

Sommersemester 2006



Neue
Ergebnisse und Perspektiven
der Radioastronomie



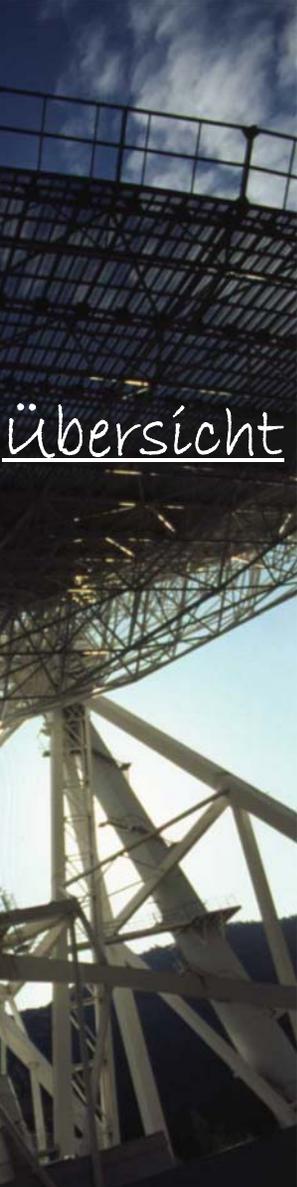
Neue Ergebnisse und Perspektiven der Radioastronomie



Themen
& Daten

- 05.05: Einführung & Übersicht
- **12.05. Radioteleskope & Radiobilder & RFI**
- 26.05. Der Radiohimmel im Licht der 21cm-Linie & Radioteleskop-Katastrophen
- **09.06.** Pulsar-Astronomie (heute & in Zukunft)
- **23.06.** AGN & Binäre Schwarze Löcher (NEUES!)
- 07.07. Maser & das Interstellare Medium & AGN & Merger
- 21.07.

12.05. Radioteleskope & Radiobilder



Übersicht

- Radiostrahlung und Radioantennen
 - Aktive Oberflächen (Effelsberg, GBT)
- Neue Radioteleskope (z.Bsp. GBT, Sardinien, Yebes)
- Neues Weltraumteleskop
- Neue Interferometer
 - Fragestellungen beim Interferometerbau
 - Neues im mm-Bereich
 - LOFAR und SKA (Antennenkonzepte)
- RFI – Radiointerferenz

	Frequency Coverage	Sensitivity Improvement	Resolution Improvement	Polarization Purity	Flexibility+ New features
LOFAR (2006-2015)	20-200 MHz	~100-1000	~100	≥ 30 dB	Digital pointing, frequency agility, all-sky FOV, time buffering
SKA (>2015)	0.1-20 GHz	~100	~10	~ 40 dB	digital + mechanical pointing, frequency agility, large FOV
submm-VLBI	40-600 GHz	~10	~10	≥ 20 dB	
ALMA (2008-2020)	40-1000 GHz	~10-100	~10	≥ 20 dB	Fast mechanical pointing, frequency agility

Table 2: Overview of the major radio astronomy projects of the coming decades and its characteristic frequencies and improvements compared to present-day telescopes.

Radioteleskope zeigen Phänomene, die für optische Teleskope unsichtbar sind



Optisch / Radio

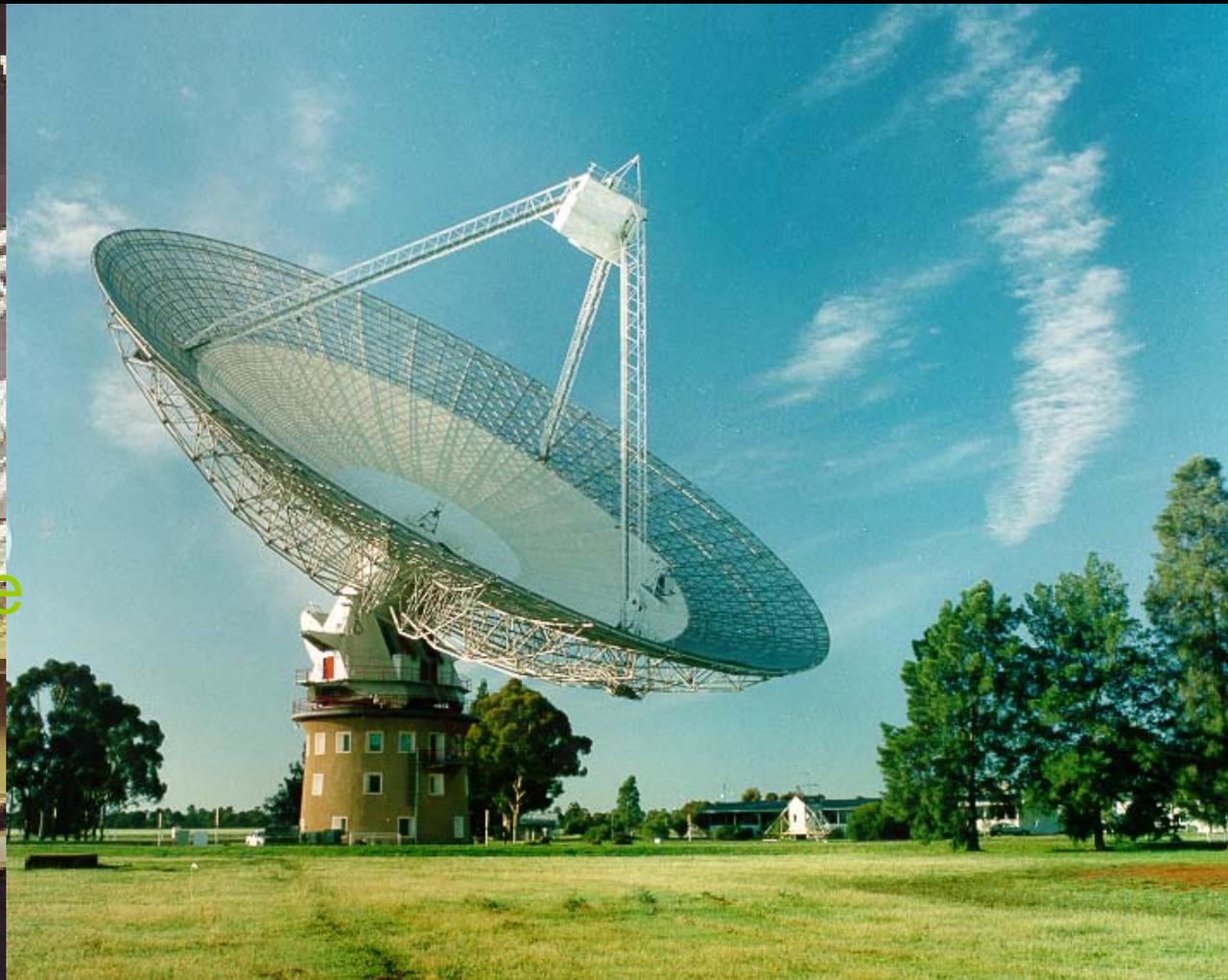


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Radioteleskope
sehen

hauptsächlich

Phänomene wie
hochenergetische
Elektronen



A large radio telescope dish is illuminated from below, creating a warm yellow glow. The dish is a complex lattice structure. In the background, a full moon is visible in a dark blue night sky. The overall scene is a night-time photograph of a radio telescope.

Radiostrahlung &
Radioantennen

Vom Weidezaun zur Parabolantenne



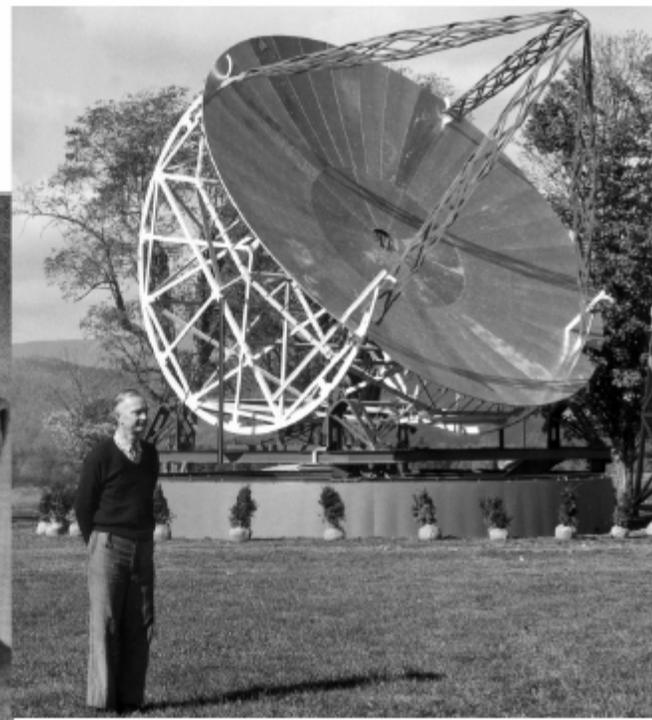
Geschichte

Karl Guthe Jansky



Geschichte

Grote
Reber



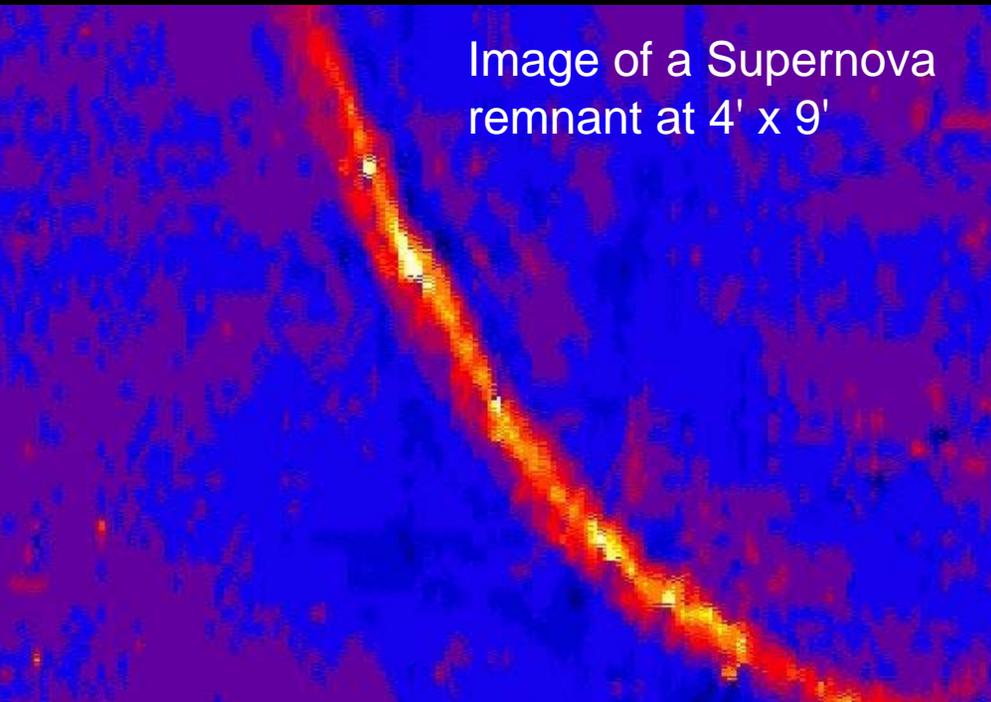
Mauritius
2km und 1km Armlänge



(151 MHz)



Image of a Supernova
remnant at 4' x 9'





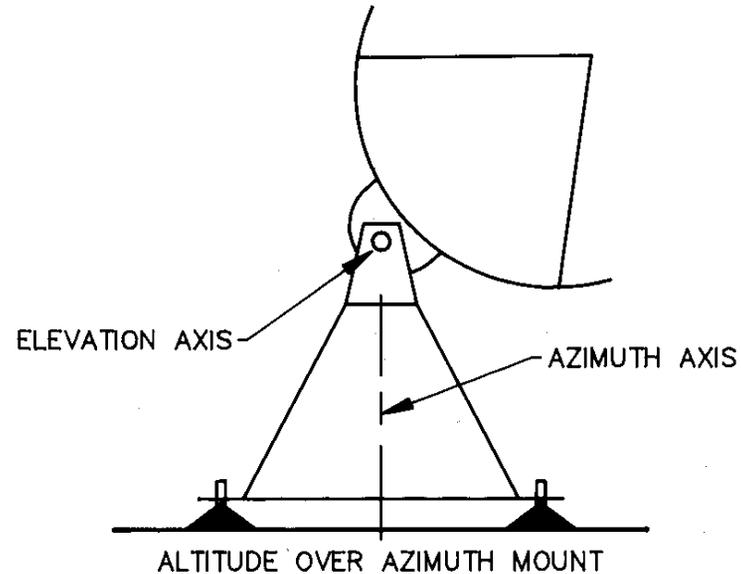
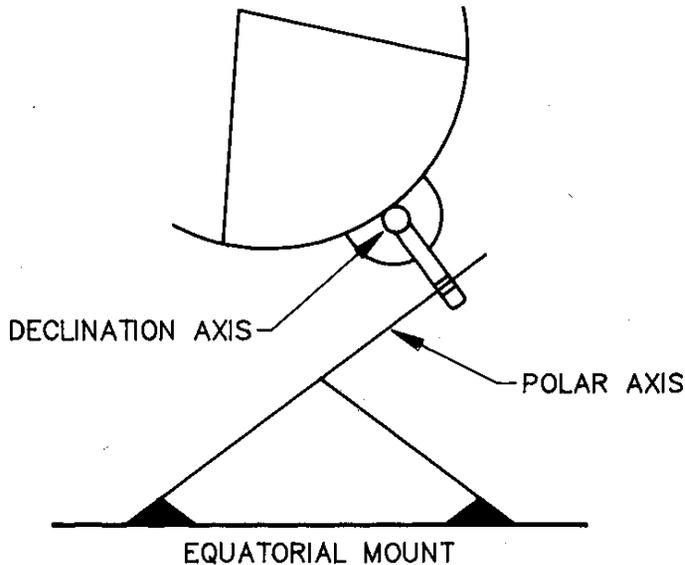
Nancay 200m x 40m



Molonglo (U. Syd)
1 mile x 40 ft.

(843 MHz)

Antennenmontierung

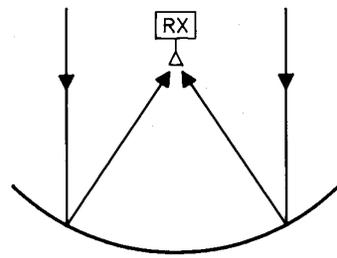


- Günstiger
- Beam rotiert nicht am Himmel
- Bessere Nachführgenauigkeit
- Probleme mit Gravitation
- Wie für optische Teleskope
- Kleine Teleskope (<25m)
- Muß nur um eine Achse rotieren

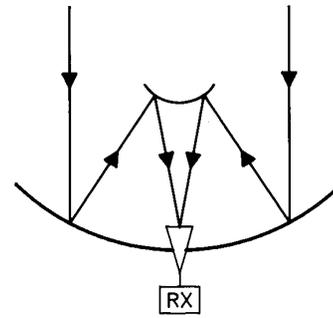
- Teurer
- Beam rotiert am Himmel
- Gravitation macht keine Probleme
- Größere Teleskope

REFLEKTOR Arter

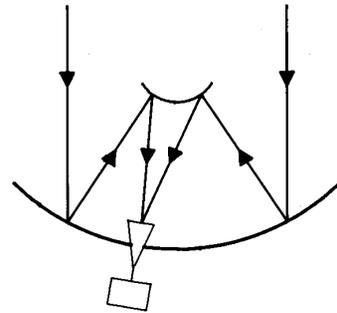
Primär Fokus
(GMRT)



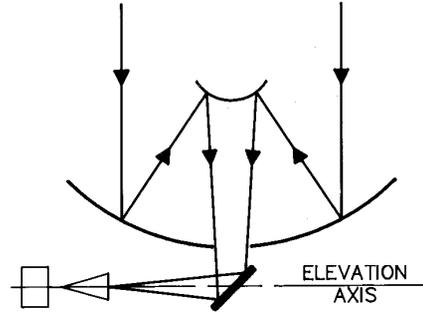
Cassegrain Fokus
(AT)



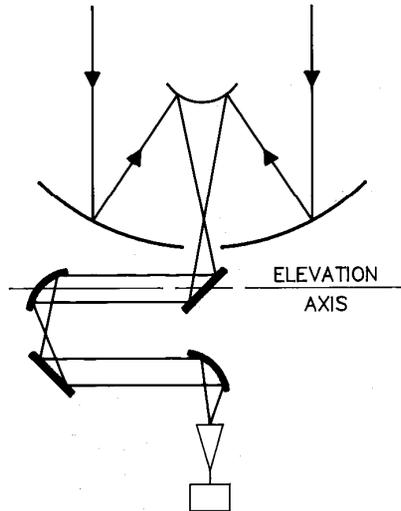
Offset Cassegrain
(VLA)



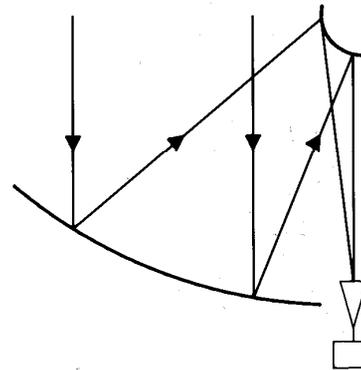
Naysmith
(OVRO)



Beam Waveguide
(NRO)



Dual Offset
(ATA)

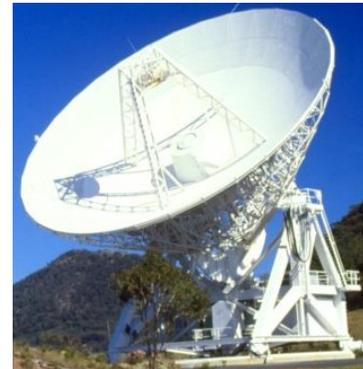


REFLEKTOR Arten

Primär Fokus
(GMRT)



Cassegrain Fokus
(AT)



Offset Cassegrain
(VLA)



Naysmith
(OVRO)



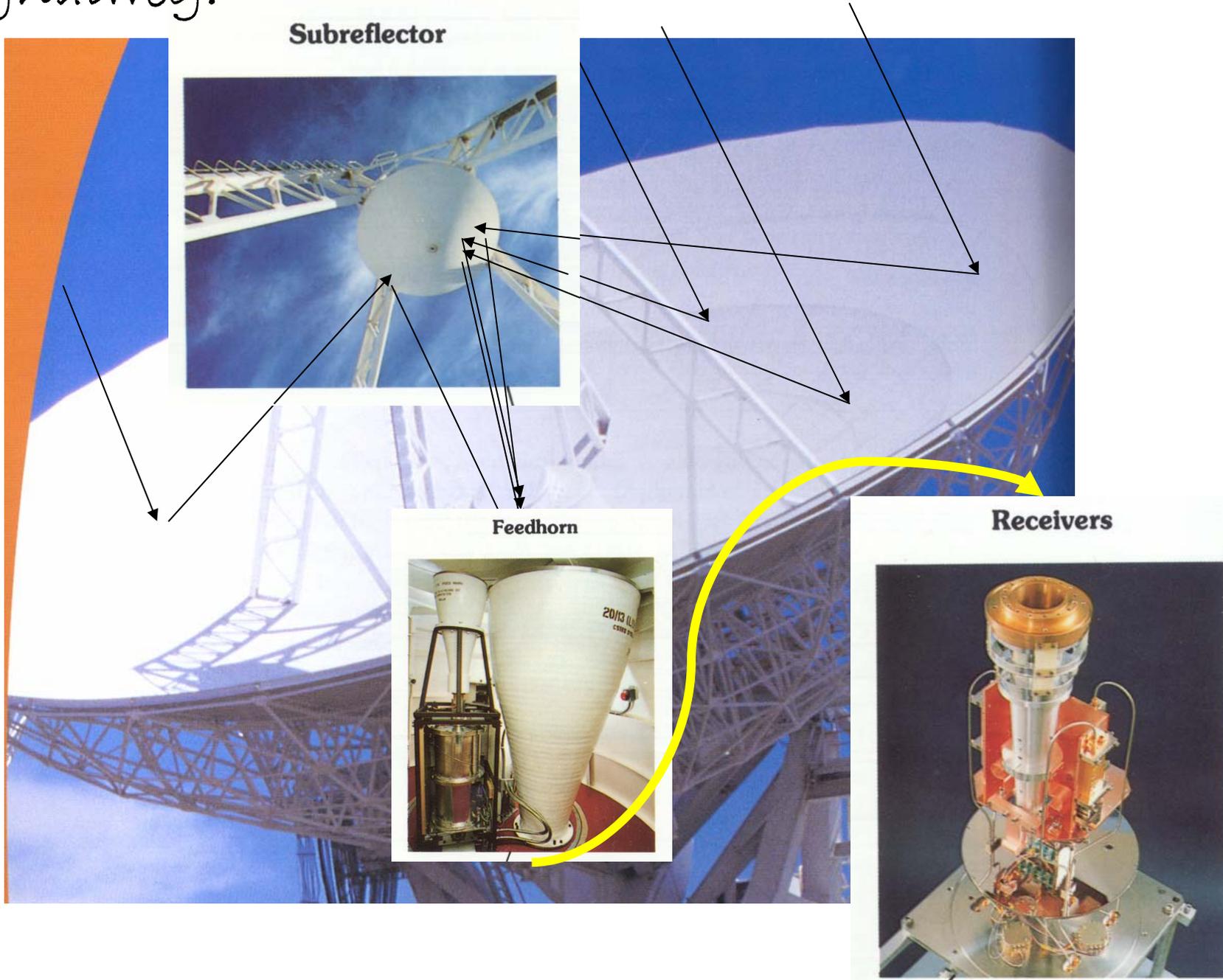
Beam Waveguide
(NRO)



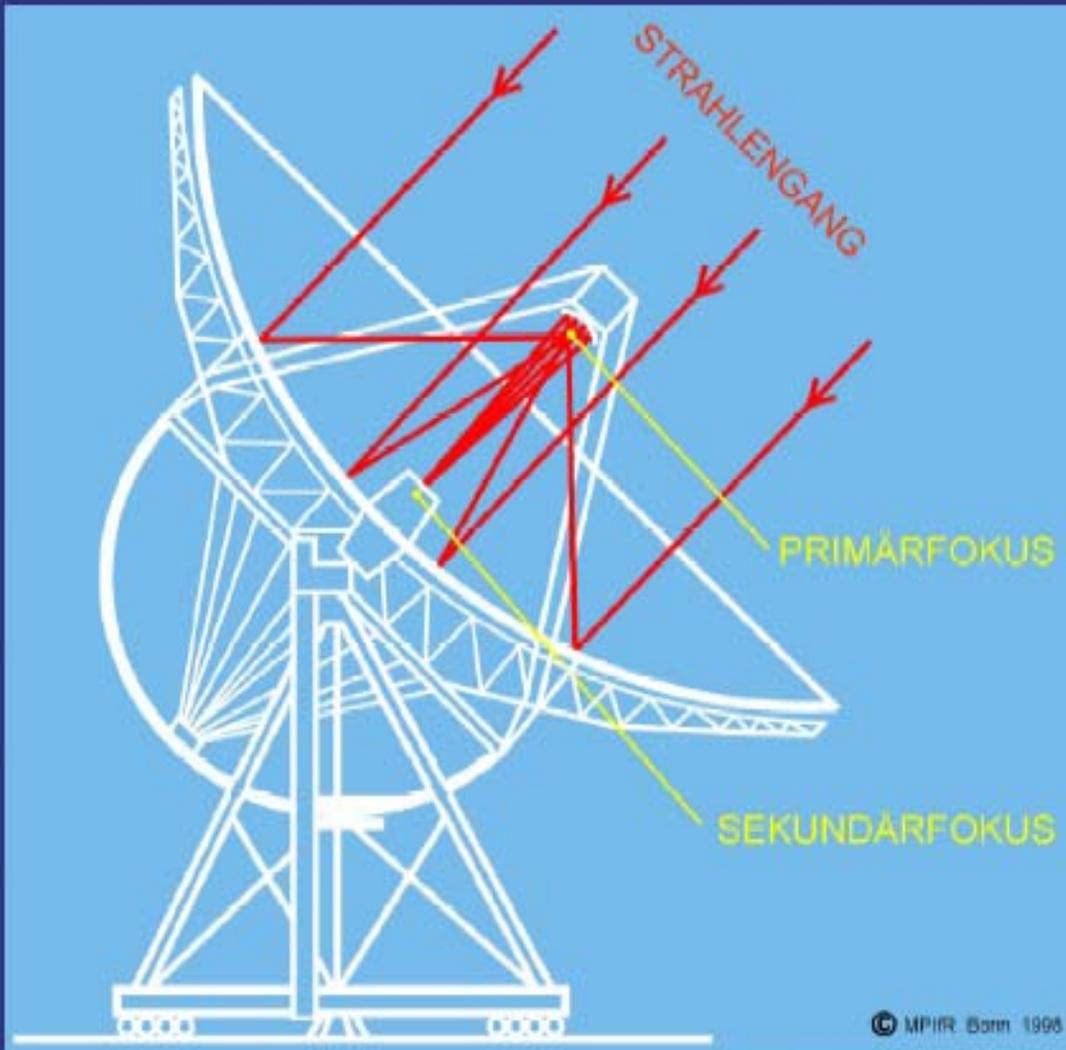
Dual Offset
(ATA)



Signalweg:

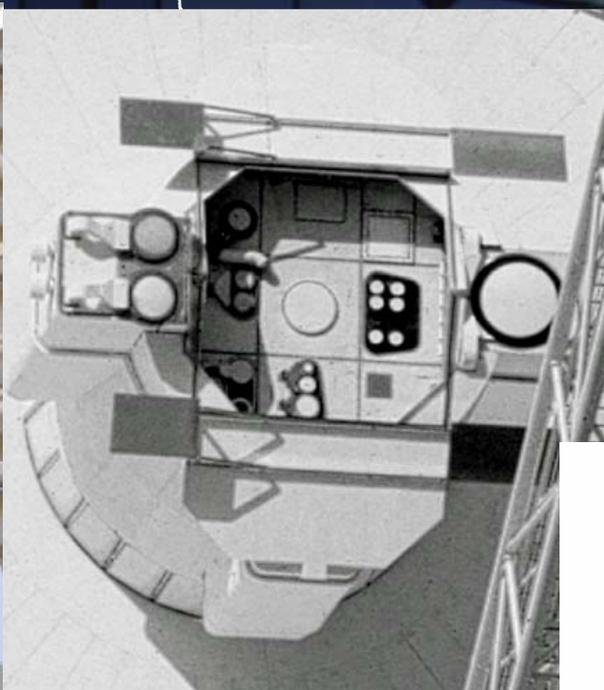


Antennen & Verstärker

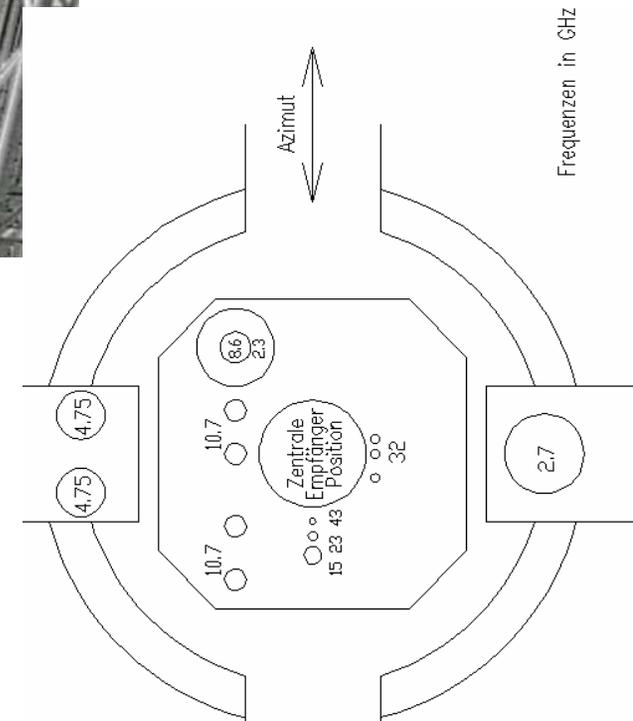


- Parabolspiegel
- Hornantennen + Verstärker
- Datenverarbeitung

Effelsberg: Primär- & Sekundärfokus



**Sekundärfokuskabine
(im Zentrum des
Hauptspiegels)**



Anordnung der Empfänger im Sekundärfokus

Die Primärfokuskabine
(30m über Hauptspiegel) kann bei
komplett gekipptem Teleskop
über diesen Gang erreicht werden

Effelsberg: Sekundärfokuskabine



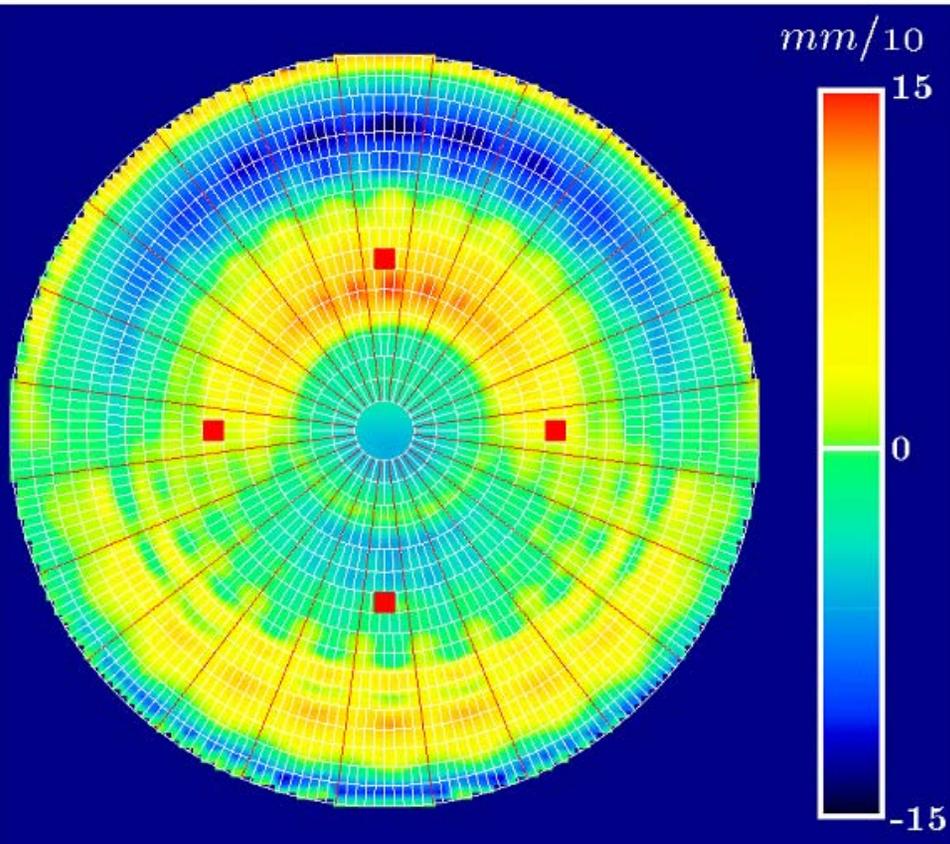
Unterhalb der Parabolantenne sieht die Sekundärfokuskabine so aus.

