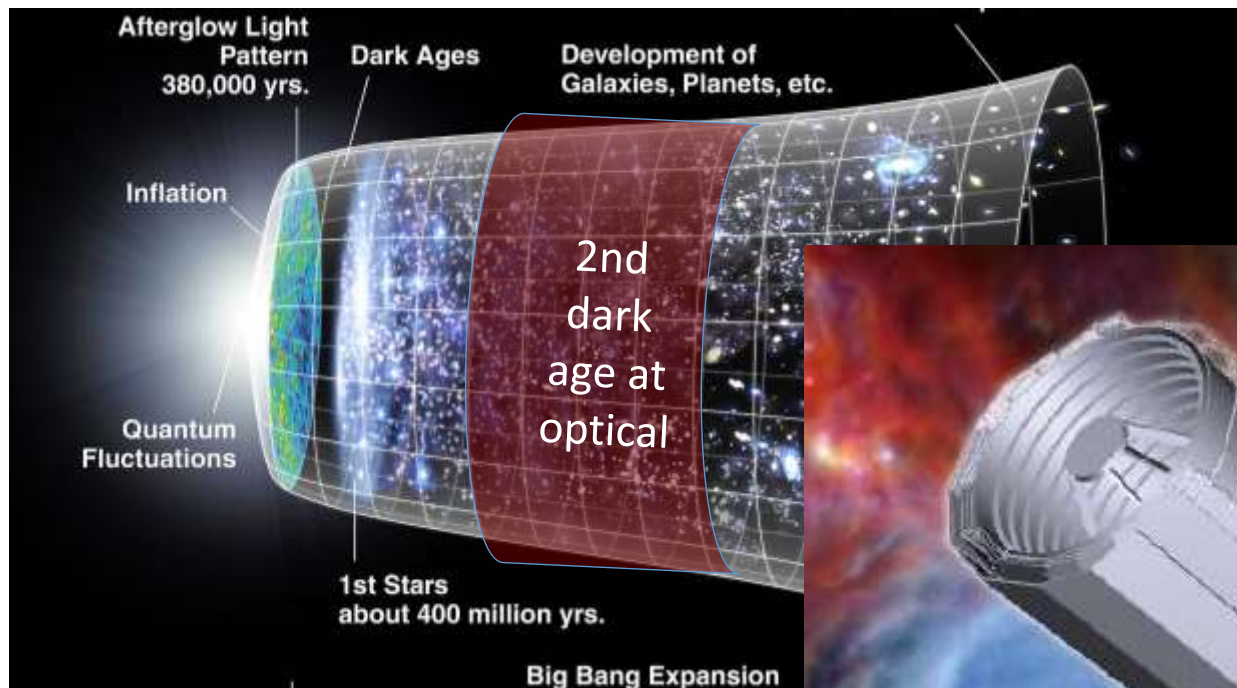


# 次世代赤外線天文衛星SPICA: 日欧共同詳細検討結果

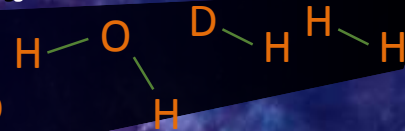
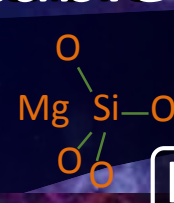
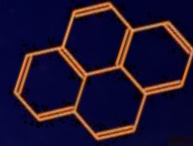
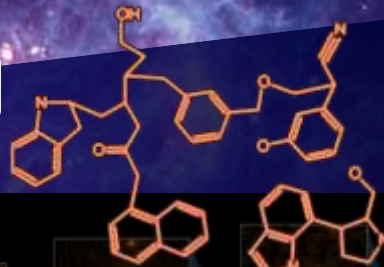
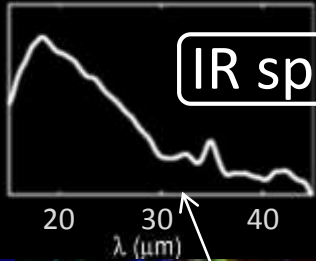
芝井 広(大阪大)、中川貴雄、松原英雄、川勝康弘(JAXA)、  
尾中 敬(東京大)、金田英宏(名古屋大)、他SPICAチーム

(日本の中間赤外線観測装置については次の講演参照)

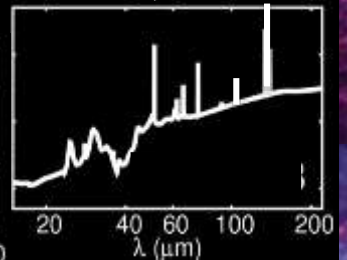
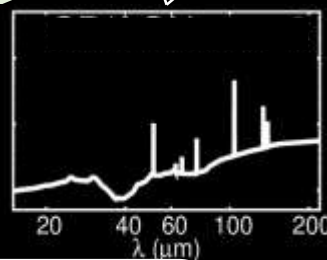
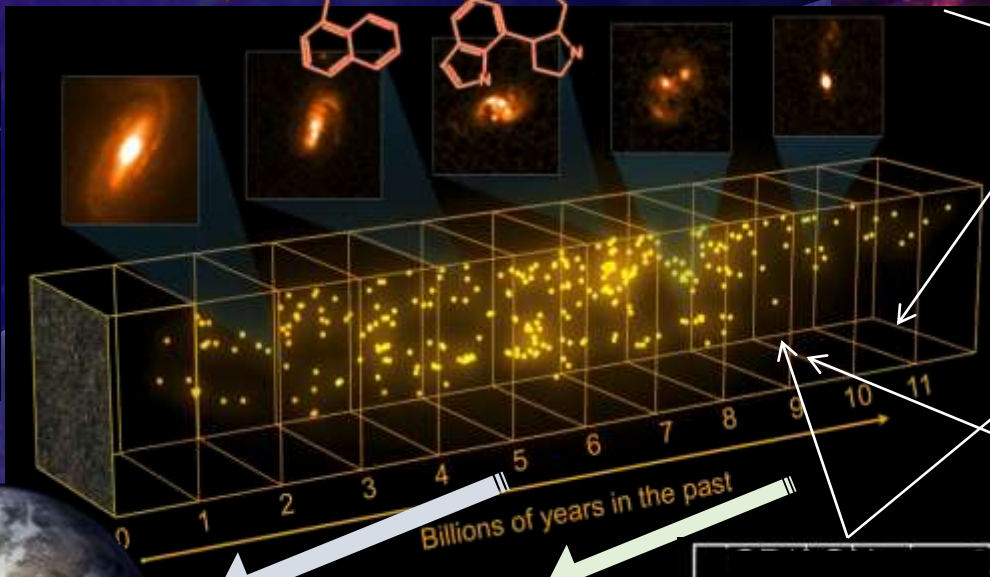
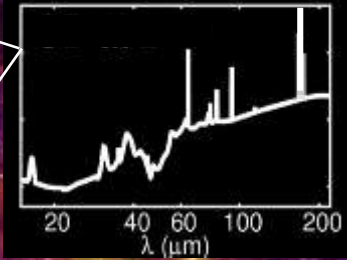


