

赤外線天文衛星「あかり」が解き明かす 星間固体物質の進化

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2012年夏の学校: 星間現象分科会

Outline:

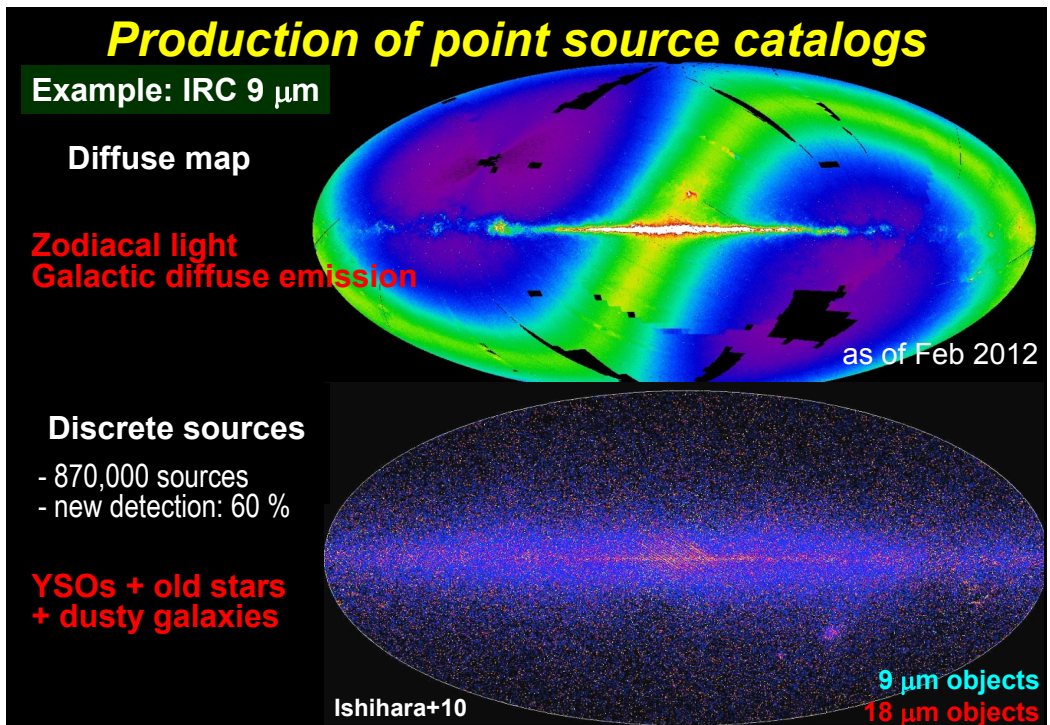
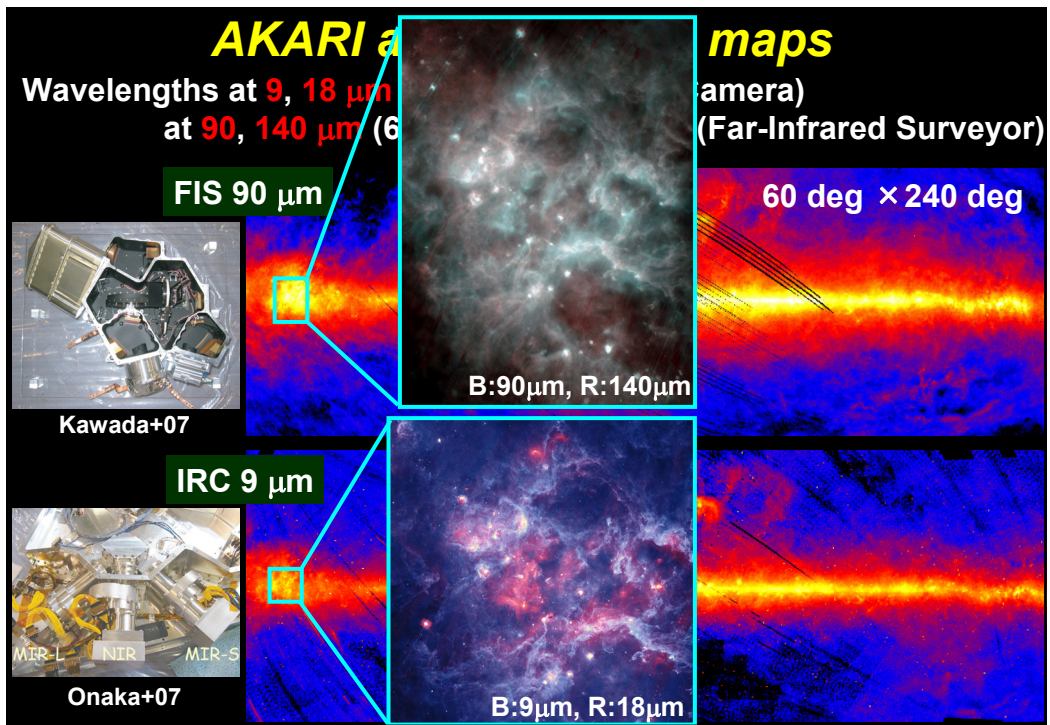
1. 「あかり」と全天観測
2. イメージング観測: 星形成活動
3. スペクトル観測: 物質進化
4. 「あかり」からSPICAへ
5. まとめ

1. 「あかり」と全天観測

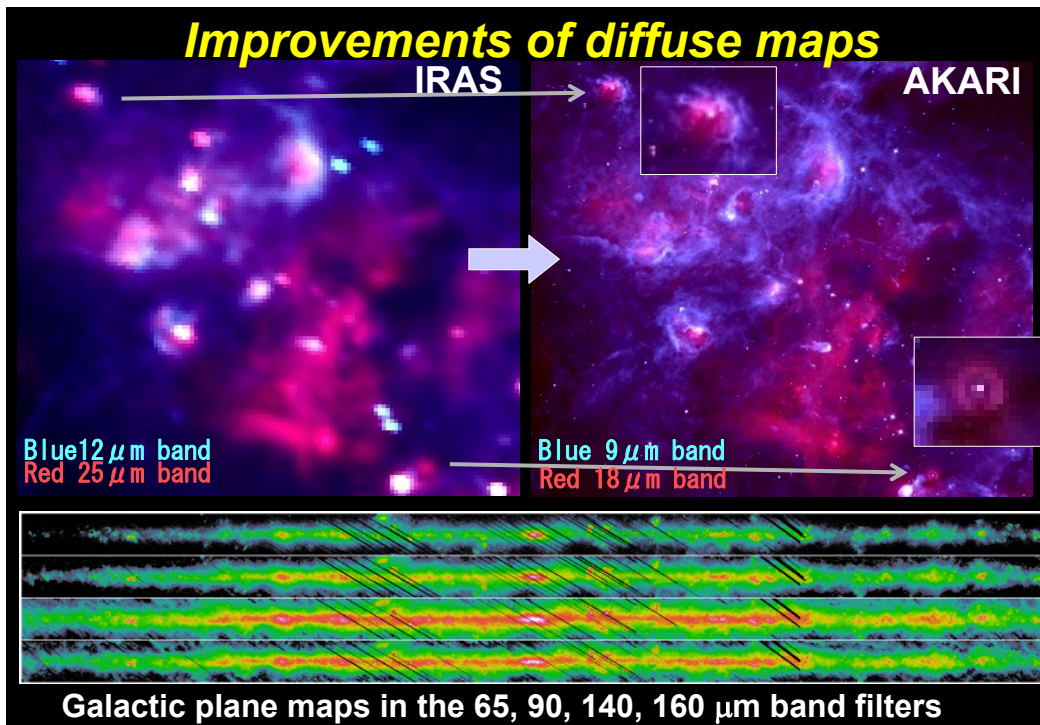
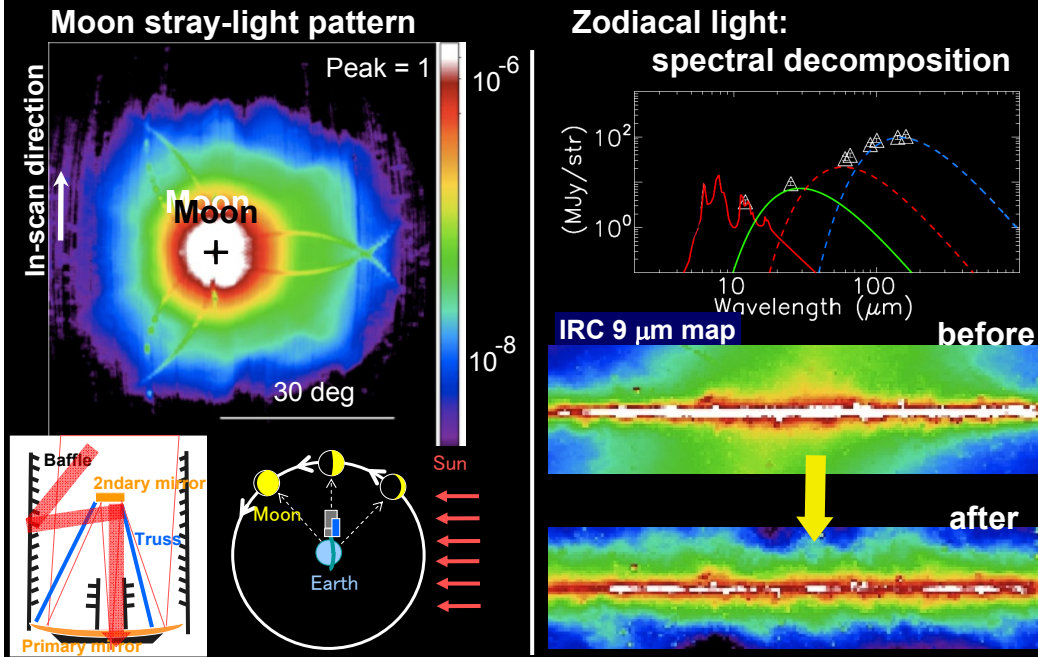
AKARI (Feb, 2006)



