GREX-PLUS：マゼラン雲の星形成・星間物質のサイエンス

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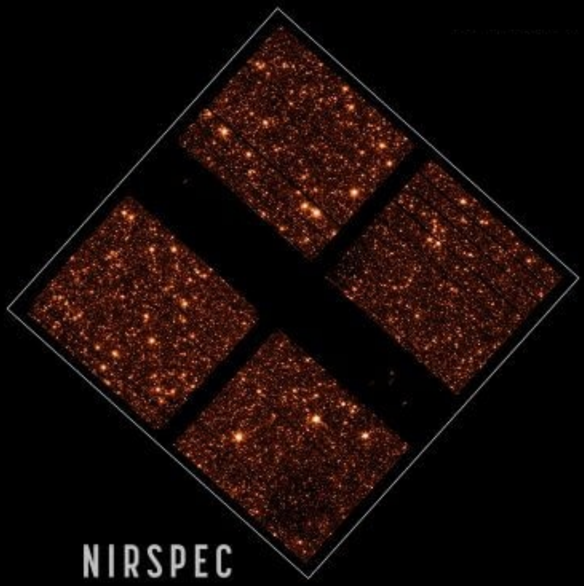
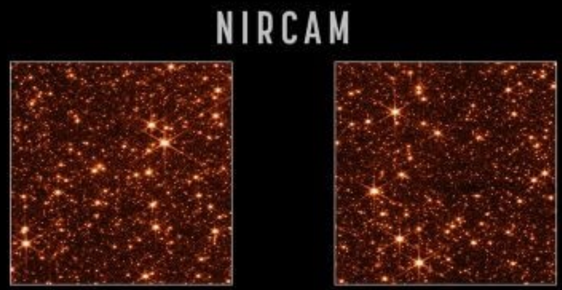
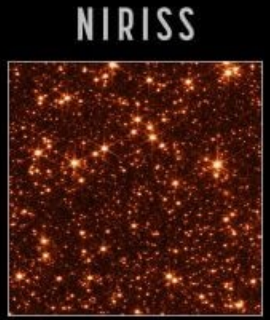
光赤天連シンポジウム, 2022.7.13 オンライン





大マゼラン雲 (のどこか)



Credit: NASA

The Large and Small Magellanic Cloud

- Nearest star-forming galaxies

 —$d_{LMC/SMC}$ = 50/60 kpc[1] (1” = 0.25/0.3 pc)

 —nearly face-on[2] (LMC, i ~35°)

- Low metallicity[3]

