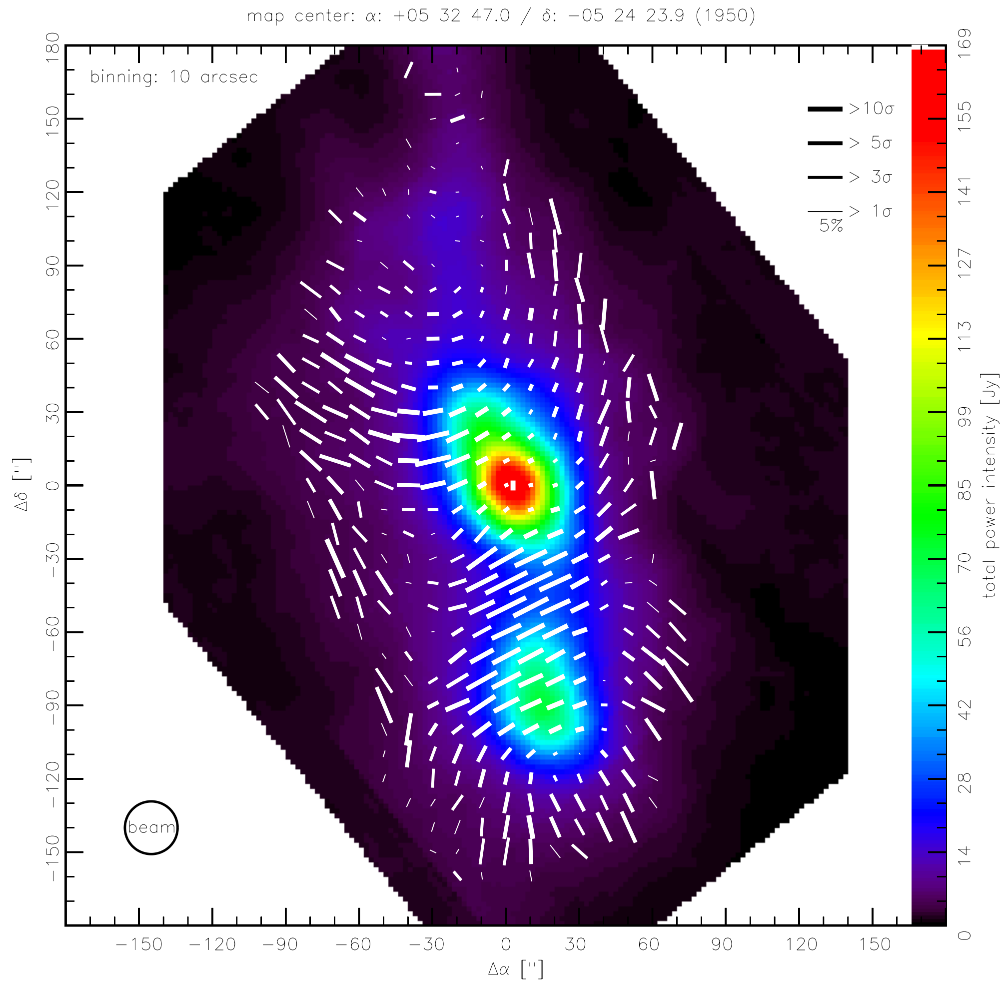

Fig. 3. Polarization degree map of Orion OMC-1 centered on IRc-2. Polarization vectors are rotated by 90° to show the inferred direction of the magnetic field. The length of the vector is proportional to the polarization degree.

maximum flux in the map is in the BN/KL area where the total power has a peak of 169 Jy/beam. In the surroundings of the peak, 1% of polarization produces a signal of about 1 Jy and a detection at 15σ is possible. We see, however, that the degree of polarization decreases going towards areas of the map where the total flux is higher. This is a well known depolarization effect, already observed in other dust clouds (see, for example, Matthews et al. 2001; Houde et al. 2002). Figure 4 shows the depolarization effect observed by PolKa in OMC-1. The magnetic field directions in our OMC-1 map are in excellent agreement with those determined by Coppin et al. (2000) at 850 μm and by Schleuning et al. (1997) at 350 and 450 μm, although our polarization degrees are higher, as expected from the arguments mentioned in the introduction.

4 Conclusion

Our polarimeter uses only metallic reflections and this gives it very low insertion losses and a high efficiency. PolKa is tunable: by simply adjusting three screws one can switch from one operating wavelength to another. Besides this, PolKa's tunability can be used to transform the half-wave plate to a quarter-wave plate with ease and the same instrument can be used to perform also circular polarization observations. The radiation is modulated directly by PolKa, without the need for a chopping secondary mirror. The modulation frequency can be much higher than when using a wobbler

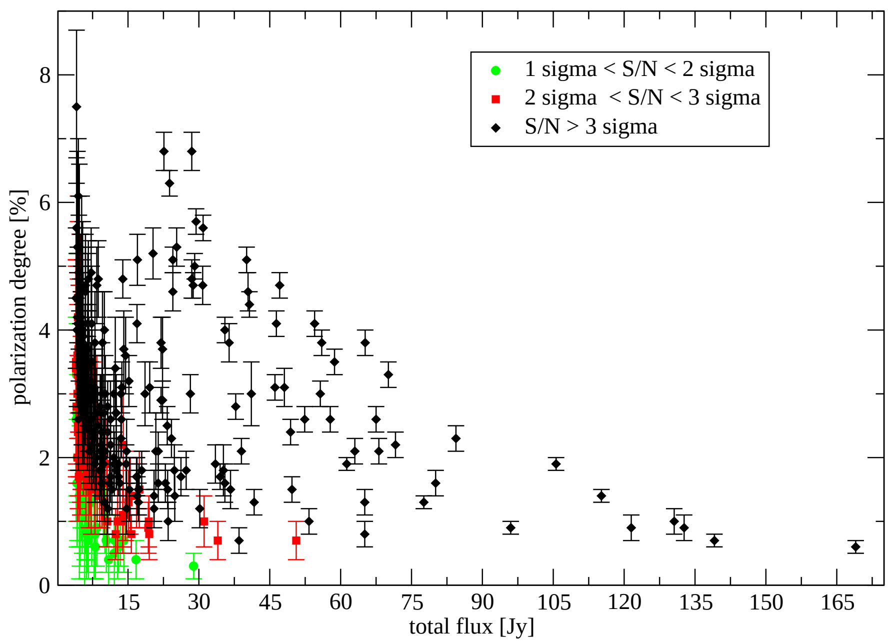

Fig. 4. Depolarization effect observed by PolKa in OMC-1. Detections better than 3σ are drawn in black.

and the polarimeter can be used even at telescopes with a fixed secondary mirror. Furthermore, the polarization signals are restored by digital phase-sensitive detection and not by fitting a sine wave to a noise-dominated signal, as commonly done in other polarization experiments. The tests at the telescope showed that PolKa is able to produce high-quality polarization data. In particular, it can produce large polarization maps with high signal-to-noise in a relatively short time. PolKa will be installed at the IRAM 30-meter MRT, where the MAMBO receiver is operating at 1.2 mm. A larger version of PolKa will be installed at the new submillimeter telescope APEX in the Atacama desert in Chile in combination with the new array LABOCA, made of 300 bolometers operating at 870 μm.