0.7 m, 6 K cooled telescope



Moon stray-light & Zodiacal light subtraction



What are we observing? ⇒ solid particles

カーボン系: C, H,
0.01 μm 以下(星間)
有機物、生命の源?
C-rich星(中質量)が供給

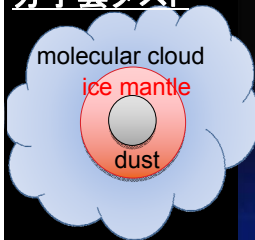


シリケート系:
Si, O, Mg, Fe,
1 μm 以下(星間)
~1km(微惑星)
O-rich星(大・小質量)が供給

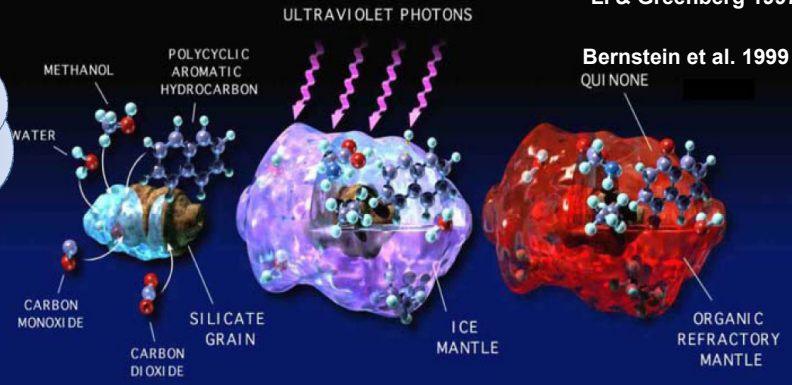


星間ダスト: 95%以上がアモルファス、silicate core-hydrocarbon mantle
Li & Greenberg 1997

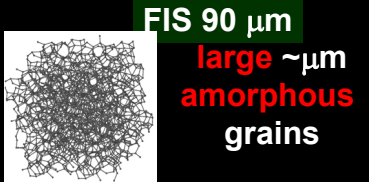
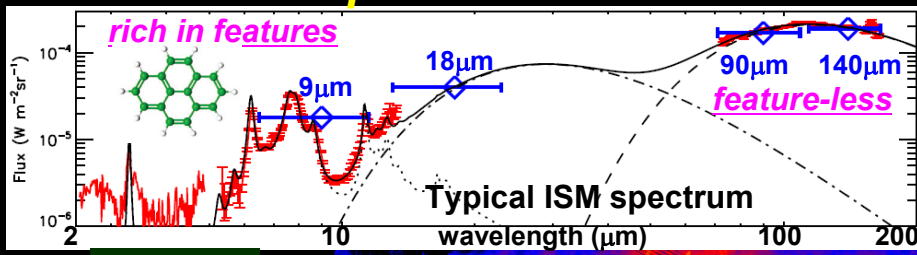
分子雲ダスト



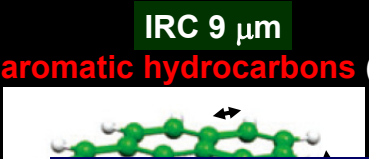
氷: H_2O , CO_2 、
生命の誕生に
重要?



AKARI infrared spectrum of the diffuse ISM

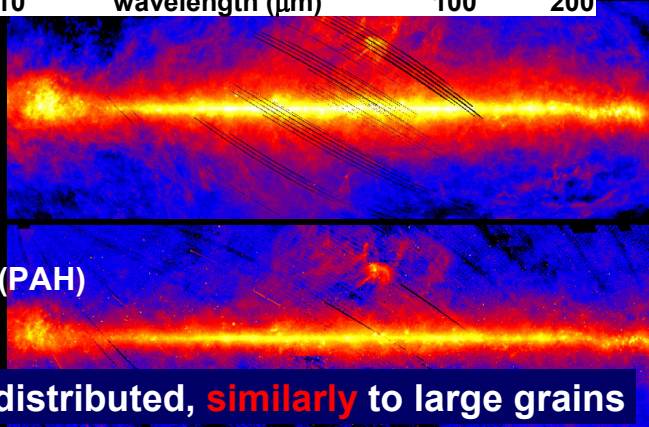


FIS 90 μm
large $\sim\mu\text{m}$
amorphous
grains



IRC 9 μm
aromatic hydrocarbons (PAH)

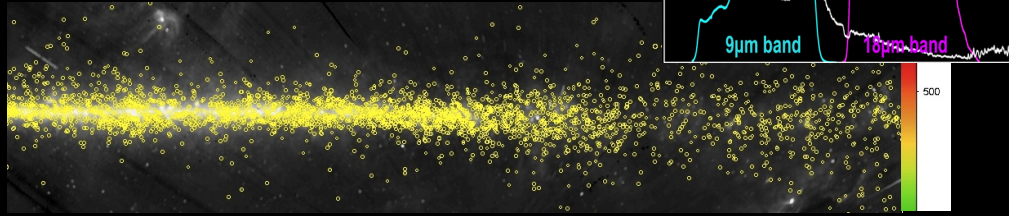
PAHs are widely distributed, similarly to large grains



