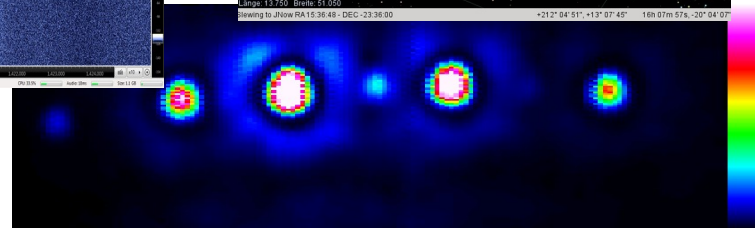
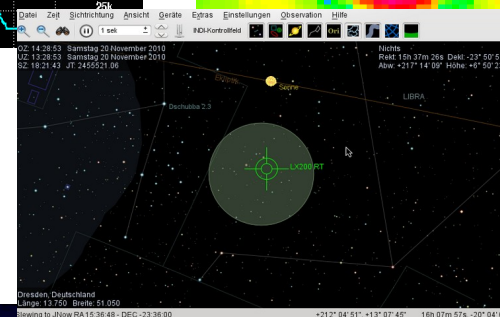
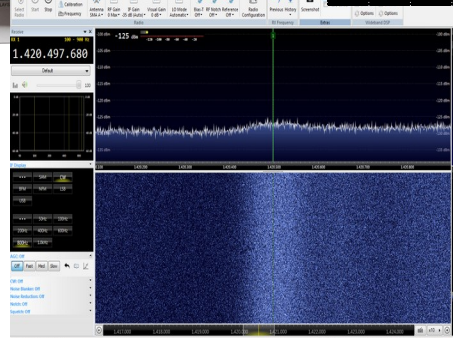
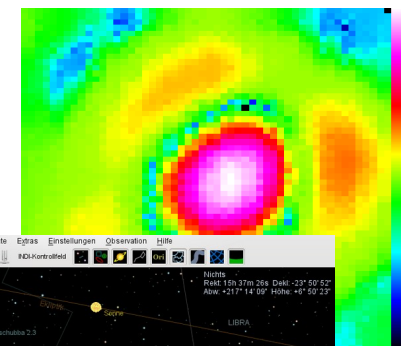
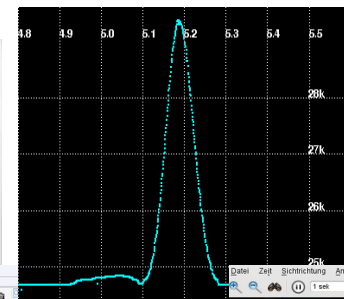
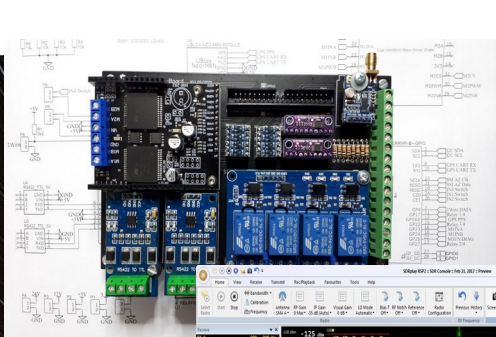
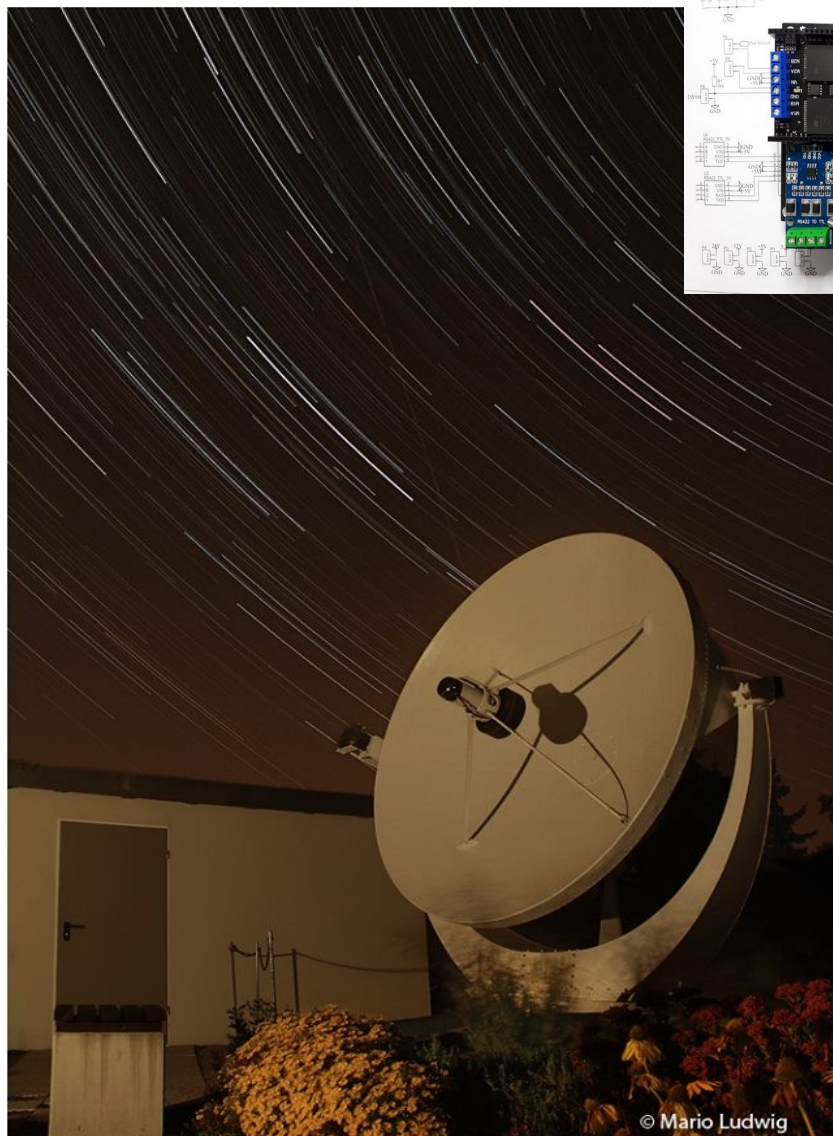


# PiRaTe – Das Pi Radio Telescope

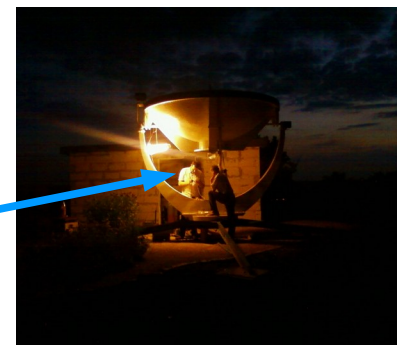
Ein 3m Amateur-Radioteleskop an der Sternwarte Radebeul  
(Dresden)

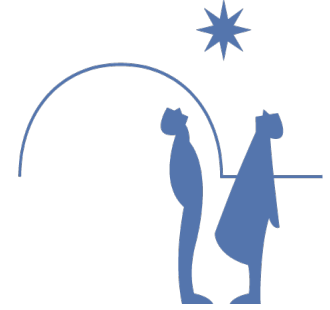


von  
Hans-Georg Zaunick

$\pi_{++}$

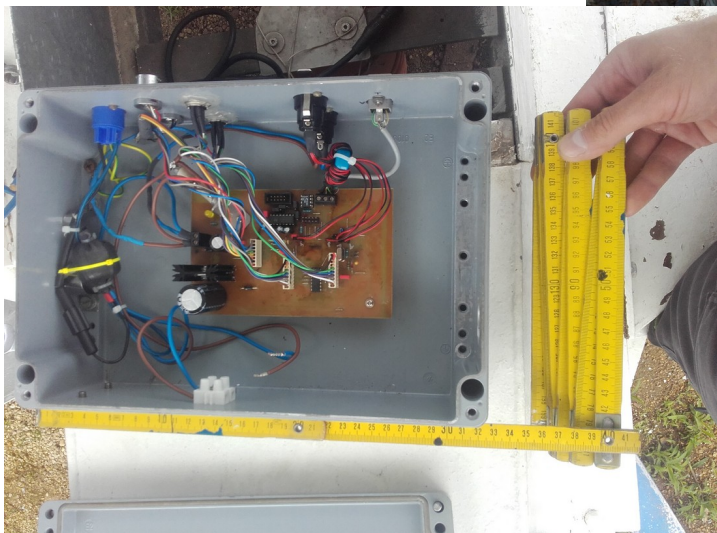
Pi and More – 22. April 2023





# Radioastronomie an der Sternwarte Radebeul

2004 Errichtung des Radioteleskops

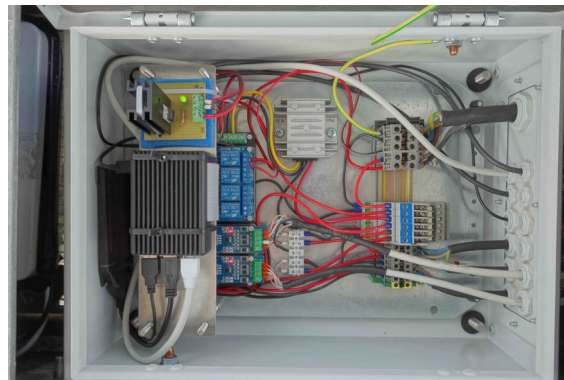
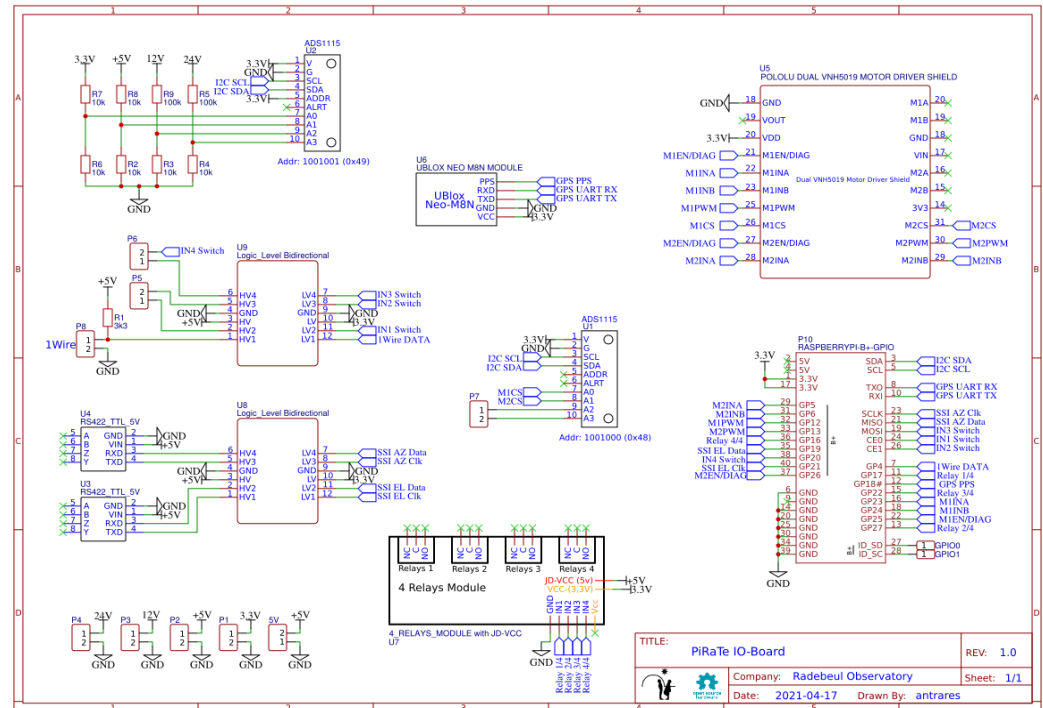
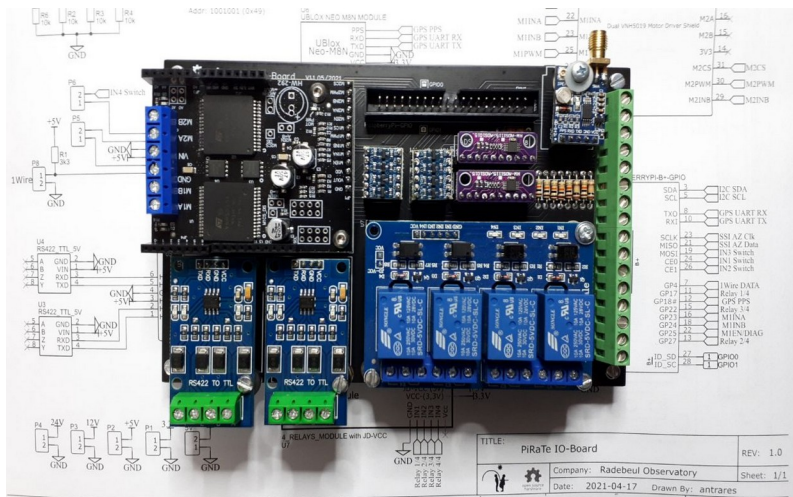


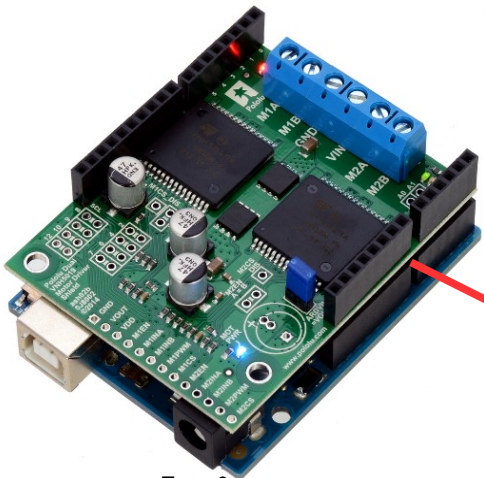
## DIY-Steuerung:

- ATMega128 mit LX200 Interface+Inkrementalencoder+PWM Motoransteuerung
- Zerstörung durch Wasserschaden 2011

# Die PiRaTe Steuerung (2021)

- Kompletter Neubau der Steuerung 2020/2021
- Raspberry-Pi + Off-the-Shelf Module und Komponenten
- Software: möglichst bestehende, modulare und Open-Source Lösungen
- Wartungsfreundlich + Robust
- Remote-Betrieb



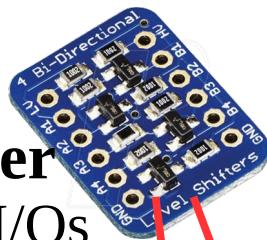


## Arduino Motor Driver Shield (Pololu)

Zum Antrieb von zwei 24V DC-Motoren @max 12A

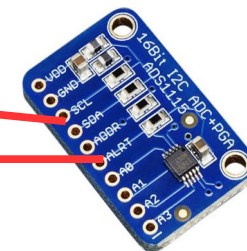
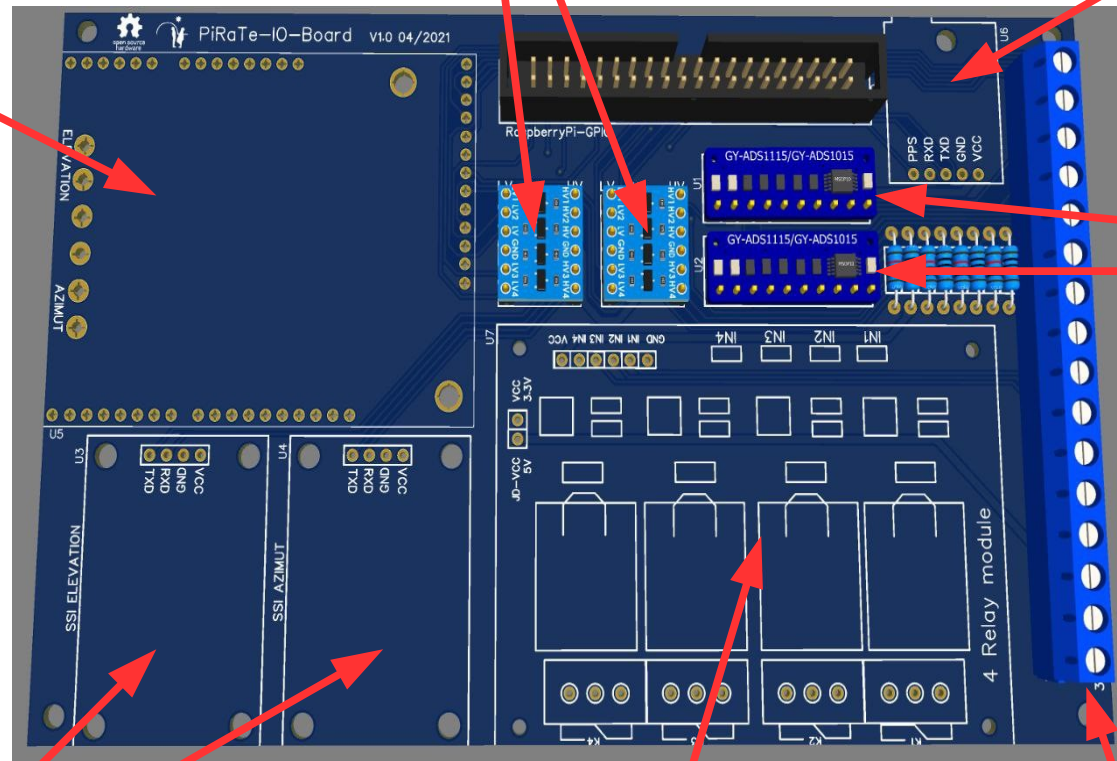
## Level Shifter