# When and How did our Universe become Material-rich and Habitable?

IR spectroscopy



IR spectroscopy



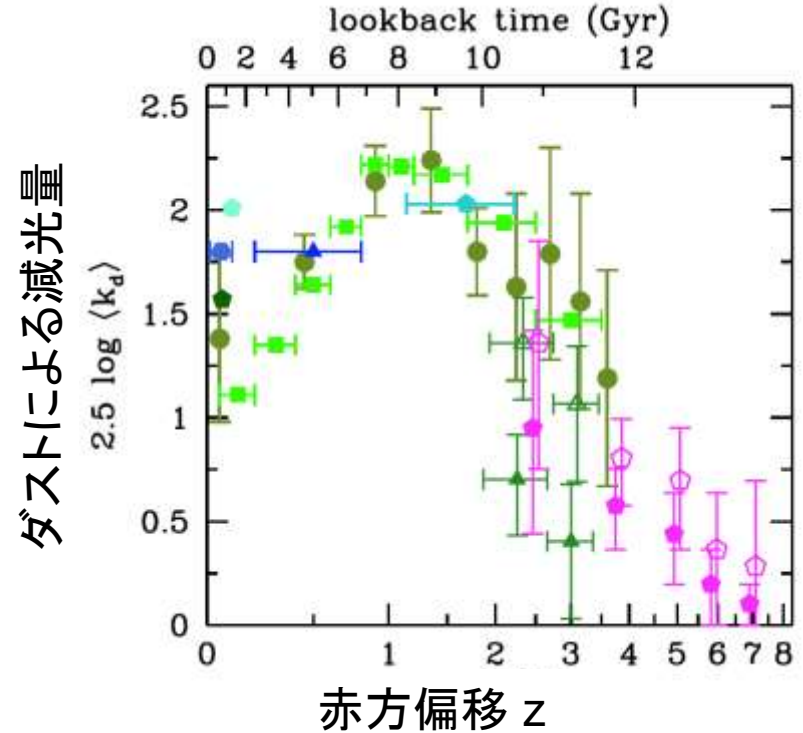
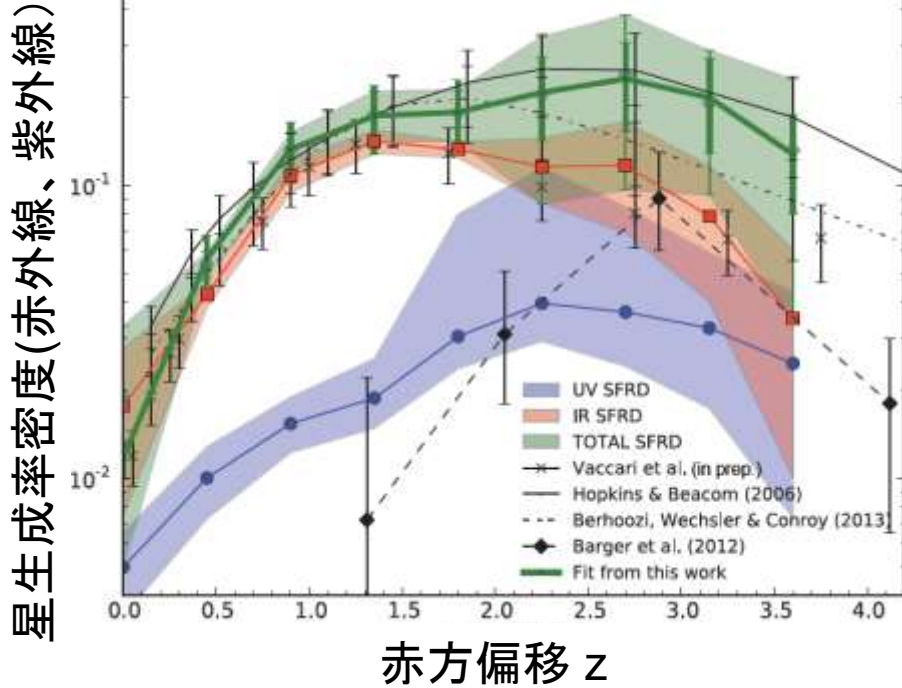
◆ Present: various targets to probe H<sub>2</sub>, H<sub>2</sub>O, mineral & planet-forming environments.

◆ 5-11 billion years ago: material enrichment through galaxy evolution.

◆ >12 billion years ago: first formation of mineral & organic matter.

# 「銀河成長最盛期」の特徴： ダストに隠された星形成の割合が高い

Burgarella et al. 2013, A&A, 554, 70



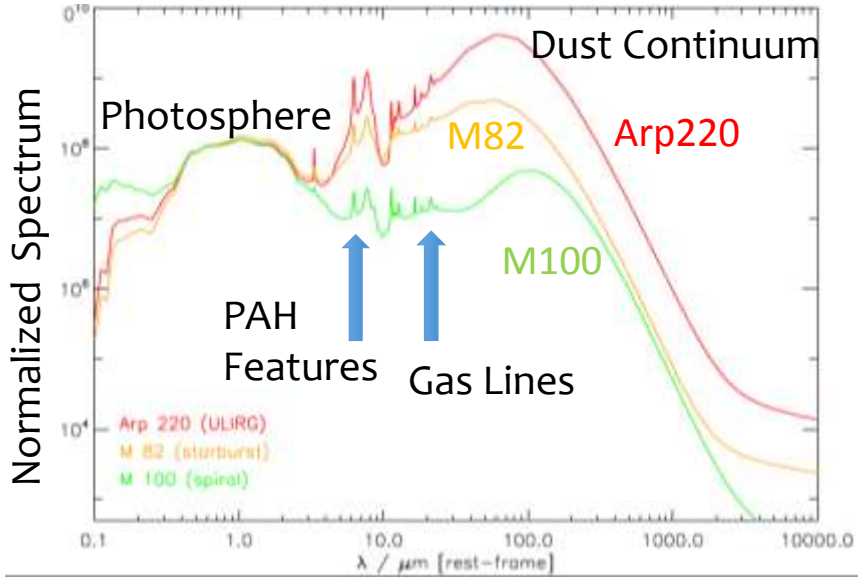
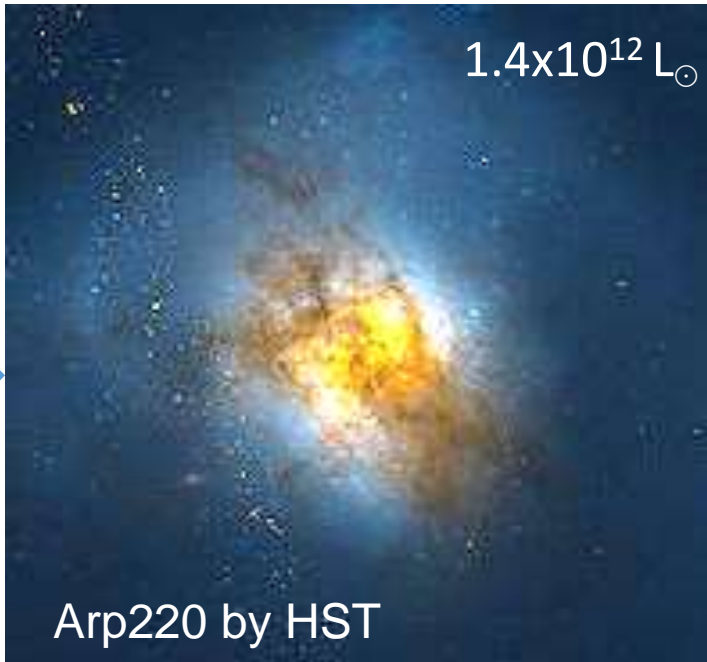
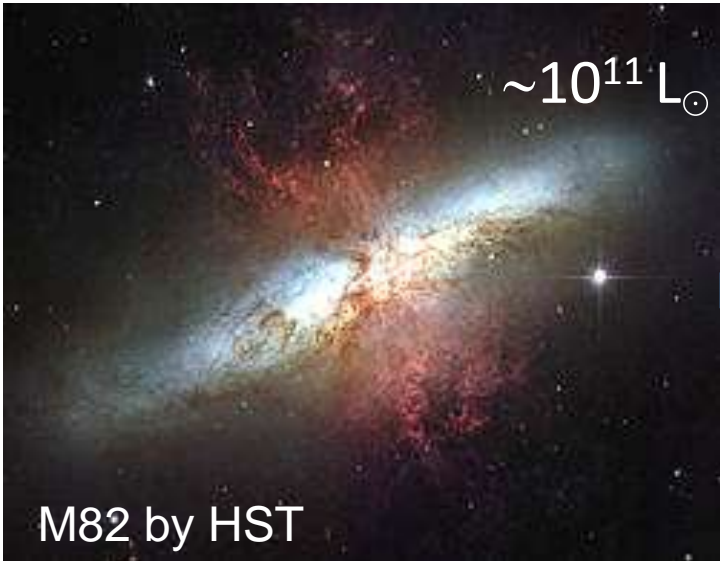
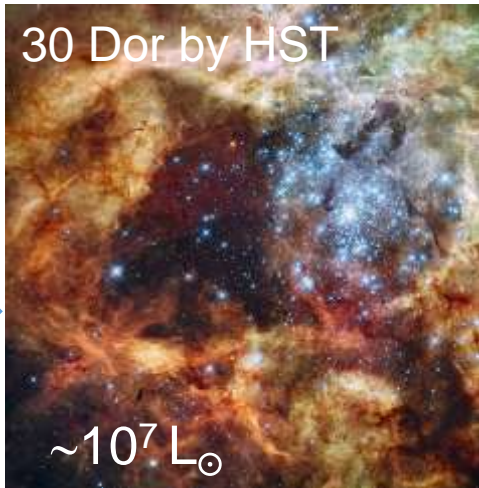
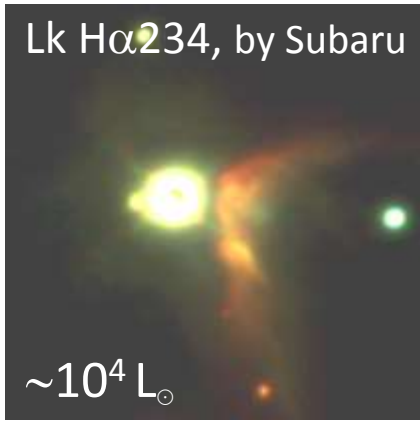
- Spitzer、「あかり」、Herschelの観測より。
- $z=1-3$ でピーク(“銀河成長最盛期”)。
- この「銀河形成最盛期」に、ダストによる減光量もピークを迎えている。

