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22 CRAF News

The newsletter of the ESF Expert Committee on Radio Astronomy Frequencies

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Editorial

We are currently living through a period of historic anniversaries. In August 2011 it will be 80 years since Karl Jansky detected the radio emission from Cassiopeia A. In April 2010, CRAF held its 50th meeting, shortly after the 50th anniversary of the recognition of radio astronomy as a radio service by the crucial Administrative Radio Conference in Geneva in 1959. That conference recommended that the radio regulations should state that:

- radio astronomy is astronomy based on the reception of radio waves of cosmic origin;
- the radio astronomy service is a service involving the use of radio astronomy.

The 1959 conference also provided a list of frequency allocations for radio astronomy up to 32 GHz – since extended up to 300 GHz – which is essentially still in force today. The year 2011 will also see the 50th anniversary of the 1961 European Broadcasting Conference in Stockholm which agreed to keep the frequency band 606-614 MHz free in order to protect radio astronomy.

Even in the 1960s, there was great demand on the radio spectrum, although the high costs of acquiring and operating a radio transmitter resulted in only national agencies or powerful commercial operators owning and operating a radio station. I have recently inherited a folder containing correspondence of radio astronomers with administrations and military authorities during the period 1962-1968, and it did surprise me to read that their problems were largely the same as ours today: radar interference at 2.7 GHz; protection for the 610 MHz band; the wish of radio astronomers to observe the red-shifted hydrogen line below the allocated band of 1400-1427 MHz, as well as possible restrictions to the operation of other radio services close to a radio observatory.

Although all these problems seem to have persisted into our times, the recent advances in electronic and signal-processing technology have not only given radio astronomy new observational techniques and a great increase in sensitivity, but also brought a growing mass-market for new radio devices and wireless communication services, which have a voracious appetite for radio spectrum. The auction of a few hundred MHz bandwidth for UMTS raised 100 billion Euro in 2002. This is more than fifty times the amount that radio astronomy is expected to spend over more than ten years on the building of one of their huge next generation radio observatories like ALMA or the SKA. These observatories will be built in the southern hemisphere, a move welcomed by some administrations in Europe. For them 'Europe is not the right location for radio astronomy'. It seems, however, as if previous generations did not see it quite like that. For them, radio astronomy was the avant-garde of radio science and several very successful observatories came into being with the support of governments, administrations and universities. Radio astronomy has given us fundamental insights into our universe, and at the same time enriched education in our universities and beyond. Today, countries outside Europe, such as South Africa, India and China, recognise the value and appeal of radio astronomy for science and engineering education. They are investing in new observatories and university departments as an indigenous source of technical scientific expertise. Such investment has been very fruitful in Europe over the last fifty years and it still continues to be so. CRAF welcomes and supports the new observatories and radio astronomical departments in the southern hemisphere, but as a complement to northern operations. It is clear that there are more reasons than the opacity of the Earth to radio waves for not 'outsourcing' European radio astronomy to remote places in the southern hemisphere.

Axel Jessner, *CRAF Chairman*

Cover
Effelsberg Radio Observatory: aerial view with the 100m telescope and the prepared LOFAR field in the foreground, seen from the south.

Report from the 50th CRAF meeting

The 50th CRAF meeting was held on 28-29 April 2010 in Göteborg (Sweden) at the Chalmers/Onsala Space Observatory. Fifteen CRAF Members plus three invited guests attended the meeting. During the afternoon of the 27 April, a wind turbine meeting was also held in the Department of Radio and Space Science, Chalmers campus. As wind turbine deployment is an important issue for several European radio telescopes, it was decided to have such a meeting to exchange information and experience between people involved in RFI activity. The results of the wind turbine meeting are discussed in another section of this newsletter.

