Appearing phase of 6.7GHz methanol maser in the process of high-mass star formation

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Introduction: high-mass star

- M_{star} > 8 solar mass
- Short lifetime $\sim 10^{6-7}$ [yr]
- Small number

High-mass stars control cosmic evolution!

- Strong feedback
- Synthesize heavy elements
- Cluster formation

Introduction

- Formation process of high-mass stars: Unclear!

⇨ 6.7GHz methanol maser: powerful tool !

①Associated with only high-mass star forming regions

②Free from extinction

③3D kinematics (Doppler shift + Proper motion) is available

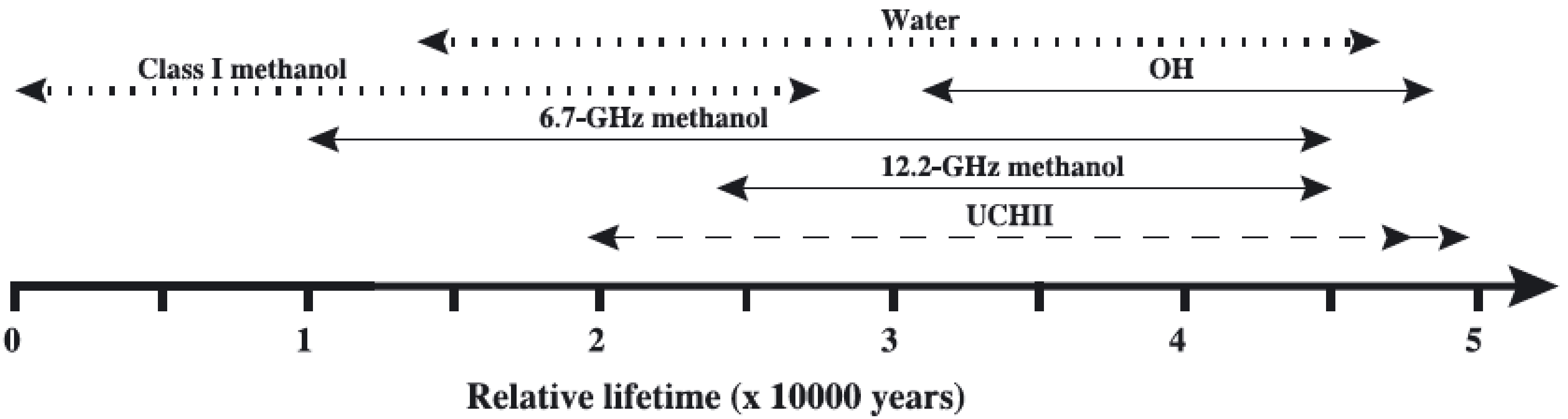
⇨ There are many studies with the maser by VLBI or single-dish

Introduction: Appearing phase

- Detection rate of 6.7GHz methanol maser
  @high-mass star YSOs: ~50% (Breen et al. 2010)

⇨ The maser dose not associate with all of high-mass YSOs.

- The maser occurrence may depend on the stellar age (Breen et al. 2010)



⇨ Is the stellar age only the matter?

Check!

Goal & Method

〈Goal〉

To determine the appearing phase of 6.7GHz methanol maser

〈Method〉

[Sample selection]

Candidate

⇨

[Observation]

Survey of 6.7GHz
⇨ detection or non-detection

＋

[Estimation of age]

