



SETI on Magic Frequency von Michael Vorbeck

Pi & Radio 11.09.2021



Vortragspunkte

- Ist die Suche nach ET überhaupt sinnvoll?
- Magic Frequency 4462MHz
- Schmalbandsignale
- Multi-LNBs a la CHIME
- Schwarmsuche in Kooperation mit SETI



Drake equation

$$N = R_{\star} \times f_p \times n_e \times f_e \times f_i \times f_c \times L$$

The number of technologically advanced civilizations in the Milky Way galaxy

The rate of formation of stars in the galaxy

The fraction of those stars with planetary systems

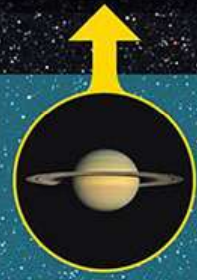
The number of planets, per solar system, with an environment suitable for life

The fraction of suitable planets on which life actually appears

The fraction of life-bearing planets on which intelligent life emerges

The fraction of civilizations that develop a technology that releases detectable signs of their existence into space

The length of time such civilizations release detectable signals into space



A

$=$

N_{ast}

\times

f_{bt}

The number of technological species that have formed over the history of the observable universe

The number of habitable planets in a given volume of the universe

The likelihood of a technological species arising on one of these planets

ET-Wahrscheinlichkeit

- Konservatives Modell: **1** sendefähige Zivilisation in unserer Milchstraße.
- Optimistisches Modell: **100** Zivilisationen in unserer Milchstraße mit 5000 Lichtjahren mittlerem Abstand zweier sendender Zivilisationen.
- Enthusiastisches Modell: **4.000.000** Zivilisationen in unserer Milchstraße mit 150 Lichtjahren mittlerem Abstand zweier sendenden Zivilisationen.



Habitable Zone in der Milchstraße

Faktoren:

Sternenentstehungsrate
Ausreichend Zeit
Metallizität
Supernovae Explosion

Lineweaver et al., Science, 303, 59 (2004)

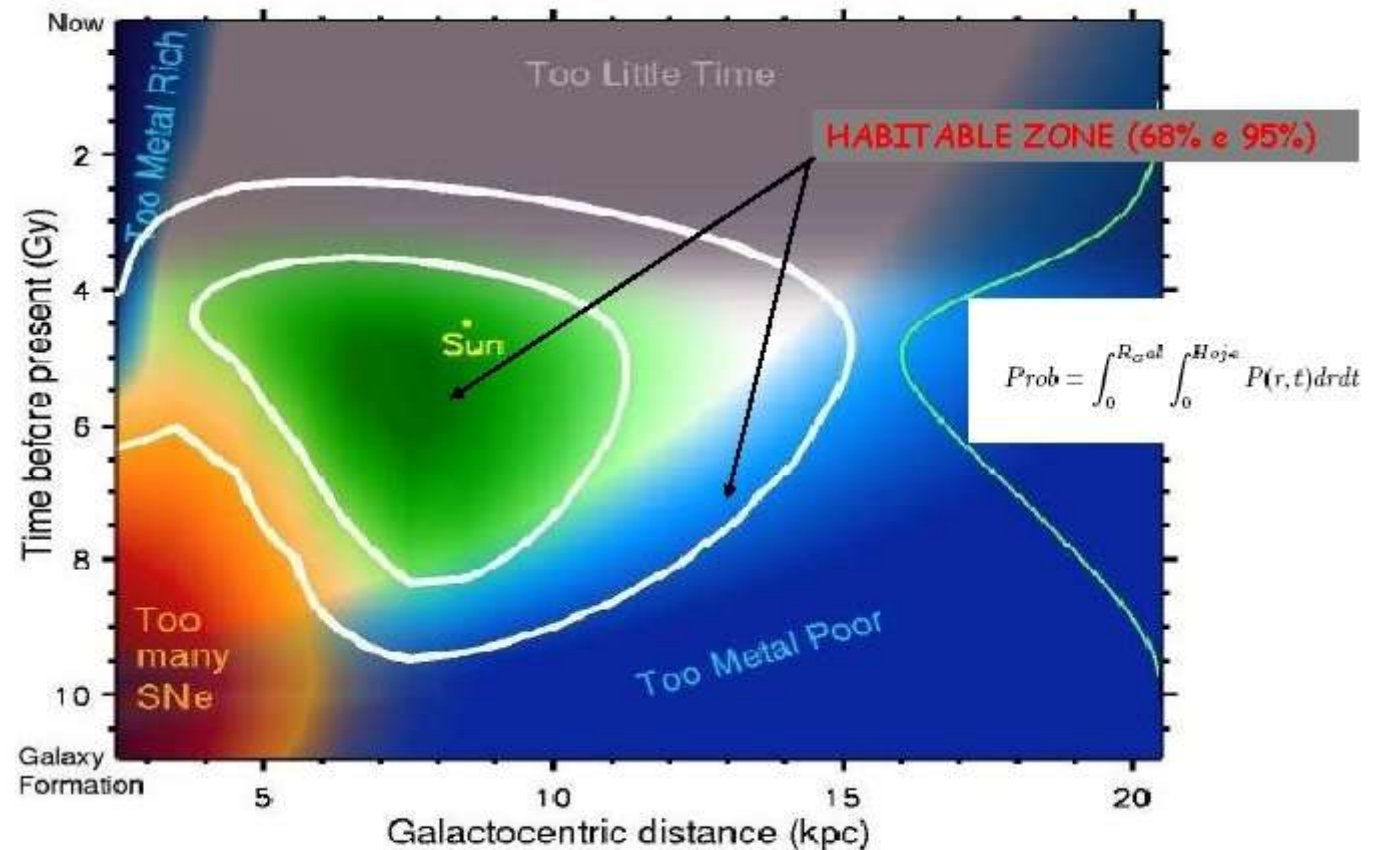
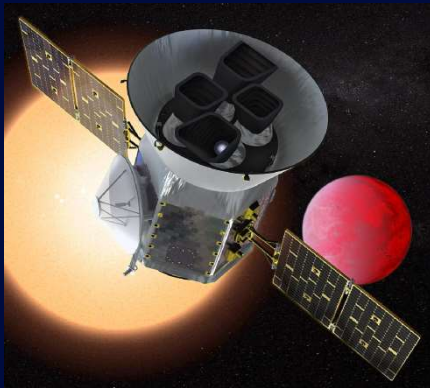


Fig. 3. The GHZ in the disk of the Milky Way based on the star formation rate, metallicity (blue), sufficient time for evolution (gray), and freedom from life-extinguishing supernova explosions (red). The white contours encompass 68% (inner) and 95% (outer) of the origins of stars with the highest potential to be harboring complex life today. The green line on the right is the age distribution of complex life and is obtained by integrating $P_{\text{GHZ}}(r, t)$ over r .

Exoplanets

via Kepler, TESS ...