この高い赤外線光度は何が担っているのか？巨大ブラックホールへの質量降着(AGN)からの寄与はどれほどか？

Madau & Dickinson 2014

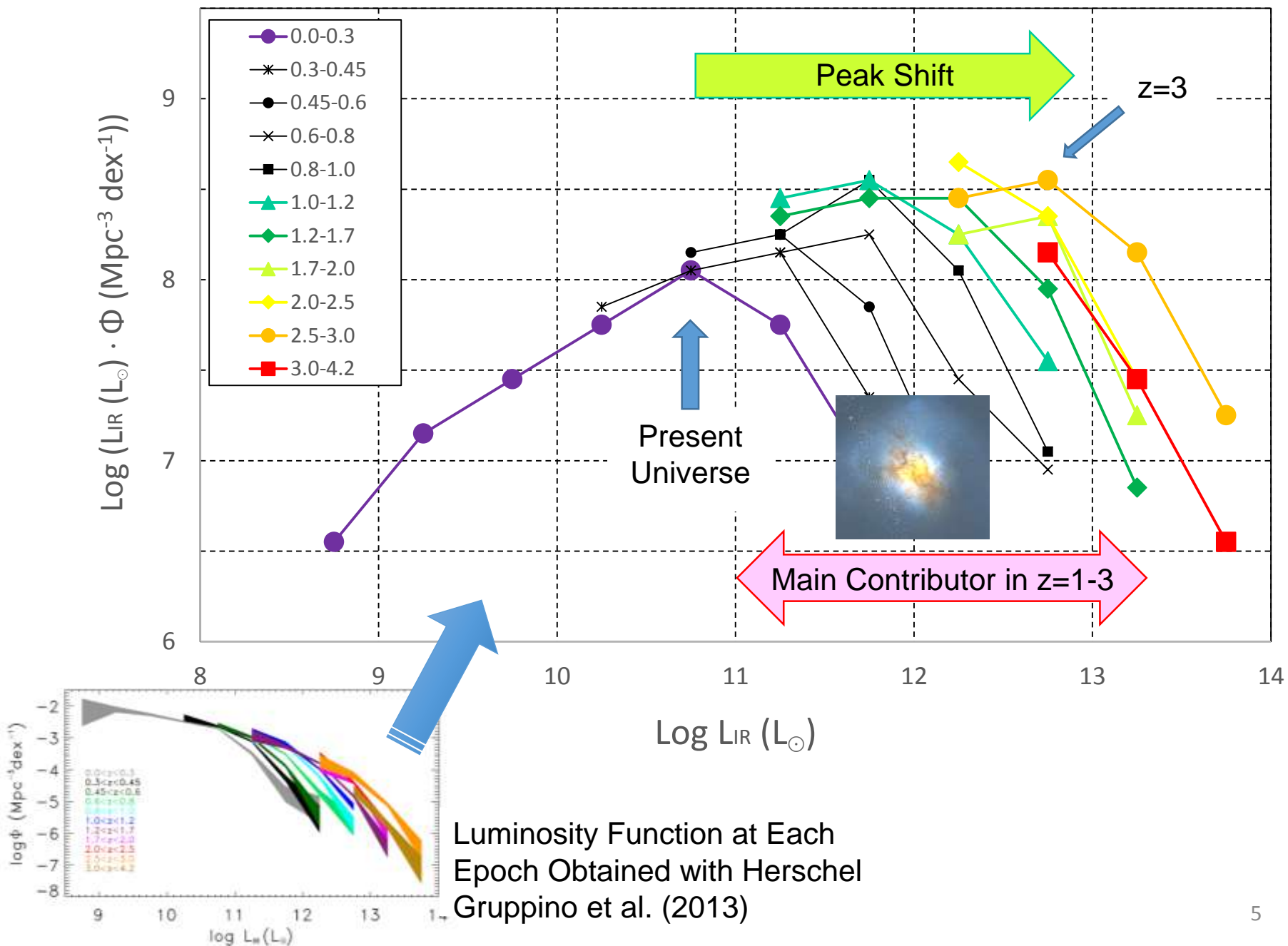
上の図では、AGNの寄与はSEDモデルにより差し引き。  
→ 図の誤差棒に現れない不定性要因。