 —LMC : ~1/2-1/3, SMC : ~1/5-1/10 of solar neighborhood

 => Excellent laboratory to study interstellar chemistry at decreased metallicity

[1]Alves, 2004, [2]Westerlund, 1990, [3]Luck et al. 1998

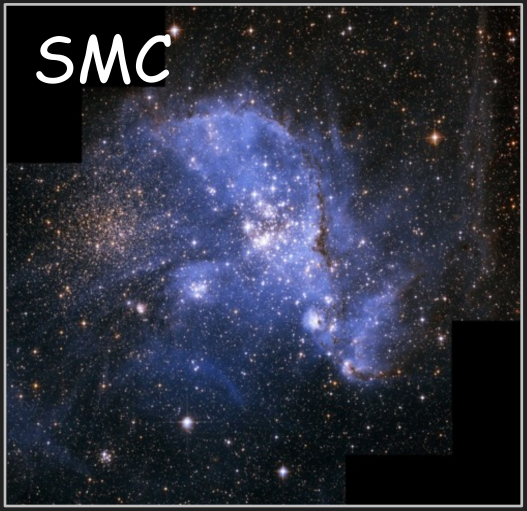
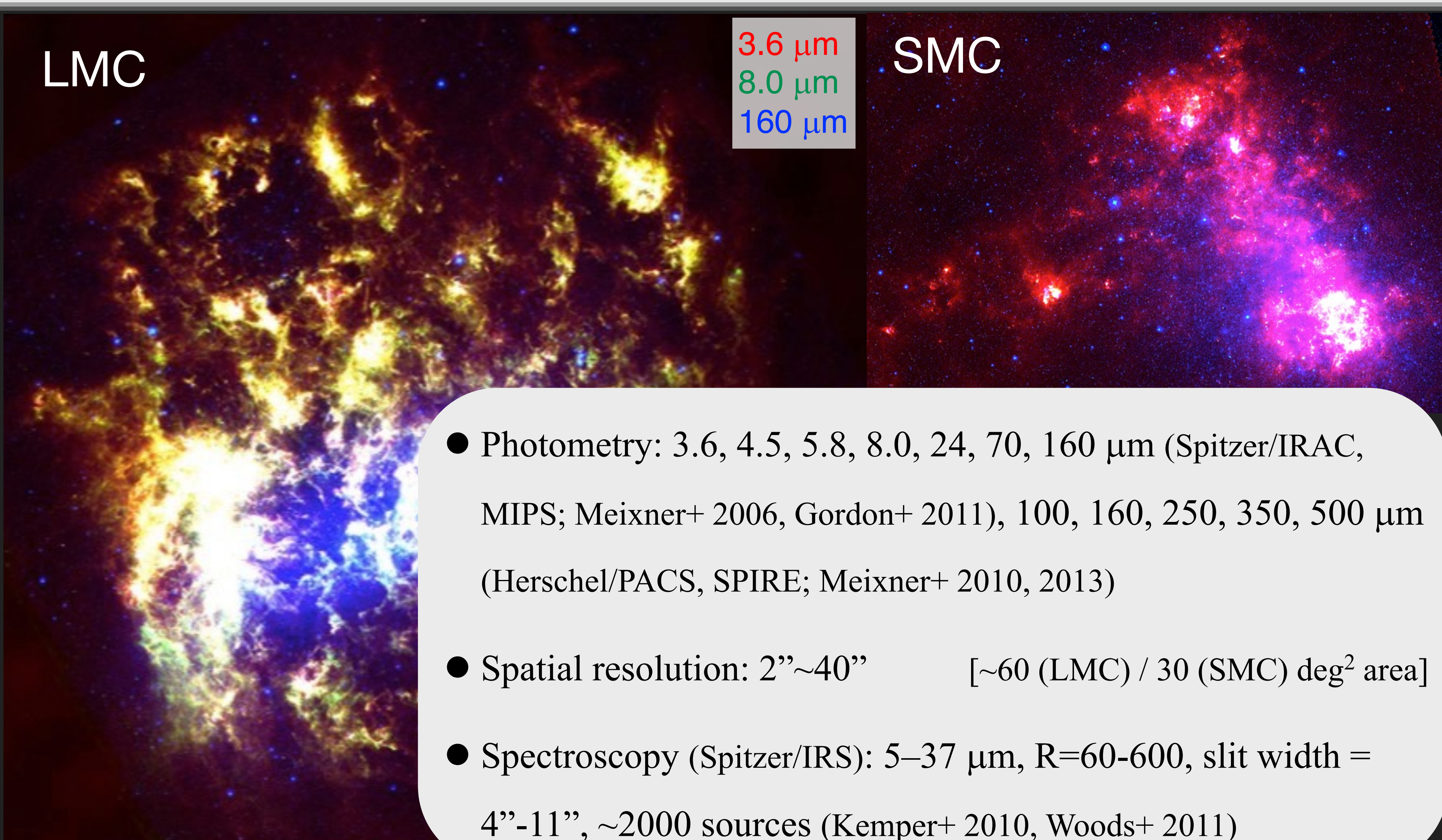


Fig.1 Optical images of the LMC and SMC
[Ref. E. Slawik (LMC), A. Nota/ESA, STScI (SMC)]

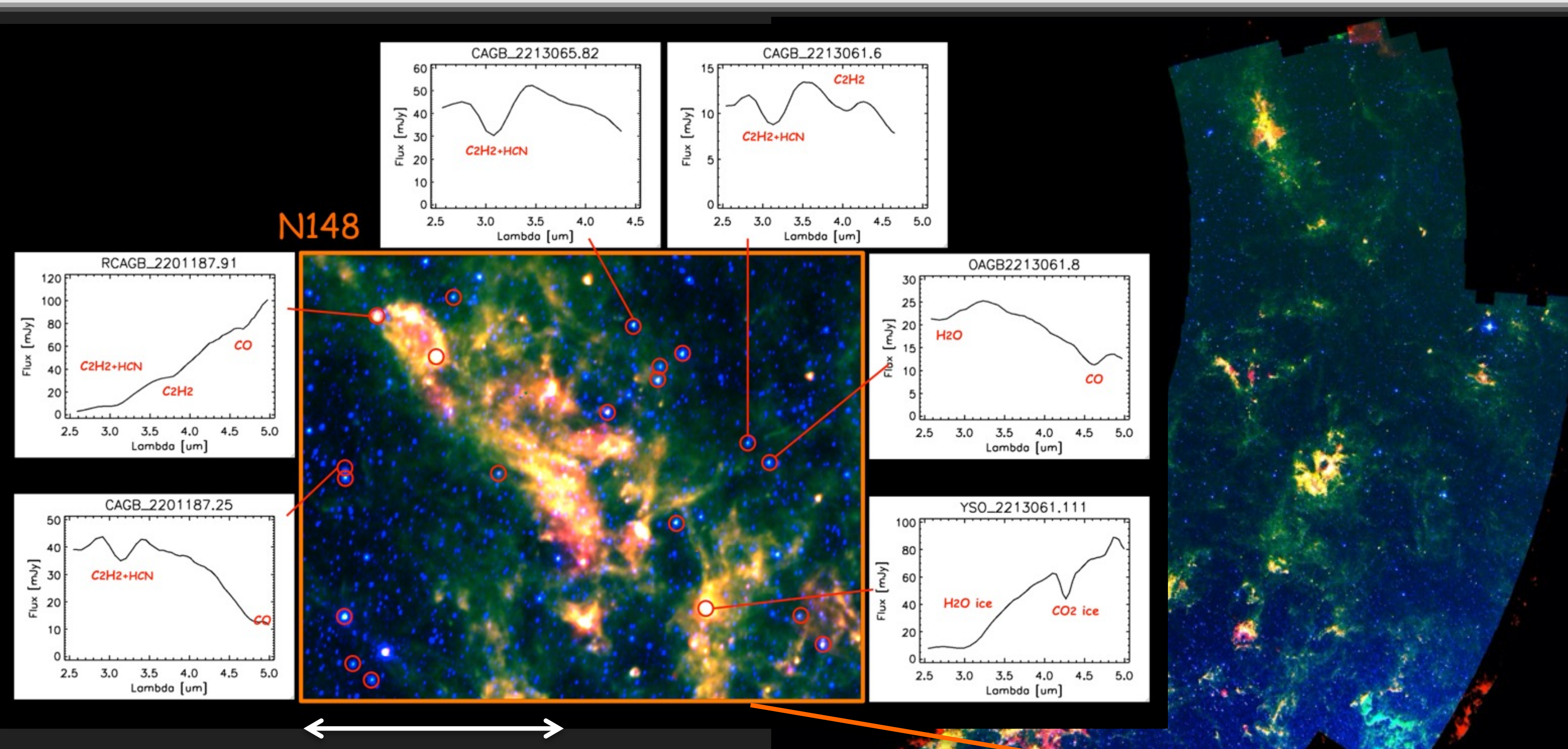
SAGE (*Spitzer*) & HERITAGE (*Herschel*) [PI. M. Meixner]