Effelsberg: Sekundärspiegel mit aktiver Optik



- Seit 1971 astronomischer Messbetrieb
- Restabweichungen des Hauptspiegels von der Idealform eines Paraboloids bei unterschiedlichen Neigungswinkeln: Ausgleich durch aktive Oberfläche
- Mitte 2006: Einsatz eines neuen Sekundärspiegels (aktive Optik mit ca. 100 Aktuatoren): Ziel ist optimaler Betrieb bei Millimeterwellenlängen
- Prinzip der homologen Verformung: die Verformungen des Hauptreflektors infolge der Schwerkraft beim Kippen werden durch die tragende Stützstruktur ausgeglichen und die Oberfläche näherungsweise in ein neues Paraboloid überführt

Effelsberg: Sekundärspiegel mit aktiver Optik



- Bild zeigt verbleibende Abweichungen von einem perfekten Paraboloid für eine Höhe von 70 Grad über dem Horizont
- **Effelsberg 2004+** (aktive Oberfläche):
 - weitere Korrektur aller 2352 Einzelplatten (Paneele) über Motorsteuerung (Aktuatoren)
 - Oder: verbleibende Abweichungen des Hauptspiegels über eine aktive Oberfläche des 6.5m-Sekundärspiegels ausgleichen

Oberflächengenauigkeit des 100-m-Hauptspiegels des Radioteleskops Effelsberg bei 70 Grad Höhe über dem Horizont.

Die Abweichungen liegen im Mittel unter 0,3 mm; es treten Extremwerte bis $\pm 1,5$ mm auf.

Effelsberg 2004+



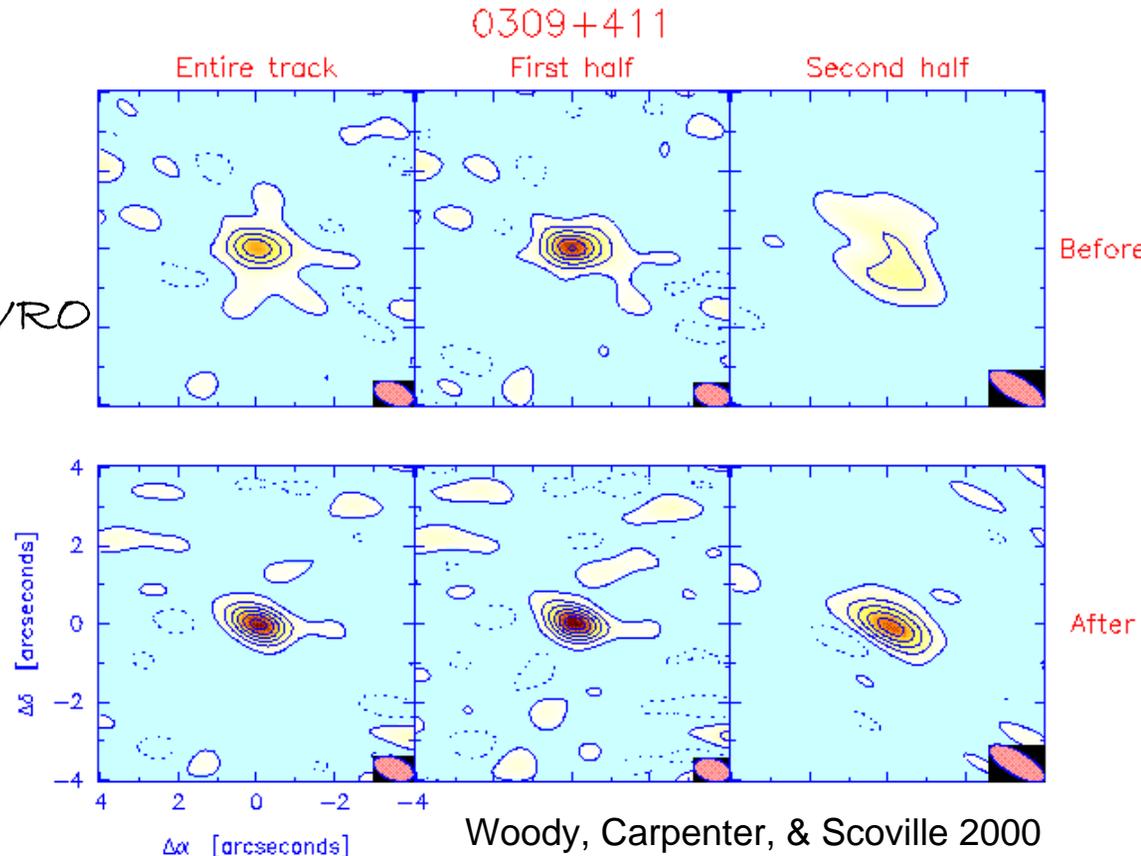
- Hohe Qualität der Oberfläche des Hauptspiegels im Bereich unterhalb von 1 cm Wellenlänge kommt bis jetzt nur für Beobachtungen vom Primärfokus aus zur Geltung, da der Sekundärspiegel für den mm-Wellenbereich zu ungenau ist. Mit dem neuen Subreflektor können auch mm-Beobachtungen vom Sekundärfokus aus gemacht werden: Vorteile für den Einsatz von Multibeamempfängern im mm-Bereich
- Vorteile:
 - Wellenlängenbereich bis 2mm für Beobachtungen im Sekundärfokus erschlossen
 - Effektive Genauigkeit des Hauptspiegels wird durch die aktive Oberfläche des Sekundärspiegels nochmals gesteigert
- Neubau des Sekundärspiegels unter Einschluß von 100 Aktuatoren bis Mitte 2006, außerdem automatischer Wechsel zwischen Primär- und Sekundärfokus->schnellerer Wechsel zwischen unterschiedl. Wellenlängen und schnelle Reaktion auf Wetterwechsel

Effelsberg 2004+



- Radiomessungen im mm-Bereich:
Schönwetterbeobachtungen!
- Große Nachfrage, starke Überbuchung

Phasenkorrektur:
22 GHz Wasserlinien Monitor, OVRO



A large radio telescope dish is illuminated from below, creating a warm glow. The dish is supported by a complex metal structure. In the background, a full moon is visible in the dark night sky. The overall scene is set against a dark, clear night sky with some faint lights visible in the distance.

Neue Einzelteleskope
- GBT
- Sardinien

Radioteleskope - Katastrophen



about patent rights if other groups learned of the results and reproduced them.

On approximately 21 March, the University of Utah decided to announce the fusion results in a press conference 2 days later. The university administration "agonized" over the decision, Brophy said, but they could wait no longer. "We decided to stop at the point where they could demonstrate fusion without explaining it," Brophy said.

Jones was not informed of the decision, although he spoke with Pons over the telephone 2 days before the planned news conference. When Jones heard Pons say at the press conference that his team had already submitted a paper to a journal, he decided that Pons had broken their agreement, and he submitted his paper to *Nature*.

At the University of Utah, the fact that Jones contacted Pons after seeing his grant application has generated widespread rumors and innuendos that Jones was attempting to steal some of the credit for Pons and Fleischmann's work. In addition to the uneasy relationship between the two schools, some of those suspicions may have come from Pons himself, who has hinted, a couple of observers said, that Jones had stolen ideas from his grant application.

But nonpartisan observers who are familiar with the situation say Jones almost certainly came up with the ideas for his work independently of and prior to seeing the University of Utah grant proposal. For his own part, Jones said he can prove the work in his paper came completely out of his own lab. "Our log books prove we have been studying this since 1986." In fact, Jones said, he had a page from his notebook dated 7 April 1986 notarized. That notarized page contains an outline of experiments his team planned to run, including explicit reference to looking for cold fusion in palladium electrodes, he said. A drawing done in May 1986 of a fusion cell looks very similar to what Pons and Fleischmann eventually used, he said, although that is not too surprising because "there are only so many ways [to design it] once you get the idea of doing electrolysis." None of his team's work was done because he saw Pons and Fleischmann's grant application. "I've stuck to my reviewer's agreement," he said. "We had our program outline and we've followed it."

Meanwhile, Utah governor Norm Bangerter has announced he will call a special session of the state legislature to provide \$5 million for a fusion center at the University of Utah, and former NASA head James Fletcher has accepted the position of director. If the discovery pans out, said Bockris of Texas A&M, "the University of Utah will be the richest university in the country in 5 years." ■ ROBERT POOL

Telescope Collapse Unraveled

The fracture of a single highly stressed steel plate has been identified as the most likely cause of the spectacular collapse of the 300-foot radio telescope at the National Radio Astronomy Observatory at Green Bank, West Virginia, last November. An independent panel appointed by the National Science Foundation, which funds the facility, and Associated Universities, Inc., which manages it, reached that conclusion after examining the suspect plate and performing a computerized stress analysis.

The panel found that parts of the telescope were under far higher stresses than would be permitted today, and that "from the beginning of its life, the structure was marginal with respect to structural failures of a minor or perhaps major nature." The plate that failed was a critical connection in the support structure of the instrument and it was subjected to high stresses when the telescope was moving. Half of the plate was recovered from the wreckage and a metallurgical analysis indicated that small cracks had been developing in it before it suddenly failed. The telescope was being swiveled when it collapsed around 10 p.m. on 15 November.

The panel absolves the managers of the facility from blame. It says there is no indication that the telescope was inadequately maintained—the plate itself was hidden from view and could not have been examined without disassembling the telescope—nor was it being operated inappropriately. The panel also notes that computerized stress analysis would identify potential failure points in telescopes built today, but these methods were not available when the instrument was built in 1962.

Now that the apparent cause of the collapse has been identified, attention is likely to focus on NSF's plans for replacing the instrument. In testimony before the House Appropriations Committee last month, NSF director Erich Bloch said that the foundation's top priority for its next major astronomy facility is an observatory to search for gravity waves. Known as the Laser Interferometer Gravity Wave Observatory, or LIGO, it would consist of a pair of facilities situated near the East and West coasts. LIGO has been in the planning and R&D stage for several years, and NSF was hoping to include funds in its 1991 budget to begin construction. The total cost would be about \$100 million.

West Virginia Senators Robert Byrd (D) and Jay Rockefeller (D) have other ideas, however. In a statement released last month, they said that replacing the collapsed telescope with a modern instrument should have higher priority than LIGO. A replacement telescope, which would cost about \$75 million, would be "the best promise for jobs, education, tourism, and scientific prestige," for their state, they said.

Byrd, who is chairman of the Senate Appropriations Committee, said he "will aggressively pursue funding" for the telescope. Rockefeller is on the Senate Commerce committee, which oversees NSF.

■ COLIN NORMAN



Before and after. The cause of the collapse has been determined, but whether the instrument will be replaced may become a political question.



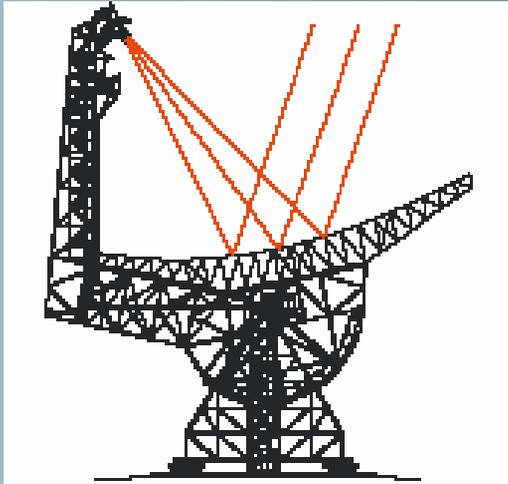
Photograph of the 300 Foot radio telescope taken on November 16, 1988. The telescope collapsed at 9:43 PM on November 15, 1988.

GBT

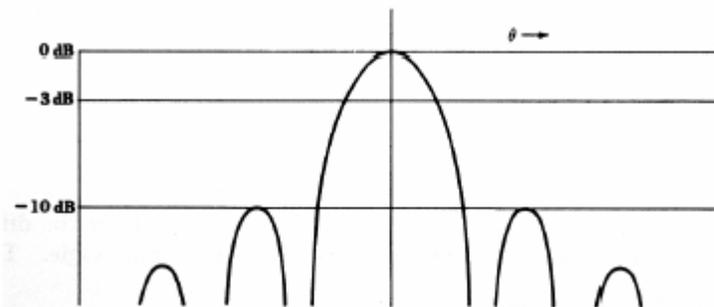
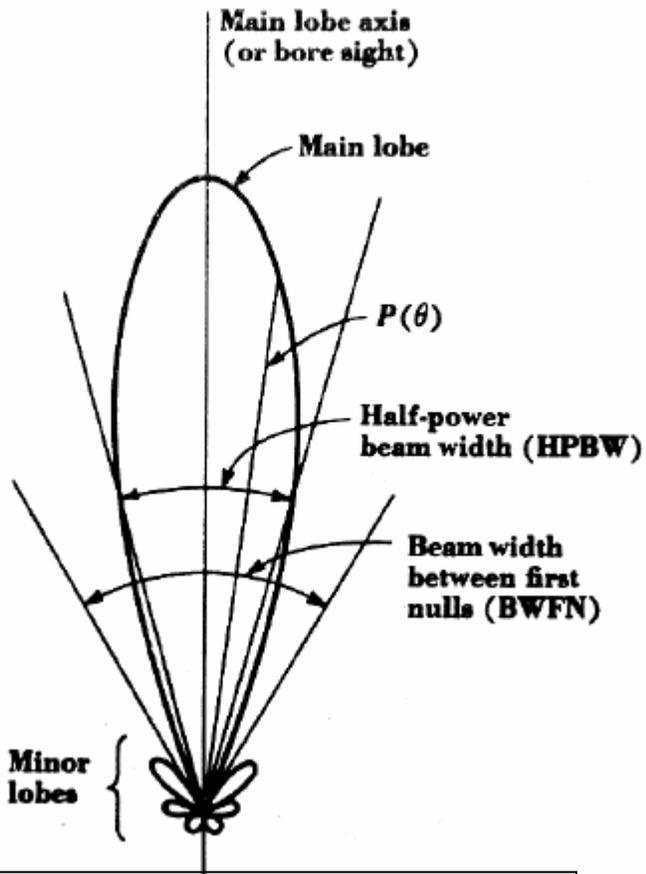


- Robert C. Byrd Green Bank Teleskop
- 100 x 110 m, 16 Mio Pfund Gewicht
- Aperturbene ungestört
- 2004 Panels können einzeln bewegt werden (Hochfrequenzbeobachtungen)
- Laser-System, Licht wird reflektiert und erlaubt die Deformation unter Gravitation, Wind und Temperaturdifferenzen zu beobachten und zu kompensieren

GBT



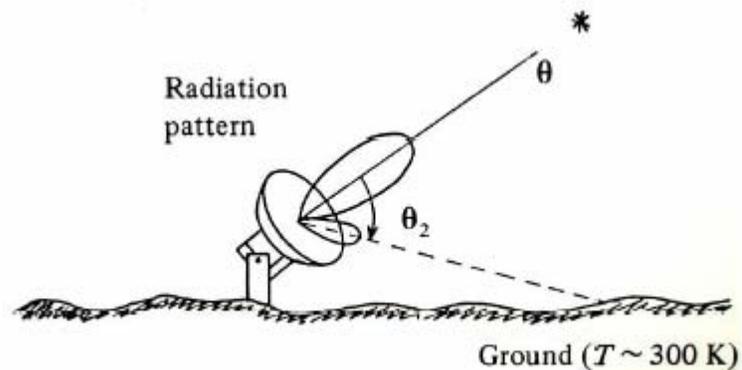
- Vorteile einer unblockierten Aperturebene:
 - Einkommendes Signal wird nicht gestört
 - Reduziert die „*sidelobes*“
 - Reduziert spektrale stehende Wellen
 - Weniger RFI



- „main beam“ entspricht dem zentralen Beugungsmaximum eines Teleskops

$$\text{HPBW} \approx \Theta_{\text{mb}} \approx 1,22 \frac{\lambda}{D} \text{ [rad]}$$

→ $\Theta_{\text{mb}} = 6,3^\circ$ für $\lambda = 21\text{cm}$ und $D = 2,3\text{m}$



„side lobes“ bzw. „stray pattern“
entsprechend den Nebenmaxima der Beugung

GBT - Aktive Oberfläche



GBT active surface system

- Surface has 2004 panels
 - average panel rms: 68 μm
- 2209 precision actuators



-actuators at corners of panels

Designed to operate in:

- open loop from look-up table
- closed loop from laser metrology system

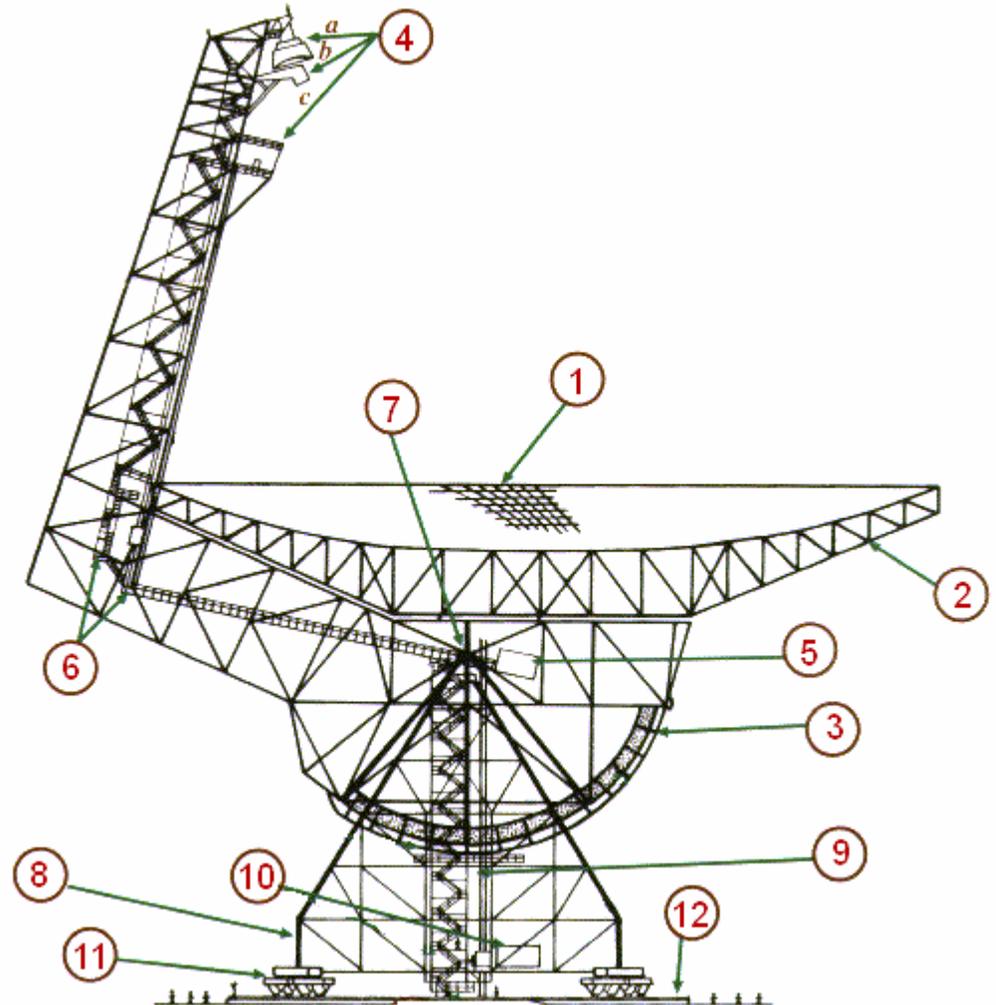


GBT



Anatomy of the GBT

1. Reflector (dish) made of 2004 adjustable aluminum panels
2. Backup Structure 13,000 steel beams, all welded construction.
3. Elevation Gear
4. Receiver Area
5. Actuator control room
6. Elevator and stairs
7. Elevation Axle
8. Alidade support structure
9. Elevator
10. Equipment Rooms
11. Azimuth Wheels and Drives
12. Azimuth Track

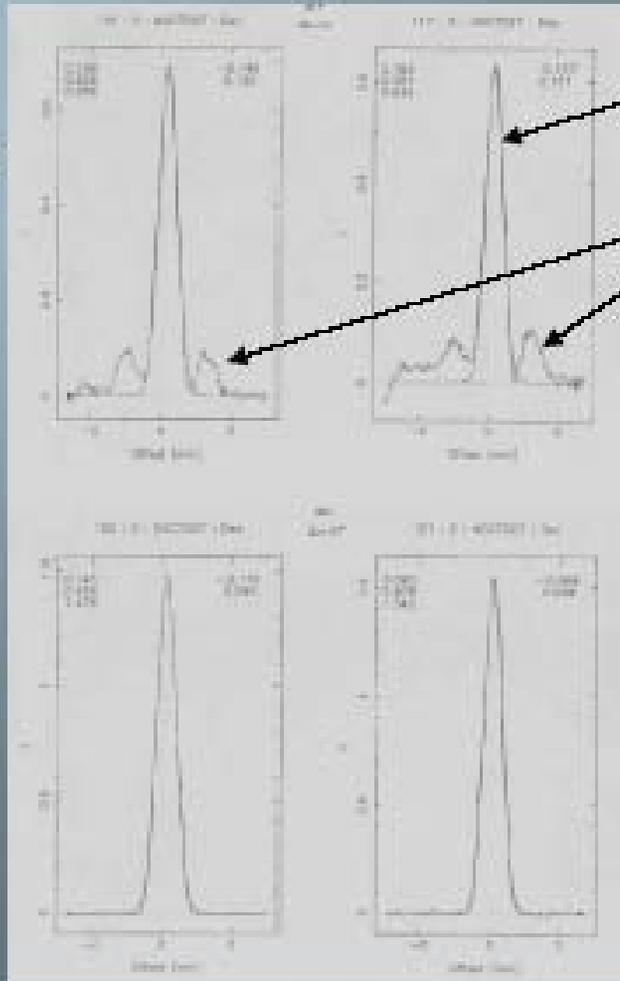


GBT - Aktive Oberfläche



Az / El Beam Shapes with Active Surface Off and On

Active Surface OFF



Main diffraction beam

Sidelobes caused by dish distortion

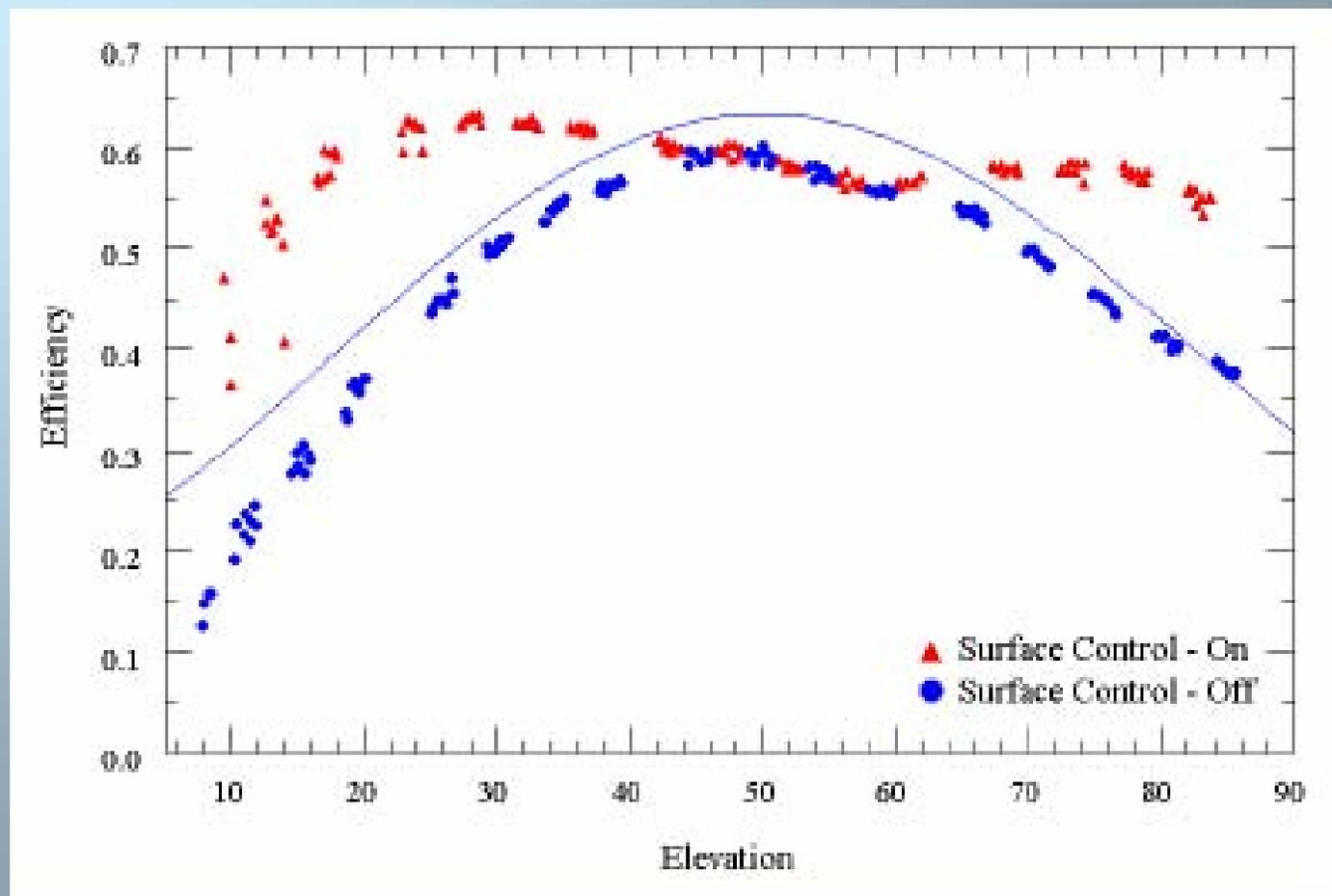
Active Surface ON



GBT - Aktive Oberfläche



Gain Elevation Curve with Active Surface On



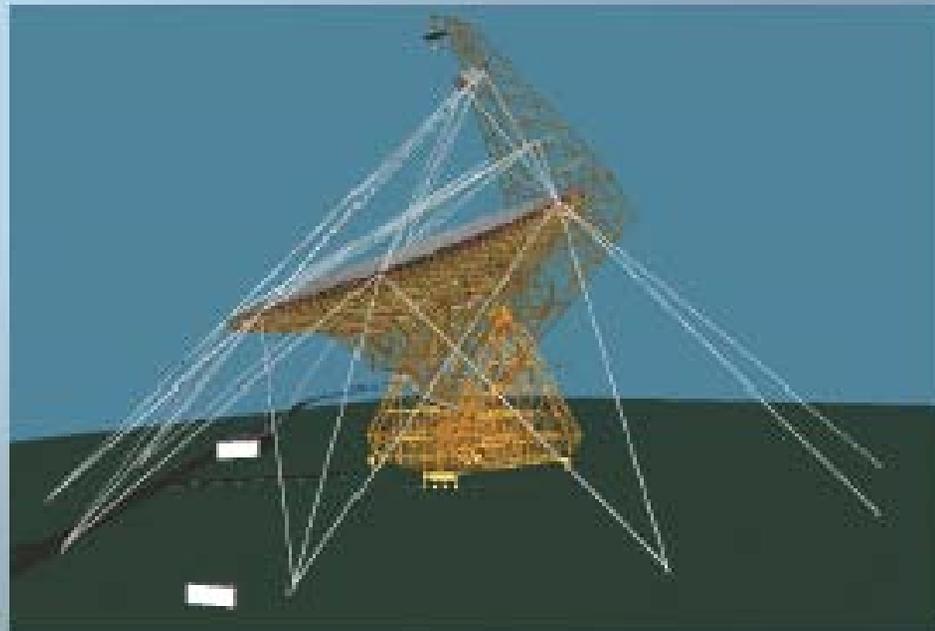
Gain:

GBT



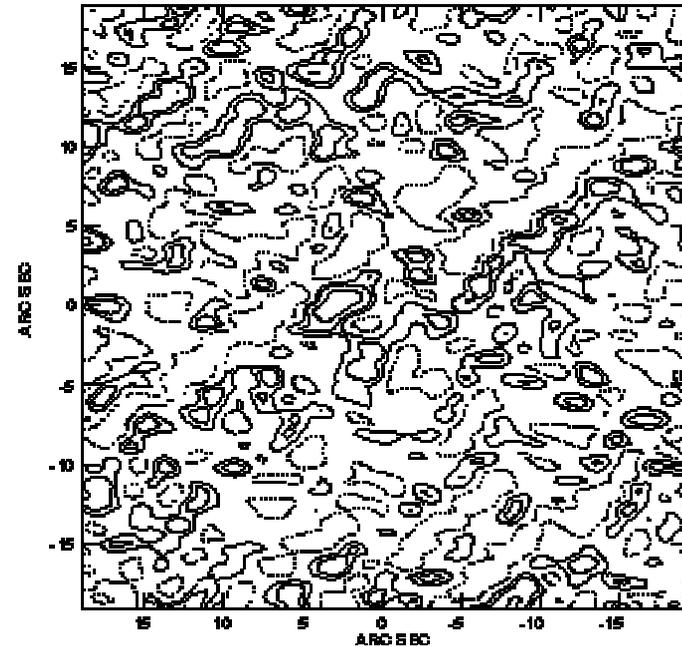
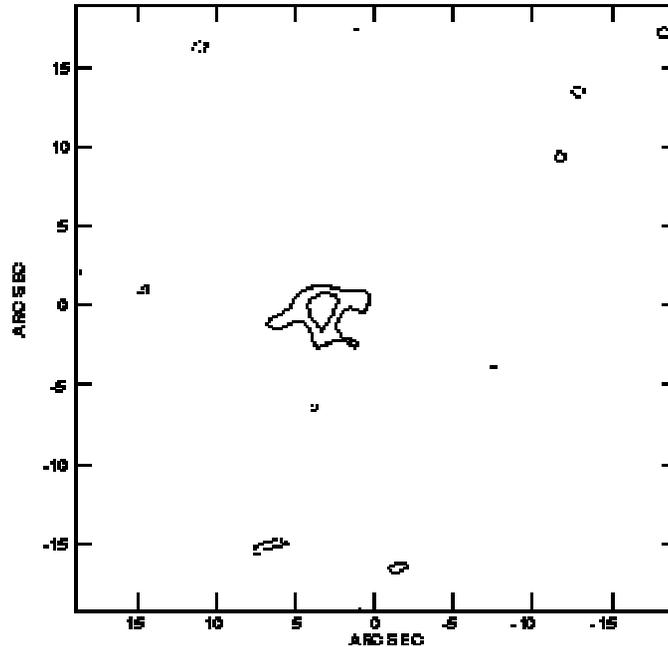
Metrology System

- Plans for 6 laser rangefinders on the feedarm for surface ranging



- 12 laser rangefinders on ground monuments for pointing and structural measurements
- Measurement Accuracy: $<50\mu\text{m}$ over 100m

Radiofrequenz-Interferenz (RFI)



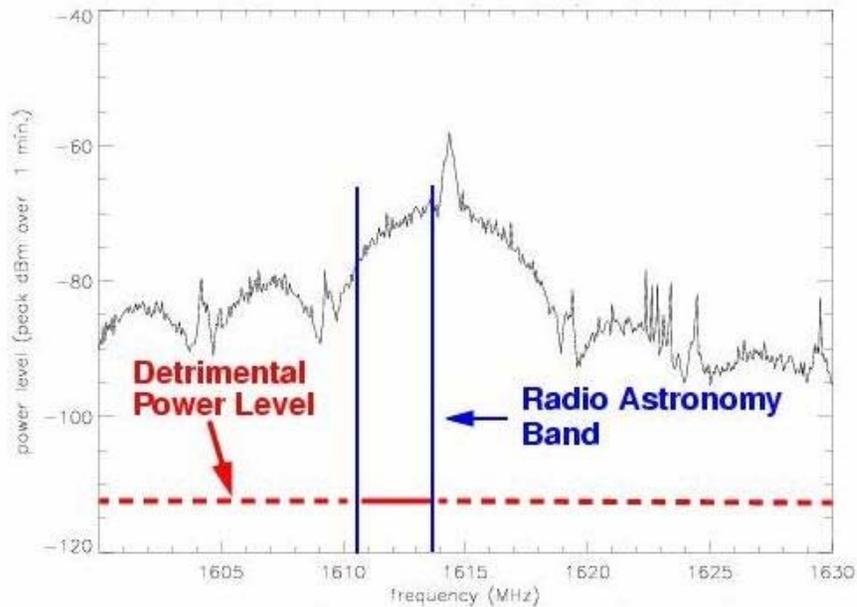
VLA Bild eines OH/IR Sterns aufgenommen bei 1612 MHz ohne Satellitensignal (links) und mit Iridium Satellit (22 Grad zum Stern) (rechts).

G.B. Taylor, NRAO/AUI.

Radiofrequenz-Interferenz (RFI)

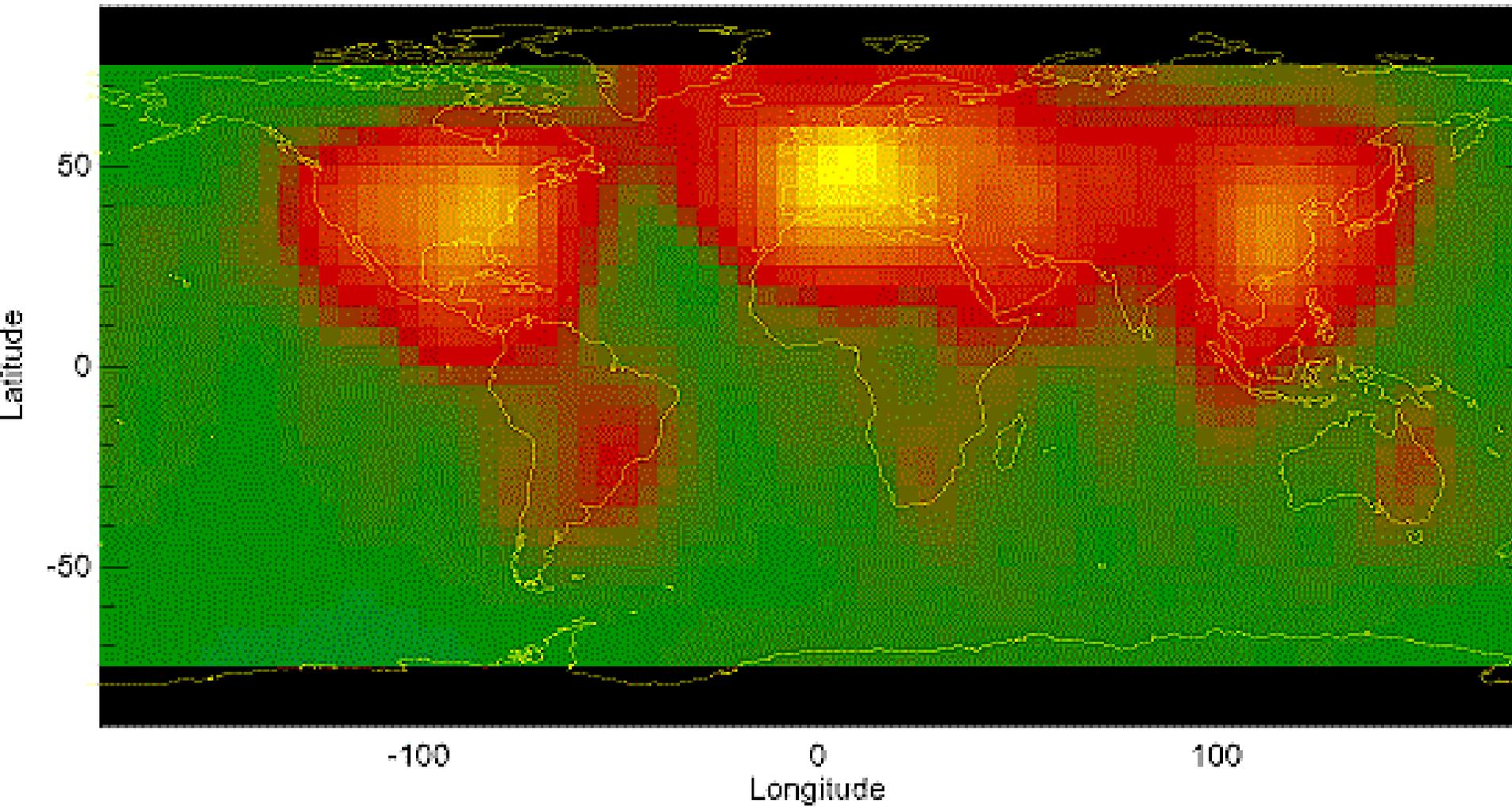


"Spillover" Into a Radio Astronomy Band by a Too-Broad Transmitter

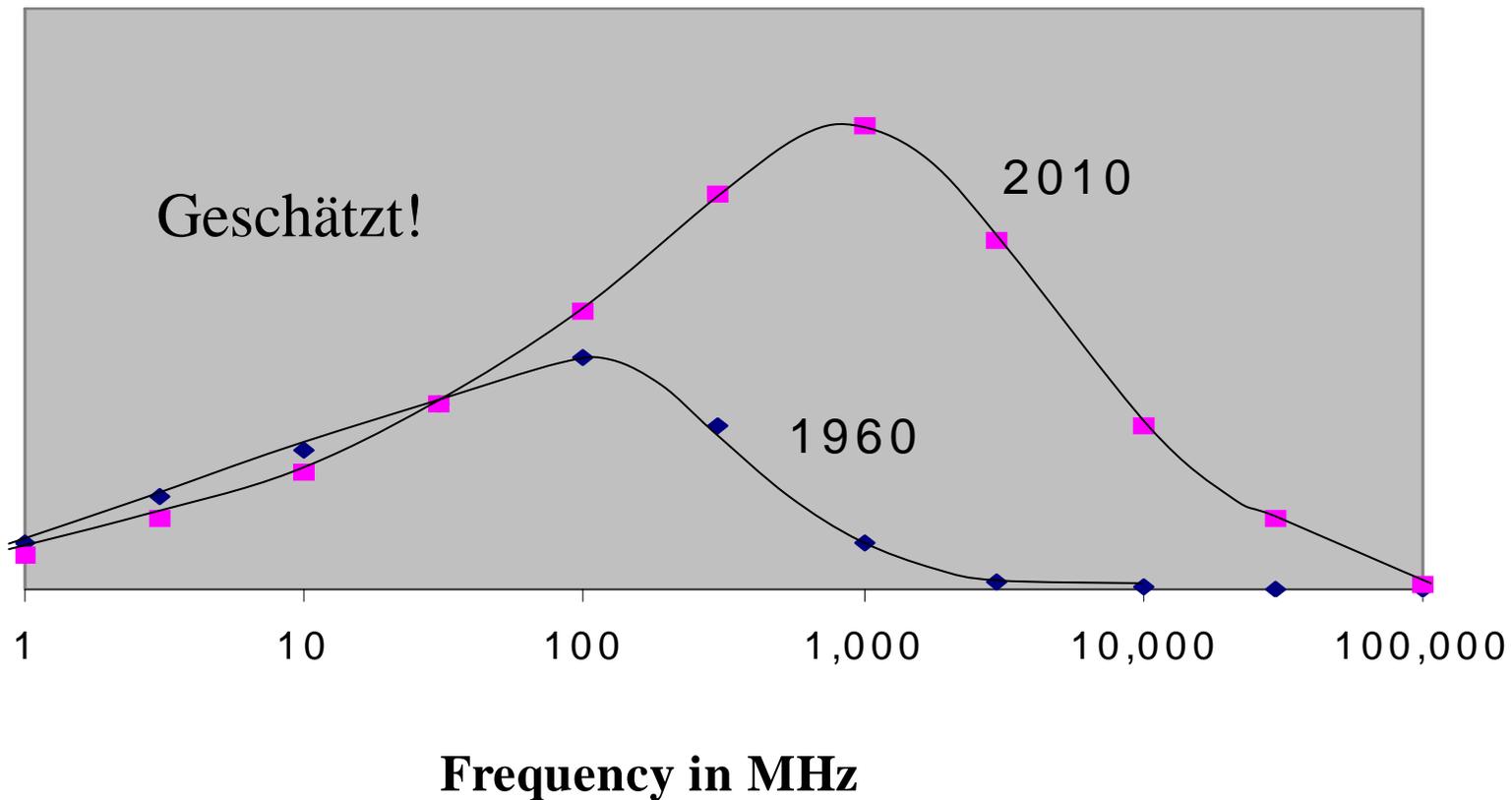


This graph illustrates interference to radio astronomy from a satellite transmitter whose signal is so broad that it spills into the band of frequencies allocated to radio astronomy by international agreement. The radio astronomy band lies between the two vertical blue lines. The horizontal red line indicates the power level defined by the International Telecommunications Union (ITU) as detrimental to radio astronomy; any signal above the red line is above this detrimental level. Instead of being designed and built to eliminate signals outside of its authorized range, this transmitter spreads radio emissions over a very wide range of frequencies, far beyond its ITU-authorized range.

Radio frequency interference (RFI)
muß beseitigt werden um Empfindlichkeit zu erreichen



Telekommunikation breitet sich aus
und wird dies weiterhin tun ...



RFI



- Signale werden rauschartig
- Der mittlere Wert ist 0 (kein Träger)
- Hohe Frequenzen dominieren
- Dies erlaubt sehr stark gerichtete Antennen
- Dadurch geringere Transmitterleistung

Einige Unterschiede



Telekommunikation

- Bandbreite
 - 10kHz bis 50MHz
- Rauschtemperatur
 - Typisch 1000° K
- Min detektierbares

Signal

- >10dB darüber

Radioastronomie

- Bandbreite
 - 1kHz bis 1000MHz
- Rauschtemperatur
 - Typisch 10° K
- Min detektierbares

Signal

- < 30dB unterhalb mit Mitteln

Ähnlichkeiten: Radioastronomie / Telekommunikation



- Beide brauchen größere Bandbreiten
- Ähnliche Frequenzen: billigere Komponenten und bessere Signalverarbeitung für Radioastronomie
- Korrelations-Erkennungstechniken werden jetzt häufiger in der Telekommunikation.

GBT: Radiointerferenz



National Radio Quiet Zone



The GBT is in a 34,000 sq km area in which transmissions from fixed (licensed) transmitters are restricted by US regulations in signal strength at the position of the GBT.

- **National Radio Quiet Zone (NRQZ, 1958):** to minimize possible harmful interference to the National Radio Astronomy Observatory in Green Bank, etc.
- 13000 Quadratmeilen
- Coordinated frequency assignments with NRAO Interference Office
- Transmitters are checked beforehand not to exceed frequency-dependent thresholds
- Reference point for calculations of transmitter power density is the prime focus of the Green Bank Telescope

Neu!! Sardinia Radio Telescope



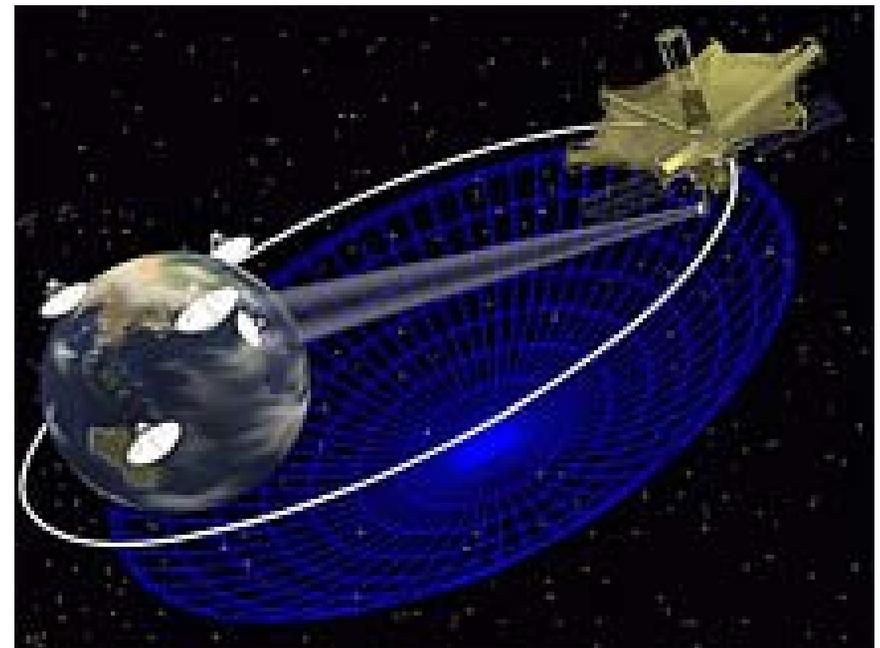
A large radio telescope dish is illuminated from below, creating a warm yellow glow. The dish is a complex lattice structure. In the background, a full moon is visible in a dark blue night sky. The telescope is mounted on a tall, white, lattice-structured pedestal. The overall scene is set against a dark night sky with some faint lights and silhouettes of trees in the distance.

Weltraum-
Radioteleskop

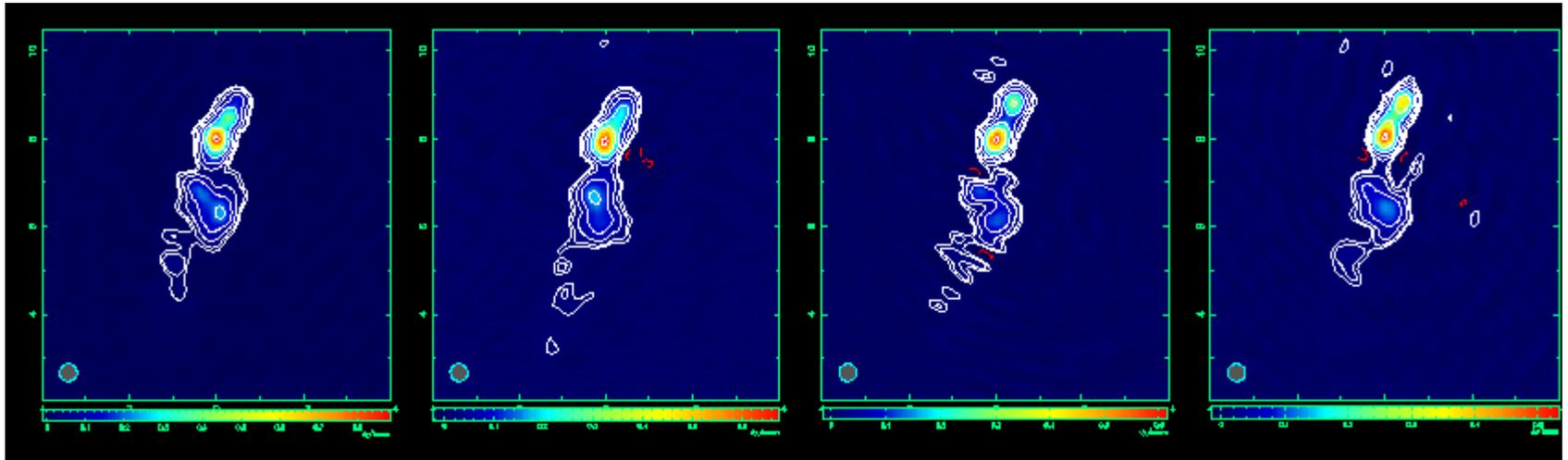
Weltraum - Radio - Teleskop



- VLBI Space Observatory Programme (VSOP) – von 1997 bis vor zwei Wochen, unterstützt durch bodengebundene Netzwerke;
- 20,000 km orbit;
- 30,000 km Basislinie;
- 1.6 und 5 GHz;
- Neue Teleskope:
 - RadioAstron;
 - ARISE;
 - **VSOP2**



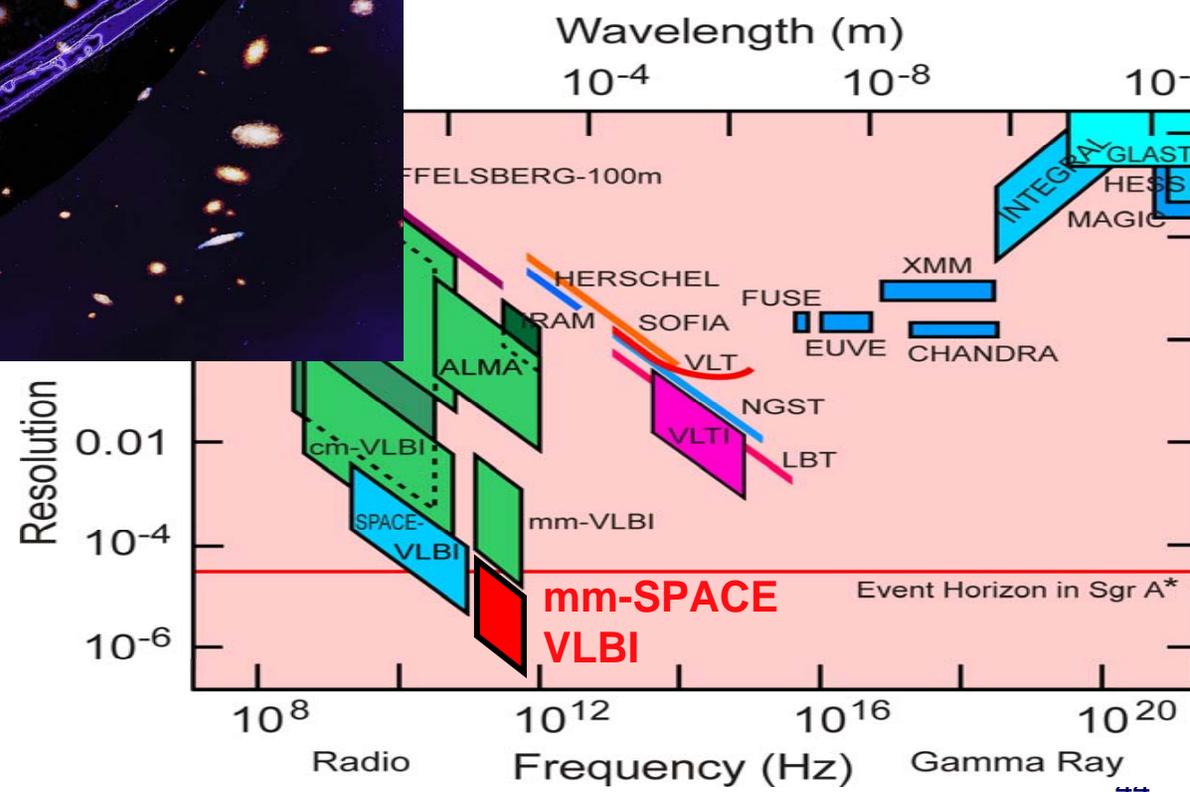
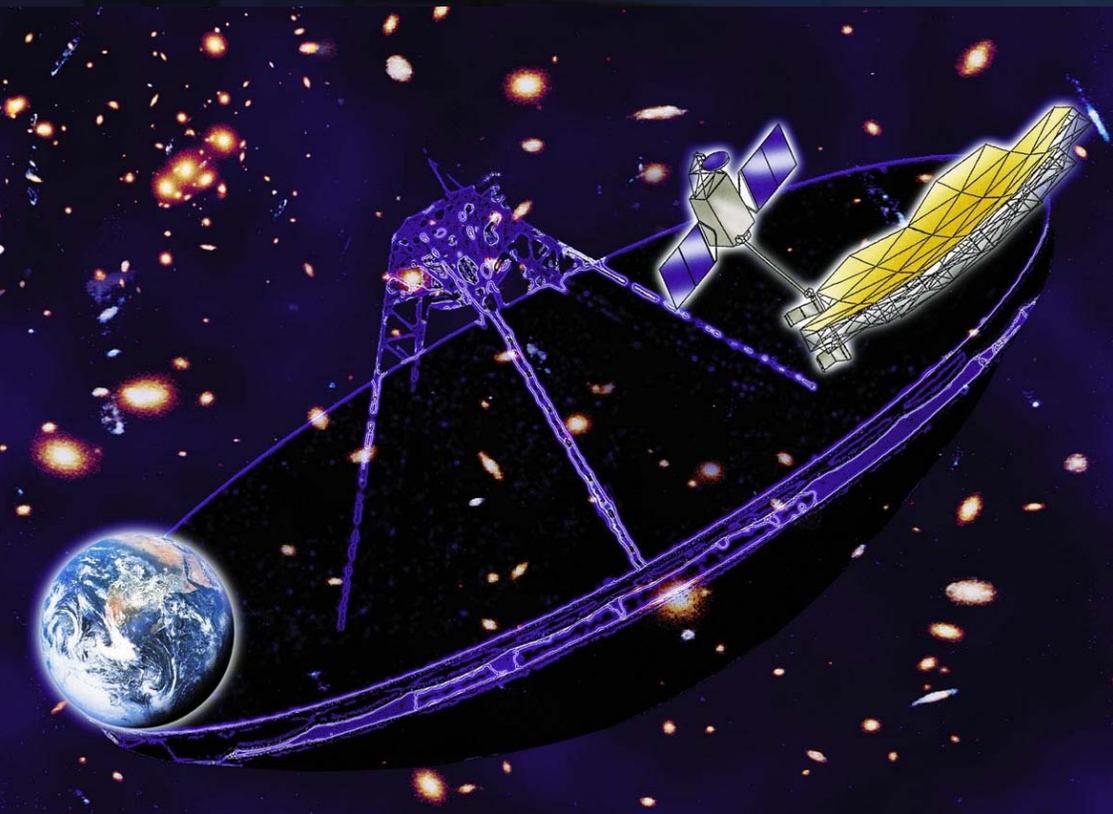
Weltraum - Radio - Teleskop



Murphy et al. (2000)

- 1928+738, helikaler Jet aufgrund eines Binären Schwarzen Lochs;
- VLBA+HALCA VSOP, 5 GHz, 0.25 mas Winkelauflösung;
- Scheinbare Geschwindigkeiten $>10c$, Strukturvariationen;

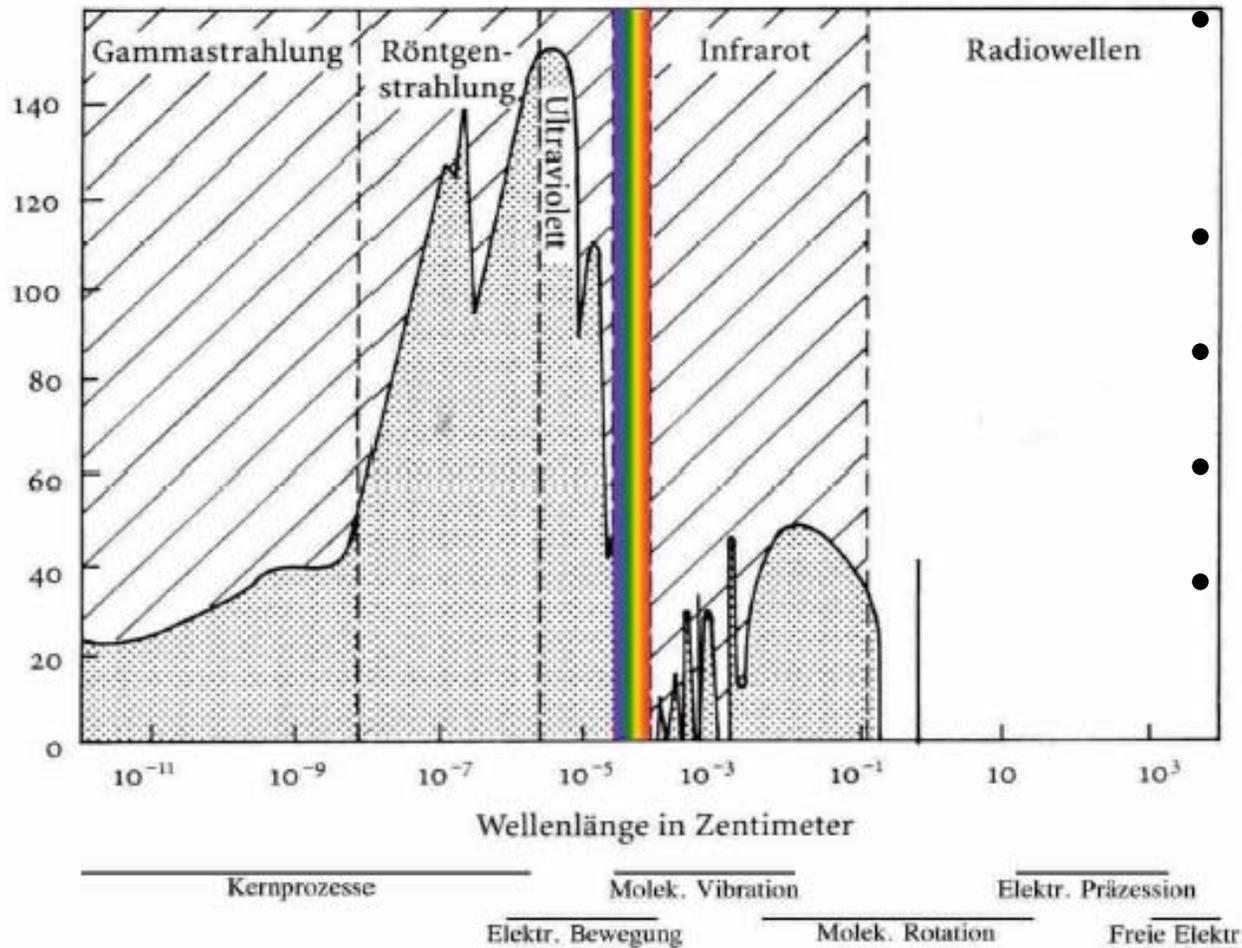
Höchste Auflösung: „mm-VSOP2“



A large radio telescope dish is illuminated from below, creating a warm yellow glow. The dish is supported by a complex metal lattice structure. In the background, a full moon is visible against a dark blue night sky. The overall scene is a night-time photograph of a radio telescope.