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Astronomical Research at the TUBITAK National Observatory

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Abstract. Telescopes, instruments, and astronomical research carried out at the TUBITAK National Observatory are briefly described. Further information can be obtained at www.tug.tubitak.gov.tr

1 Introduction

After a sight testing survey in Turkey (Aslan et al. 1989), TUBITAK National Observatory(TUG) was established on the mountain Bakirlitepe of West Taurus Mountains (Height: 2547 m, Longitude: $2^{\mathrm{h}}1^{\mathrm{m}}20^{\mathrm{s}}$ East, Latitude: $36°49'30''$ North). Affiliated to TUBITAK (Scientific and Technical Research Council of Turkey), TUG was opened officially in 1997 and started proper scientific observations in September 2000. It is reached via the small skiing village of Saklikent, which is about 50 km west of the city of Antalya. The mountain road from Saklikent to the observatory is about 7 km. The Main Building consists of guest rooms, a computer room, a library, and a workshop. Its south-facing side has a specially designed passive solar heating window system.

2 The telescopes

TUG has two telescopes, 150 cm and 40 cm in diameter, on Bakirlitepe, and a Danjon Astrolabe stationed in the Akdeniz University Campus. A robotic telescope of 45 cm diameter (ROTSE III) will soon be placed on the mountain in collaboration with the Michigan University. Designated as RTT150, the 150-cm telescope is a joint facility between IKI–RAN (Space Research Institute of the Russian Academy of Sciences), EAO–KSU (Engelhardt Astronomical Observatory - Kazan State University), and TUG. It is of Ritchey–Chrétien type, made by LOMO Inc., St. Petersburg, Russia. It has two Cassegrain foci (with and without corrector) at F/8 and F/16, and a coude focus at F/48, with plate scales 18, 9, and 2.9 arcseconds per mm, respectively.

3 Night-sky quality

Statistics on the night-sky quality are accumulating, which show that the fraction of clear nights (photometric plus spectroscopic) is about 80 to 90% during summer and 50 to 60% during winter. The average night-time wind speed during summer is about 6 m/s; it is somewhat higher in winter. An automated weather station, constructed at the observatory, will soon start recording digital meteorological data. The distribution of astronomical seeing as a funtion of airmass, measured at the RTT150, is shown in Fig. 1. The mean values of some extinction coefficients are given in Table 1.

4 Instruments

Cassegrain Instruments:

- Imaging CCD: chip: LORAL - LICK3 2048×2048 B.I., pixel size 15 micron (LN cooled),
- AP47p CCD camera: chip: Marconi 1024×1024 and pixel size 13 micron (thermoelectric cooling)

Table 1. Mean values of some extinction coefficients at TUG

k	values	errors
k_u	0.42	$\pm$ 0.02
k_b	0.26	$\pm$ 0.02
k_v	0.15	$\pm$ 0.01
k_r	0.12	$\pm$ 0.02
k_i	0.06	$\pm$ 0.01

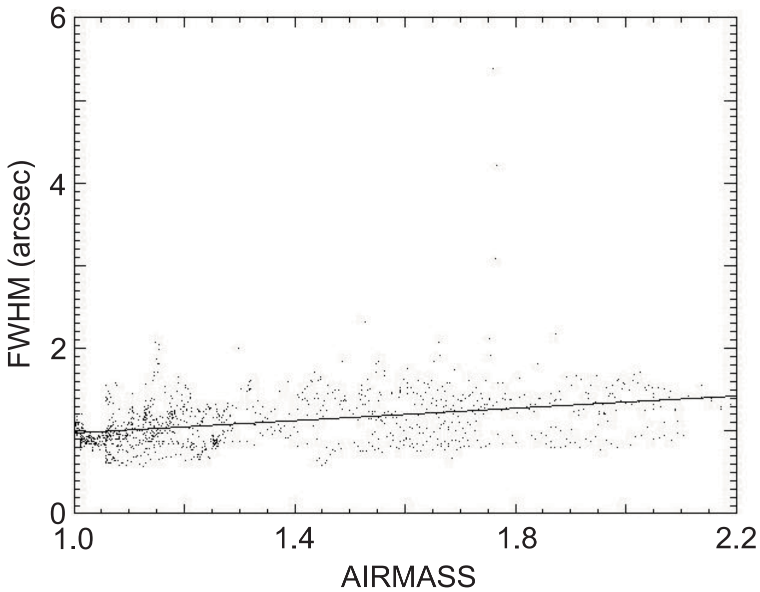

Fig. 1. Atmospheric seeing at the RTT150 plotted as a function of airmass (Parmaksizoglu et al. 2002)

- Andor DW436 CCD camera: chip: Marconi 2048×2048 and pixel size 15 micron (thermoelectric cooling)
- TFOSC (TUG Faint Object Spectrograph and Camera): It is under construction at Copenhagen University Observatory. Delivery is expected by the end of November 2003. The instrument will be a multi-purpose instrument of focal reducer type, to be used at the F/7.7 cassegrain focus of RTT150, with two modes of operation: (a) direct imaging (field of view 13.5 arcminute square), (b) low-medium resolution spectroscopy in the wavelength range 3300–10000 Å with resolution R $\sim$ 200–4000 using a set of normal and echelle grisms. The chip of its CCD camera will be Fairchild 447 (15 micron, 2048×2048).

Coudé instruments:

- Echelle CCD Spectrograph: It has been constructed at the Special Astrophysical Observatory and Kazan State University. It is a high resolution instrument with R = 40000–100000, S/N > 100, and wavelength range 3500–9500 Å. It is being installed in the telescope's coudé room.
- DEFPOS (Dual Etalon Fabry-Perot Optical Spectrometer): It has been constructed jointly by Cukurova University, Adana and Middle East Technical University, Ankara. It is under test. DEFPOS has been designed to investigate the faint optical interstellar Hα emission from the interstellar medium at $4'$ angular resolution and 20 km/s radial velocity resolution.