# Star Forming Regions of Various Scales

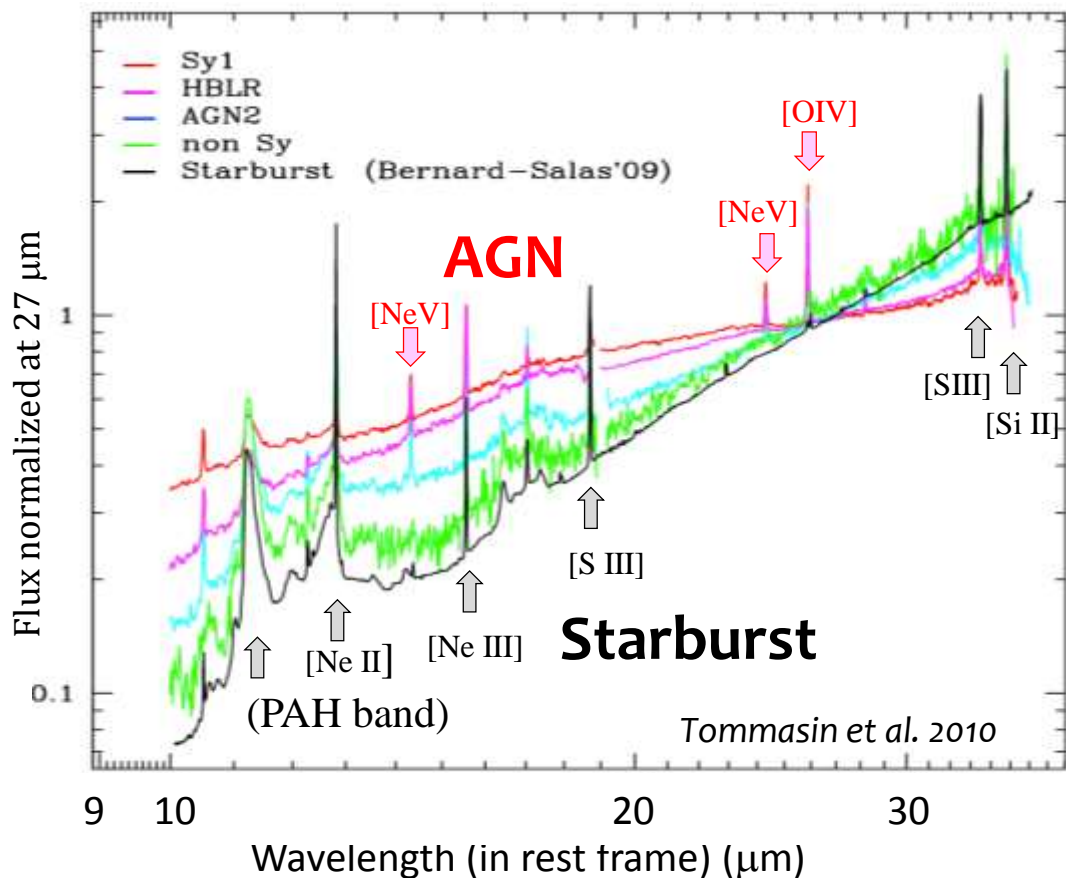


10 kpc

# Luminosity Evolution of Main Contributor in Each Epoch

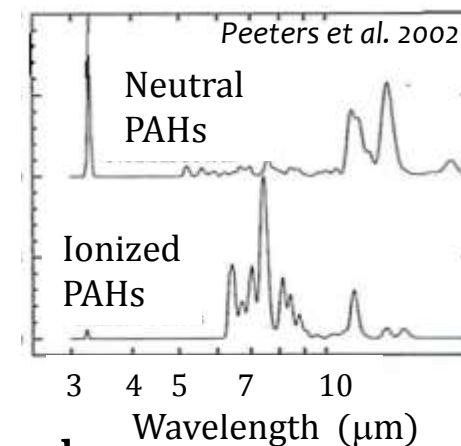
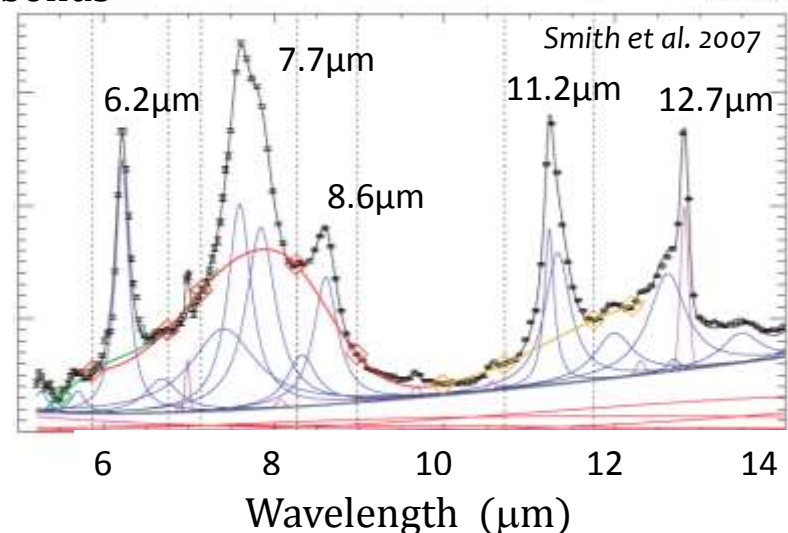
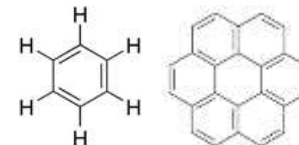


# Gas Lines and PAH bands as a diagnostic tool of SF Activity



## PAH (polycyclic aromatic hydrocarbons)

Broad emission features originated from C-C and C-H bonds



Relative Strength of PAH bands is an indicator of SF activity strength.

**Merit of PAH bands:**  
stronger than gas lines

[Ne V], [O IV] are robust tracer of AGN; hard radiation field.

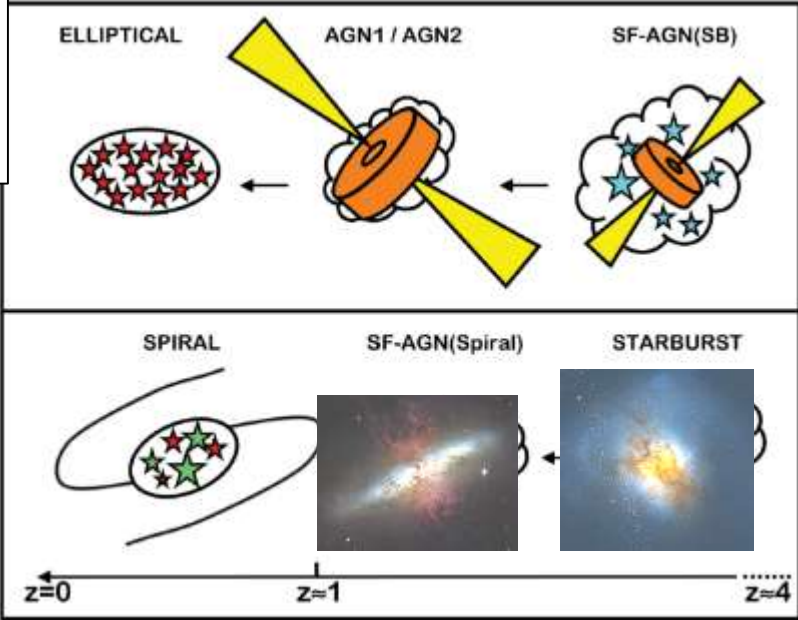
[Ne II] [S III], [O III], [N III], etc.: tracer of gas density, temperature, metallicity of SF galaxies.

### Merit of Gas Lines:

simple excitation physics → reliable estimate of physical conditions of SF activity.

# Interplay of Galaxies/AGNs, Stars, and Materials

## Galaxy Evolution



How Galaxies made Stars/Planets and Materials During Their Growth in  $z=1-3$ ? (Mass-Production Factory)

Did AGN accelerate or decelerate production?

Did Heavy Elements accelerate production? How much?

Element/  
Material  
Production

Interstellar  
Clouds

Trigger

Cooling by Heavy Elements

Life?

Stars/Planets

**Star/Planet  
Formation**

AGB  
SNe

Supply of Heavy Elements  
Supply of Solid Materials

O C N  
Fe Si Mg

H, He  
from  
IGM

Silicate  
Ice,,,,,

PAH

CO  
H<sub>2</sub>O  
etc,

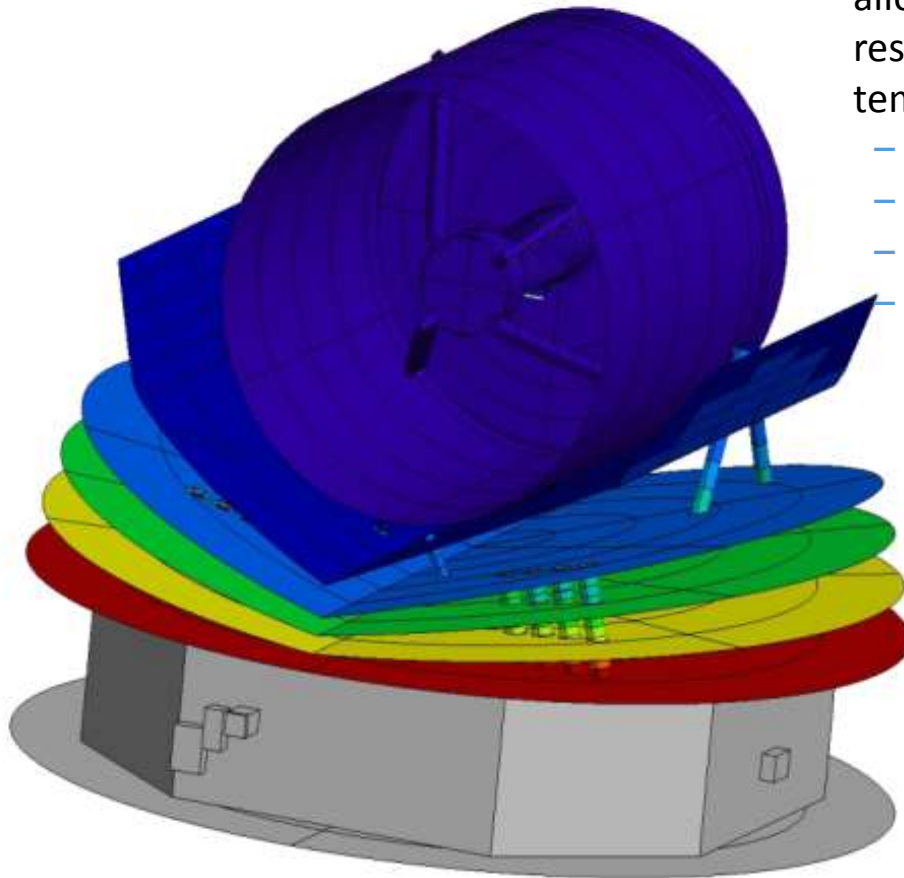
# PLAN-D (New SPICA)検討状況

1. ESA-JAXA共同技術検討
  - ・ **技術的、かつ規模的に実現可能な**、次世代極低温冷却赤外線望遠鏡の参照モデルが得られた。
  - ・ 両機関それぞれの規模枠に収めるため、日欧の**役割分担を再調整**した。
  - ・ ベースラインは、望遠鏡有効**口径2m**、**温度6K**以下冷却する「横置き」構造。
2. 欧州遠赤外装置(SAFARI)がFourier分光から**Grating分光**に変更(最終決定待ち)。**米国有力研究者が正式参加**。
3. 日欧研究者の合意
  - ・ コミュニティー、ボトムアップの支援(光赤天連、コアサイエンスチーム)
  - ・ **コアサイエンス**を一層明確化して日欧宇宙機関にミッション提案。
  - ・ **口径2.5m**、**温度8K**が必要。  
(来週、Utrechtで日欧合同の全体会)
  - ・ 系外惑星トランジット観測可能性の検討
4. 今後の予定
  - ・ JAXA側 **今夏 ΔMDR+SRR相当(国際)審査+計画変更審査**。
  - ・ ESA側 今年募集開始予想の**M5**に提案。
  - ・ **2025年度打ち上げ**。