Für digitale I/Os



## Ublox GNSS Receiver

Zeitsync des RPi und Koordinaten für Astro-Magic



## ADS1115 Breakout Board

- 4ch 16bit ADC
- Zum Messen der Motorströme, Versorgungsspannungen, Analoge Eingänge

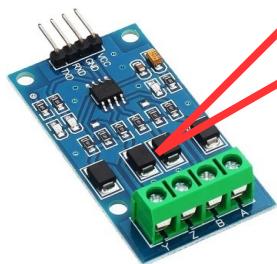
## 4ch Relais-Modul

Zum Schalten und Walten



## RS422-TTL Converter

Anschluß der Pos-Encoder (SSI diff. bus)



## Digital+Analog I/Os+1wire

PiRa

# Positions-Encoder

Encoder an übersetzter  
Sekundärwelle der  
Azimutachse

## Entscheidung für Industriestandard Absolut-Encoder:

- Ultrarobust, IP65
- Seriellles SSI Interface
- Differentielle Datenleitungen f. hohe Störfestigkeit
- Gleiches System/Protokoll – viele Hersteller
- 12 oder 13 bit Single-Turn und Multi-Turn Auflösungen
- Viele Angebote Ebay, AliExpress: 30...800€



Baumer Multiturn-Drehgeber, absolute Encoder  
GXM2S.Z20

Artikelzustand: Gebraucht

Preis: EUR 49,00

Sofort-Kaufen

In den Warenkorb

Preisvorschlag:

Preisvorschlag senden

Auf die Beobachtungsliste

Versand aus Deutschland Lieferung in ca. 3 Werktagen 30 Tage Rücknahme

Abholung: Lieferung an Abholstation möglich

Versand: EUR 5,20 Standardversand | Weitere Details

Standort in: Deutschland, Deutschland

Versand nach: Weltweit | Anschlussliste anzeigen

Lieferung: Bis ca. Sa. 11 Sep. nach 35452

Zahlungen: PayPal VISA Mastercard S-PAY

Sicher einkaufen

eBay-Ki Sie erhalten oder bei Mehr

Angaben zu santacruz\_1 (86 100% Positive B Angemeldet als

Preisvorschlag besseren Preis

PiRaTe - Pi++ 22.04.23



Encoder mit direkter Kopplung der Elevationsachse

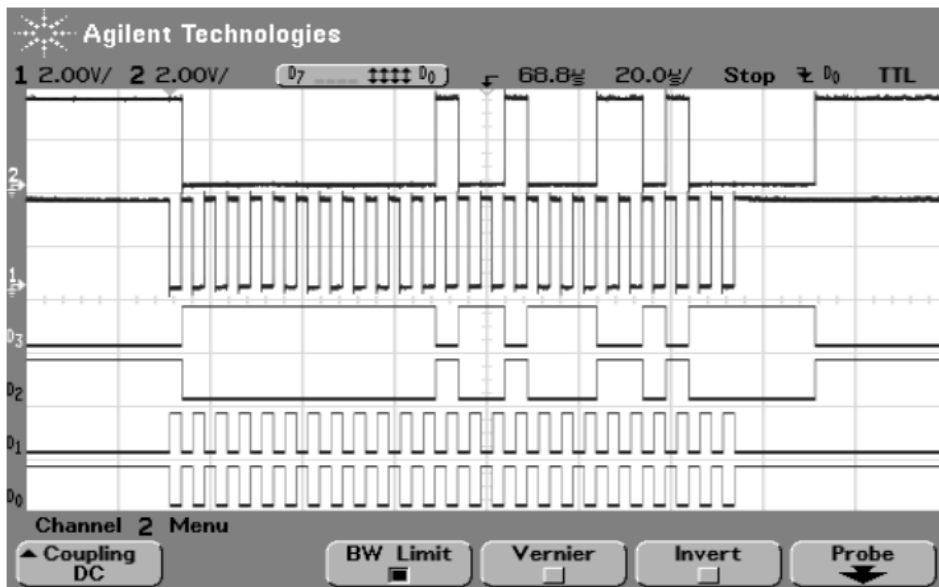
# Positions-Encoder

# Serielles Diff. SSI Interface

- Auslese mit RPi SPI Interface + Umsetzung mit RS422-TTL-Konverter

- 3 Byte lesen+Gray Decoding  
Drehung an Geber 1

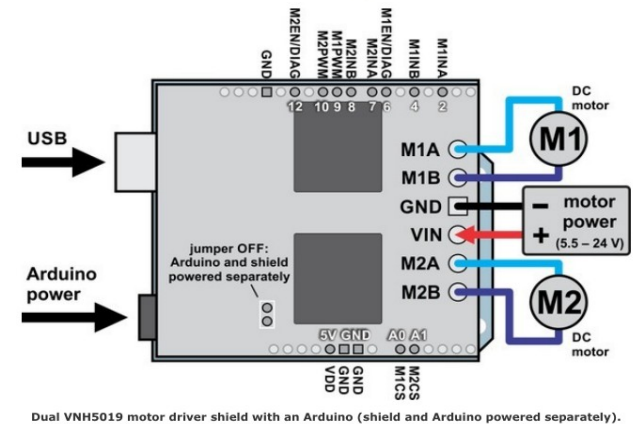
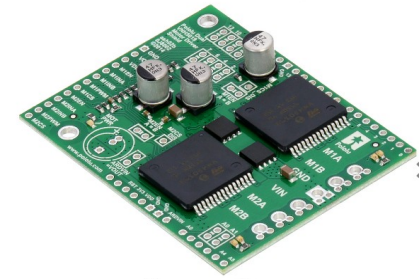
## Drehung an Geber 2

[illegible]

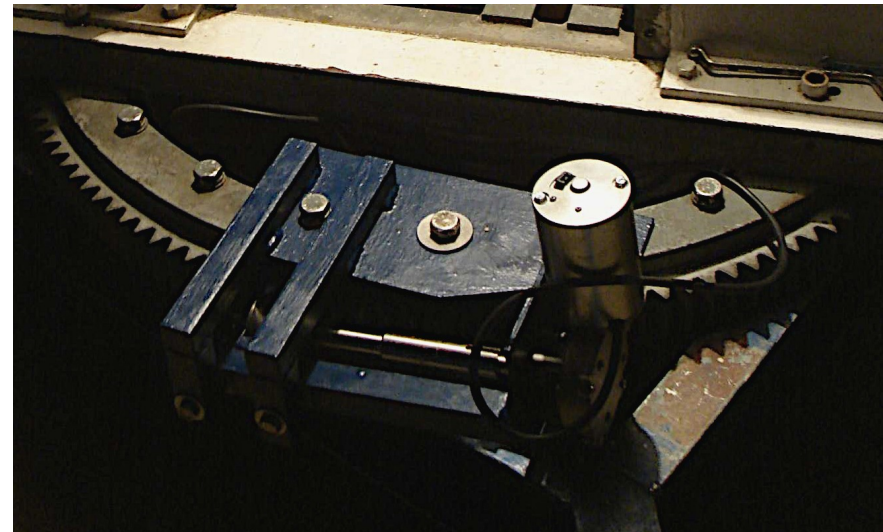
# Antrieb

## VNH5019 Motor Driver Shield

- Einfaches Interface: PWM, Enable, Dir  
→ GPIO Pins (Benutzung der Hardware-PWM)
- Zusätzlich Analogausgang zur Messung der Motorströme → ADC (ADS1115)



Antrieb der Elevationsachse -  
Rutschkupplung



Antrieb der Azimutachse -  
Schneckengetriebe

# Software

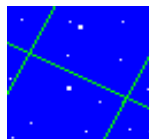
## Steuerung über INDI Protokoll



<https://www.indilib.org/>

- Open Source, Cross Platform, 22 Client-Apps verfügbar (inkl. IOS / Android)
- Weit verbreitet zur Steuerung von Remote-Teleskopen
- XML-basierter Datenaustausch
- Treiber beschreiben sich selbst (describe)
- Clients stellen vom Treiber gewünschte Eigenschaften zur Laufzeit zum Lesen/Schreiben zur Verfügung
- Steuerung eines Treibers mit mehreren Clients (lokal oder remote)

*Cartes du Ciel*



HNSky



iIndi



Telescope.touch



Stellarium

# Software

## Fernsteuerung - KStars



RT300 Camera - Mozilla Firefox

plotfile.eps - sun\_scan\_24082021\_2.pdf - Mozilla Firefox

plotfile.eps - sun\_scan\_24082021\_2.pdf

KStars

File Time Pointing View Tools Data Observation Settings Help

LT: 11:23:03 AM Wednesday, August 25, 2021

nothing

Regulus

Pi RadiotelesCope

Sun

Dresden, Germany

Approximate FOV: 6.0 degrees

+137° 29' 12", +43° 50' 59" 10h 32m 14s, +11° 47' 22"

INDI Control Panel

Weather Watcher GPSD Pi Radiotelescope

Main Control Connection Options Encoders Axes Monitoring Motion Control Site Management Motors

Connection **Connect** Disconnect

On Set **Track** Slew

Eq. Coordinates RA (hh:mm:ss) 10:17:31 0:00:00 DEC (dd:mm:ss) 10:37:42 0:00:00 Set

Abort Motion **Abort**

Tracking **On** Off

Parking **Park(ed)** UnPark(ed)

Scope Status

Idle Slew Tracking Parking Parked

2021-08-25T09:22:08: [INFO] Telescope slew is complete.  
2021-08-25T09:22:08: [INFO] Slewing to RA: 10:17:24 - DEC: 10:39:00  
2021-08-25T09:22:06: [INFO] Telescope slew is complete.  
2021-08-25T09:22:05: [INFO] Slewing to RA: 10:17:24 - DEC: 10:48:00  
2021-08-25T09:22:04: [INFO] Telescope slew is complete.

Clear Close

Wed 25.08.2021 11:23:03 CEST

24 Aug 2021 09:30 UTC Radio Astronomy Group - Observatory Radebeul (Germany)

Sun @ 12 GHz

Dec / deg

RA / h

File Edit View Bookmarks Settings Help

1629883262,521138242 139.5687 48.0514 10.29404 15.0425 39.6357 0.0564 20.3  
1629883264,961832574 139.8601 47.8756 10.28775 14.8010 39.6124 0.0564 20.3  
1629883267,301875535 139.8601 47.7438 10.29211 14.6012 39.5976 0.0566 20.3  
1629883269,516038052 140.1516 47.6120 10.28417 14.4796 39.5961 0.0566 20.3  
1629883271,832384366 140.0943 47.4801 10.29091 14.3758 39.6044 0.0564 20.3  
1629883274,125408383 140.3129 47.3483 10.28625 14.1945 39.6067 0.0565 20.3  
1629883276,420056196 140.3129 47.1725 10.29180 14.0344 39.6112 0.0564 20.3  
1629883278,701877639 140.4274 47.0407 10.29122 13.8822 39.6368 0.0565 20.3  
1629883281,077578694 140.5419 46.9088 10.29089 13.7299 39.6524 0.0565 20.3  
1629883283,373155581 140.6564 46.7770 10.29026 13.5775 39.7101 0.0565 20.4  
1629883285,799833820 140.7292 46.6452 10.29138 13.4368 39.7757 0.0566 20.4  
1629883288,166914800 140.8957 46.5573 10.28752 13.3099 39.8179 0.0565 20.4  
1629883290,456191577 140.8957 46.4254 10.29175 13.1894 39.9301 0.0564 20.4  
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1629883295,087832593 141.0779 46.1178 10.29380 12.8572 40.2579 0.0566 20.3  
1629883297,880604128 141.1455 46.0739 10.29292 12.7980 40.3437 0.0563 20.3  
1629883300,201689108 141.4005 45.8541 10.28843 12.5255 40.5904 0.0582 20.3  
1629883302,470052681 141.4005 45.8102 10.29019 12.4853 40.6224 0.0583 20.3  
1629883304,910656253 141.5775 45.6344 10.28810 12.2748 40.6068 0.0575 20.3  
1629883307,193938789 141.5775 45.5026 10.29225 12.1539 40.5137 0.0566 20.3  
1629883309,520340177 141.7544 45.3707 10.28862 11.9835 40.2224 0.0565 20.3  
1629883311,780892157 141.8221 45.2389 10.29004 11.8436 39.0735 0.0566 20.3  
1629883314,218753415 141.9886 45.0631 10.28799 11.6357 39.8446 0.0565 20.3  
1629883316,546388839 141.9886 44.9313 10.29209 11.5146 40.0194 0.0565 20.3  
1629883318,886843578 142.1811 44.7995 10.28792 11.3397 41.0924 0.0663 20.3  
1629883321,176381670 142.1811 44.6676 10.29200 11.2184 42.1963 0.0856 20.3  
1629883323,441868113 142.3633 44.4918 10.28912 11.0059 44.4058 0.1387 20.3  
1629883325,809990204 142.3633 44.3600 10.29345 10.8845 45.4003 0.1696 20.3  
1629883328,084489240 142.5558 44.2721 10.28771 10.7499 46.8692 0.2274 20.3  
1629883330,375623720 142.5558 44.1403 10.29175 10.6284 47.1026 0.2354 20.3