- Photometry: 3.6, 4.5, 5.8, 8.0, 24, 70, 160 μm (Spitzer/IRAC, MIPS; Meixner+ 2006, Gordon+ 2011), 100, 160, 250, 350, 500 μm (Herschel/PACS, SPIRE; Meixner+ 2010, 2013)
- Spatial resolution: 2”~40” [~60 (LMC) / 30 (SMC) deg^2 area]
- Spectroscopy (Spitzer/IRS): 5–37 μm, R=60-600, slit width = 4”-11”, ~2000 sources (Kemper+ 2010, Woods+ 2011)

Fig.2 Three-color images of the LMC/SMC. Red: 3.6 μm, Green: 8.0 μm, Blue: 160 μm [constructed based on the SAGE/HERITAGE archival data at IPAC]

LSLMC (*AKARI*) [PI. T. Onaka]



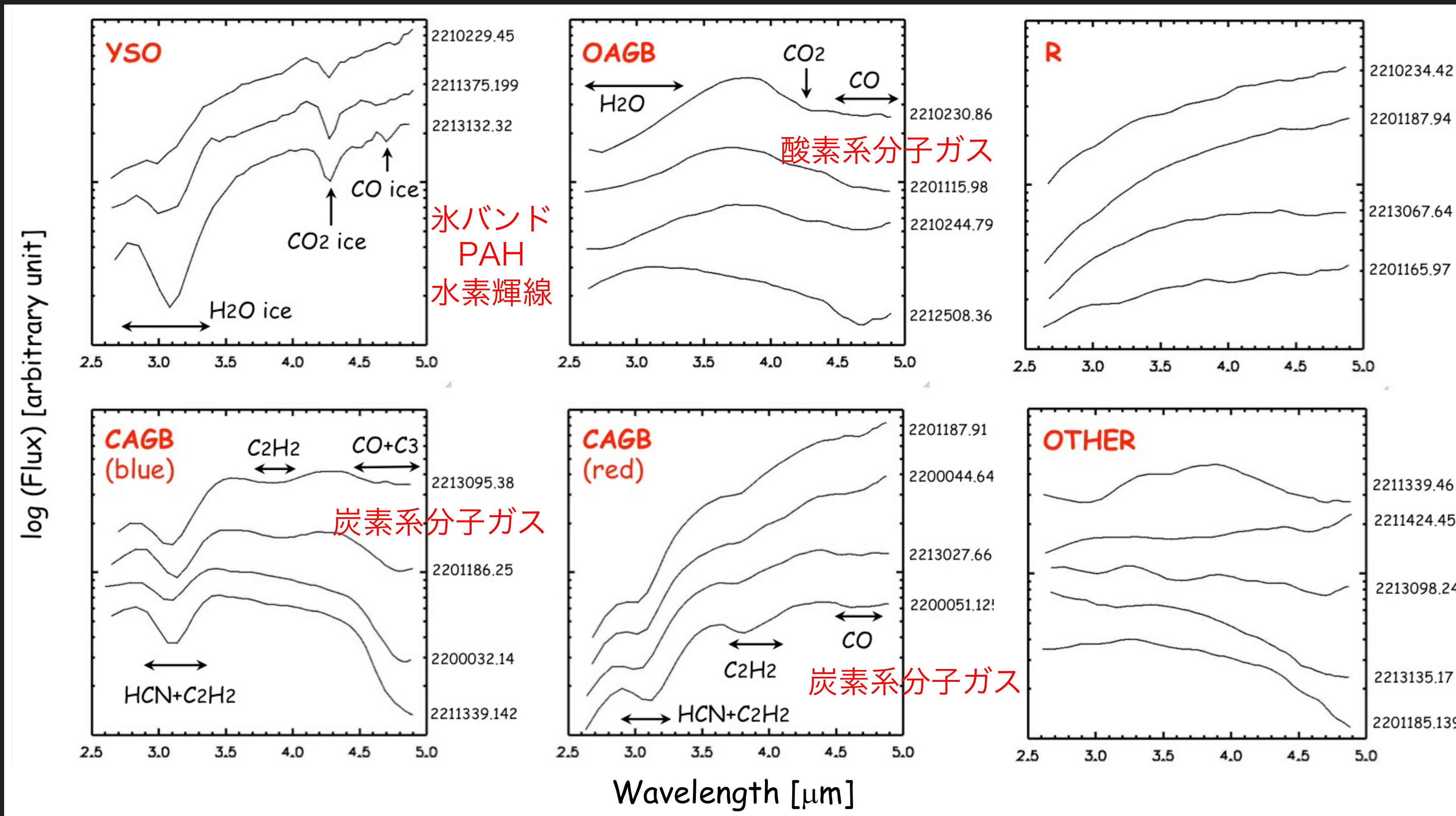
- Photometry: 3.2, 7.0, 11, 15, 24 µm (Ita+ 2008, Kato+ 2012) —650,000 (3µm) and 52,000 sources (24µm), limit = 24µJy (3µm)
- Spatial resolution: 4”~10” [~10 deg^2 area, 600 pointing]
- Spectroscopy: 2.5–5 µm, R=15-40, slitless, ~1750 sources in the catalog (Shimonishi+ 2013)

