About this document

This is a report on the tests of EMIR after the installation of the upgrade of the dichroic D13 and work on the relative alignment of the bands.[1] The upgrade of D13 improves the performance (T_{rec}) when E090 and E230 are used simultaneously, in particular for E230 near 270 GHz.

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1 D13 is the dichroic used to combine the beams of EMIR band 1 – E090 and band 3 – E230.

Revisions

2017-02-01 v1.0   HU   first released version. reviewed by SN, CM

Issues

During the technical time (TT, project t07-16) we encountered various issues – some of them not directly related to the upgrade of D13 or to the improvement of the alignment of bands:

1. The first night of TT was scheduled between VLBI shifts at 3mm (E090). To avoid changes between VLBI- and non-VLBI setups, we had planned to use E090 only at the standard VLBI frequency. However, during he night it was decided for technical reasons to not continue the VLBI session and we changed the strategy for our TT accordingly.

2. TAPAS was not functioning correctly.

3. The data and log files were not properly organized into the project t06-16 directories observationData/2016*/scans/*

   The above 2 items made the organization / logging / tracking of our tests difficult.

4. The frequencies in the listing of calibration values in MIRA can be inconsistent in some configurations.

5. For several test setups we tuned E230 with an LI frequency near the upper limit documented on the EMIR Users Guide wiki at the time (http://www.iram.es/IRAMES/mainWiki/EmirforAstronomers#Sky_frequencies).
   In discussions after the TT NCS it became clear that this limit was too high
   (26 Oct 2016, at 18:18, Navarro <navarro@iram.es>) [2]
   !! Test data obtained for E230 with these tunings are therefore not valid and are not used in this report. This is in particular the case for setups with which we tried to observe simultaneously the J=1-0 and 3-2 lines of HCN !!
   Actually, with the current limits it seems not possible to command directly the frequencies of the J=1-0 and 3-2 lines of HCN to observe them, e.g., centered in VESPA (26 Jan 2017, at 12:26, Navarro <navarro@iram.es>).

   √ The wrong upper limit on the wiki page has been corrected to 263.5 GHz √

6. The source intensities observed using only E230 were significantly lower (by 20 – 30%) than those seen at the same frequencies using the combination of E090 and E230. The reason was found to be that after the re-alignment of E090 and E230 the EMIR optics were not re-adjusted for observations with only E230.

   !! On-sky data from these tests are therefore not valid and are not used in this report !!

   Results for the receiver temperature Trec *may be OK*, assuming the E230 beam was not significantly misaligned on the calibration loads.
   !! Anyhow, they should be regarded with care !!
   √ Later on the optics was improved for observations with only E230.
   (31 Oct 2016, at 13:53, Santiago Navarro <navarro@iram.es>)

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2 The essential parts of this email and others mentioned below are reproduced in the Appendix.

Pointing scans indicate that this improvement was successful, although there are some reservations.
(24 Nov 2016, at 10:50, Claudia Marka <marka@iram.es>)

7. However, this last modification (for E230) may have left the EMIR optics not optimized for observations using only E330. On the other hand some quick tests appeared to show that observations with only E330 are OK.
(10 Jan 2017, at 10:23, Pablo Torne <torne@iram.es>)

A software modification has been implemented so that for observations using only E330 (band 4) the dichroic D24 is used instead of the mirror MR34.
(02 Jan 2017, at 20:08, Santiago Navarro <navarro@iram.es>
18 Jan 2017, at 13:27, jlsantaren <jlsantaren@iram.es>)
This modification has been tested on a technical level (Santiago Navarro).

Astronomical tests of this modification for E330 remain to be done. (2017-02-01)

Alignment

We checked the beam alignment for the band E090 with E230.
We used backends BBC and NBC.

E090 & E230
Band 1 and Band 3 combined by dichroic D13

When we use E090 and E230 combined by dichroic D13 we get residual pointing offsets that agree within ~ 2" (Figure 1). The subbands and polarizations of E090 and E230 each agree within ~ 1".

If for the same frequency setup we use only E090, without D13, the residuals agree within better than 1" (Figure 2).

If we use only E230, the residuals agree within about 1.2" (Figure 3).