() radioid

() radioid

hgz : bash

data : bash

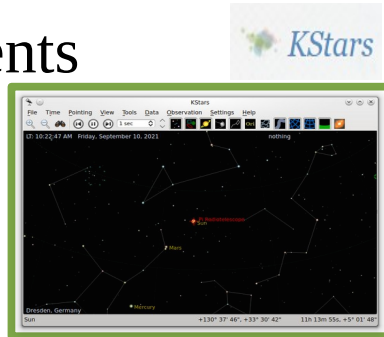
# Software



## Der Radiotelescope Task Scheduler - RaTSche

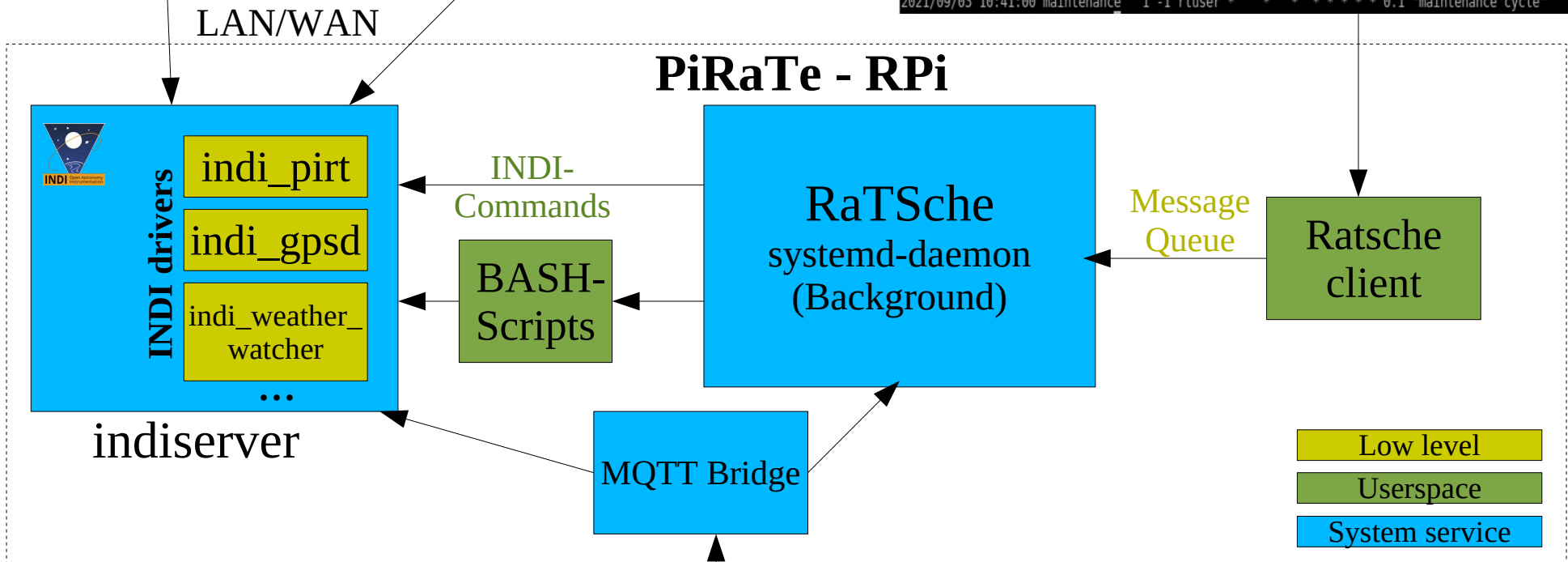
### Clients

```
pi@pi300:~$ indi_getprop -t 1 -l "Pi Radiotelescope.*" | head
Pi Radiotelescope.CONNECTION.CONNECT=on
Pi Radiotelescope.CONNECTION.DISCONNECT=off
Pi Radiotelescope.DRIVER.INFO.DRIVER.NAME=Pi Radiotelescope
Pi Radiotelescope.DRIVER.INFO.DRIVER.EXEC=indi_pirt
Pi Radiotelescope.DRIVER.INFO.DRIVER.VERSION=1.0
Pi Radiotelescope.DRIVER.INFO.DRIVER.INTERFACE=1
Pi Radiotelescope.POLLING.PERIOD.PERIOD_MS=200
Pi Radiotelescope.AZ_ENC.SETTING.AZ_ENC_ST_BITS=12
Pi Radiotelescope.AZ_ENC.SETTING.AZ_ENC_MT_BITS=12
Pi Radiotelescope.EL_ENC.SETTING.EL_ENC_ST_BITS=13
pi@pi300:~$
```



### Definition von Tasks - Taskfiles

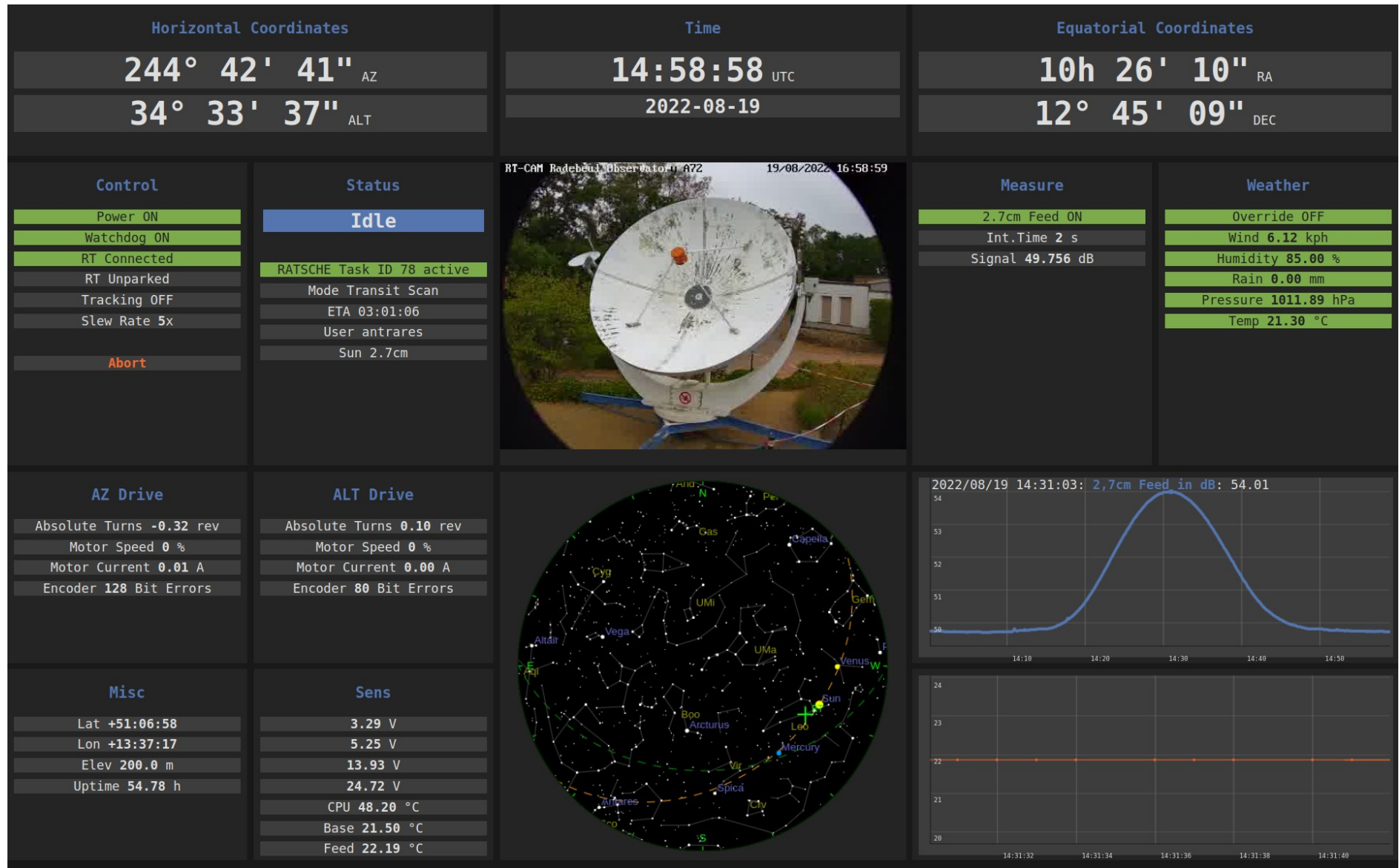
```
# start_time mode priority alt_period user x1 y1 x2 y2 stepx stepy int_time ref_cycle max_duration comment
2021/09/04 11:30:00 unpark 1 0 rtuser * * * * * 0.1 "unpark"
2021/09/01 10:50:00 maintenance 1 0 rtuser * * * * * 1 "maintenance cycle"
2021/09/03 17:28:00 drift 1 0 rtuser 180 60 * * * * 5 * 0.5 "transit scan test"
2021/09/04 14:15:00 track 1 -1 rtuser 10.9 7.0 * * * * 10 * 1.0 "test sun track 12GHz"
2021/09/03 18:30:00 horscan 2 0 rtuser 170 24 190 34 0.5 0.5 0.5 * 0.1 "Test scan Az/Alt"
2021/09/04 11:31:00 equiscan 2 1 rtuser 10.7 4 11.25 10 0.015 0.15 1 * 3 "sun scan 12GHz"
2021/09/04 13:30:00 park 1 0 rtuser * * * * * 0.1 "park"
2021/09/03 10:41:00 maintenance 1 -1 rtuser * * * * * 0.1 "maintenance cycle"
```



# Software

## Das WebUI-Dashboard

JS-Frontend mit MQTT-Endpoints für INDI-Variablen und Ratsche Tasks



# Software



## Der WebUI-Task-Scheduler

JS-Frontend mit MQTT-Endpoints für INDI-Variablen und Ratsche Tasks

Task List																		09:16:02 UTC	
Task	Date	Time	Mode	Priority	Alt-Period	User	lower left X	lower left Y	upper right X	upper right Y	increment X	increment Y	Int-Time	Ref-Cycle	Max-Duration	Elapsed	ETA	Status	Comment
80	2022/08/20	13:00:00	Park Scope	immediate when free	-1 h	antrares	0:00:00	0:00:00	0:00:00	0:00:00	0	0	0 s	0	00:06:00	00:00:00	00:06:00	Queued	park scope
79	2022/08/20	09:12:00	RA/Dec Grid Scan	immediate when free	-1 h	antrares	9:28:09	4:53:34	10:28:09	19:53:34	0.033	0.5	5 s	0	02:00:00	00:03:58	01:56:02	Active	Sun Scan 2.7cm
78	2022/08/19	14:00:00	Transit Scan	immediate when free	-1 h	antrares	244:37:41	34:33:37	0:00:00	0:00:00	0	0	2 s	0	04:00:00	04:00:00	00:00:00	Finished	Sun 2.7cm
77	2022/08/18	13:34:00	Transit Scan	immediate when free	-1 h	antrares	235:51:14	39:36:50	0:00:00	0:00:00	0	0	10 s	0	01:00:00	01:00:00	00:00:00	Finished	Sun 2.7cm
74	2022/08/18	10:05:00	RA/Dec Grid Scan	immediate when free	-1 h	antrares	8:03:27	5:53:43	10:33:27	25:53:43	0.066	1	1 s	0	06:00:00	01:21:14	00:00:00	Finished	Sun/Venus 2.7cm
72	2022/08/16	16:25:00	Maintenance	ignore	-1 h	antrares	0:00:00	0:00:00	0:00:00	0:00:00	0	0	0 s	0	06:00:00	05:59:60	00:00:00	Finished	...
71	2022/08/16	13:11:00	Transit Scan	immediate when free	-1 h	hgz	0:00:00	51:00:00	0:00:00	0:00:00	0	0	1 s	0	06:00:00	03:10:50	00:00:00	Stopped	longtime north pole, 2.7cm, secondary antenna
70	2022/08/16	08:47:00	Transit Scan	immediate when free	-1 h	hgz	148:04:23	48:58:14	0:00:00	0:00:00	0	0	2 s	0	02:00:00	02:00:00	00:00:00	Finished	transit scan sun, 2.7cm, secondary antenna
68	2022/08/15	10:00:00	Transit Scan	immediate	-1 h	uku	180:00:00	90:00:00	0:00:00	0:00:00	0	0	1 s	0	00:03:22	00:00:00	00:00:00	Cancelled	Spectrum/Raum
67	2022/08/15	09:27:00	RA/Dec Grid Scan	immediate	-1 h	hgz	9:02:23	5:20:40	10:14:23	22:50:40	0.033	0.5	2 s	0	03:00:00	02:19:30	00:00:00	Finished	Sun Scan 2.7cm secondary antenna
64	2022/08/15	03:00:00	RA/Dec Grid Scan	immediate	-1 h	antrares	23:45:55	-10:17:49	0:45:55	4:42:11	0.017	0.25	5 s	0	04:00:00	04:00:00	00:00:00	Finished	Moon 2.7cm
63	2022/08/14	21:44:00	Az/Alt Grid Scan	low priority	-1 h	antrares	150:00:00	25:00:00	200:00:00	38:00:00	0.5	0.5	1 s	0	05:00:00	03:21:02	00:00:00	Finished	Sats 2.7cm
62	2022/08/14	20:03:00	Az/Alt Grid Scan	immediate when free	-1 h	Thomas	170:00:00	25:00:00	190:00:00	35:00:00	1	1	1 s	0	01:00:00	00:22:26	00:00:00	Finished	Astra/Hotbird test
61	2022/08/12	12:20:00	Maintenance	ignore	-1 h	antrares	0:00:00	0:00:00	0:00:00	0:00:00	0	0	0 s	0	24:00:00	23:59:60	00:00:00	Finished	...
60	2022/08/11	13:00:00	Goto RA/Dec	immediate	-1 h	uku	9:24:51	15:11:26	0:00:00	0:00:00	0	0	0 s	0	00:06:00	00:00:25	00:00:00	Finished	Sun
59	2022/08/11	11:00:00	RA/Dec Grid Scan	immediate when free	-1 h	uku	9:04:47	10:11:40	9:44:49	20:11:40	0.133	2	5 s	0	01:00:00	00:07:05	00:00:00	Finished	Sun
57	2022/08/09	21:51:00	RA/Dec Grid Scan	immediate when free	-1 h	antrares	19:04:58	-30:06:40	19:24:57	-25:06:40	0.066	1	5 s	0	03:00:00	00:06:27	00:00:00	Finished	Moon 93% Scan
56	2022/08/08	21:20:00	RA/Dec Grid Scan	immediate	-1 h	uku	17:52:43	-30:16:28	18:10:43	-25:16:28	0.1	1	5 s	0	01:00:00	00:00:00	00:00:00	Cancelled	Moon 80% Scan
55	2022/08/07	15:05:00	RA/Dec Grid Scan	asap when optimal	-1 h	hgz	8:45:30	11:27:30	9:30:30	21:27:30	0.02	0.25	1 s	0	03:00:00	02:02:21	00:00:00	Finished	Sun Scan
54	2022/08/07	15:00:00	RA/Dec Grid Scan	asap when optimal	-1 h	hgz	9:07:60	11:27:30	9:07:60	21:27:30	0.02	0.25	1 s	0	03:00:00	00:01:58	00:00:00	Stopped	Sun Scan
53	2022/08/07	09:30:00	RA/Dec Grid Scan	asap when optimal	-1 h	hgz	8:37:60	6:27:30	9:37:60	26:27:30	0.02	0.3	2 s	0	04:00:00	04:00:00	00:00:00	Finished	Sun Scan
52	2022/08/06	17:00:00	Az/Alt Grid Scan	immediate when free	-1 h	antrares	170:16:12	28:34:12	175:46:12	34:04:12	0.25	0.25	10 s	0	04:00:00	01:49:20	00:00:00	Finished	test Astra 1
51	2022/08/06	15:00:00	RA/Dec Grid Scan	immediate when free	-1 h	hgz	8:34:50	9:11:44	9:34:50	24:11:44	0.033	0.5	2 s	0	02:00:00	01:42:41	00:00:00	Finished	Sun Scan
50	2022/08/06	13:02:00	RA/Dec Grid Scan	asap when optimal	-1 h	hgz	8:04:50	4:11:44	10:04:50	29:11:44	0.02	0.3	5 s	0	05:00:00	01:55:13	00:00:00	Stopped	Sun Scan
49	2022/08/06	12:54:00	RA/Dec Grid Scan	asap when optimal	-1 h	hgz	8:34:50	5:41:44	9:34:50	27:41:44	0.02	0.25	5 s	0	04:00:00	00:06:02	00:00:00	Stopped	Sun Scan
48	2022/08/05	21:20:00	Park Scope	immediate	-1 h	Thomas	0:00:00	0:00:00	0:00:00	0:00:00	0	0	0 s	0	00:06:00	00:00:26	00:00:00	Finished	park rt
47	2022/08/05	20:55:00	Goto Az/Alt	low priority	-1 h	Thomas	173:01:12	31:19:12	0:00:00	0:00:00	0	0	0 s	0	00:06:00	00:00:21	00:00:00	Finished	goto Astra 1 A-H
46	2022/08/05	17:52:00	RA/Dec Grid Scan	immediate when free	-1 h	hgz	14:26:11	-25:03:00	15:26:11	-10:03:00	0.035	0.5	10 s	0	04:00:00	02:20:14	00:00:00	Stopped	Scan Moon
45	2022/08/05	11:38:00	RA/Dec Grid Scan	immediate when free	-1 h	antrares	8:32:02	9:23:47	9:32:02	24:23:47	0.1	1	10 s	0	00:00:00	00:40:51	00:00:00	Finished	Sun Scan
44	2022/08/05	00:42:00	RA/Dec Grid Scan	immediate when free	-1 h	antrares	8:32:12	9:23:04	9:32:12	24:23:04	0.066	1	10 s	0	04:00:00	01:02:46	00:00:00	Finished	Sun Scan
43	2022/08/04	19:30:00	Az/Alt Grid Scan	immediate when free	-1 h	antrares	170:31:12	28:49:12	175:31:12	33:49:12	0.2	0.2	10 s	0	12:00:00	02:28:26	00:00:00	Finished	Astra 1 A-H 19,2° Ost
42	2022/08/03	14:40:00	Transit Scan	immediate when free	-1 h	uku	172:00:00	32:50:13	0:00:00	0:00:00	0	0	20 s	0	01:00:00	01:00:00	00:00:00	Finished	Moon transit
40	2022/08/01	15:45:00	Goto RA/Dec	immediate when free	-1 h	uku	11:38:46	6:13:55	0:00:00	0:00:00	0	0	0 s	0	01:00:00	00:00:15	00:00:00	Finished	Moon transit
39	2022/08/01	15:00:00	Tracking Scan	immediate when free	-1 h	uku	11:37:19	6:28:48	0:00:00	0:00:00	0	0	10 s	0	00:06:00	00:00:00	00:00:00	Cancelled	Moon transit
38	2022/08/01	14:30:00	Goto RA/Dec	immediate	-1 h	uku	11:40:08	5:59:13	0:00:00	0:00:00	0	0	0 s	0	00:06:00	00:00:26	00:00:00	Finished	Moon transit
37	2022/08/01	12:15:00	Goto Az/Alt	immediate when free	-1 h	uku	138:00:00	39:06:00	0:00:00	0:00:00	0	0	0 s	0	01:00:00	00:00:02	00:00:00	Finished	Moon transit
35	2022/08/01	01:45:00	Goto Az/Alt	immediate when free	-1 h	uku	139:00:00	39:10:23	0:00:00	0:00:00	0	0	0 s	0	01:00:00	00:00:22	00:00:00	Finished	Moon transit
34	2022/07/31	13:00:00	Goto Az/Alt	immediate when free	-1 h	uku	175:00:00	50:21:04	0:00:00	0:00:00	0	0	0 s	0	00:30:00	00:00:00	00:00:00	Stopped	Moon transit
31	2022/07/29	10:15:00	Transit Scan	immediate when free	-1 h	uku	175:00:00	57:30:00	0:00:00	0:00:00	0	0	20 s	0	01:30:00	01:30:00	00:00:00	Finished	sun transit
30	2022/07/29	10:15:00	Goto Az/Alt	immediate when free	-1 h	uku	175:00:00	57:30:00	0:00:00	0:00:00	0	0	0 s	0	01:30:00	00:00:00	00:00:00	Stopped	sun transit
27	2022/07/26	10:33:00	Transit Scan	immediate when free	-1 h	hgz	227:49:12	58:46:12	0:00:00	0:00:00	0	0	10 s	0	03:00:00	03:00:00	00:00:00	Finished	transit scan moon+sun
26	2022/07/26	10:31:00	Goto RA/Dec	immediate when free	-1 h	hgz	6:00:00	26:35:24	0:00:00	0:00:00	0	0	0 s	0	00:06:00	00:00:10	00:00:00	Finished	goto start pos for moon transit scan