Distributions of PAHs & large grains and their suppliers

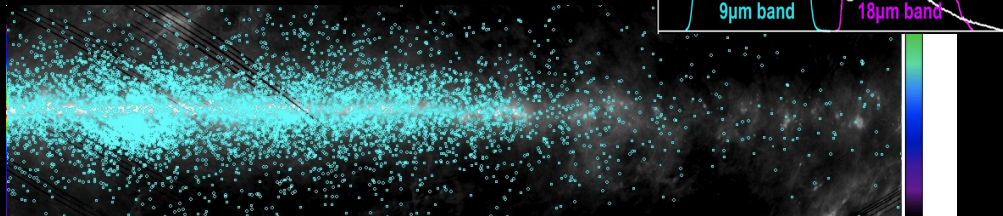
有機物(PAH)の分布

Yellow: C-rich AGBs ... from mid-IR Point Source Catalog



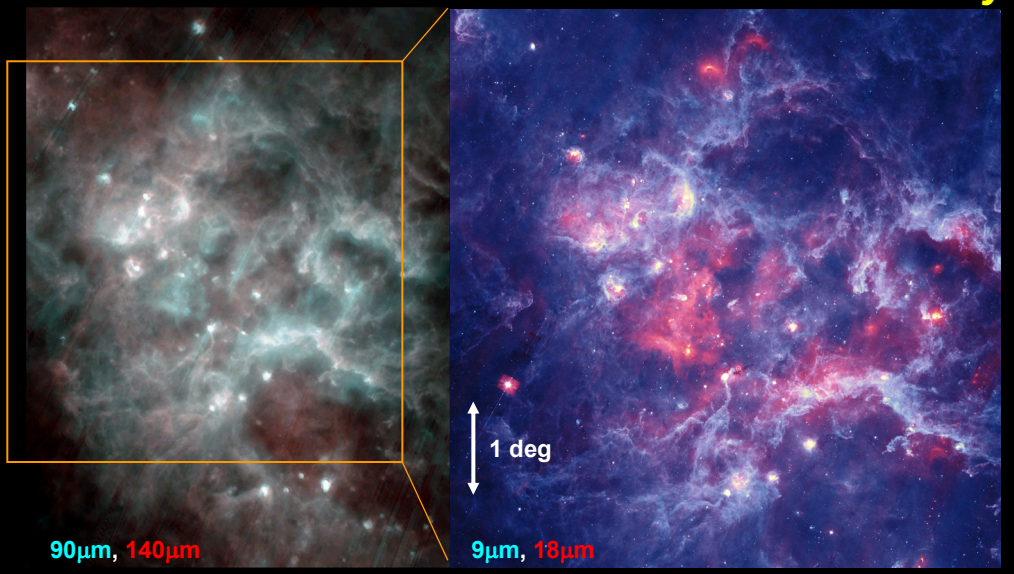
岩石系粒子(シリケート)を含むlarge grainsの分布

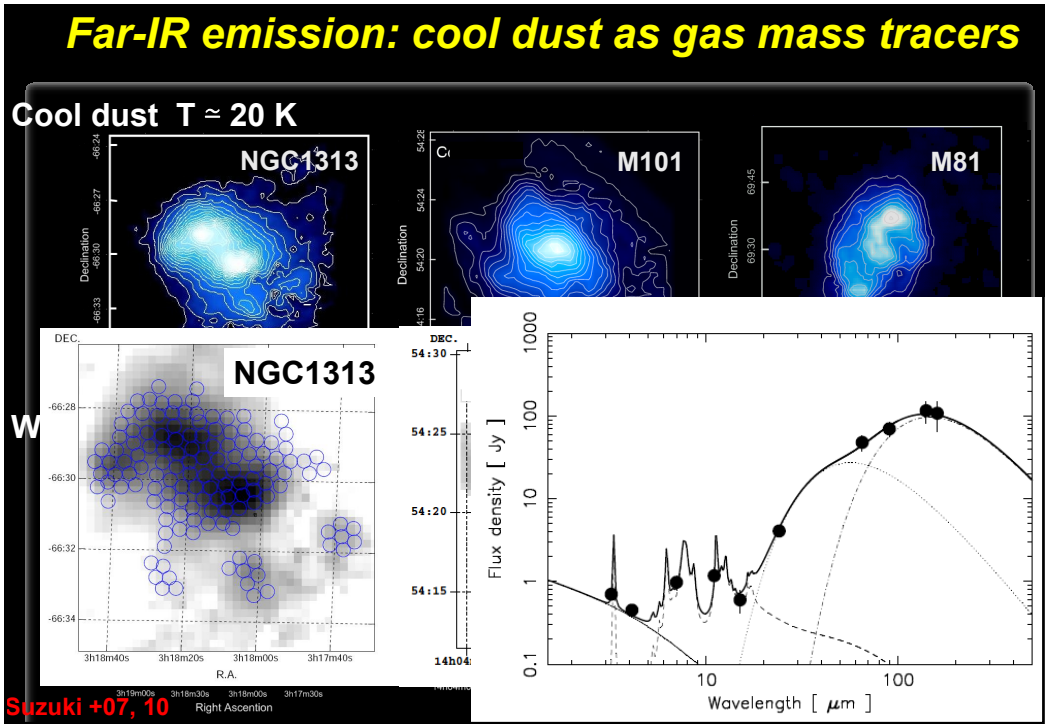
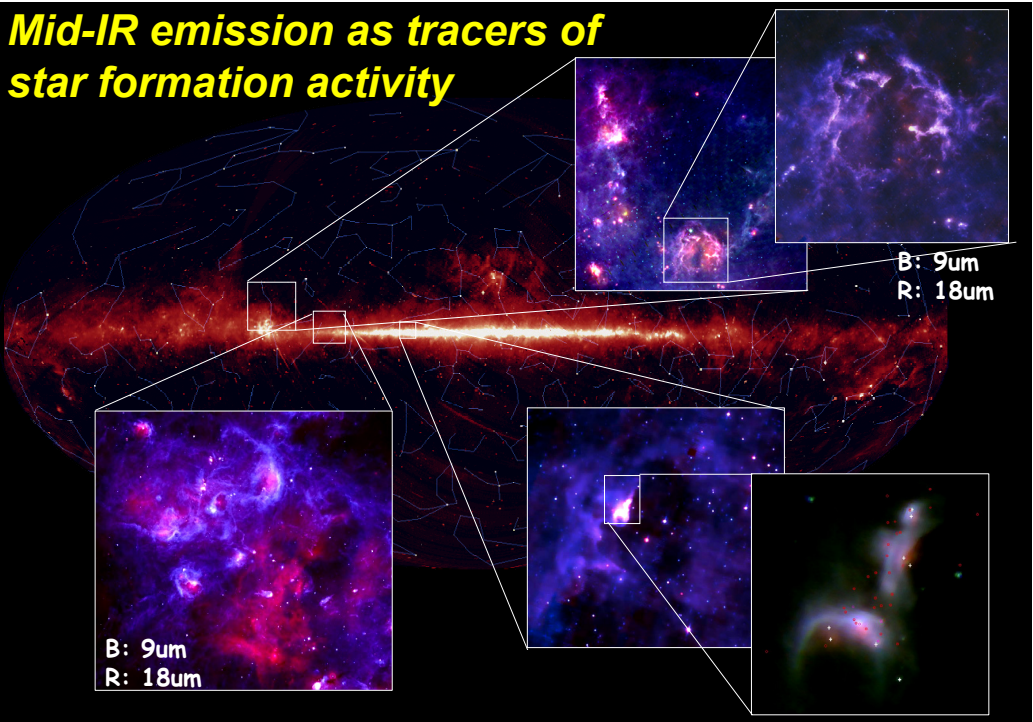
Blue: O-rich AGBs ... from mid-IR Point Source Catalog

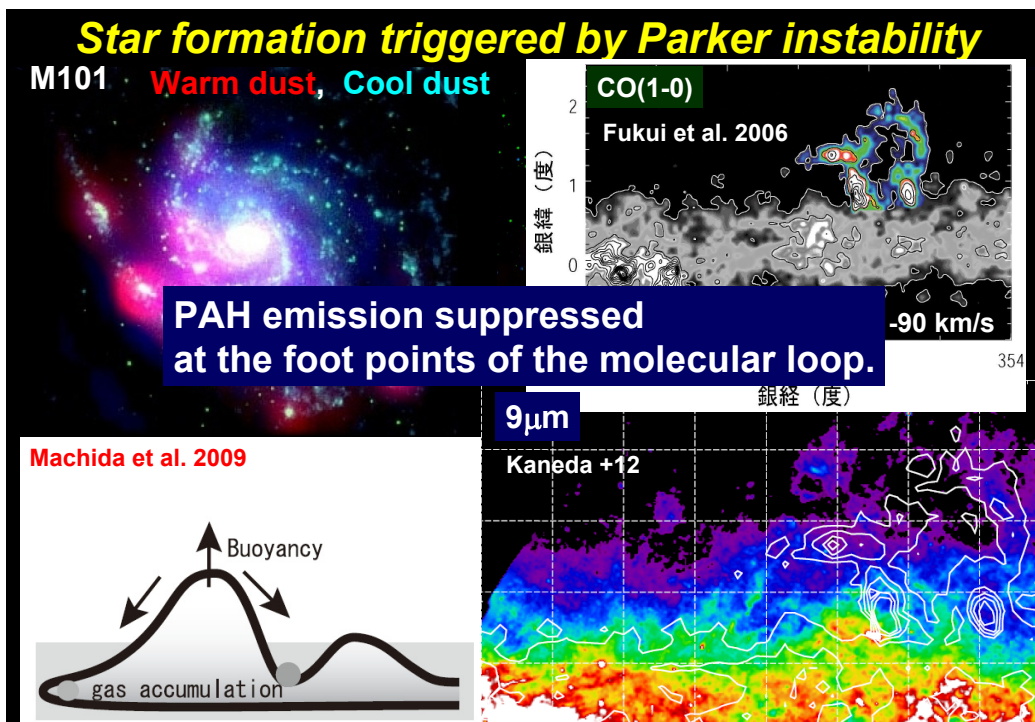
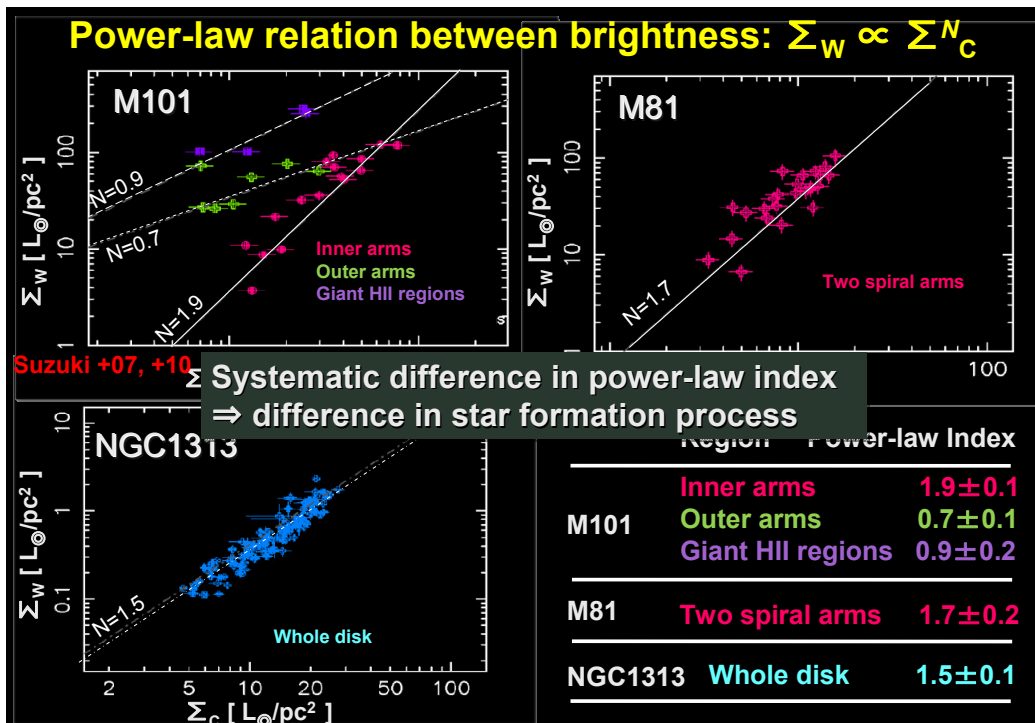