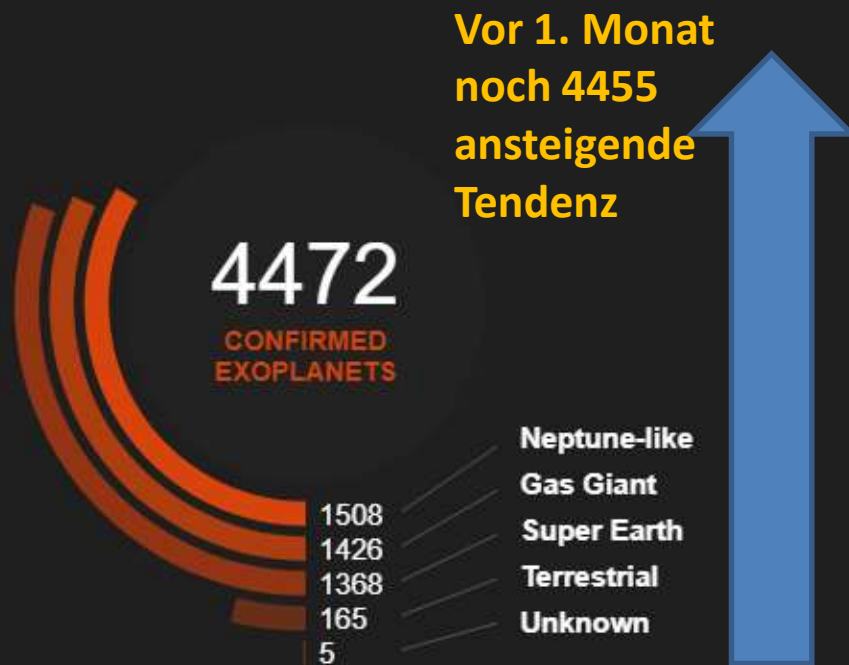


Exoplanets

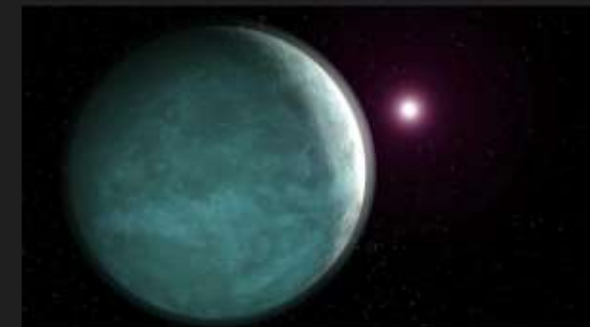
<https://exoplanets.nasa.gov/>



Planet Types



New Discovery



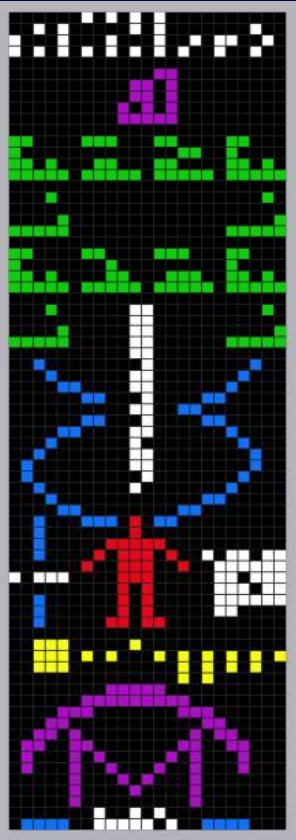
PLANET NAME
TOI-2406 b

PLANET TYPE
Neptune-like

DISCOVERY DATE
2021

DETECTION METHOD
Transit

Arecibo-Message 1974



Die Arecibo-Aussendung (10Hz FSK) erfolgte am 16.11.1976 in Richtung des Kugelsternhaufens M13 (25.000 Lichtjahre entfernt) mit einer Aussendung von 1MW auf 2,388 GHz – kann dort aber nur mit einer Antenne mit mehreren 10qkm Antennenfläche empfangen werden

...



Messaging to extraterrestrial intelligence (METI)



Bisher:

- Mehrfache Aussendungen zuletzt das sog. „Wow Reply“ 2012 zum Hipparcos Sternensystem 63 Lj. entfernt im Sternbild des Orion
- Leistungen zw. 100kW-1MW bei ausreichendem Antennengewinn (Arecibo 70dB)
- Modulation meist FSK
- Polarisiert als Zeichen eines ET-Signals (natürl. Signale: random polarisation)
- Spektrum innerhalb der Wellenlänge 1-20cm (29-1,5GHz)
- Länge, Dauer, Inhalt, Fehlerkorrektur, wiederkehrend ...

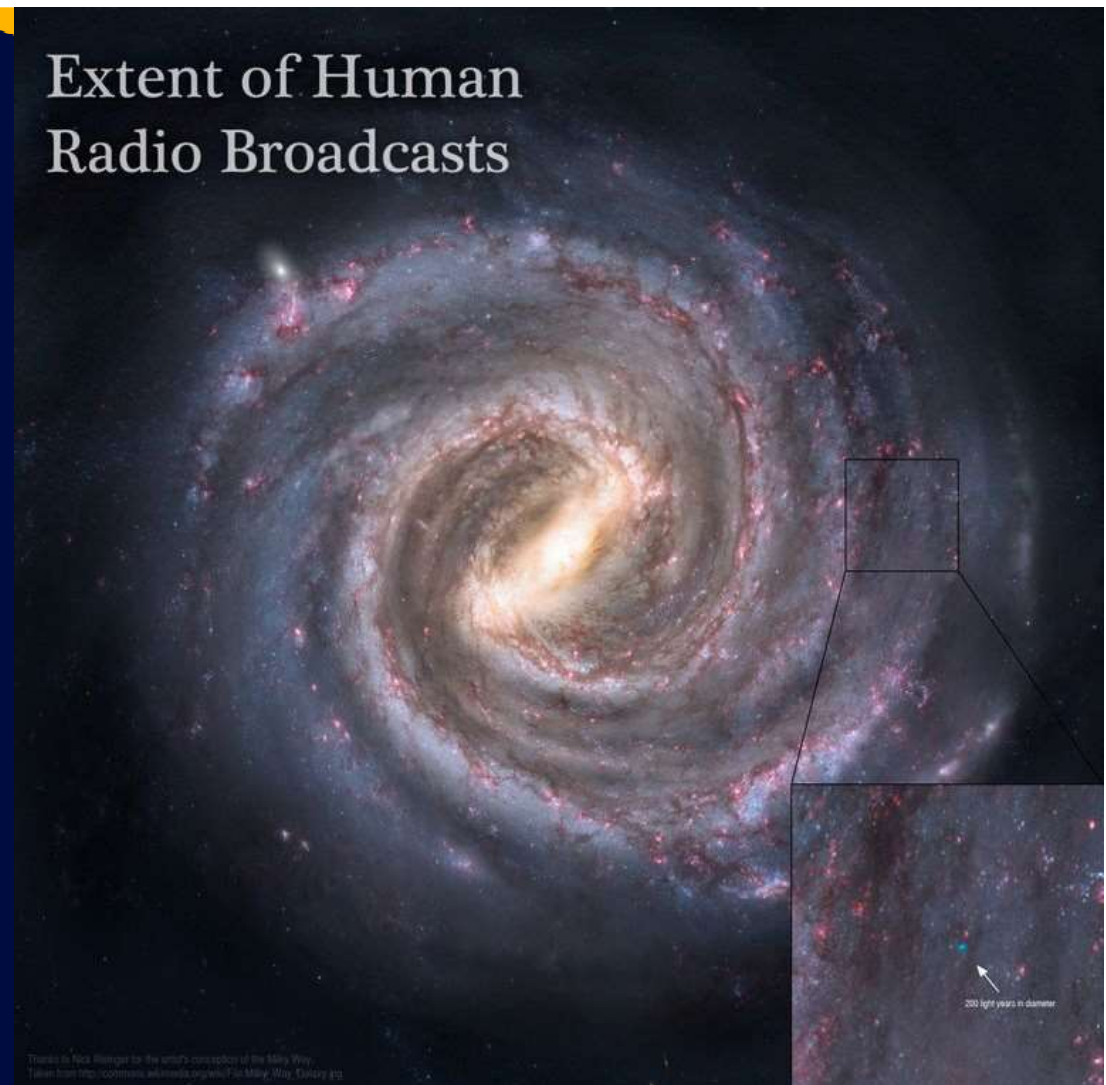


Radiosignale

Reichweite eines Arecibo-Signals
ca. 10.000 Lichtjahre

=> d.h. beim „optimistischen
Modell“ könnten wir mit 10 ETIs
in Reichweite rechnen