Neue mm-Teleskope

Radiofenster

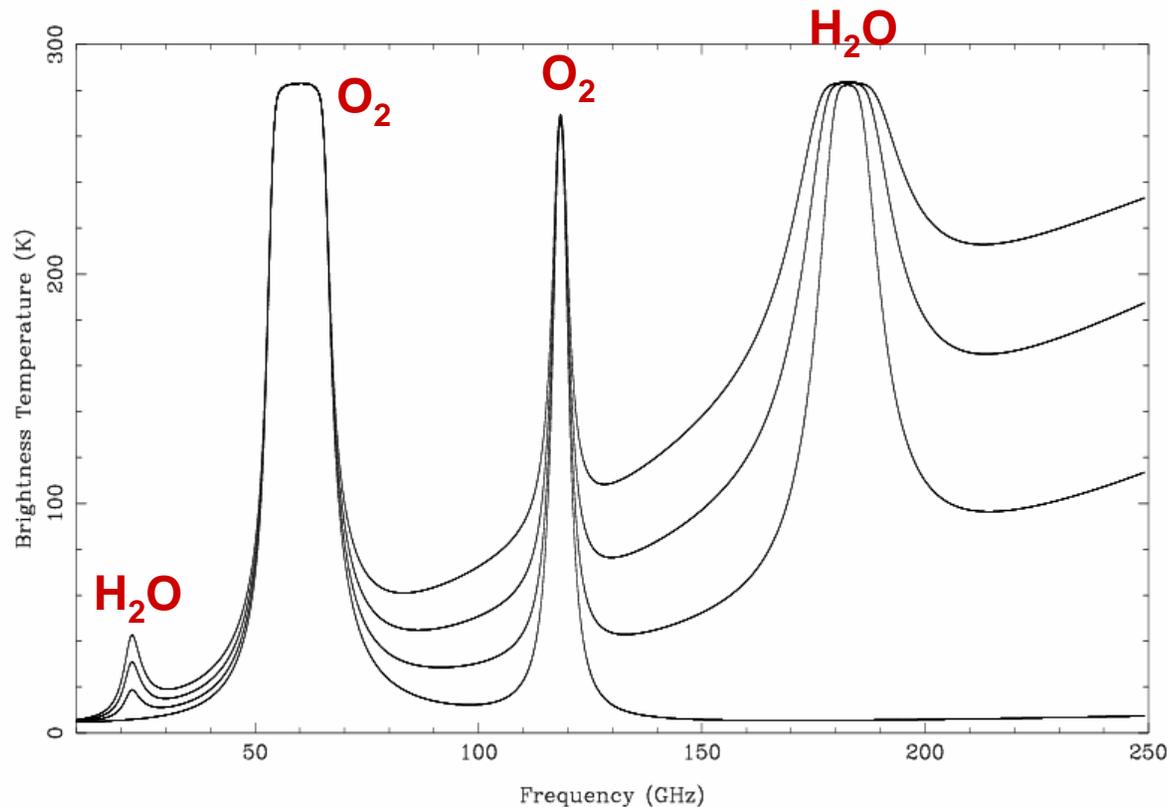


- Molekülaborption in der Troposphäre: H₂O (13.5mm, 1.63 mm), O₂ (5mm; 5+2.52 mm)
- N₂ und CO₂ bei höheren Frequenzen
- Interstellare Moleküle beobachten
- Teleskop-Side entsprechend wählen
- Niederfrequentes Ende: freie Elektronen der Ionosphäre absorbieren die Strahlung wenn Frequenz unterhalb der Plasmafrequenz (4.5 MHz nachts, 11 MHz tagsüber)

Das Problem bei mm-Wellenlängen



- Stringentere Anforderungen an die Instrumente
- Phasenfluktuationen aufgrund H_2O in der Troposphäre
- Troposphären Emission / Opazität signifikant



R. Sault

mm-VLBI: Anforderungen an die Instrumente



1. **Oberflächengenauigkeit:** Wenn σ die r.m.s. Oberflächenungenauigkeit in μm , dann ist die Oberflächeneffizienz gegeben durch die Ruze Gleichung:

$$\eta_{\text{sf}} = \exp [-(4\pi\sigma/\lambda)^2]$$

Für $\lambda=3\text{mm}$ und $\sigma=200\ \mu\text{m}$, $\eta_{\text{sf}}=0.54$. Antennen "Holographie" kann genutzt werden, um großskalige Ungenauigkeiten in der Antennenform zu diagnostizieren.

2. **Gesichtsfeld** (Primärbeam Größe):

$$\theta_{\text{FWHM}} \approx \lambda/D \approx 620''/D[\text{m}] \text{ bei } 3\text{mm}$$

$$\text{BIMA: } D=6.1\text{m}, \theta_{\text{FWHM}} = 100''$$

$$\text{ATCA: } D=22\text{m}, \theta_{\text{FWHM}} = 30''$$

Für große Quellen müssen Bilder zusammengesetzt werden (Mosaik)

mm-VLBI: Anforderungen an die Instrumente



3. **Pointing Genauigkeit:** Um Bilder mosaikartig zusammensetzen zu können, eine typische Pointing Genauigkeit von $\Delta\theta < \theta_{\text{FWHM}}/20$ wird benötigt. ATCA benötigt $\sim 1.5''$ Pointing Genauigkeit!

4. **Korrelator Bandbreite:**

$$1 \text{ MHz} \approx \lambda_{\text{mm}} \text{ km s}^{-1}$$

Die gleiche Bandbreite bedeckt nur 1.4% des Geschwindigkeitsbereiches bei 3 mm verglichen mit 21 cm!

5. **Elektronisches Phasenrauschen:** steigt mit Frequenz, schwierig zu kalibrieren (hängt nicht von Antenne ab). Für VLA bei 22 GHz, $\phi_{\text{rms}} \sim 10^\circ$.

6. **Basislinien Fehler:** $\Delta b \sim 0.5 \text{ mm}$ führt zu $\Delta\phi \sim 10^\circ$.

Heute: Höchste Auflösung mit mm-VLBI Beobachtungen



Die Teleskope:

100m Effelsberg, Deutschland

6x15m Plateau de Bure, Frankreich

30 m Pico Veleta, Spanien

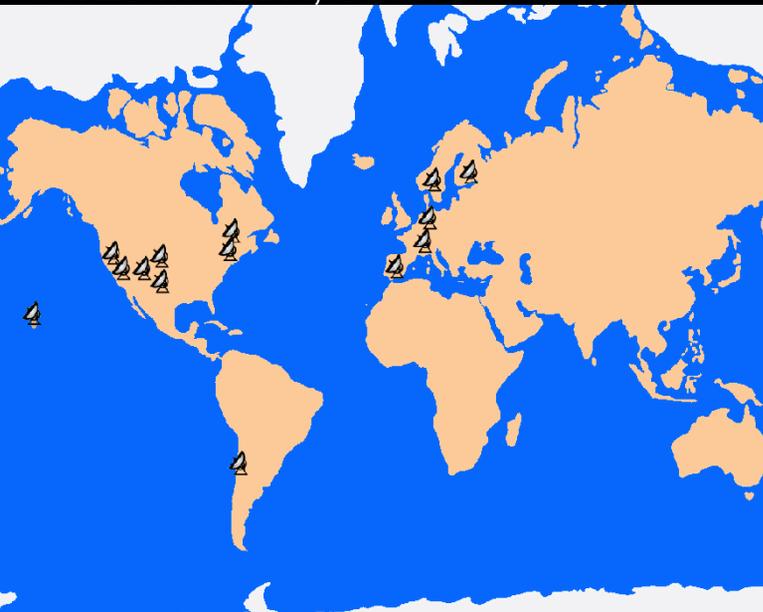
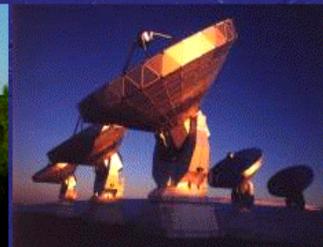
20 m Onsala, Schweden

15 m Metsähovi, Finland

8 x 25 m VLBA, USA

45 Mikro-Bogensekunden Auflösung bei 86 GHz

The Global mm-VLBI Array



For comments which help to improve this page, please contact [J. Klare](#) or [T.P. Krichbaum](#)

3mm VLBI, Sgr A* mit den 3 größten europäischen mm-Antennen:



Effelsberg 100 m (MPIfR)



Plateau de Bure, 6 x 15 m (IRAM, France)



Baseline lengths (km):

	PdB	PV
EB	658	1700
Pdb		1146

Pico Veleta 30 m (IRAM, Spain)

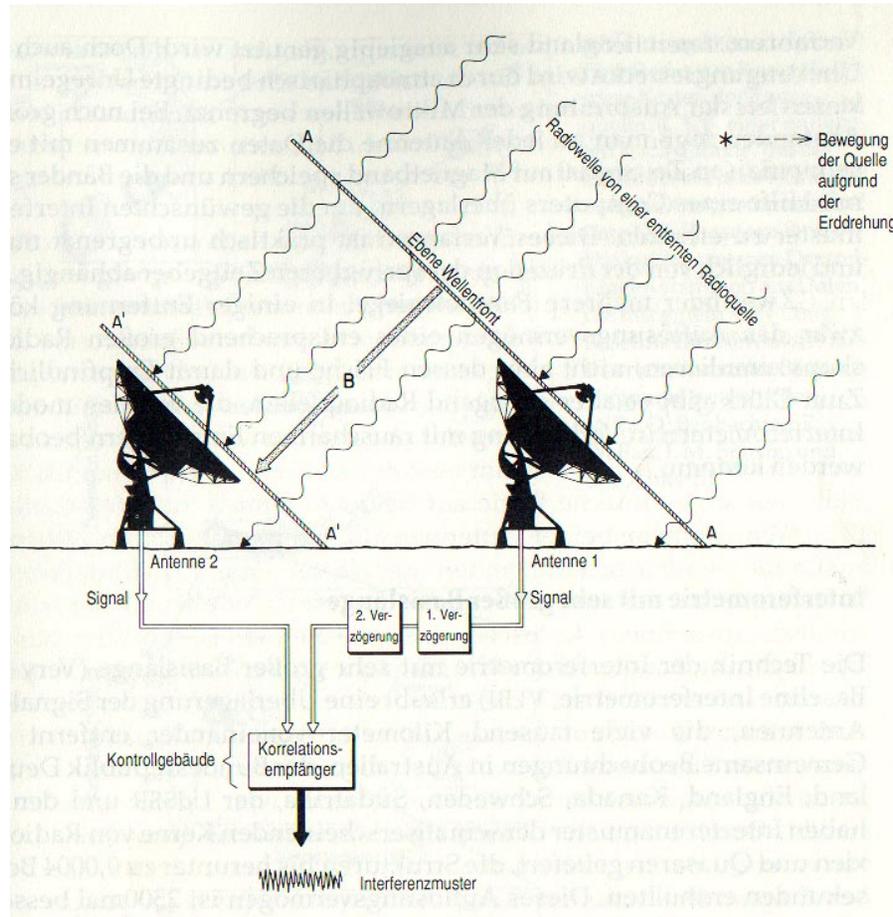


fringe spacing: 0.4 – 1.1 mas, sensitivity > 60 mJy (7σ)

A large radio telescope dish is illuminated from below, creating a warm yellow glow. The dish is supported by a complex metal structure. In the background, a full moon is visible in a dark blue night sky. The overall scene is a night-time photograph of a radio telescope.

Neue Interferometer

Very Long Baseline Interferometry (VLBI)



Schema für Interferometrie

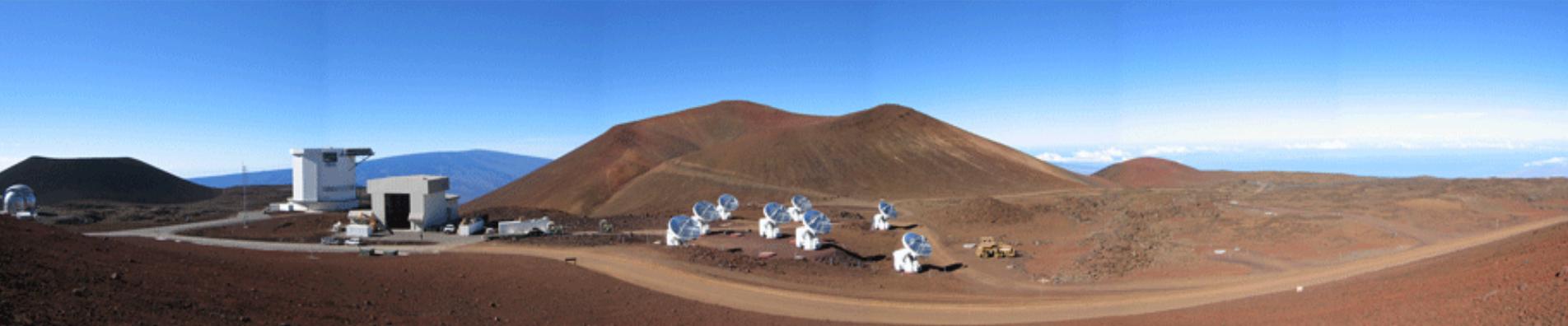
A large radio telescope dish is illuminated from below, creating a warm yellow glow. The dish is supported by a complex metal lattice structure. In the background, a full moon is visible in a dark blue night sky. The overall scene is a night-time photograph of a radio telescope.

Neue MM -Interferometer

The Sub-Millimeter Array (SMA)

Smithsonian Astrophysical Observatory + Academia Sinica
Institute of Astronomy and Astrophysics, Mauna Kea, Hawaii,

8 x 6m telescopes, 180-900 GHz



Summary of existing and future mm/submm arrays



Telescope	altitude (feet)	diam. (m)	No. dishes	A (m ²)	ν_{\max} (GHz)	
BIMA ¹	3,500	6		10	280	250
OVRO ¹	4,000	10		6	470	250
CARMA ¹	7,300	3.5/6/10	23	800	250	
NMA	2,000	10		6	470	250
IRAM PdB	8,000	15		6	1060	250
JCMT-CSO ²	14,000	10/15	2	260	650	
SMA ³	14,000	6		8	230	850
ALMA ⁴	16,400	12		64	7200	850

¹BIMA and OVRO will be combined and moved to a higher site to become CARMA

²First instrument to obtain submm fringes; will probably be used with the SMA

³Currently has 5 antennas, first fringes obtained in September 1999 at 230 GHz

⁴Currently under development, planned for full operation by 2010

Zukunft: LMSA (Japan)



Large Millimeter Submillimeter Array
(LMSA)

50 Antennen mit je 10m Durchmesser

Radio-Interferometer der Zukunft



- *Apertursynthese*-Techniken werden seit mehr als 40 Jahren genutzt (1974 Nobelpreis für Martin Ryle) – was kommt als Nächstes?
- Warum planen wir neue Teleskope
 - Weil wir können (neue Technologien), weil wir nicht nicht können (oder wir fallen in der Wissenschaft zurück), um mit der nächsten Generation optischer/IR-Teleskope Schritt zu halten, um neue Entdeckungen zu machen (neuer Parameter-Raum), um das ferne Universum zu untersuchen (Kosmologie, wie immer ...)
- Wie werden sie aussehen?
- Was sind die “challenges”?

Interferenz mehrerer Teleskope

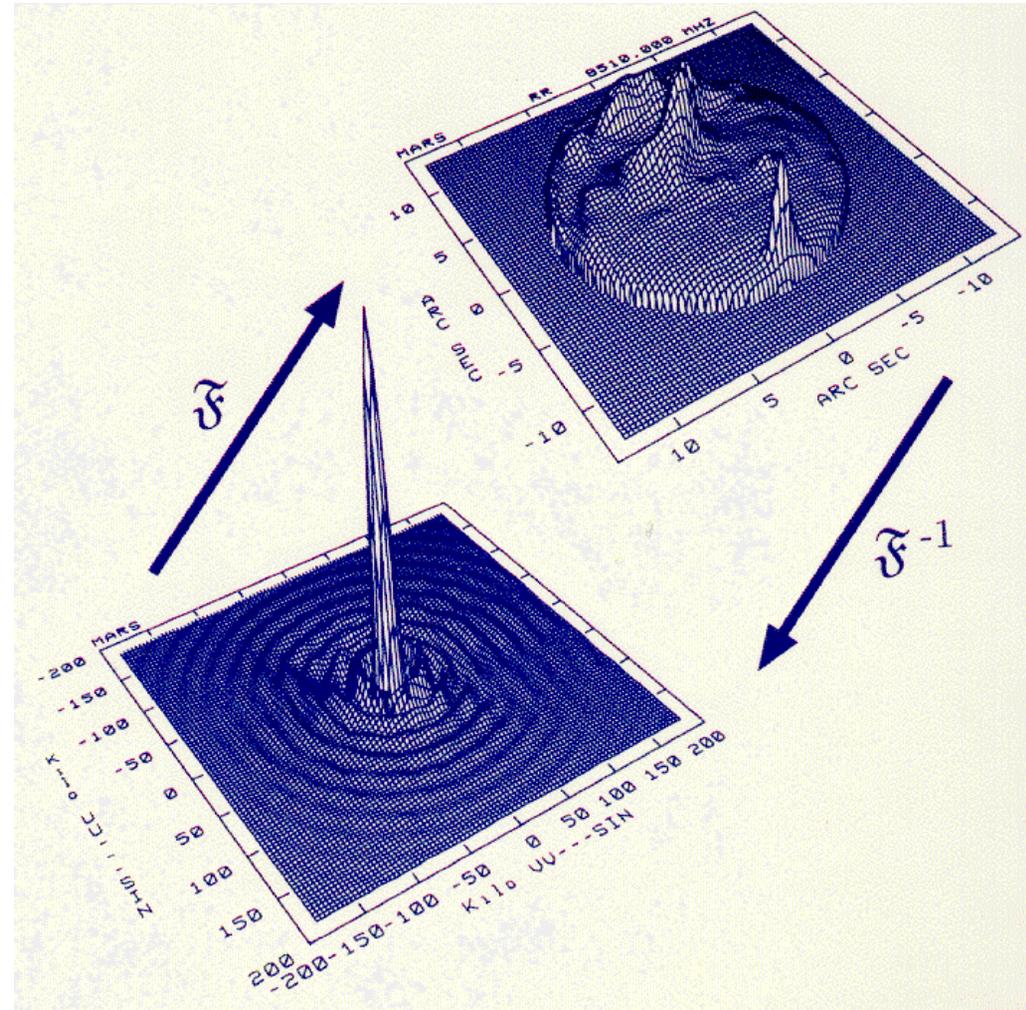


- **Zusätzliche Probleme:**
 - Möglichst optimale uv-Ebene
 - mm-Interferometrie: Wasser in der Atmosphäre
 - Datenverbindung/-transport
 - Mehrere beams
 - Riesenteleskope: Antennendesign?
 - RFI

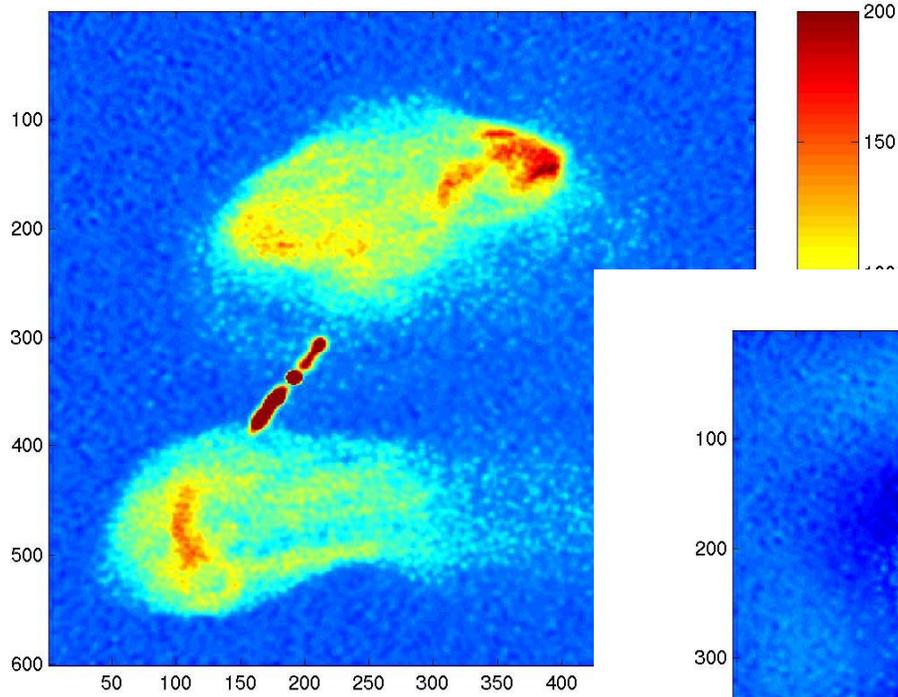
Optimale Nutzung der uv-Ebene



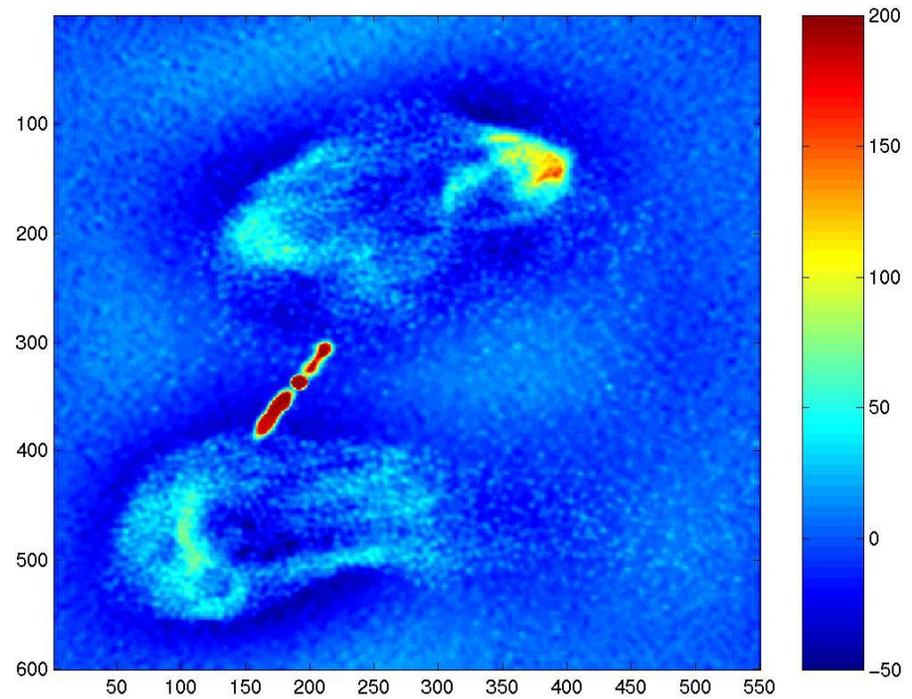
- Test dreier verschiedener Konfigurationen:
 - UV Bedeckung optimiert in einem kreisförmigen Netzwerk
 - Zufällige gaussförmige Verteilung
 - Systematische gaußförmige Verteilung