2. イメージング観測: 星形成活動

Dust emission as tracers of star formation activity

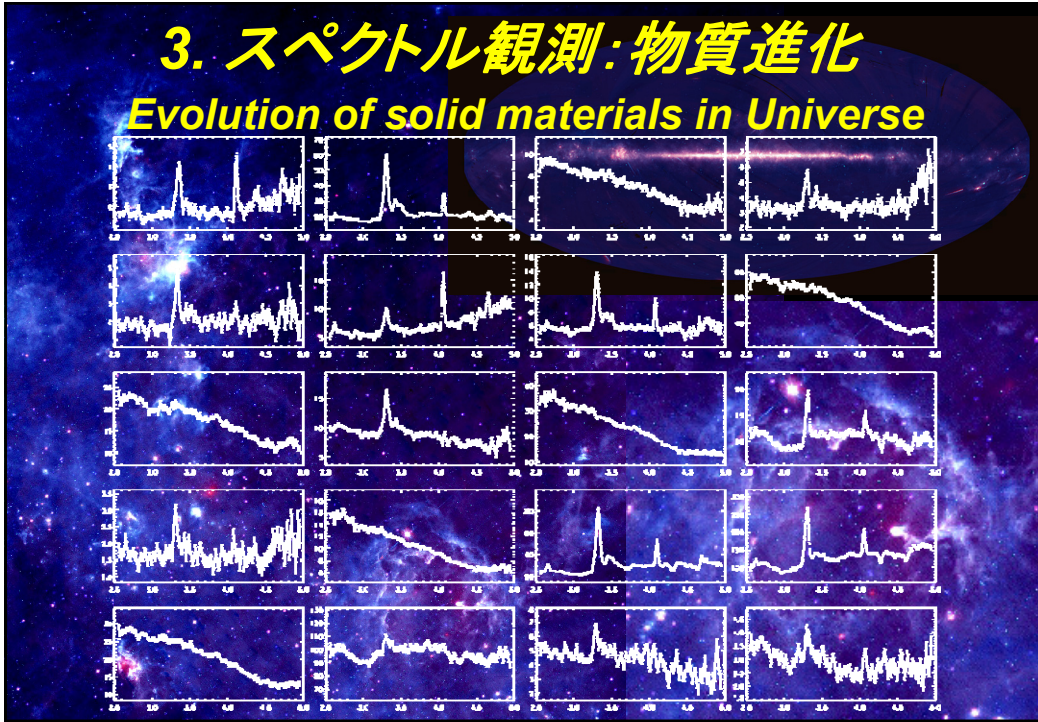




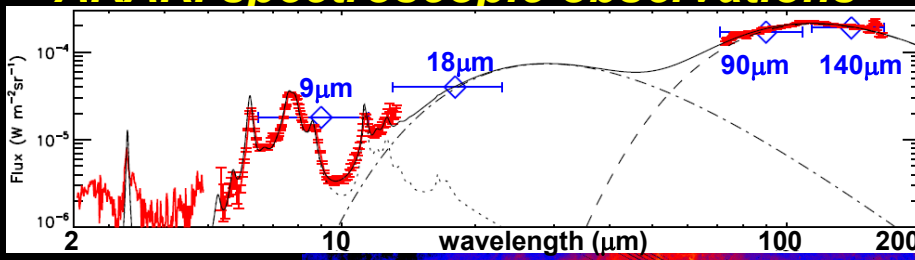


3. スペクトル観測: 物質進化

Evolution of solid materials in Universe



AKARI spectroscopic observations

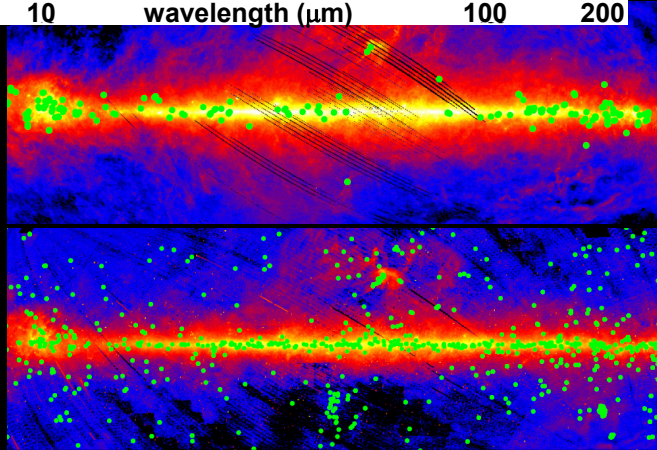


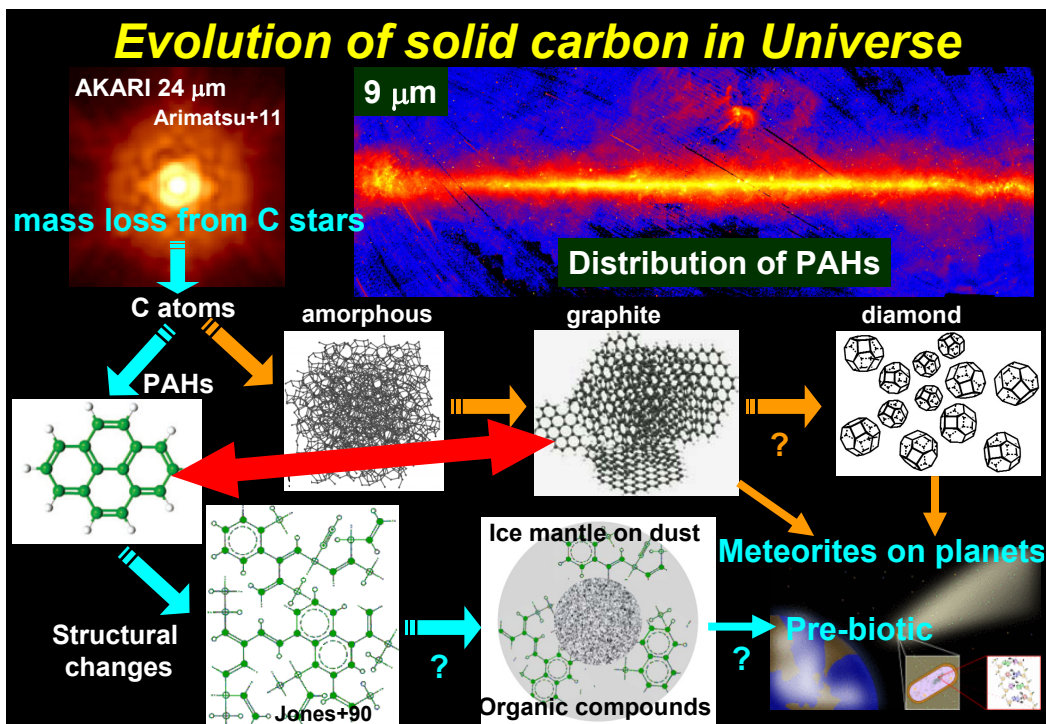
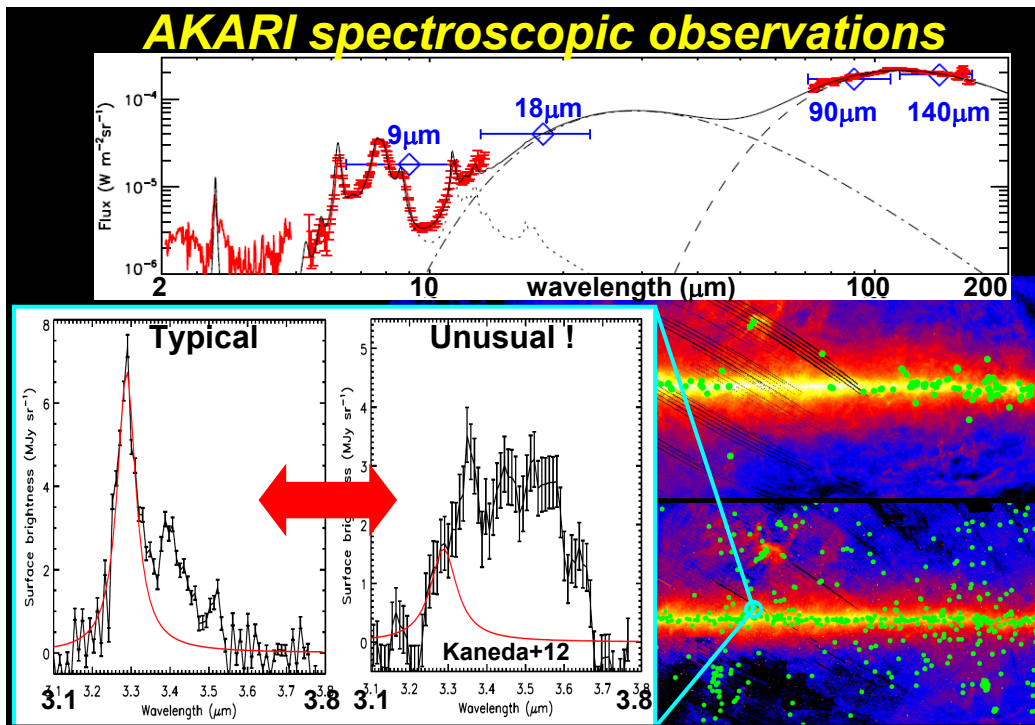
FIS