Extent of Human Radio Broadcasts





Voraussetzungen für den Empfang von ET:

1. Außerirdische Intelligenz mit techn. Entwicklungsstand ähnlich der Erde
2. Nachhaltigkeit dieses Entwicklungsstandes
3. Suche nur in der Heimatgalaxie / Außenarme
4. Suche nach schmalbandigen Signalen
5. Suche zw. 1-10GHz
6. Scannen anstatt punktuell herumstochern

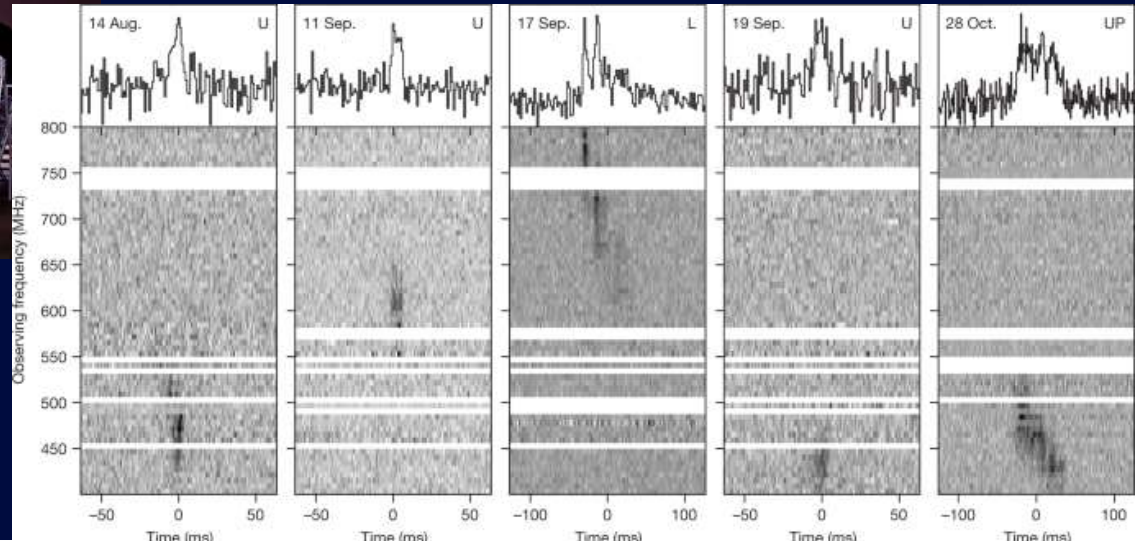
Beispiel RFB (Radio Fast Burst) CHIME

Dauer: 1-9mS

Range: 10MHz – 8GHz

Ursprung: Magnetare?

CHIME Telescope
4 x 20m x 100m
Range: 400-800MHz






Beispiel RFB (Radio Fast Burst)

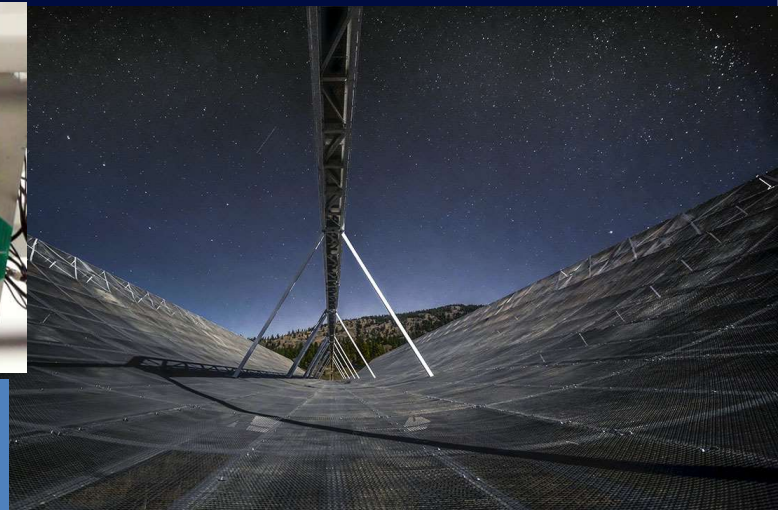
Seit Entdeckung der FRBs

2007 – 2017 (10J): 140 FRBs

CHIME allein nur in 2018 (1J): 535 FRBs



1024 Clover-Leaf-Antennen
& Software-Fokussierung





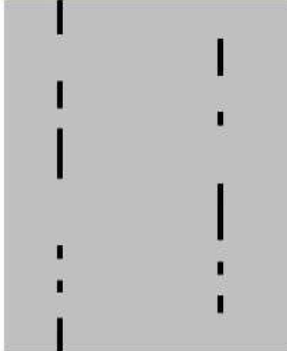
ET-Signale: <300Hz Bandwidth

Mode	Needed SNR in 2500 Hz	Net data speed in bits/s	Needed Eb/N0
SSB voice	+10 dB	20*	+31 dB
CW (ZRO-test, by ear)	-18 dB	0.54	+16 dB**
CW (QRSS-3, waterfall)	-26 dB	0.13	+14 dB**
CW (RSCW, 12 wpm)	-12 dB	4	+13 dB**
OPERA-2	-23 dB	0.23	+14 dB***
RTTY	-5 dB	32	+14 dB
PSK31	-10 dB	31	
WSPR	-29 dB	0.45	
WSPR-15	-38 dB	0.056	
JT65 (for EME)	-24 dB	1.54	+5 dB****
Coherent BPSK on VLF	-57 dB	0.0058	-1 dB
Theoretical limit			-1.59 dB

WSPR Bandbreite= 5,9Hz
CW (60WPM) = 50Hz

In May 2014, DF6NM and Paul Nicholson in England did an experiment (and reported about that on the RSGB LF mailing list) in which they transported a net 46 bit message on 8270 kHz in 132 minutes, over 1028 km with an effective transmit power of less than 10 μ W.

ET-Signale: was wird erwartet?

Parameter	Three types of single-valued frequency function		
Type	1. Constant	2. Continuous	3. Discrete
Author (<i>"Here"</i>)	Radio Engineer	Composer, Painter, Architect	Scientist
Language	"of Nature"	"of Emotion"	"of Logic"
Information	Is absent	Analog	Digital
Sonogram of transmitting signals			
Analysis (<i>"There"</i>)	Astrophysical	Art criticism	Linguistic

ET-Signale: Modulation? (FSK/FM)

SETI: The transmission rate of radio communication and the signal's detection, P. A. Fridman, ASTRON, Oude Hoogeveensedijk 4, 7991PD Dwingeloo, The Netherlands, 05/2011

The transmission rate of communication between radio telescopes on Earth and extraterrestrial intelligence (ETI) is here calculated up to distances of 1000 light years. Both phase-shift-keying (PSK) and frequency-shift keying (FSK) modulation schemes are considered. It is shown that M-ary FSK is advantageous in terms of energy. Narrow-band pulses scattered over the spectrum sharing a common drift rate can be the probable signals of ETI. Modern SETI spectrum analyzers are well suited to searching for these types of signals. Such signals can be detected using the Hough transform which is a dedicated tool for detecting patterns in an image. The time-frequency plane