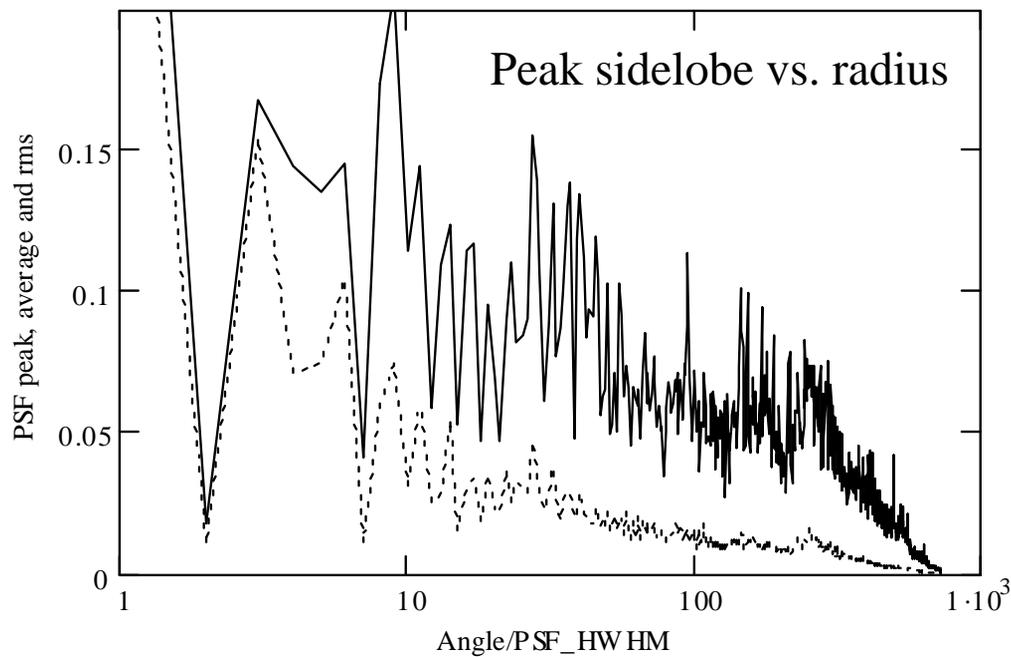
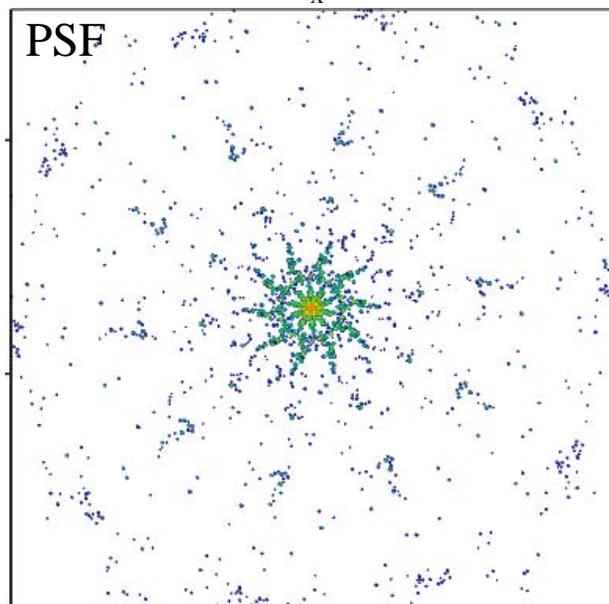
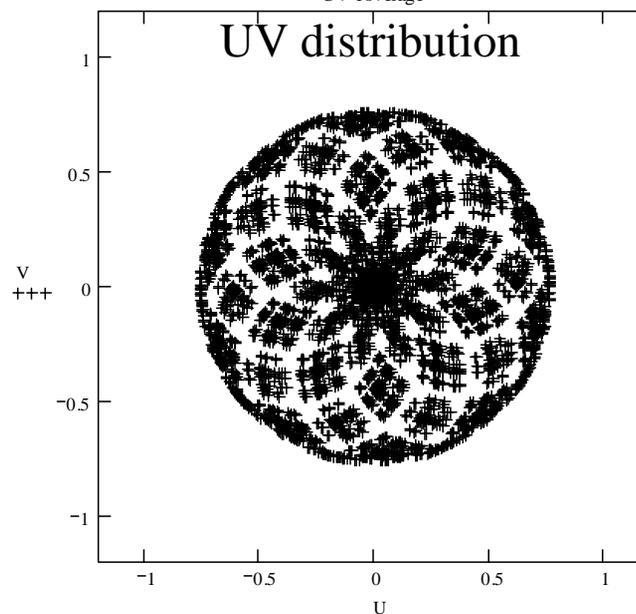
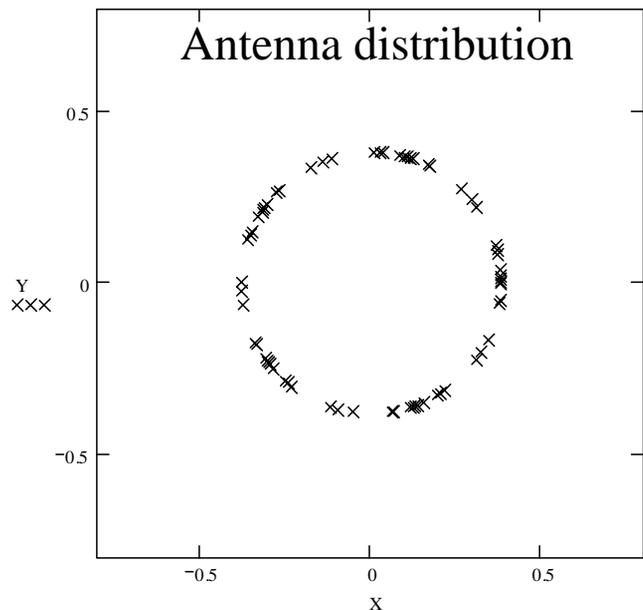
Fehlende kurze Basislinien



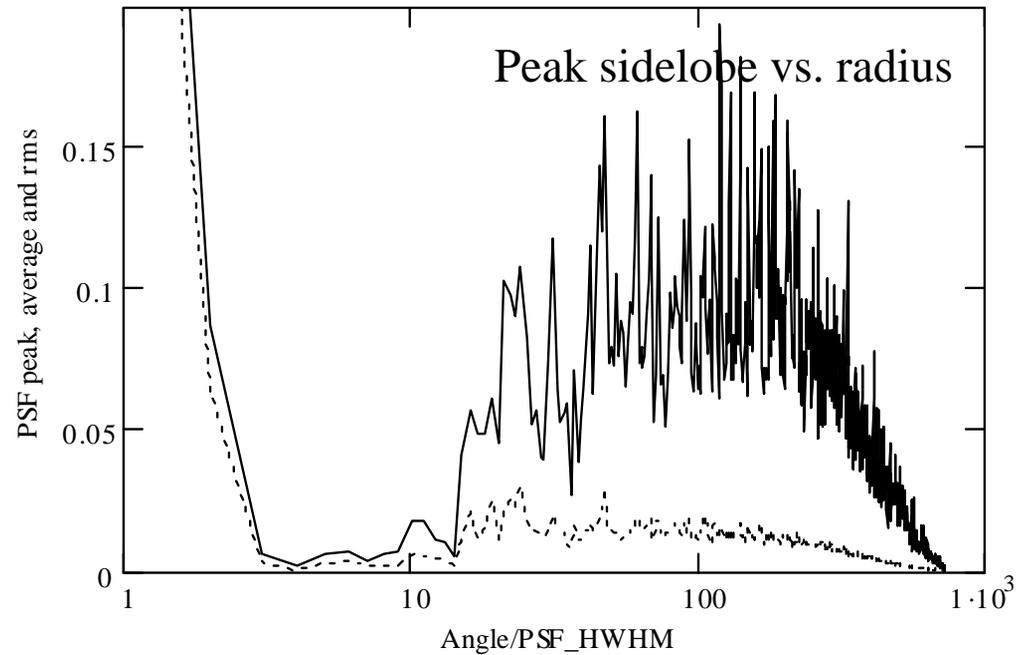
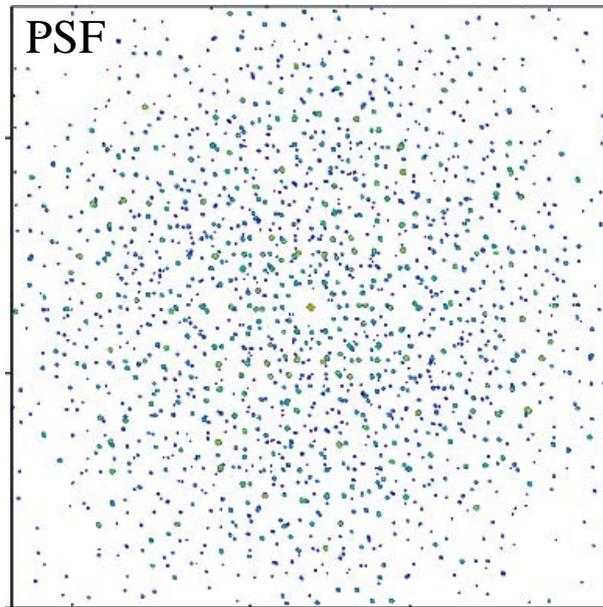
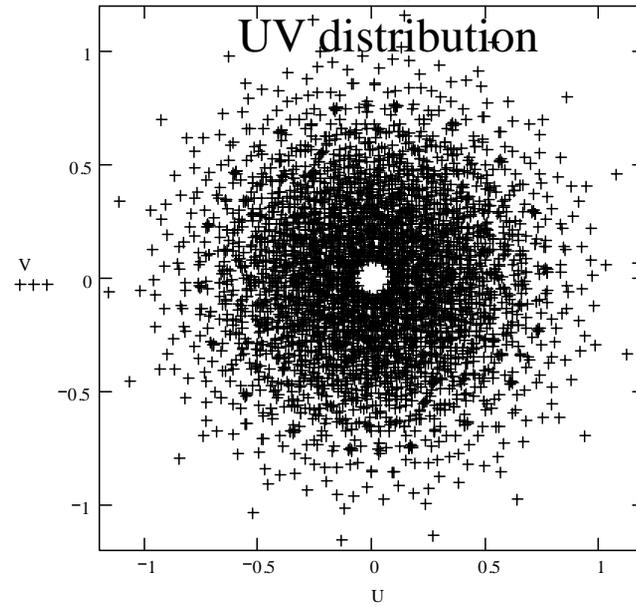
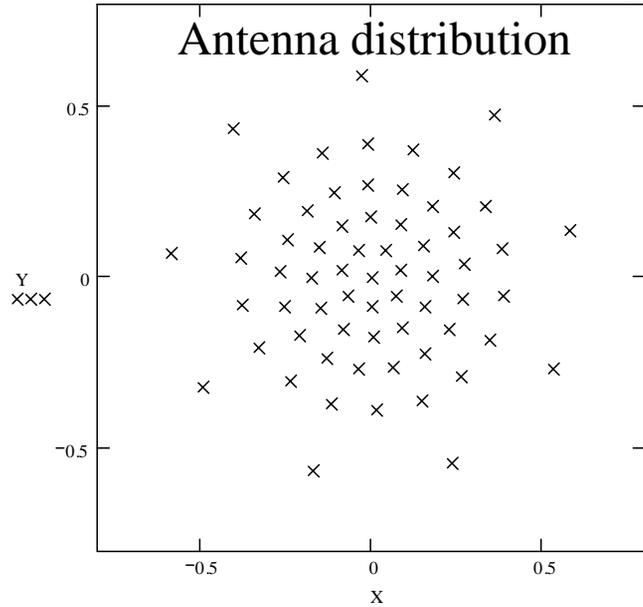
Keine kurzen
Basislinien



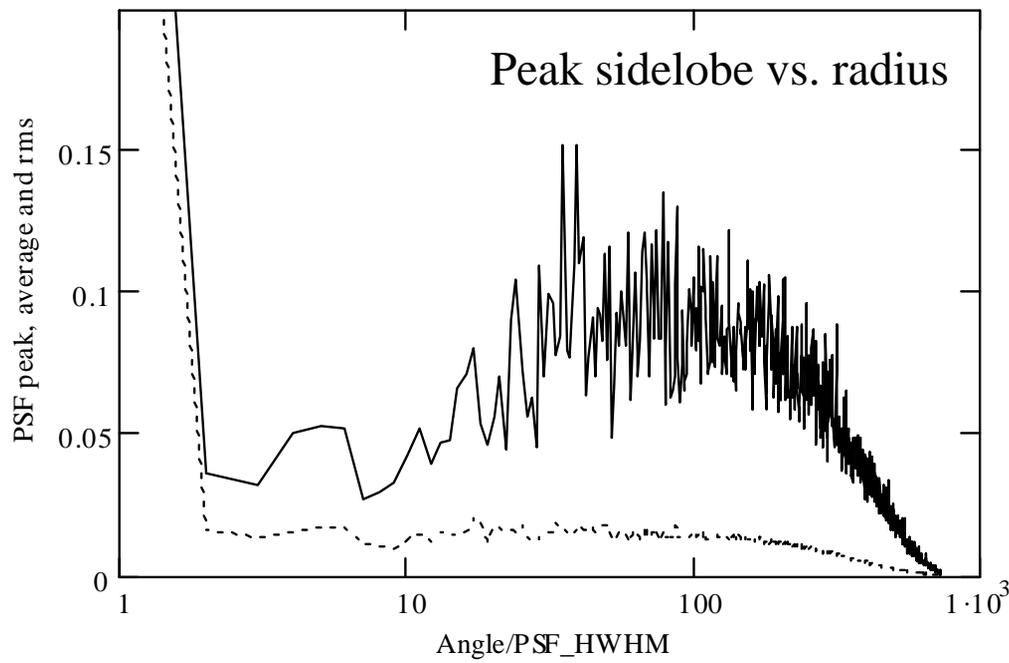
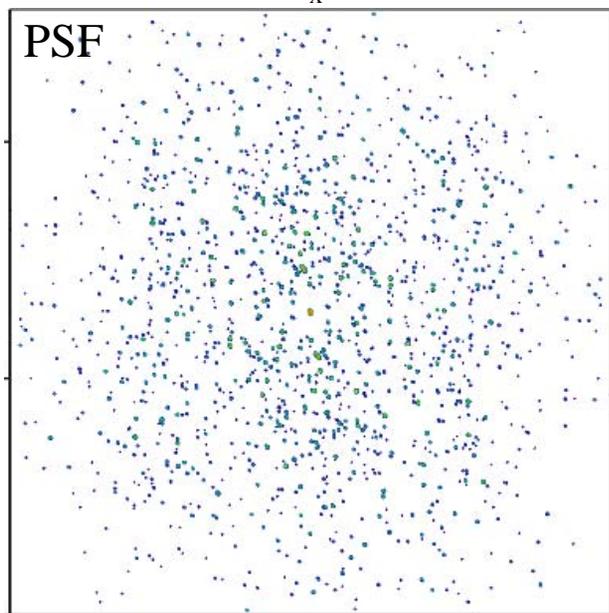
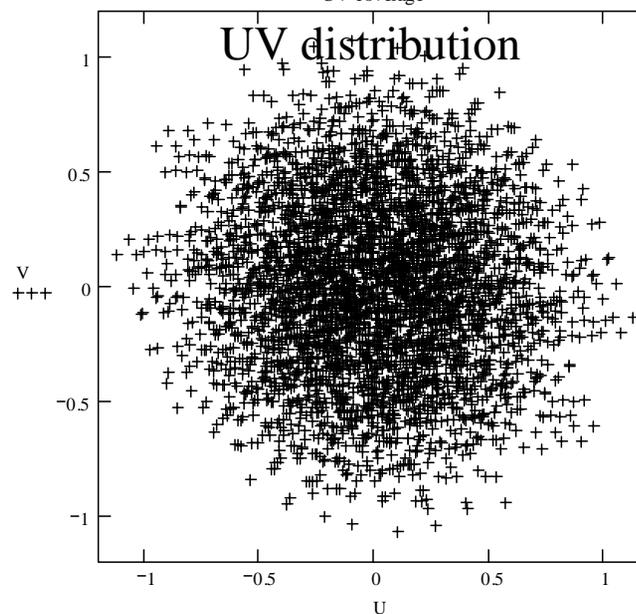
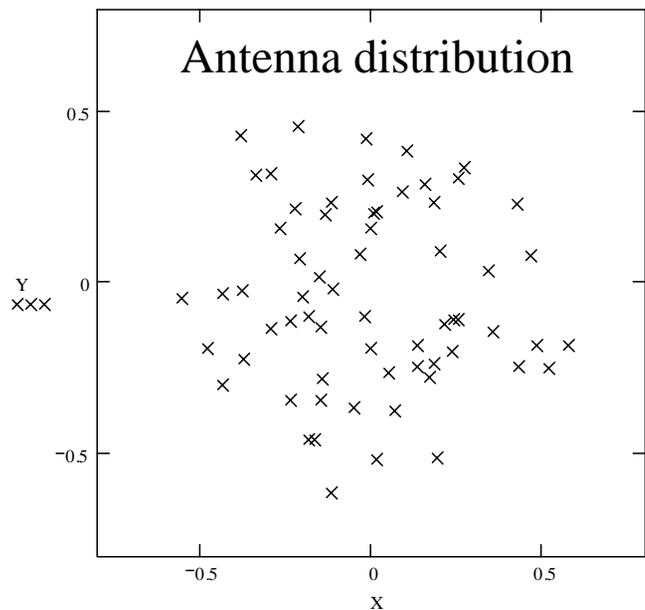
Kreisförmig



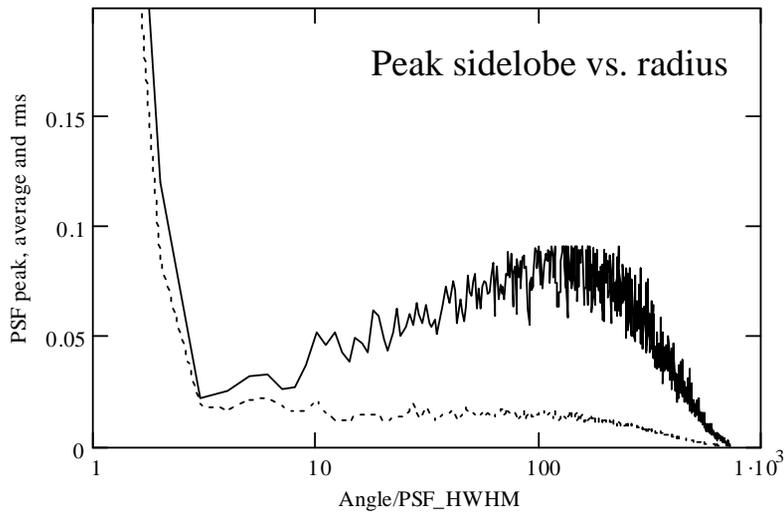
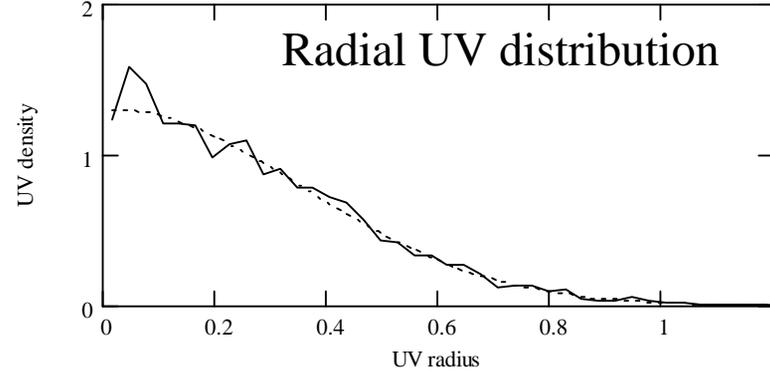
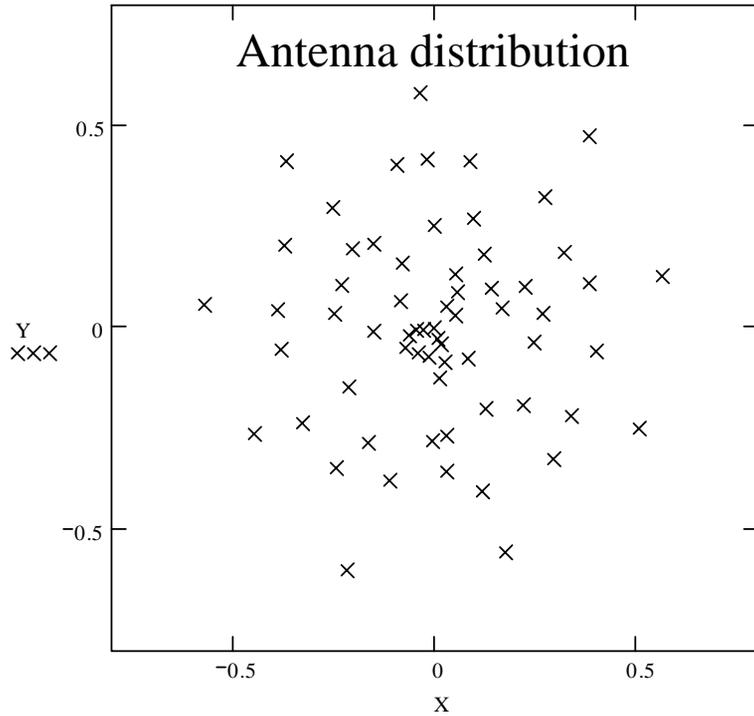
Systematisch



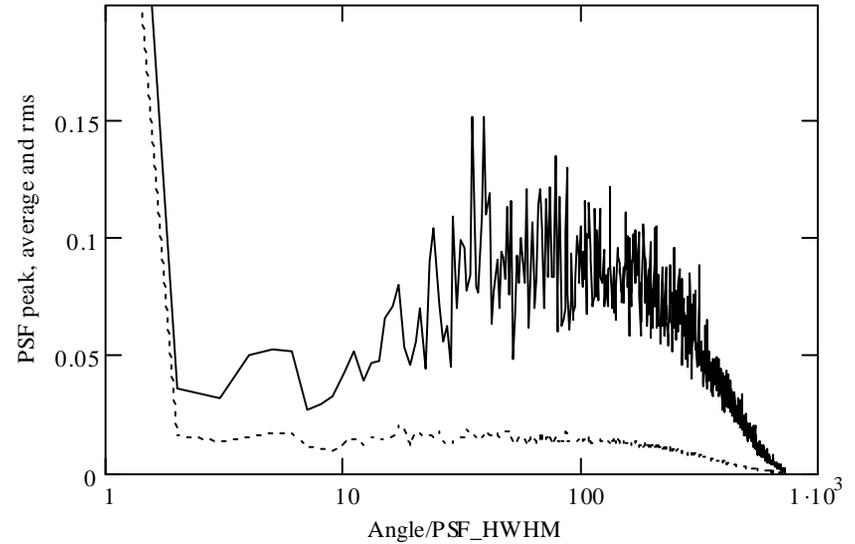
Pseudo Zufällig



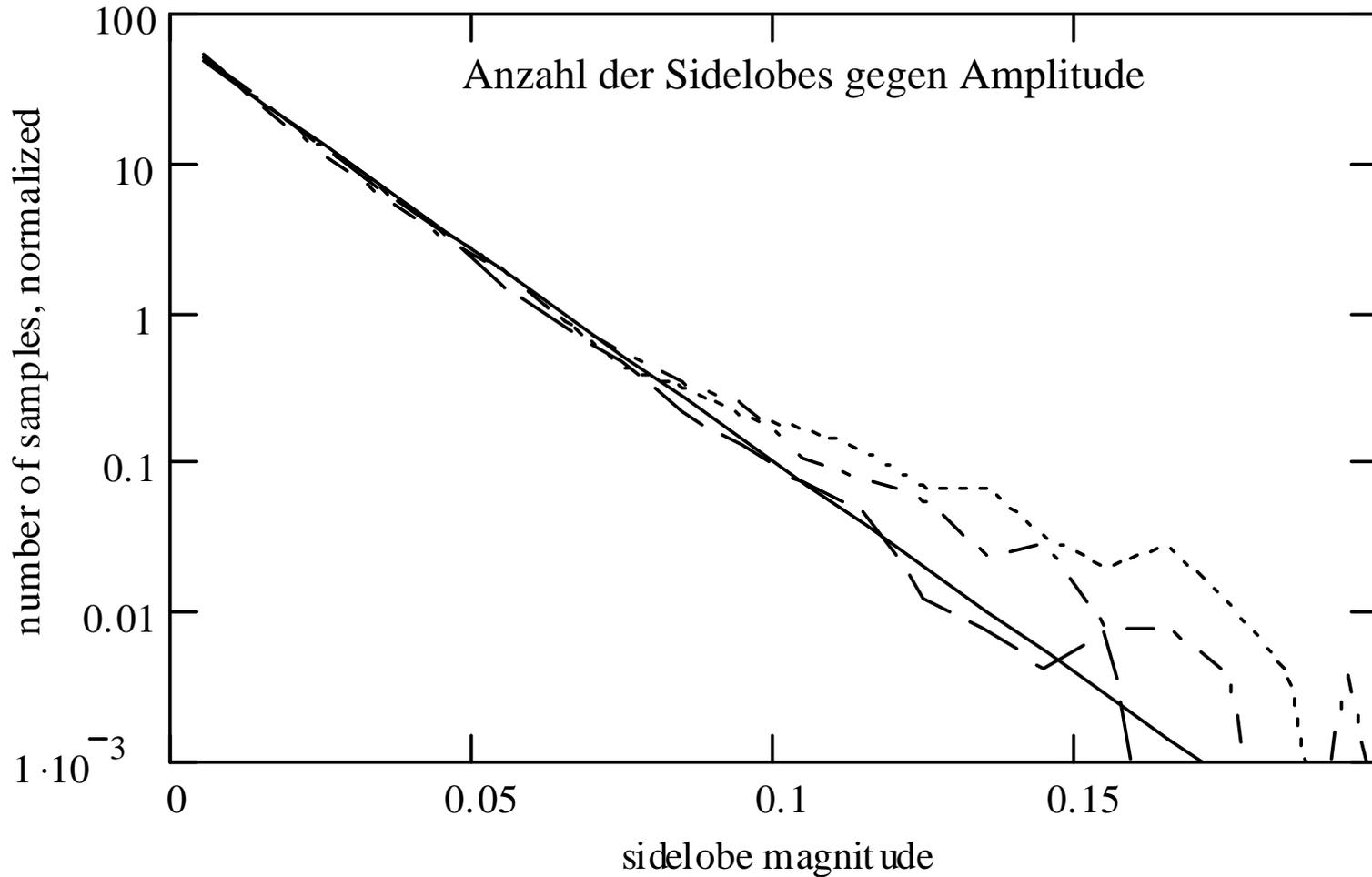
Zusätzliche kurze Basislinien



Ohne zusätzliche kurze Basislinien



Verteilung der Sidelobes



Gepunktet: kreisförmige Anordnung, Gestrichelt: pseudo-zufällig und systematisch (Punkt-Strich)
Durchgezogene Linie: theoretische Verteilung für pseudo-zufällige Verteilungen

Evolution großer Antennen-Netzwerke

EVN

Parabol Antennen durch die Post/Internet verbunden



Evolution großer Antennennetzwerke



Parabol Antennen verbunden durch optische Faserkabel

Evolution großer Antennennetzwerke

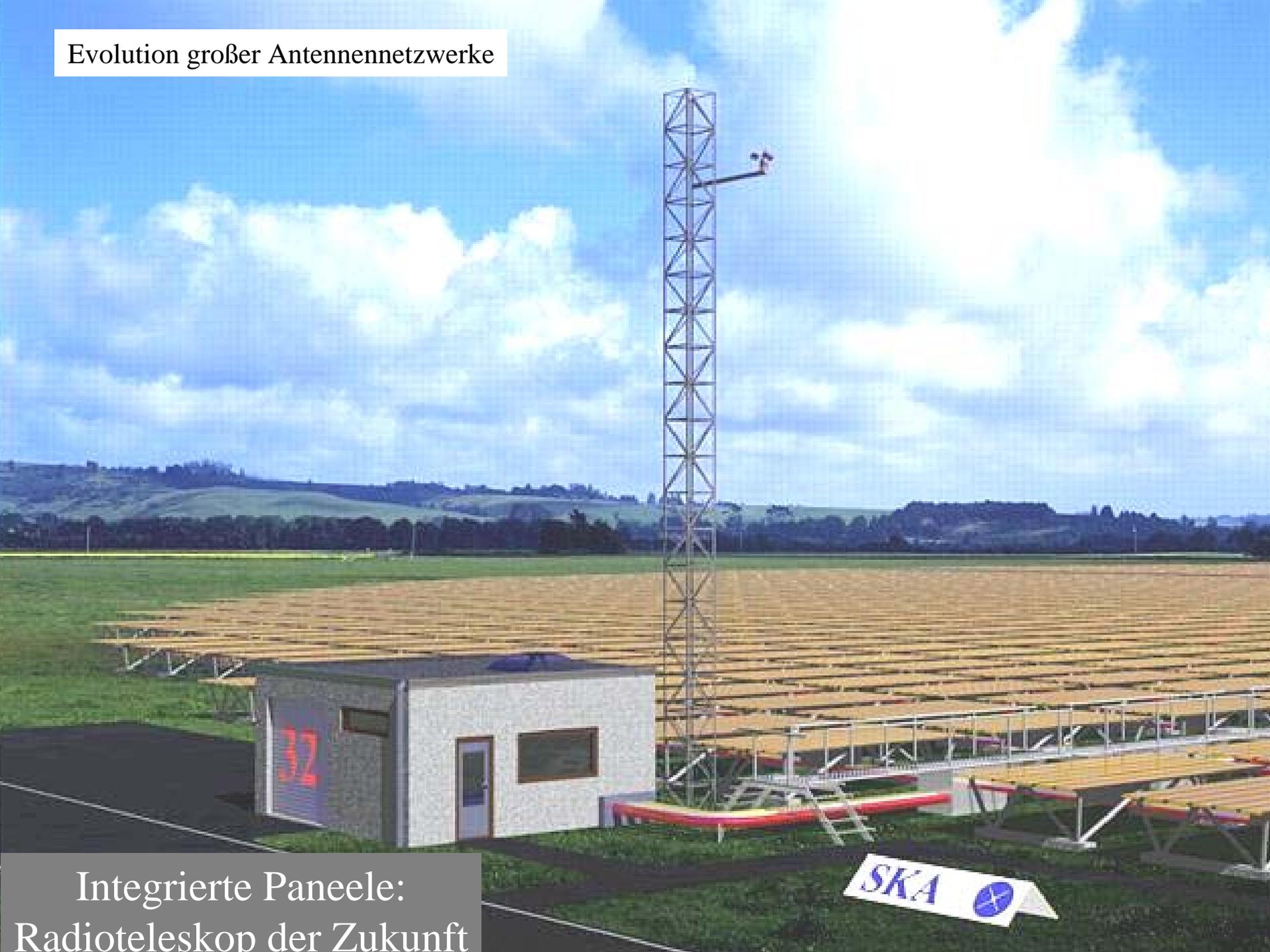


10^4 all-sky RF sensors
spread over 400 km
connected by optical fibers

Ersetzen mechanische Signalverarbeitung
durch komplett elektronische Signalverarbeitung

LOFAR

Evolution großer Antennennetzwerke



Integrierte Paneele:
Radioteleskop der Zukunft



Radiointerferometer: Heute, Gestern und Morgen



	Technology (date)	Computing (T-OPS)	Storage (Peta-Bytes)	Data transport (G-bits/s)
European VLBI Network	1995	50 (custom processor)	1,0 (custom tapes)	0,3 (mail)
Distributed Tera- scale Facility	2001	12	0,45	40
e-MERLIN	2002	100 (custom processor)	1,0 (0,5 T- Byte/day)	320
LOFAR	2003	40 (distributed+cluste r)	0,6 (+distributed)	4000 (custom network)

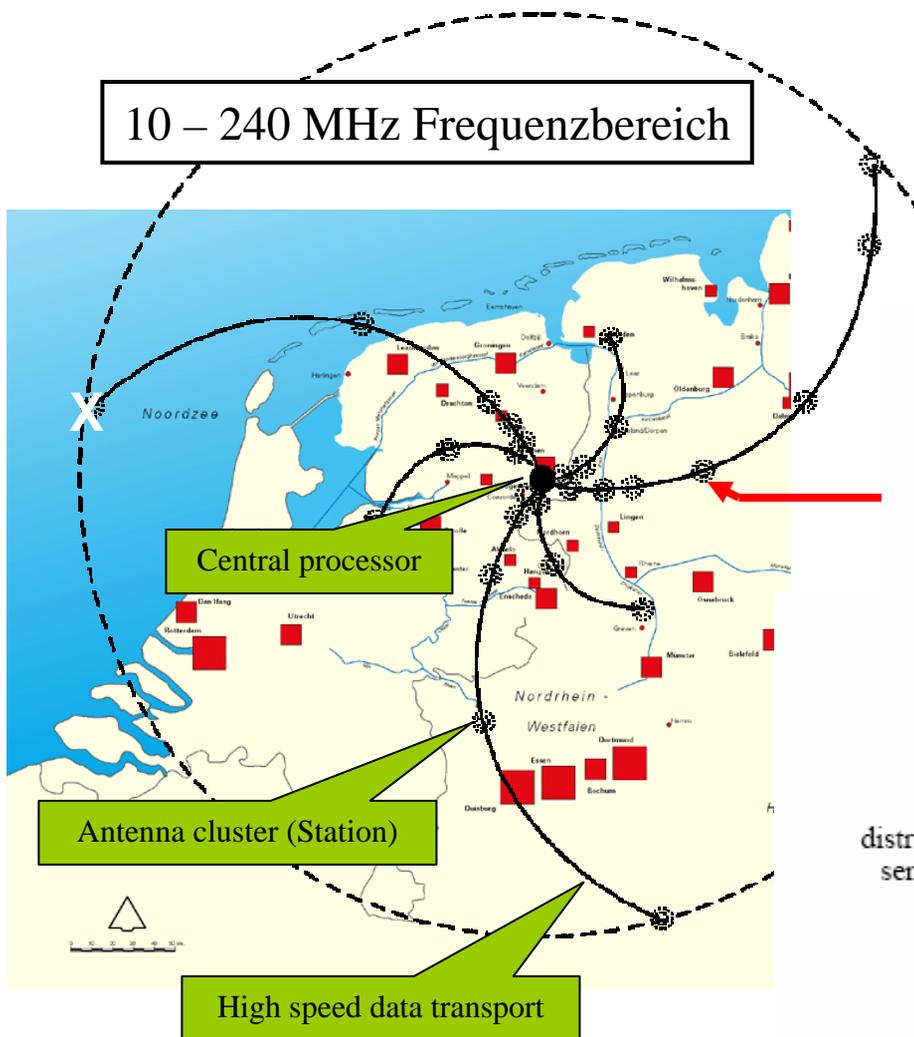
A large radio telescope dish is illuminated from below, creating a warm yellow glow. The dish is supported by a complex metal lattice structure. In the background, a full moon is visible against a dark blue night sky. The overall scene is a night-time photograph of a radio telescope.

