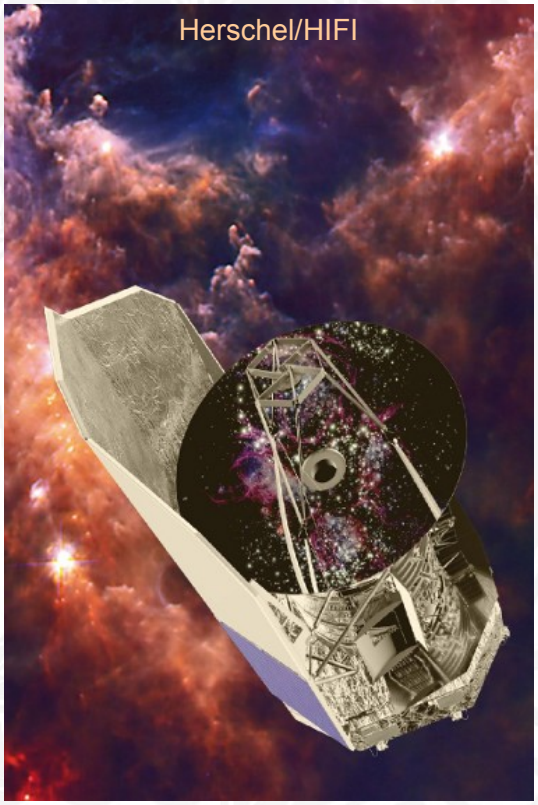
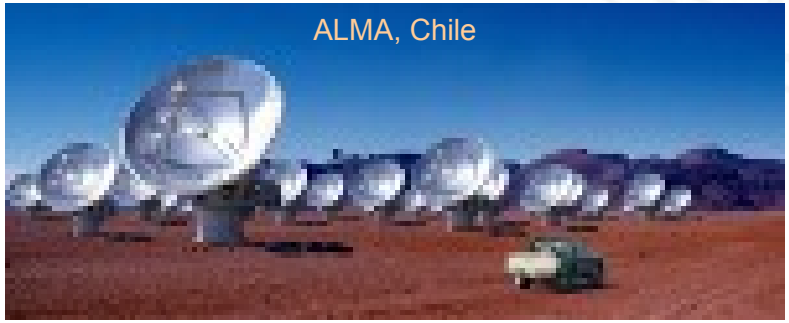
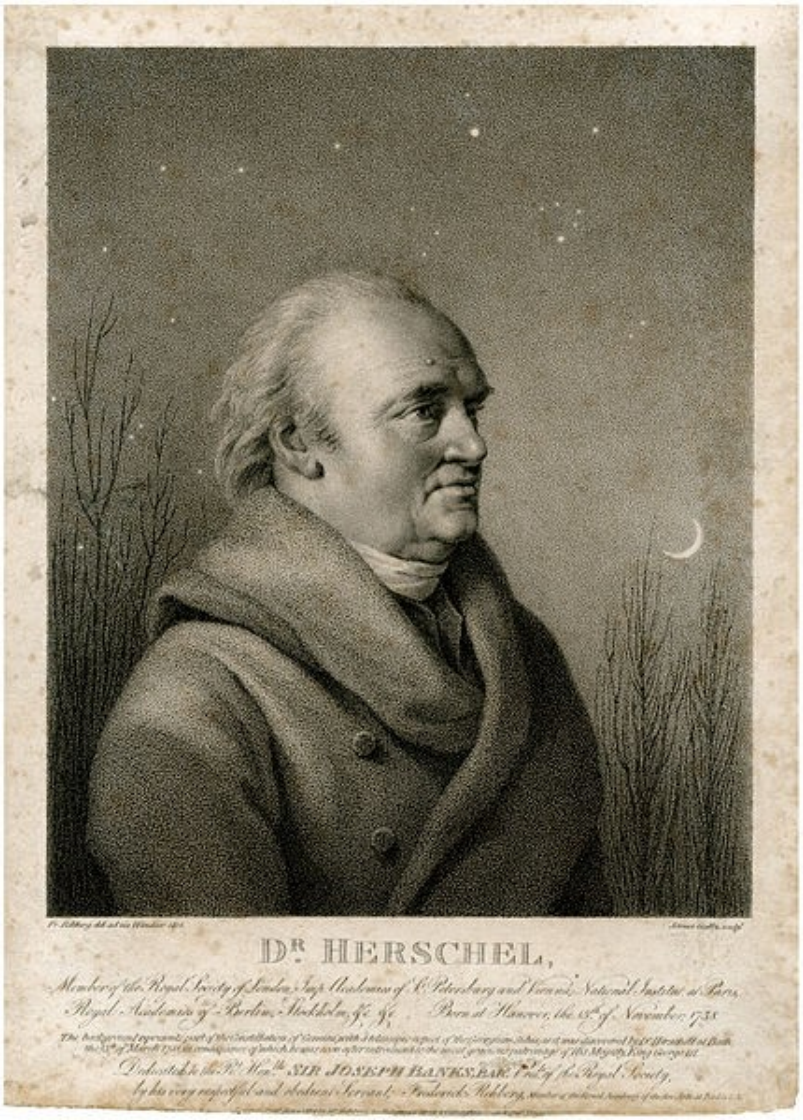