# Results- Temperature Levels

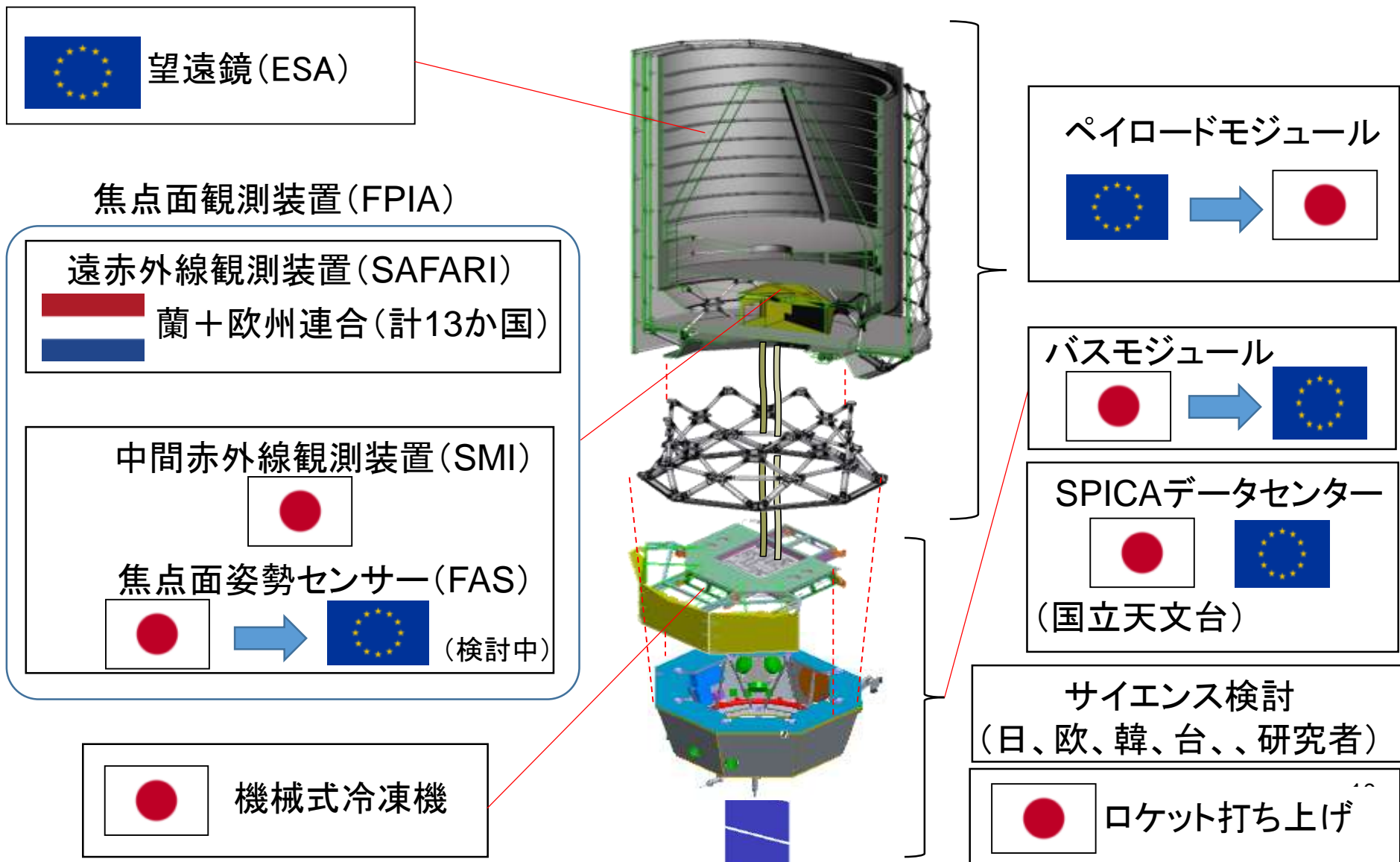
Attribute: Temperature



- parasitic heat load from harness has been considered
- allocations are based on latest available SPICA results, accounting for the difference in temperature levels and taking 100% margin
  - heat load on 1<sup>st</sup> V-groove: 1000 mW
  - heat load on 1<sup>st</sup> V-groove: 1000 mW
  - heat load on 3<sup>rd</sup> V-groove: 400 mW
  - heat load on shield: 70 mW

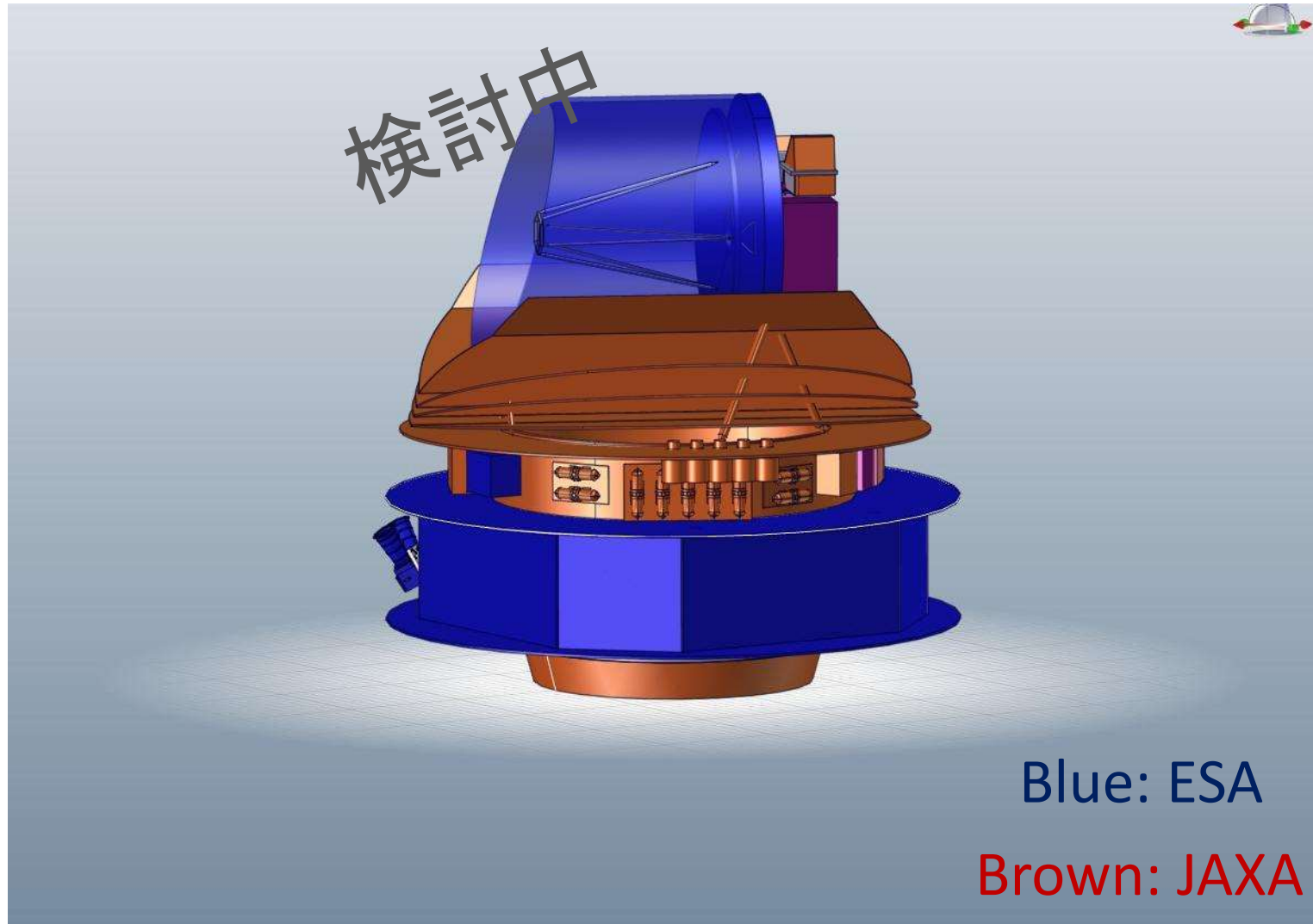
- |                            |                |
|----------------------------|----------------|
| • <b>STA baffle</b>        | <b>&lt;5 K</b> |
| • shield (top side)        | 21 K           |
| • 3 <sup>rd</sup> V-groove | 54 K           |
| • 2 <sup>nd</sup> V-groove | 109 K          |
| • 1 <sup>st</sup> V-groove | 161 K          |
| • SVM (top side MLI)       | 243 K          |
| • SVM                      | 273 K          |