observed 2016−10−01 scan 42
E090 & E230 using D13
BBC

E090 with D13

E230 with D13

E090 without D13

E230 without D13

LSB   □ ■

USB   △ ▲

Horizontal   □ △

Vertical   ■ ▲

Δ Az [arc sec]
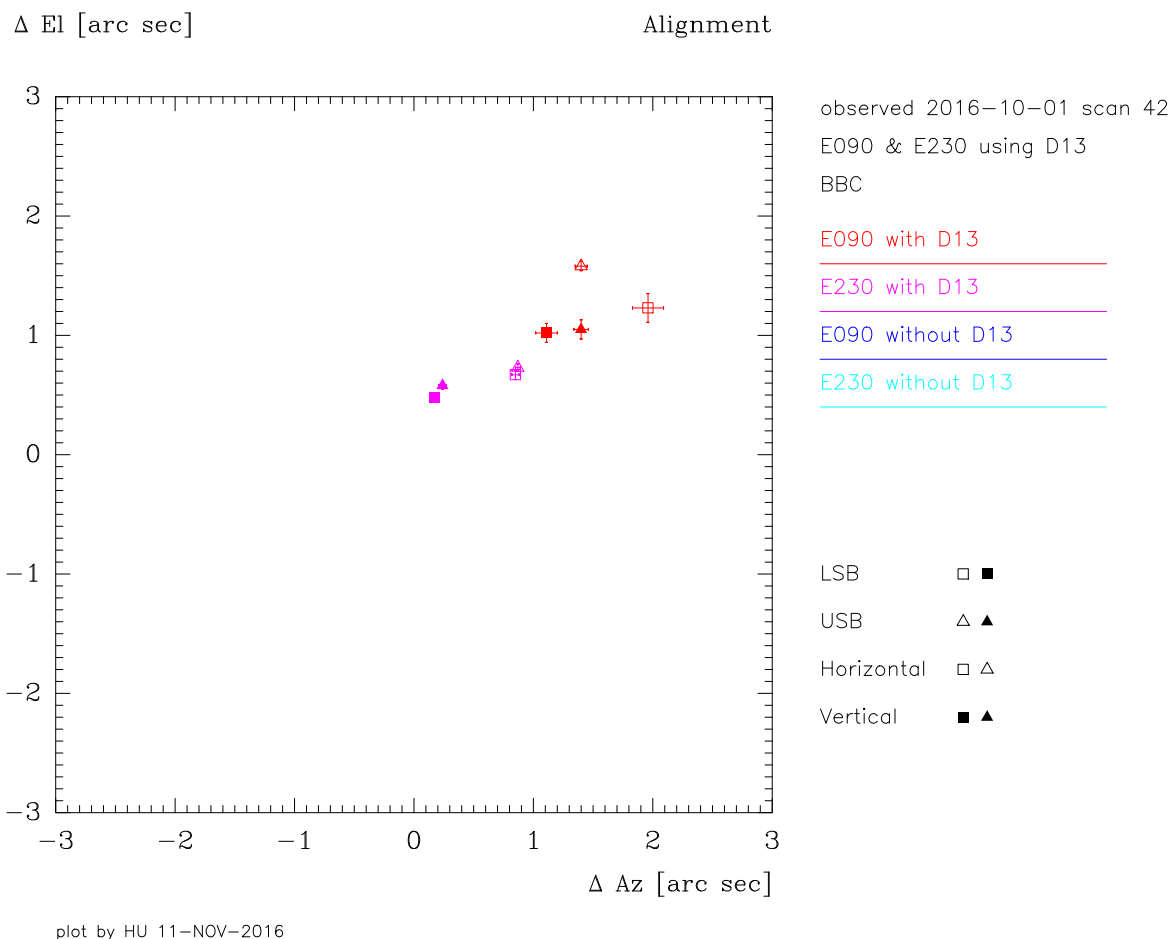
plot by HU 11−NOV−2016

Figure 1
Alignment of E090 and E230 combined with dichroic D13. Shown are the residual pointing offsets with the formal errors from Gaussian fits by MIRA to standard pointing cross scans with beam switching.
The pointing corrections commanded in paKo were 1" and 0";
the "automatic" Nasmyth offsets were −39.5" and +5.5".
The focus was checked and optimized before the pointing scan and commanded to −1.15 mm.
The frequency setup was
E090 CH3CN 73.590217 LO
E230 CH3CN 202.258159 LO
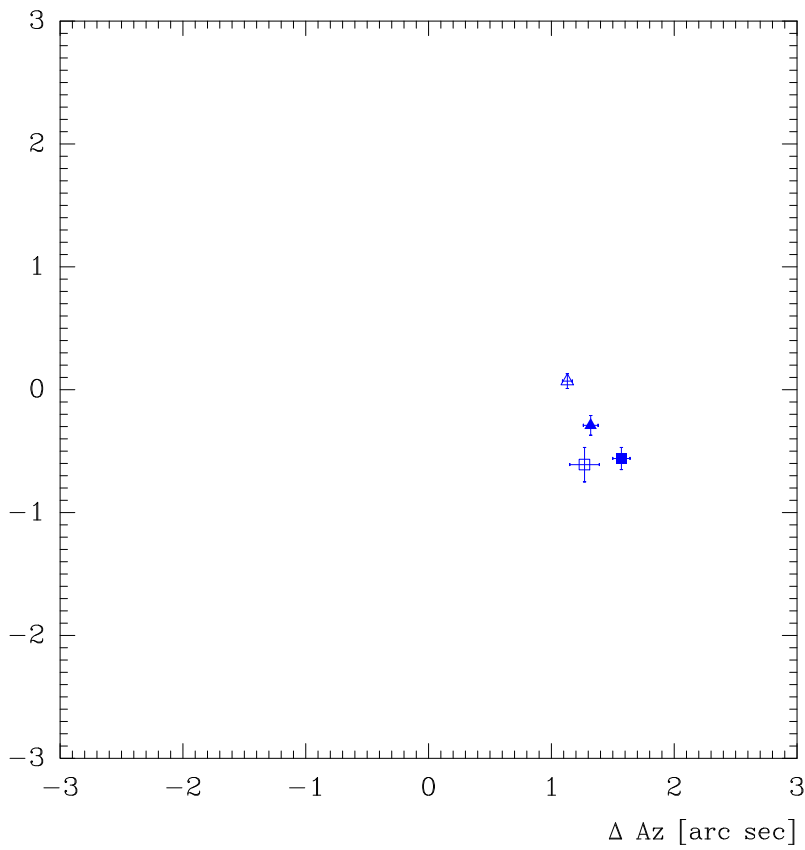so that in the BBC backends the central frequencies are
75.020 GHz for E090 LSB
91.020 GHz for E090 USB
203.688 GHz for E230 LSB
219.688 GHz for E230 USB.

Figure 2
Alignment of E090 sidebands and polarizations without dichroic; i.e., only E090 selected in paKo.
The focus was checked and optimized before the pointing scan and commanded to –1.10 mm.
Pointing corrections, Nasmyth offsets, and frequency setup were as in Figure 1.
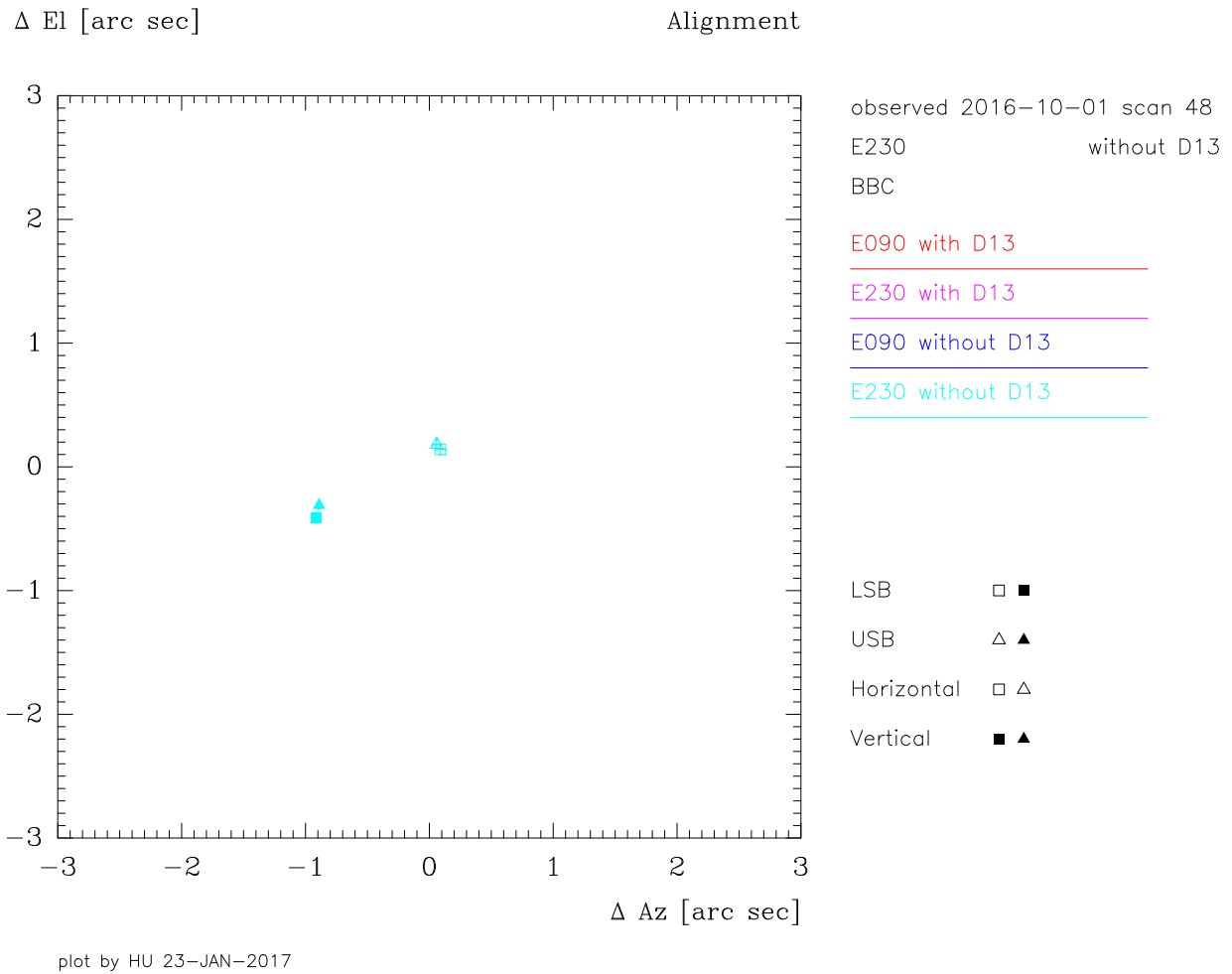
Figure 3
Alignment of E230 sidebands and polarizations without dichroic D13; i.e., only E230 selected in paKo.
The focus was checked and optimized before the pointing scan and commanded to −1.30 mm.
Pointing corrections, Nasmyth offsets, and frequency setup were as in Figure 1.
Note: these data were taken when E230 without the dichroic was not yet properly aligned. These results should therefore be regarded with caution. In particular the difference of the correction seen to those in the 2 previous figures do probably not reflect the current system.