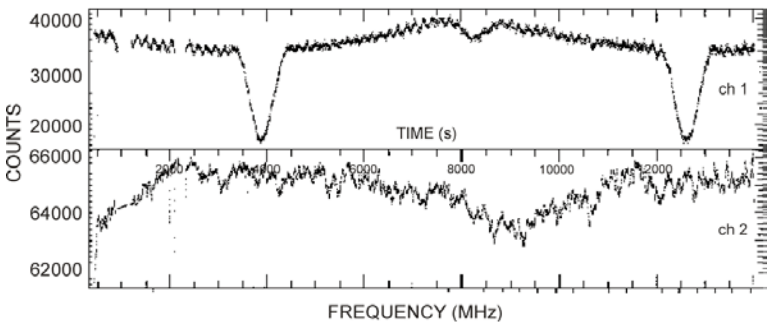

Fig. 2. Photometry of the white dwarf PG 1336 at TUG (Akan 2002)

5 Ongoing research projects

Ongoing observational projects are listed below, with the participants indicated in brackets.

Optical monitoring of gravitational lens systems (TUG+KSU)
Deep photometry of distant galaxies in selected fields (IKI)
Investigation of the shift between HIPPARCOS frame and the ICRF (KSU+TUG)
Optical counterparts to gamma-ray bursts and soft gamma-ray repeaters (TUG+IKI+KSU)
Photometry of selected cataclysmic variables (KSU)
Disk precession and quasi-periodic oscillations in cataclysmic variables (TUG)
Deep imaging of nova shells (TUG)
Rapid optical variability of x-ray sources and microquasars (KSU+TUG+IKI)
Narrow-band imaging to identify supernova remnants (SNR) in nearby spiral galaxies (TUG)
Stellar oscillations in white dwarfs (TUG)
Observations of variable stars in selected globular clusters (TUG)
Kinematics of the thin and thick disk in the Galaxy (TUG+Vilnius University)
Short- and long-time photometry of selected quasi-periodic variable stars (TUG)
Infrared photometry of red variables (TUG)
Near Earth objects (KSU+TUG)
Astrolabe observations of Solar diameter (TUG)

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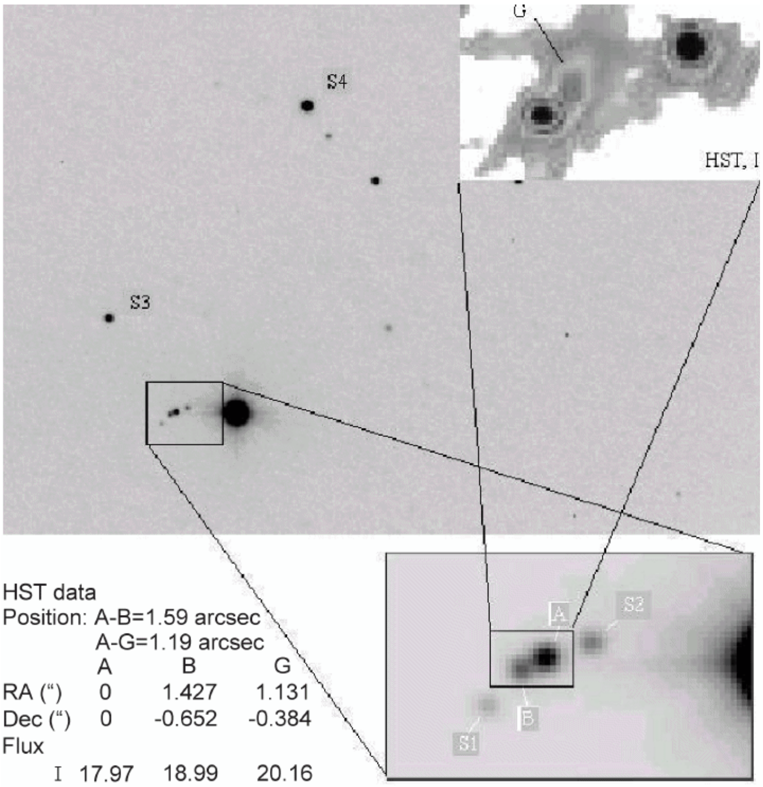

Fig. 3. Field of the gravitational lens system SBS 1520+530 obtained with RTT150 at TUG (Khamitov et al. 2002)

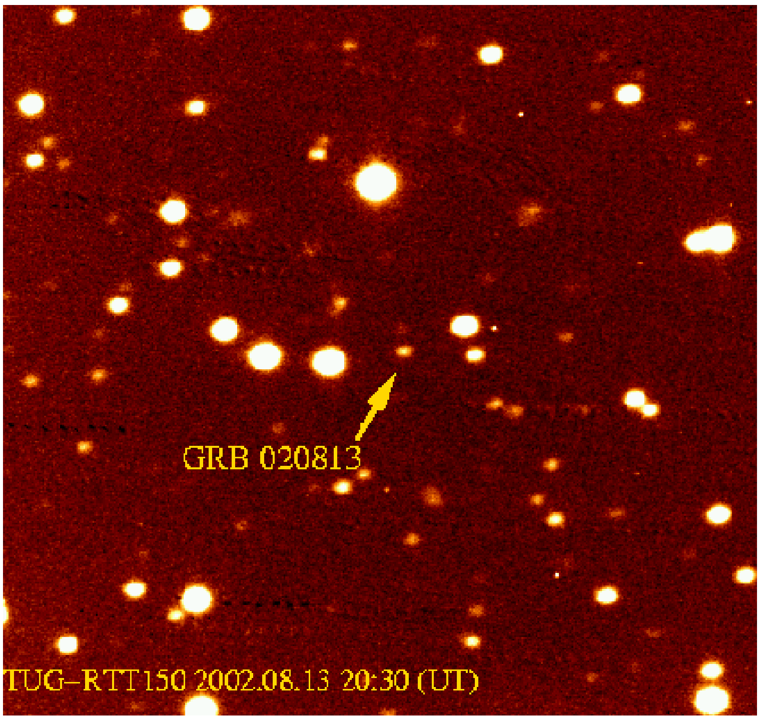

Fig. 4. Afterglow of GRB 020813 as observed at TUG with RTT150 (Kiziloglu et al. 2002)