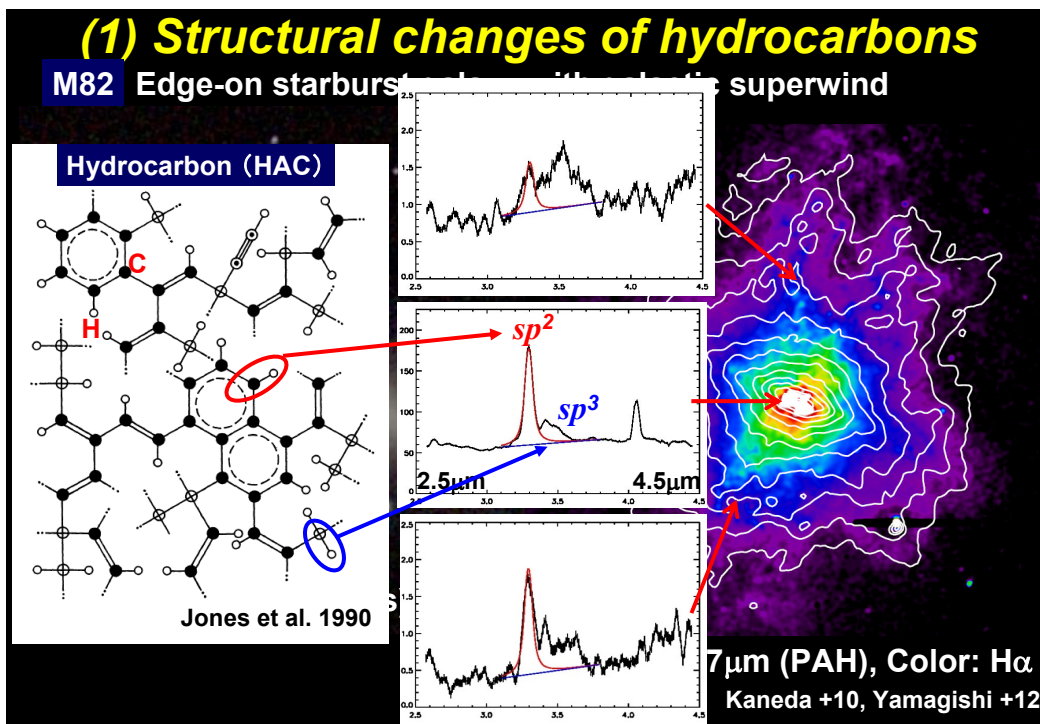
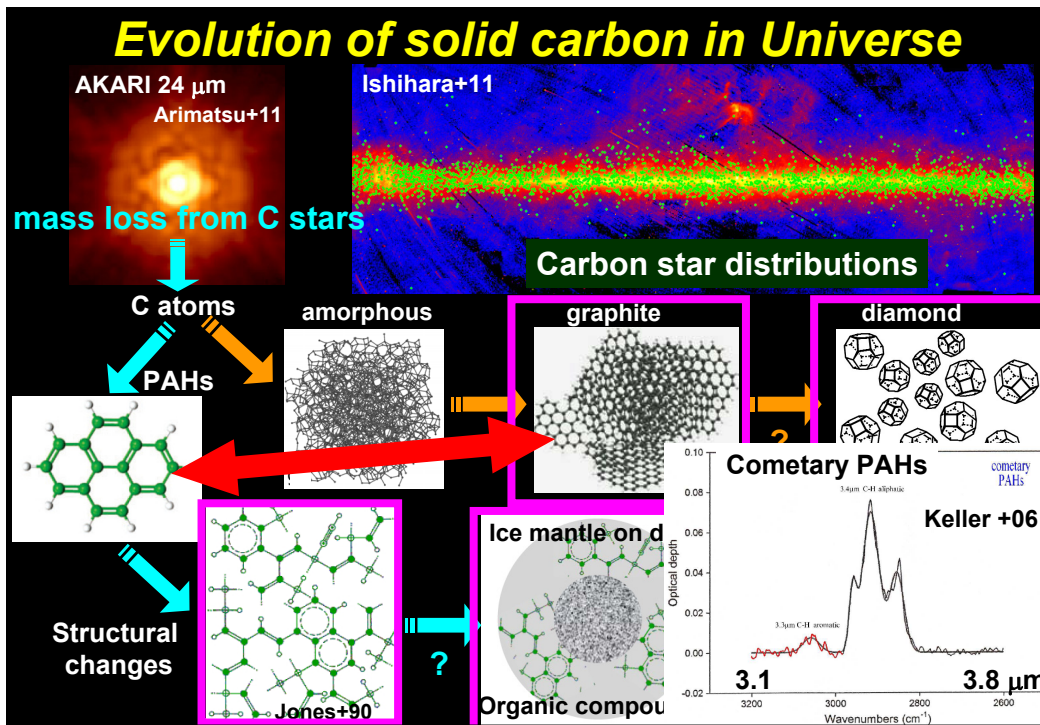
70 - 160 μm
~600 observations