SFB 956
Cologne | Bonn

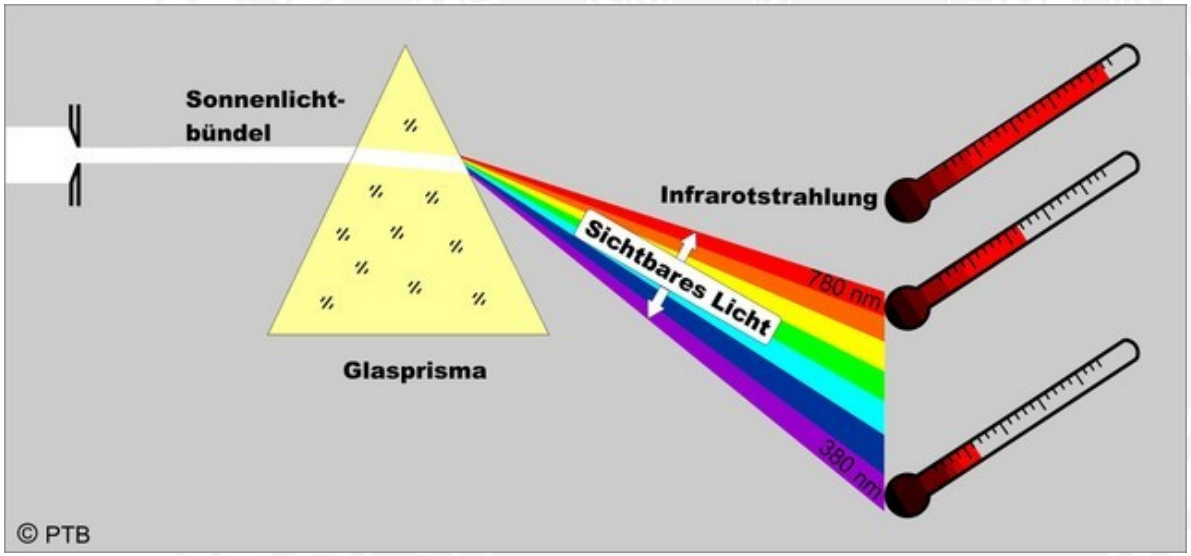



# Was ist submm-Astronomie?

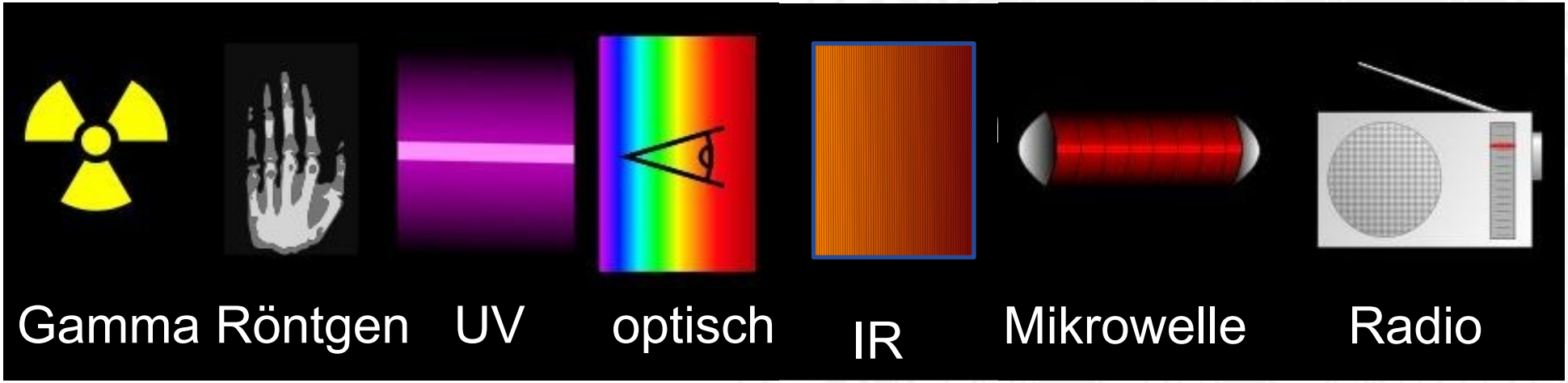

# Das “andere” Licht

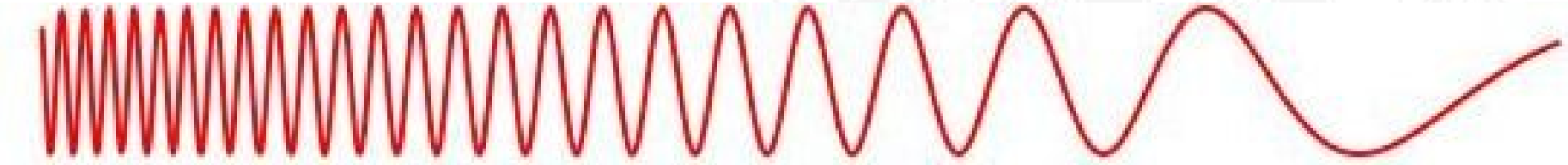



Friedrich Wilhelm Herschel, englisch
William Herschel, 1738-1822

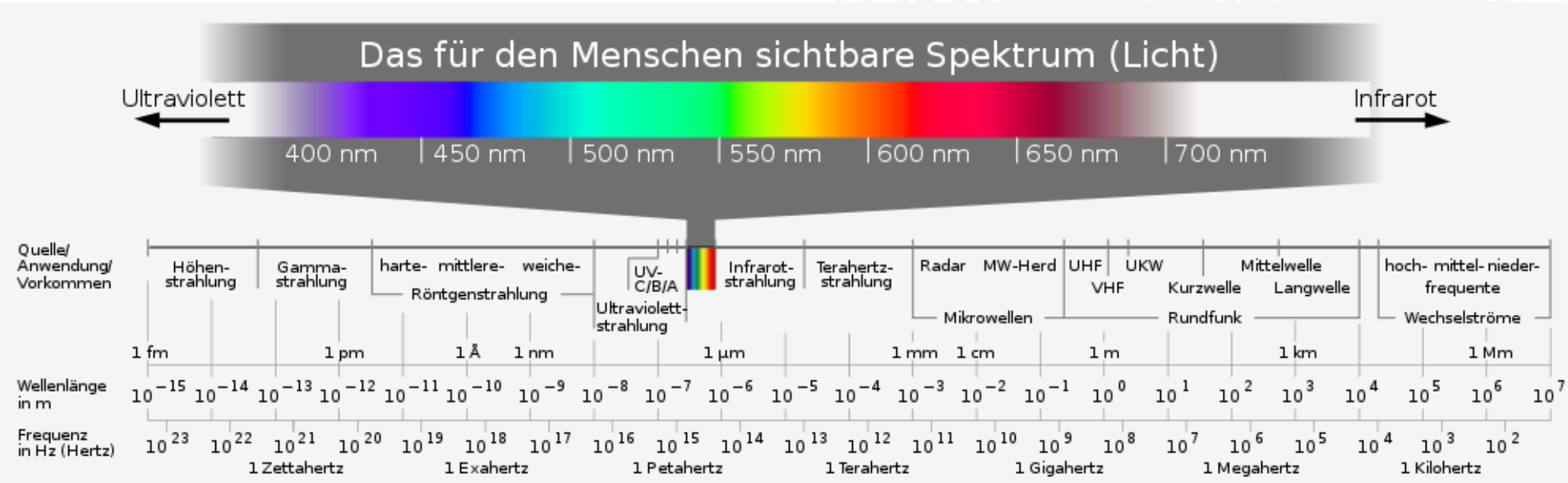
# Die Spektralperspektive

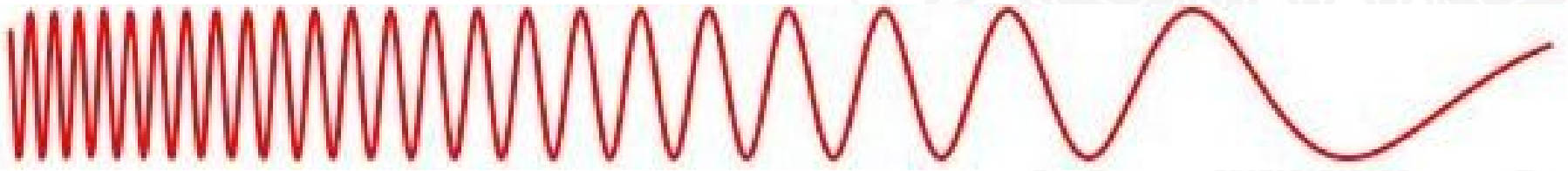


→ **Komplementäre Informationen über Struktur und Physik**

# Die Spektralperspektive



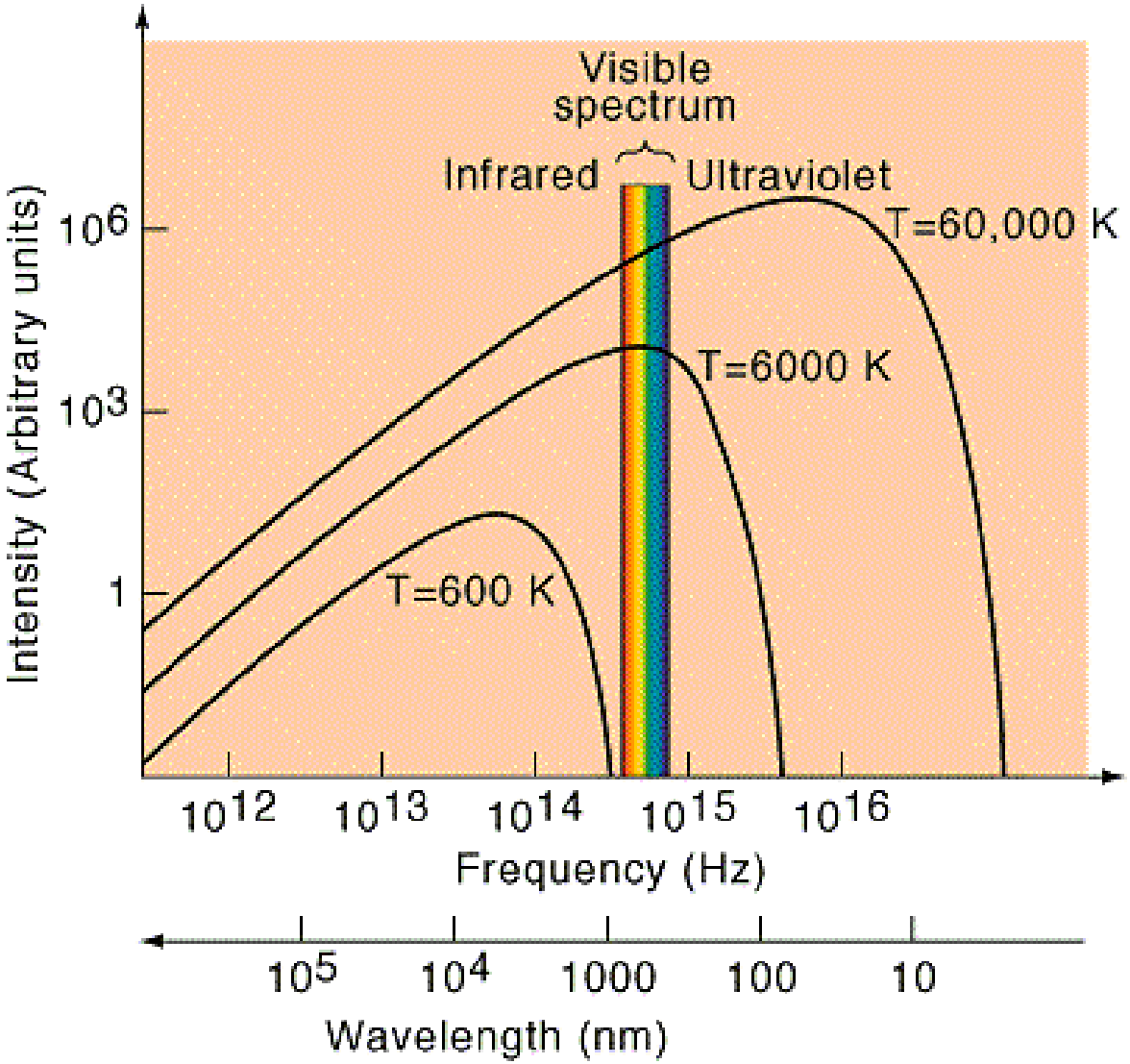



**Viel mehr Information, als wir mit dem Auge wahrnehmen können.**

- **Submm-Bereich: Wellenlänge λ = 100µm - 1mm**

# Was strahlt bei submm-Wellenlängen?

- **Das Plancksche Strahlungsgesetz**



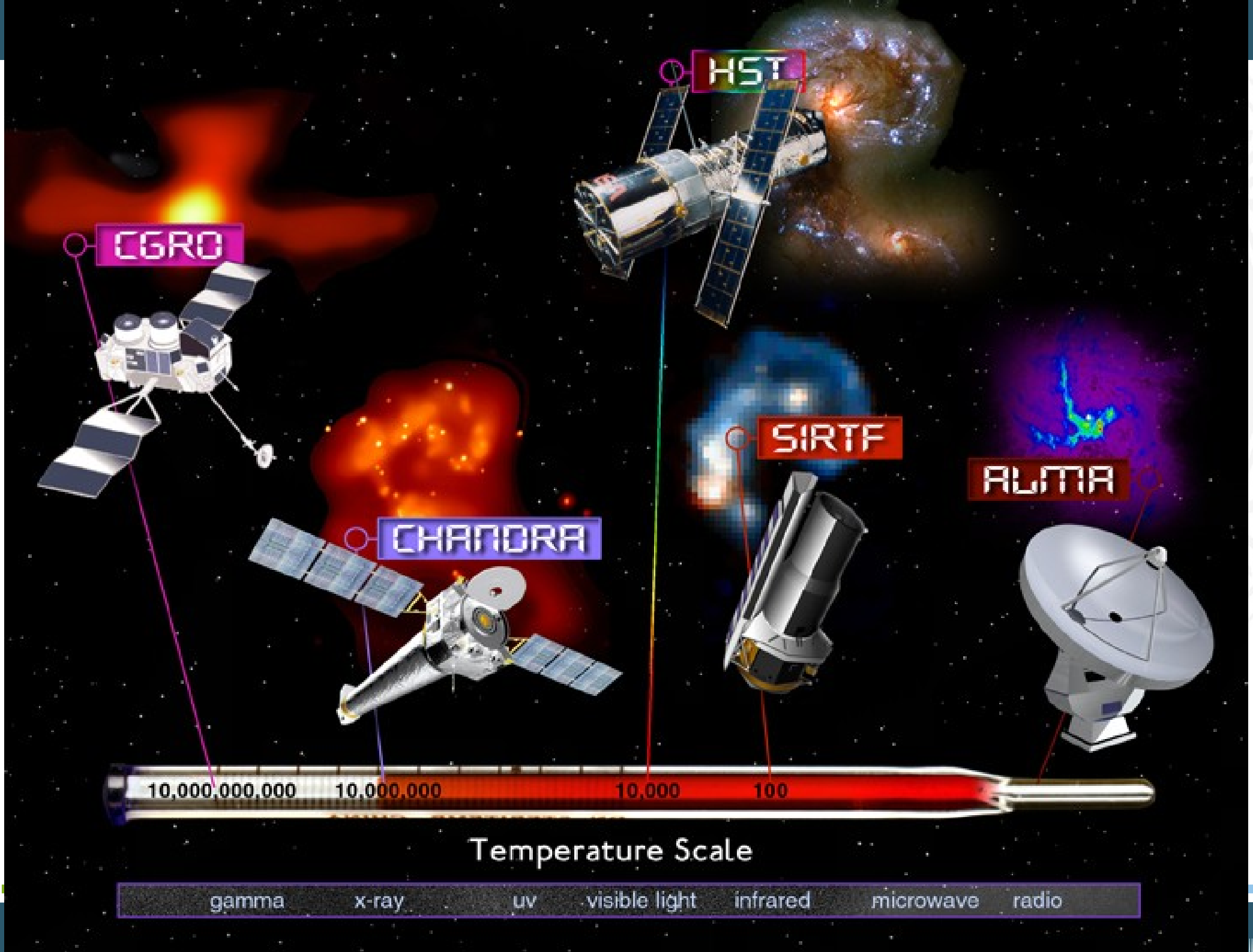

**Wiensches Verschiebungsgesetz:**

Jeder Körper strahlt am hellsten bei einer Wellenlänge die umgekehrt proportional zu seiner Temperatur ist:

$$\lambda_{\max} = 3\mathrm{mm}\frac{\mathrm{K}}{T}$$

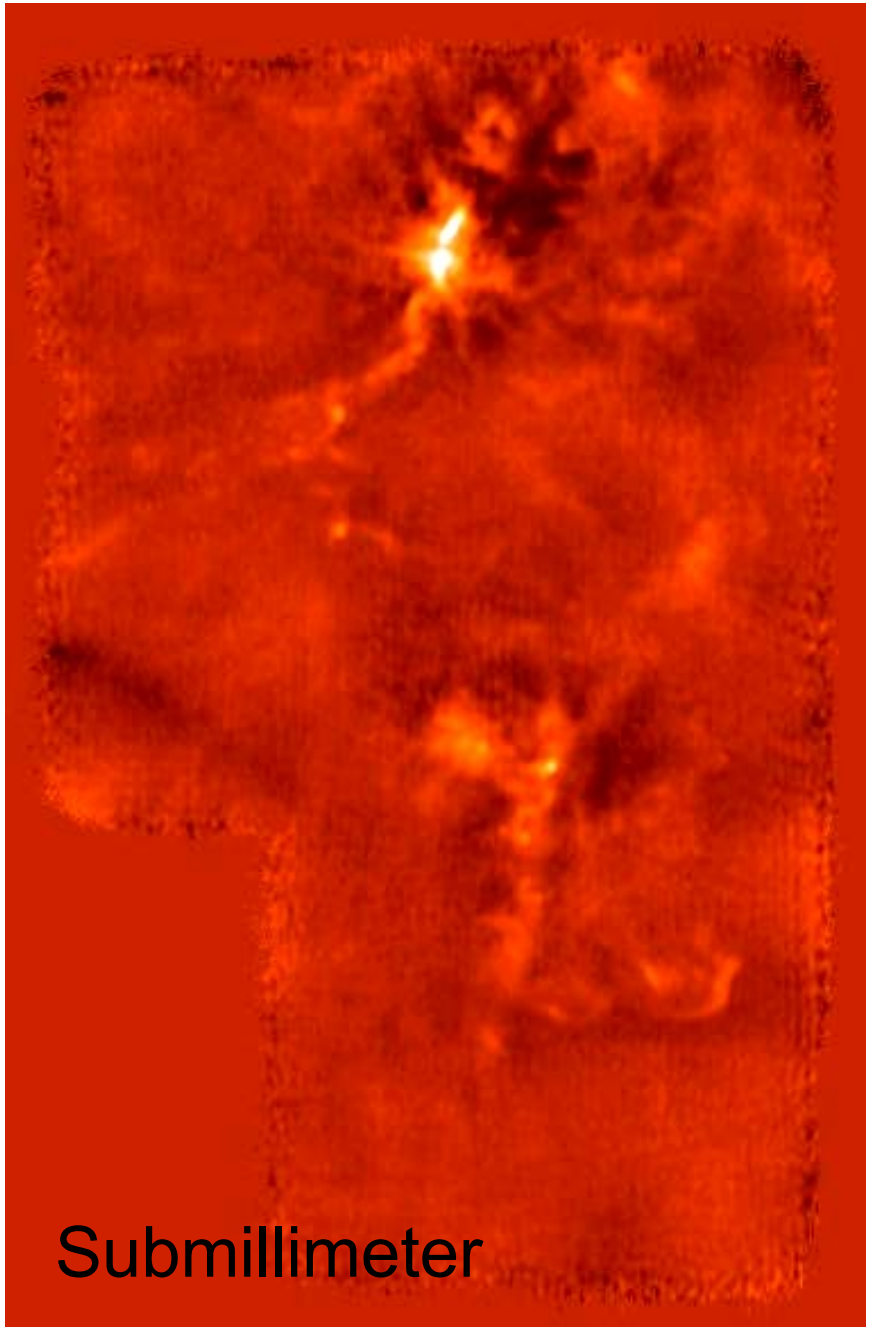
→ Im submm-Bereich empfangen wir Strahlung von kaltem Material:

*T*=3-100K (-270... -170°C)


HST
CGRO
SIRTF
ALMA
CHANDRA
10,000,000,000
10,000,000
10,000
100
Temperature Scale
gamma
x-ray
uv
visible light
infrared
microwave
radio

# Was strahlt bei submm-Wellenlängen?

# Submm - optisch




# Herschel observations


Dust and gas in extended filaments of the interstellar medium

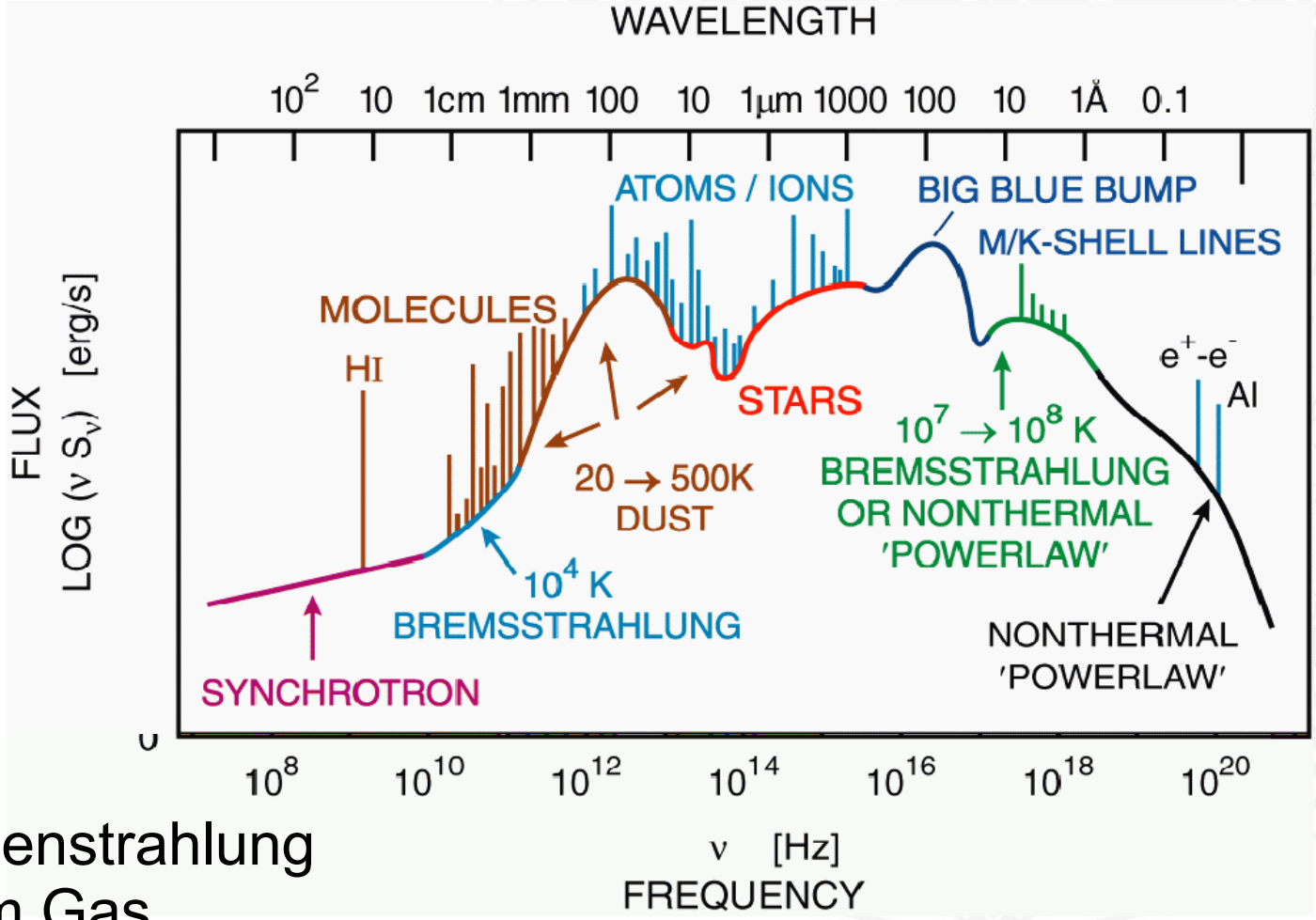
# Was strahlt bei submm-Wellenlängen?

- **Interstellarer Staub**

**Silikat- und Kohlenstoffteilchen:**

- organisches Material und Eis-mäntel
- Teilchengrößen typisch 0.1 µm (einige Å bis einige µm)
- irreguläre Struktur