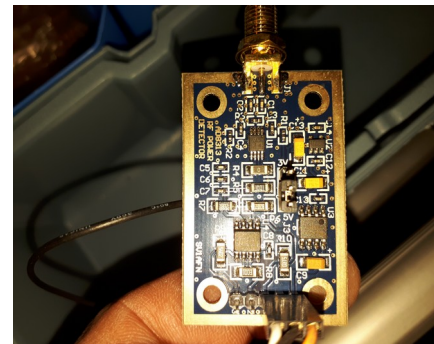
# Empfangstechnik

## Kommerzielle Sat-TV Technik: Ku-Band (10,7..12,75 GHz)

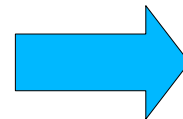


### Zum Messen der Feldstärke:

- Für erste Versuche: Satfinder
- Besser: log. Detektor (AD8313)



RF Power Detector –  
Makis (SV1AFN)  
<https://www.sv1afn.com/>

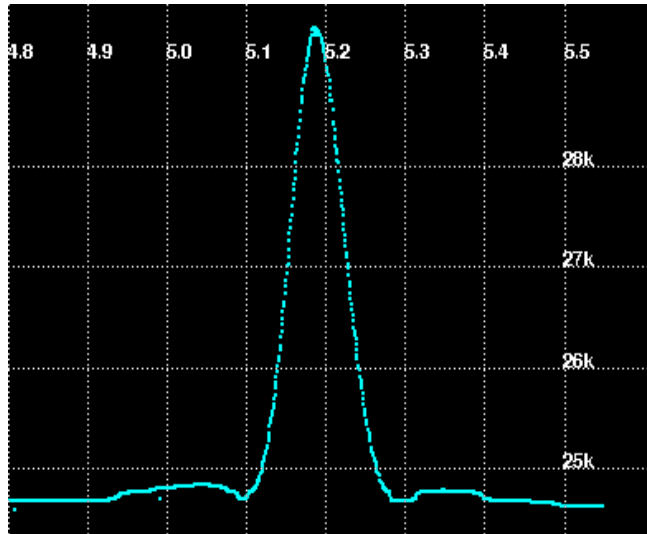


### Exzellente Hardware für Radioastronomie

**Sat-LNB (Preis: 5€)**  
Rauschmaß: „0.1dB“  
(tatsächlich eher ~0.8dB)

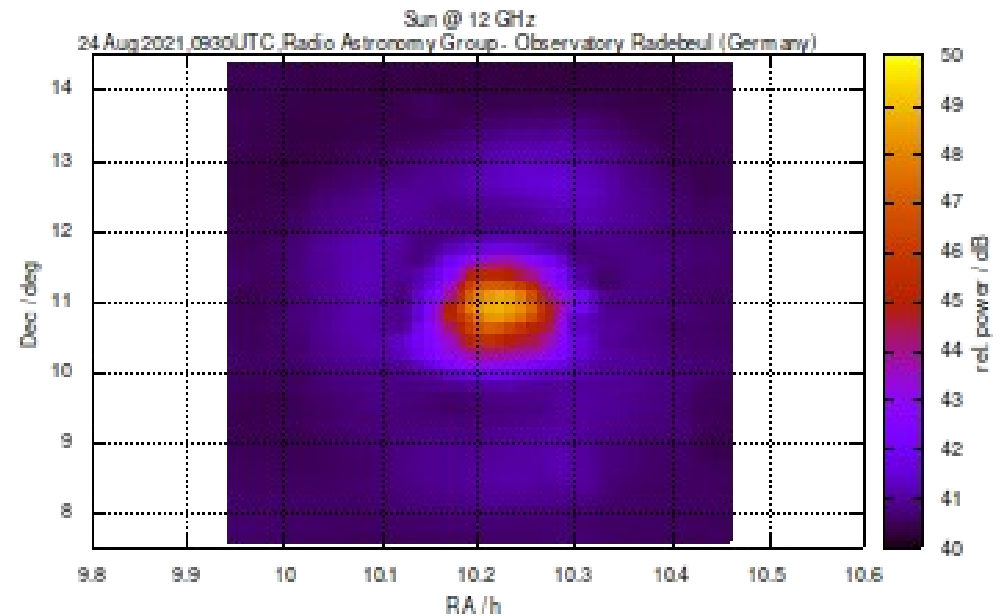
# Beobachtungen – Ku-Band

## Sonne



- 2d Rasterscan mit wählbarem Stepping automatisiert durch Definition eines 2d-Scan-Tasks → Abfrage von INDI-Variablen in Loop
- Aufzeichnen der Koordinaten und des dB-linearen Outputs am log. Detektor (AD8313)

```
piert300:~/data/ratsche $ head -n 29 task_equscan20210907_26149
# RA/Dec Grid Scan
# Task ID: 4
# Submit time: 2021/09/07 07:15:49.000000000
# Schedule time: 2021/09/07 07:14:30.000000000
# Start time: 2021/09/07 07:15:49.185791000
# Max run time: 3h
# User: hgz
# Priority: 2
# Comment: Sun scan 12GHz
#-----
# Start coordinates: RA=10.8h Dec=2deg
# End coordinates: RA=11.4h Dec=10deg
# Step size: RA=0.015h = 0.225deg Dec=0.2deg
# Integration time: 1s
# time az alt ra dec adc1 adc2 temp
1630998981.930211523 119.4603 24.0573 10.80048 2.0289 41.4095 0.0557 15.6
1630998985.030842082 119.4655 24.2330 10.79463 2.1734 41.4005 0.0557 15.6
1630998987.866254766 119.2053 24.4088 10.80228 2.4504 41.3335 0.0557 15.6
1630998990.817548058 119.1168 24.5846 10.80089 2.6415 41.2864 0.0558 15.6
1630998993.595627824 118.9399 24.7604 10.80425 2.8767 41.2479 0.0558 15.6
1630998996.609384481 118.9399 24.9801 10.79701 3.0602 41.2117 0.0558 15.6
1630998999.400686753 118.7733 25.1120 10.80141 3.2533 41.1803 0.0557 15.6
1630999002.296033808 118.6796 25.2877 10.80050 3.4467 41.1532 0.0557 15.5
1630999005.042792340 118.5183 25.4196 10.80459 3.6371 41.1231 0.0558 15.5
1630999007.830178121 118.5183 25.5954 10.79893 3.7836 41.1174 0.0557 15.5
1630999010.586022431 118.3518 25.8151 10.79972 4.0497 41.0920 0.0558 15.5
1630999013.385297222 118.1488 25.9469 10.80582 4.2606 41.0694 0.0558 15.5
1630999016.246383991 118.1488 26.1227 10.80014 4.4068 41.0763 0.0557 15.5
1630999019.252241028 118.0812 26.2106 10.80108 4.5136 41.0767 0.0557 15.5
```

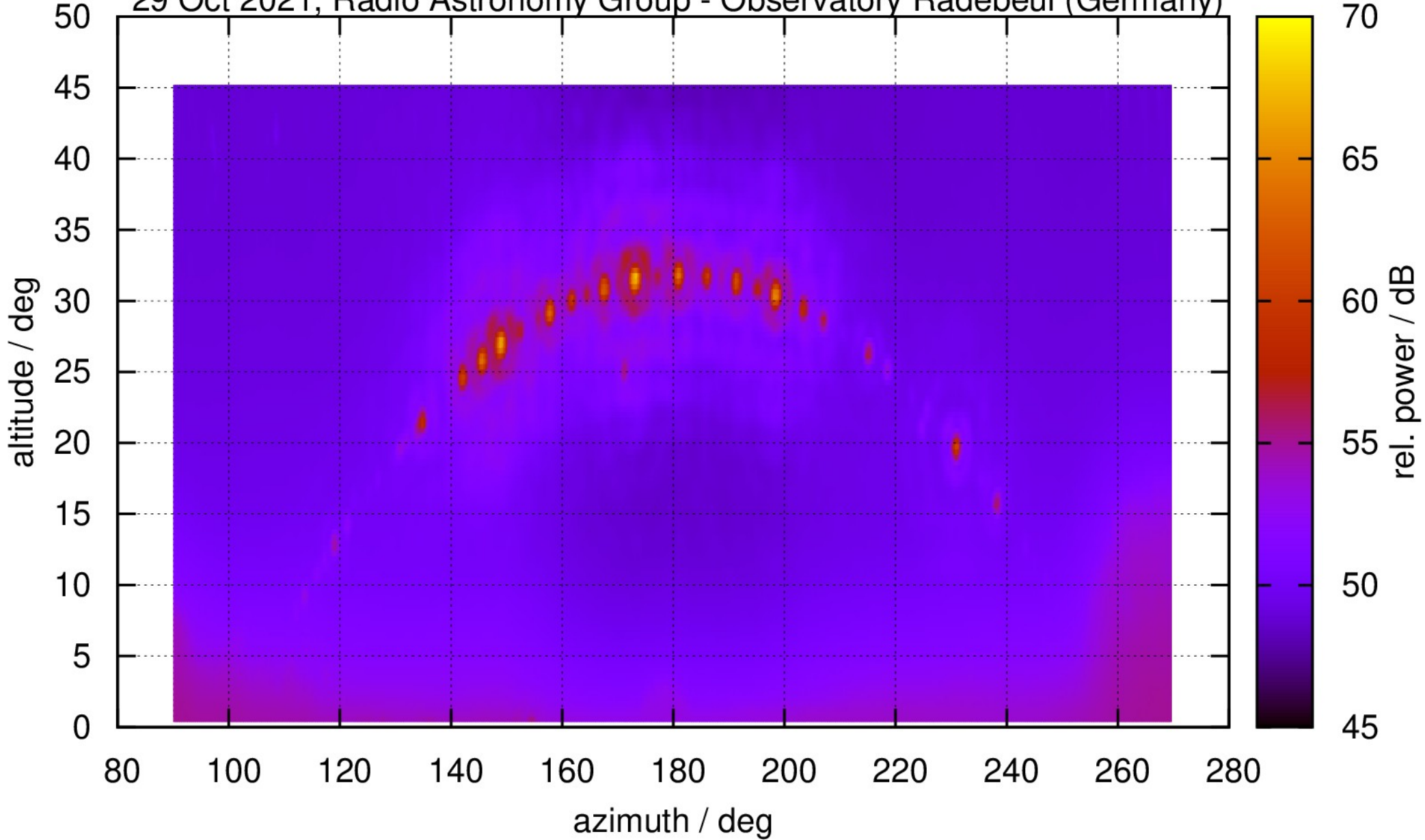


**Problem:** Sat-LNB optimiert für Offset-Schüsseln – Ausleuchtung im Primärfokus des Radioteleskops <50%

# Beobachtungen – Ku-Band

# Geostationary Satellites @ 12 GHz

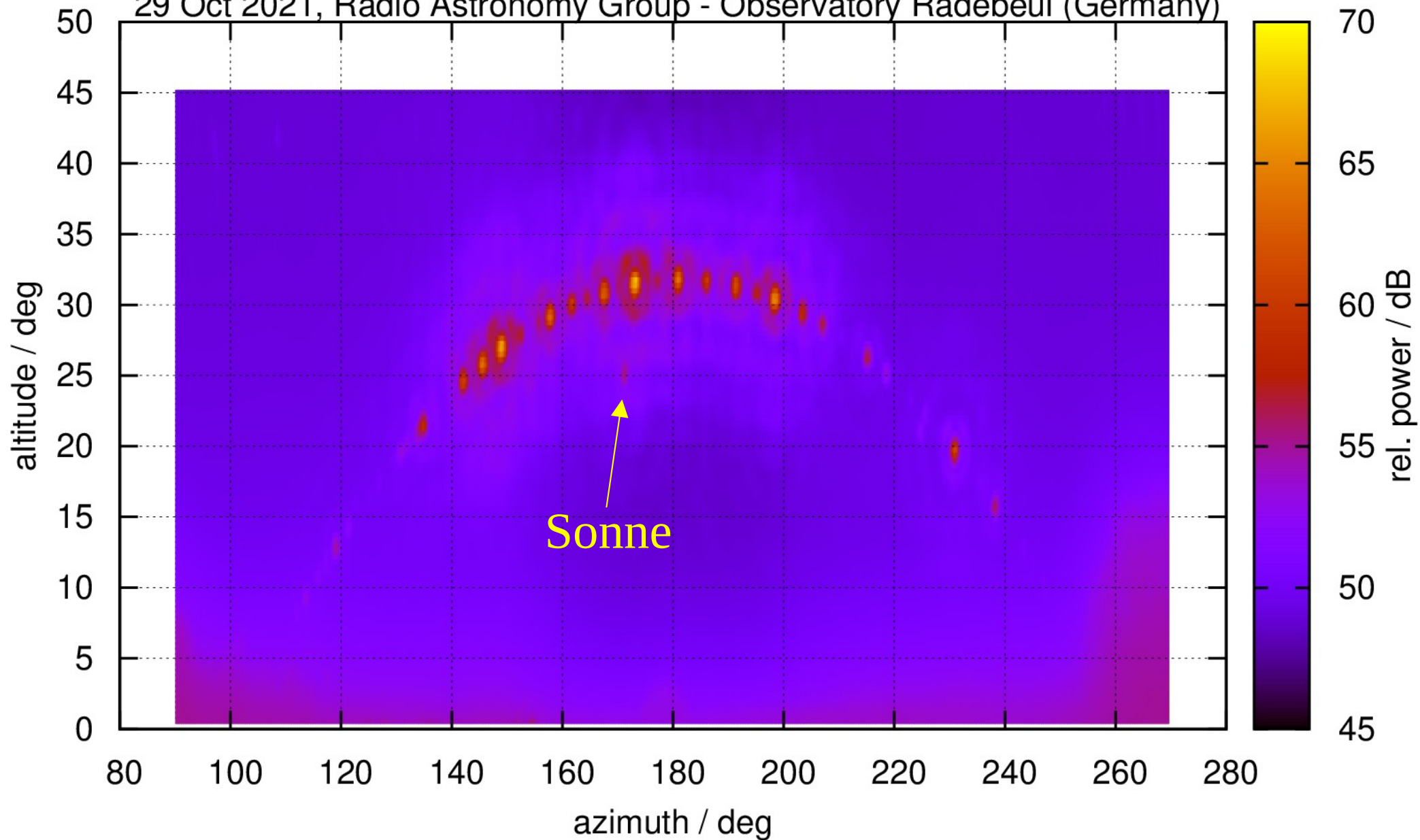
29 Oct 2021, Radio Astronomy Group - Observatory Radebeul (Germany)