IRC

2 - 13 μm
~6000 observations



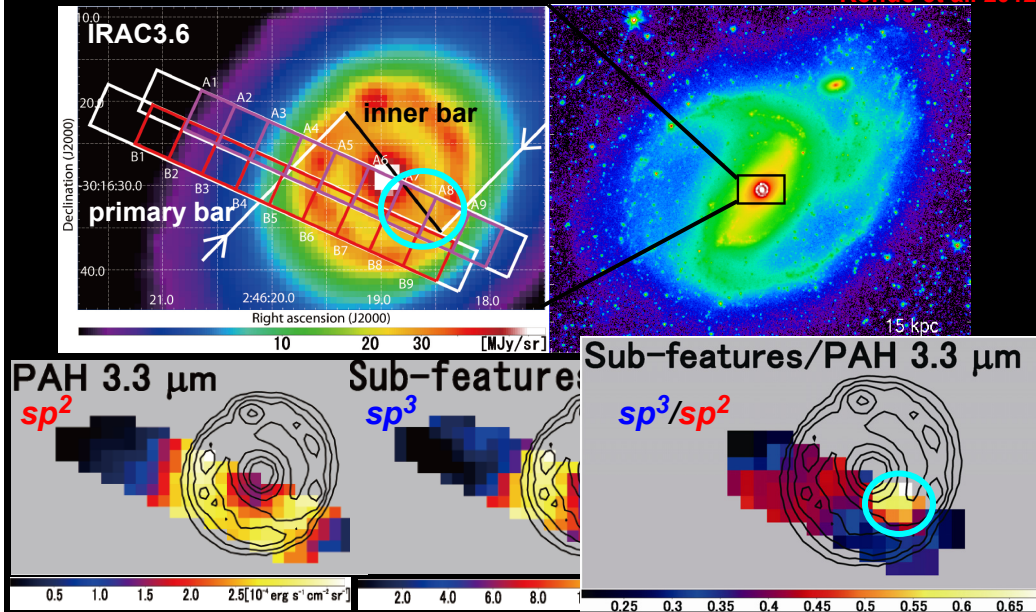




Processing of dust at the AGN-fueling bar of NGC1097

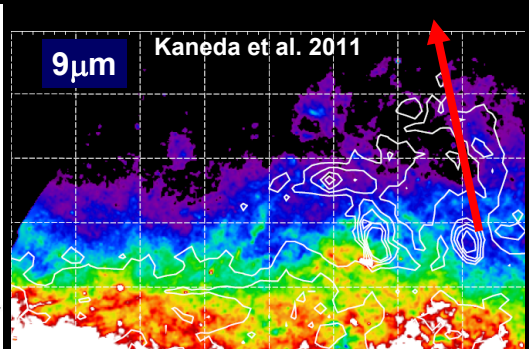
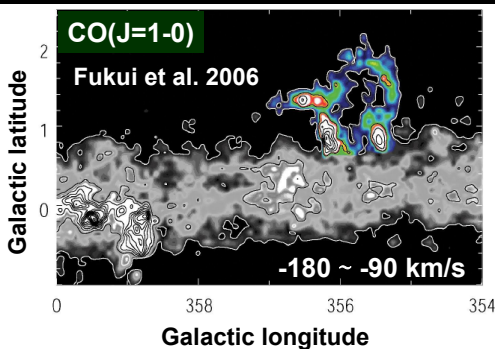
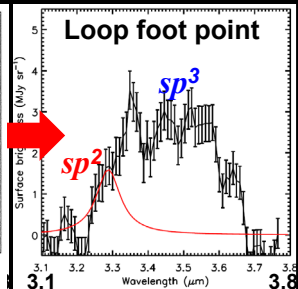
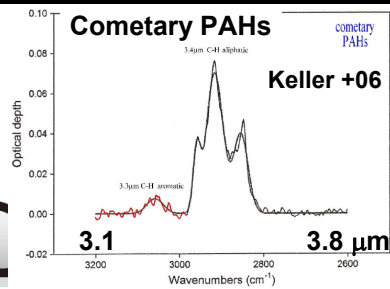
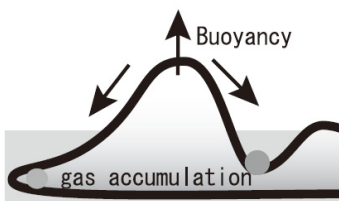
NGC1097 barred spiral galaxy with a starburst ring and AGN

Kondo et al. 2012

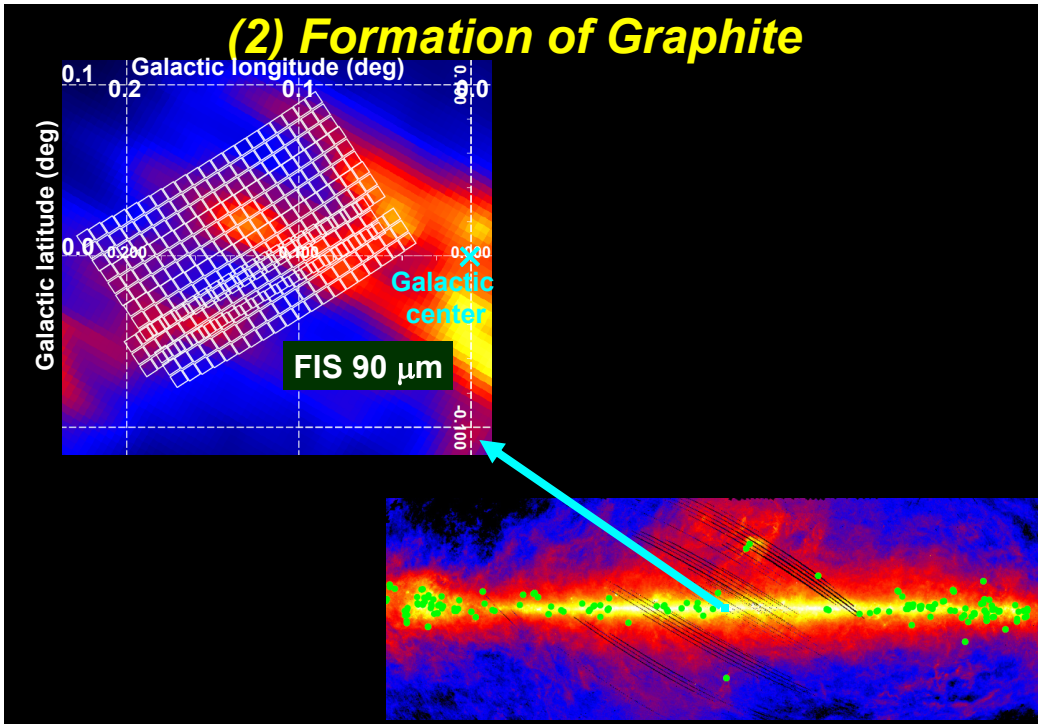


Processing of dust at the GC molecular loop

Machida et al. 2009

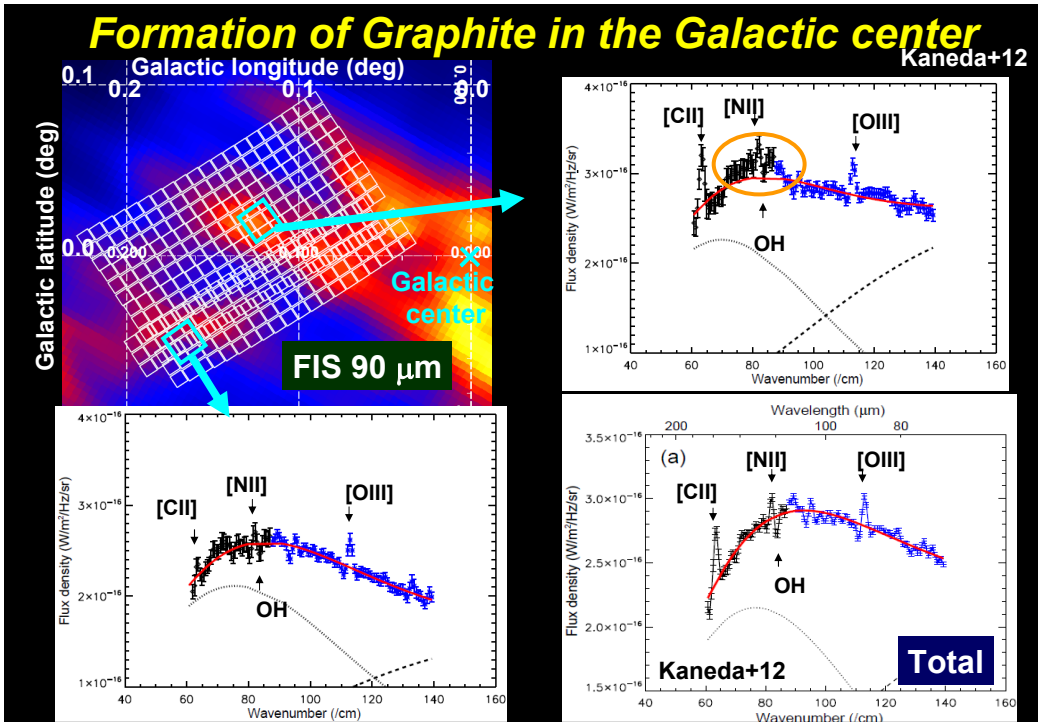


(2) Formation of Graphite

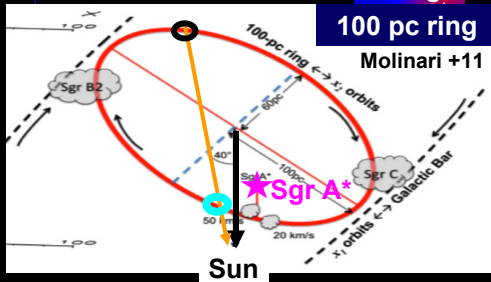
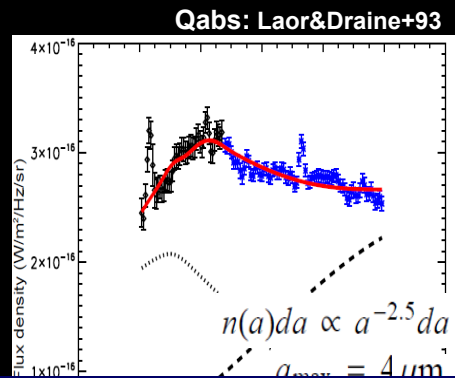
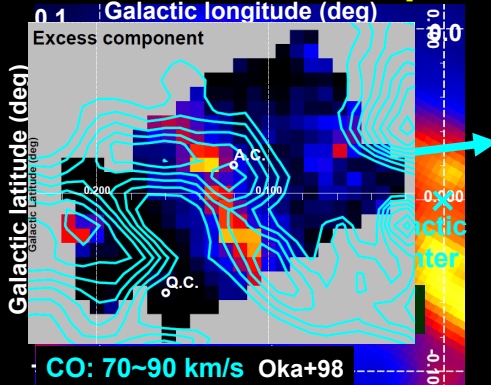


Formation of Graphite in the Galactic center

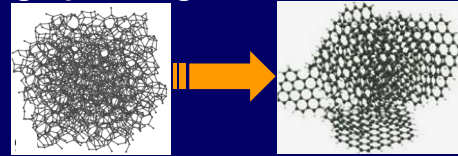
Kaneda+12



Formation of Graphite in the Galactic center

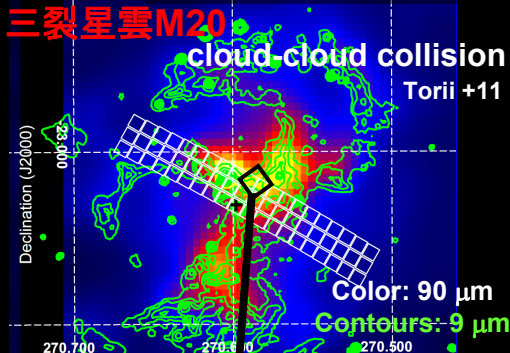


Annealing at ~3000 K needed to graphitize grains.