- **Was strahlt im submm-Bereich?**

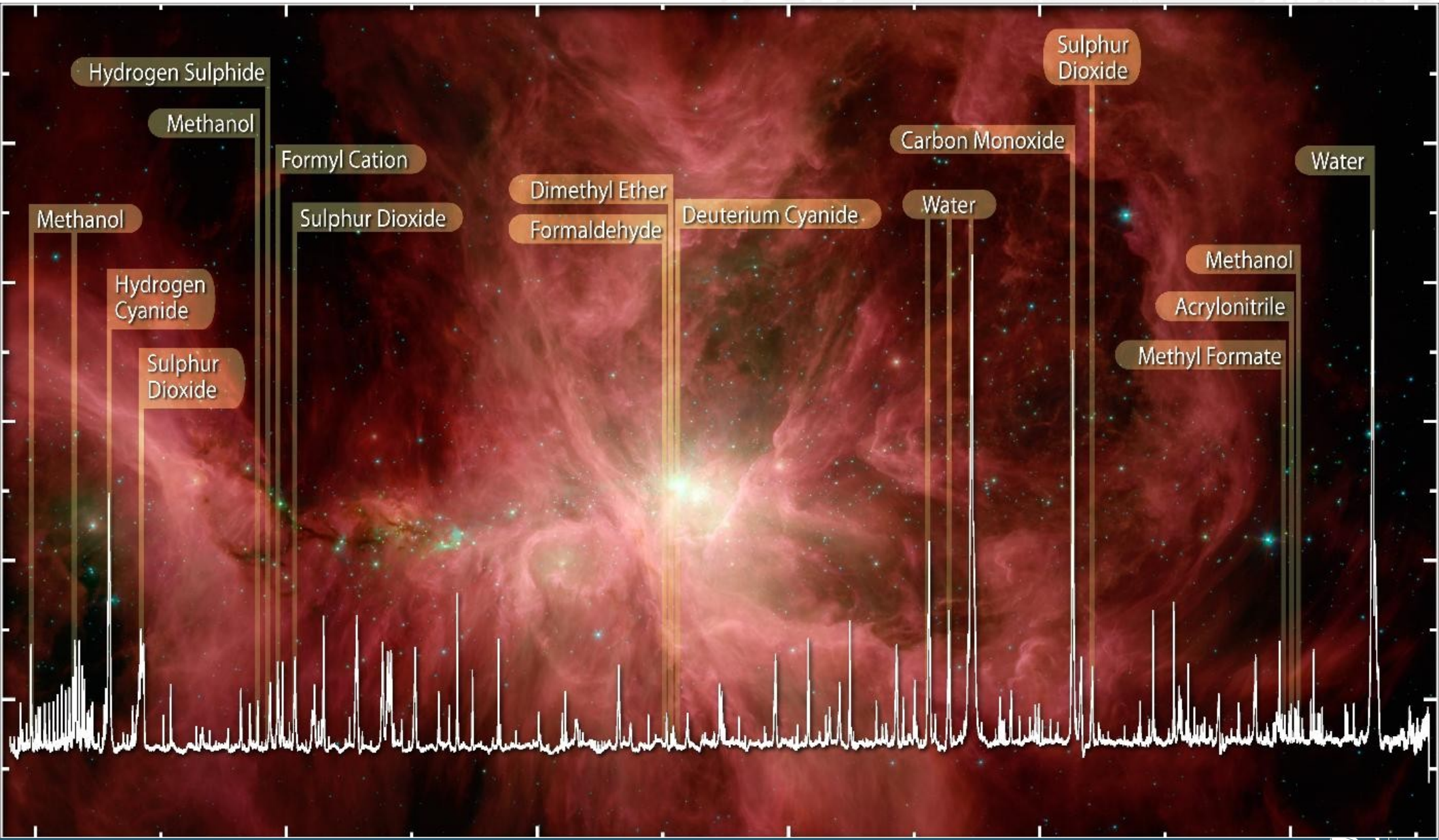



• Zusätzliche Linienstrahlung von interstellarem Gas

  • Atome und Moleküle

  • erlaubt Zusammensetzung der Gases zu analysieren

# Spektroskopie:

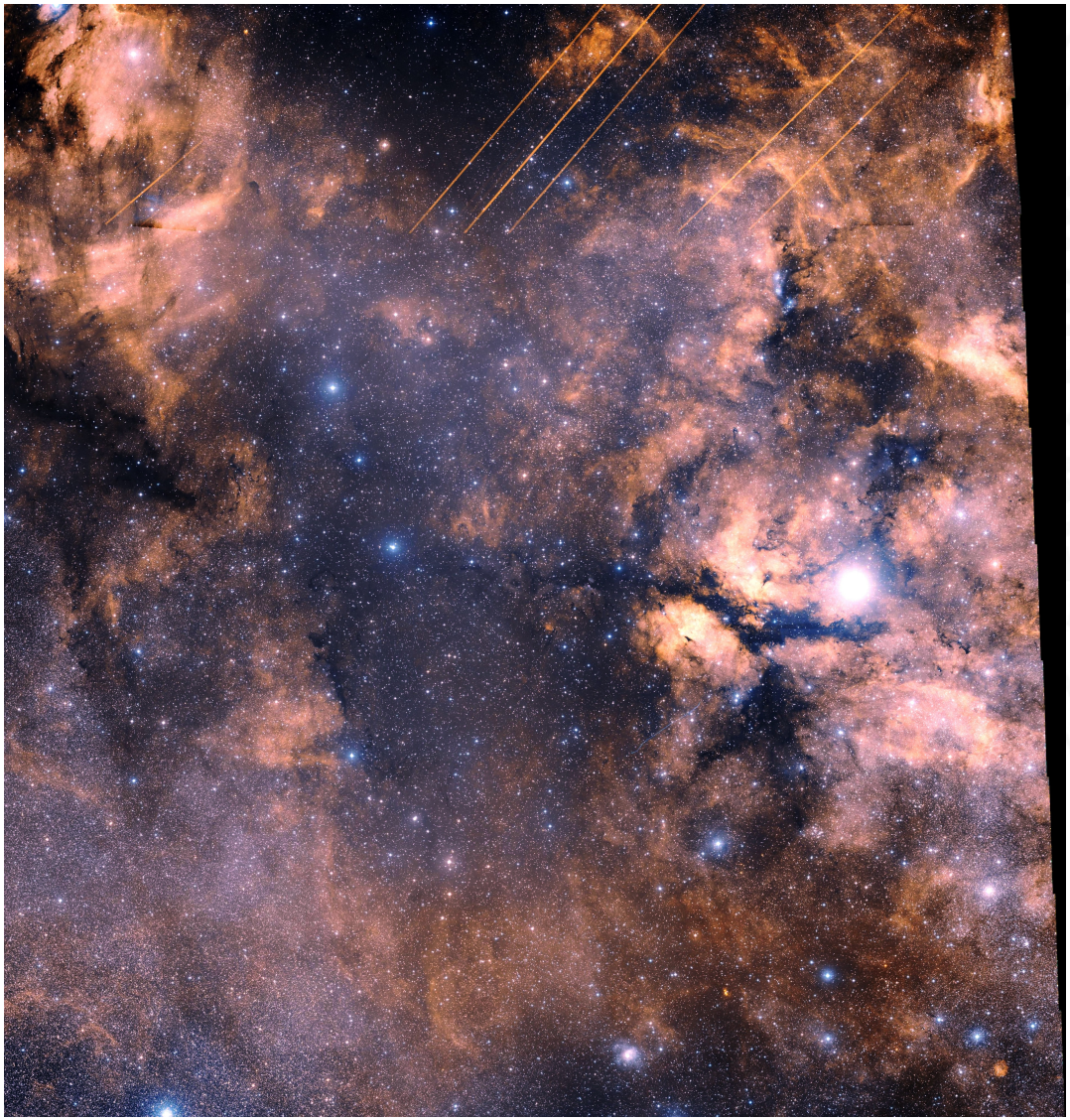


# Inter-stellare Moleküle

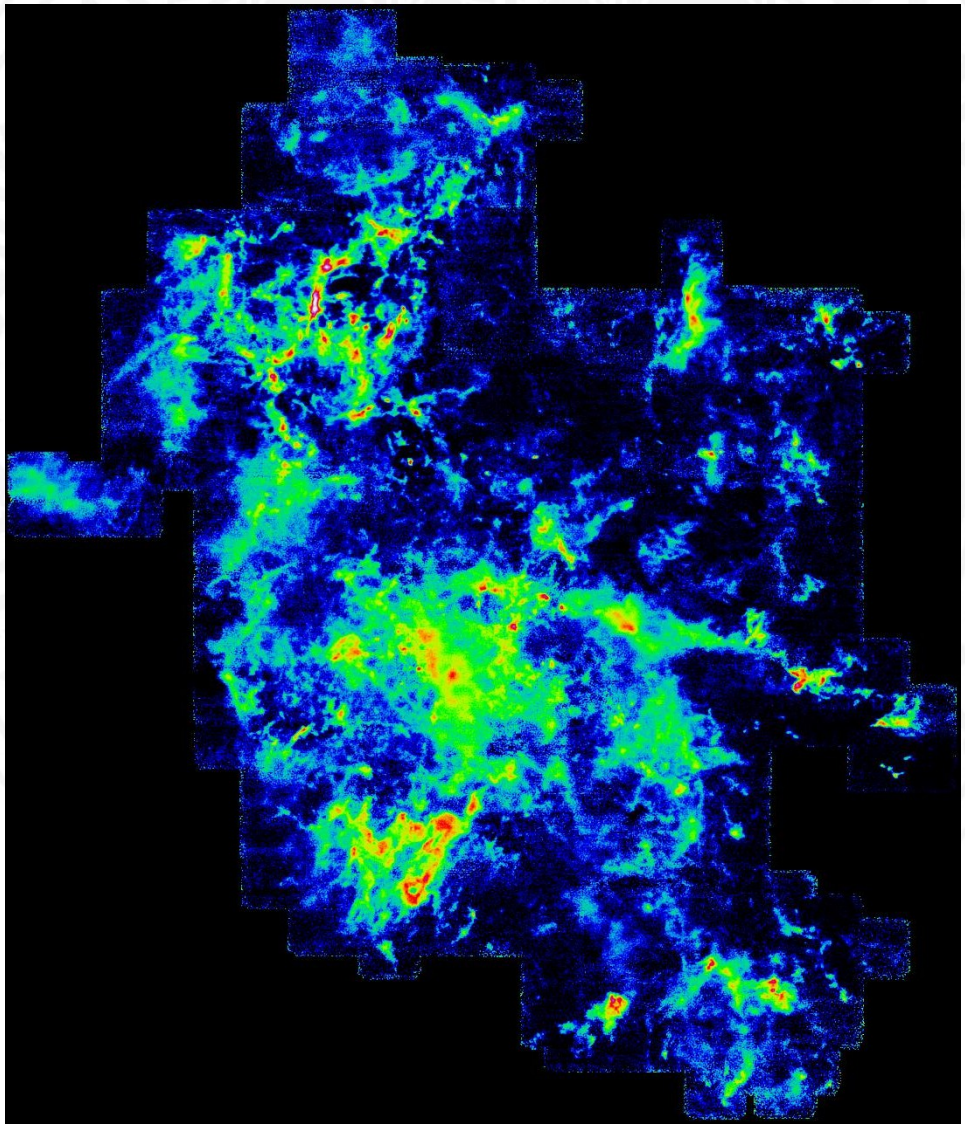
Stand: Dezember 2013

| 2 atoms | 3 atoms | 4 atoms | 5 atoms | 6 atoms | 7 atoms | 8 atoms | 9 atoms | 10 atoms | 11 atoms | 12 atoms | >12 atoms |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_2$ | $C_3$* | *c*-$C_3H$ | $C_5$* | $C_5H$ | $C_6H$ | $CH_3C_3N$ | $CH_3C_4H$ | $CH_3C_5N$ | $HC_9N$ | *c*-$C_6H_6$* | $HC_{11}N$ |
| AlF | $C_2H$ | *l*-$C_3H$ | $C_4H$ | *l*-$H_2C_4$ | $CH_2CHCN$ | $HC(O)OCH_3$ | $CH_3CH_2CN$ | $(CH_3)_2CO$ | $CH_3C_6H$ | $C_2H_5OCH_3$? | $C_{60}$* 2012 |
| AlCl | $C_2O$ | $C_3N$ | $C_4Si$ | $C_2H_4$* | $CH_3C_2H$ | $CH_3COOH$ | $(CH_3)_2O$ | $(CH_2OH)_2$ | $C_2H_5OCHO$ | *n*-$C_3H_7CN$ | $C_{70}$* |
| $C_2$** | $C_2S$ | $C_3O$ | *l*-$C_3H_2$ | $CH_3CN$ | $HC_5N$ | $C_7H$ | $CH_3CH_2OH$ | $CH_3CH_2CHO$ | $CH_3OC(O)CH_3$ 2013 | | |
| CH | $CH_2$ | $C_3S$ | *c*-$C_3H_2$ | $CH_3NC$ | $CH_3CHO$ | $C_6H_2$ | $HC_7N$ | | | | |
| $CH^+$ | HCN | $C_2H_2$* | $H_2CCN$ | $CH_3OH$ | $CH_3NH_2$ | $CH_2OHCHO$ | $C_8H$ | | | | |
| CN | HCO | $NH_3$ | $CH_4$* | $CH_3SH$ | *c*-$C_2H_4O$ | *l*-$HC_6H$* | $CH_3C(O)NH_2$ | | | | |
| CO | $HCO^+$ | HCCN | $HC_3N$ | $HC_3NH^+$ | $H_2CCHOH$ | $CH_2CHCHO$ (?) | $C_8H^-$ | | | | |
| $CO^+$ | $HCS^+$ | $HCNH^+$ | $HC_2NC$ | $HC_2CHO$ | $C_6H^-$ | $CH_2CCHCN$ | $C_3H_6$ | | | | |
| CP | $HOC^+$ | HNCO | HCOOH | $NH_2CHO$ | | $H_2NCH_2CN$ | | | | | |
| SiC | $H_2O$ | HNCS | $H_2CNH$ | $C_5N$ | | $CH_3CHNH$ 2013 | | | | | |
| HCl | $H_2S$ | $HOCO^+$ | $H_2C_2O$ | *l*-$HC_4H$* | | | | | | | |
| KCl | HNC | $H_2CO$ | $H_2NCN$ | *l*-$HC_4N$ | | | | | | | |
| NH | HNO | $H_2CN$ | $HNC_3$ | *c*-$H_2C_3O$ | | | | | | | |
| NO | MgCN | $H_2CS$ | $SiH_4$* | $H_2CCNH$ (?) | | | | | | | |
| NS | MgNC | $H_3O^+$ | $H_2COH^+$ | $C_5N^-$ | | | | | | | |
| NaCl | $N_2H^+$ | *c*-$SiC_3$ | $C_4H^-$ | HNCHCN 2013 | | | | | | | |
| OH | $N_2O$ | $CH_3$* | HC(O)CN | | | | | | | | |
| PN | NaCN | $C_3N^-$ | HNCNH 2012 | | | | | | | | |
| SO | OCS | $PH_3$? | $CH_3O$ 2012 | | | | | | | | |
| $SO^+$ | $SO_2$ | HCNO | $NH_4^+$ 2013 | | | | | | | | |
| SiN | *c*-$SiC_2$ | HOCN | $H_2NCO^+$ (?) 2013 | | | | | | | | |
| SiO | $CO_2$* | HSCN | | | | | | | | | |
| SiS | $NH_2$ | $H_2O_2$ | | | | | | | | | |
| CS | $H_3^+$ (•) | $C_3H^+$ (?) 2012 | | | | | | | | | |
| HF | SiCN | HMgNC 2013 | | | | | | | | | |

