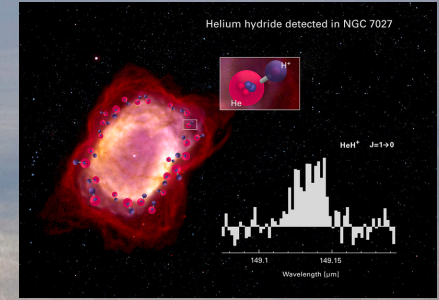




# German Instrument Development Perspective

22-Jun-2020

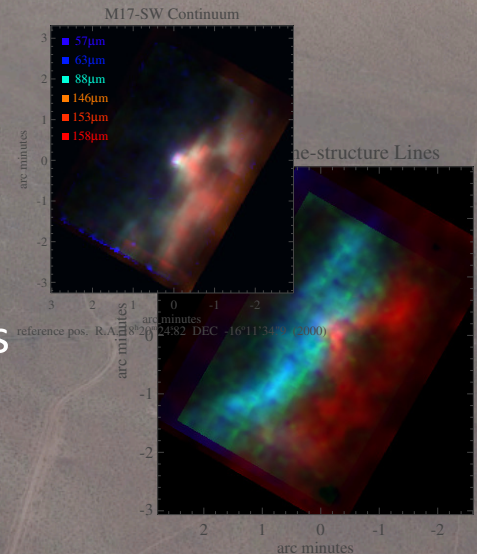


Bernhard Schulz

Deputy Director

SOFIA Science Mission Operations, NASA Ames

Deutsches SOFIA Institut, Univ. Stuttgart





# Overview



German Instrumentation Development  
German Funding Landscape  
SOFIA's Unique Abilities  
Room to Grow





# German Instrumentation Development



- SOFIA Instruments developed in Germany
  - FPI+: Camera 0.36 – 1.10  $\mu\text{m}$ , PI: Jürgen Wolf
    - Science: Occultations, SSOs
    - Permanently installed guider camera on SOFIA
    - **Upgrade options:** Red filter and/or NIR Channel
  - FIFI-LS: IF-Spectr. 51 – 200  $\mu\text{m}$ , R = 600 – 2,000, PI: Alfred Krabbe
    - Science: Star Formation, ISM, PDRs [OI], [OIII], [CII], [NII], ... extragalactic
    - Became SOFIA facility instrument
    - Atm. water vapor characterization essential, resolved by self calibration
    - **Upgrade options:** Detectors (KIDs) and more pixels (factor  $\sim 10$ )
  - GREAT: Heterodyne Spectr. 63 – 612  $\mu\text{m}$  (0.49-4.74 THz) 7 bands, R =  $10^6$  –  $10^8$ , PI: Jürgen Stutzki
    - Science: ISM, PDRs, hi-res. mol. spectroscopy, ... mostly galactic
    - PI Instrument, highly successful complex cutting edge modular design
    - Fully exploits SOFIA's unique possibility of continuous technology upgrades
    - **Upgrade options:** More detectors (7 add. HFA pixels, Super GREAT), additional bands (28 $\mu\text{m}$ )





# German Funding Landscape



- German SOFIA Funding Model
  - DLR funds SOFIA operations
  - Main instrument funding sources:
    - DFG (Deutsche Forschungsgesellschaft) who fund Universities
    - MPG (Max Planck Gesellschaft)
- Timing issue since NASA declared end of SOFIA prime mission
  - Instrument development until first observing campaign takes 5-6 years
  - NASA requiring senior review (cancellation review) every 3 years prevents long-term perspective for funding agencies
- Many capable German institutes who can build infrared instruments
- MoU between NASA and DLR will be renewed this year
- → a stipulation for a longer operational period beyond a senior review (3+3 year solution) would remove that tension