SED fitting
⇨ get many physical parameters

⇨

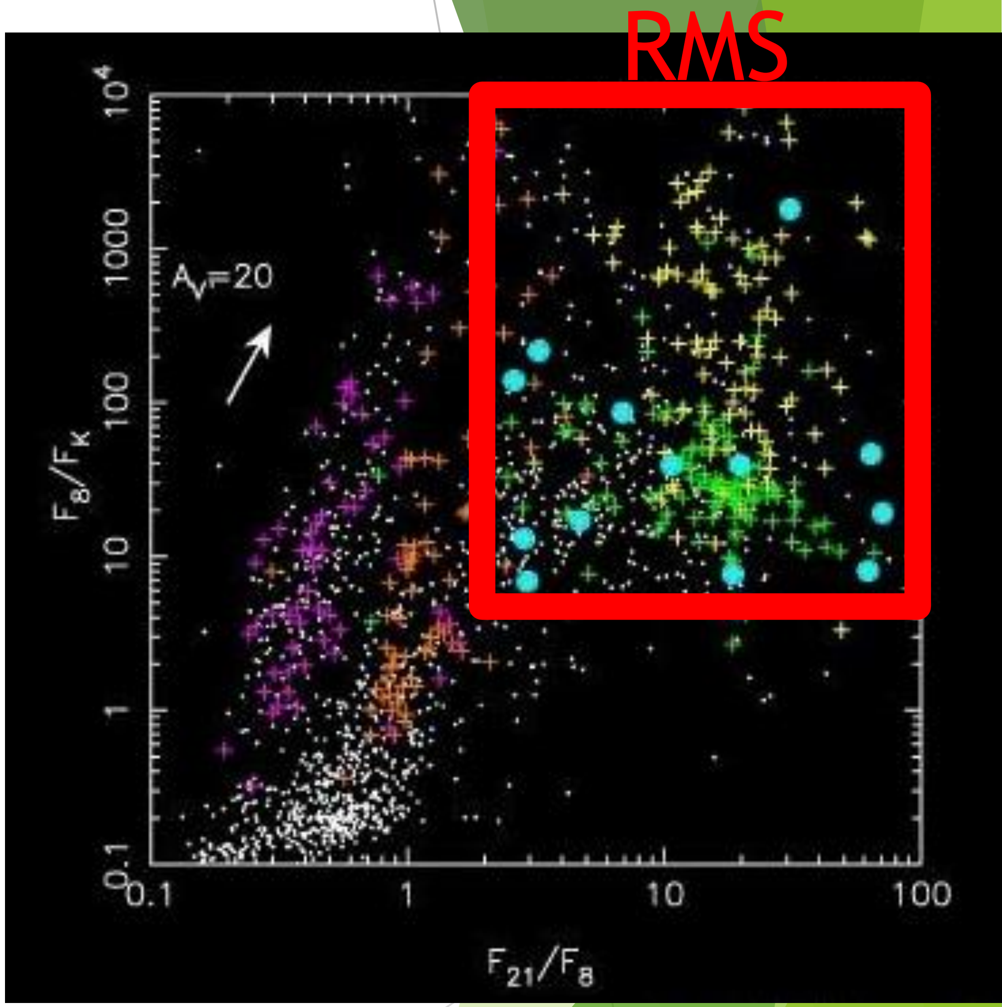
[Discussion]

Comparing stellar ages between detected objects and non-detected objects
⇨ Goal!

Sample selection: Red MSX Source

- A part of MSX_Point Source Catalog (4918 sources)
- Resolution 18”
- Source showing IR excess
- Total 2202 Sources
- Classification by many follow-up observations(e.g., continuum, NH_3, etc)

⇨ Good sample!



• Massive YSOs + UC HII regions

PN + C stars + OH/IR stars

Observations & Results

- Observational Instrument : Yamaguchi 32m telescope
- Target sources : 584 RMS $(\mathrm{Dec} > -20°, 0° < l < 180°)$

  (YSO, HII region, YSO/HII region)