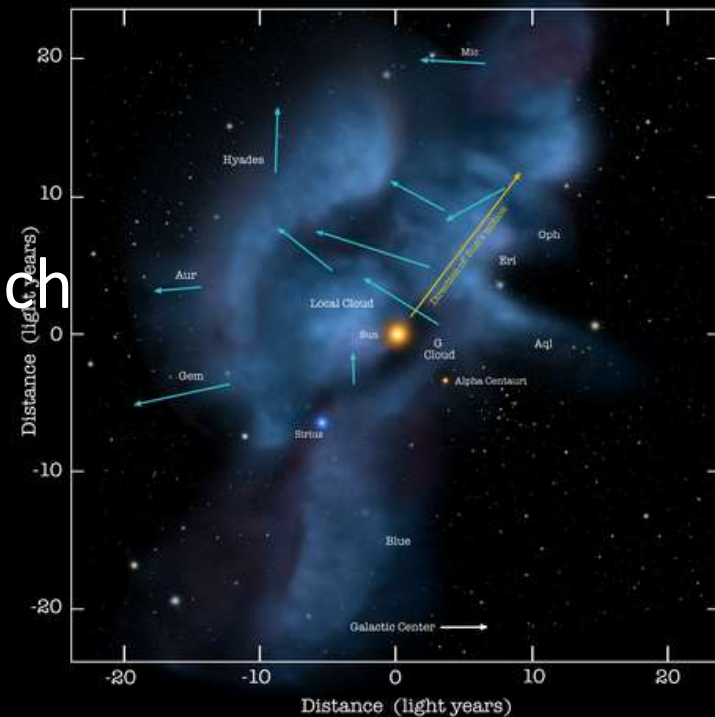
ET-Signale: Frequency-Range?

Eingrenzung:

- > 1 GHz => zuviel Man-made Noise
unterhalb von 1GHz
- < 10 GHz => oberhalb Reflektion
Atmosphäre

ET-Signale: Polarisation?

Polarisation:
keine spezif., da
unser
Sonnensystem sich
innerhalb einer
interstell.
Wasserstoff-
/Staub-Wolke
befindet



ET-Signale: Magic Frequency

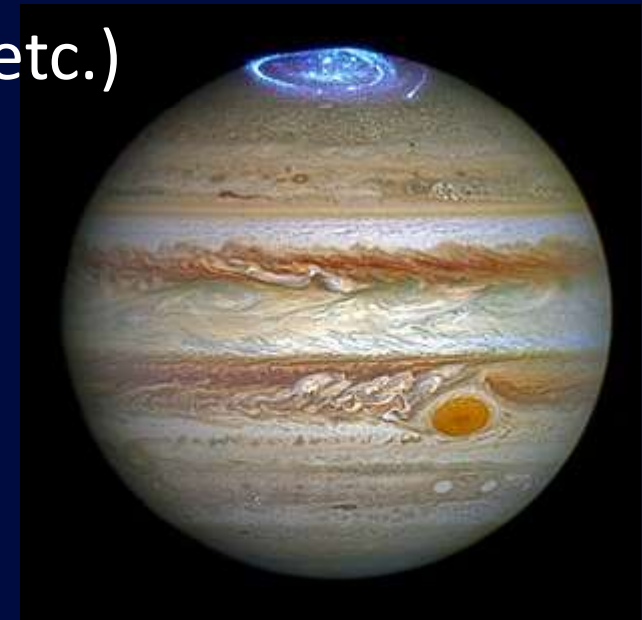
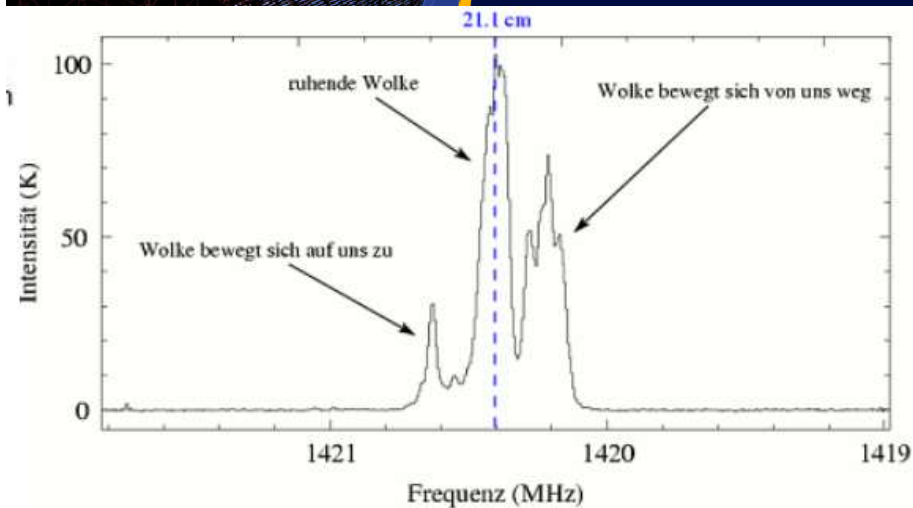
Observational frequency bands were selected to be free of strong radio frequency interference (RFI) and often encompass certain "magic" frequencies such as the H_I line (1.420 GHz), $\sqrt{2}H_I$ (2.008 GHz), $2H_I$ (2.840 GHz), πH_I (4.462 GHz), the methanol maser line (6.667 GHz) and 8.4 GHz because it is close to the upper limit of ATA's receivers.

communications, suitable energy potentials will be reached at infrared or optical wavelengths. Should that occur, our representations about optimum wavelength will of course change. Exact values of wavelength may even take on "magic" values. For example, $6.72 \text{ cm} = 21 \text{ cm} / \pi$, would be known to all technological civilizations as the ratio of two universal constants, one physical (the radio emission line of interstellar neutral hydrogen) and the other mathematical.

Sie ist unabhängig von einem ggf. anderen numerischen ET-System:
Magic Frequency = $\pi \times H_I$ (1.42 GHz) = 4.462 GHz

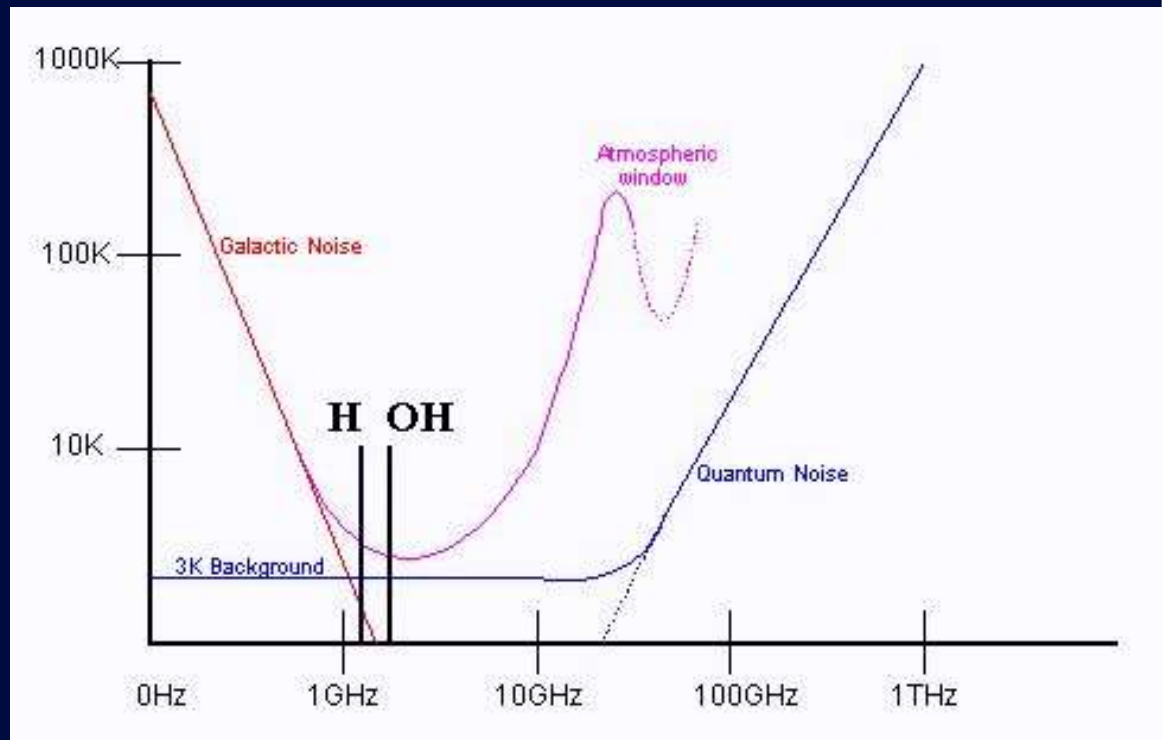
ET-Signale: nicht auf Emissionslinien (no Maser – no waterhole)


Maser = stimulierte Spektrallinien-
Emissionen (z.B. Aurora, Wasserstoff,
Methanol, Hydroxyl etc.)