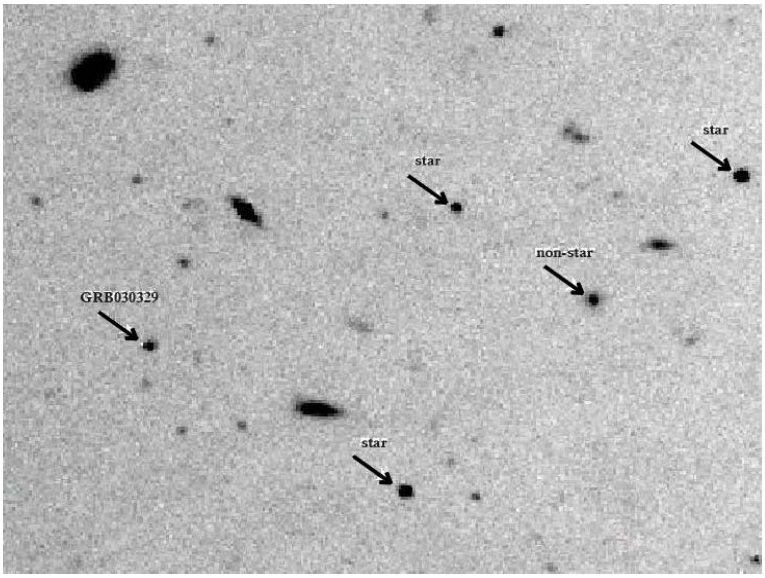

Fig. 5. Afterglow of GRB 030329 as observed at TUG with RTT150 (Khamitov et al. 2003)

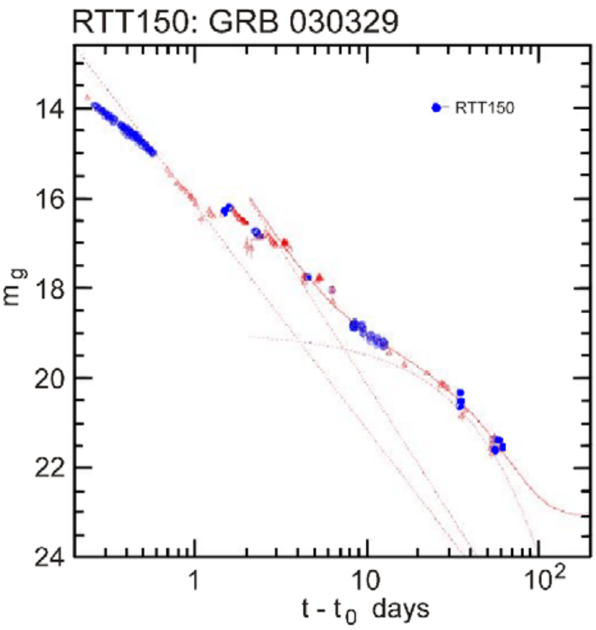

Fig. 6. Optical afterglow of GRB 030329 observed with RTT150 at TUG for 100 days following the outburst (Burenin et al. 2003)

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DEFPOS (Dual Etalon Fabry-Perot Optical Spectrometer)

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Abstract. DEFPOS (Dual Etalon Fabry-Perot Optical Spectrometer) has been designed to investigate H II regions by observing Hα emission from the interstellar medium (ISM). More detailed investigations of the characteristics including power consumption, temperature, ionization state, kinematics and spatial distribution of this warm ionized gas have been carried out in the University of Wisconsin by detection of the optical line emissions from these faint sources through Fabry-Perot spectrometer. The facility that also provided a velocity resolved H-Alpha survey of the Galaxy is called WHAM which stands for Wisconsin H-Alpha Mapper. DEFPOS has been designed to carry out a smiliar study by detecting the Hα emission from the selected regions of Galactic ISM observable on the northern sky. It will be used in coudé exit of the 1.5-m telescope (RTT150) located at Bakirlitepe near Antalya. Besides interstellar work, DEFPOS will be used to observe the earth atmosphere to examine the state of telluric hydrogen and its variation. This observation will also help to subtract the atmospheric effect from the interstellar observations.

1 Introduction

DEFPOS has been designed to investigate the faint, optical interstellar Hα emission from the interstellar medium at $4'$ angular resolution and 20 km/s radial velocity resolution. The presence of ionized gas in the Galaxy has traditionaly been associated with the bright ionized regions near hot stars called Strömgren spheres or classical H II regions. We now know that these classical H II regions contain only about 10% of the ionized hydrogen in the Galaxy. The remaining 90% is in the form of warm (around 10000 °K), low density ($0.1\,\mathrm{cm}^{-3}$), fully ionized regions which fill approximately 20% of the volume within a 2-kpc thick layer about the Galactic plane. This warm ionized medium is now recognized as a major component of the interstellar medium. The required ionizing power is $1 \times 10^{-4}\,\mathrm{erg\,s}^{-1}$ per cm^2 of the Galactic disk near the solar circle. More detailed investigations of the characteristics including power consumption, temperature, ionization state, kinematics and spatial distribution of this warm ionized gas have been carried out in the University of Wisconsin by detection of the optical line emissions from these faint sources through Fabry-Perot spectrometer with 1° angular resolution and 12 km/s radial velocity resolution. The facility that also provided a velocity resolved H-Alpha North Sky Survey of the Galaxy is called WHAM which stands for Wisconsin H-Alpha Mapper. DEFPOS has been designed to carry out a similar study by detecting the Hα emission from the selected regions of Galactic ISM observable on the northern sky. It will be used at the coudé focus of the 1.5-m telescope (RTT150) located at Bakirlitepe, Antalya. The coudé exit of RTT150 has not been working so DEFPOS has been set up in a room at the RTT150 building. Through a hole in the ceiling of the room DEFPOS has observed the zenith with a 4° field of view. It will be moved to the coudé room as soon as the coudé exit of the telescope is settled.

DEFPOS has been located at Turkish National Observatory operated under the administration of TUG Institute of TUBITAK (Scientific and Technical Research Council of Turkey) and situated approximately 50 kilometers south-west of Antalya, Turkey. TUG's location is $2^{\mathrm{h}}1^{\mathrm{m}}20^{\mathrm{s}}$ East and $36°49'30''$ North and its elevation is 2547 m.