- Detected source:99 sources

  ⇨ new detections for 2 sources

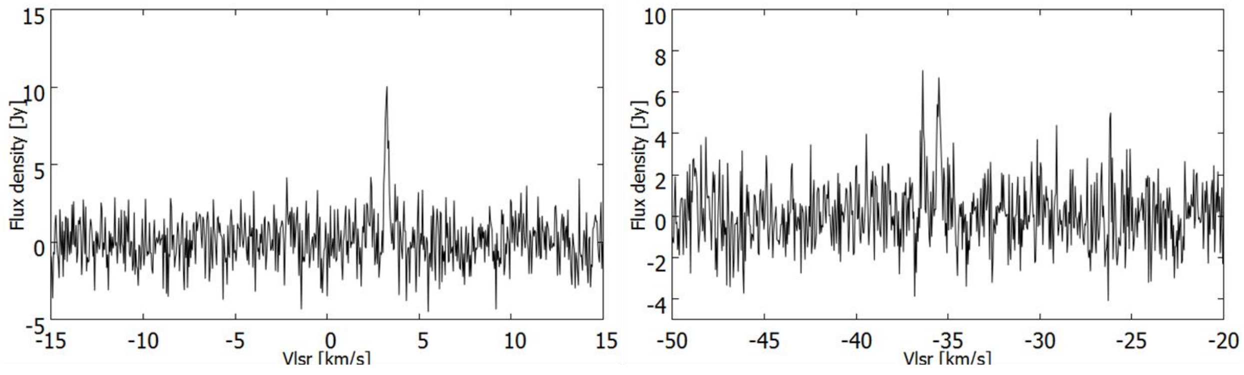


Fig. left:G052.2025+00.7217A, right:G084.9505-00.6910

Table. Observational parameter

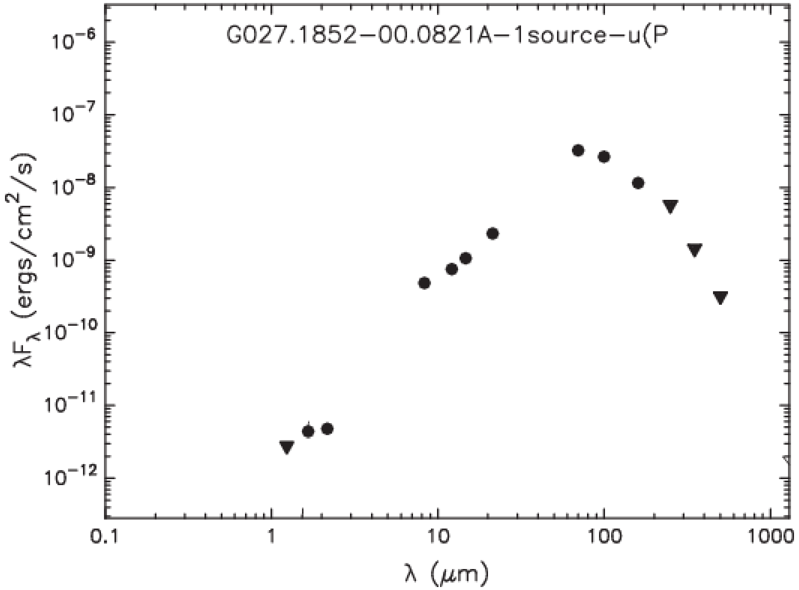
aperture	32 m
beam size	5.1’
aperture efficiency	～60%
Tsys	～250 K
bandwidth	8 MHz
spectral channel	8192
velocity resolution	0.044 km/s
integration time	840 s
rms noise level	～1.4 Jy

Estimation of age: SED fitting

- Used Tool: SED Fitting Tool(Robitaille et al. 2006)
- Used data: 2Mass, MSX, MIPS, IRAS, PACS, SPIRE

  ※MIPS if no PACS,

  IRAS(upper limit) if no PACS ＆ MIPS
- Number of sources: 50 sources (detected source:16, non-detected source:34)