NEWS ZU
- LOFAR

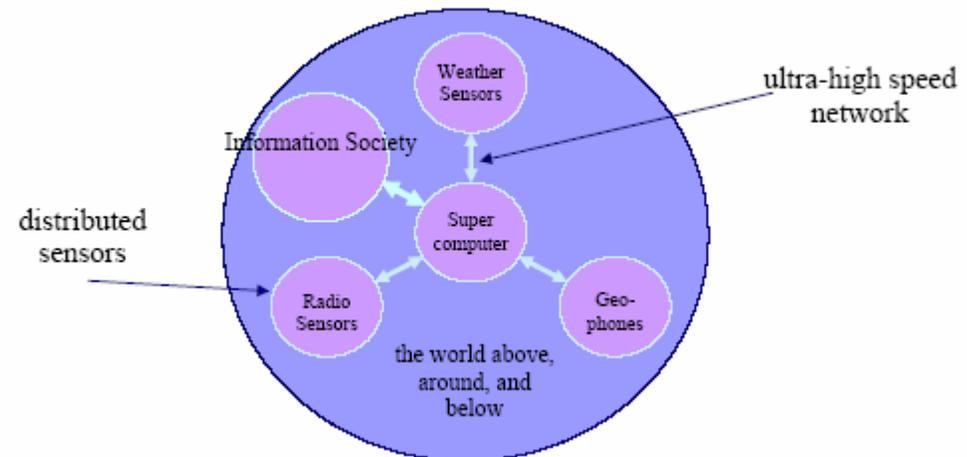
LOFAR



Wide area sensor network: WASN



- radio dipoles for radio astronomy creating a virtual telescope, studying: cosmology, space weather, ionosphere, high-energy particles
- particle detectors: measuring cosmic ray induced particle showers
- geophones for monitoring tectonic activity and ground water levels through micro-earthquakes
- weather stations for real-time weather and storm evolution monitoring
- microphones for infrasound applications
- water level sensors for enabling precision agriculture.

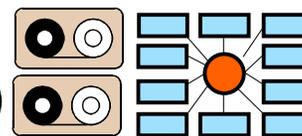
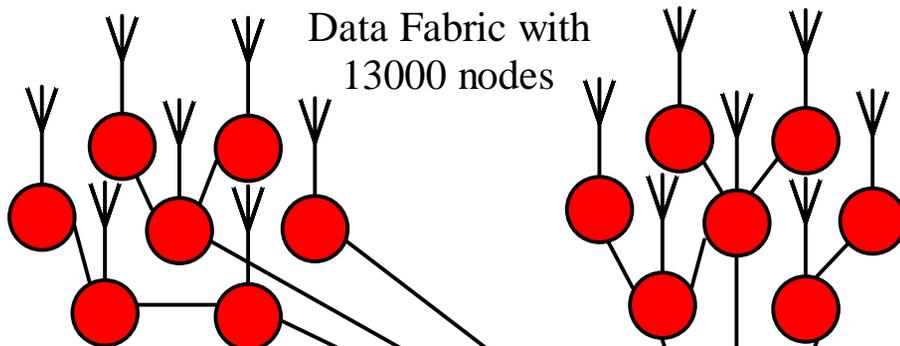


LOFAR



Letzte Meile: wireless
Data rate: 5-10 Gbps
Noch nicht möglich!!

Data Fabric with
13000 nodes

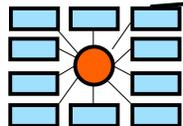


Data Processing Plant

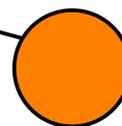
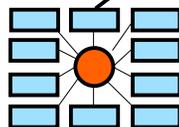
Terabytes!

**Data
GRID**

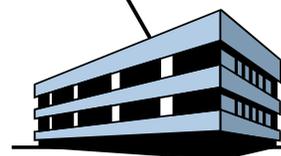
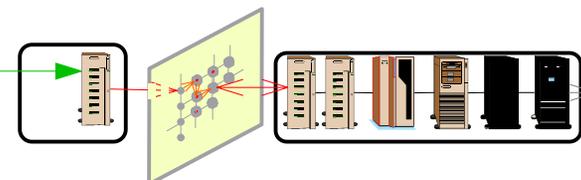
-Cooperative usage of distributed
computer resources
-virtualization



User post processing

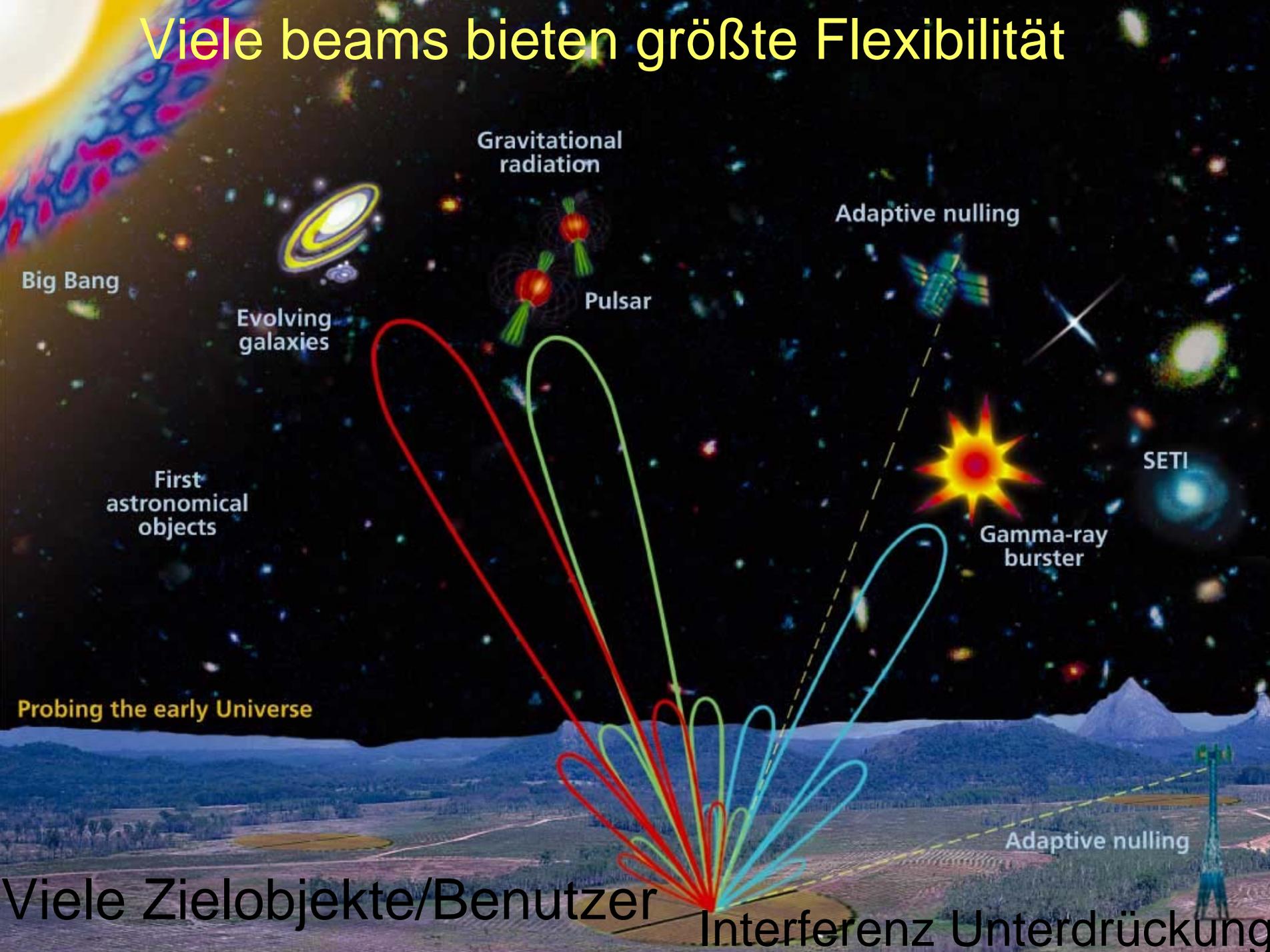


on-line hybrid data processing cluster



Control Center(s)

Viele beams bieten größte Flexibilität



Big Bang

Evolving galaxies

Gravitational radiation

Pulsar

Adaptive nulling

SETI

Gamma-ray burster

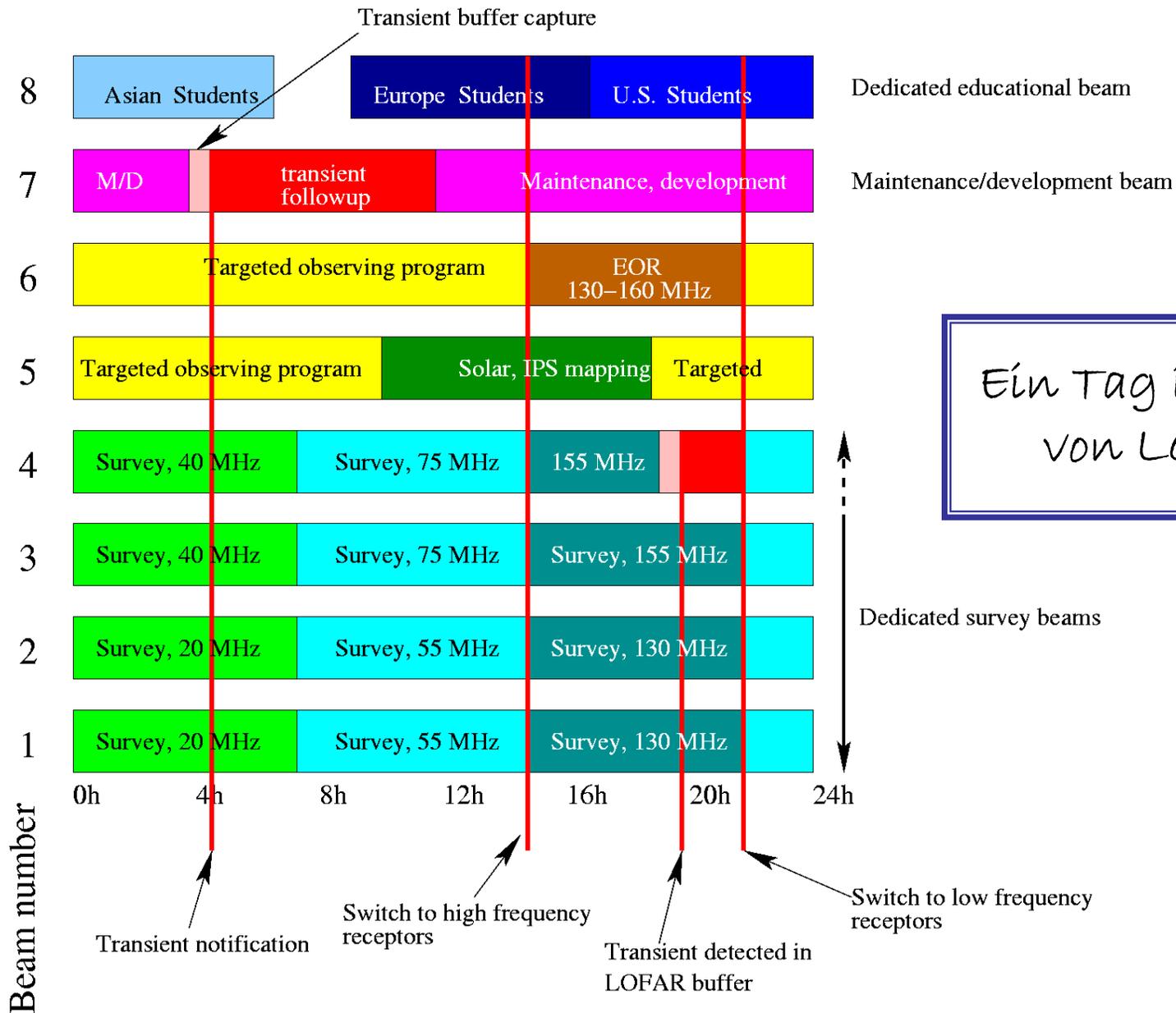
First astronomical objects

Probing the early Universe

Adaptive nulling

Viele Zielobjekte/Benutzer

Interferenz Unterdrückung



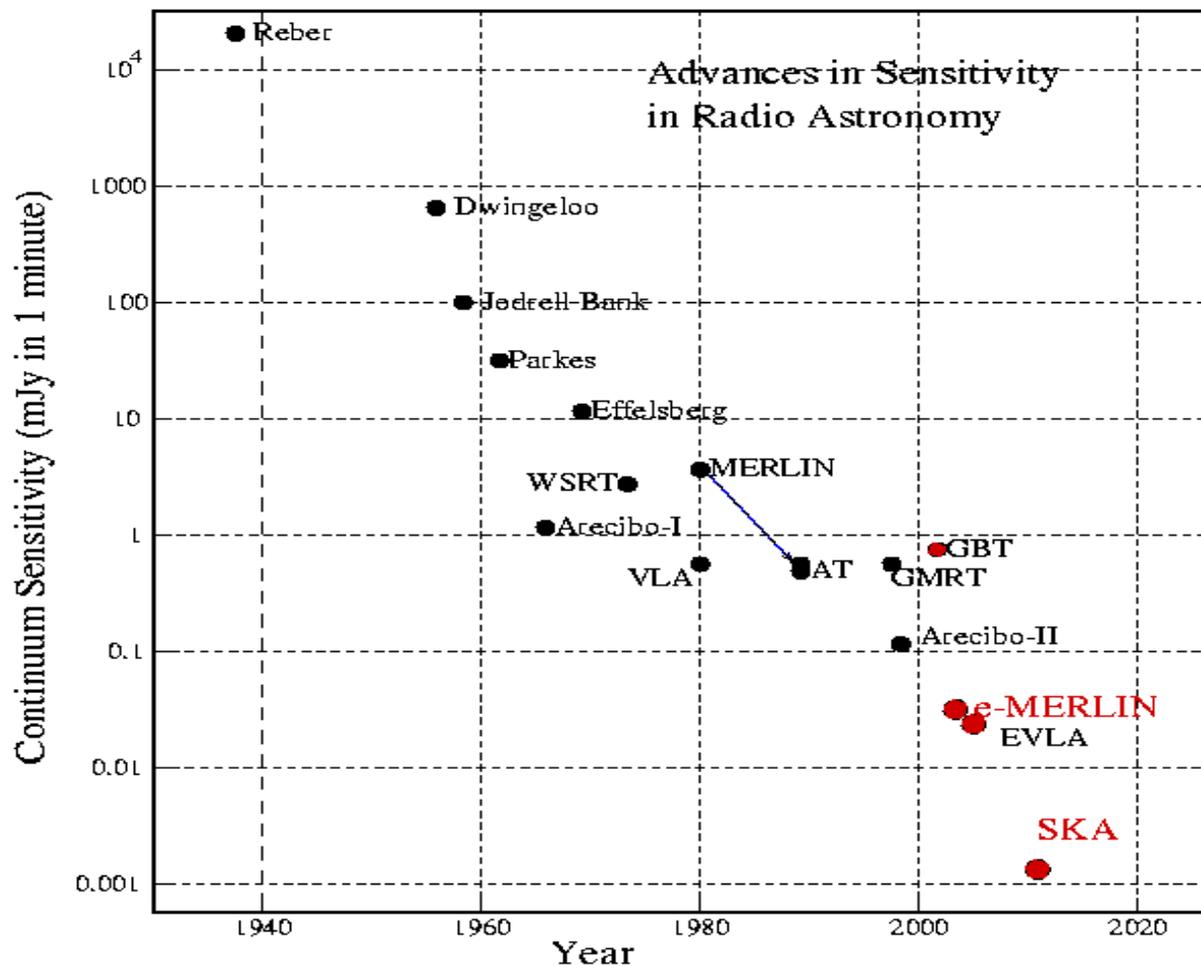
Ein Tag im Leben
von LOFAR



NEWS ZU
- SKA



Empfindlichkeit der Radioteleskope...

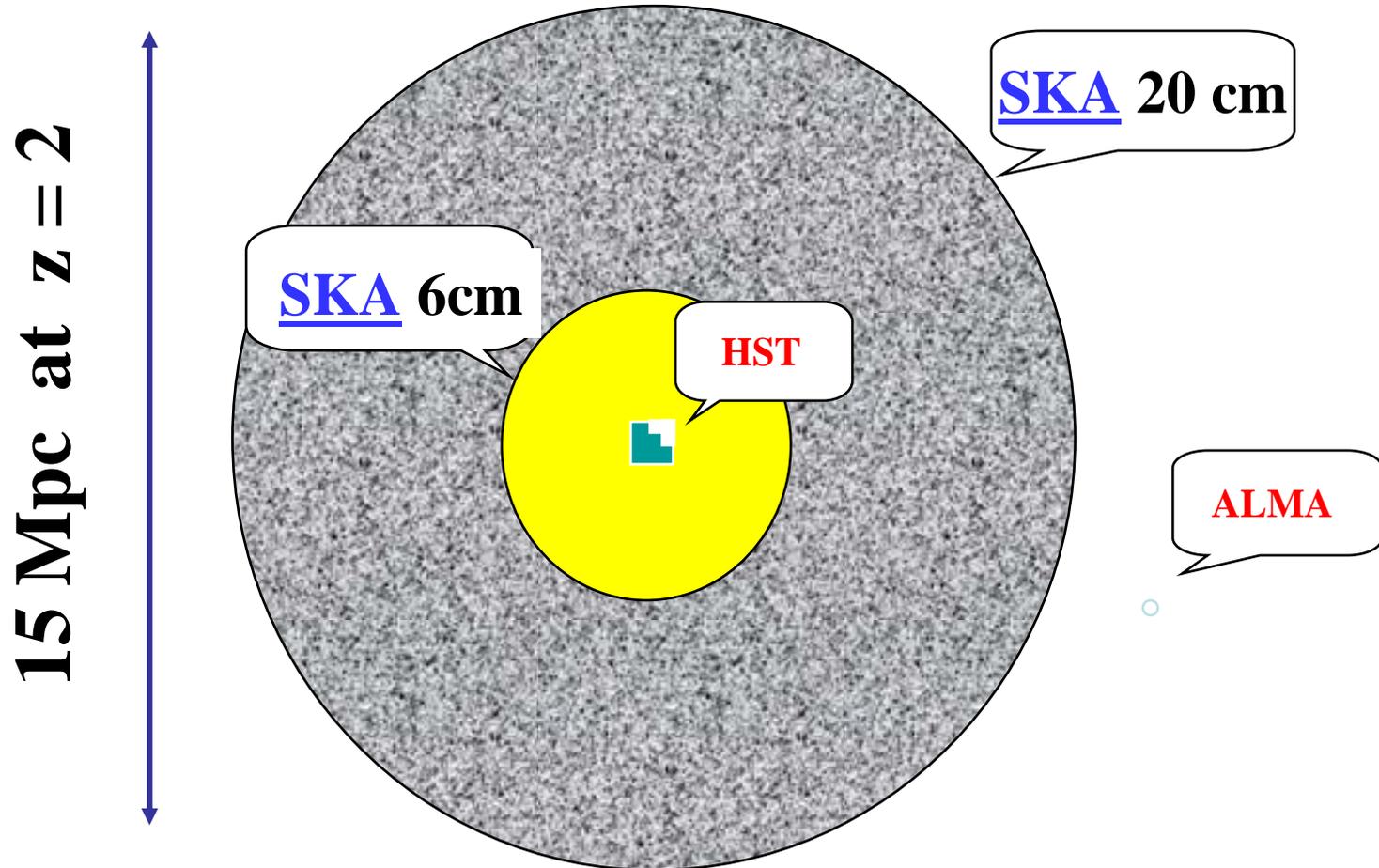


VLA und Arecibo bedeuteten einen solchen Fortschritt in der **collecting area**: für Jahrzehnte nicht geändert !

Technologischer Schritt notwendig für die Zukunft!

SKA's 1° Gesichtsfeld

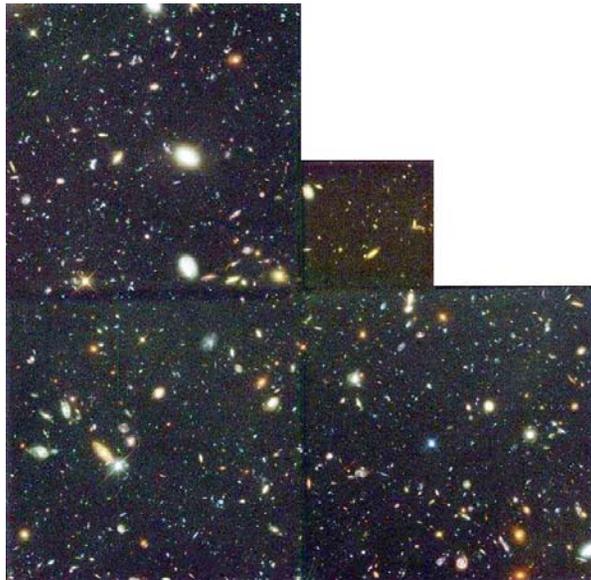
für Durchmusterungen und "vorübergehende" Phänomene
in 10^6 Galaxien!



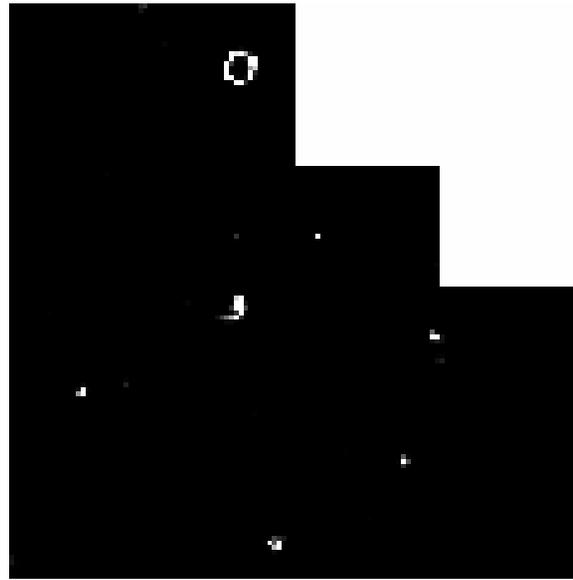
Eines der besten Argumente



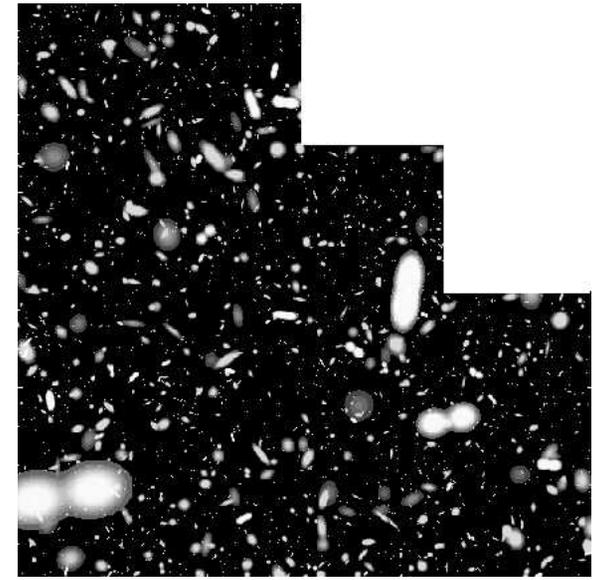
HST



VLA



SKA

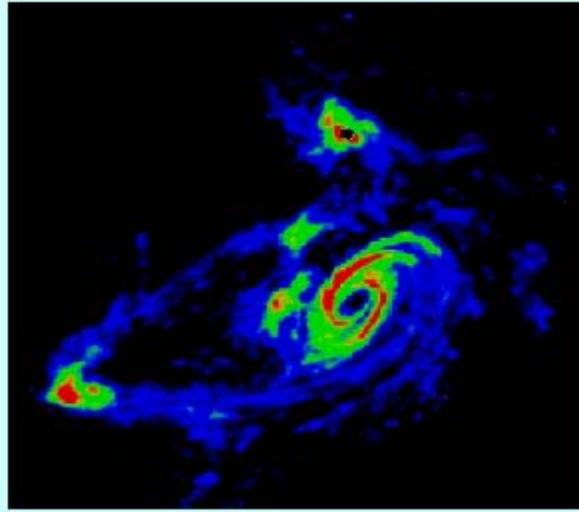


Optische Teleskope haben in den letzten Jahren die "normale" Galaxienpopulation bis $z \sim 3$ untersucht

... und noch eins ...