ET-Signale: nicht auf Emissionslinien (no Maser – no waterhole)

Wenn eine ET-Gesellschaft Spektrallinien-Emissionen beforschen will, dann wird sie auf deren Frequenzen sicherlich nicht senden wollen.





Daher bleibt es
daher bei der
notwendigen
Suche auf der
Magic

Frequency:
 $\pi \times \text{HI}$ (1.42
GHz)
= 4.462 GHz

ET-Signale: bisherige Funde

das neue „WOW-Signal“ in 2010

TYC 1220-91-1
Star
02 08 29.2327 +22 26 58.504

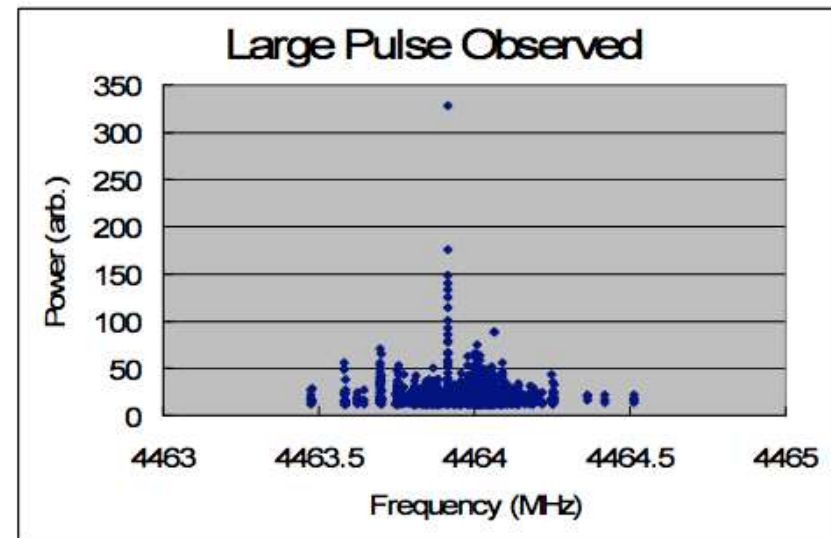


Figure 4: A pulse with maximum power $>300\sigma$ above the noise background was observed on a nearby star (~ 100 LY, (J2000 RA, Dec) = (32.211809 $^{\circ}$, 22.441734 $^{\circ}$)) in the HabCat Catalog (Turnbull, 2003). This pulse is interesting since it appears to arrive from the direction of a potentially habitable star and because it appears very close (within the expected Doppler shift tolerance caused by relative motion) to the “magic” PiHf frequency of 4462.3 MHz, this signal appeared in only one observation and never thereafter. Given the proximity of this source, we do not expect substantial fading in the ISM; hence the signal is really not present, most of the time.

A large satellite dish antenna is shown from a low angle, looking up. The dish is made of a grid of metal and is set against a clear blue sky. A bright yellow curved line runs along the right edge of the image.

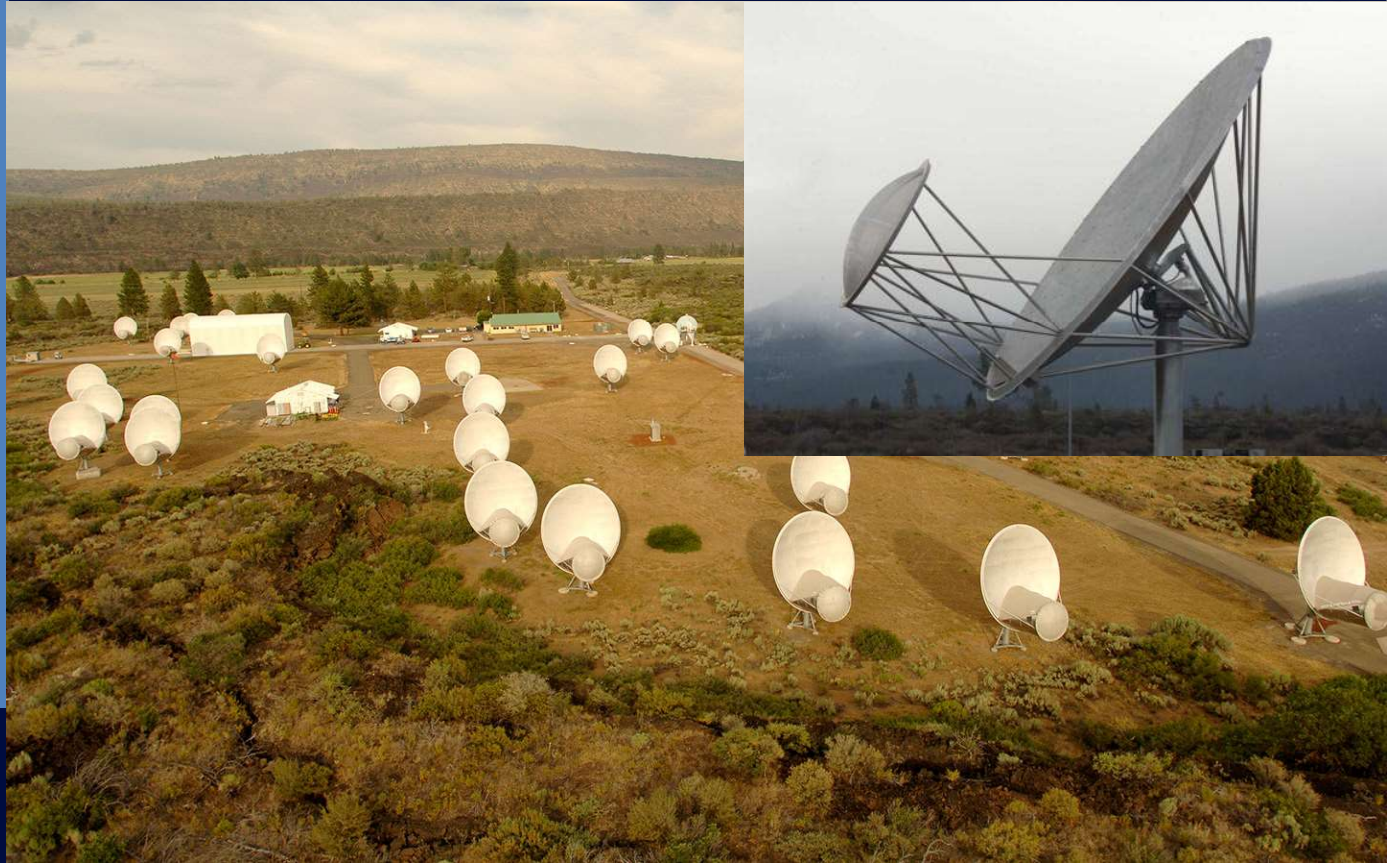
Wow!