Performance of the new Dichroic D13 for Band 1 E090 & Band 3 E230

The dichroic D13 used to combine E090 and E230 increases the receiver temperatures T_{rec} compared to observations that use only a single band as shown in the following figures.

Measured with the broad-band continuum backend BBC for E090 this increase is in the range of about 8 to 25 K, for E230 in the range of about 10 to 25 K, except at the highest frequencies in the Vertical polarization, where the increase is about 40 to 50 K.

This performance of the new D13 at high frequencies in E230 is much better than that of the previous ("old") D13 which caused an increase of T_{rec} by several 100 K (Figure 7).

With the dichroic D13, the receiver temperatures for E090 are < 55 K.

With the dichroic D13, the receiver temperatures for E230 are < 100 K except for high frequencies, ~ 272 GHz, where they can reach ~ 150 K, in particular in the Vertical polarization.

To measure the data in the following figures we used the EMIR frequency setups:

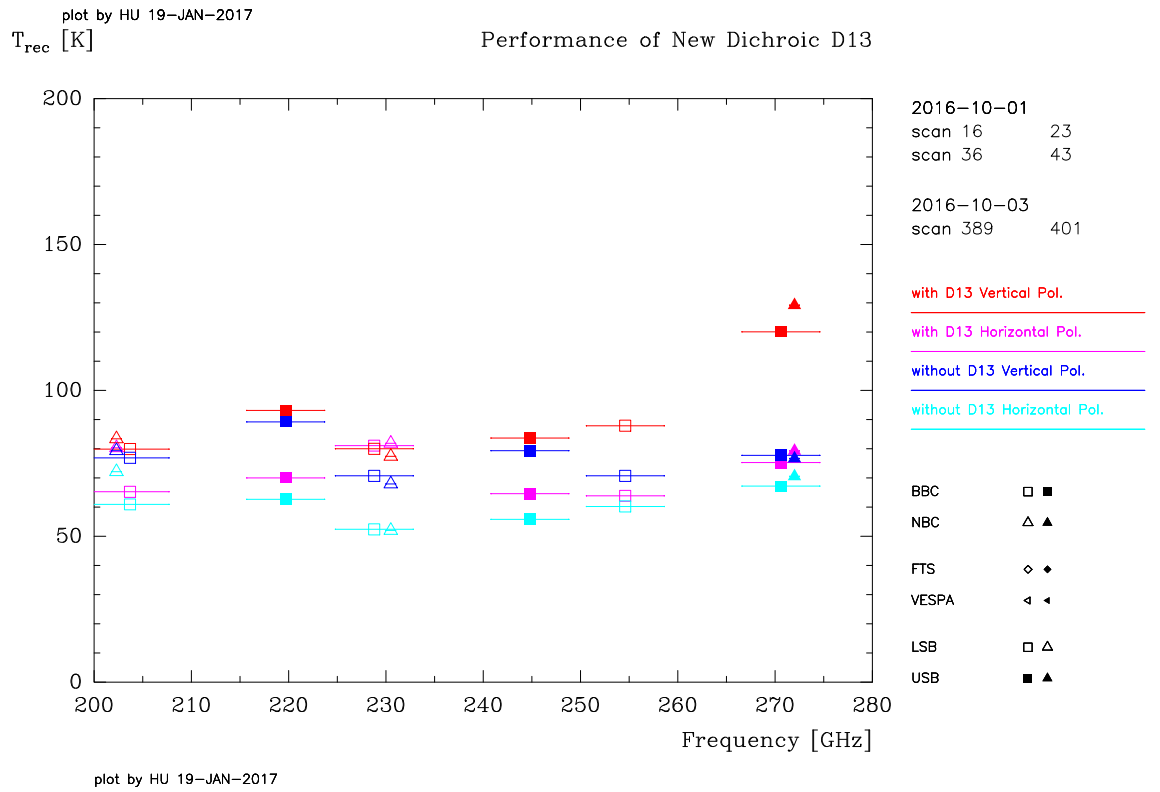| E090	CH3CN	73.590217	LO	E230	CH3CN	202.258159	LO
E090	CS	97.980965	LI	E230	CO	230.537994	LI
E090	CO	115.271204	UO	E230	HNC	271.981111	UO

Details are given in the Appendix.