Infrared Spectra obtained by *AKARI* LSLMC

生まれたばかりの星
(原始星)

年老いた星
(酸素星)

ただただ赤い天体



年老いた星
(炭素星)

激しい質量放出を
している炭素星

???

Fig.4 Classification of LSLMC sources based on their NIR spectra [Shimonishi+ 2013]

GREX-PLUS Survey of the Magellanic Clouds

10σ sensitivity
—: GREX-PLUS img (20min)
---: GREX-PLUS spec (R=30,000, 20min)
---: JWST spec (R=1000-3000, 30min)
—: VMC img
—: AKARI LSLMC img
---: AKARI LSLMC spec (R=30)
—: Spitzer SAGE img (10σ)
---: Spitzer IRS spec (R=100, 30min)

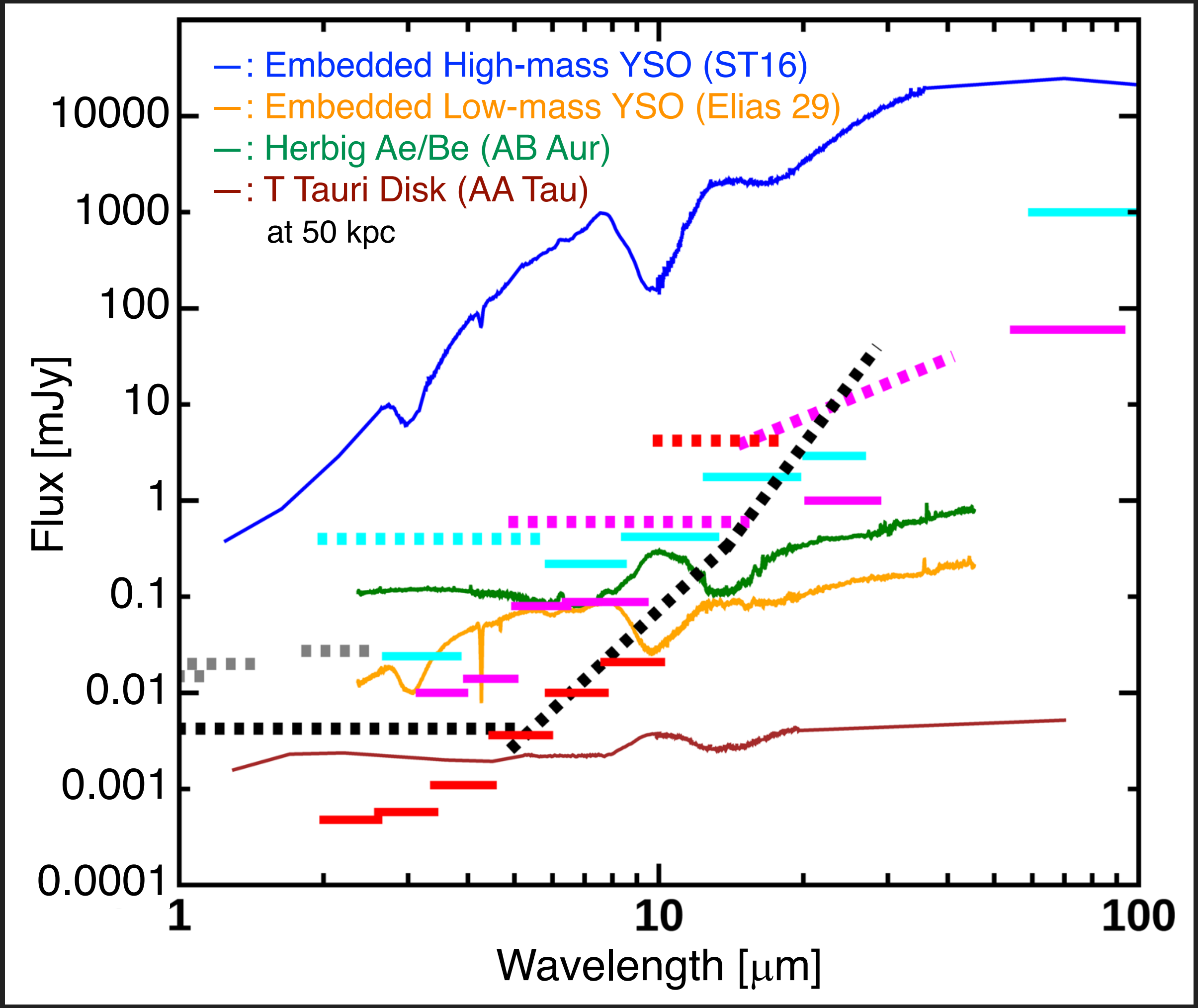


Fig.5 Sensitivities and wavelength coverages of the LMC observations by AKARI, Spitzer, JWST, and GREX-PLUS

GREX-PLUS Observations of YSOs in the LMC/SMC

- GREX-PLUS will detect all most all of solar-mass YSOs in the MCs

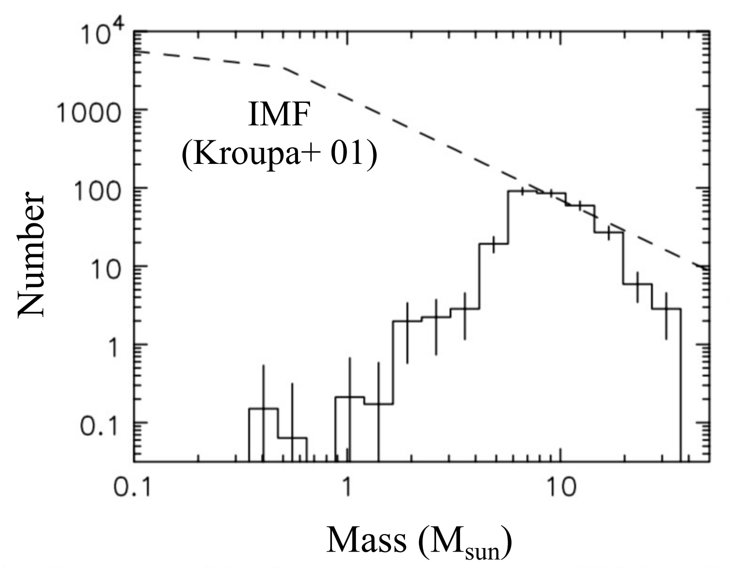


Fig.6 Mass distribution histogram for YSOs in the LMC [Whitney+ 08].