Es hatte alle Eigenschaften eines interstellaren Leuchtfuers (Beacon)

Problem: keine Wiederholung!

Suche nach ET u.a. mit dem Allen Telescope Array (ATA)

- 42 Gregorian Offset-Dishes (6x7m) mit 2,4m Sub-Reflektor und Baseline aller Teleskope von 300m

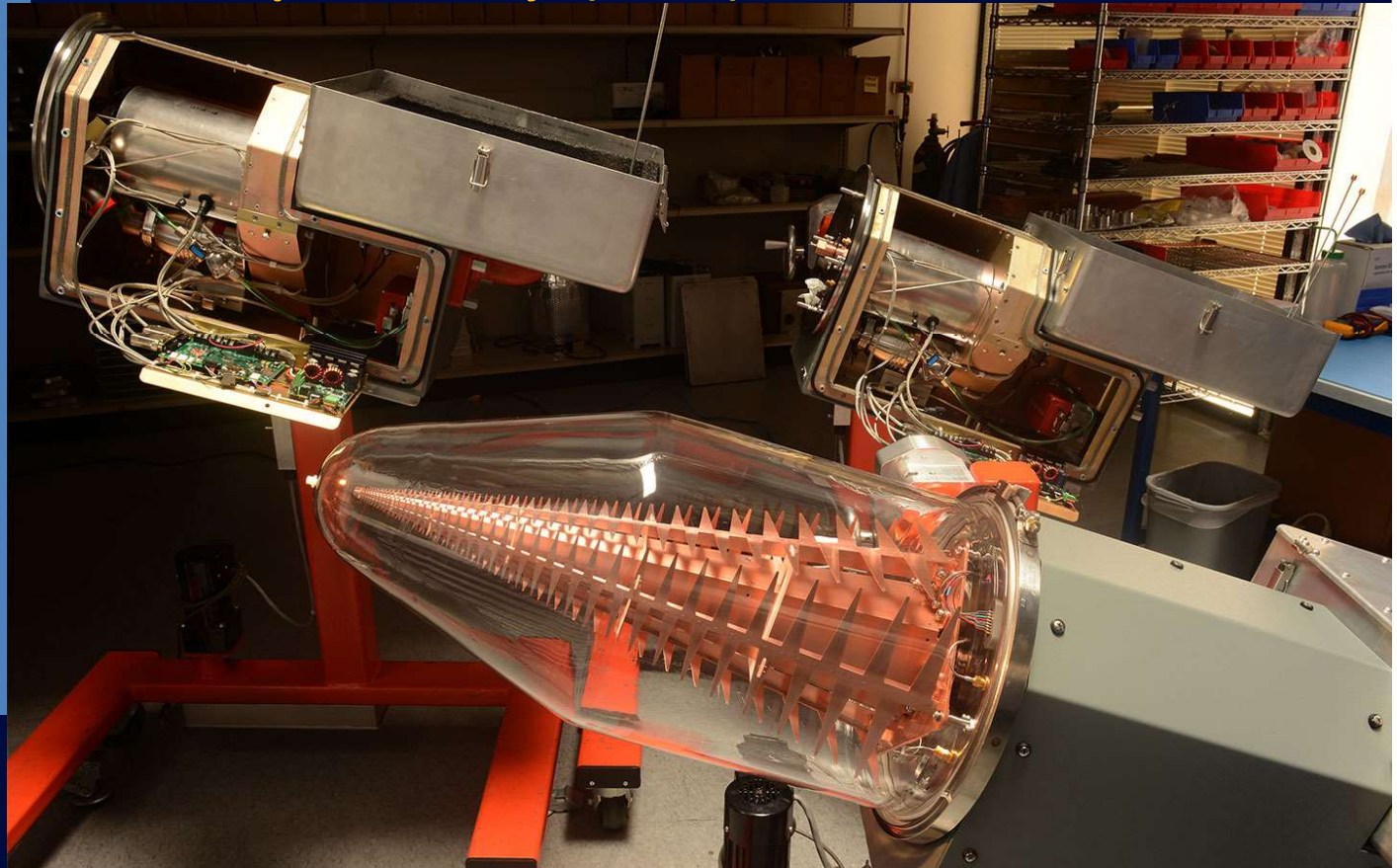


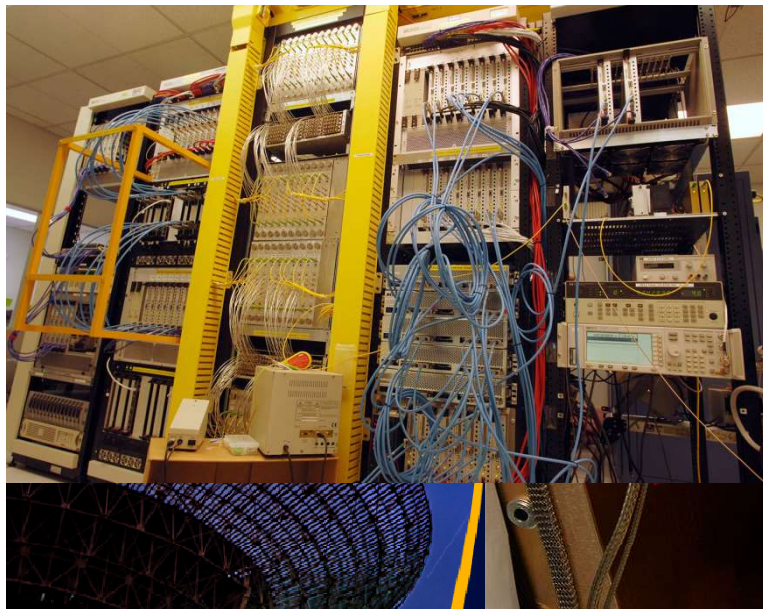
Suche nach ET u.a. mit dem Allen Telescope Array (ATA)

Feed

auf -200 Grad Celsius (45K)
gekühlt mit
Log-Period.
Antenne

$0,5 - 11\text{GHz}$
($2 \times 100\text{Mb/s}$)