Figure 4
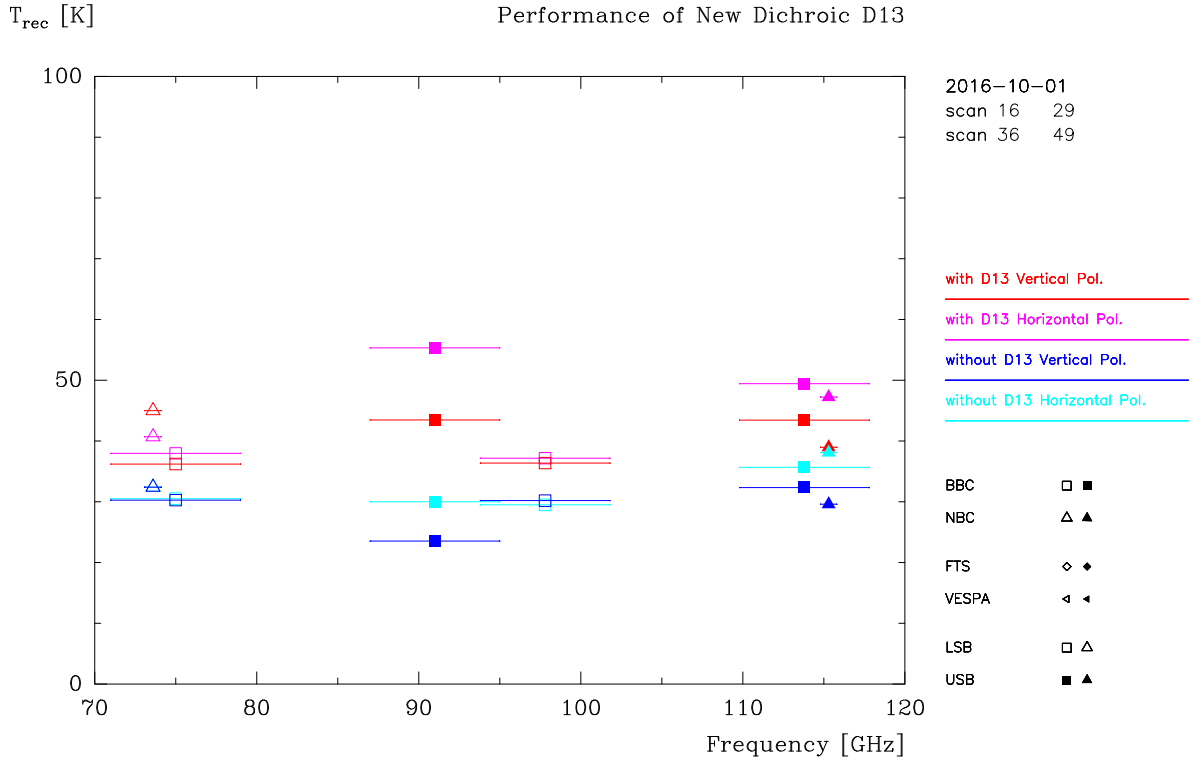Receiver temperatures in band 1 E090 (top) and band 3 E230 (bottom) from dual-band observations
with the new dichroic D13 shown in red and magenta, compared to receiver temperatures form
single-band observations without D13 shown in blue and cyan. Data are only from the continuum
backends BBC and NBC. The horizontal bars represent the bandwidth.
Details about the frequency setups are given in the text.