...to image and survey HI

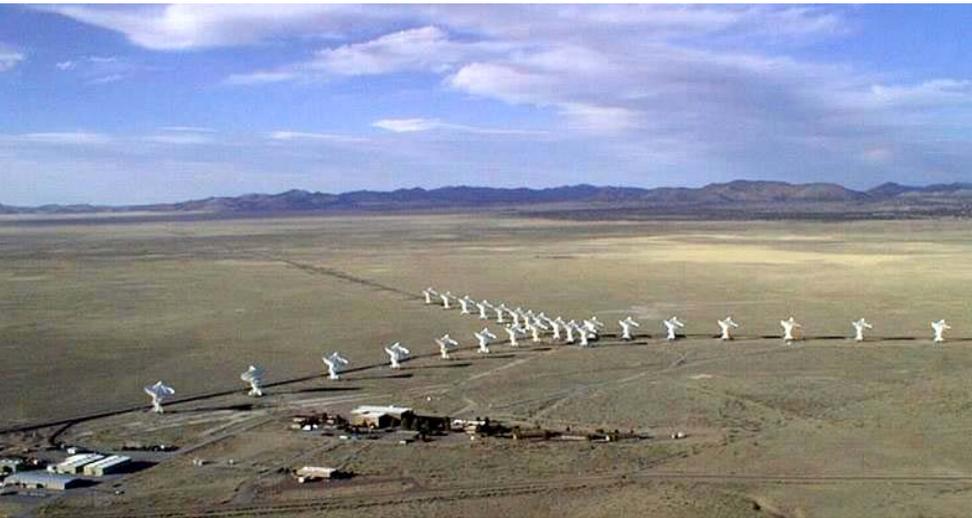


however
HI is very weak!

The universe in starlight ... and in 21cm hydrogen line

- Weitere Argumente: große Kollektorfläche (Empfindlichkeit), lange Basislinien für hohe Auflösung (Konfusion bei geringen Flußdichten), für gute uv-Bedeckung: viele Stationen

SKA: Kollektorfläche



100 x VLA

10 x Arecibo



In Kürze

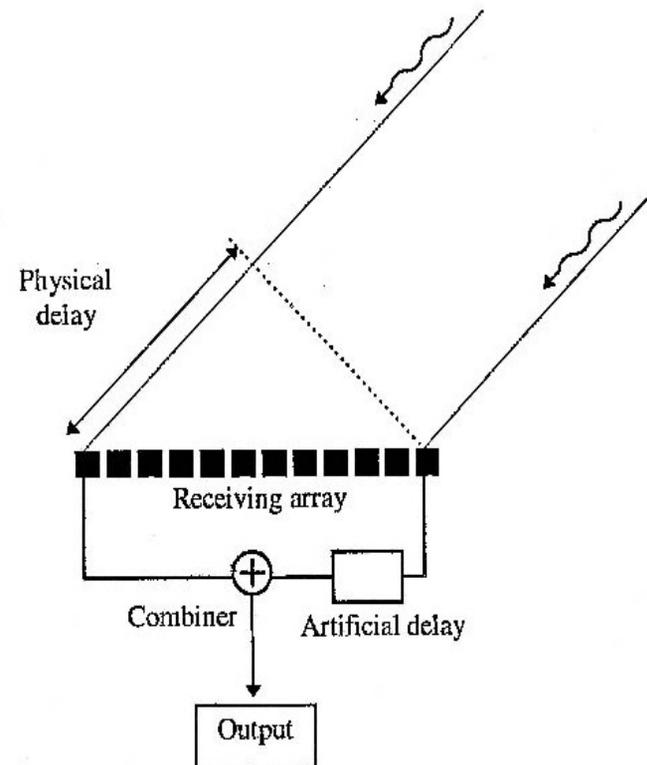
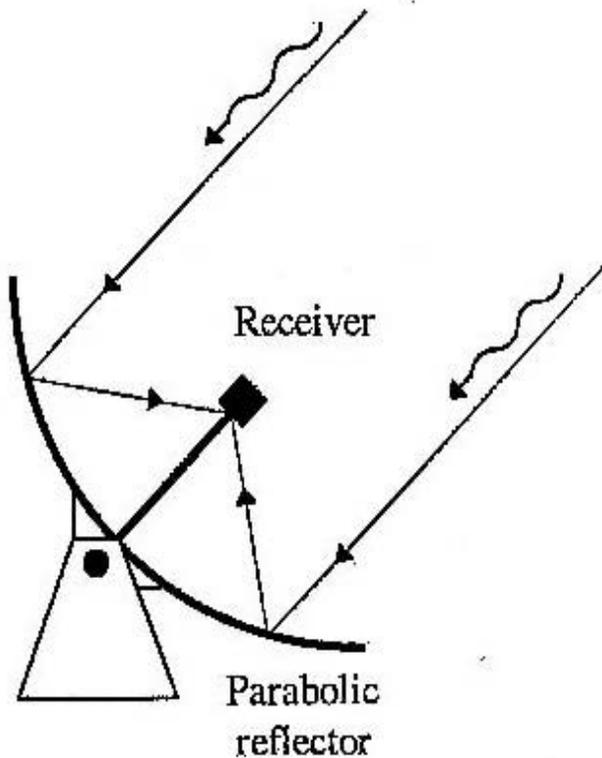


- Next generation radio telescope
- • Frequency range 0.15 - 25 GHz
- • Collecting area of 10^6 m²
- • >50 x sensitivity & $>10^5$ survey
- speed of today's best instruments
- • A 'discovery' instrument

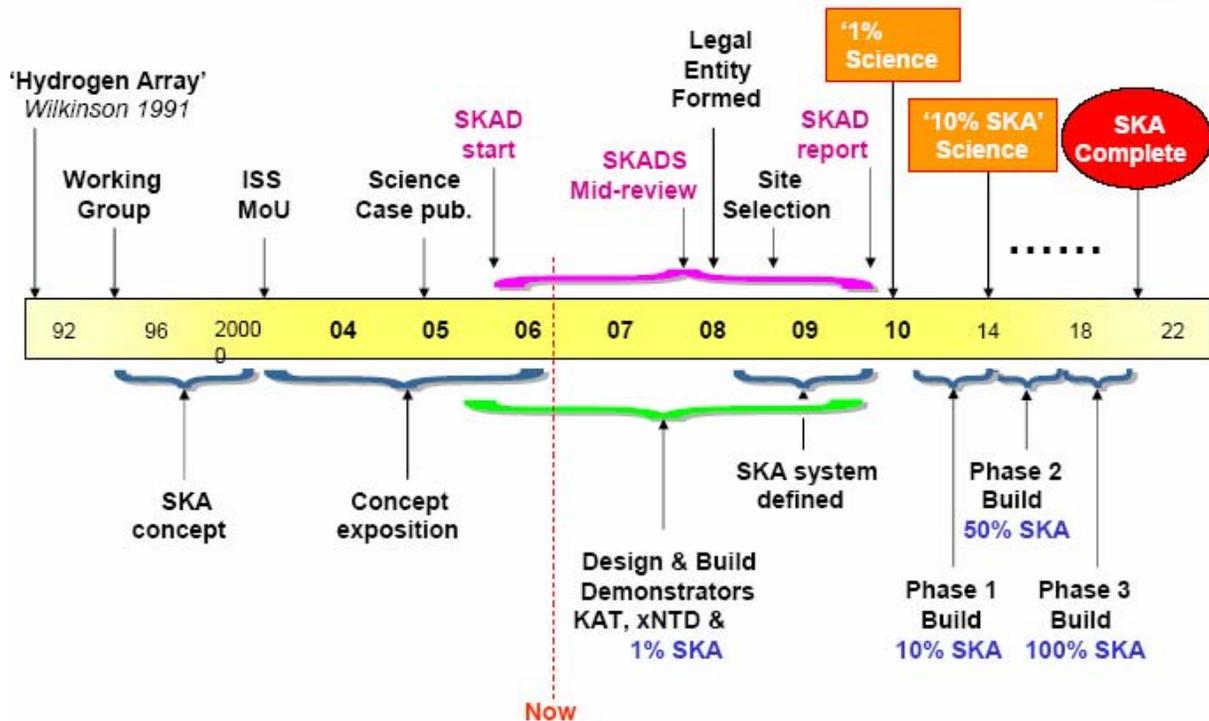
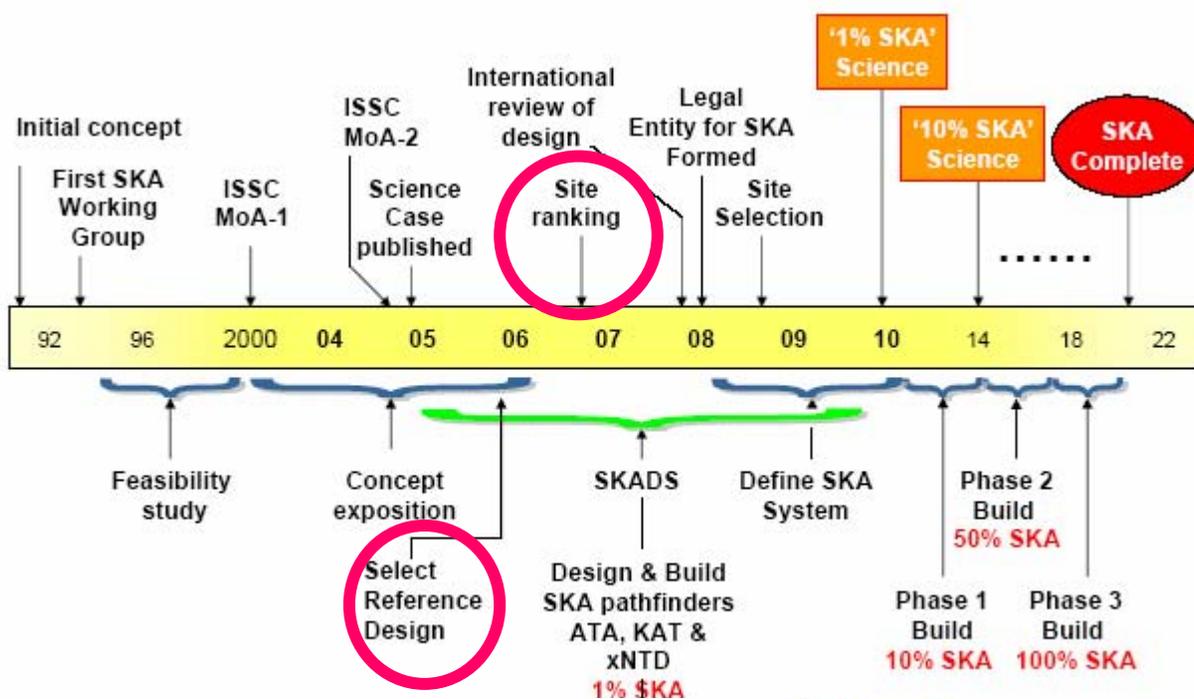
Phased array - das Konzept



Ersetzt mechanisches Pointing & beam forming auf elektronischem Wege



The revolution in radio telescopes – wide FOV

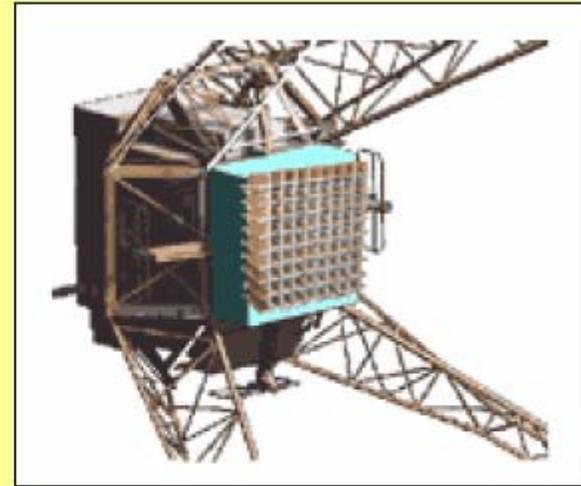


SKA: Phased Arrays



Aperture Arrays

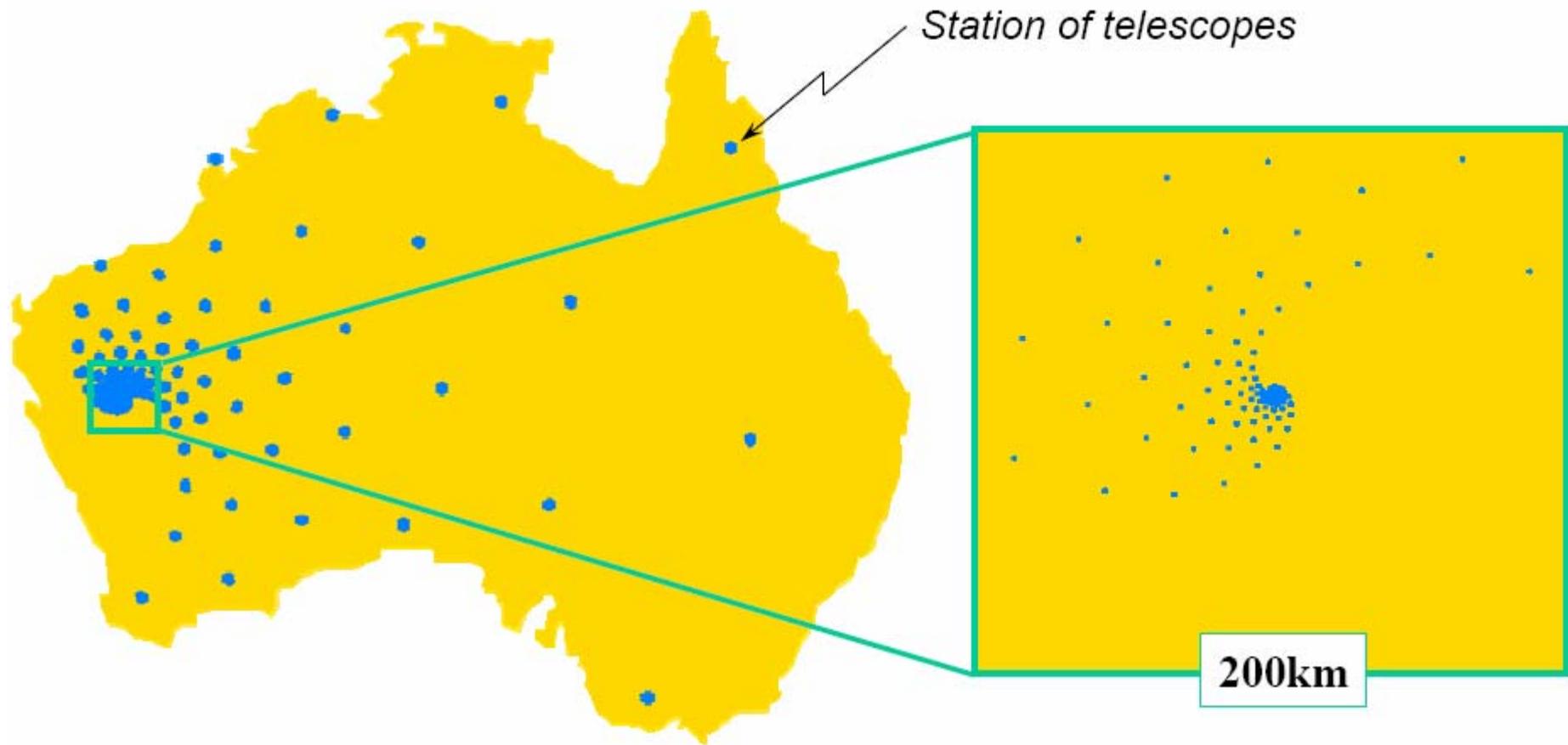
“electronic fish-eye lens”



Focal Plane Arrays

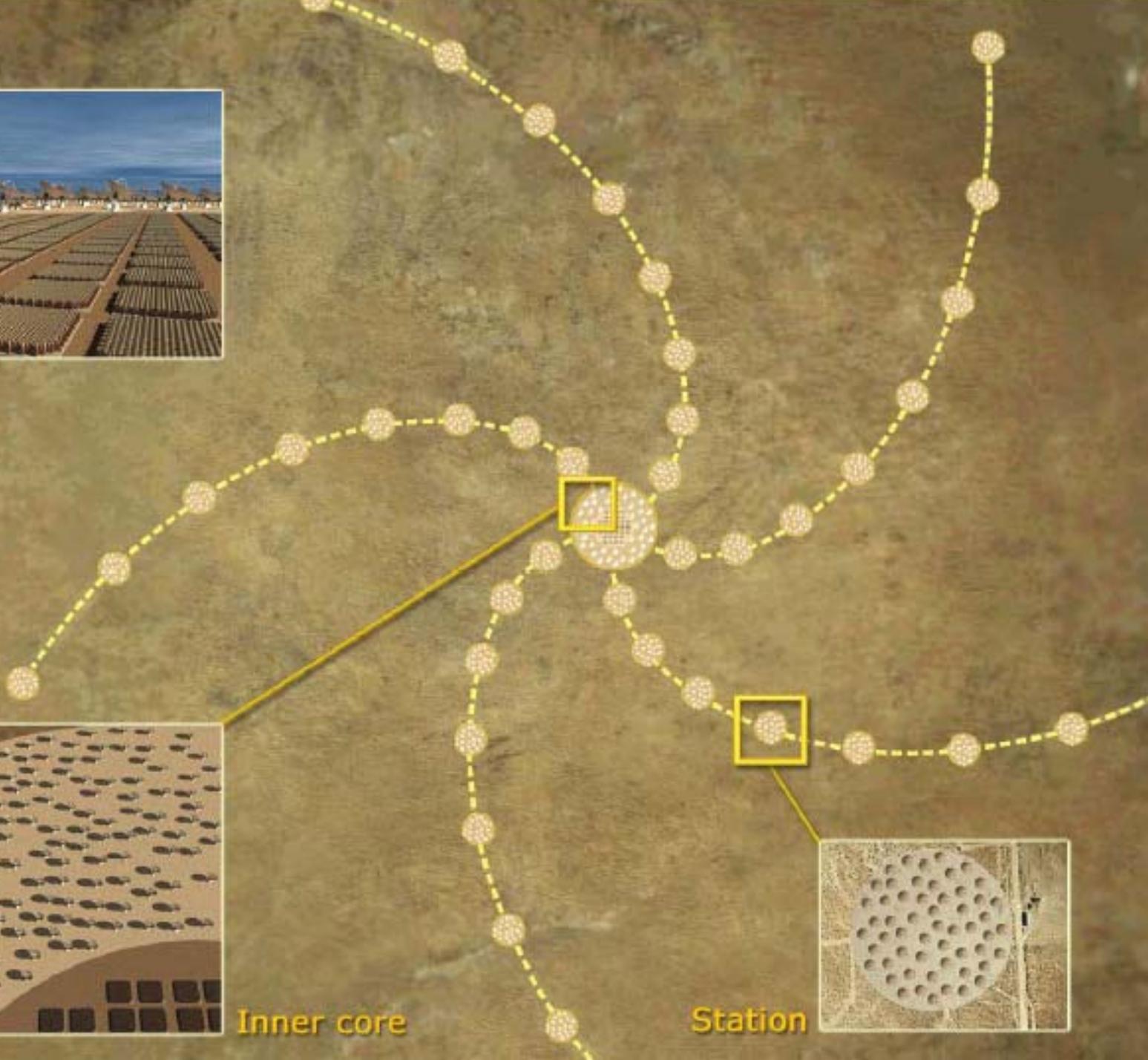
“radio cameras”

SKA: eine mögliche Konfiguration



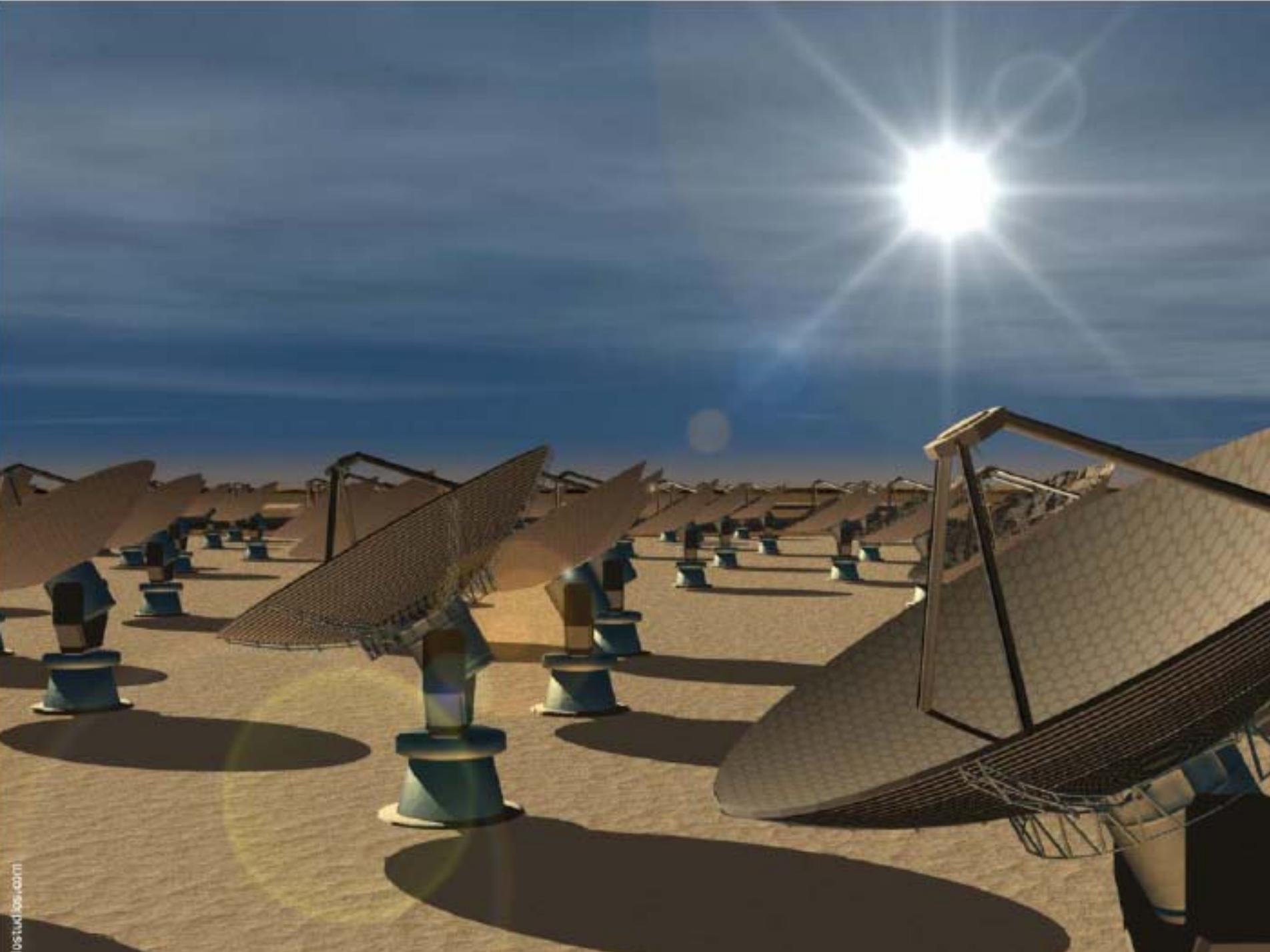


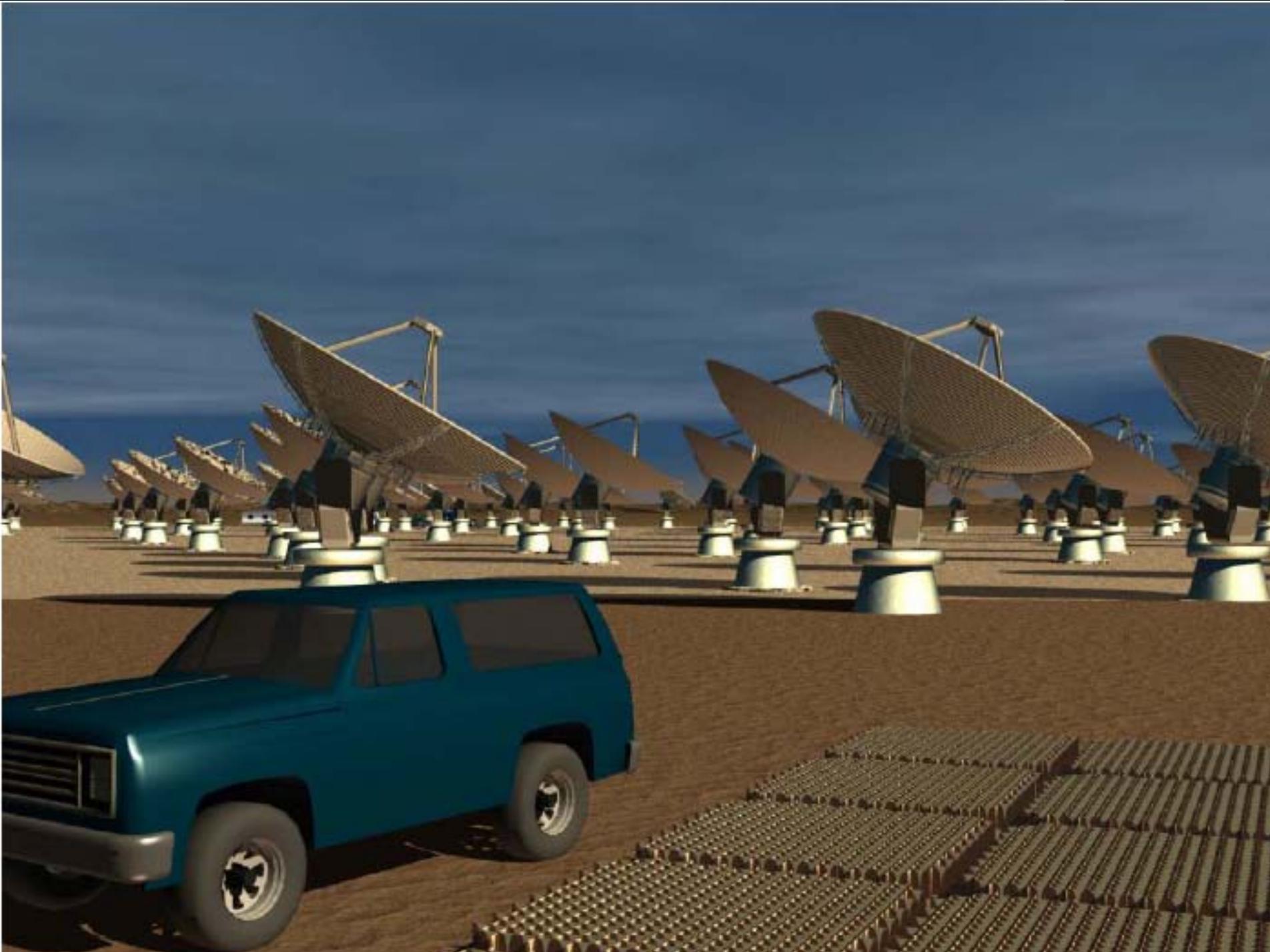
Inner core



Station







SKA Design Studies - SKADS



EC SKADS

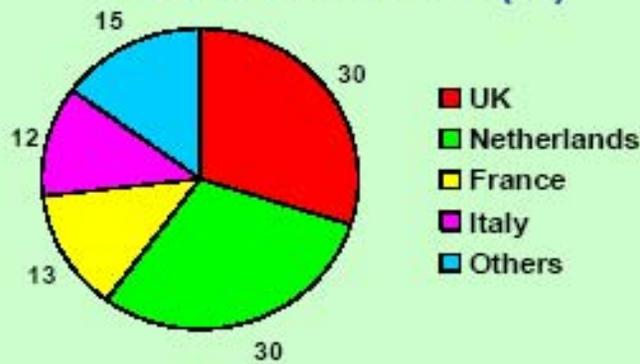


- FP6-based initiative
- Consortium: 29 institutions
- Total funding: €38m
- EC funding : €10.44m
- Start: end 2005
- Complete: mid 2009

UK SKADS

- 6 institutions
- Total project £7.6m
- EC contribution £2m (€3m)
- Key science and tech. projects
- Strong 'technical triangle'
Manchester, Oxford, Cambridge

Share of EC funds (%)



UK is a
key participant
of EC-SKADS

SKADS



2 teams building similar systems:

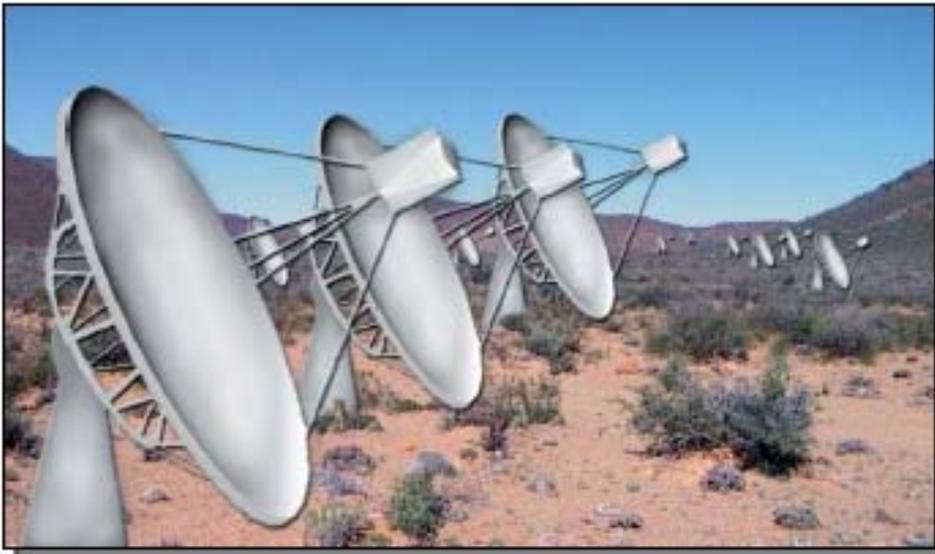
- Australia **xNTD**
- South Africa **KAT**
- Natural partners UK SKADS team
- Test bed for **2-PAD** technology
- Systems are funded:
\$50M for KAT / \$30M for xNTD