The following key items were among the many different topics discussed during the CRAF meeting:

- **CRAF Frequency Manager report for 2009**
  The Frequency Manager (FM) presented his annual report for 2009, highlighting the fact that the risk of losing frequency bands currently allocated to RAS is very high. During 2009, the FM had spent a lot of time maintaining and updating the CRAF website. The FM pointed out that the number of international meetings that could impact on the frequency bands allocated to and used by radio astronomy was dramatically increasing. The CRAF plenary session approved the FM's report.
- **Future organisation of CRAF**
  An official letter has been sent to the directors of the EU observatories to inform them about the precarious financial and manpower situation of CRAF.
- **Contract extension of the CRAF Frequency Manager**
  The contract extension of the CRAF FM was discussed in a closed meeting restricted to funding institution representatives, an invited adviser and the CRAF Secretary.
- **Main issues currently of interest to radio astronomy**
  – ***CEPT matters:***
  1. UWB:
     - Level Probing Radar (LPR) in the frequency bands 6-8.5 GHz, 24.05-26.5 GHz, 57-64 GHz and 75-85 GHz;
     - UWB Airborne applications operating in the bands 3.1-4.8 GHz and 6.0-8.5 GHz;
     - LAES/LT2 in the frequency bands 3.4-4.8 GHz and 6-8.5 GHz
     - Automotive UWB SRR at 24 GHz
     - SRR/WLAM 26 GHz;
  2. Iridium
  3. Wind turbines

  – ***ITU matters:***
  1. Agenda Item 1.6/Resolution 950 on the use of the frequencies between 275 and 3 000 GHz.
  2. Agenda Item 8.1.1, Issue C, Resolution 673 (WRC-07), Draft New Report ITU-R [ESSENTIAL ROLE OBSERVATIONS], available from: *http://ties.itu.int/u/itu-r/ede/rsg7/rwp7c/r7c-earthobs/*
  3. Agenda Item 1.20 High Altitude Platform Stations (spectrum identification for gateway links for high altitude platform stations (HAPS) in the range 5850-7075 MHz in accordance with Resolution 734 (Rev. WRC 07).
  4. Agenda Item 1.8 'to consider the progress of ITU R studies concerning the technical and regulatory issues relative to the fixed service in the bands between 71 GHz and 238 GHz, taking into account Resolutions 731 (WRC 2000) and 732 (WRC 2000)'.

The next CRAF meeting was scheduled for the 4 November 2010, at the National Astronomical Observatory (OAN), Madrid (Spain).

Pietro Bolli

A new Italian mobile laboratory for RFI monitoring

The scheme for the RFI monitoring systems adopted at the Sardinia Radio Telescope and Medicina (Bologna) has two different elements: (1) a fixed station with antennas placed on a tower close to the radio telescope; and (2) a mobile laboratory to provide closer access to the RFI transmitter. The combination of these facilities provides the

Figure 1.
The mobile laboratory for RFI monitoring.

highest probability of detecting and identifying all kinds of possible RFI and the determination of their characteristics such as amplitude, central frequency, bandwidth, modulation type and content, azimuth direction, polarisation and finally the exact location of the transmitting source (by using triangulation with the mobile laboratory). A modern mobile unit (based on a Mercedes Sprinter 315 CDI – 4 driving wheels) equipped with state-of-the-art radio frequency instrumentation has recently been purchased for the SRT project. The mobile unit has been manufactured by a leading Italian company, G. Barberi. The vehicle has a retractable telescopic mast that can reach a maximum height of 11 m (orientable in azimuth either electronically or manually), on which antennas, an electric polariser and a room-temperature front-end box can be accommodated. The front-end consists of different band-pass filters selectable through switches controlled by a unit inside the van. The microwave filters are followed by a commercial low noise amplifier and they are designed to ensure an input power in the amplifier lower than the amplifier 1 dB-compression point. The RF signal is transferred along a coaxial cable with a spiral configuration around the mast to the laboratory inside the van for data processing using an Agilent PSA 4446 spectrum analyser and a professional receiver ICOM IC-R9500 installed in an anti-vibration rack. The upper operational frequency limit is 18 GHz under normal conditions, but with minor modifications it can be extended to 40 GHz. The mobile station is self-powered by the van's alternators or auxiliary batteries connected to inverters to provide 220 V @ 50 Hertz. The main electrical characteristics of the mobile RFI monitoring systems are a noise figure lower than 6 dB up to 18 GHz and a very high 1 dB compression point.