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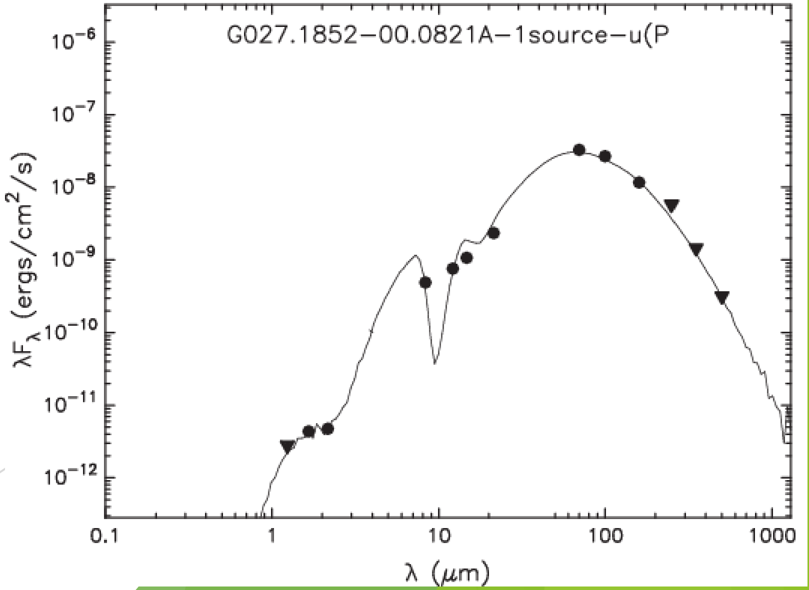
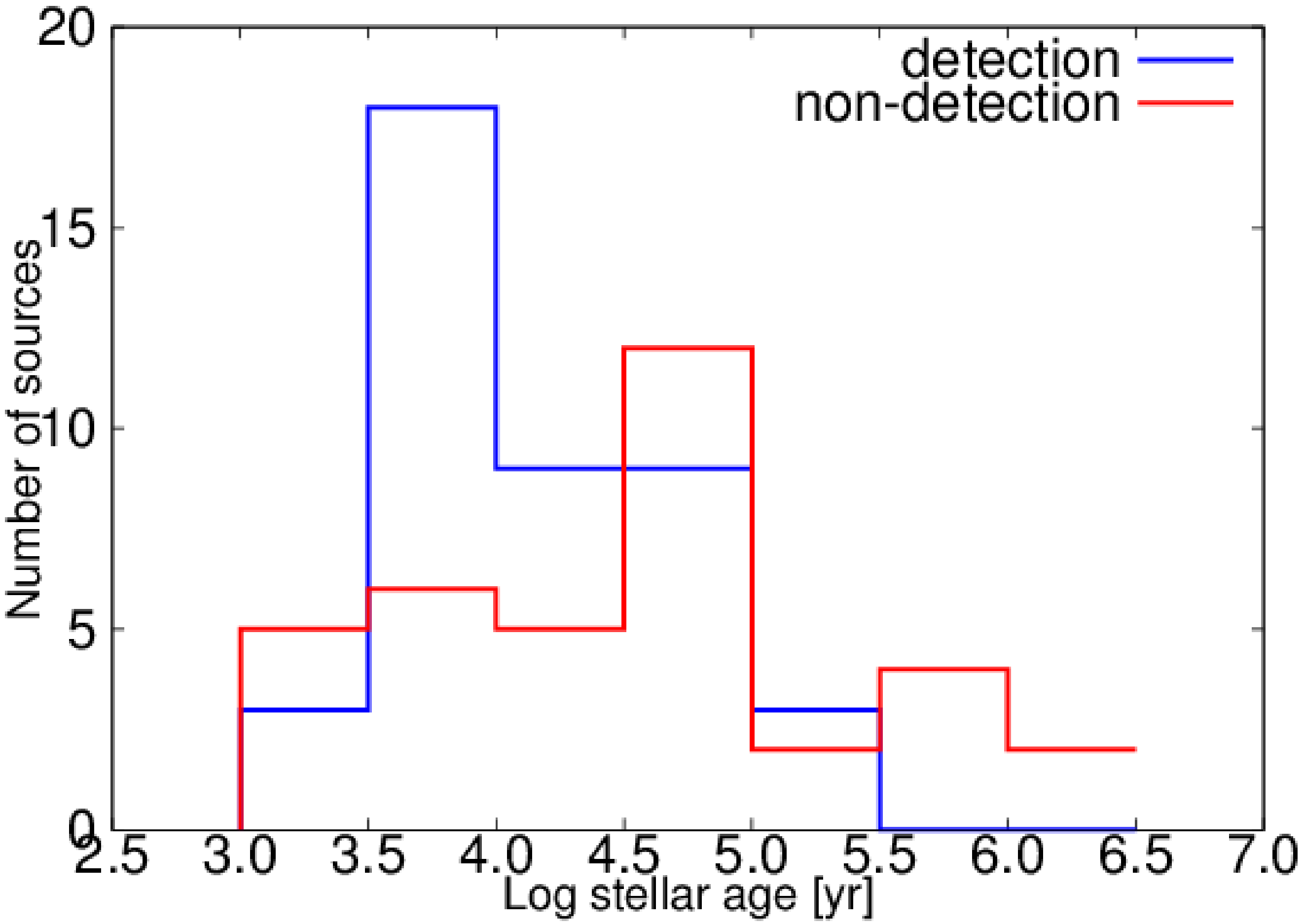
(χ^2fit from 200000 SED models)