Figure 5. Here data are shown only for band E090 for the spectrometers FTS and VESPA as well as for the continuum backends BBC and NBC. Data with D13 are in the upper panel, data without D13 in the lower panel.
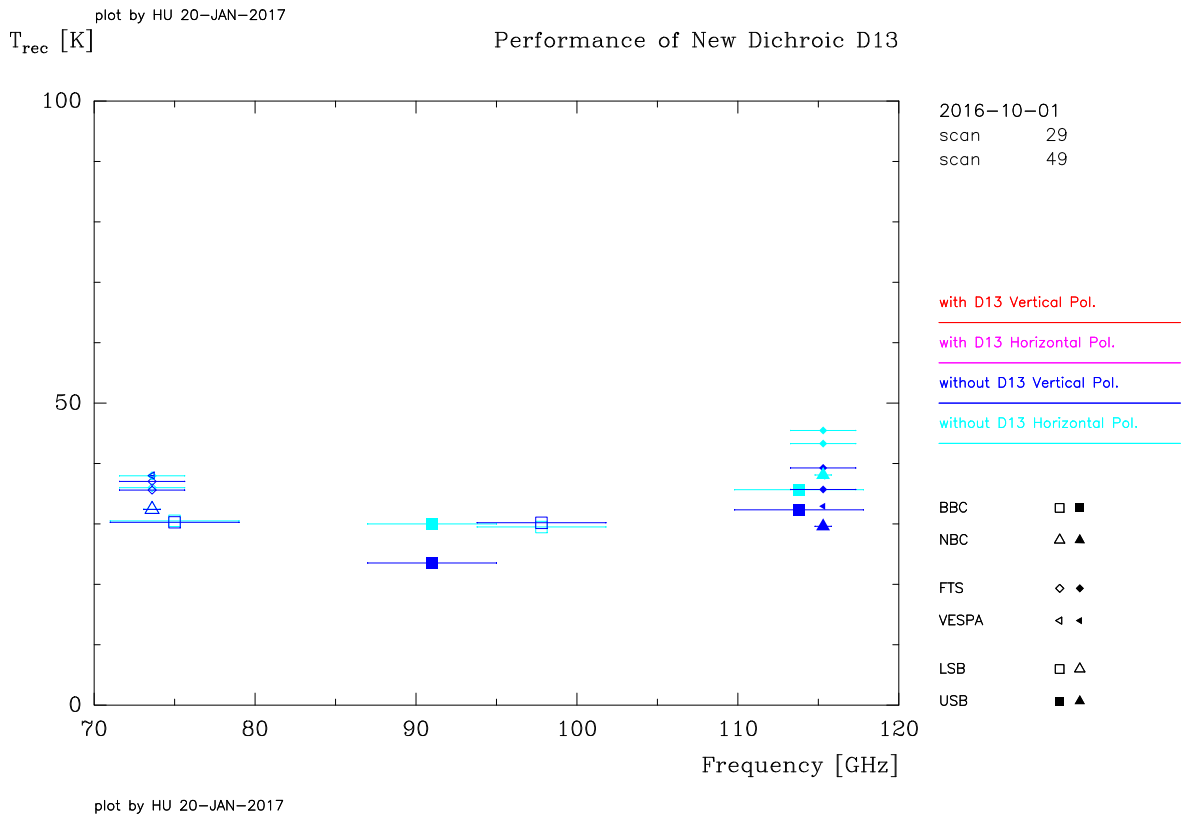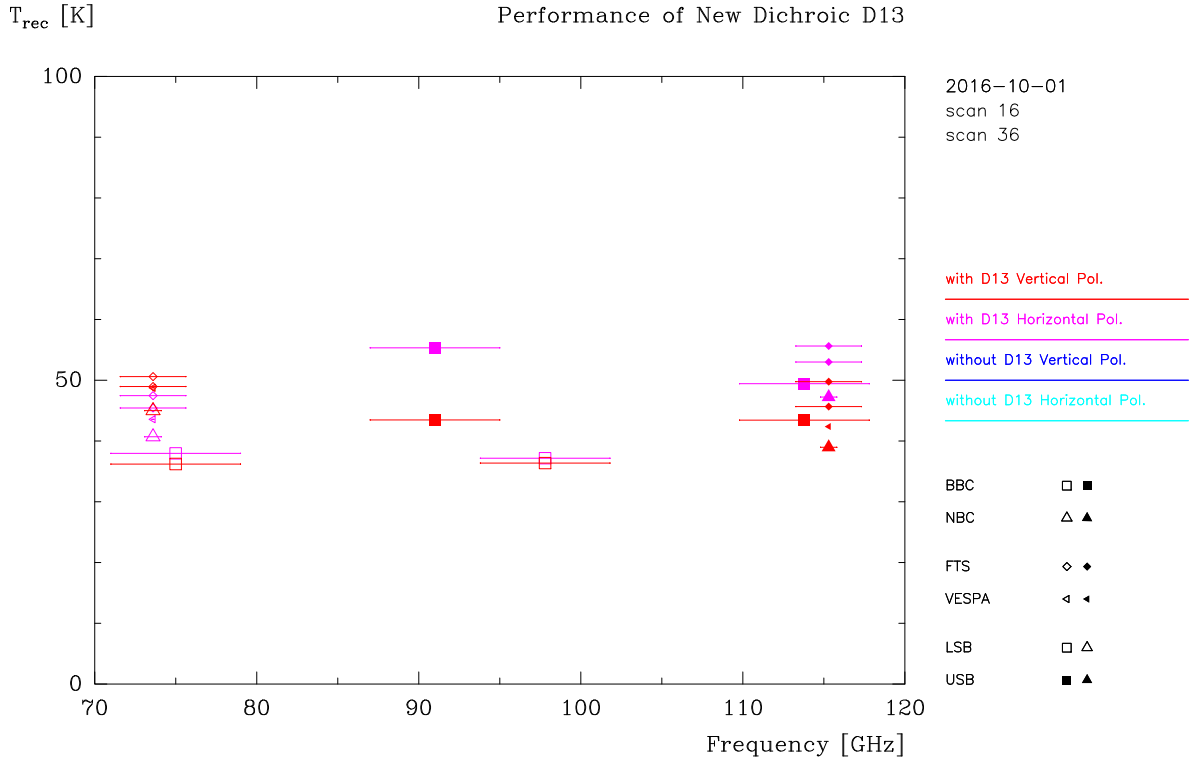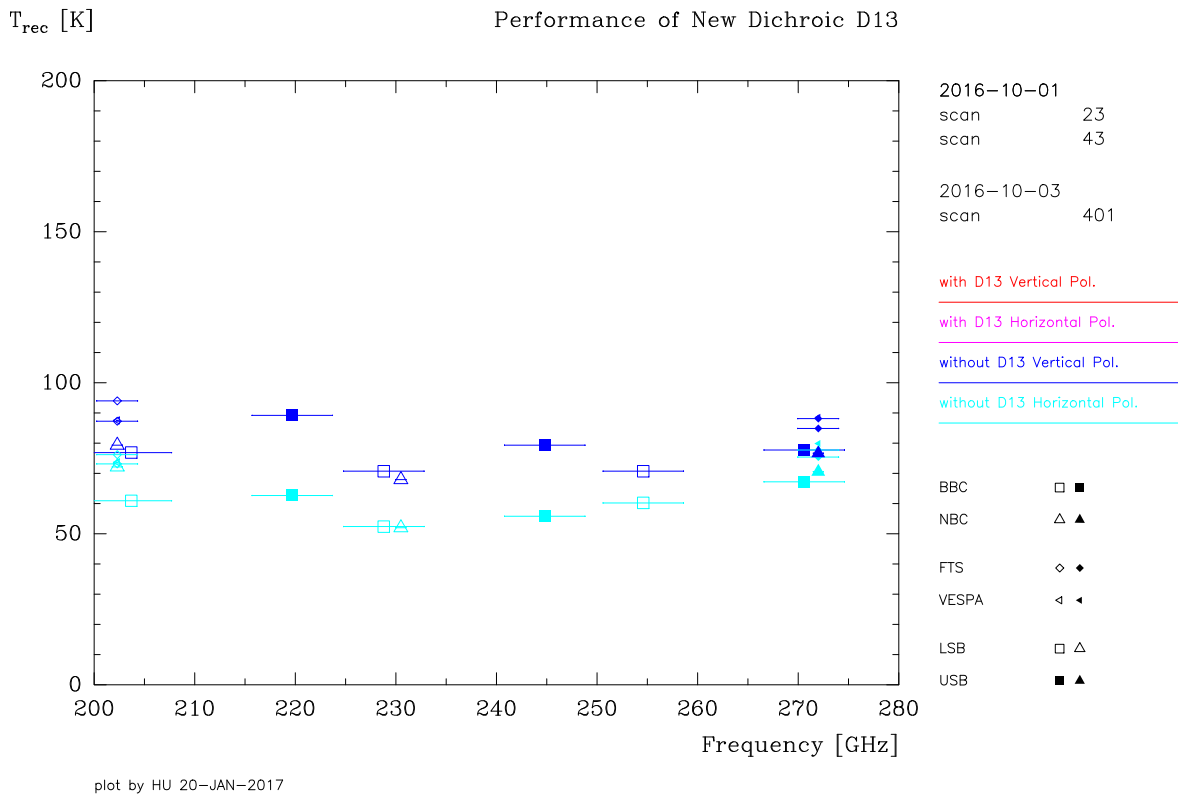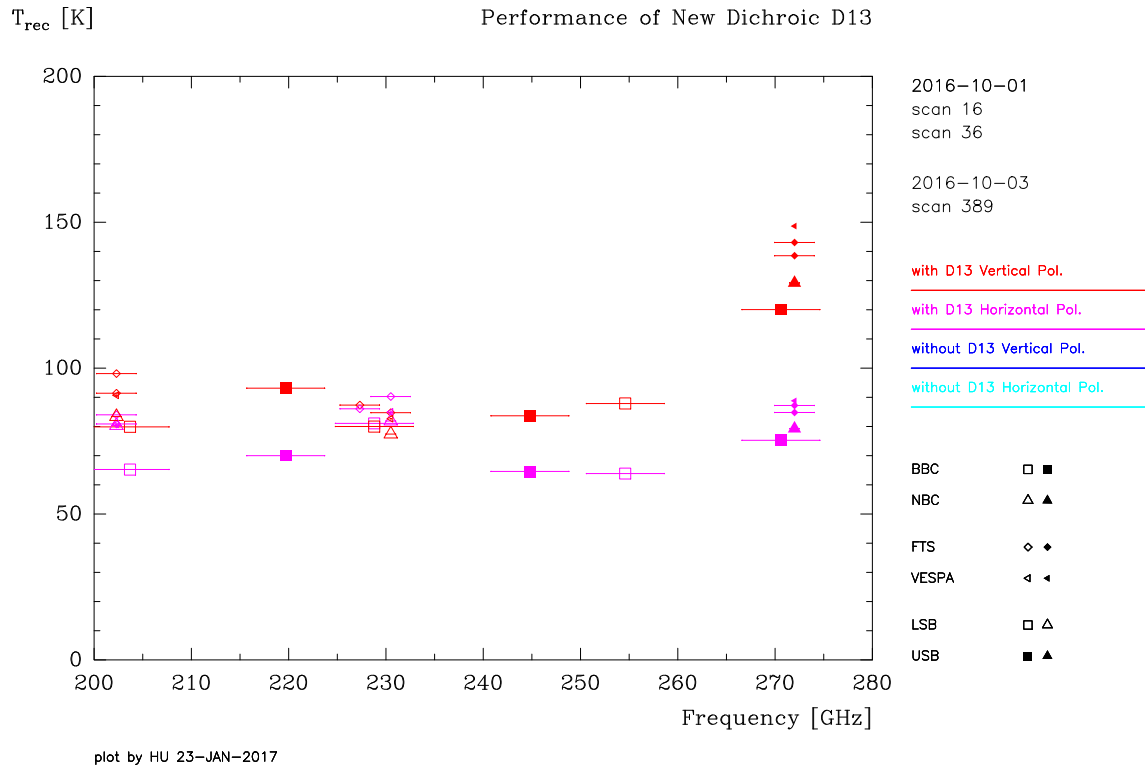
Figure 6. Here data are shown only for band E230 for the spectrometers FTS and VESPA as well as for the continuum backends BBC and NBC. Data with D13 are in the upper panel, data without D13 in the lower panel.