Pietro Bolli

Wind turbine meeting

A wind turbine meeting was held on 27 April 2010 at the Department of Radio and Space Science, Chalmers, Göteborg, Sweden prior to the CRAF50 meeting. The main reason for the meeting was to exchange information and experience on the impact of wind turbines on radio astronomy. Both CRAF members and invited external people participated. The first talks provided a general overview of the concept of RFI. A representative from the Swedish National Administration, PTS, described the permission process for wind turbines in Sweden (*https://www.vindlov.se/*). The meeting then discussed measurements from both primary and secondary radiation from wind turbines and their implications. The current status of wind turbines, both existing and planned, in the vicinity of radio telescopes in Europe was presented and discussed. The meeting ended with a proposed assessment scheme which can be found on the CRAF webpage.

The participants at the meeting agreed that wind power deployment should be encouraged by radio astronomers. However, it was demonstrated that wind turbines in the vicinity of radio observatories (<30-50 km) can be potential sources of interference emanating from their power electronics and telemetry, as well as from the reflections of other transmitters (*i.e.* fixed links sharing the band with RAS) that would normally be shielded by the terrain. Wind turbines placed very close to the telescope can even function as a variable 'artificial moon'. The topic is new for CRAF and administrations alike. The importance of having radio astronomy involved in the local planning procedures of wind turbines near radio telescopes was emphasised.

The presentations given at the meeting can be found at: *http://www.craf.eu/windturb.htm*

Pietro Bolli & Michael Lindqvist

The Chile earthquake and the geodetic observatory TIGO

In the early morning hours at 03:34 local time, the fifth strongest earthquake ever recorded released its energy in the subduction zone in central-southern Chile. The immediate country-wide power outage indicated the magnitude of this natural hazard. For more than 2 minutes and 30 seconds the Earth´s crust underwent accelerations up to 0.6 g in all three spatial directions. The distribution of aftershocks indicated a rupture zone of ~600km along the coastline. As the earthquake focus started at a depth of ~35km, movements of several metres in the ocean floor resulted. These movements triggered at least three observed tsunami waves, washing away several coastal villages and destroying the docks and harbour of the town of Talcahuano. The urban regions of Concepción and Talca suffered building collapses and the traffic infrastructure was severely affected by destroyed bridges. The earthquake was one of many in the long history of seismic events along the coastline of Chile. The continental Nazca plate on the bottom of the Pacific Ocean is moving at ~6-7cm/year towards the South-America plate. As a result of this never-ending push, the Andean mountain chain is still being folded by the subducting Nazca plate.

Figure 2.
The geodetic observatory TIGO in Concepción, Chile. The photo shows the radio telescope for VLBI (right) and the satellite laser ranging system (middle). This observatory made significant observations towards an understanding of earthquake processes because of its location in the zone of the Chile earthquake of 2010.

The Chile earthquake of 2010 occurred right in a seismic gap zone, where a stronger earthquake had been expected for several decades.

The Transportable Integrated Geodetic Observatory (TIGO) of the German Federal Agency for Cartography and Geodesy (Bundesamt für Kartographie und Geodäsie, BKG) has been operating at the campus of Universidad de Concepción since 2002. TIGO has all the necessary instrumentation for it to be a geodetic reference point for the most accurate global geodetic reference frame, the ITRF. Thus, TIGO operates a 6m-radio telescope with an offset-mounted feed at its primary focus, which is used for Very Long Baseline Interferometry (VLBI). There is also a two-colour satellite laser ranging system (SLR) and various GPS/GLONASS and Galileo receivers in the space domain. TIGO also operates three hydrogen masers and three cesium standards in the time domain in order to produce its own time scale. In the gravity field domain, a superconducting gravity meter monitors Earth tides, and the absolute gravity meter measures the actual value of g. This ensemble is further complemented by some local sensors for meteorological, hydrological and seismological parameters. Most of the instruments have been in operation since 2002 and have, over an eight-year period, provided seismic records of motion in a global context; *i.e.* with respect to observatories on other continents.

The Chile earthquake was strong enough that in the urban area of Concepción, the energy supply was interrupted for four days, the water supply interrupted for five days, and communication (wired telephone, mobile phone, Internet) interrupted for one week. The lack of communication led to the unfortunate situation in which the government in Santiago made decisions, such as refusing international offers of help, without knowing the real extent of the destruction in the regions.

TIGO, as a permanent monitoring station, was equipped to generate its own energy through solar panels and diesel generators. This was essential in order to continue monitoring with the instruments which had not been affected. The German emergency evaluation team installed its base at TIGO, taking advantage of its autonomous supply of energy and water. The team communicated using satellite phones, which, at that time, was the only possible means of exchanging information with the rest of the world.