→ the (past) activity of Sgr A*?

Other pieces of evidence for graphite

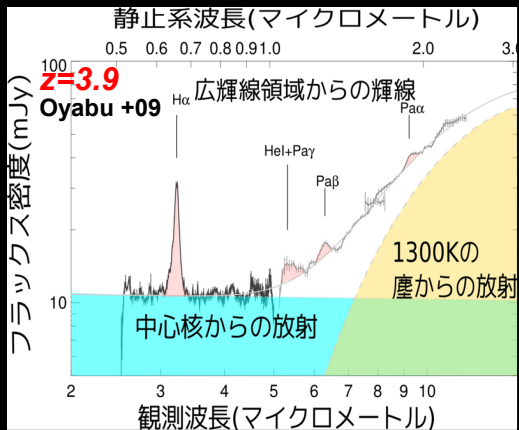
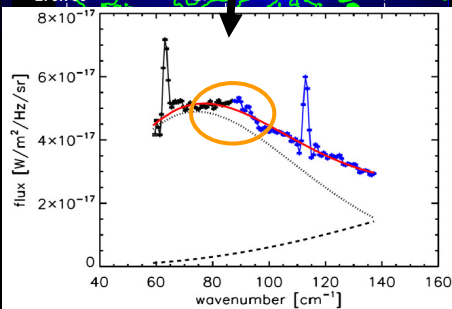


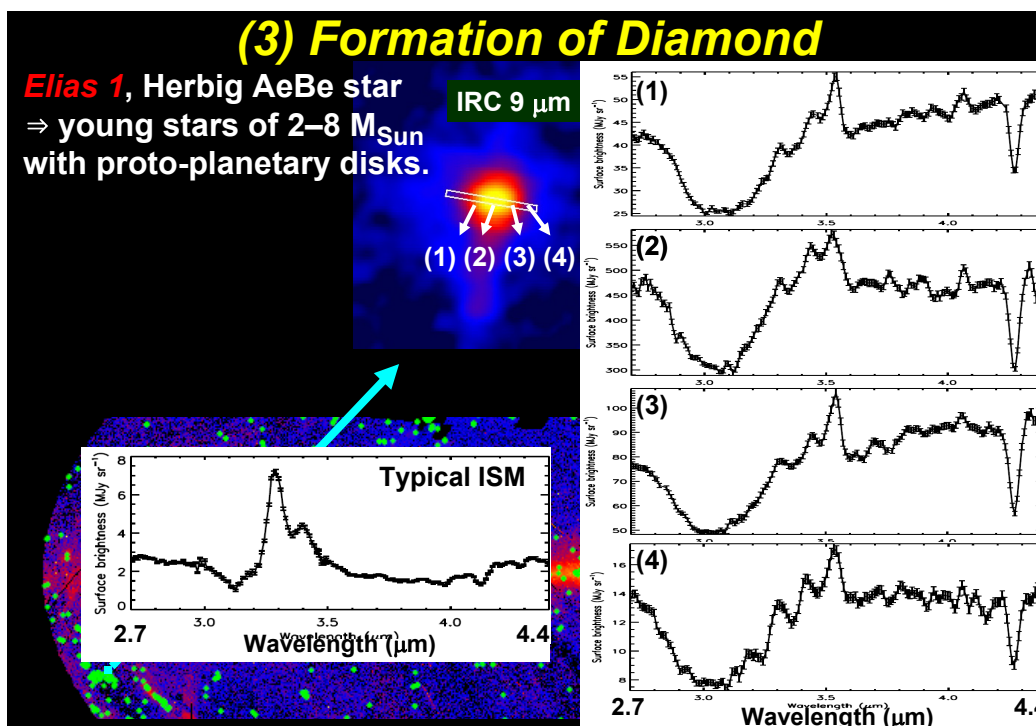
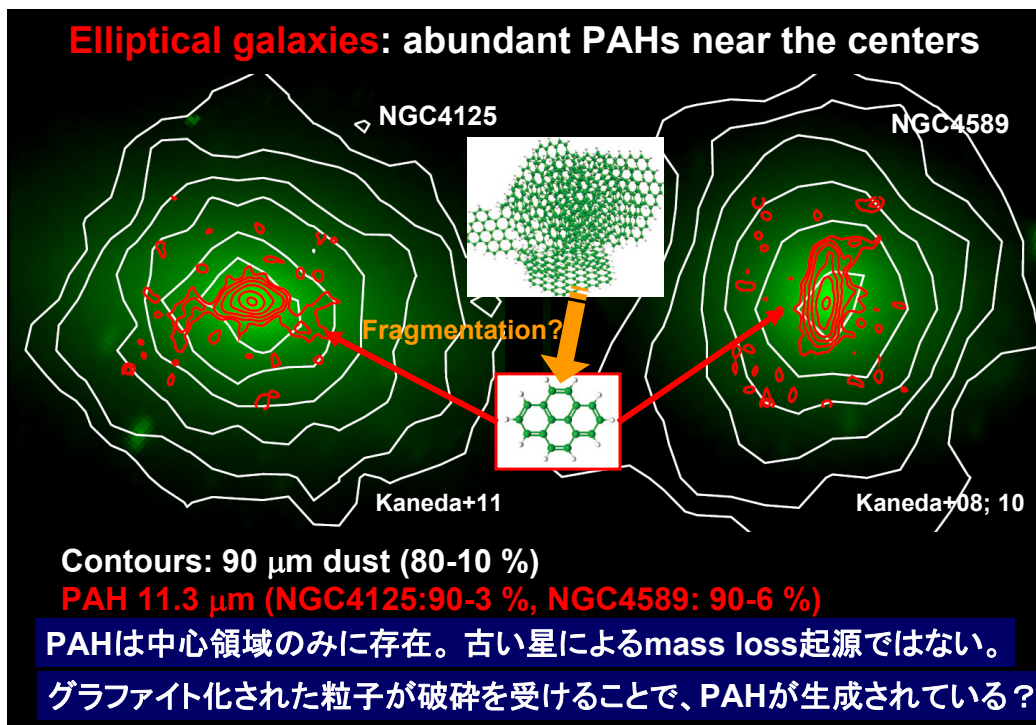
AGN dusty torus

観測されるダスト温度が高すぎる。

昇華温度: typical ~1400K

Graphite ~3000 K

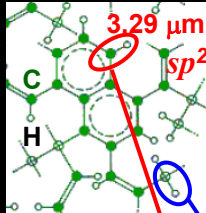




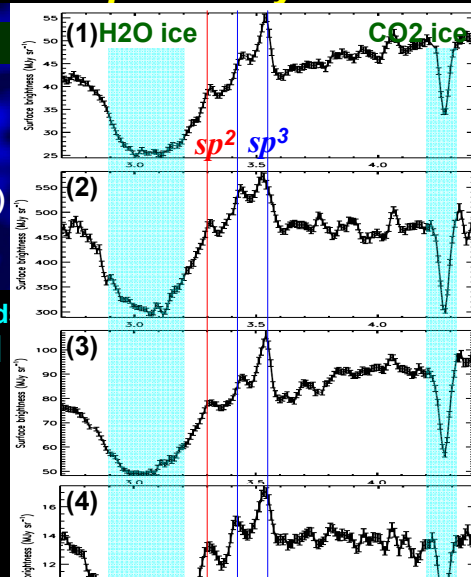
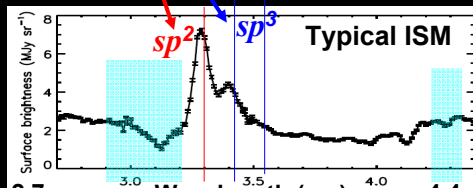
Formation of Diamond in proto-planetary disks

Elias 1, Herbig AeBe star
 ⇒ young stars of 2–8 M_{Sun}
 with proto-planetary disks.