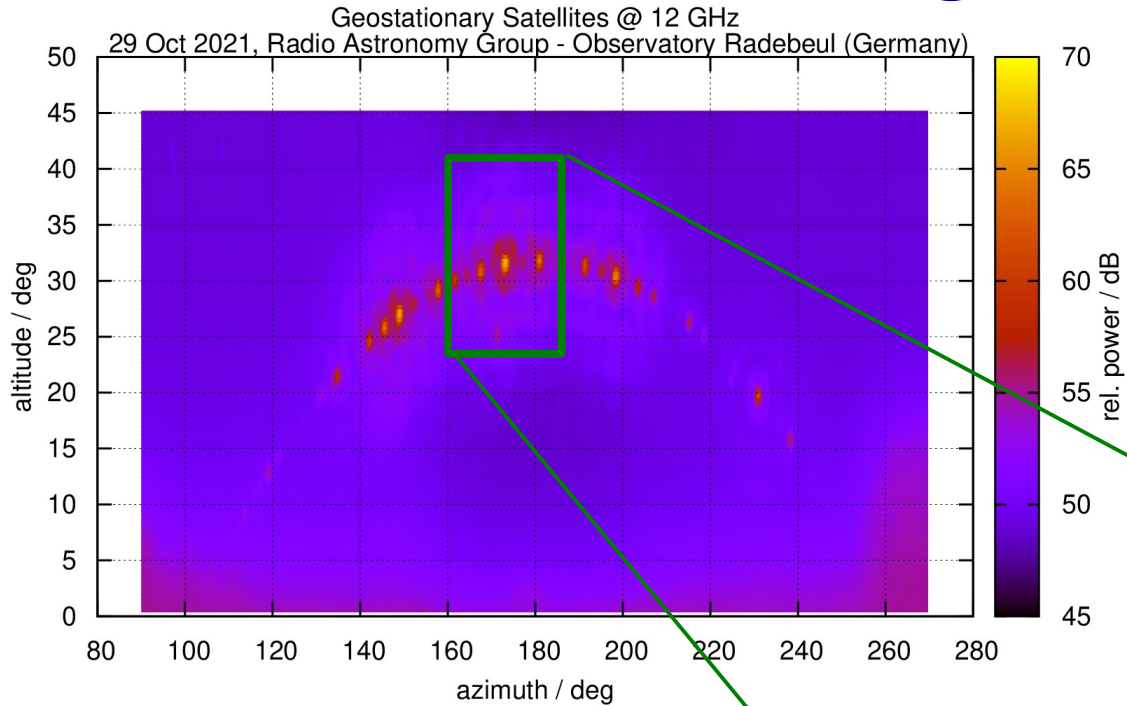
# Beobachtungen – Ku-Band

Geostationary Satellites @ 12 GHz

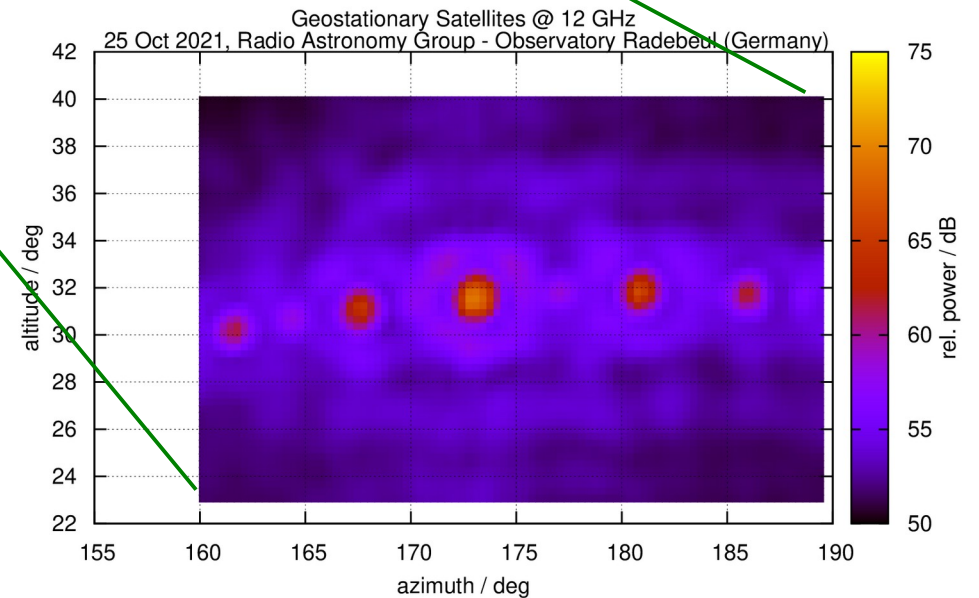
29 Oct 2021, Radio Astronomy Group - Observatory Radebeul (Germany)



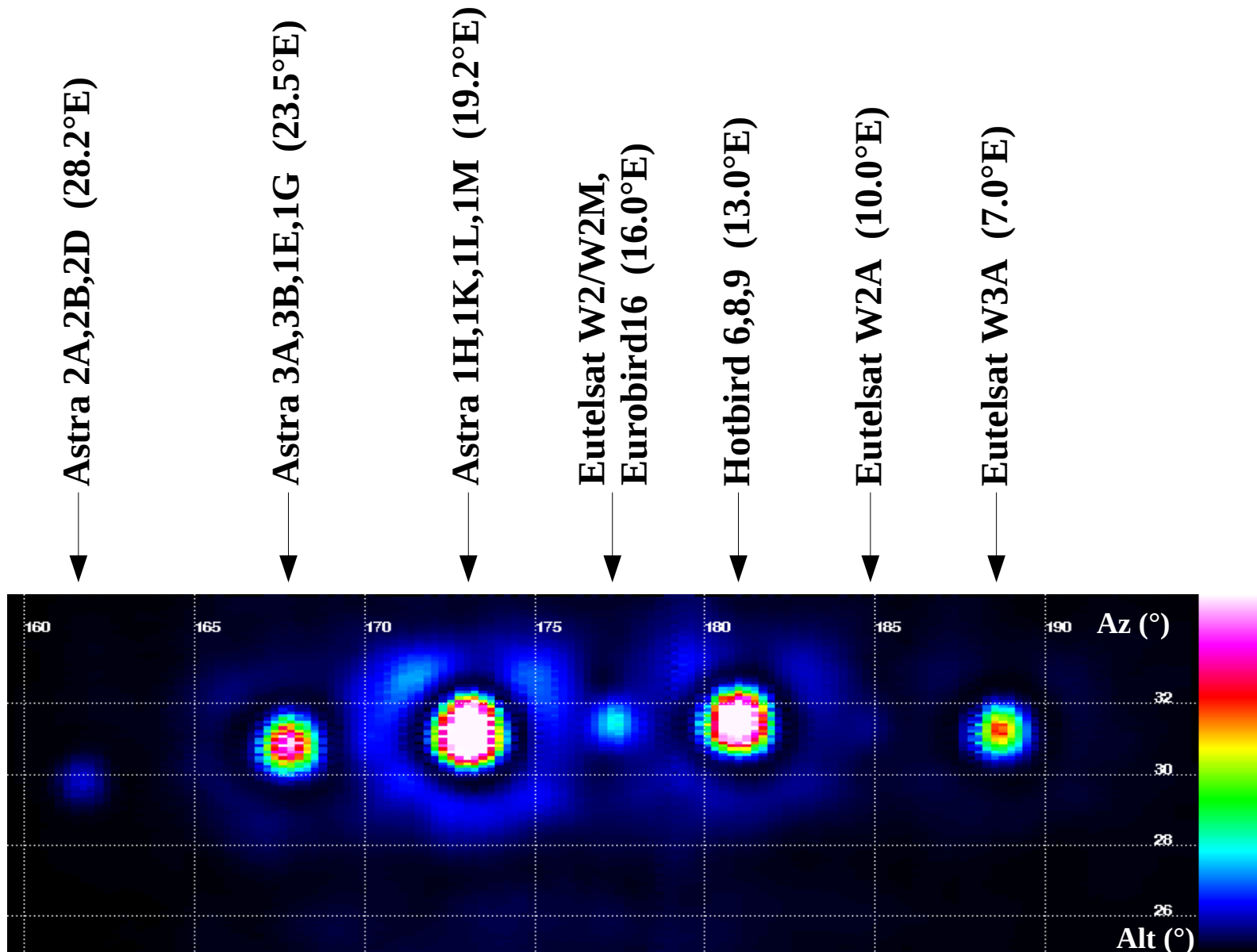
# Beobachtungen – Ku-Band



**TV-  
Satelliten**

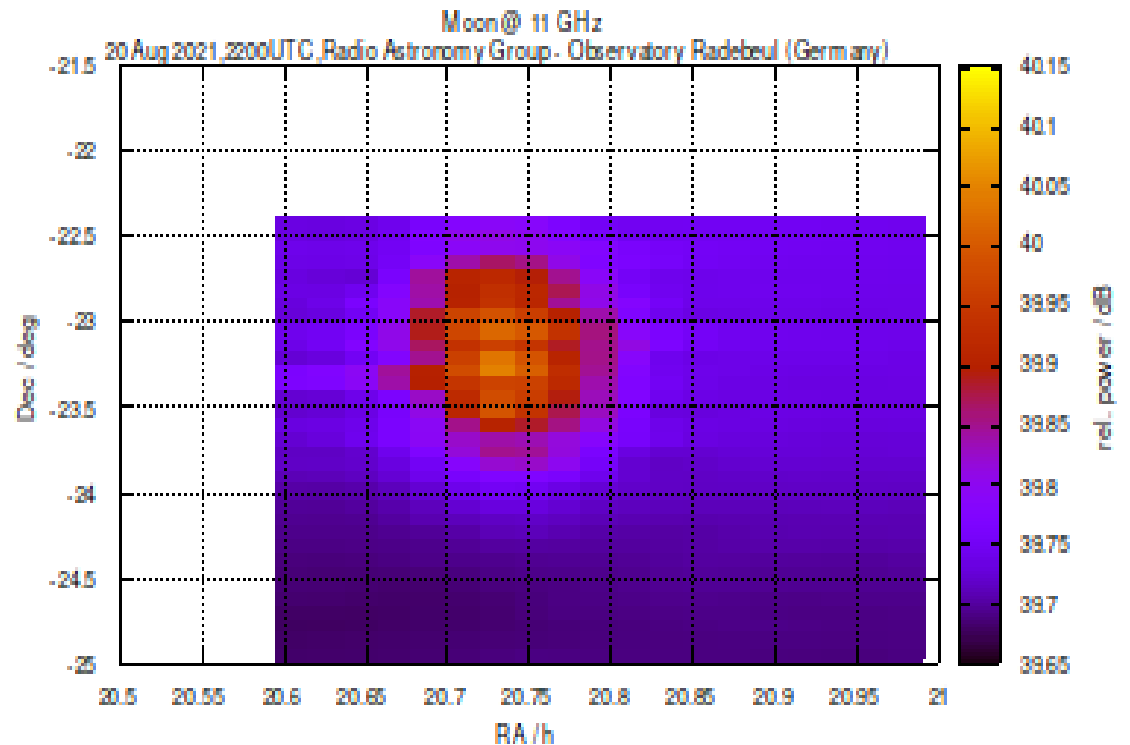
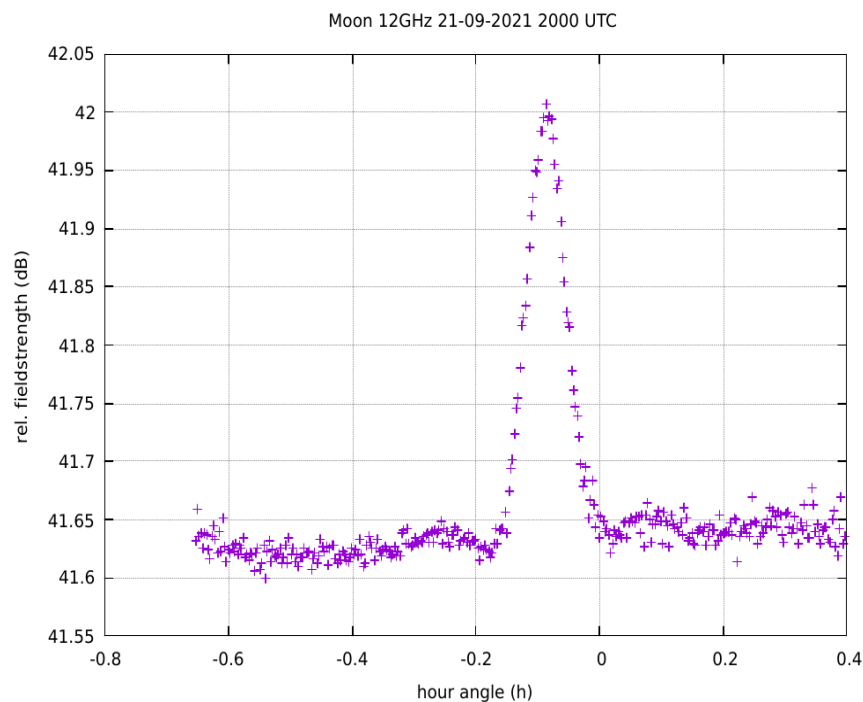