Discussion 1
detection vs non-detection for stellar age histogram



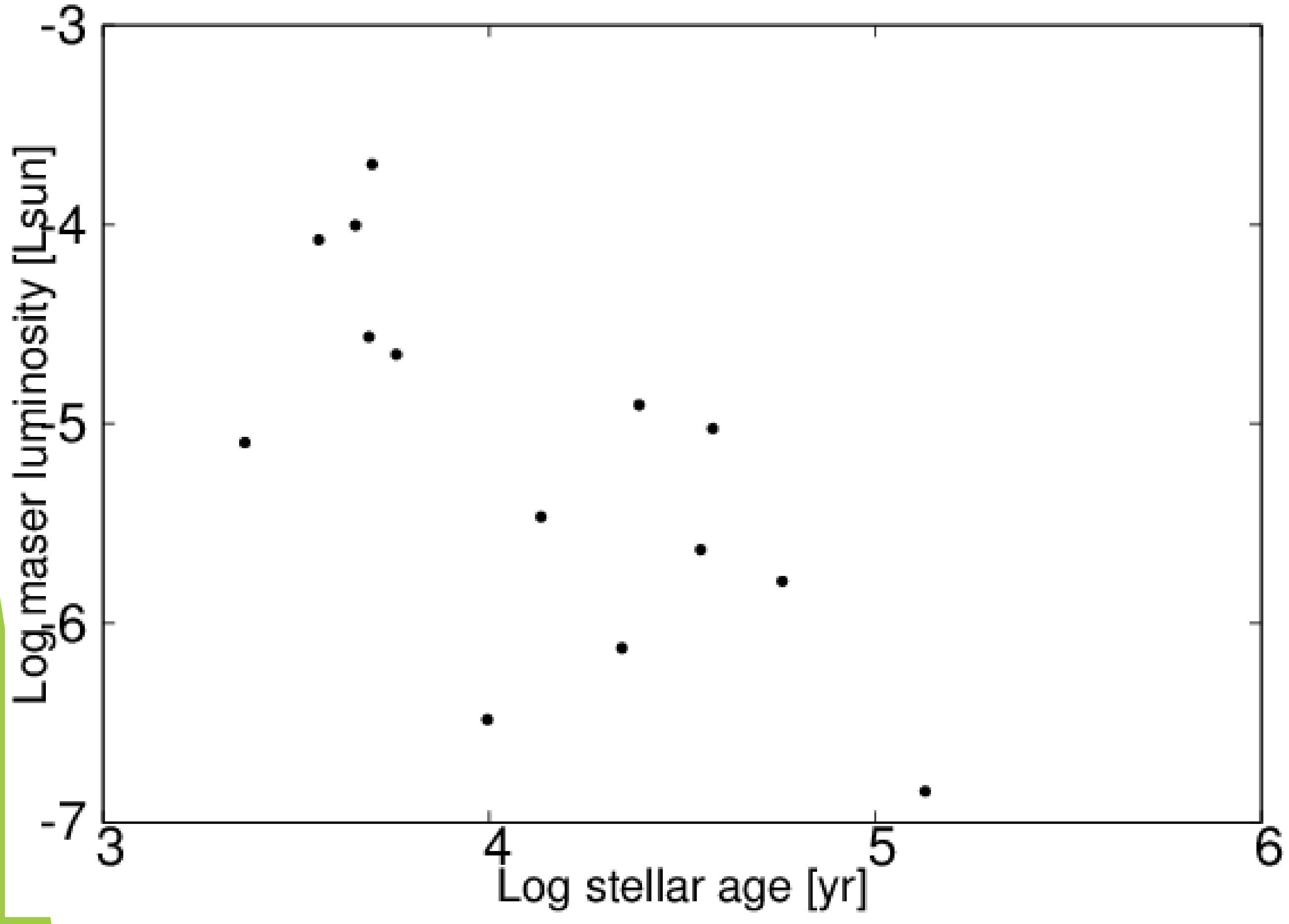
6.7GHz methanol maser tend to be associated with the rather earlier evolution phase.