Soon after the earthquakes, extensive looting of grocery stores, pharmacies and other shops began and a curfew became necessary in order for civilised life to return. In all, it took approximately two weeks for the staff of companies and institutions to return to their work. These two weeks were necessary for repairs, both at home and at workplaces; fixing broken pipes and taking down collapsed walls and fences. The work at the observatory started with the same rhythm. Checks had to be carried out to verify that the instruments were still working properly. By then it was already known, thanks to TIGO's continuous GPS/GLONASS records, that the observatory site had moved 3.04m to the west. The questions were whether the platforms were still horizontal and whether it was a pure translation or whether new azimuth offsets needed to be introduced. As far as the radio telescope was concerned, there was no evidence of a need for new encoder offsets and hence it became operational again on 15 March. The most affected instrument was the SLR-System. Its telescope had moved and the optical laser table had been hit by its housing container. This required repairs to the various optical components and a completely new installation, which took approximately six weeks. Another unexpected surprise was the fact that all the helium gas bottles, which had been standing chained to the wall, were found on the

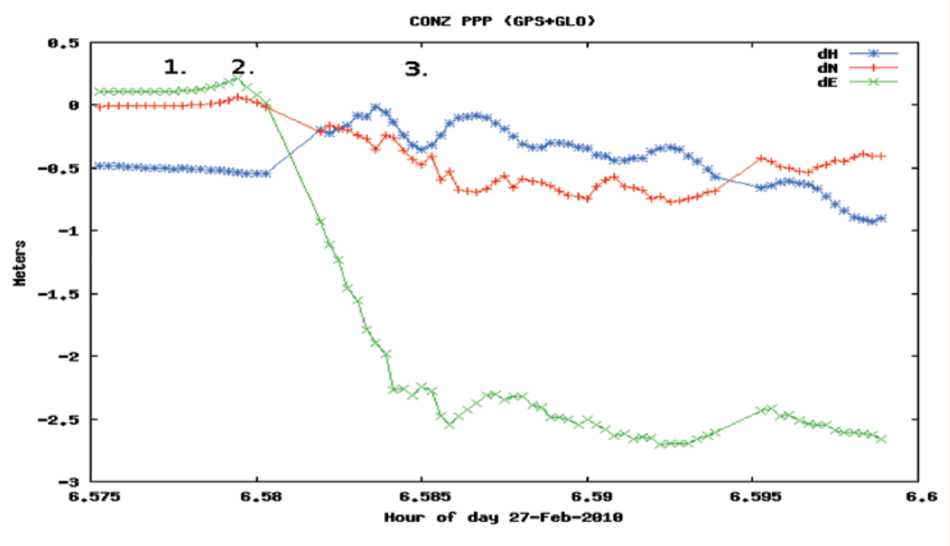

Figure 3. GPS/GLONASS position in the three components: height, north and east vs. time during the earthquake recorded with 1-second samples at TIGO station CONZ. The three earthquake phases are marked with the numbers **1.** kick; **2.** displacement of 3m in 30s; **3.** seismic movements during rupture process.

ground. The strength of the chains had been insufficient to resist the earthquake. One of the 72 battery cells was found to have broken and had contaminated the battery room, which needed a complete decontamination and reinstallation.

Step by step, the earthquake problems have been resolved so that TIGO is now working almost as before.

Meanwhile, several research teams and analysis groups have looked at the TIGO data. They are unique in earthquake research. The solar-battery powered GPS/GLONASS receiver recorded 1-second samples throughout the earthquake showing an unseen sequence of positions of how the displacement occurred (see Figure 3). Three phases can be distinguished. In the first phase a 10s-long strong movement in a direction towards the north-east occurred, which was an accelerated kick in the same direction of motion as had been monitored in the previous eight years with a velocity of 35mm/year. It can be interpreted as the Nazca plate triggering the earthquake. The second phase had a duration of approximately 30s in which a large displacement of more than 3m took place. This was the moment when both continental plates, the Nazca and South-American, decoupled and slipped in opposite directions. The third phase showed movements of ~30cm in the three components during the following two minutes of earthquake. This was the time when the rupture between the two plates propagated from the epicentre, mainly to the north but also to the south. Concepción received seismic waves from all directions, and therefore some high buildings could not withstand the acceleration forces.