KAT/xNTD Aims

- **Science delivery**
- Technology demonstration
Hardware & software
- Test possible SKA site
- Attract the full SKA

Description

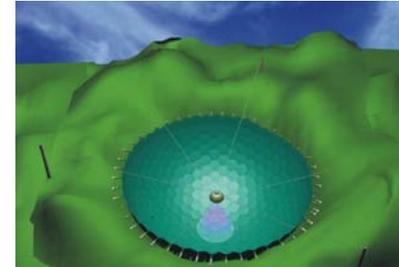
- 20 x 15m Dishes
- 0.7 – 1.75 GHz
- Fitted with phased FPAs
- FOV 50 deg²
- Baselines <10Km
- **Completion 2009**



SKA Antennen Konzepte



US ATA



**China
KARST**



**Australia
Luneburg
Lenses**



**Canada
Large
reflector**



**Dutch
phased array**



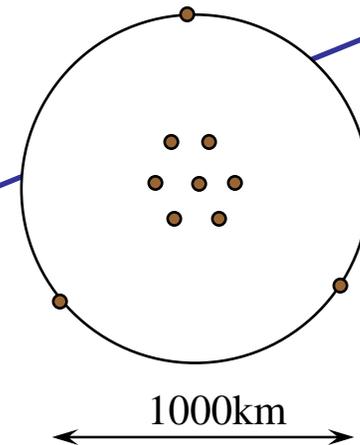
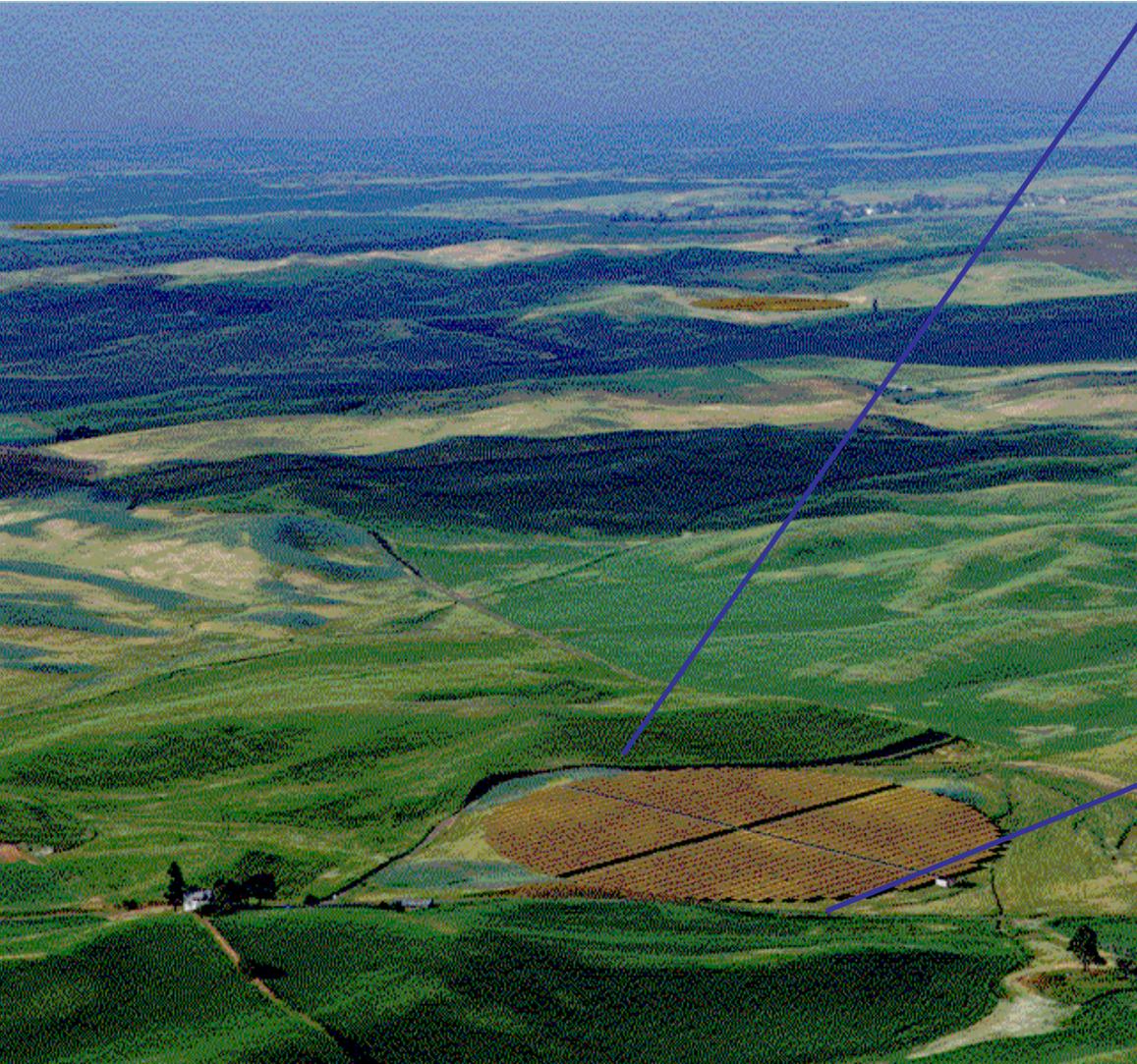
**Australia
cylindrical
paraboloid**

Parabolic Reflector Array

(SETI Institute, USA)

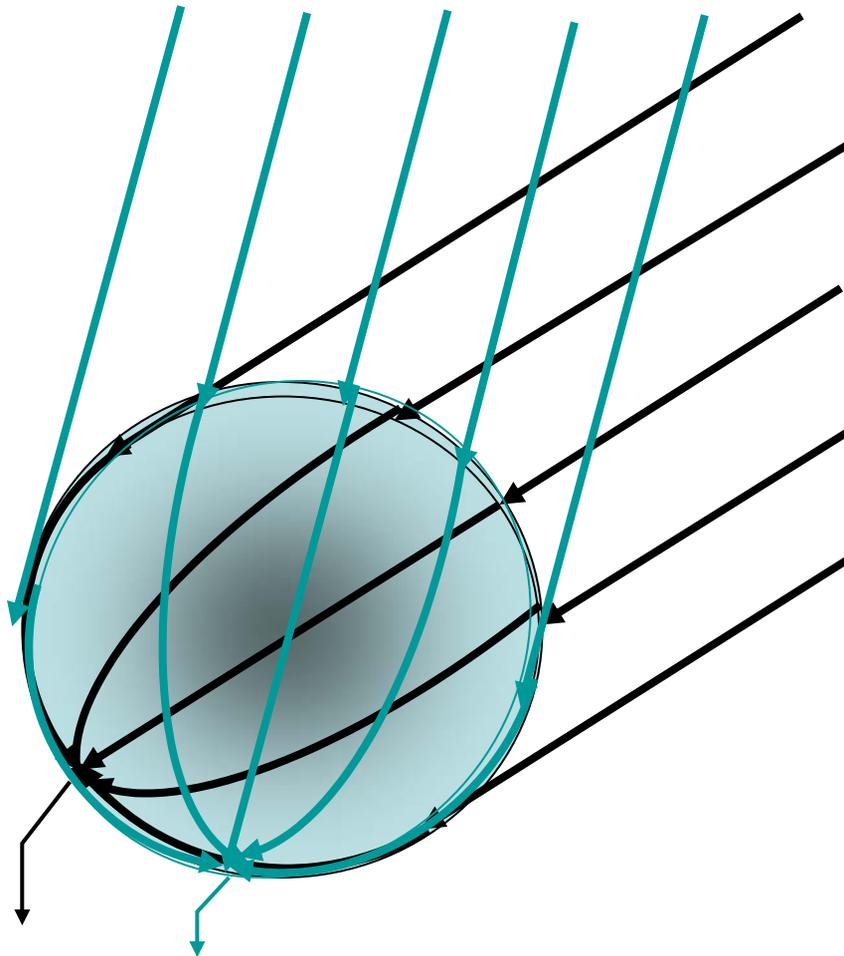


Phased array (Netherlands)



(Courtesy NFRA)

Luneburg Linse (Australien)

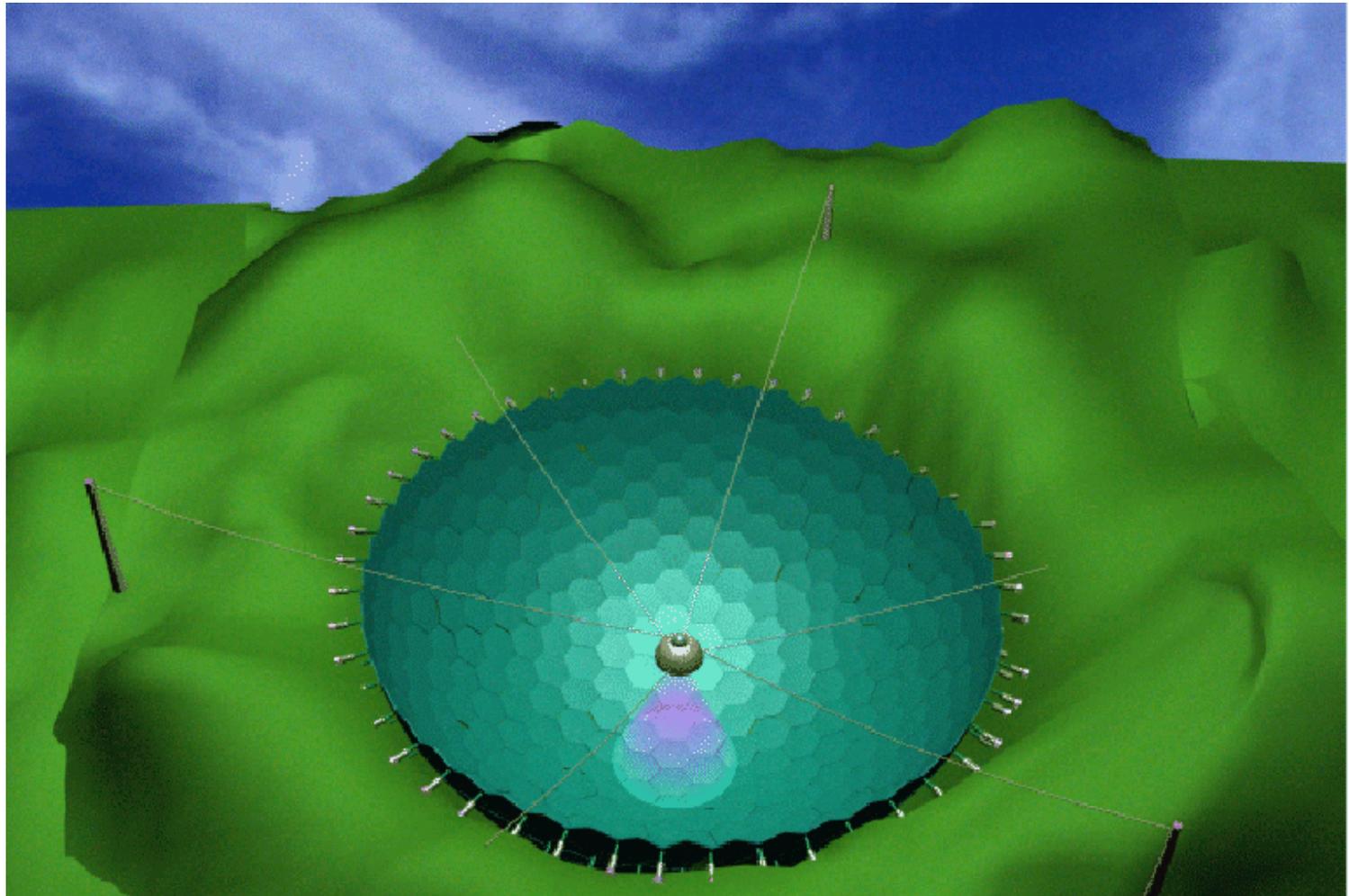


- Sphärische Linse mit variabler Durchlässigkeit
- kollimierter beam wird auf die andere Seite der Sphäre fokussiert
- Beam kann aus jeder Richtung kommen

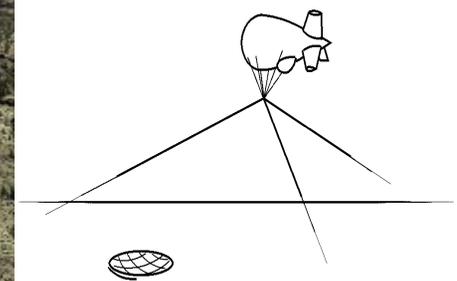
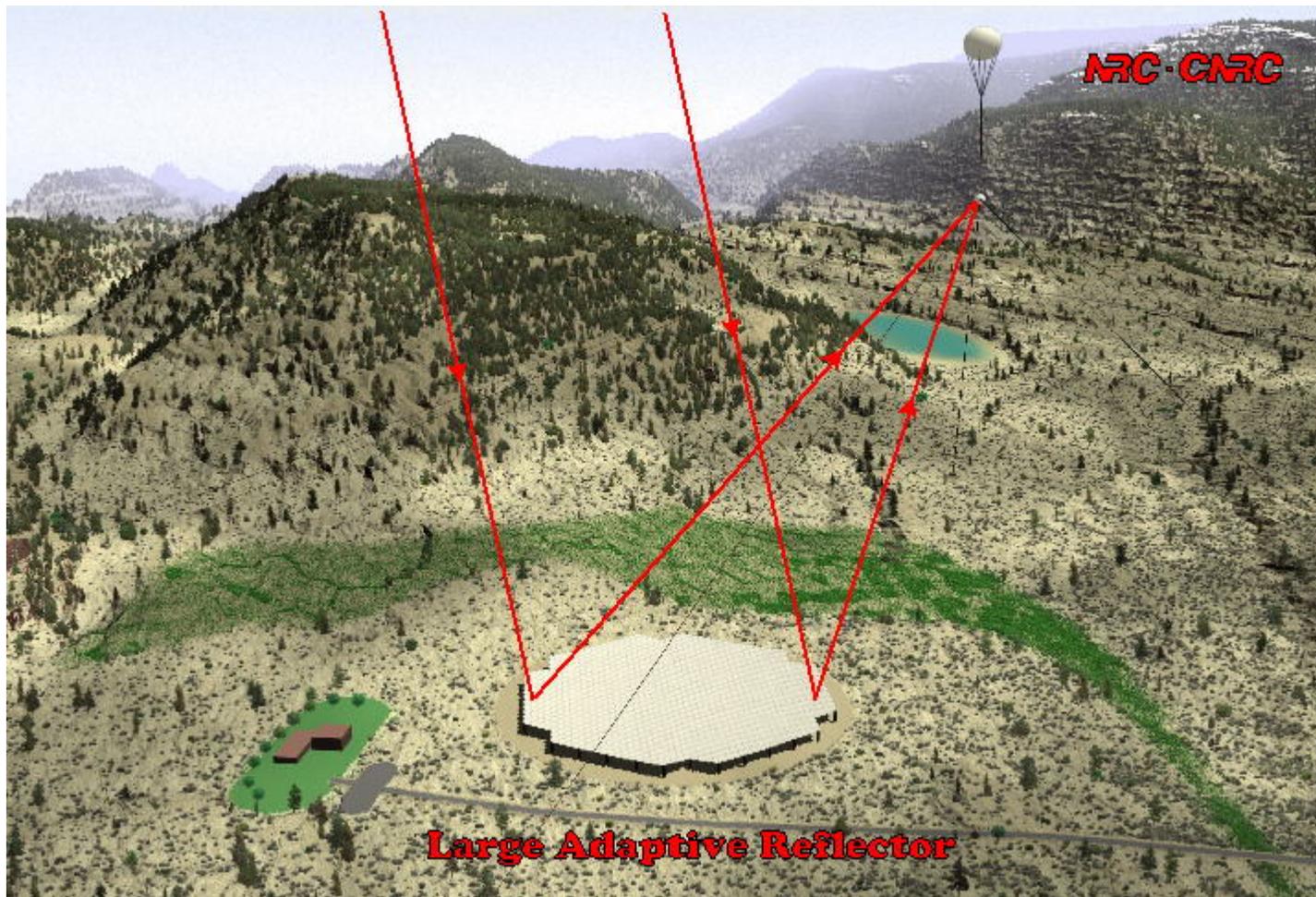
Array station of Luneberg lenses



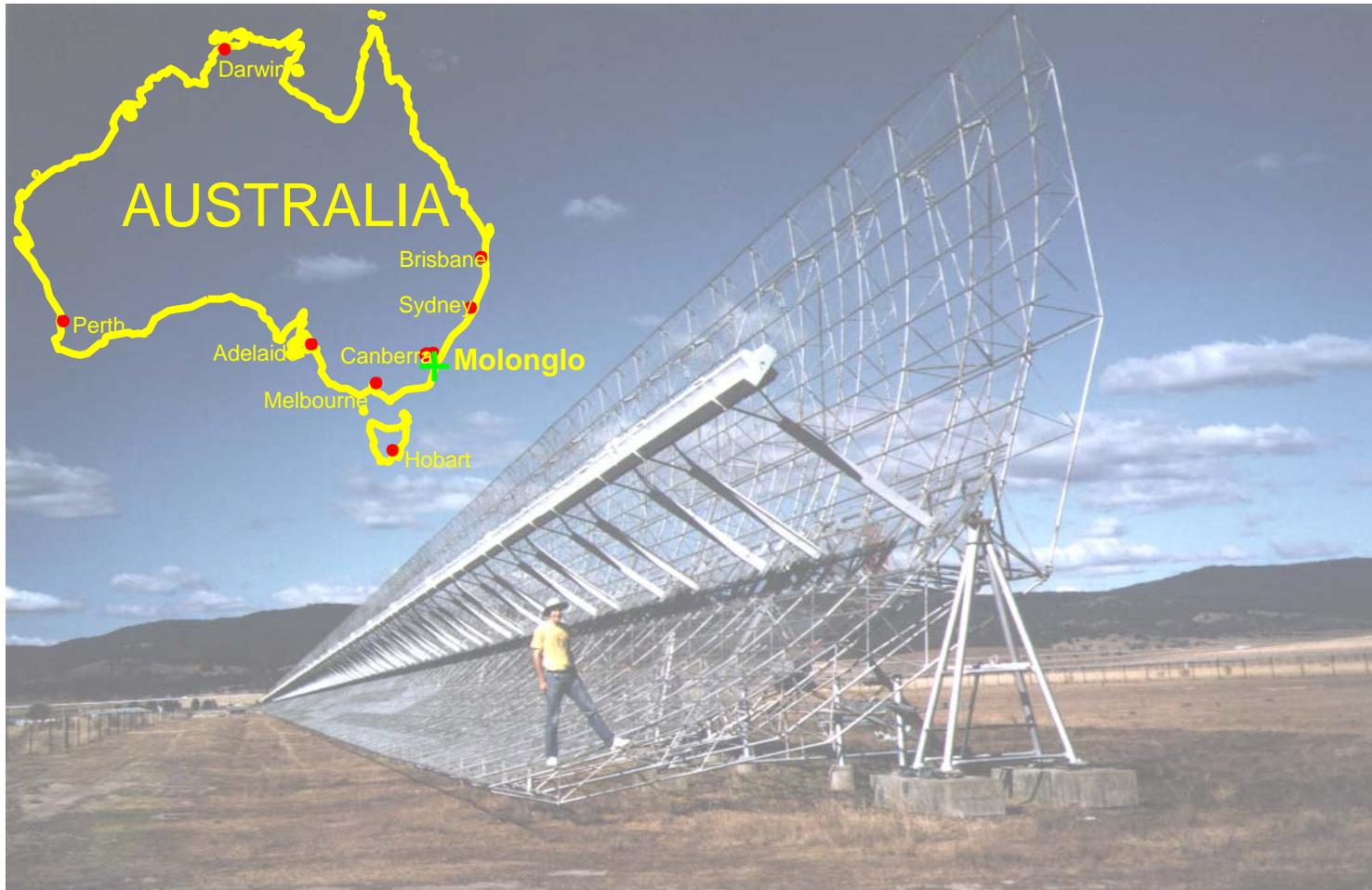
Large [Arecibo-like] Reflectors (China)



Aerostat-mounted receiver above Large Adaptive Reflector (Canada)



Molonglo SKA cylindrical array prototype



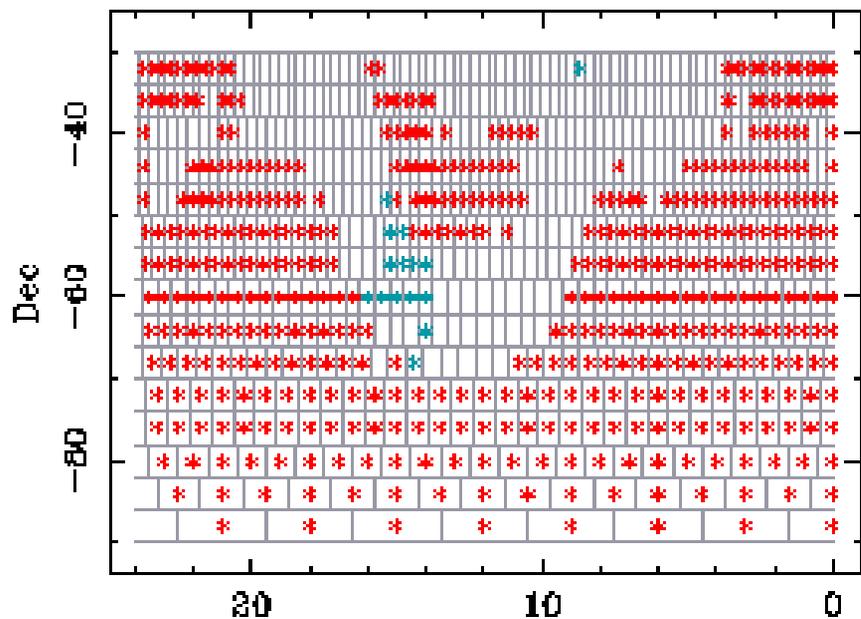


SUMSS:



SUMSS is a deep radio survey of the entire sky south of declination -30 degrees, made using the [MOST](#)

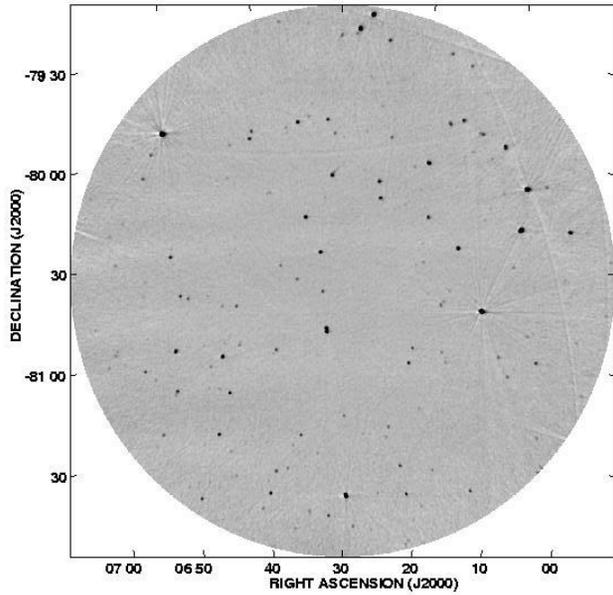
Available SUMSS Mosaics at 2004-Jul-14



Molonglo Observatory
Synthesis Telescope

471 Extragalactic mosaics and
15 Galactic mosaics have now been released,
covering an area of about 5450 square
degrees, Completion: 90%, expected: 300 000 radio sources

Current wide-field imaging with MOST (843 MHz, 12hr synthesis, 2.7° diameter field)



Current Survey (1997-2003):

The Sydney University Molonglo Sky Survey (SUMSS), imaging the whole southern sky ($\delta < -30^\circ$) at 843 MHz to mJy sensitivity with $45''$ resolution (i.e. similar to NVSS).

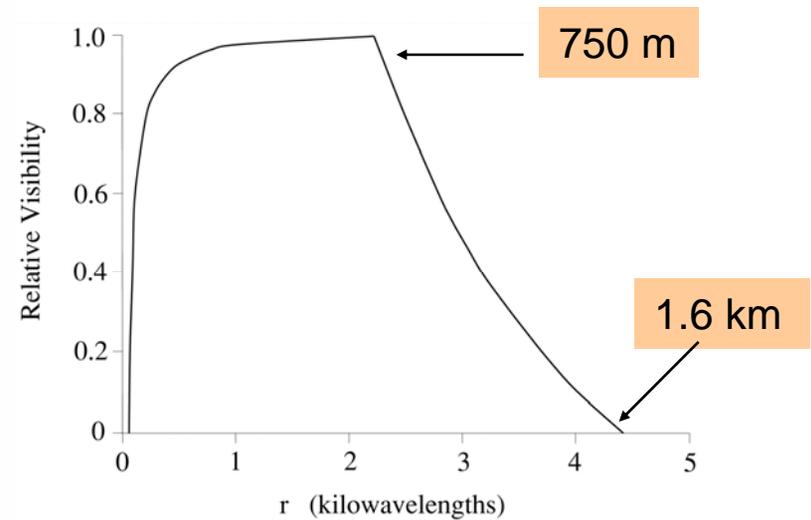
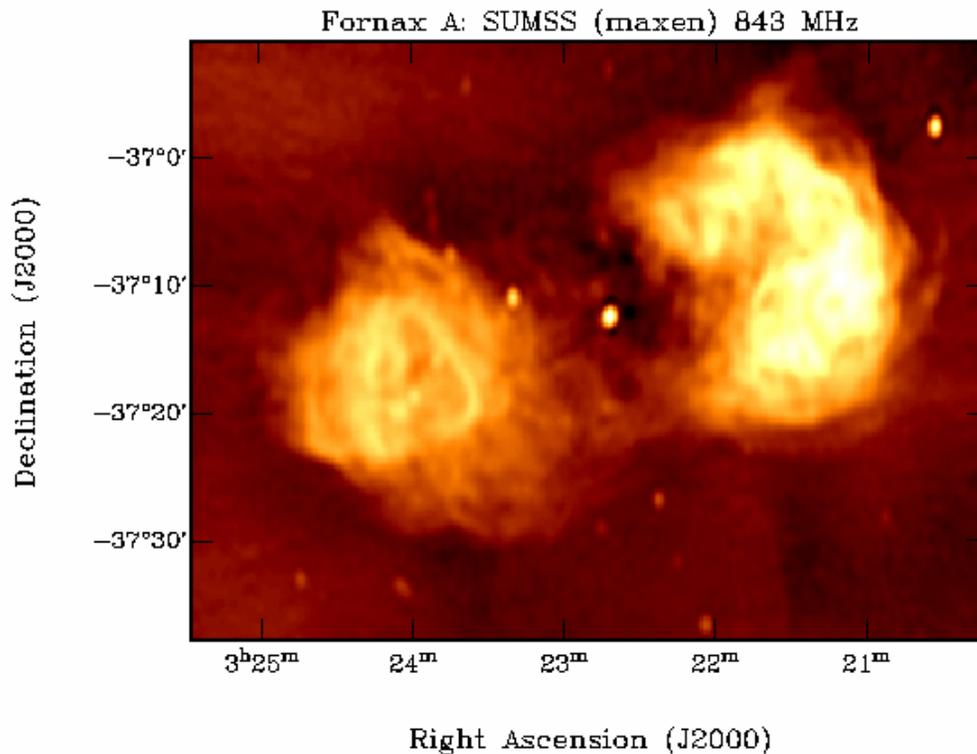


Photo: D. Bock

Next: Use existing telescope as SKA testbed **and** science facility:

- Large collecting area ($18,000 \text{ m}^2$)
- Wide field of view
- Continuous uv coverage

Zylindrischer Paraboloid: kontinuierliche uv-Bedeckung ergibt exzellente Bildqualität



(Bock et al. 1999)

- kontinuierliche uv-Bedeckung von 90 m bis 1.6 km in 12hr Synthesis-Beobachtungen
- SKA wird ebenfalls komplette uv-Bedeckungen haben