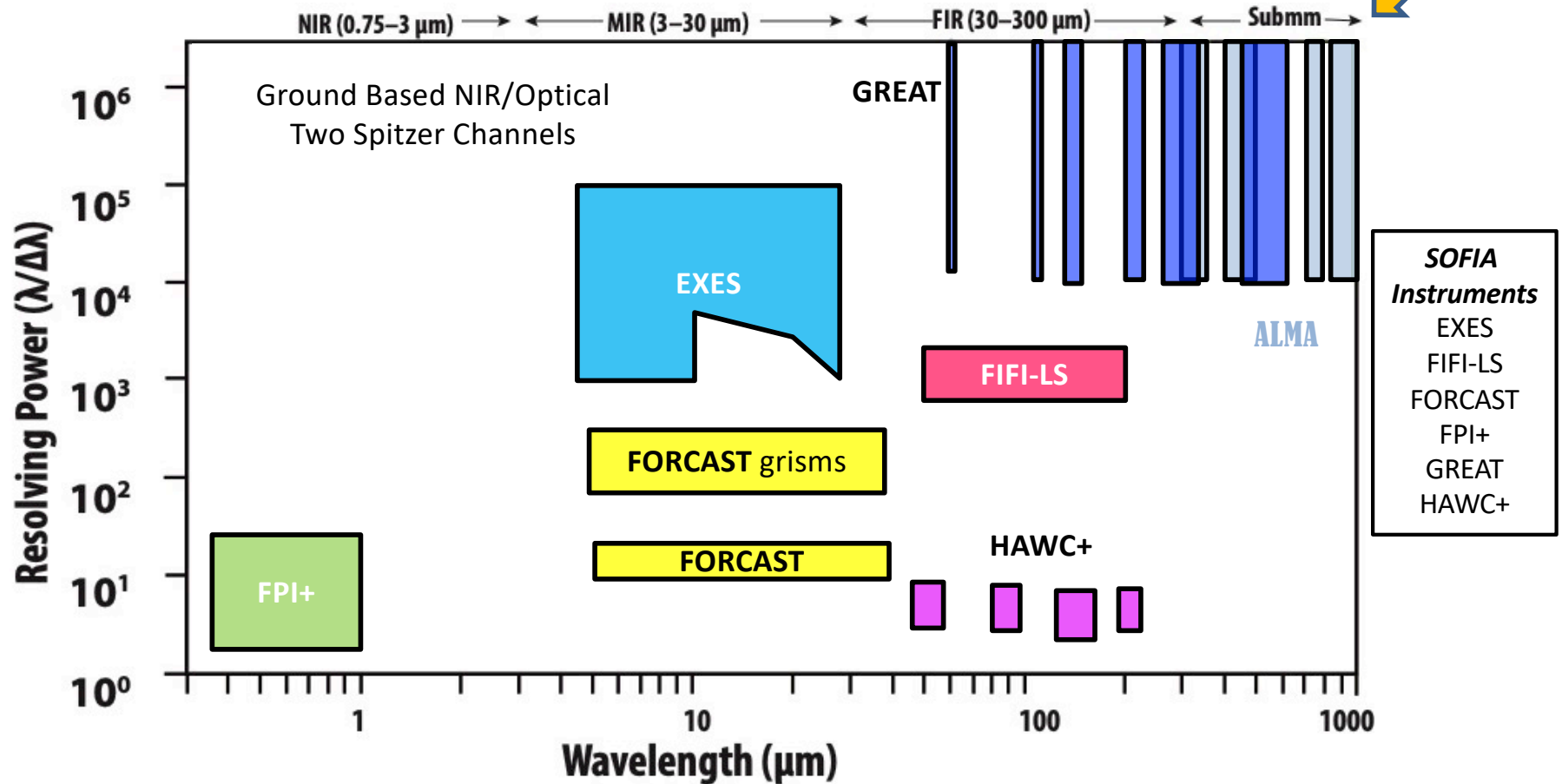
*German funding is available  
provided  
the SOFIA lifetime outlook  
fits the project*