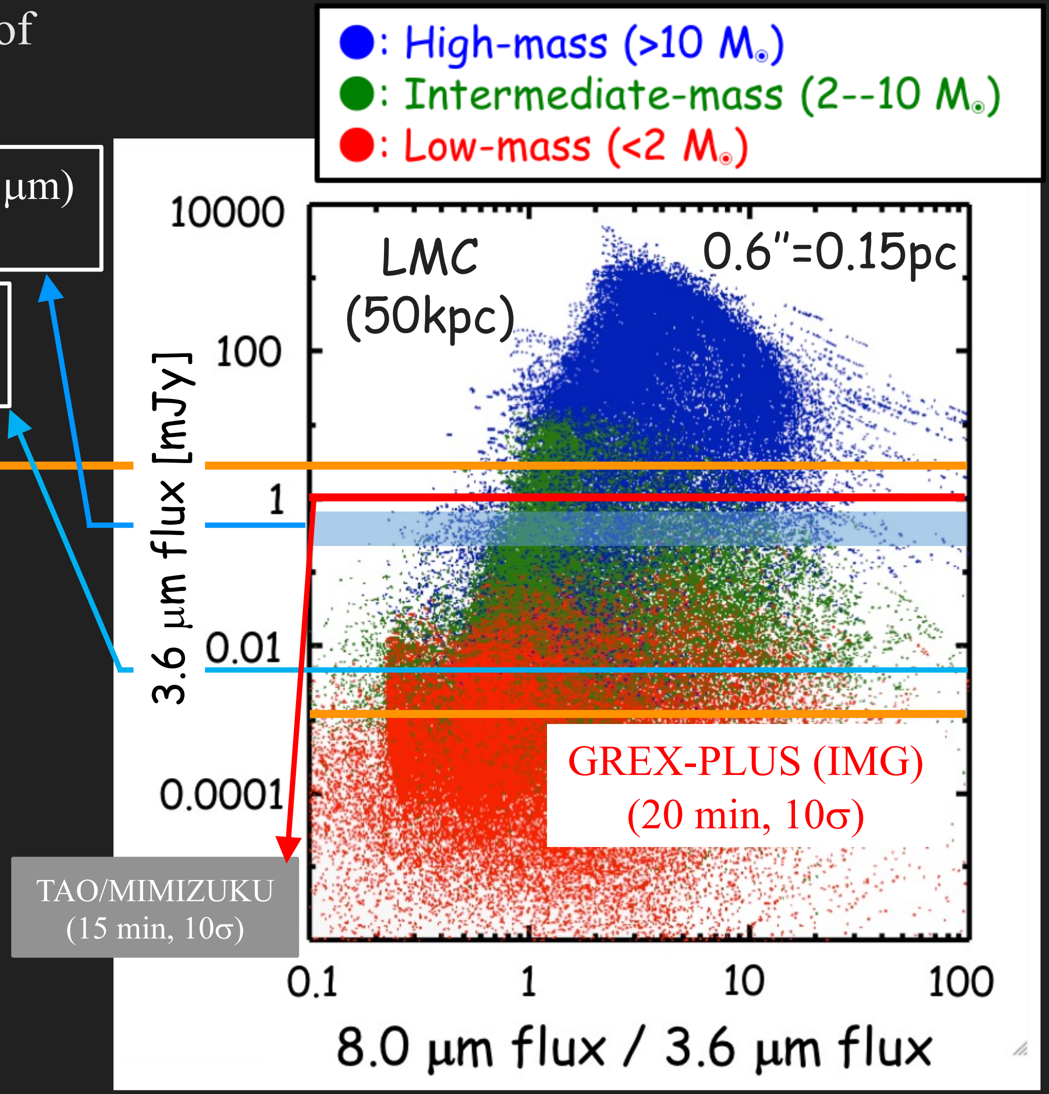


Fig.7 Predicted flux and color of YSOs in the LMC (Based on the YSO model by Robitaille et al. 2008)

High-resolution MIR Spectroscopy of Massive YSOs

- Various molecular absorption lines are seen in the MIR region of massive YSOs*
  —H_2O, CO_2, C_2H_2, HCN, CH_4, NH_3, etc.
  —They arise from hot gas in the vicinity of the protostar (T_{gas} >300 K)
  —Ice absorption bands are also seen (H_2O: 6 μm, CH_4: 7,7 μm, NH_3: 9 μm, CH_3OH 9.7 μm, CO_2: 15.2 μm, COMs: 5-7 μm)
  —PAH and ionized metal emission lines are seen for evolved sources

*See Boogert+ 98;van Dishoeck+ 96, 04; Gonzaliz-Alfonso+ 98; Boonman+ 00, 03ab, Lahuis+ 00, 06; Dungee+ 18; Indrilo+ 20