# Molekülwolken

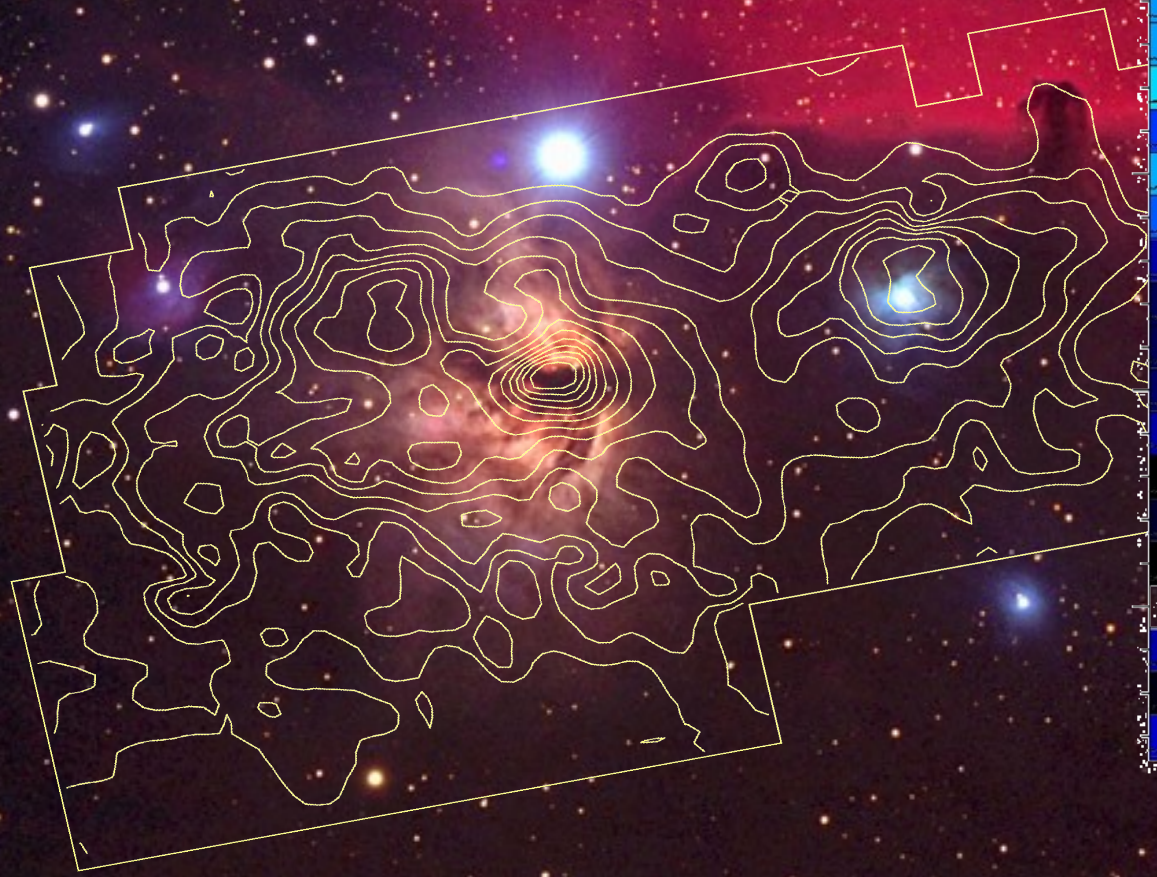


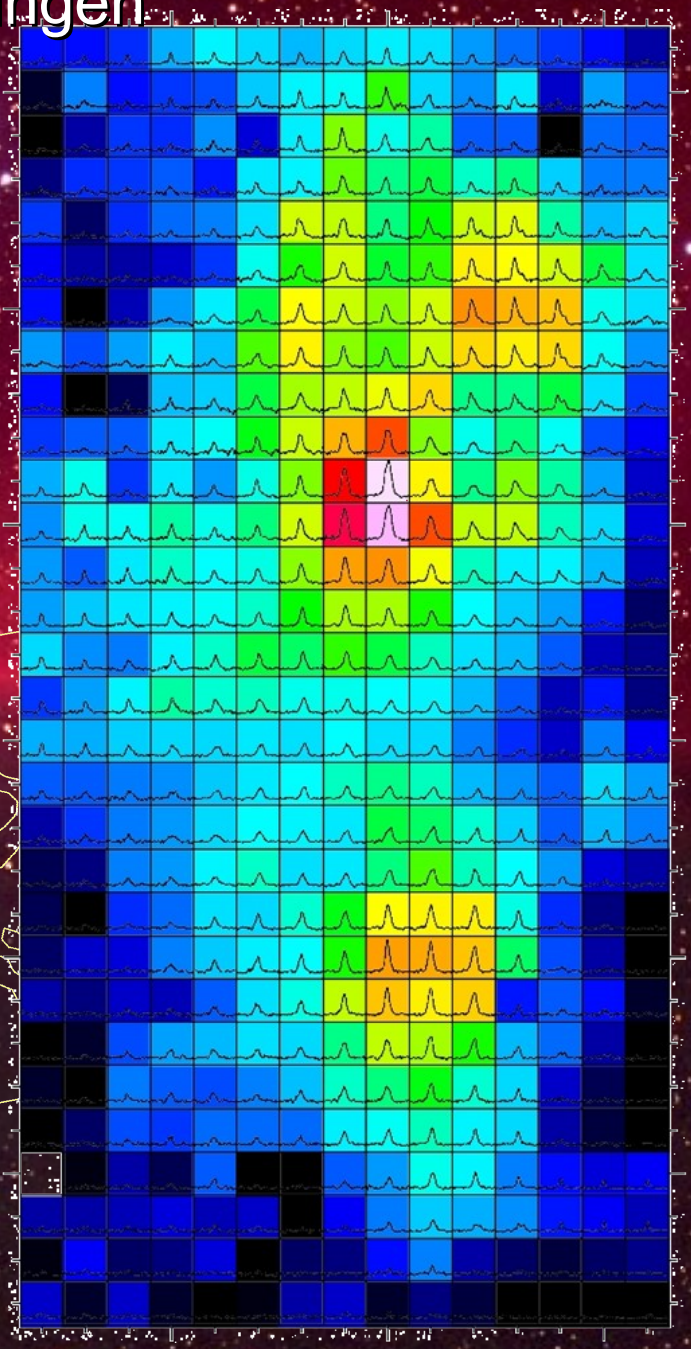
**Optisches Bild**



**FCRAO $^{13}$CO survey**
**Gesamtemission**

# Analyse spektroskopischer Beobachtungen



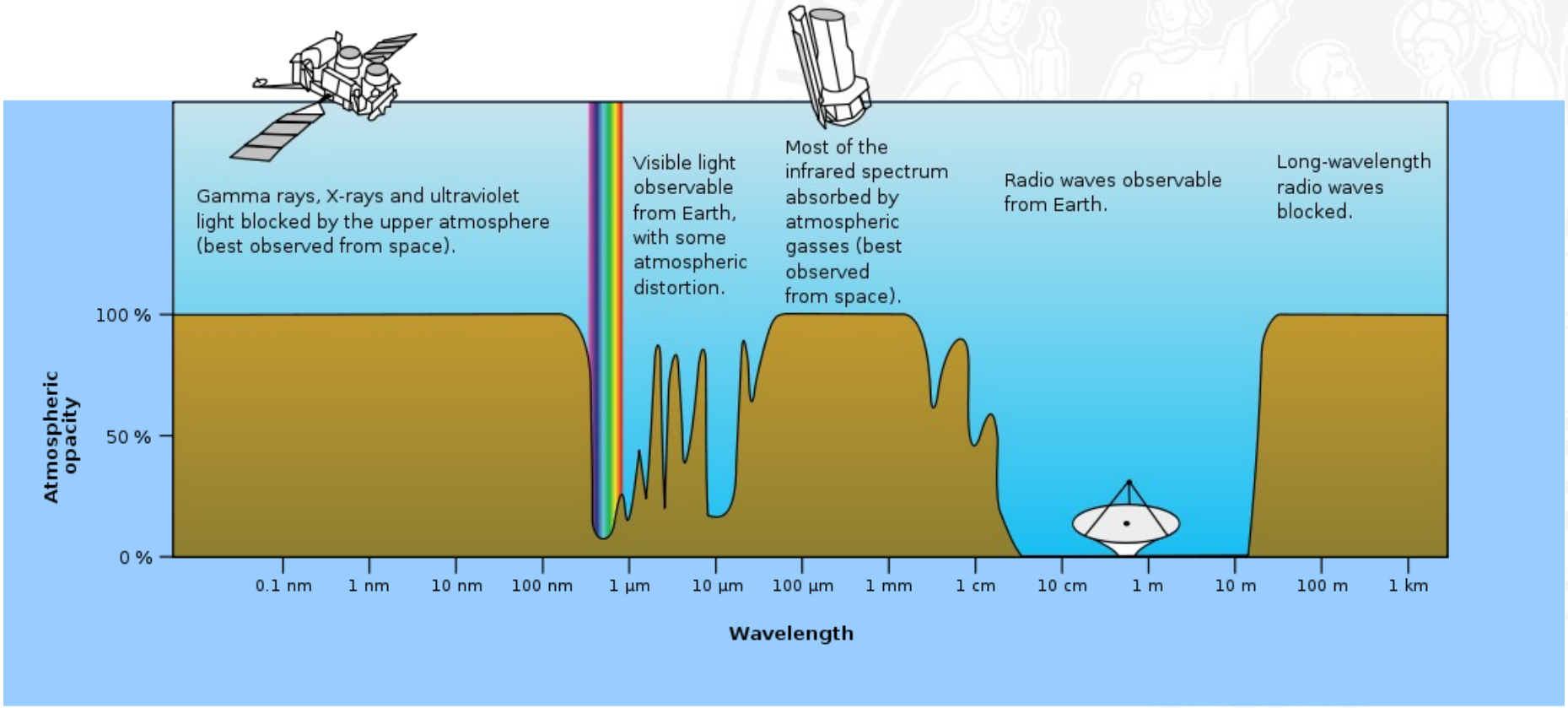


# Die Geschwindigkeitsstruktur

Durch den Dopplereffekt kann man bei verschiedenen Frequenzen verschiedene Geschwindigkeiten des Materials beobachten.

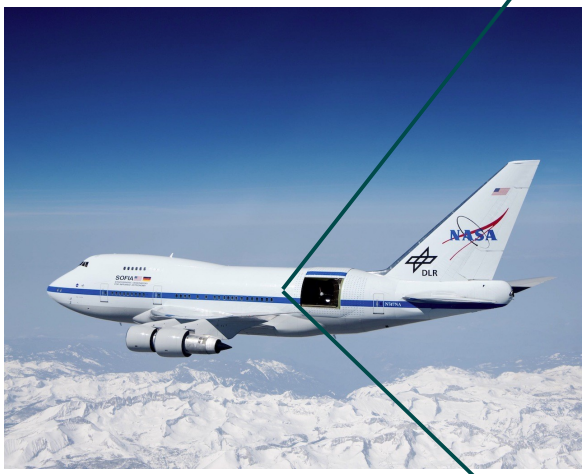
→ Sehr komplexe turbulente Struktur interstellarer Wolken

- **Atmosphäre ist nur für Wellenlängen λ zwischen 0.4 und 2μm und bei Radiowellenlängen > 3cm durchsichtig**