IRC 9 μm

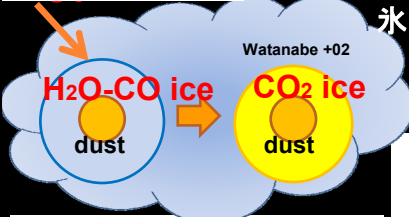


3.4 – 3.6 μm : sp^3 C-H bond
 3.53 μm ⇒ diamond

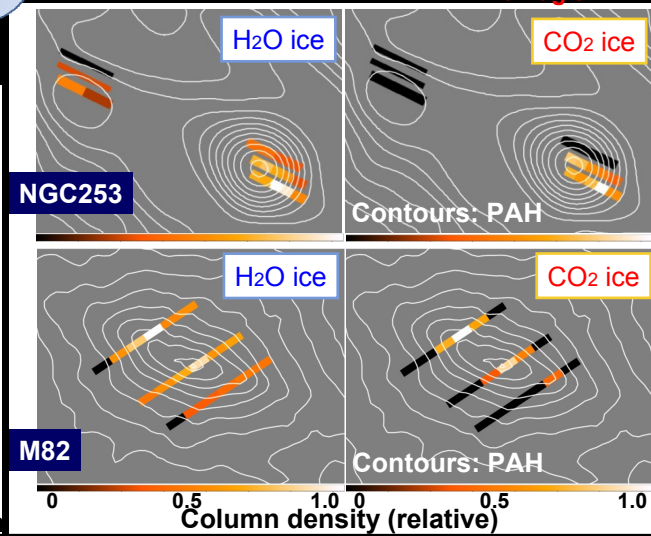
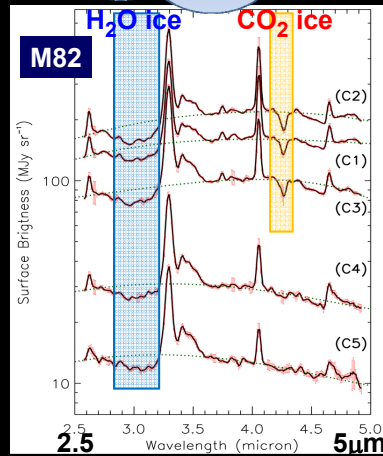


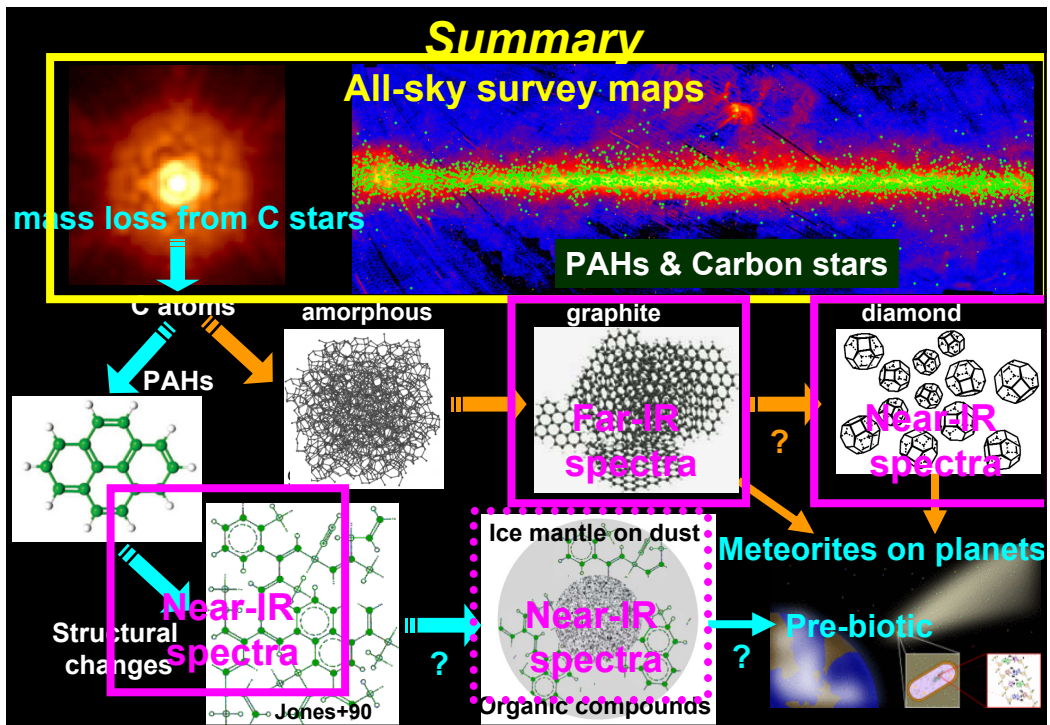
A low-mass companion showing large X-ray flares: Goto et al. 2009
 PAHs ⇒ nanodiamond by irradiation of highly energetic particles?

Cosmic-ray? formation of icy mantle: abundant CO₂ ice



氷の昇華温度 H₂O: 90 K, CO₂: 50 K, CO: 16 K
 星間CO₂氷が銀河中心近くに多く存在
 温度を上げないで、反応を進めるには?
 Yamagishi+11





4. 「あかり」からSPICAへ

AKARI (Feb, 2006) vs **SPICA (2022)**

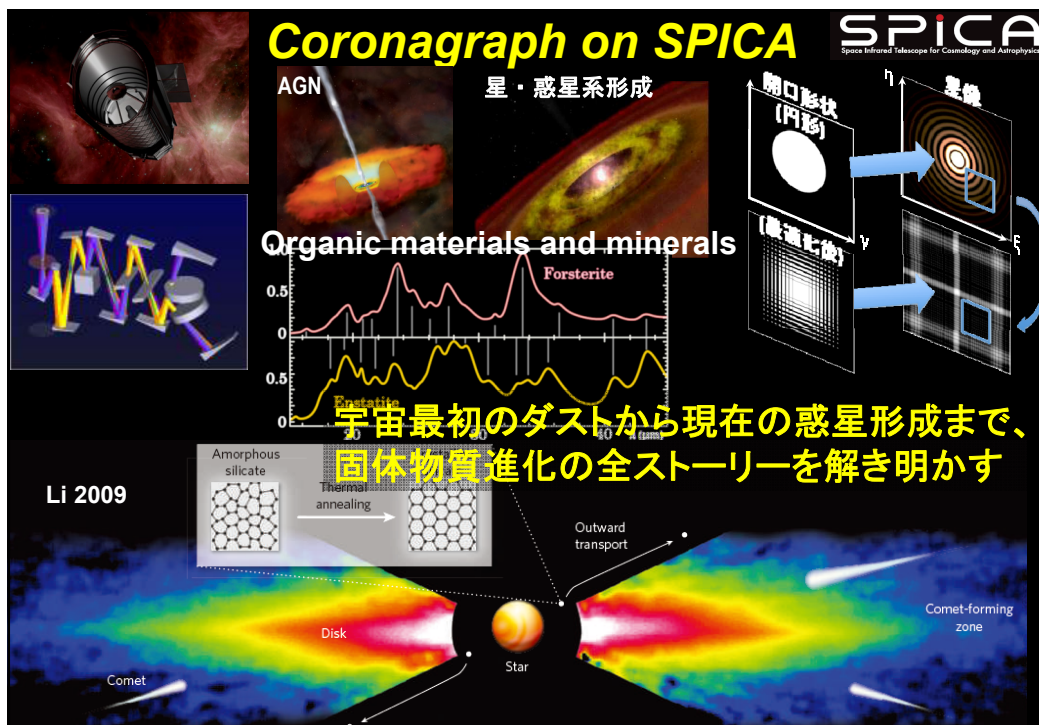
AKARI: 0.7 m, 6 K, 2 - 180 μm

SPICA: 3.2 m, 6 K, 5 - 210 μm

Many lattice vibration modes are included in SPICA

much better angular resolution is crucial.

Structural changes



5. まとめ

- ・宇宙赤外線観測は、「固体微粒子」(ダスト)が主役
- ・「あかり」は、ダスト(とくに有機物PAH)の全天分布を明らかにした
- ・ダスト・PAHの測光観測から、星形成率や物質総量が見積れる
- ・スペクトル観測は、ダストの変性・進化を捉えた。(1)炭化水素の構造変化、(2)グラファイト・ダイヤモンド化、(3)氷マントルの生成
- ・星周で作られた微粒子が変遷を経て、惑星系・AGNトラスの材料へと行き着く。SPICAは、固体物質進化の全ストーリーを明かす。