# Beobachtungen – Ku-Band



# Beobachtungen – Ku-Band

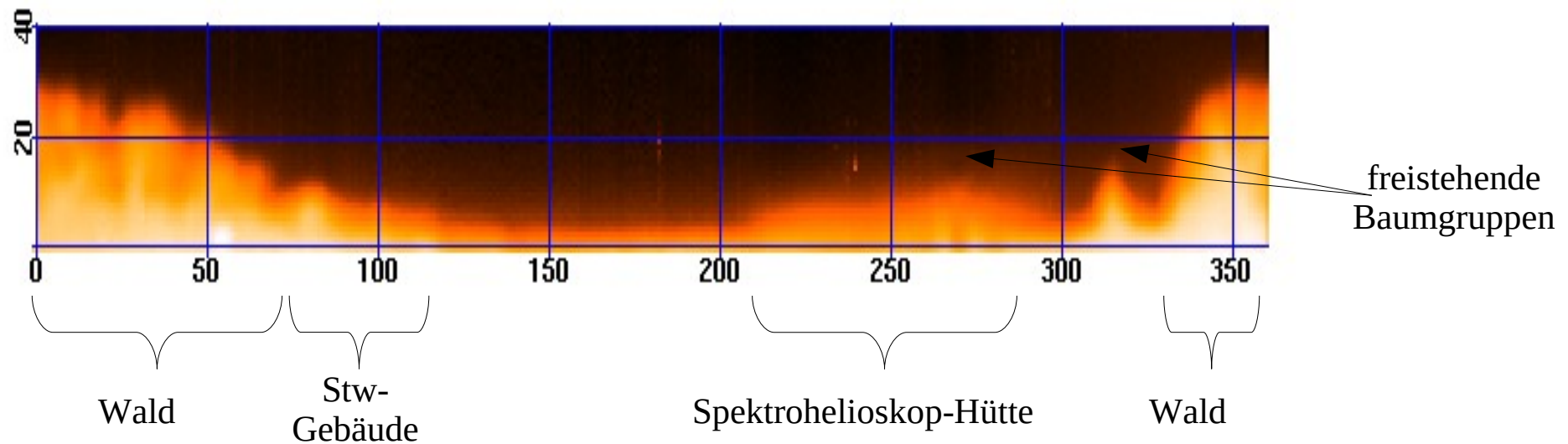
## Mond



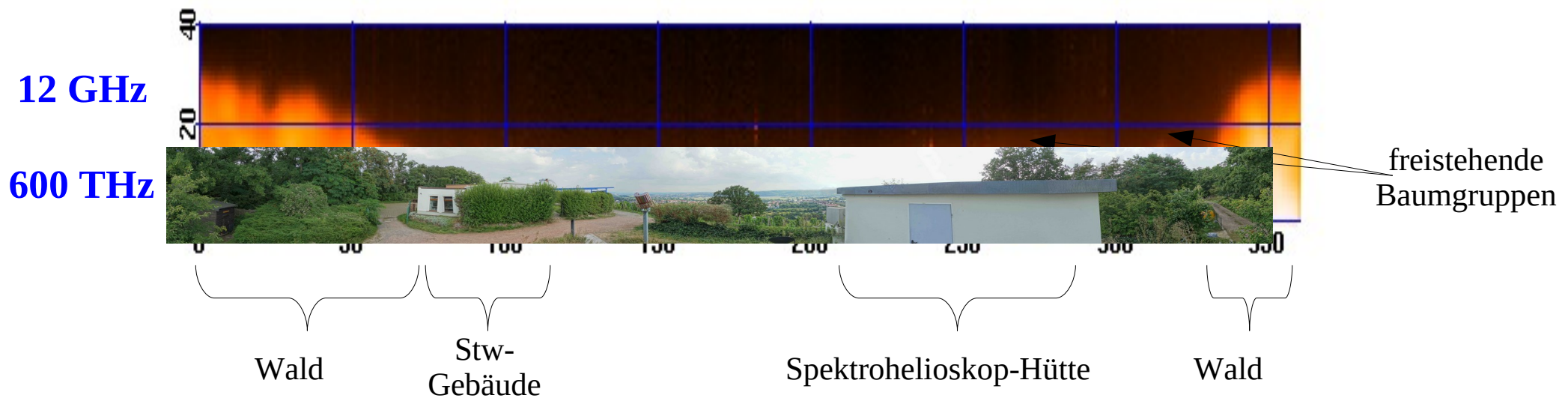
96% Beleuchtung

# Beobachtungen Horizontlinie@12GHz

12 GHz



# Beobachtungen Horizontlinie@12GHz

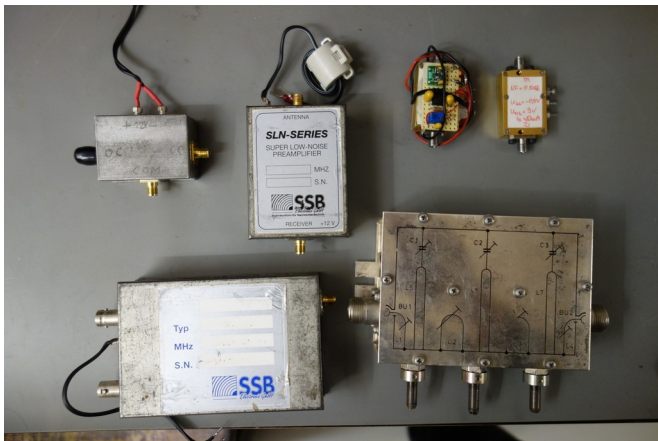
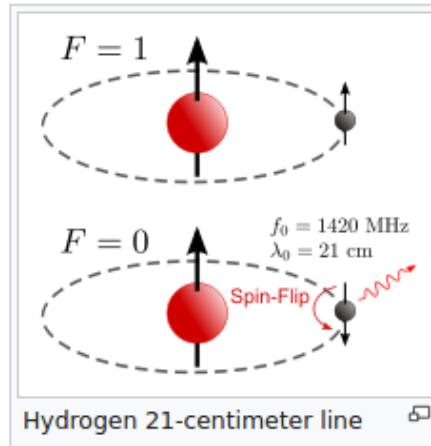




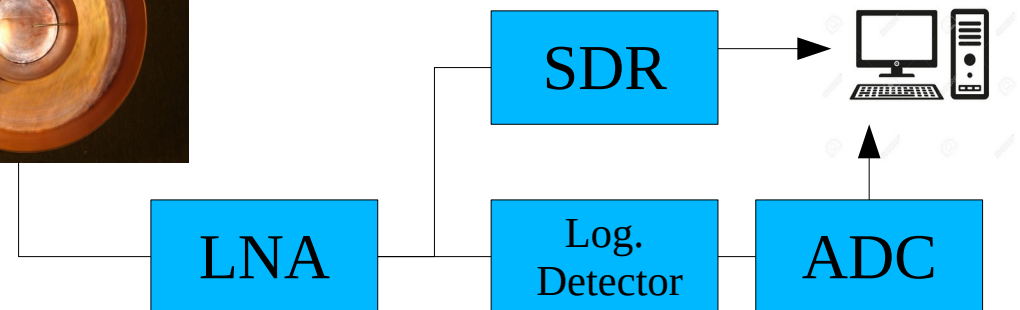
WIKIPEDIA  
The Free Encyclopedia

# Empfangstechnik 1420 Mhz/21cm/HI-Linie

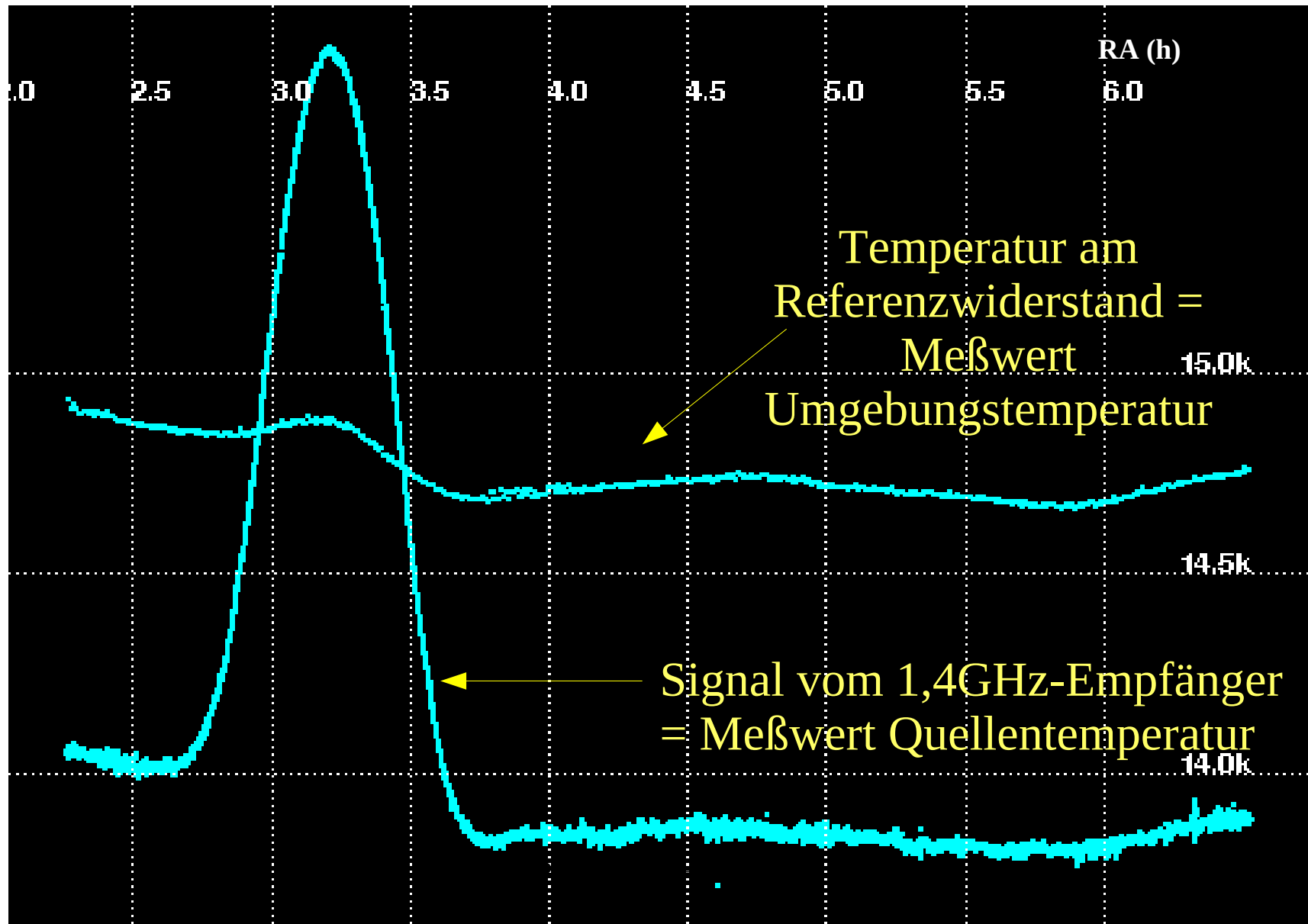
The **hydrogen line**, **21-centimeter line**, or **H I line**<sup>[1]</sup> is the **electromagnetic radiation spectral line** that is created by a change in the energy state of neutral **hydrogen atoms**. This electromagnetic radiation has a precise frequency of 1 420 405 751.768(2) **Hz**,<sup>[2]</sup> which is equivalent to the **vacuum wavelength** of 21.106 114 054 160(30) **cm** in **free space**. This wavelength falls within the **microwave** region of the **electromagnetic spectrum**, and it is observed frequently in **radio astronomy** because those **radio waves** can penetrate the large clouds of interstellar **cosmic dust** that are **opaque** to **visible light**. This line is also the theoretical basis of the **hydrogen maser**.



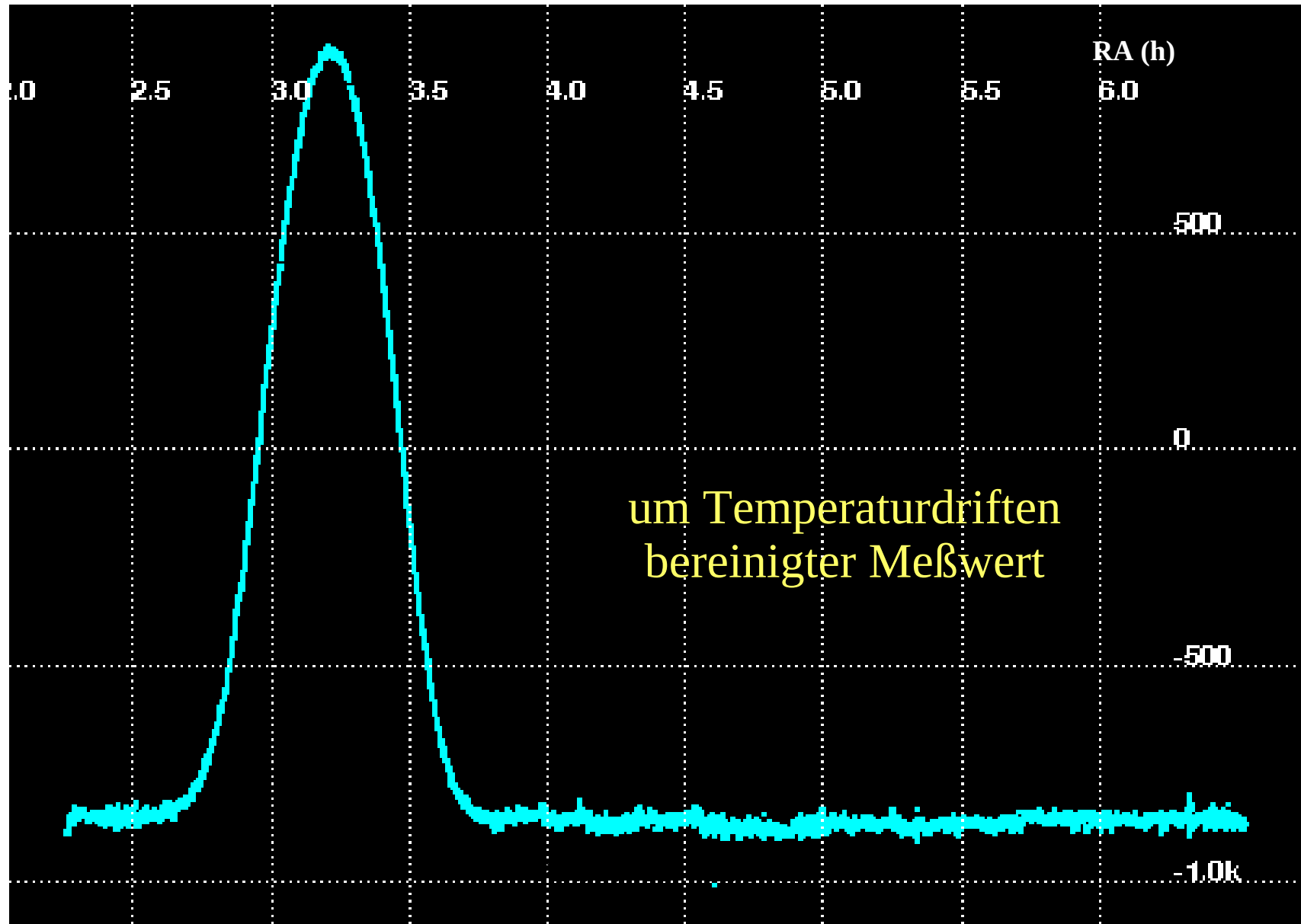
Hohlleiter-Choking-Erreger  
(Kumar Feed)



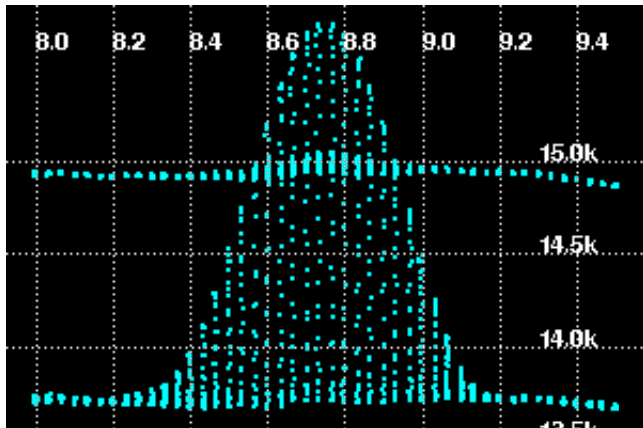
# Beobachtungen Sonne@21cm



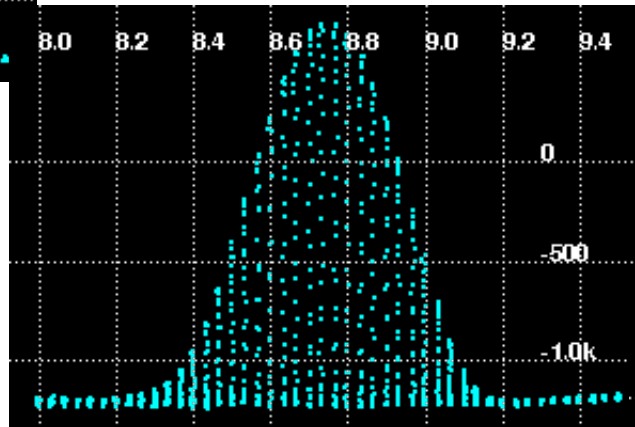
# Beobachtungen Sonne@21cm



# Beobachtungen Sonne@21cm

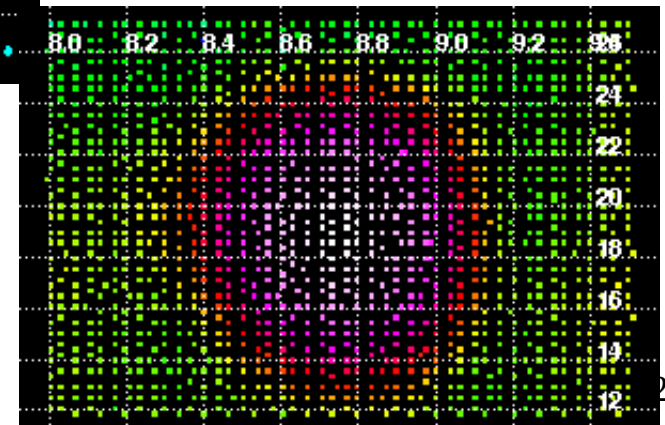


→ Scan in regelmäßigem Gitter  
(Äquatorial/Horizontalssystem)