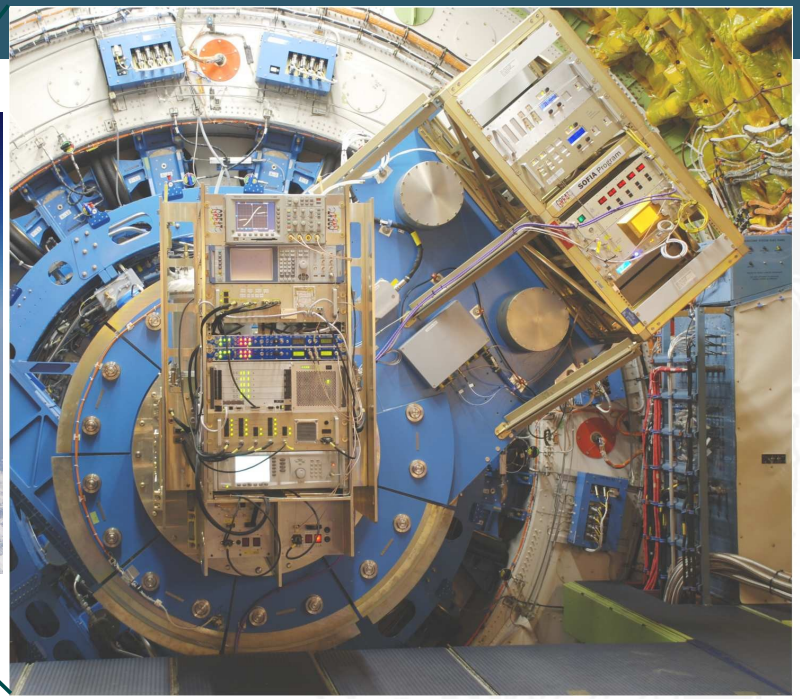



**Das langwellige Ende des submm-Bereich ist noch von hohen Bergen zugänglich.→ Alle anderen Wellenlängen können nur außerhalb der Atmosphäre beobachtet werden.**

# Beobachtungen

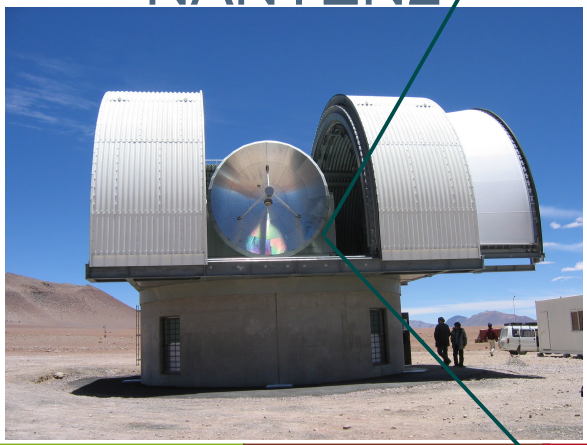


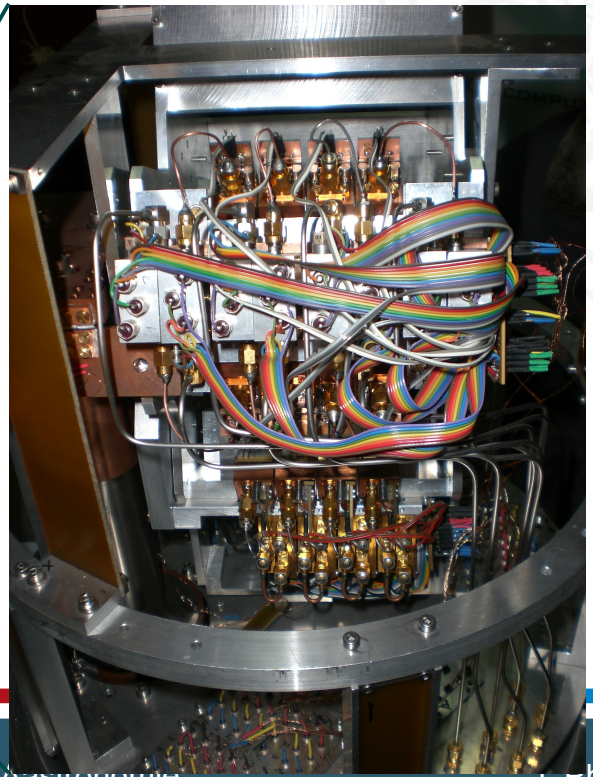

GREAT auf SOFIA

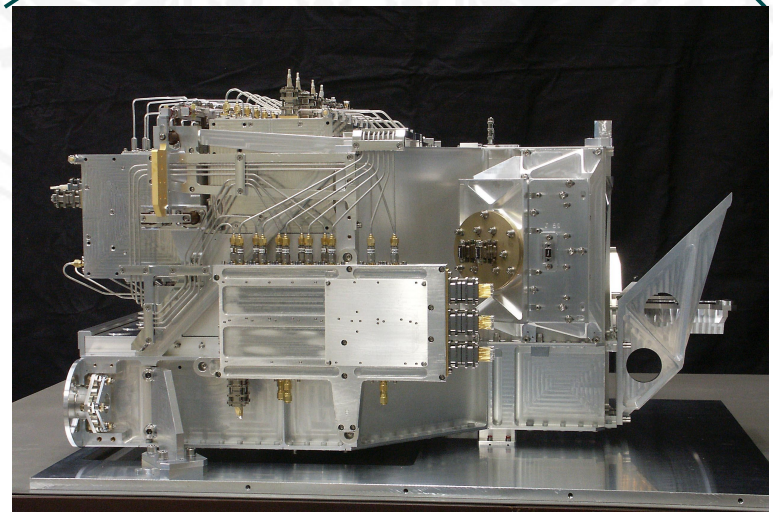


Herschel

SMART an NANTEN2







# NANTEN 2

- Nan Ten (Japanisch: Südhimmel)
- 4 m Teleskop
- Observations 0.35µm-1.5mm
- SubMm-Array-Receiver at Two Frequencies (SMART)
- Unser “Hausteleskop”