Figure 7
Receiver temperatures in Band 3 E230 measured at PV with and without the *OLD* dichroic D13. Colors red and magenta represent Vertical and Horizontal polarizations with D13, blue and cyan without D13. Open symbols are lower sideband LSB, filled symbols upper sideband USB, squares are backend BBC, and triangles NBC. The horizontal bars at the data points show the (approximate) bandwidth.

Appendices

Frequency Setups

paKo scripts to set up each frequency are for E090:

```
!
!  Id:  @ emir-d13-e090-vlbi.pako , v 1.1 2016-09-14 Hans Ungerechts
!
 pako\RECEIVER "E090" "VLBIE090" 85.850    "LI" /doppler "fixed" -
  /gainImage   -13.0 db /tempLoad L L  /efficiency 0.95 0.95  /scale "antenna" -
  /horizontal   LI   /vertical   LI
!


!
!  Id:   @ emir-d13-e090-ch3cn.pako , 1.0 2016-09-08 Hans Ungerechts
!
pako\RECEIVER "E090"  "CH3CN(4-3)" 73.590217 "LO" /doppler "Doppler" -
 /gainImage   -13.0 db /tempLoad L L /efficiency   0.95 0.95 /scale "antenna" -
 /horizontal  LO /vertical   LO
!


!3
!  Id:  @ emir-d13-e090-cs.pako , v 1.0 2016-09-06 Hans Ungerechts
!
pako\RECEIVER "E090" "CS(2-1)" 97.980965 "LI" /doppler "Doppler" -
 /gainImage   -13.0 db /tempLoad L L /efficiency   0.95 0.95 /scale "antenna" -
 /horizontal  LI  /vertical   LI
!


!
!  Id:  @ emir-d13-e090-co.pako , v 1.0 2016-09-06 Hans Ungerechts
!
 pako\RECEIVER "E090" "12CO(1-0)" 115.271204 "UO" /doppler "Doppler" -
  /gainImage   -13.0 db /tempLoad L L /efficiency   0.95 0.95 /scale "antenna" -
  /horizontal  UO   /vertical   UO
!


!
!  ID:  @ emir-d13-e090-hcn.pako , v 1.0 2016-09-28 Hans Ungerechts
!
pako\RECEIVER "E090" "HCN(1-0)" 88.6316024 "LI" /doppler "Doppler" -
 /gainImage   -13.0 db /tempLoad L L /efficiency   0.95 0.95 /scale "antenna" -
 /horizontal  LI   /vertical   LI
!
```
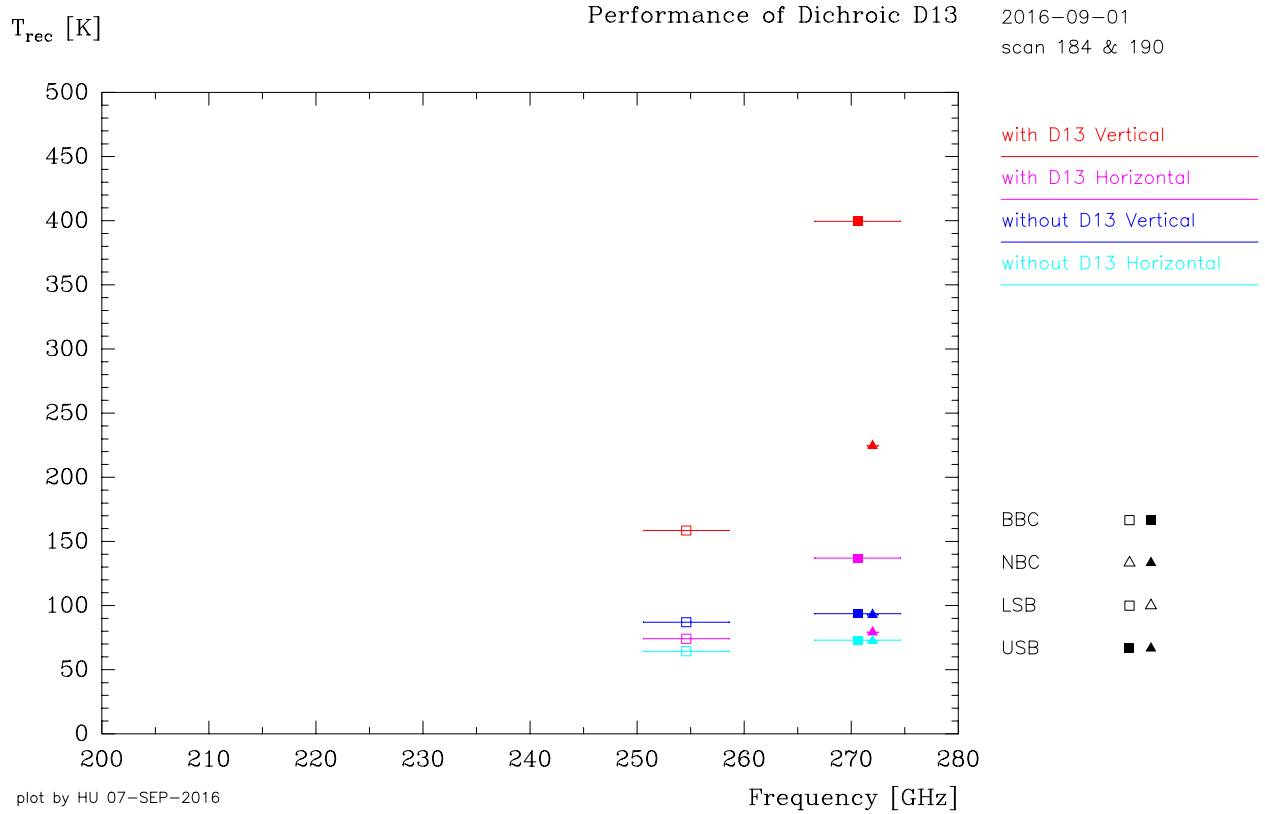
E230

```
!
!  Id:  @ emir-d13-e230-ch3cn.pako , v 1.0 206-09-08 Hans Ungerechts
!
pako\RECEIVER "E230" "CH3CN(11-10)" 202.258159 "LO" /doppler "Doppler" -
 /gainImage   -13.0 db /tempLoad L L /efficiency   0.92 0.92 /scale "antenna" -
 /horizontal  LI  /vertical   LI
!
```