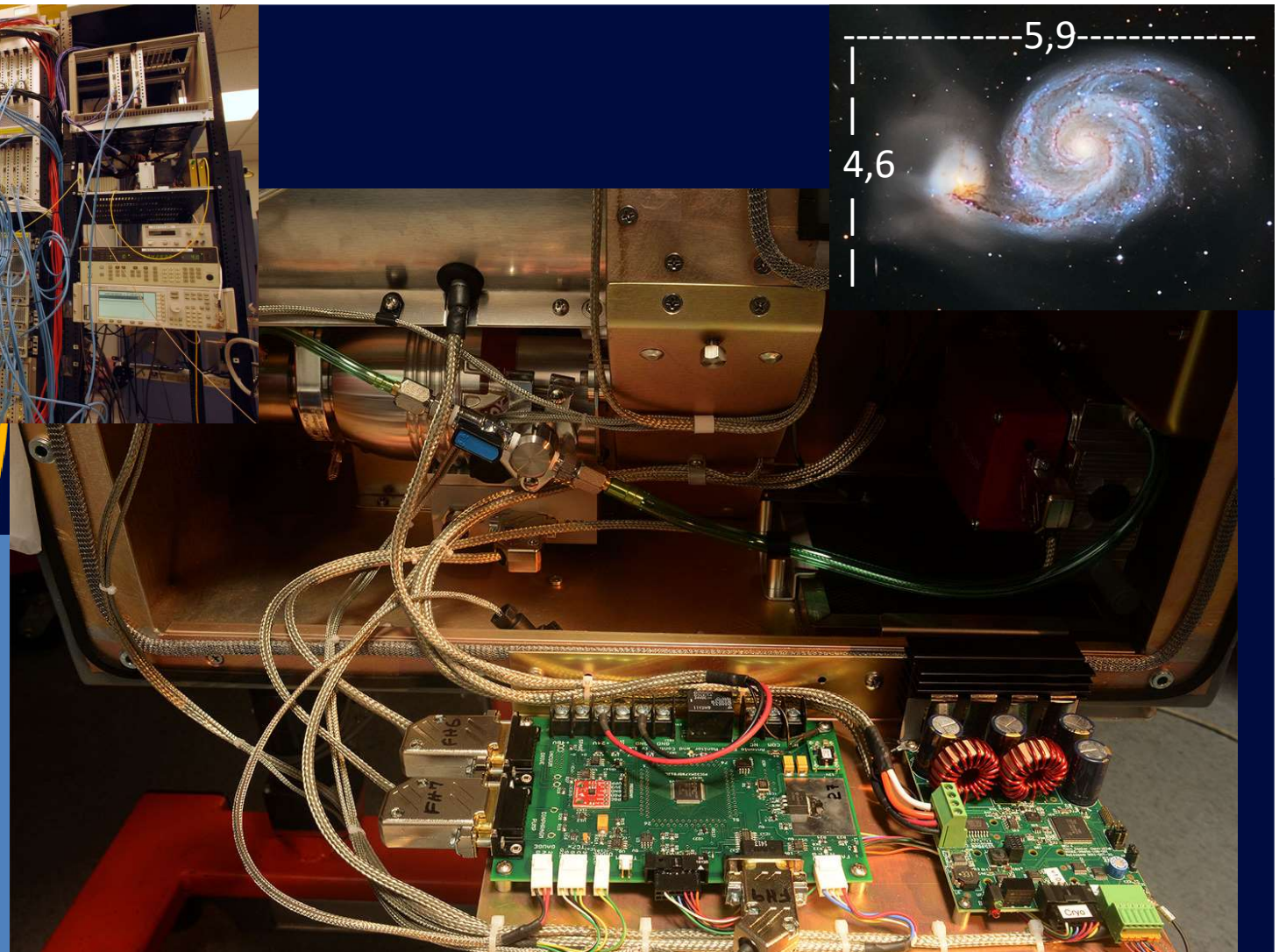




GPU-Racks &
Elektronik im
Feed

Beamforming
(2,45 Grad ca.
1/3 v. M51)

=> 8Gb/s





Suche nach ET u.a. mit dem Allen Telescope Array (ATA)

- Tagsüber astronomische Forschung
- Nachts vollautomatisierte Suche nach ET (workhorse SETI search system)
- Bisher 200 Mio brauchbare Signale ausgewertet – aber ohne Hinweis auf ET

Bisher: Huckepack-Suche bei
Radioteleskopen während der
radioastronom. Forschungsarbeit
=> Breakthrough Listen



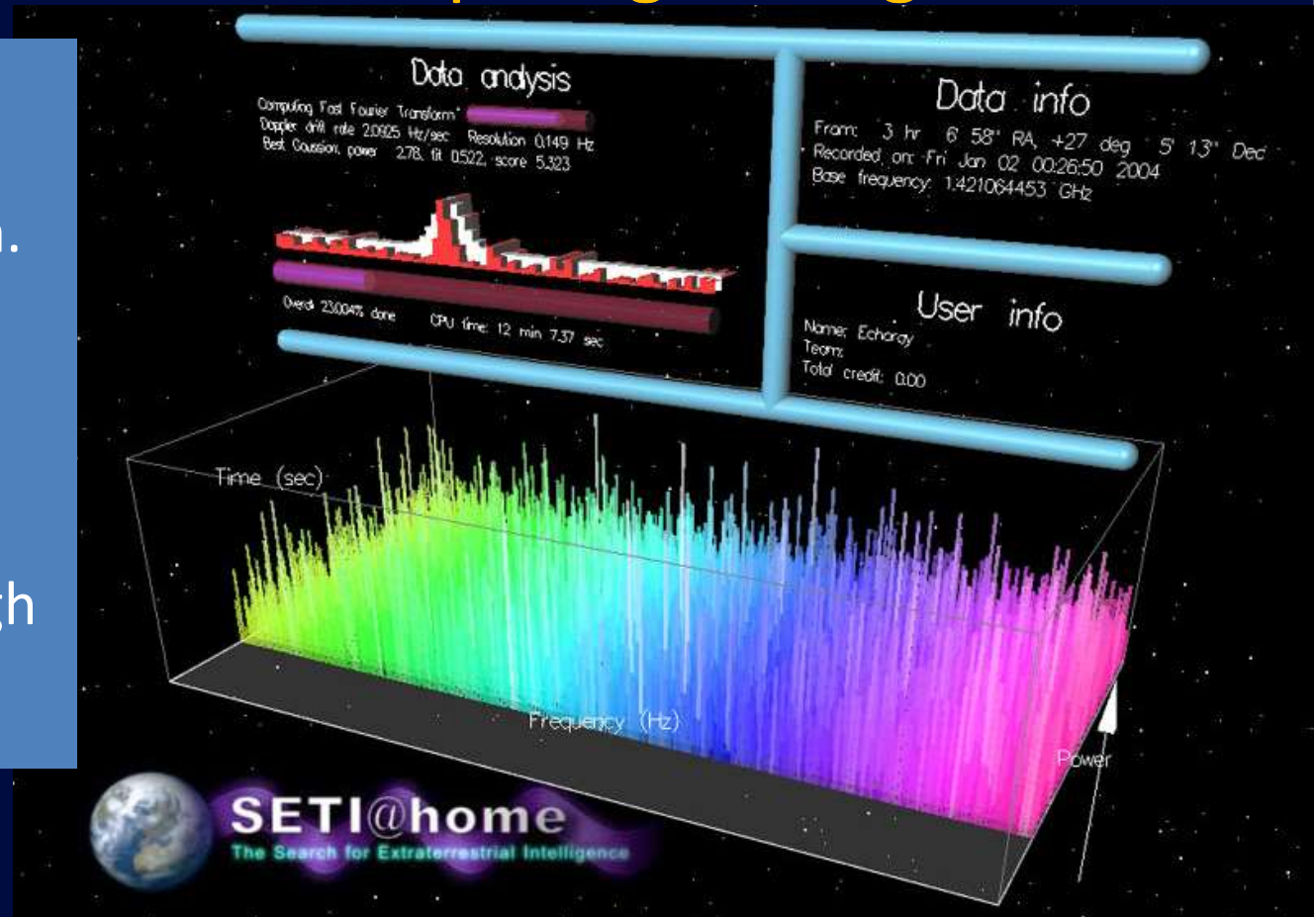
mit Cloud Computing der Signale

2004-2020

Hintergrund-Signale
bei radioastronom.
Forschung
ausgewertet via
Boinc ...