2 Instrumentation

A schematic diagram of DEFPOS is shown in Figure 1. There is no pre-etalon optics. So light from the zenith with a 4° field of view passes through the entrance aperture and is transmitted through an interference filter F whose FWHM is 15 Å. The Hα filter limits the bandwidth of the spectrometer to the desired value and reduces the parasitic light level. Then the beam passes through the Fabry-Perot interferometers E1 and E2 which are put in separate pressure chambers. Next the lens L focuses the beam onto the CCD. The CCD camera which has been used for these observations is a Loral LICK3 back illuminated tinned and AR-coated CCD which resides in an Infrared Labs dewar. A San Diego State University controller sits on the dewar and is connected to a control card in a Sun Ultra1 computer via fiber optics communication cable. The chip consists of an array 2048×2048 square pixel, each of which has an area of $15\,\mu\text{m} \times 15\,\mu\text{m}$. The CCD is cooled with liquid nitrogen to a temperature of about −110 °C. The Sun computer is used for both controlling CCD and data taking issue. The pressure to tune the system of the chambers is changed independently to a value such that the two Fabry-Perot interferometers transmit the same wavelength simultaneously. After these pressures are determined we let the chambers stay at these pressure values and this is controlled by the pressure control system. The absolute pressure in each of the chambers is measured by sensors, sampled by an A/D converter and the valves are controlled by a data acquisition system. A mechanical vacuum pump and N2 gas controls the pressure between 0.02 and 2.50 bars. The pressure control system and monitoring are performed by a PC. Pressure sensors and temperature sensors are connected to an A/D converter card (PCL–818H High Performance DAS). An acquisition daemon samples the proper sensors, controls the pressure and vacuum valves for both chambers through parallel port. The status of the pressure system is logged and diplayed.

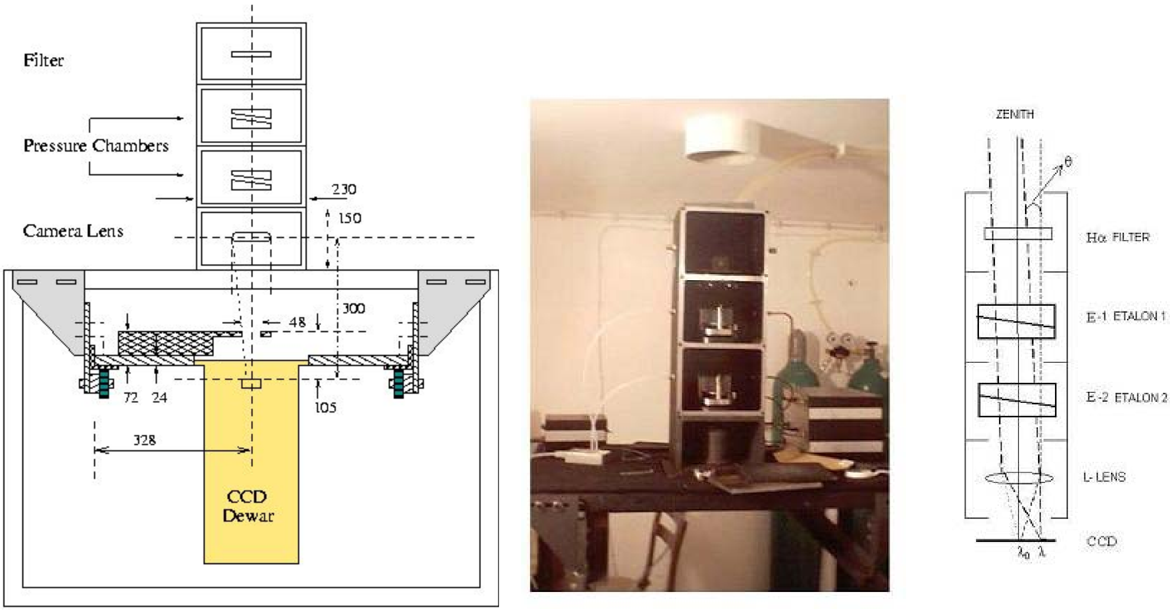

Fig. 1. *Left:* Mechanical layout of the instrument. *Right:* The picture of the instrument and the optical layout. Light from zenith passes through the aperture and is transmitted through an interference filter F. After passing through the etalons E1 and E2, the beam is focused onto the CCD by a lens L.

3 Objectives

DEFPOS will be used to investigate H II regions by observing faint, optical interstellar Hα line emission from the Galaxy and extragalactic sources with a 4′ field of view. Despite the fact that H II is a significant component of the interstellar medium, the origin and physical conditions within the warm ionized medium (WIM) remain poorly understood. Questions such as how the WIM is ionized, what is the source of heating and how its structures are formed have yet to be fully answered. The Wisconsin H-Alpha Mapper has mapped the entire sky ($\delta \geq -30°$) in the brightest emission line of this gas, Balmer Hα with a 1° field of view. DEFPOS will broaden our understanding of the observed structures with a $4'$ field of view in the WIM revealed by the WHAM Sky Survey. We will closely examine the details of the spatial structure of the gas, as well as the physical conditions associated with both the diffuse and filamentary structures with higher spatial resolution.

Interstellar studies are also very important to all astronomers because virtually all astrophysical observations must look through the earth atmosphere and through the material in the interstellar medium. Both the earth atmosphere and the ISM modify the radiation on the way from the source to the observer. Detailed knowledge of the composition and distribution is required to be understood and remove the effect of these translucent screens. DEFPOS will be used to observe both the Hα from WIM and earth atmosphere. Four samples observed on 1st August 2003 are given in Figures 2, 3, 4 and 5. The Galactic and atmospheric Hα lines on each spectrum are shown. The observed Galactic region covered $1° < b < -26°$ and $74° < l < 113°$. Each exposure's integration time has been 1200 seconds. Our future plan is to design a second Fabry-Perot spectrometer with larger etalons coupled to a siderostat for independent study from RTT150.

Acknowledgments

This work has been supported by Cukurova University, Middle East Technical University, Sabanci University and TUG. WHAM, The Wisconsin H-Alpha Mapper, is funded by the National Science Foundation.