---

[3] @ emir-d13-e090-cs   is equivalent to RECEIVER E090 /default

```
!⁴
!  Id:  @ emir-d13-e230-co.pako , v 1.0 2016-09-08 Hans Ungerechts
!
pako\RECEIVER "E230" "CO(2-1)" 230.537994 "LI" /doppler "Doppler" -
 /gainImage  -13.0 db /tempLoad L L /efficiency  0.92 0.92 /scale "antenna" -
 /horizontal  LI  /vertical  LI
!


!  Id:  @ emir-d13-e230-hnc.pako , v 1.0 2016-09-06 Hans Ungerechts
!
 pako\RECEIVER "E230" "HNC(3-2)" 271.981111 "UO" /doppler "Doppler" -
  /gainImage  -13.0 db /tempLoad L L /efficiency  0.92 0.92 /scale "antenna" -
  /horizontal  UO /vertical  UO
!
```

E150

```
!⁵
!  Id:  @ emir-d13-e150-cs.pako , v 1.0 2016-09-14 Hans Ungerechts
!
 pako\RECEIVER "E150" "CS(3-2)" 146.969055 "LI" /doppler "Doppler" -
  /gainImage  -13.0 db /tempLoad L L /efficiency  0.93 0.93 /scale "antenna" -
  /horizontal  LI /vertical  LI
!
```

paKo scripts for standard frequency combos with continuum backends BBC and NBC

E090   CH3CN   73.590217 LO   E230   CH3CN   202.258159 LO

```
!
!  Id:  @ emir-d13-e090-ch3cn-e230-ch3cn-cont.pako , v 1.0 2016-09-09 H
Ungerechts
!
 pako\RECEIVER /clear
 !
 @ emir-d13-e090-ch3cn.pako
 @ emir-d13-e230-ch3cn.pako
 !
 backend /clear
 backend bbc /def
 backend nbc /def
 !
```

E090   CS   97.980965 LI   E230   CO   230.537994 LI

```
!
!  Id:  @ emir-d13-e090-cs-e230-co-cont.pako , v 1.0 2016-09-14 Hans Ungerechts
!
 pako\RECEIVER /clear
 !
 @ emir-d13-e090-cs.pako
 @ emir-d13-e230-co.pako
 !
 backend /clear
 backend bbc /def
 backend nbc /def
!
```

---

[4] @ emir-d13-e230-co   is equivalent to RECEIVER E230 /default

[5] @ emir-d13-e150-cs   is equivalent to RECEIVER E150 /default

E090   CO   115.271204 UO   E230   HNC   271.981111 UO

```
!
!  Id:  @ emir-d13-e090-co-e230-hnc-cont.pako , v 1.0 2016-09-08 Hans Ungerechts
!
 pako\RECEIVER /clear
 !
 @ emir-d13-e090-co.pako
 @ emir-d13-e230-hnc.pako
 !
 backend /clear
 backend bbc /def
 backend nbc /def
 !
```

E090   CS   97.980965 LI   E150   CS   146.969055 LI

```
!
!  Id:  @ emir-d13-e090-cs-e150-cs-cont.pako , v 1.0 2016-10-03 Hans Ungerechts
!
 pako\RECEIVER /clear
 !
 @ emir-d13-e090-cs.pako
 @ emir-d13-e150-cs.pako
 !
 backend /clear
 backend bbc /def
 backend nbc /def
!
```

Continuum Backends BBC and NBC can be added with

```
!
!   @   emir-d13-bbc-nbc.pako , 1.0 2016-08-31 Hans Ungerechts
!
backend bbc /def
backend nbc /def
!
```

– this works independently of the receiver configuration

Spectrometers FTS and WILMA in standard configuration can be added with

```
!
! Id:  @  emir-d13-fts-wilma.pako , 1.0 2016-09-06 Hans Ungerechts
!
backend fts   /def
backend wilma /def
!
```
– this works independently of the receiver configuration

VESPA setup is less automatic and depends on the EMIR subbands selected with the paKo command RECEIVER[6].

For example, VESPA for E090 LO and E230 LO in both polarizations can be added with:

```
!
!  Id:  @  emir-d13-e090-lo-e230-lo-vespa.pako , v 1.0 2016-09-09 Hans Ungerechts
!
backend vespa 1 0.080 120 0 e090 hor lo
backend vespa 2 0.080 120 0 e090 ver lo
backend vespa 3 0.080 120 0 e230 hor lo
backend vespa 4 0.080 120 0 e230 ver lo
!
```

and similar for other subband combinations:

```
!
!  Id:  @  emir-d13-e090-li-e230-lo-vespa.pako , v 1.0 2016-09-14 Hans Ungerechts
!
 backend vespa 1 0.080 120 0 e090 hor li
 backend vespa 2 0.080 120 0 e090 ver li
 backend vespa 3 0.080 120 0 e230 hor lo
 backend vespa 4 0.080 120 0 e230 ver lo
!


!
!  Id:  @  emir-d13-e090-li-e230-li-vespa.pako , v 1.0 2016-09-09 Hans Ungerechts
!
 backend vespa 1 0.080 120 0 e090 hor li
 backend vespa 2 0.080 120 0 e090 ver li
 backend vespa 3 0.080 120 0 e230 hor li
 backend vespa 4 0.080 120 0 e230 ver li
!


!
!  Id:  @  emir-d13-e090-uo-e230-uo-vespa.pako , v 1.0 2016-09-14 Hans Ungerechts
!
 backend vespa 1 0.080 120 0 e090 hor uo
 backend vespa 2 0.080 120 0 e090 ver uo
 backend vespa 3 0.080 120 0 e230 hor uo
 backend vespa 4 0.080 120 0 e230 ver uo
!


!
!  Id:  @  emir-d13-e090-li-e150-li-vespa.pako , v 1.0 2016-09-14 Hans Ungerechts
!
 backend vespa 1 0.080 120 0 e090 hor li
 backend vespa 2 0.080 120 0 e090 ver li
 backend vespa 3 0.080 120 0 e150 hor li
 backend vespa 4 0.080 120 0 e150 ver li
!
```