# NANTEN 2





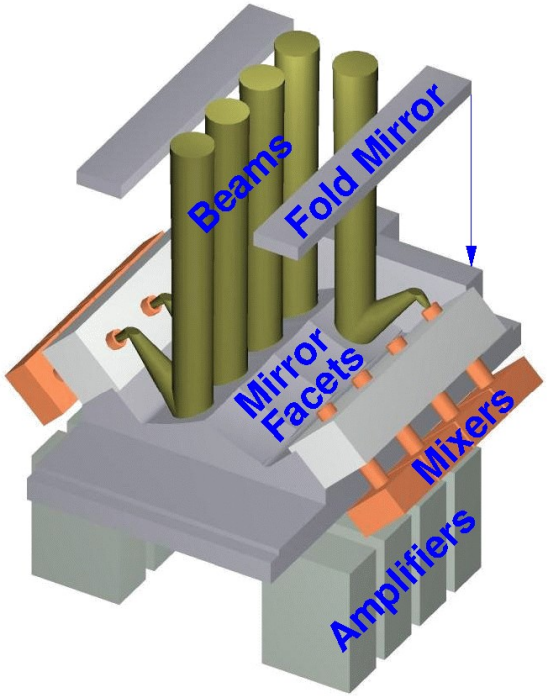
San Pedro

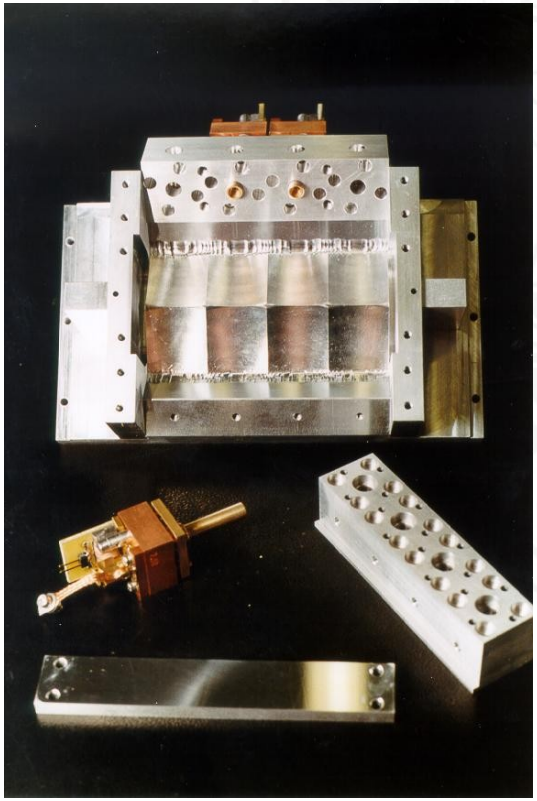
Atacama desert

# SMART

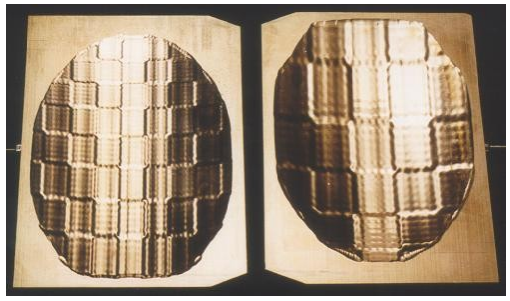
## Empfänger im Haus entwickelt:
K. Jacobs , U. Graf

monolithic integrated optics



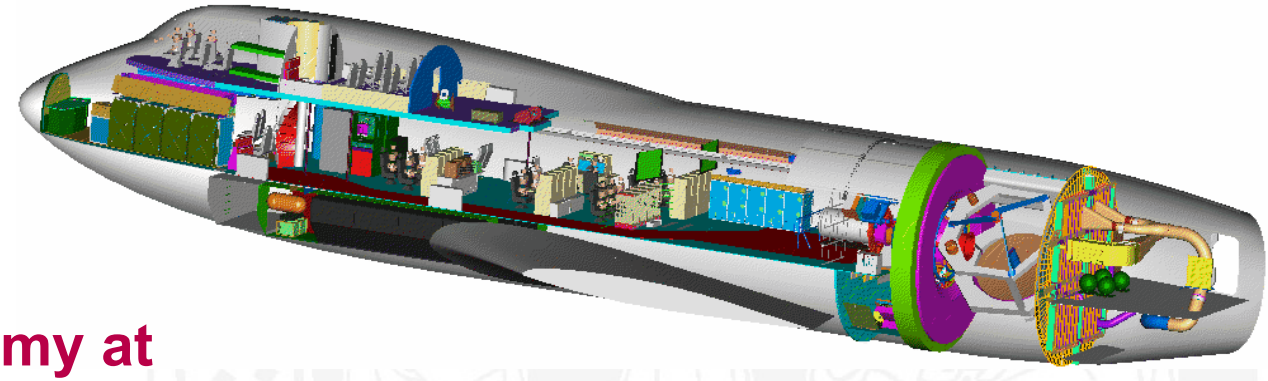



LO multiplexing: imaging Fourier grating splits singel LO beam into pattern of LO beams for detector array



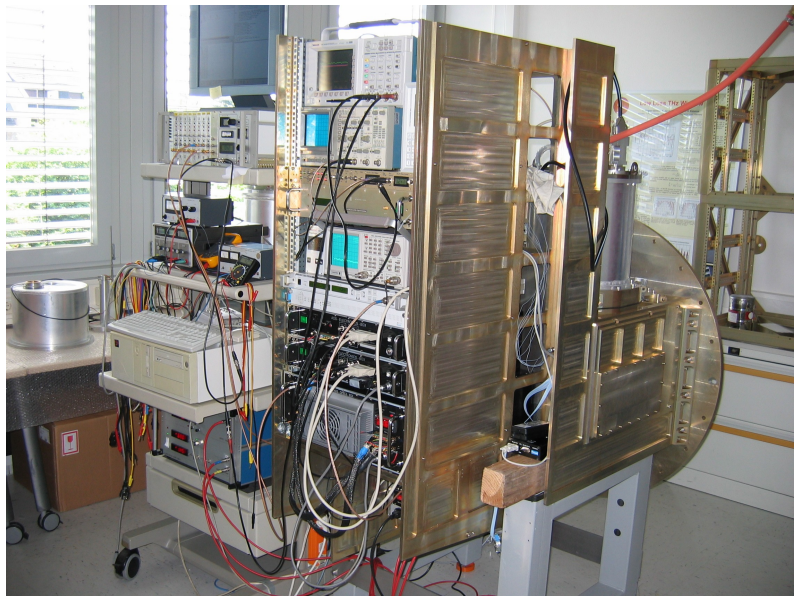
## Stratospheric Observatory for Infrared Astronomy