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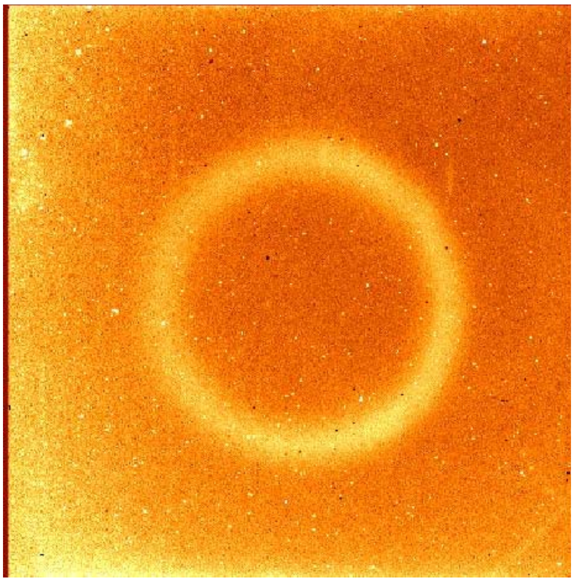

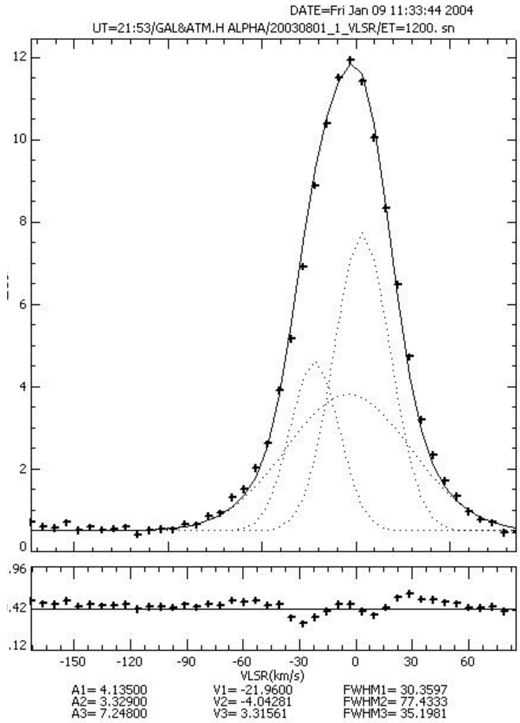

Fig. 2. *Above:* The Hα image on the CCD chip. *Right:* The corresponding spectrum. The exposure time is 1200 seconds. Observed region: $-0^\circ\!.49 < b < -3^\circ\!.7$ and $75^\circ\!.6 < l < 78^\circ\!.01$. $V_{\rm LSR}$: -20.69 km/s to 21.96 km/s.

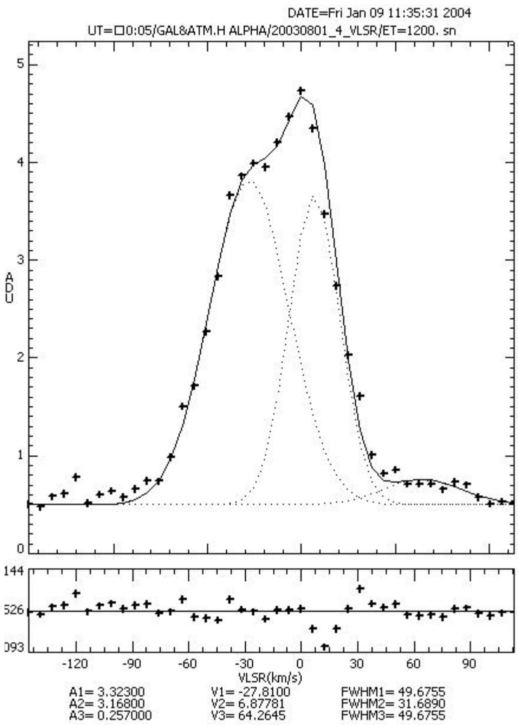

Fig. 3. The exposure time is 1200 seconds. Observed region: $-18^\circ\!.6 < b < -20^\circ\!.6$ and $95^\circ\!.1 < l < 98^\circ\!.8$. $V_{\rm LSR}$: -27.18 km/s to -27.73 km/s.

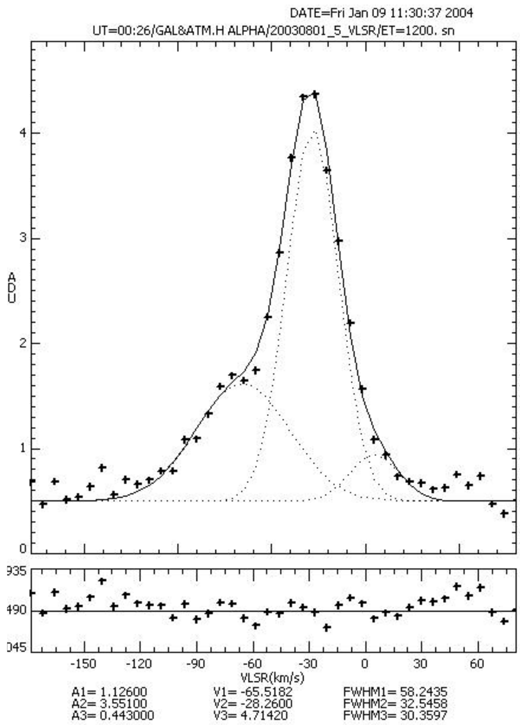

Fig. 4. The exposure time is 1200 seconds. Observed region: $-20^\circ\!.7 < b < -22^\circ\!.4$ and $98^\circ\!.9 < l < 102^\circ\!.9$. $V_{\rm LSR}$: -27.76 km/s to -28.17 km/s.

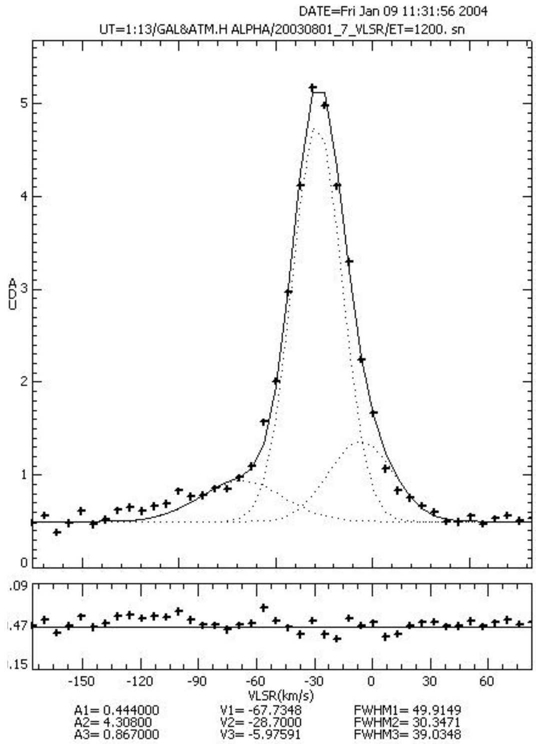

Fig. 5. The exposure time is 1200 seconds. Observed region: $-24^\circ\!.2 < b < -25^\circ\!.1$ and $108^\circ\!.5 < l < 112^\circ\!.7$. $V_{\rm LSR}$: -28.51 km/s to -28.60 km/s.