# Science Instruments on SOFIA

synergy with ALMA



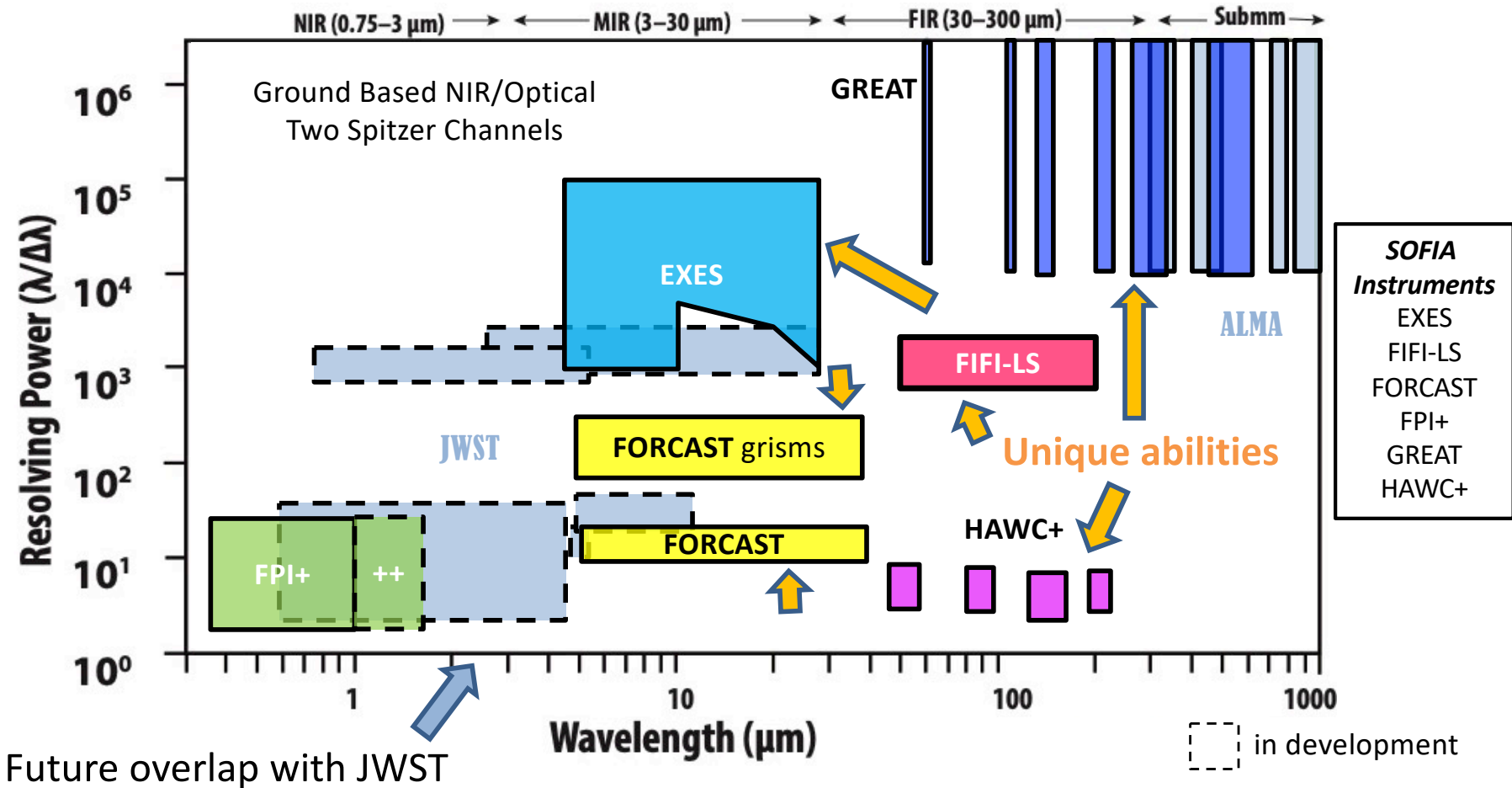
- SOFIA Instruments**
- EXES
  - FIFI-LS
  - FORCAST
  - FPI+
  - GREAT
  - HAWC+

ALMA Atacama Large Millimetre Array (Chile)





# Science Instruments on SOFIA



**ALMA** Atacama Large Millimetre Array (Chile)  
**JWST** James Webb Space Telescope (in development)





*A core strength of SOFIA lies in  
high resolution spectroscopy*







# SOFIA Is Unique



- Access to Mid- and Far-Infrared
  - No satellite mission beyond  $28\mu\text{m}$  within the next decade
  - Unlike many balloon experiments the instruments are returned safely
  - Flexible and comprehensive instrument suite
- Fast turn-around for new instruments
  - State of the art technology (allowable to have “problems”)
  - Instrument access in flight
  - Broken instruments can be repaired and flown again
- World-wide access
  - Northern and Southern hemisphere
  - Occultations





# Room to Grow



- SOFIA instrumentation can always be improved
- Increase wavelength coverage
  - 40-50 $\mu$ m and more Heterodyne bands
    - science demand? Ideas?
- Add other observing modes
  - spectral resolution, polarimetry...
    - science demand? Yes! Ideas?
- Increase sensitivity
  - Better detectors for high resolution spectroscopy
    - some improvement
  - More detectors for rapid spectral mapping
    - big potential
    - Mapping time shrinks linearly
    - 8 arcmin Focal Plane





# Pixels in SOFIA Focal Plane



	<b>Telescope Diameter [m]</b>	2.5	
	<b>Focal Plane diameter [arcmin]</b>	8	
	<b>FOV Area [arcsec<sup>2</sup>]</b>	180956	
<b>wavel.</b>	<b>FWHM</b>	<b>Pixel area*</b>	<b>Pixel number</b>
<b>[micron]</b>	<b>[arcsec]</b>	<b>[arcsec<sup>2</sup>]</b>	
40	3.4	2.9	62642
60	5.1	6.5	27841
120	10.2	26.0	6960
160	13.6	46.2	3915
300	25.5	162.5	1114

\* use >Nyquist sampled pixel size

More pixels reduce integration time linearly

More pixels in spectral direction effect similar savings in integration time

There are no large detector arrays for the FIR or Submm!