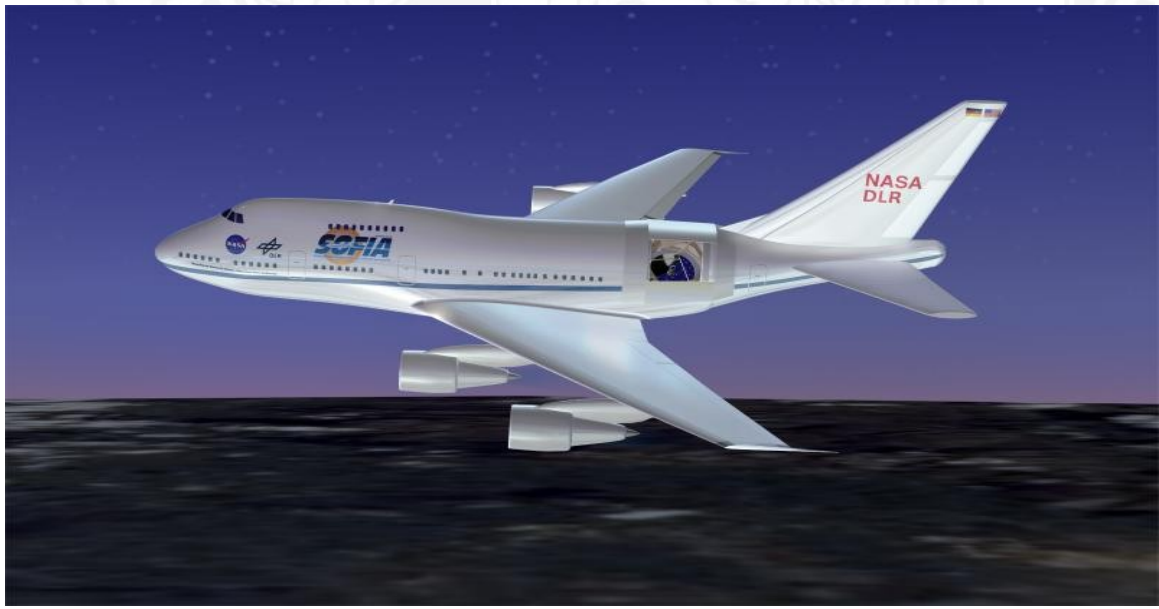
- Boing 747
- 2.7m-Teleskop



## German Receiver for Astronomy at Terahertz-Frequencies (GREAT)

- Entwicklung in Köln und Bonn



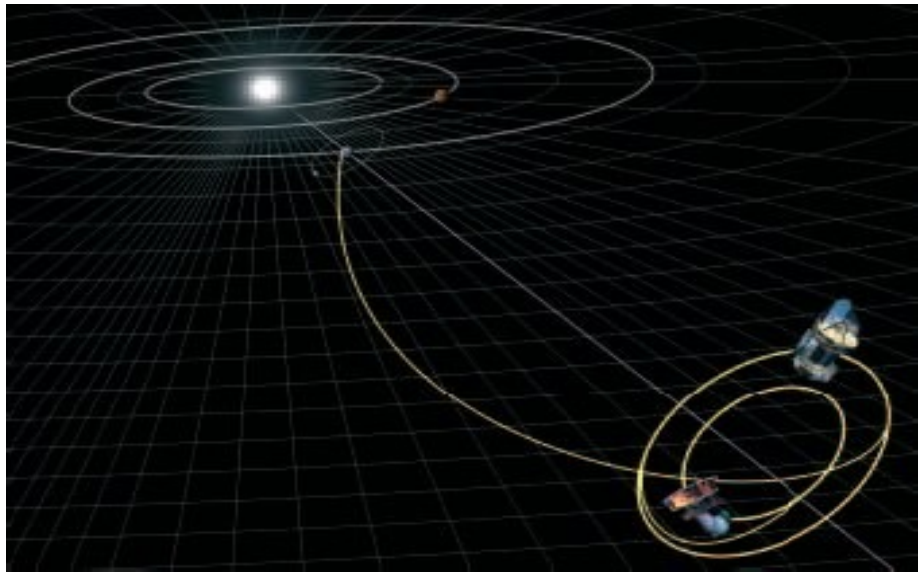


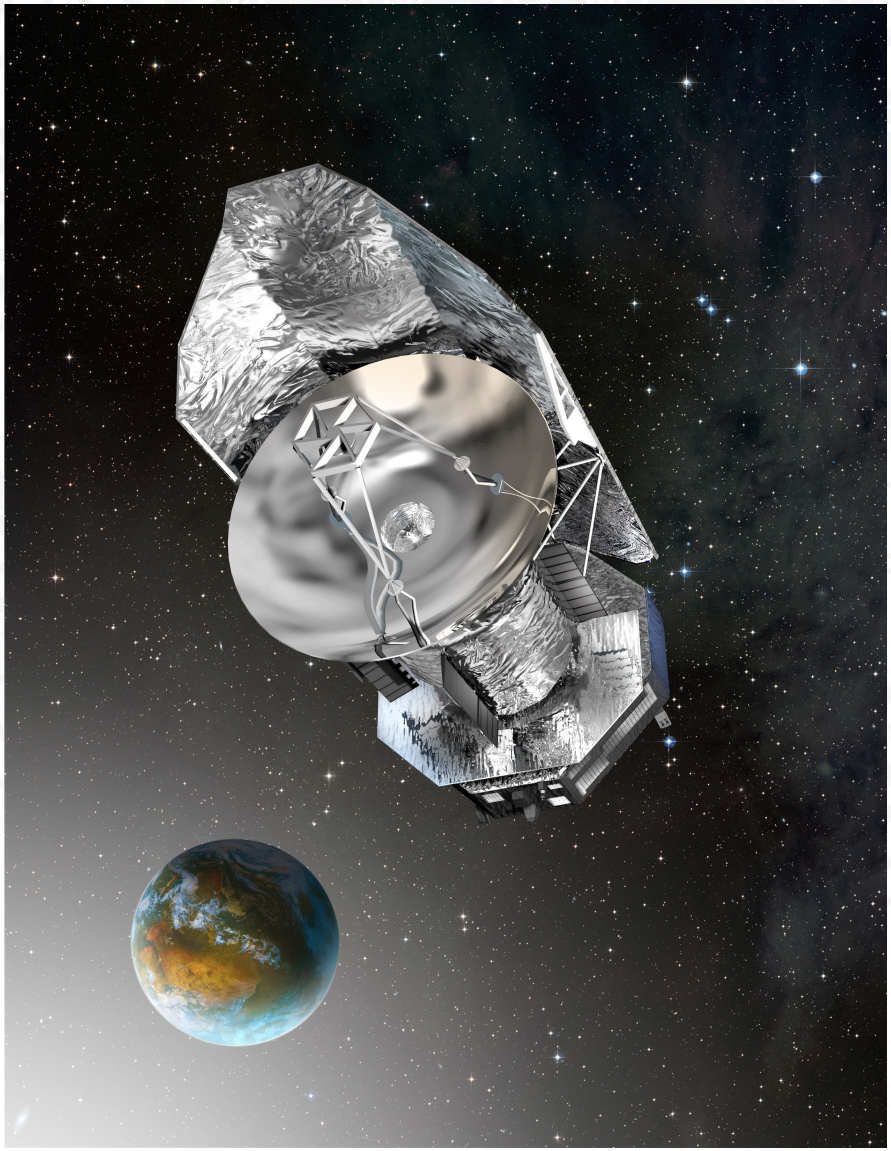
# SOFIA

- 2.7m Telescop onboard a Boing 747
- GREAT-receiver (Köln/Bonn): 1.2 - 4.7 THz

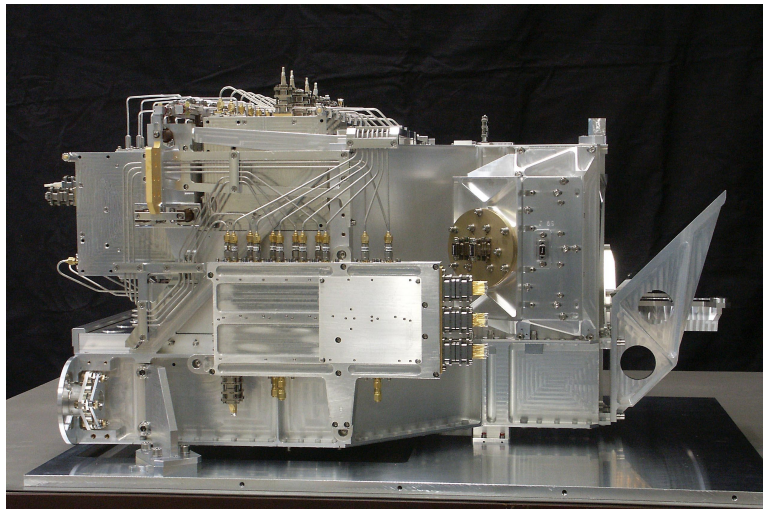
- **Herschel space observatory**

  - Größtes Weltraumtelekop
  - 14. Mai 2009 – 29. April 2013
  - 0.35 - 4.7 THz
  - Orbit im L2 des Erde-Sonne-Systems



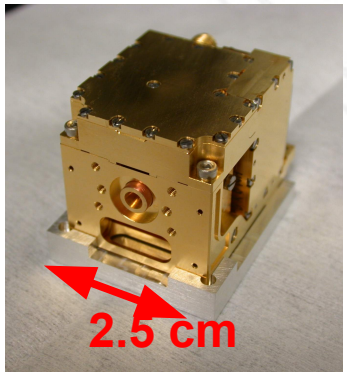


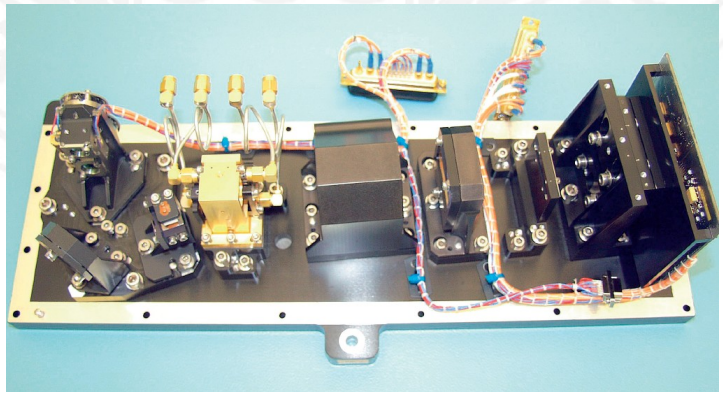
## HIFI-Instrument




Kölner Entwicklungen:

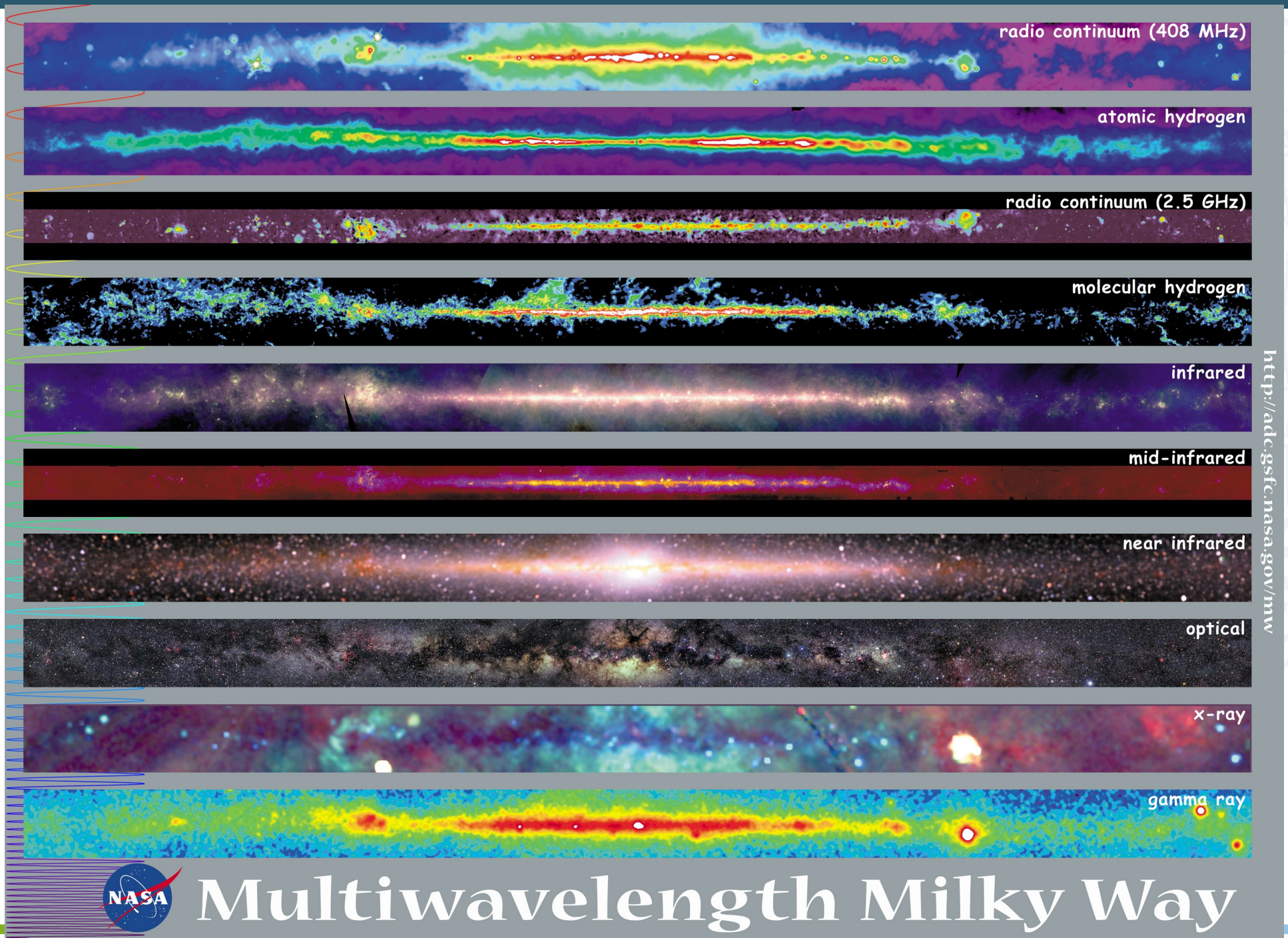
- Hardware:
  Detektoren & Spectrometer
- HIFI-Datenzentrum in Köln



# Ergebnisse

# Was gibt es noch?



# The big picture