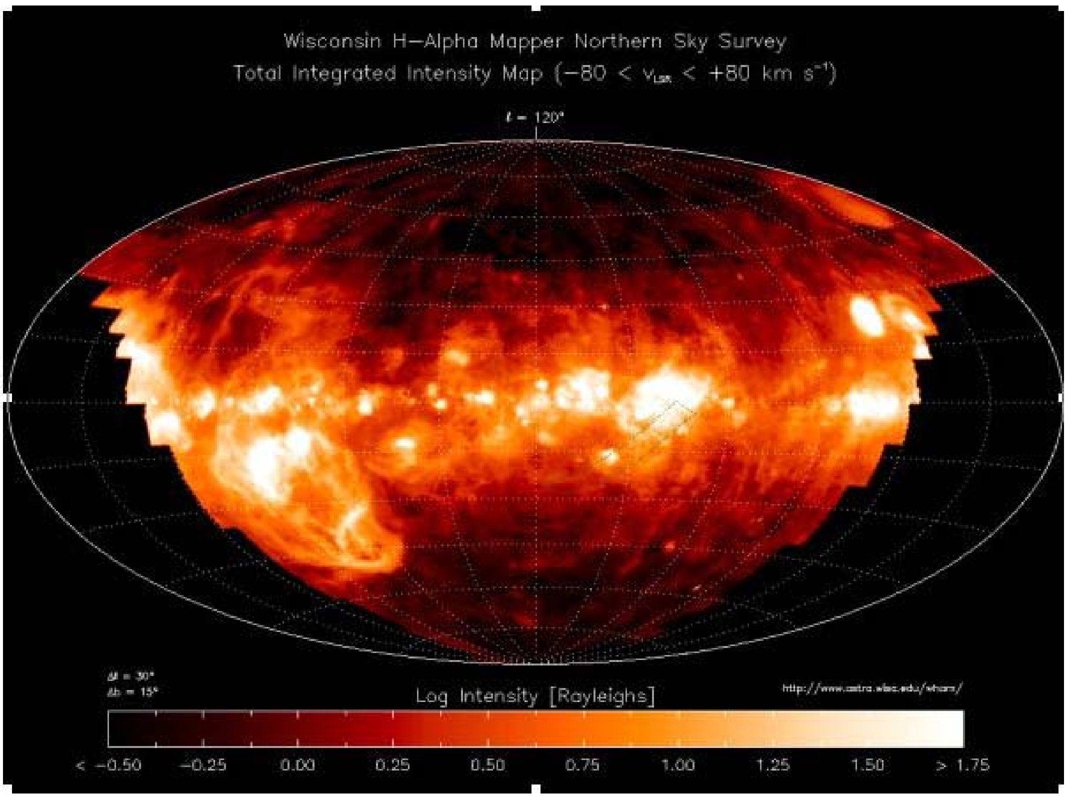

Fig. 6. The Hα Northern Sky Survey of the Galaxy provided by WHAM facility. The dotted line which has been placed on the map shows the observed region corresponding to our data shown above.

"The Magnetized Interstellar Medium"
8–12 September 2003, Antalya, Turkey
Eds.: B. Uyanıker, W. Reich & R. Wielebinski

The Erciyes University Radio Telescope Project for Neutral Hydrogen Observations in Galaxy

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Abstract. Over 40 years investigations of H I and other molecules such as OH, CO, SO etc. in our Galaxy and in other galaxies are being made. In Turkey, there are no results from observations made by radio techniques up to now. We have designed a radio telescope, a 5-m dish, with a receiver working in the 1420 MHz range.

1 Marmara Radio Telescope: MRT-2

In Turkey the first radio astronomical observations have been made with the 2-m Marmara Radio Telescope (MRT-2) which was bought from Kharkov Radio Astronomy Institute (RIAN, Ukraine) at the Marmara Research Center of the Turkish Scientific and Technical Research Council (TUBITAK-MAM) between 1996–1997. Observations have been made in the 85–115 GHz frequency range. The telescope has been designed for CO observations in the Milky Way, but due to sensitivity problems only Ozone (O3) and radiometrical Moon and Sun observations can be performed.

2 Erciyes Radio Telescope: ERT-5

Three 5-m dishes were obtained from Turkish Telecom on 19 February 2002. At the same time two pedestals for the telescopes were constructed as shown in Fig. 1.

The required electronics devices such as radiometric receiver, mechanical parts etc. are being constructed by us, and others such as H I spectrometer, oscilloscope, low-noise amplifiers etc. will be obtained through research projects in the near future.

3 The Telescope Scheme

The radio telescope block diagramme is seen in Fig. 2 below. The telescope consists of a 5-m dish, LNA, IF amplifier, spectrometer, detector, A/D converter, support system, azimuth step motor, encoder (azimuth), elevation step motor, encoder (elevation), control computer, and recorder. The instruments obtained by 2003 are as follows:

– Digital multimeter
– Step motors
– Encoders
– LNA (4, 6 and 10 GHz)
– A/D interface card
– Spectrum analyzer
– Computers for control room and printer
– Weather monitor

Fig. 1. The pedestal for a 5-m radio telescope as of February 2003

4 Future Work

Radiometric observations will be carried out at 3–4 different wavelengths in the frequency region from 1 to 20 GHz. The first stage of the system consists of a one-dish radio telescope and will be ready at the end of 2003. The final stage will be an interferometer of nearly 100 meters baseline consisting of at least 3 antennas, 5 meters diameter each. Each telescope will be set 100 meters apart inside the campus. The mechanical parts of the first telescope have been constructed. If we have enough encouragement we will obtain a hydrogen receiver and observe background radiation of the Galaxy.