The displacement of more than 3 metres was confirmed by the independent methods of VLBI and SLR. These kinematic results showed that, over decades, the South-America plate had been squeezed like a sponge and it then expanded again when both plates separated. Scientists are now interested in whether all the accumulated energy has been released or not. If yes, then the number of aftershocks should slowly decrease and fade out. If not, another large earthquake may occur in the now fragile ruptured zone. In this regard the directions of the pre-seismic and post-seismic motions contain a clue. Strain and stress will be built up if both motion directions are not at 180° to each other, and it is therefore important to continue measurements. Figure 4 shows the collected point position.

These examples demonstrate how geoscientists are using microwave techniques (Global Navigation Satellite Systems, Very Long Baseline Interferometry) in order to improve the understanding of our Earth system. The observation capabilities are dependent upon interference-free radio environments. It is hoped that future generations may be able to predict earthquakes and hence reduce the associated economic losses. From the above examples it is clear that we are just beginning to discover the mechanisms inside the Earth´s interior, and many more years of further studies await us.

Hayo Hase

RFI2010 – The RFI Mitigation Workshop (29-31 March 2010, Groningen, The Netherlands)

Radio interference is increasingly affecting the quality of data obtained by the Radio Astronomy Service (RAS) and the Earth Exploration (Satellite) Service (EESS). The increased sensitivity of instrumentation for passive use of the spectrum at radio astronomy stations, and the intensifying use of the spectrum by active users, lead to increasing data loss. The avoidance of this interference, and its removal if it enters data, are of great interest to the observatories. The RFI Mitigation Workshop, the third in a series, considered RFI mitigation in radio astronomy in

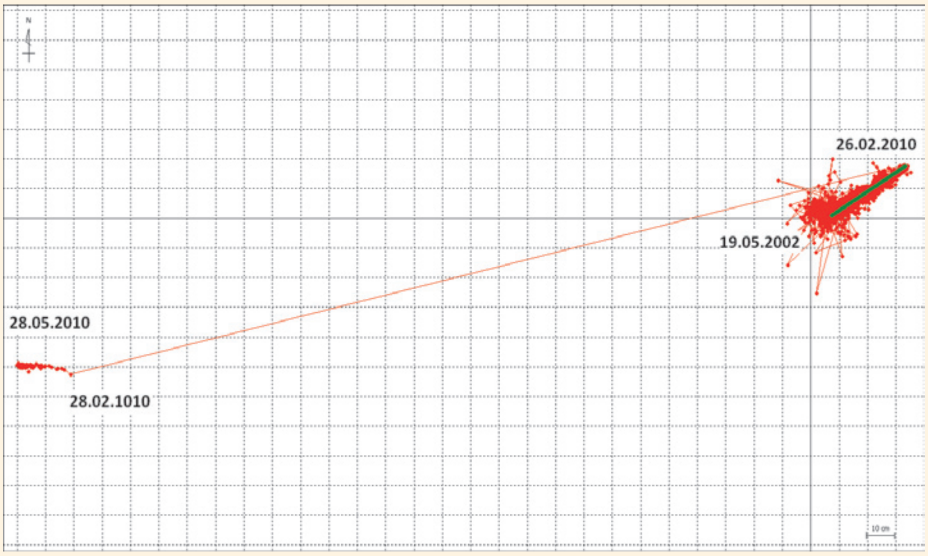

Figure 4.
Walking map of the geodetic monument CONZ measured by GPS/GLONASS. From *19* May 2002 until *26* February 2010, a clear north-east motion of approximately 35mm/year is evident. 30s of earthquake displaced the point by more than 3m. During *three* post-seismic months the motion is oriented towards the west.

all its facets, with the goal of facilitating the implementation of instrumental and data processing techniques. The workshop aimed to take a forward look at their application to existing instruments and to the next generation of radio astronomy instruments, such as the SKA and its pathfinders, and LOFAR. Historically, RFI mitigation has been given a relatively low priority by many observatories and by their users. However, the changing operational conditions and the objective of increased sensitivity of new instruments will force observatories and their users to embrace RFI mitigation solutions.