# PLAN-Bでの役割分担 → 新分担案



# Extended PLM + SVM Configuration

Technically Feasible and Financially Affordable  
as a Collaborative Mission by Both Space Agencies



# New SAFARI concept with grating

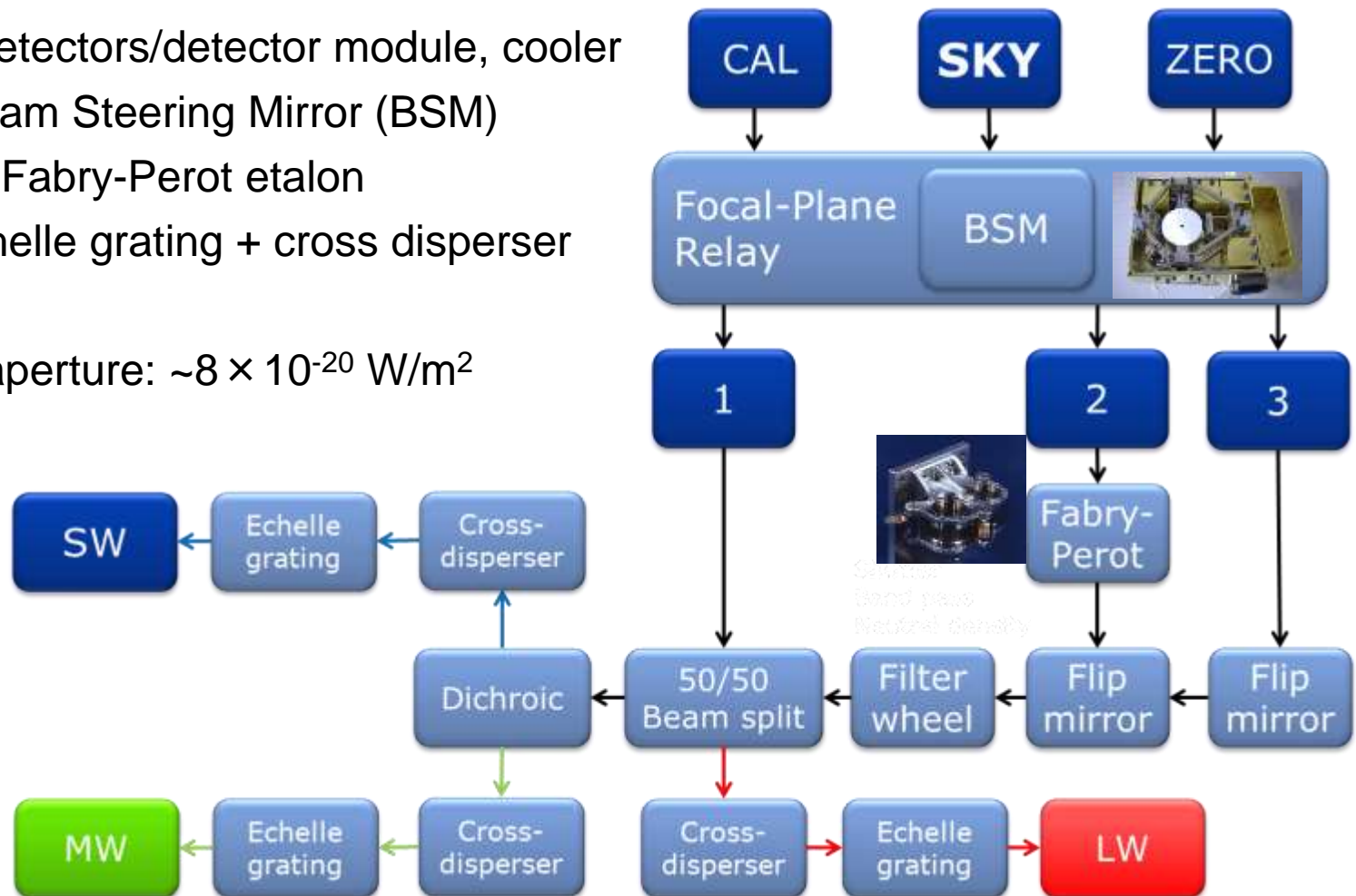
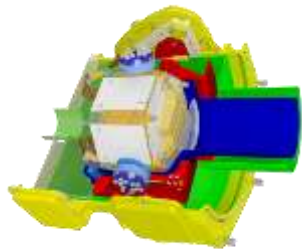
Likely to be achievable with SAFARI consortium

Heritage:

- SAFARI detectors/detector module, cooler
- SPIRE Beam Steering Mirror (BSM)
- ISO/SWS Fabry-Perot etalon
- BLISS echelle grating + cross disperser

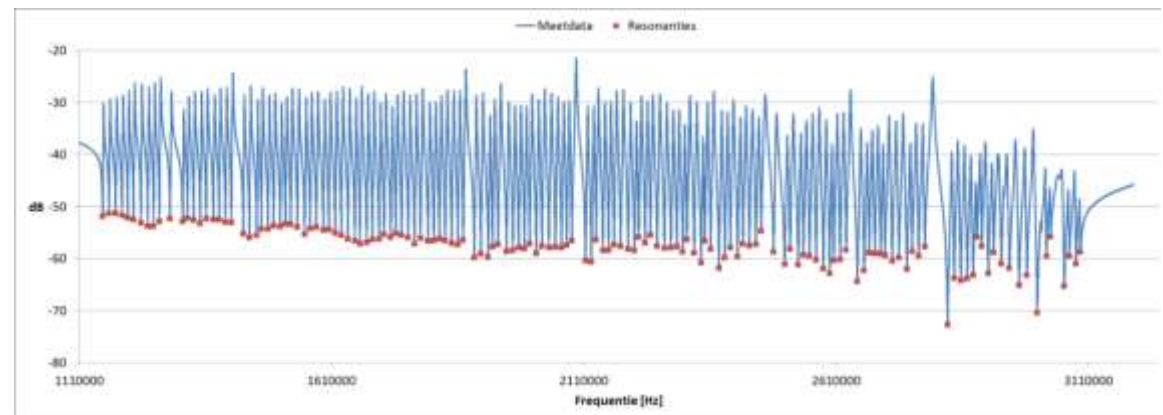
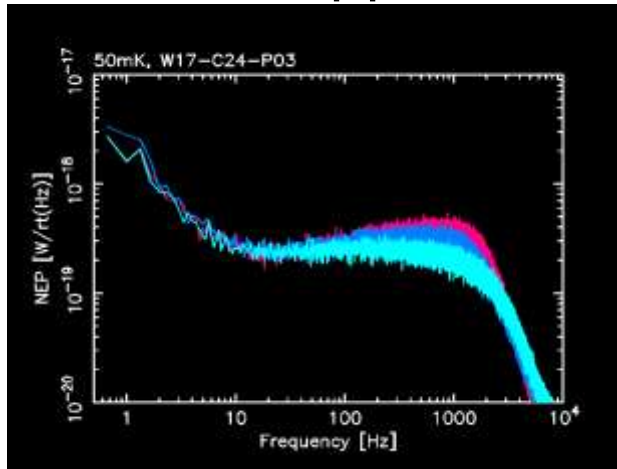
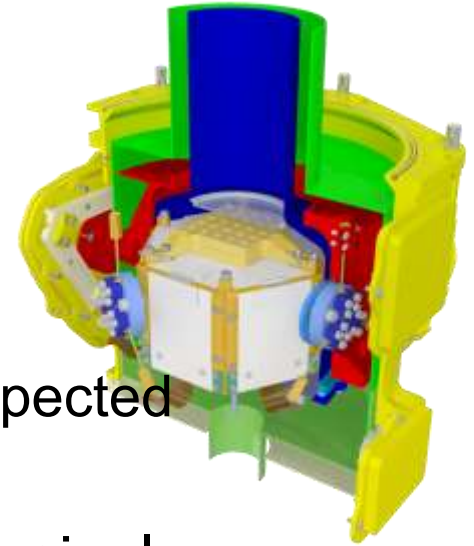
Sensitivity:

- For 6 m<sup>2</sup> aperture:  $\sim 8 \times 10^{-20}$  W/m<sup>2</sup>



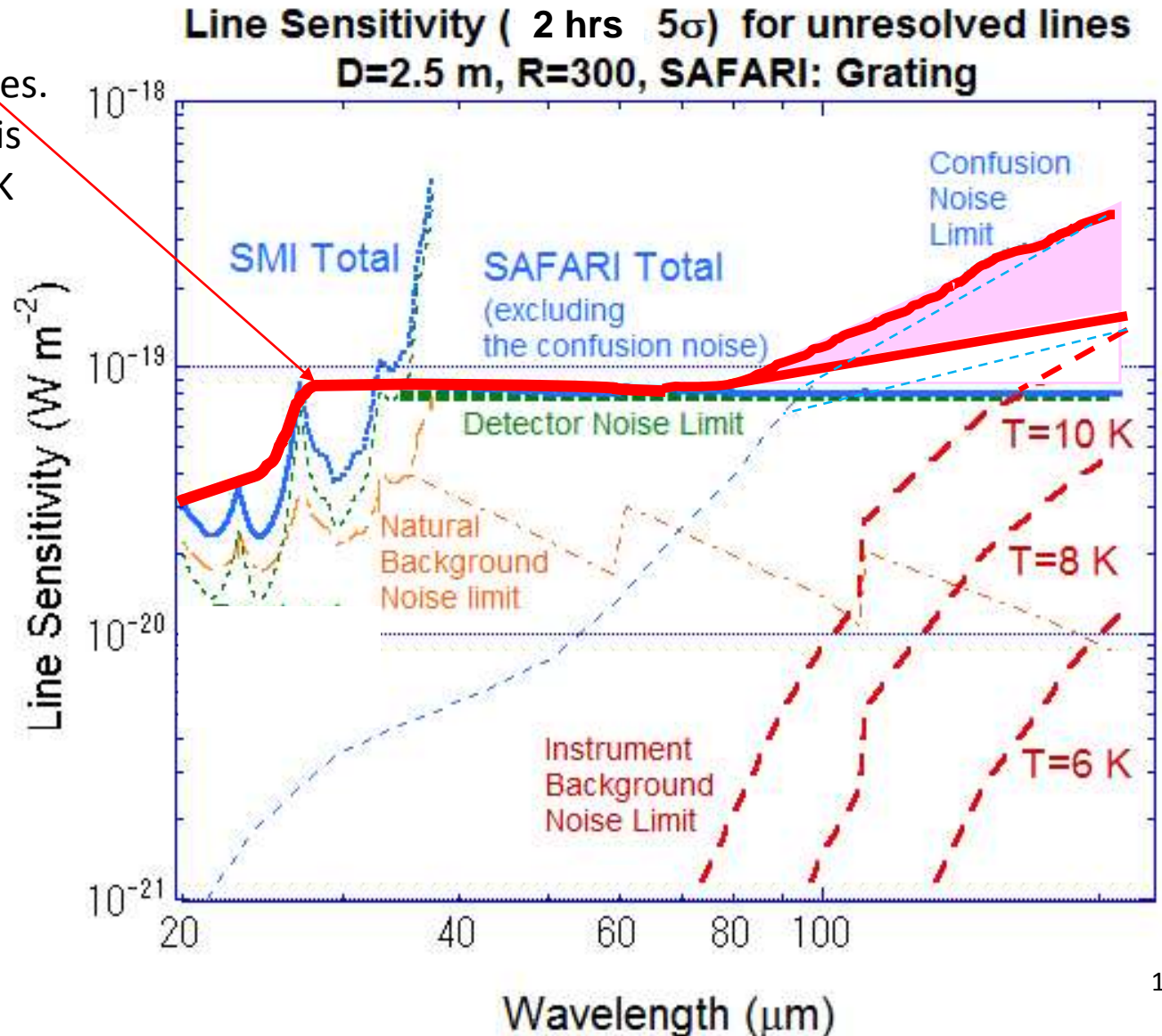
# Performance of TES and Electronics

- $2.5 \times 10^{-19} \text{ W/Hz}^{1/2}$  demonstrated in the lab.
- Cambridge 388-pixel LW array measured
- SRON 64 and 72-pixel SW arrays measured
- $20 \times 20$  SW array fabrication demonstrated
- Measured optical efficiency  $\sim 60\%$   $\rightarrow >80\%$  expected
- 160 pixels/channel FDM demonstrated
- Design well established – thermal, mechanical, EMC/magnetic shielding (SAFARI/ATHENA FPA)  
 $\rightarrow$  all applicable to Grating based spectrometer



# 予想スペクトル線検出感度

- SAFARI (Grating)
  - Detector Noise dominates.
  - Telescope temperature is required to be below 8 K
- SMI-Spec
  - Read-out Noise of the detector array dominates.



# SMI R50 1deg<sup>2</sup> blind survey + SAFARI-grating follow-up

Obs. time: SMI-Cam (R50) = 42days (10hrs/field x100, 1 field = 6' x 6', sensitivity based on 2.5 m telescope).  
 Detectable with 10 hrs exp. for the 1 deg<sup>2</sup> area.

z	0-1	1-1.5	1.5-2	2-2.5	2.5-3	3-4	>4
<b>PAH galaxies total</b>	<b>1833</b>	<b>3060</b>	<b>3978</b>	<b>2499</b>	<b>1733</b>	<b>549</b>	<b>60</b>
Log <sub>10</sub> L <sub>IR</sub> / L <sub>sun</sub>							
>13	0	2	9	25	46	23	20
12.5 – 13.0	6	65	159	258	313	161	40
12.25 – 12.5	26	182	351	351	356	175	0
12.0 – 12.25	89	552	552	540	484	146	0
11.75 – 12.0	219	779	812	652	404	44	0
11.5 – 11.75	415	988	1031	540	135	0	0
11.0 – 11.5	1018	599	1114	141	0	0	0
<11	60	0	0	0	0	0	0
Galaxies for gas line diagnosis	12447	5428	3005	2012	1506	386	N.A.