---

[6] Of course, for VESPA one could also select different resolutions and bandwidth. The examples shown here give 12% of the NBC bandwidth and use 100% of the VESPA hardware.

```
!
!  Id:  @  emir-d13-e090-li-vespa.pako , v 1.0 2016-09-30 Hans Ungerechts
!
 backend vespa 1 0.080 120 0 e090 hor li
 backend vespa 2 0.080 120 0 e090 ver li
!


!
!  Id:  @  emir-d13-e090-lo-vespa.pako , v 1.0 2016-09-30 Hans Ungerechts
!
 backend vespa 1 0.080 120 0 e090 hor lo
 backend vespa 2 0.080 120 0 e090 ver lo
!


!
!  Id:  @  emir-d13-e090-uo-vespa.pako , v 1.0 2016-09-30 Hans Ungerechts
!
 backend vespa 1 0.080 120 0 e090 hor uo
 backend vespa 2 0.080 120 0 e090 ver uo
!


!
!  Id:  @  emir-d13-e230-li-vespa.pako , v 1.0 2016-09-30 Hans Ungerechts
!
 backend vespa 1 0.080 120 0 e230 hor li
 backend vespa 2 0.080 120 0 e230 ver li
!


!
!  Id:  @  emir-d13-e230-lo-vespa.pako , v 1.0 2016-09-30 Hans Ungerechts
!
 backend vespa 1 0.080 120 0 e230 hor lo
 backend vespa 2 0.080 120 0 e230 ver lo
!


!
!  Id:  @  emir-d13-e230-uo-vespa.pako , v 1.0 2016-09-30 Hans Ungerechts
!
 backend vespa 1 0.080 120 0 e230 hor uo
 backend vespa 2 0.080 120 0 e230 ver uo
!


!
!  Id:  @  emir-d13-e150-li-vespa.pako , v 1.0 2016-09-30 Hans Ungerechts
!
 backend vespa 1 0.080 120 0 e150 hor li
 backend vespa 2 0.080 120 0 e150 ver li
!
```

Emails

On 26 Jan 2017, at 12:26, Navarro <navarro@iram.es> wrote:

```
With the standard E090 LO box the hard minimum is 82.5 GHz. The minimum center
of UI band would be at 88.75 GHz. Usually we take a small safety margin and this
is why, on the web page the UI limit it is advertised at 89 GHz. This limit, is
probably good enough to observe the HCN molecule in UI with the FTS but probably
not for the VESPA backend.
```

On 18 Jan 2017, at 13:27, jlsantaren <jlsantaren@iram.es> wrote:

```
18-January-2017. Biweekly 30m staff meeting at Granada
Frontends
The dichroic D24 is always present for all the E330 configurations (even
in single receiver mode).
```

On 10 Jan 2017, at 10:23, Pablo Torne <torne@iram.es> wrote:

```
Test: during project 121-16 using E3 and E1+E3, a quick comparison of the
intensity measured in the E1+E3 versus E3 alone setups was made on Uranus and a
line calibrator. The intensities in the E3 band seem consistent within 10% in
both setups. Data available under "test" for more precise comparison.
```

(Note: this test was done before the software change for E330 / D24.)

02 Jan 2017, at 20:08, Santiago Navarro <navarro@iram.es> wrote:

```
The alignment of the E330 beam alone could not be checked so be better assume it
could be wrong, and always use the dichroic filter till we verify it. Following
an idea from Hans, we could always select the dichoic when the E330 is used, no
matter if it is used in parallel with the E150, or not. This is probably the
easiest solution. For this we would have to slightly modify the program made by
Walter to control the sliding table so the D24 is inserted in the optical path
as soon as the E330 is selected in "pako". No modification in "Pako" would be
needed.
```

On 24 Nov 2016, at 10:50, Claudia Marka <marka@iram.es> wrote:

```
we tried the pointings with E0+E2/E2 this night when the opacity decreased
since it seemed the only chance according to the weather forecast. However,
no planet was available and consecutive pointings drifted by ~2" with
unstable baselines in the last scans; therefore it might serve only as an
indication.

Data are in account "pools-16" (/    /), scan 42-58; of which scan 50 is a
reliable pointing (i.e. after optimized pointing corrections) with E0+E2,
and scan 56 the best pointing with E2 alone. The average peak temperatures
of LSB and USB appear to be consistent within ~5%, suggesting that both with
E2 alone and in combination E0+E2 the fluxes are similar:

scan 50: E2 LSB 1.466K, USB 1.471K
scan 55: E2 LSB 1.526K, USB 1.479K
```

On 31 Oct 2016, at 13:53, Santiago Navarro <navarro@iram.es> wrote:

On Oct. 29th the E230 beam was finally aligned. The weather was good but unstable, not good enough to extract quantitative conclusions. Anyway it was clear that, using E230 alone, the intensity on Venus was higher than before and hopefully the same as with the E0-E2 combination. A final check on a stable weather is pending.

The adjustment of the MR34 mirror implies (as Hans pointed out) that now the E330 beam, when used in single band mode, is not correctly illuminating the secondary. It is then recommended that E330 observations should only be done in parallel with the E150 band.

On 26 Oct 2016, at 18:18, Navarro <navarro@iram.es> wrote:

Frequencies higher than 263.5 GHz should be observed in UI mode. Observations on LI mode, even if possible, show signs of spurious lines in the spectrum. The EMIR for astronomers web page will be adapted to the new frequency range.

On 02 Jun 2016, at 12:00, Pablo Mellado <mellado@iram.es> wrote:

- A new dichroic to replace the existing E090/E230 filter has been received and measured in Grenoble. Performance is much better on the high frequency part of the 1.3mm band and slightly worse on the 3mm band. We plan to replace it asap.

On 15 Jun 2016, at 16:10, Carsten Kramer <kramer@iram.es> wrote:

The new, better E0/E2 Dichroic has arrived from Grenoble. It is planned to replace it during heavy maintenance in September. Realignment should also bring improvement of current E0/E2 alignment. The procedure to change dichroic, align, test, commission will be developed.

On 06 Jul 2016, at 15:09, Carsten Kramer <kramer@iram.es> wrote:

Anne-Laure and Santiago discuss remaining problems after E0/E1 upgrade last November: Focus difference E0-E2 of 0.2mm was expected from new E0 optics, currently it is ca. 0.4mm and cannot be changed. Band-Alignment offsets should be reduced during heavy maintenance by adjusting dichroics for E0/E1 and E0/E2 combination. Adjustment will be check with laser and on-sky (TBC). Spectroscopic polarimetry projects are on hold until problems are understood, tests foreseen for July 18/19th by GP.

On 13 Jul 2016, at 16:51, Carsten Kramer <kramer@iram.es> wrote:

can you please prepare commissioning of the new EMIR dichroics (with a new alignment) which Santiago and Dave plan to install during heavy maintenance in September, 26-29.

Note that the exact starting and ending times of the following 3mm VLBI session are not yet clear. The online schedule is yet preliminary. In any case, the TBA slot on 4-October could be used for commissioning, but there will probably be more time available already the day before: http://www.iram.fr/IRAMFR/PV/sche/16/s39v1.html