Interference inside bands allocated to radio astronomy and the passive services always leads to data loss for the passive users of the spectrum in either the time or frequency domains, even if interference mitigation is applied. Permissible percentages of data loss for RAS bands defined in the ITU-R literature amount to approximately 5% in time or frequency. Interference mitigation may facilitate the partial use of active bands for passive observations. However, data loss for observations in bands allocated to other services needs to be accepted because the astronomers operate there under a no-protection principle. In fact, radio astronomers increasingly observe outside bands allocated to the RAS in order to perform (highly sensitive) broadband continuum studies and to search for red-shifted spectral line emissions from galaxies in the distant universe. However, it should be noted that the ability to mitigate interference cannot be used as an excuse for generating unwanted emissions inside the passive RAS bands.

There is no generic method to mitigate each class of interference. Although simple excision of the affected data using visualisation for identification of the RFI and just accepting the associated data loss have been the remedies under most circumstances, such a method becomes cumbersome when using broadband and multistation interferometer systems. Recent advances in technology and computing must be exploited in order to mitigate the effects of interference. All methods depend on the detectability of the interference (*i.e.* the interference-to-noise ratio, INR) and therefore the implementation of different mitigation methods at specific points in the data path may be advisable to reduce the detrimental effects of RFI. Strong interference may be mitigated earlier in the signal path. The different methods of mitigating radio frequency interference considered in the RFI2010 Workshop address both the issue of avoiding RFI and of removing it from the astronomical data.

The RFI2010 Workshop successfully presented a great variety of mitigation options and displayed encouraging results with both on-line and off-line data processing. Since there is no universal method for RFI mitigation, the choice of the mitigation method depends on the RFI characteristics, the type of telescope and the type of observations being made. As noted above, multiple methods need to be used to remove both strong and weaker RFI from data. However, the cumulative effect of the implementation of RFI mitigation at various stages is not a linear sum, as RFI algorithms are generally non-linear processes that depend on the INR and the characteristics of the RFI, and the latter change after each mitigation step. The result is that a quantitative evaluation of the methods is not always possible and the removal of RFI can not only raise the noise level but also affect the gain calibration of instruments in an incalculable way. Further implementation of RFI mitigation in single-dish and array instruments will show the potential of each of the various methods.

The subjects discussed during the RFI2010 Workshop covered a very wide range:

- measurement of the spectrum environment, characterisation of the RFI at the telescope and ways to eliminate sources of interference;
- spectrum management approaches, the regulatory methods of protecting the radio telescopes;

- existing quiet zones and those for new generation radio telescopes;
- spectrum challenges for radio telescopes such as cognitive radio and ultra-wide band applications;
- RFI mitigation methods and at which stage in the data path to use them optimally;
- digital and sub-space filtering using peculiar characteristics of the RFI;
- various methods of pre-correlation thresholding of RFI in the time and frequency domains used in wide-band spectrometers;
- adaptive noise cancellation of specific RFI signals;
- spatial filtering with array instruments;
- statistical methods to identify RFI components in the data and how to remove them;
- RFI mitigation algorithms built into software correlators;
- automatic post-correlation RFI detection and flagging algorithms applied to newly built telescopes with high data rates such as the Allen Telescope and LOFAR; and
- post-correlation methods to identify and remove the signals of distinct terrestrial sources (at the horizon) during post-correlation processing.

The 41 presentations of this workshop can be found at *www.astron.nl/rfi/*. The refereed papers will be published at the free-access web-based Proceedings of Science under RFI2010 at *pos.sissa.it*. The papers may also be found on SAO/NASA ADS. There were 72 registered participants in the workshop held at the Hampshire Plaza Hotel in Groningen, The Netherlands.

This workshop was organised by ASTRON and NAIC with financial support from ASTRON, URSI International, the Engineering Forum of RadioNet FP7, and the SKA Project Development Office, and in collaboration with CRAF and IUCAF. The first workshop was held in Bonn, Germany (2001); the second in Penticton, Canada (2004).

Willem A. Baan

Committee on Radio Astronomy Frequencies (CRAF)

CRAF is an Expert Committee of the European Science Foundation. Established in 1988, it represents all the major radio astronomical observatories in Europe. Its mission is to coordinate activities to keep the frequency bands used by radio astronomers in Europe free from interference.

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