Seit 2016

Projekt „Breakthrough
Listen“



Ausblick und zukünft. Entwicklung

Bei der ET-Suche
mehr mit Multi-
LNBS scannen
anstatt punktuell
herumstochern

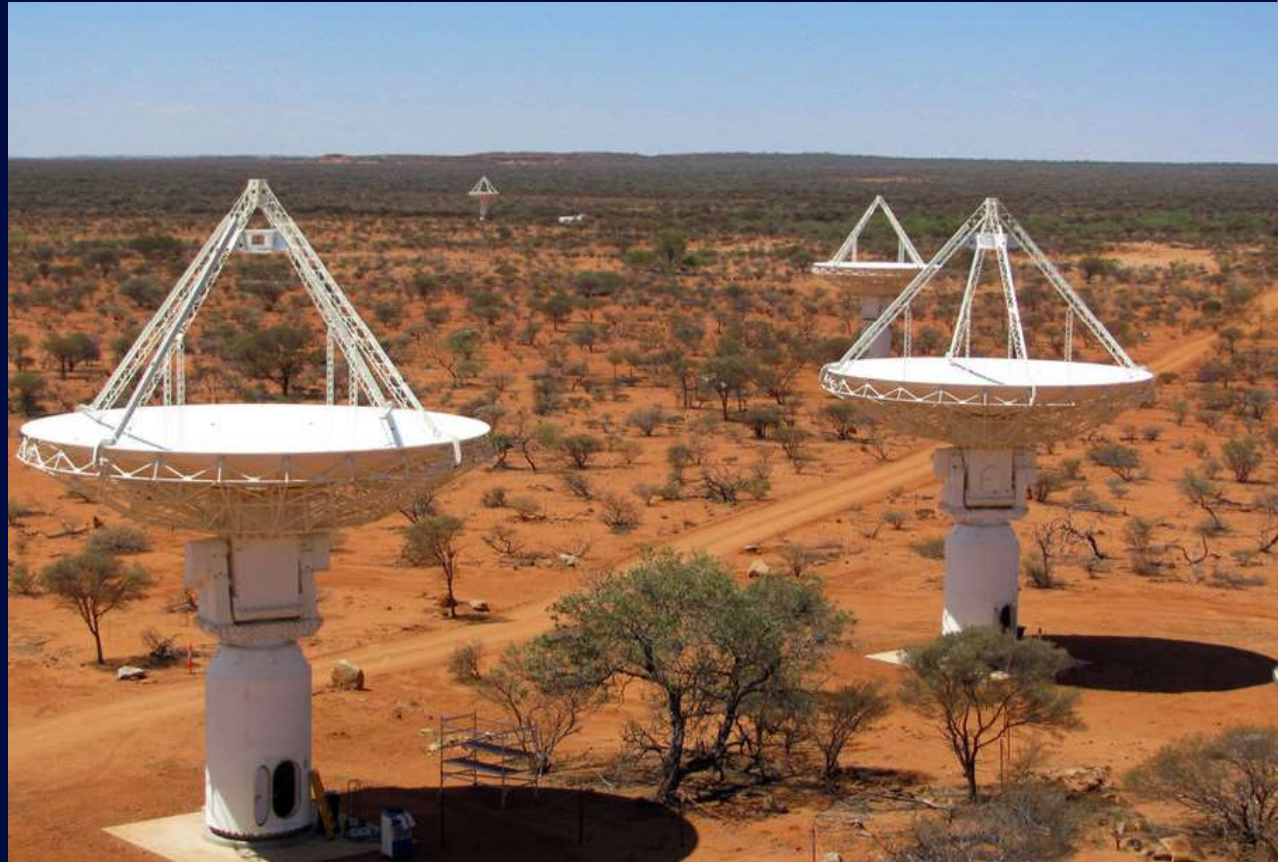
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Australian Square Telescope Array Pathfinder (ASKAP)

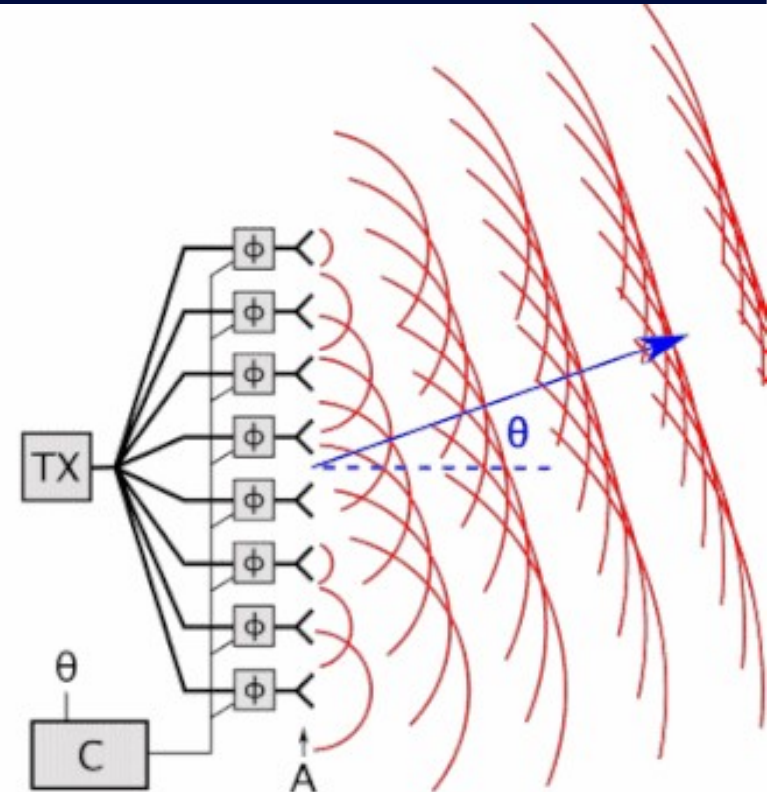
36 x 12m Teleskope
mit 4000qm
Empfangsfläche
gesamt seit 2012
und Phased-
Array-Feed (PAF)

Range: 0,7-1,8GHz
BW: 300MHz



Mit Phased Array Feed ...

Dish: 188 LNBS
Blickfeld:
5,5 x 5,5 Grad



... ET-Simulation ...

Projekt: Tiny Groundstation



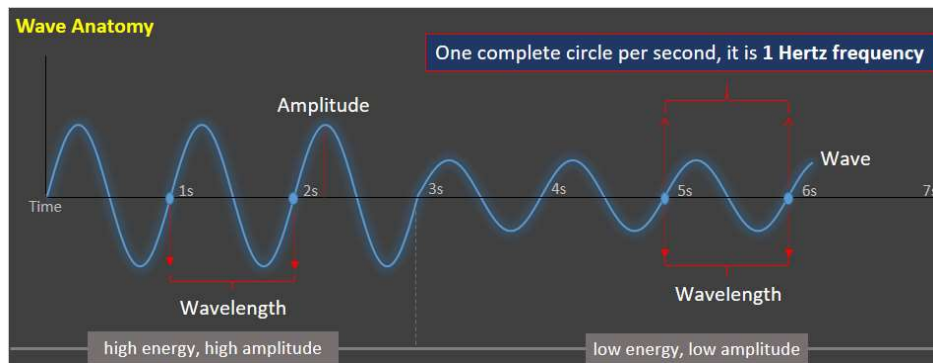
... über Cloud Listening ...

Open Source global network of satellite ground-stations



... auf der Magic Frequency

4462 MHz



www.telecompedia.net



Frequencies used in radio communication

3–30 Hz	30–300 Hz	300–3000 Hz	3–30 kHz	30–300 kHz	300 kHz – 3 MHz	3–30 MHz	30–300 MHz	300 MHz – 3 GHz	3–30 GHz	30–300 GHz	300 GHz – 3 THz
10^5 – 10^4 km	10^4 – 10^3 km	10^3 – 100 km	100– 10 km	10–1 km	1 km – 100 m	100–10 m	10–1 m	1 m – 10 cm	10–1 cm	1 cm – 1 mm	1 mm – 0.1 mm
ELF	SLF	ULF	VLF	LF	MF	HF	VHF	UHF	SHF	EHF	THF



... zum möglichen
Kontakt mit



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