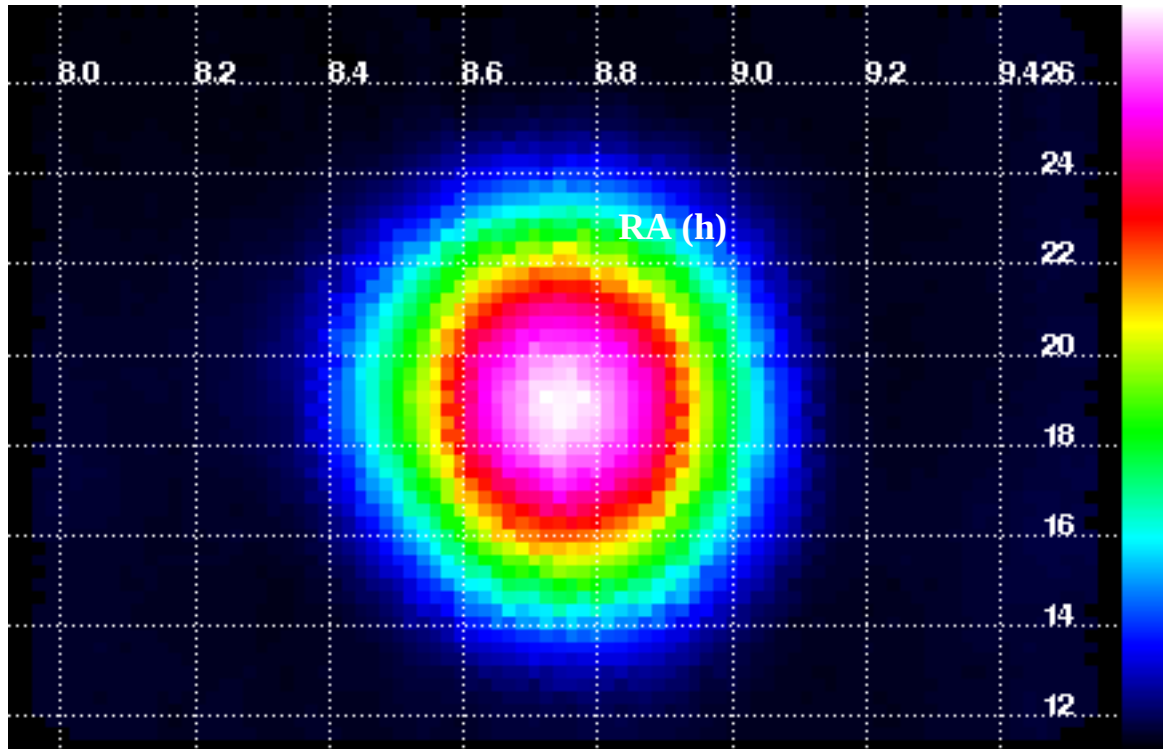


→ Referenzbereinigung

→ Füllen des Raumgitters mit Meßwerten

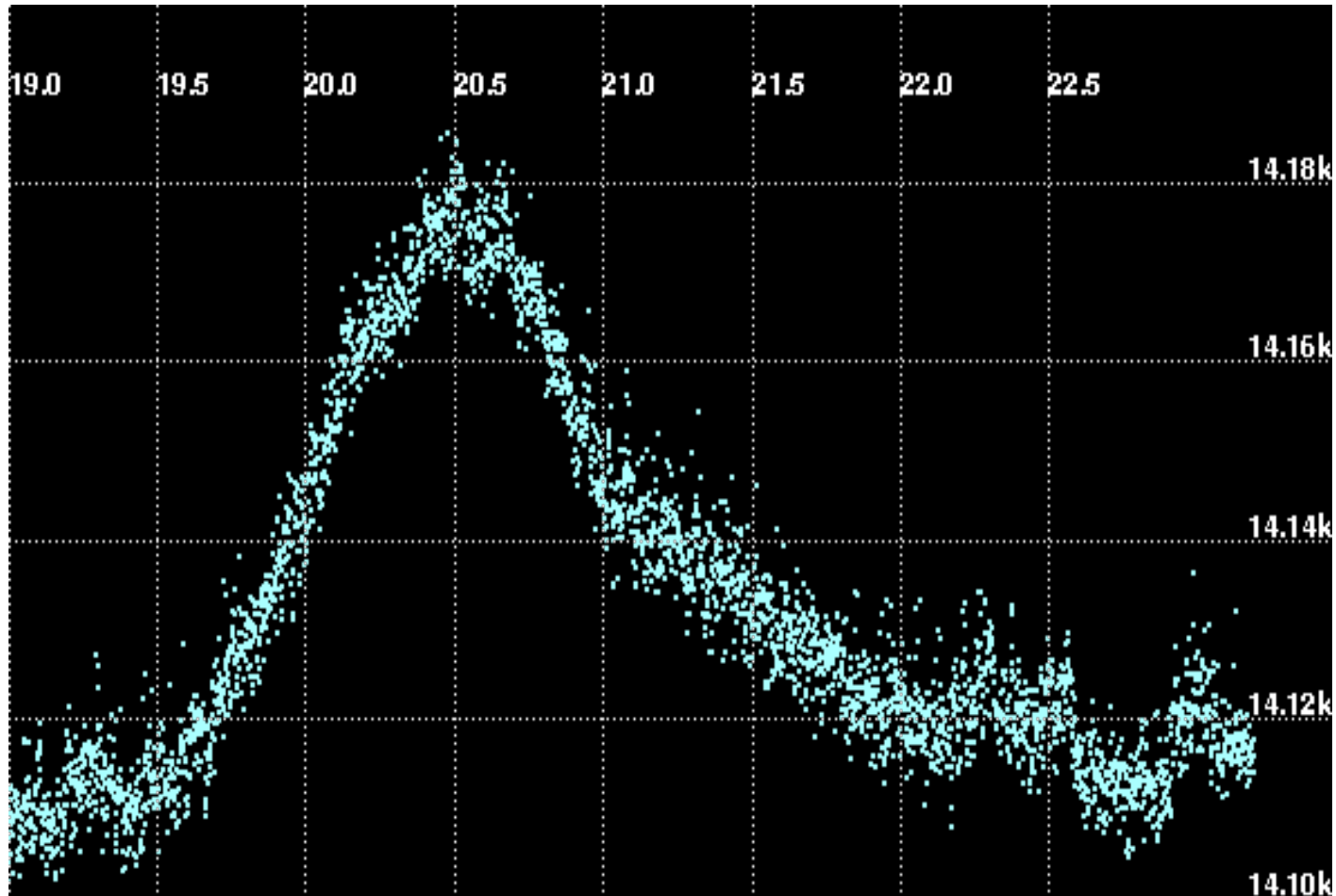


# Beobachtungen Sonne@21cm



- Anpassen des Binnings
- (vorsichtige) Interpolation fehlender Gitterpunkte („Löcher“)

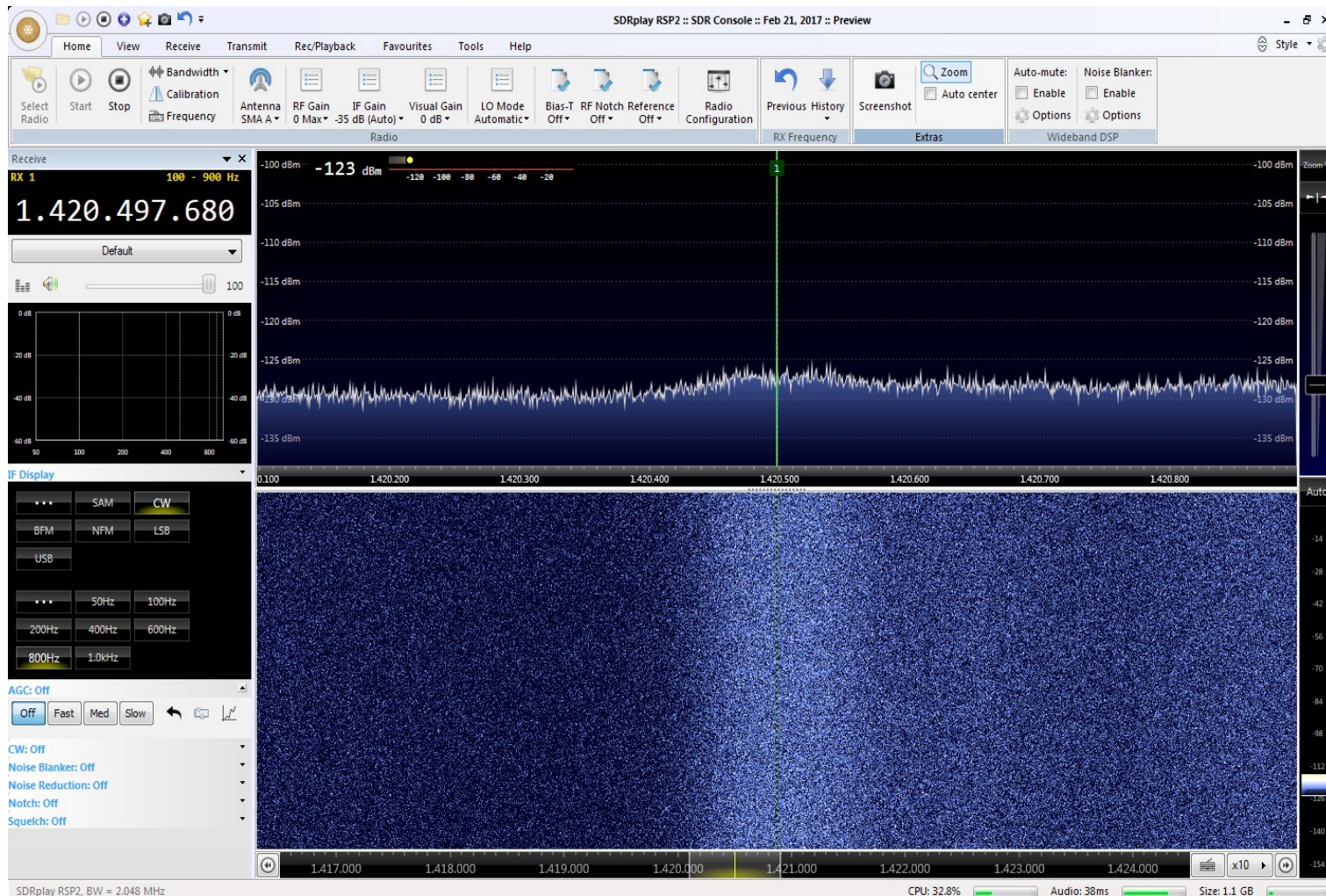
# Beobachtungen Milchstrasse@21cm



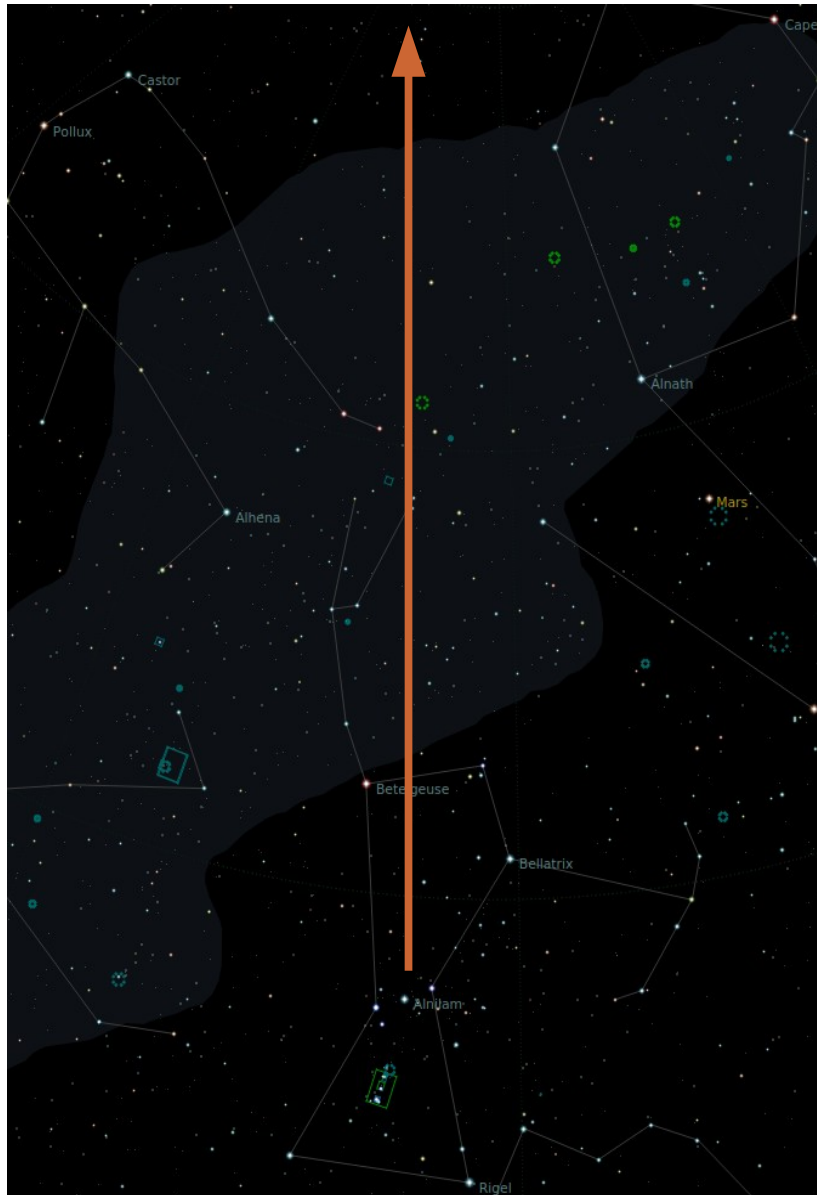


# Beobachtungen Spektrum@21cm

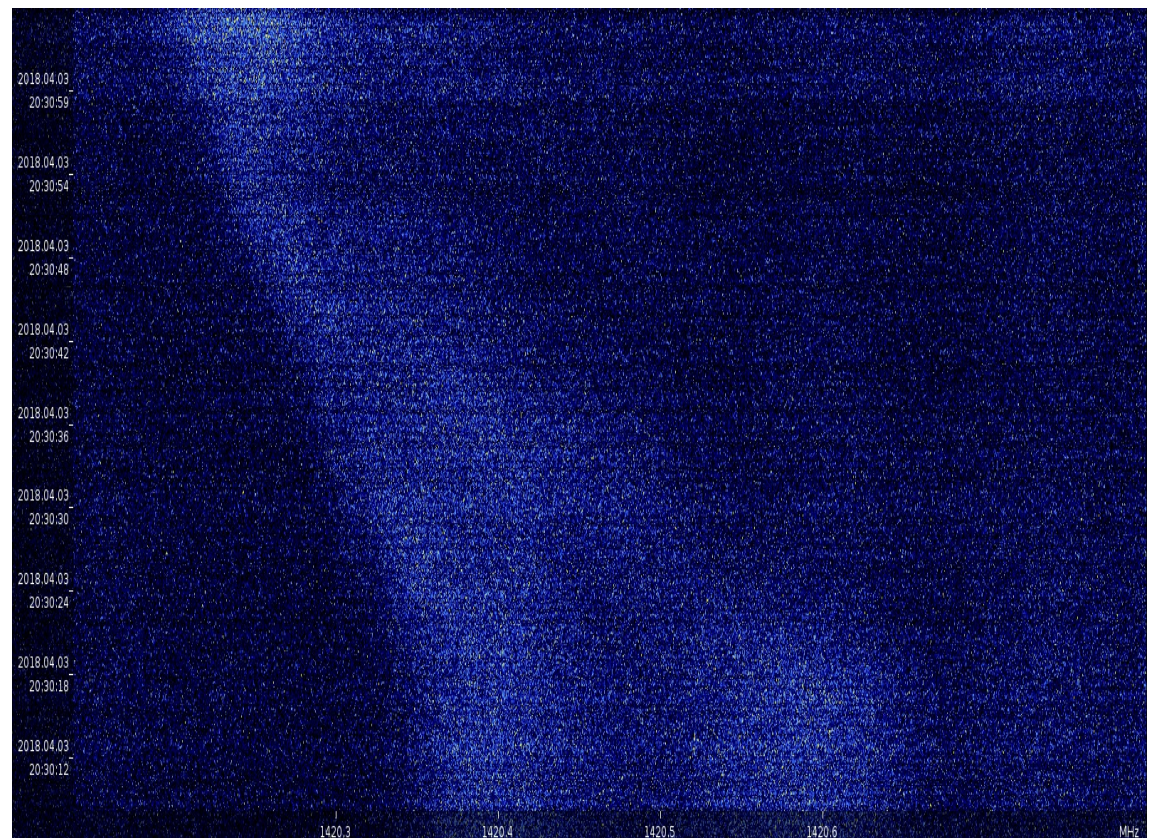
Auswertung mit USB-SDR Stick, Anbindung als WebSDR geplant



# Beobachtungen Milchstrasse@21cm



**Bewegung durch einen Milchstraßenarm**  
→ 21cm-Linie Doppler-verschoben, je nach  
Radialgeschwindigkeit



# Das Projekt

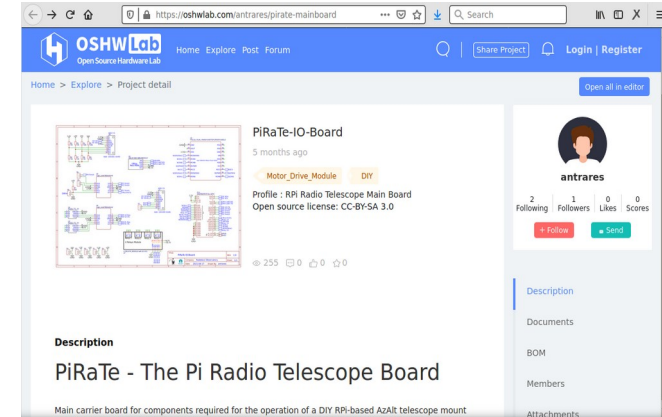
PiRaTe ist...