Acknowledgments

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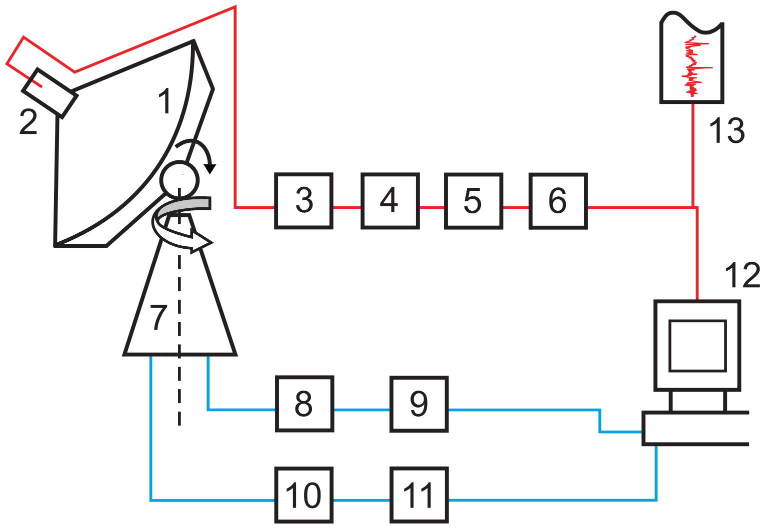

Fig. 2. The telescope block diagramme: 1) 5-m dish, 2) LNA, 3) IF amplifier, 4) Spectrometer, 5) Detector, 6) A/D Converter, 7) Support System, 8) Azimuth Step Motor, 9) Encoder (azimuth), 10) Elevation Step Motor, 11) Encoder (elevation), 12) PC, 13) Recorder

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ROTSE–III Station in Turkey

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(on behalf of ROTSE–Turkey Group)

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[2]Middle East Technical University, Physics Department, 06531 Ankara, Turkey
[3]TÜBITAK National Observatory, Akdeniz Universitesi Yerleskeşi, 07058 Antalya, Turkey

The robotic fast-response optical telescope system ROTSE–III (`http://www.umich.edu/~rotse`) is now at a phase to establish a world-wide network for continuous participation in the observations of Gamma-Ray Burst (GRB) alerts, regularly distributed through internet and other communication channels (`aavso-grb-list@informer2.cis.McMaster.CA`). Following negotiations and talks among parties, it was decided to install one of the four Global ROTSE Network (GRN) locations at the National Observatory of Turkey (TUG). The Observatory is located on the Taurus Mountains in southwestern Turkey.

After a feasibility report [1] had been presented to TUG, an internal decision was reached to participate in the program. Prof. Carl Akerlof, ROTSE Programs Director, was invited to visit Turkey in February 2002. His program included two meetings at İstanbul University with Turkish scientists from different institutions who were interested in various aspects of the ROTSE experiment. He also visited the TUG Observatory site located at Saklıkent, to the west of the city of Antalya. The geographic coordinates of the site (Bakırlıtepe) where telescopes are located are

$$\mathrm{LAT\,(TUG)} = 36^\circ 49' 30''\ \mathrm{N};\ \mathrm{LON\,(TUG)} = 02^{\mathrm{h}}01^{\mathrm{m}}20^{\mathrm{s}}\ \mathrm{E};\ \mathrm{Elevation\,(TUG)} = 2540\ \mathrm{m}.$$

The excellent seeing conditions and other relevant parameters of the observatory site were given in [2].

The present instrumentation at TUG (other than the ROTSE station) consists of 2 optical telescopes: T150 and T40 (the numbers are the mirror diameters in cm). Both telescopes have standard photomeric and imaging devices. A spectroscope is also being procured for T150. The site has a guest house with a small library, conference room, internet as well as lodging and catering facilities.

The present organisation of the Turkish team includes a score of scientists from 6 Universities who are listed in Table 1 along with their areas of expertise. In addition to running the ROTSE-III/Turkey station on a day-to-day basis, the Turkish groups aim to organize GRB-candidate follow-up observations using the TUG facilities (in coordination with other ROTSE groups) as well as to investigate the possibilities of using ROTSE data in other fields. Since the end-products of ROTSE observations is proven to be a rich source for important astronomical contributions in areas other than GRBs, our members plan to use it in fields of their expertise like monitoring of novae, cataclysmic variables, supernovae, pulsars and various types of binary stars and other variable sources, depending on the quality and extent of data available. The technical expertise to keep ROTSE and its internet connections running and alive will be available at all times without interruption.

In April 2002, a light background measurement device was acquired (from Prof. Akerlof) on loan, to see the background lighting with respect to ROTSE needs. These measurements will be summarised elsewhere. The main encloser unit has been shipped to Turkey in October 2003 and has been properly installed at Bakırlıtepe near Antalya, the site of the Turkish National Observatory. The optical instrumentation is to arrive and put into full operation in Spring 2004, starting to contribute to the global observing program of the collaboration. (We are also 'constructing' a local internet site where our reports and work as well as addresses to reach the ROTSE-Turkey research team members will be available soon.)

We expect that the ROTSE-Global collaboration will greatly enhance the possibilities for a final solution for the Gamma-Ray Burst phenomena. It will be a privilege for TUG members to contribute to the solution of one of the outstanding problems [3]) of present-day astrophysics.

Table 1. Global ROTSE Network – ROTSE-Turkey Group Members

	Name, Last Name	Institution, Location	Topics of interest
1.	Mehmet Emin Özel (*)	ÇOMÜ, Çanakkale	GRBs, gamma-ray sources
2.	Ümit Kızıloğlu (**)	ODTÜ, Ankara	GRBs, opt. instrum., COs
3.	Aysun Akyüz	Univ. Çukurova, Adana	GRBs, cluster of galaxies
4.	Talat Saygaç	İstanbul University	GRBs, binary systems
5.	Hasan Esenoğlu	İstanbul University	cataclysmic variables (CV)
6.	Şölen Balman	METU, Ankara	dwarf novae, novae, CV
7.	Ali Alpar	Sabancı Univ., İstanbul	GRBs, neutron stars, pulsars
8.	Altan Baykal	METU, Ankara	Compact Objects (CO), timing
9.	Nuri Emrahoğlu	Univ. Çukurova, Adana	observational aspects
10.	Zeki Aslan (***)	TNO/TUG, Antalya	stars, clusters, astrometry
11.	Nihal Ercan	Bosphorus Univ., İstanbul	X-ray sources
12.	Osman Demircan	ÇOMÜ, Çanakkale	binary sources, general astro.
13.	Rennan Pekünlü	Ege Univ., İzmir	binary sources, general theory
14.	Hakkı Ögelman	Univ. of Wisconsin	compact objects, HE astrophysics
15.	Ersin Göğüş	Univ. of Alabama	GRBs, Soft Gamma Repeaters

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(**) ROTSE–Turkey Coordinator (technical/instrumental aspects): umk@astroa.metu.edu.tr
(***) TUG Director (administrative aspects): aslan@tug.tug.tubitak.gov.tr

Internet sites

ROTSE-III: http://www.umich.edu/~rotse
Turkish National Observatory TUG: http://www.tug.tubitak.gov.tr
ROTSE–Turkey site (under construction): http://astroa.physics.metu.edu.tr/~umk/rotse

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[2] Aslan, Z. et al. (1989) *Astron. Astrophys.* **208**, 385–391.
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