Typical Galaxies to be Diagnosed

# SMI R50 $1\text{deg}^2$ blind survey + SAFARI-grating follow-up

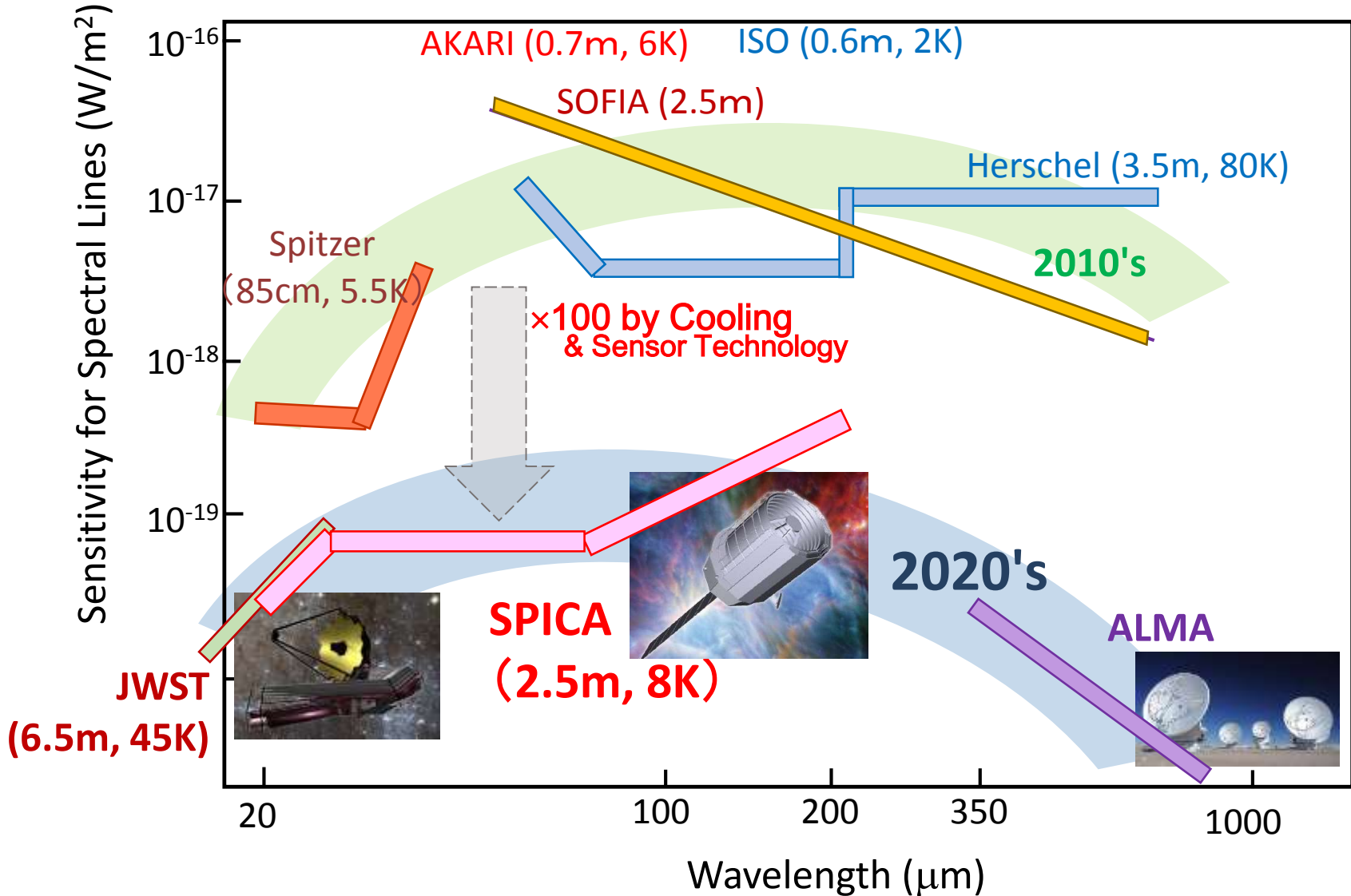
Obs. time: SMI-Cam (R50) = 42days (10hrs/field x100, 1 field = 6' x 6', sensitivity based on 2.5 m telescope). **SAFARI: sensitivity  $8 \times 10^{-20} \text{ W/m}^2$  (2 hr, 5  $\sigma$ ). Detectable with **10 hrs exp.** for the **1 deg<sup>2</sup>** area.**

z	0-1	1-1.5	1.5-2	2-2.5	2.5-3	3-4	>4
PAH galaxies total	1833	3060	3978	2499	1733	549	60
<b>Galaxies for gas line diagnosis</b>	<b>12447</b>	<b>5428</b>	<b>3005</b>	<b>2012</b>	<b>1506</b>	<b>386</b>	<b>N.A.</b>
$\text{Log}_{10} L_{\text{IR}} / L_{\text{sun}}$							
>13	0	2	11	30	58	31	0
12.5 – 13.0	8	69	173	280	173	173	0
12.25 – 12.5	34	189	355	427	135	0	0
12.0 – 12.25	120	588	601	501	47	0	0
11.75 – 12.0	316	842	861	628	153	0	0
11.5 – 11.75	658	1259	870	80	0	0	0
11.0 – 11.5	2962	2511	182	0	0	0	0
<11	8349	98	0	0	0	0	0

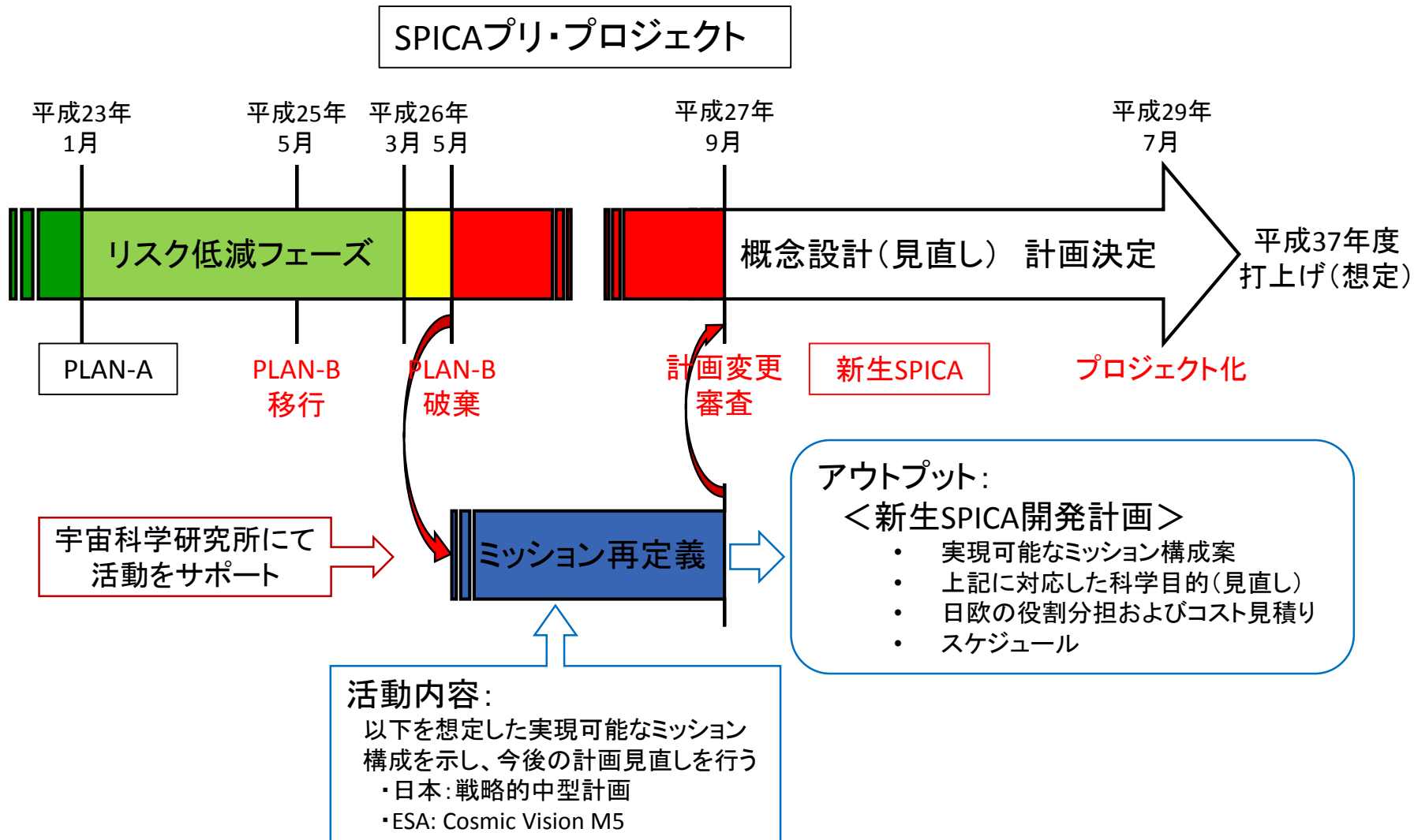
Typical Galaxies to be Diagnosed



# Comparison of Infrared Telescopes



# SPICAミッション再定義のための活動計画 (全体スケジュールの中の位置づけ)



# SPICAプロジェクト実施体制

JAXA、ESAおよび欧州コンソーシアムとの密接な協力で、衛星全体の開発を進める。国内体制としては、JAXA宇宙科学研究所をコアとして、JAXA研究開発本部・環境試験技術センターなどのJAXA内の密接な協力および、国立天文台、国内大学研究機関との密接な協力で開発を進める。特に日本が担当する焦点面観測機器については、大学コンソーシアムが主体となって開発を行う。