## Hardware

Basis-PCB und Beschreibung der verwendeten  
Add-On Boards



<https://oshwlab.com/antrares/pirate-mainboard>



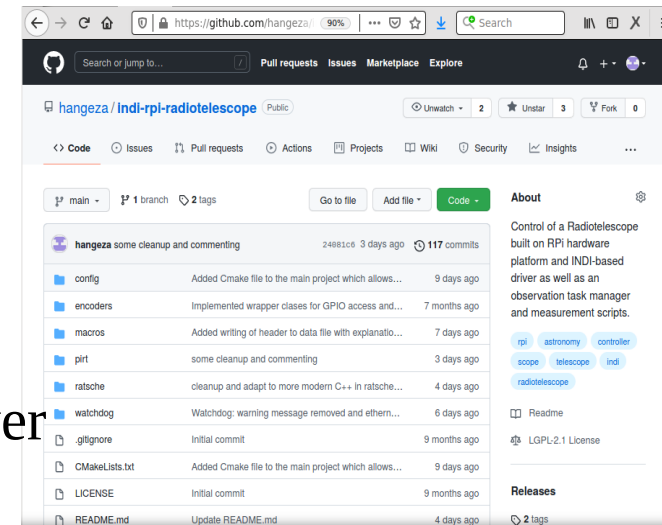
## Software :

- indi-pirt – INDI-Treiber für RPi
- RaTSche – Radiotelescope Task Scheduler
- rt\_scripts – Bash-Macros für komplexe Mess-/Positionierungsprogramme
- Service macros – systemd service units für indiserver und ratsche
- RTData – 1d und 2d Visualisierung von Datenreihen



<https://github.com/hangeza/indi-rpi-radiotelescope>

<https://github.com/hangeza/RTData>



# Die Radioastronomie-Gruppe

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Torsten Bacher (DD)

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[antrares@c3d2.de](mailto:antrares@c3d2.de)



22.10.12

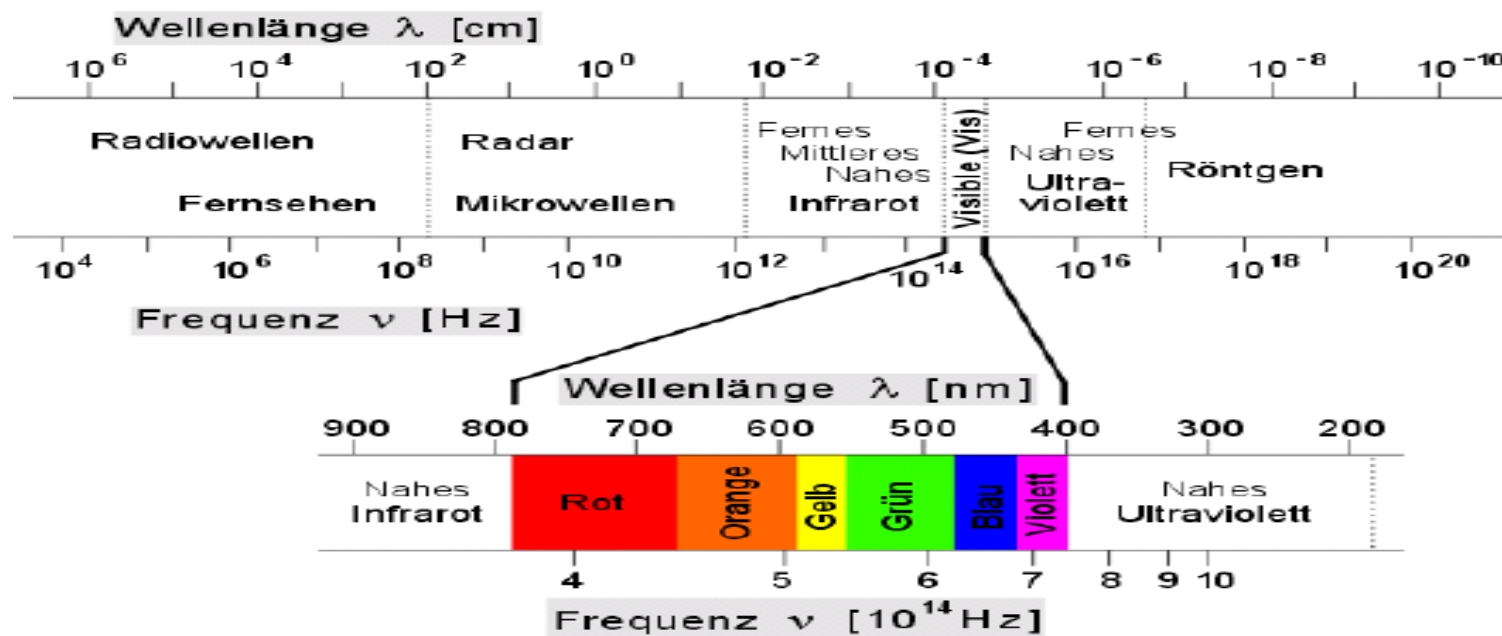
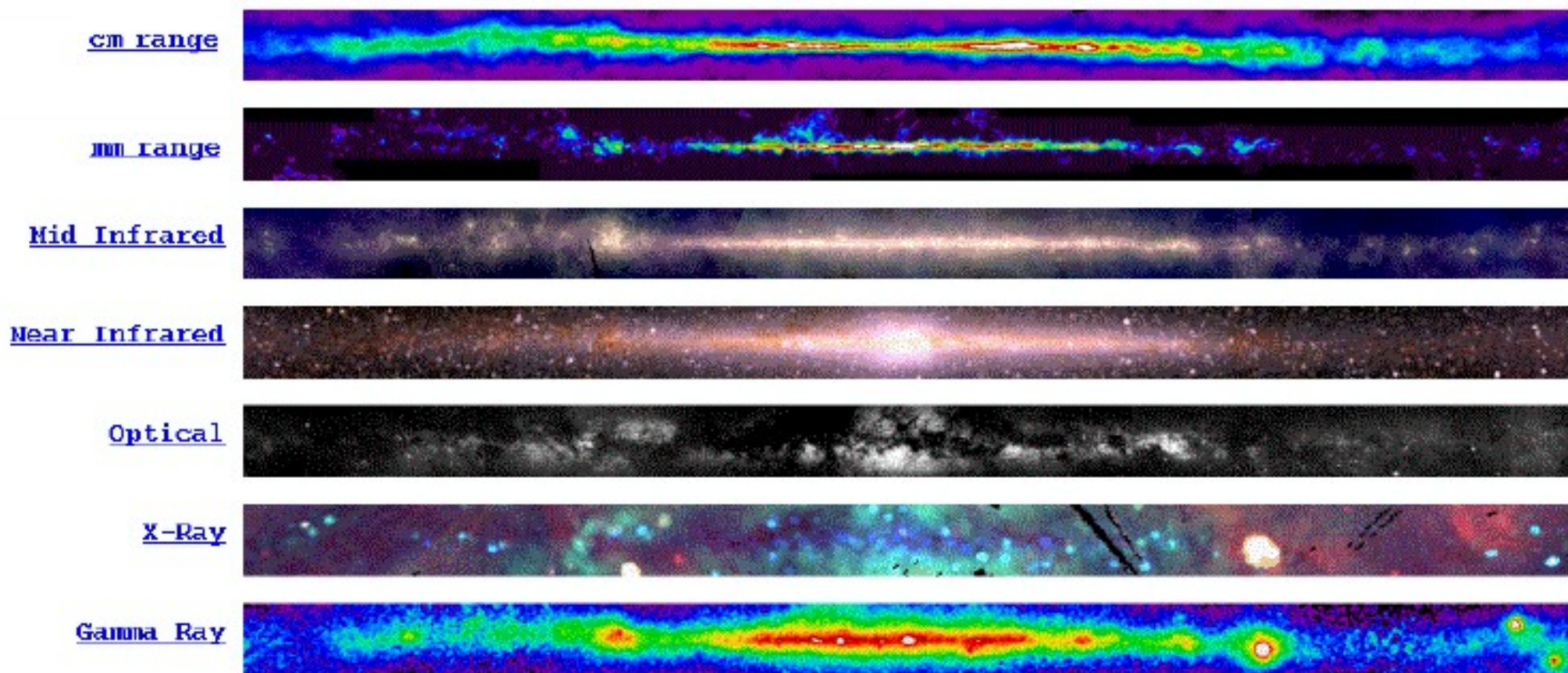
31

# Backup Slides

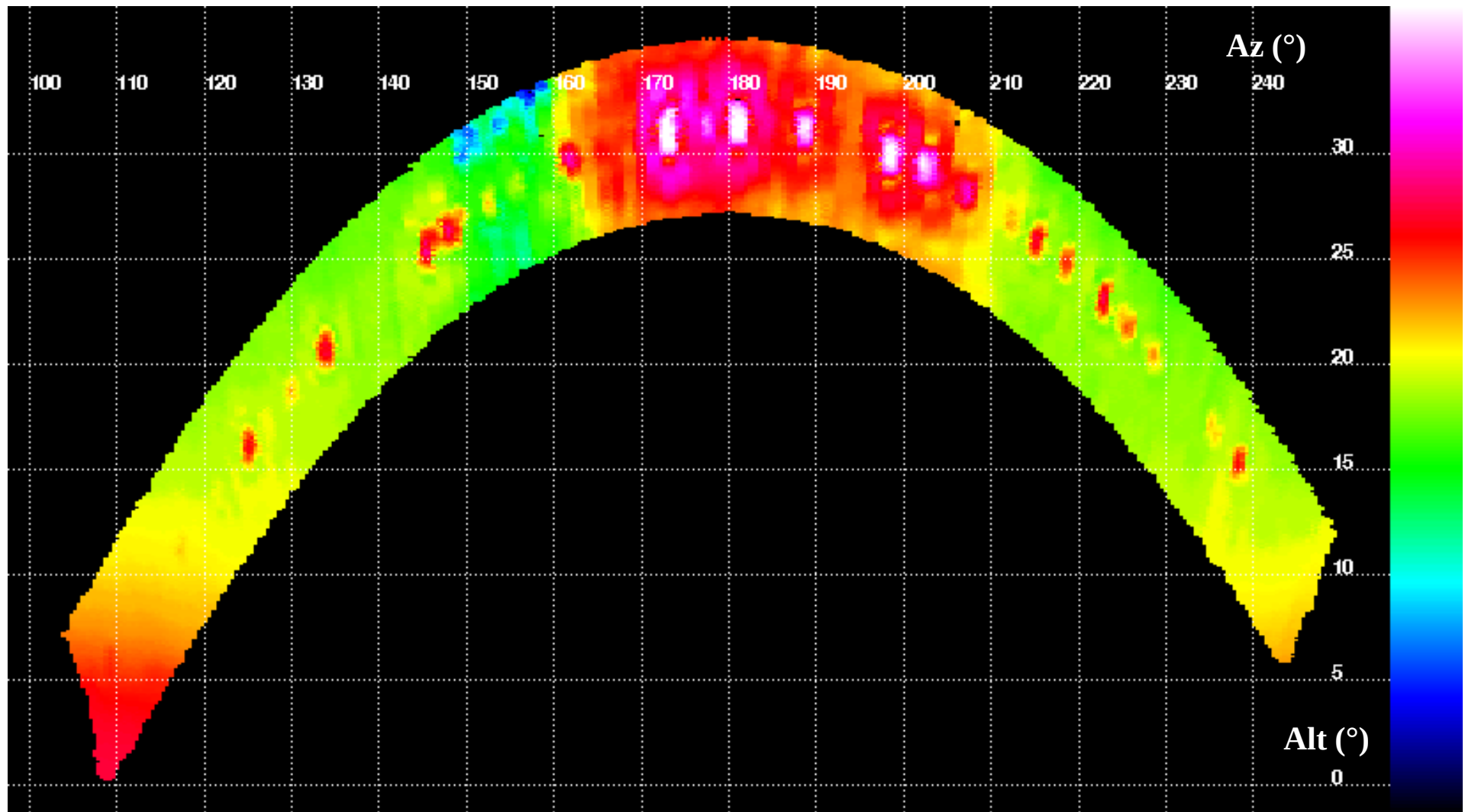
# Vergleich der benutzten Feedsysteme

Beobachtungs- frequenz (GHz)	Feedsystem	Rauschzahl (dB)	Gain an Sonne (dB)	Theoret. Auflösung (°)	Gemessene Auflösung (°)
11	Sat-LNB	0,3	10	0,64	1,0
1,4	Ringdipol	0,5	6	5	7,8
1,4	Rillenhorn	0,5	10,5	5	5,45

$$\sin\alpha = 1.22 \frac{\lambda}{D}$$

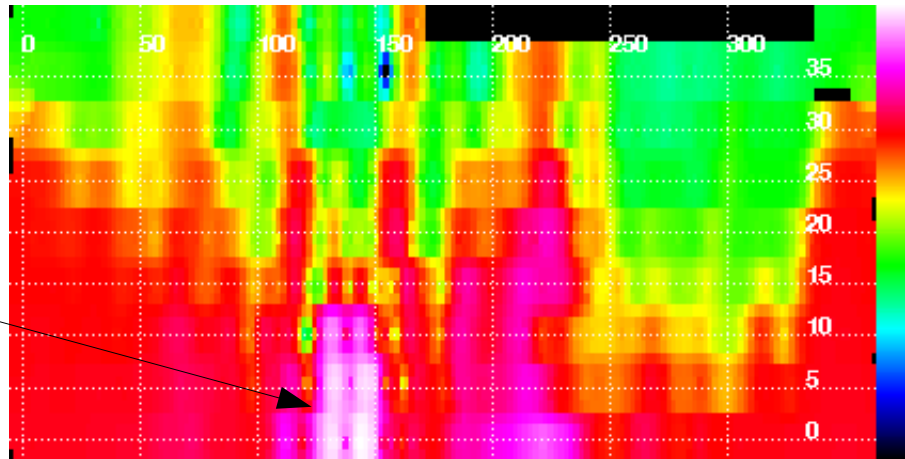


# Beobachtungen – Ku-Band

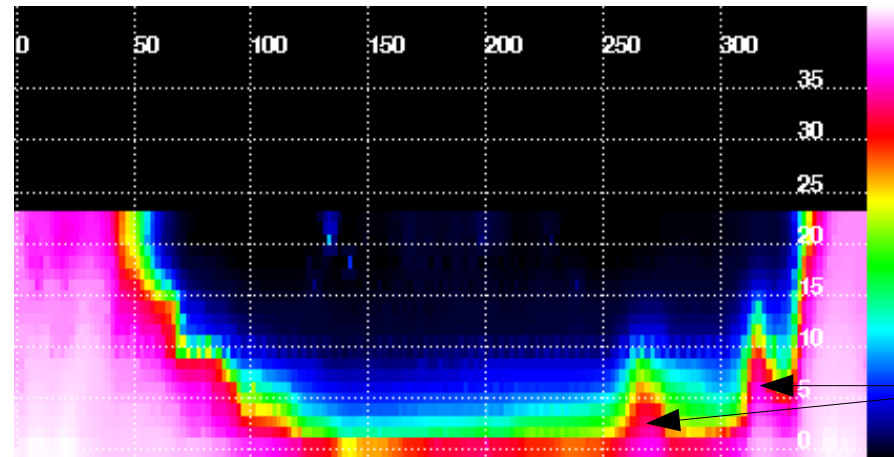


# Beobachtungen Horizontlinie@1,4GHz

Tschechischer  
TV-Sender  
(703,25 Mhz),  
Einmischen als  
Subharmonische  
von 1,4GHz



1,4 GHz



12 GHz

freistehende  
Baumgruppen

Wald Stw- Gebäude SPH Wald