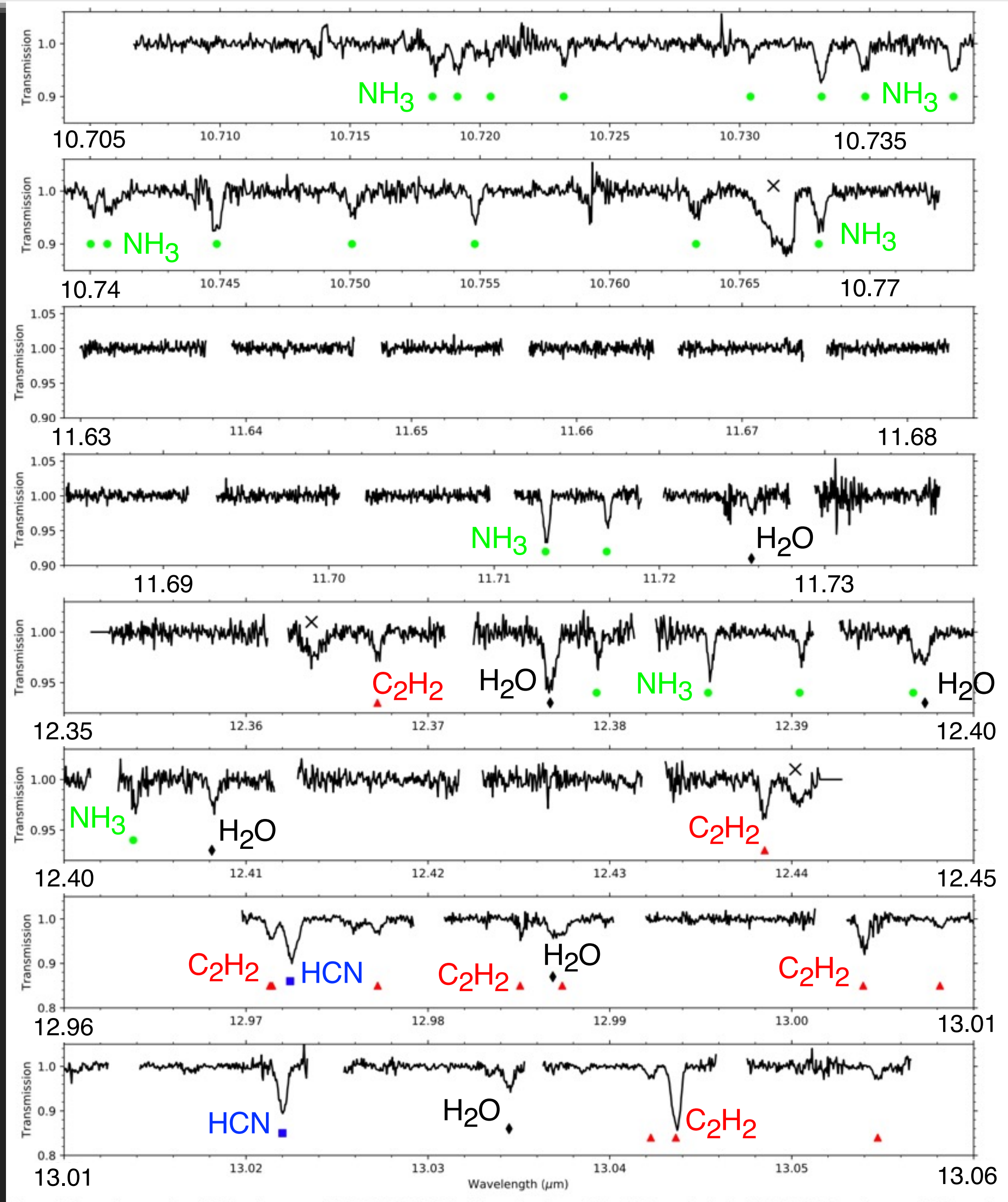
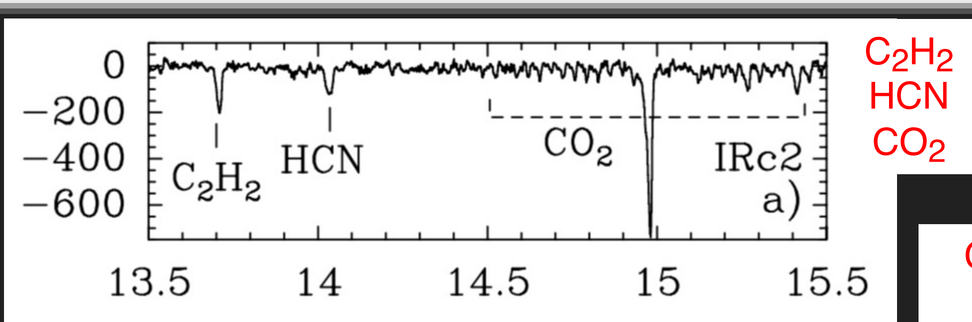
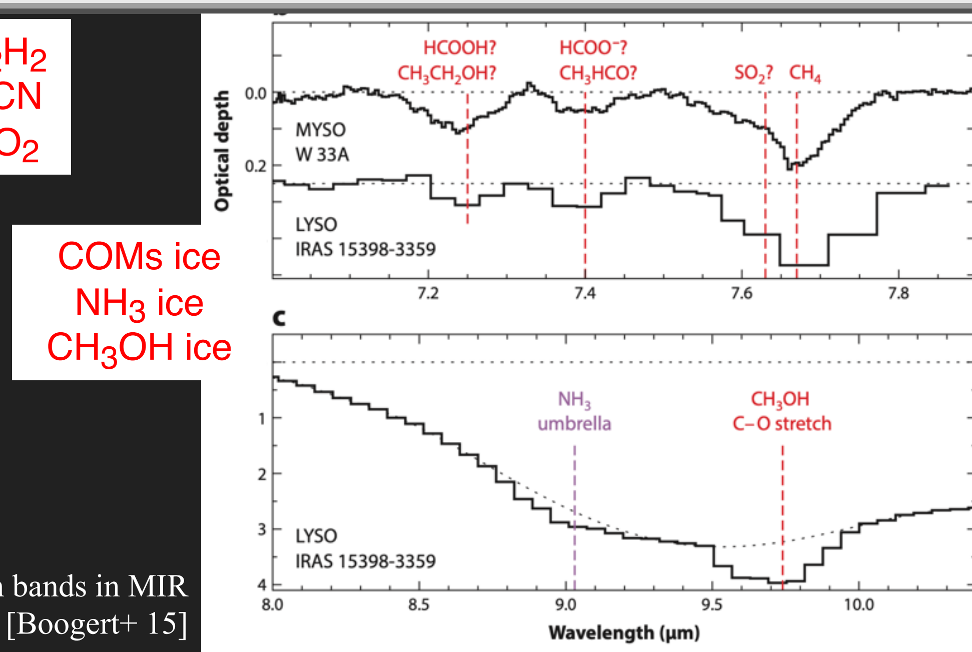


Fig.8 Gemini/TEXES spectra of a massive embedded YSO, AFGL2136 IRS1 (R=85,000) [Indrilo+ 2020].