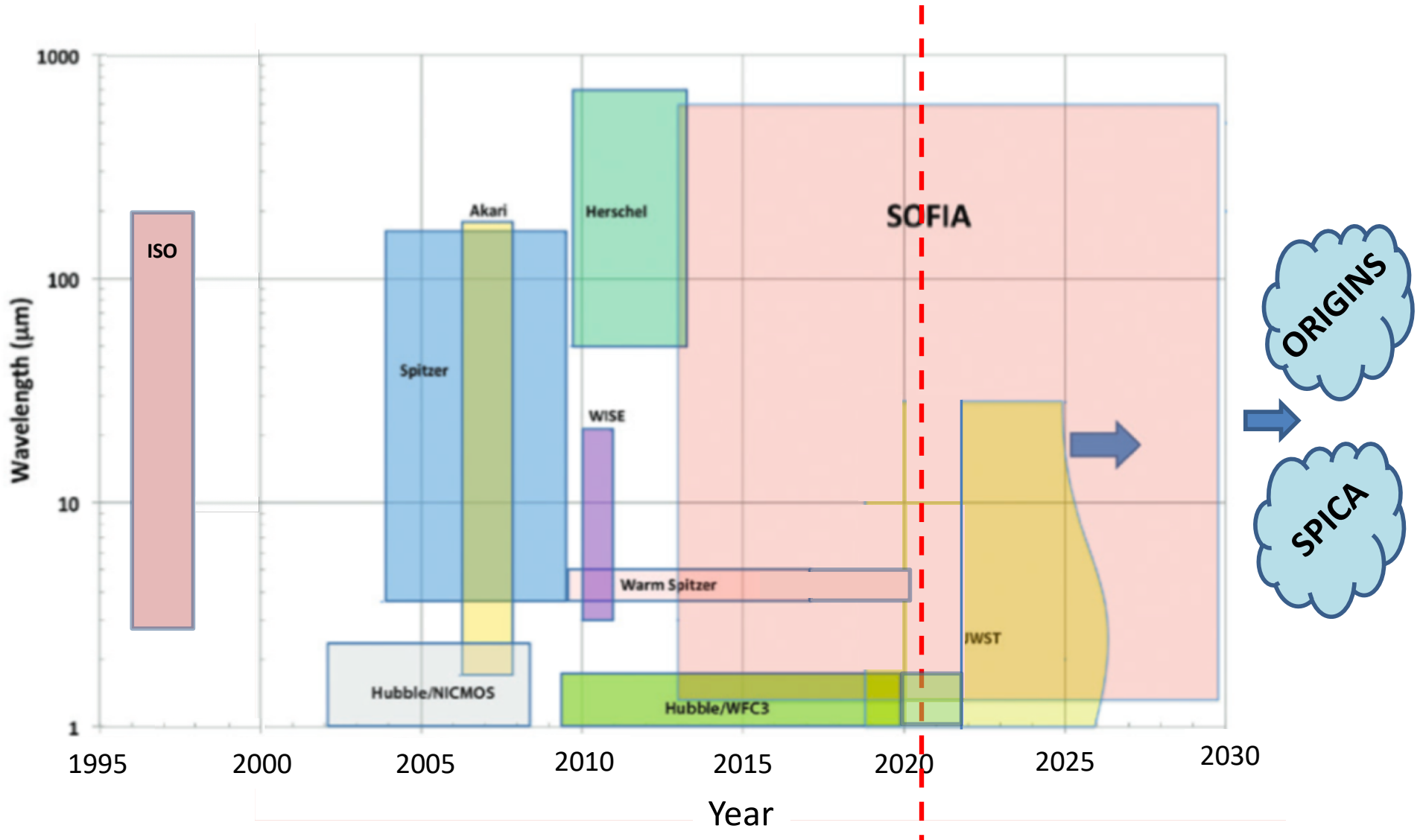


*Infrared Astronomy needs a dedicated  
detector development program*





# Mid-/Far-IR Observatories in Time





# *The Sky is Wide Open*



*Syd Myers @ 2019*