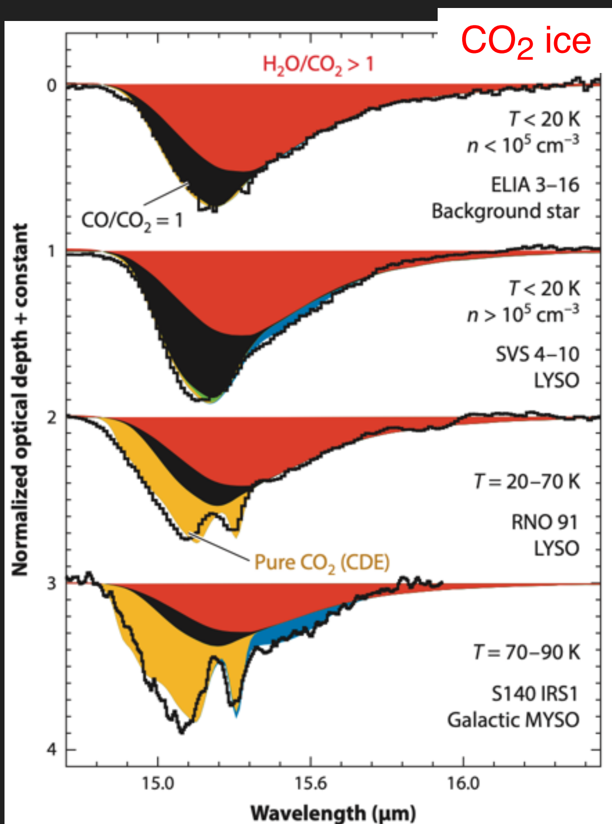
High-resolution MIR Spectroscopy of Massive YSOs



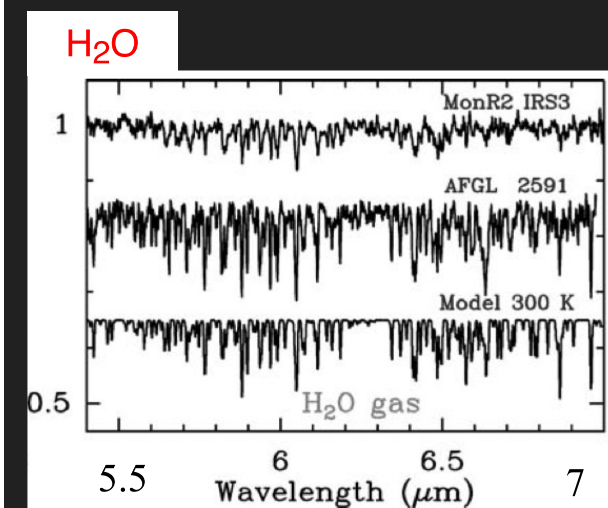
ISO-SWS spectrum of Orion IRc2 (R=3500) [Boonman+ 03]



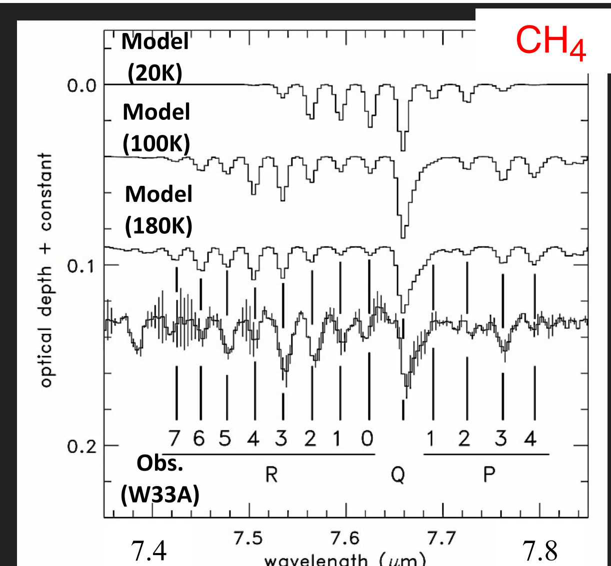
Ice absorption bands in MIR [Boogert+ 15]



CO_2 ice band at 15.2 μm [Boonman+ 03]



H_2O ν_2 ro-vibrational line [van Dishoeck 2004]



CH_4 ν_2/ν_4 ro-vibrational lines [Boogert+ 1998]

Summary

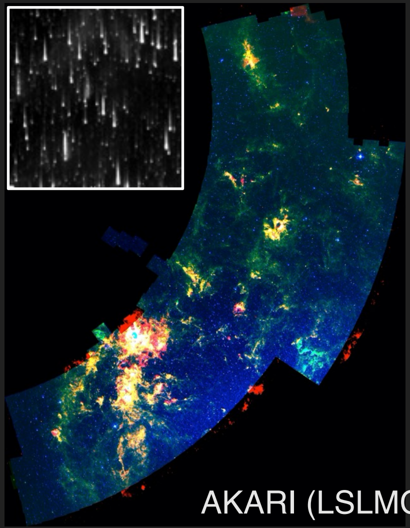
- GREX-PLUSは、これまでに無い高い感度で熱赤外線域のマゼラン雲の姿を描き出す
- AKARI/Spitzer/Herschelは大質量原始星の研究を銀河系外（マゼラン雲）へと広げた、GREX-PLUSはこれを小質量原始星に拡張し、銀河全体での幅広い質量範囲におよぶ星形成の様子を明らかにする
- マゼラン雲内に既に同定されている数百の大質量原始星の高分散分光により、原始星近傍の高温ガスの化学診断が可能になる
- 高分散分光については、5μm~のカバレッジがサイエンスの幅を大きく広げる

銀河のどこで星が生まれ、そこではどのような物質進化があり、
それらは銀河の局所的な環境や大局的な構造とどう関連しているのか?

AGBサイエンスも重要!

Diffuseダストも重要!

Spitzer, Herschel (SAGE, HERITAGE)



AKARI (LSLMC)