But!
They separate clearly on the stellar age.

We found an anti-correlation between the maser luminosity and stellar age!

Discussion 2
An anti-correlation: maser luminosity－stellar age

New trend



Anti-correlation
(correlation coefficient: -0.70)

⇩

why?

⇩

Study: correlation between maser luminosity and other parameter
(e.g., Bolometric luminosity, accretion rate…etc)

Results: research of correlation

	Correlation coefficient	Result
Bolometric luminosity－maser luminosity	0.63	△
Accretion rate－maser luminosity	0.90	○
Accretion luminosity－maser luminosity	0.84	○
Accretion luminosity－bolometric luminosity	0.76	○
Accretion rate－stellar age	-0.71	○

Strong correlation：①Accretion rate－maser luminosity
②Accretion rate－stellar age

why?

⇩

The Strong correlation between maser luminosity and stellar age is caused by accretion rate.

We propose one hypothesis.

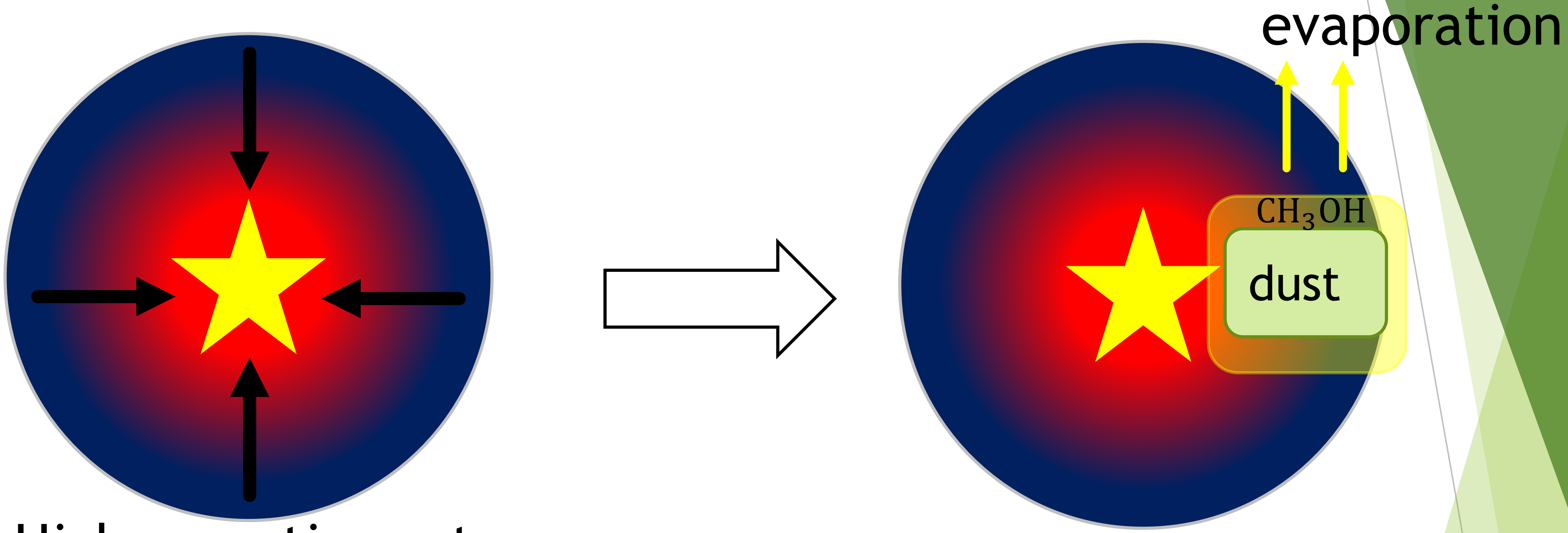
High accretion rate can cause higher methanol column density by enhanced dust evaporation, consequently increasing the maser luminosity.

⇨ There are two possible ways!

[c.f. One of the emission condition]

- Column density of methanol molecular $> 2 \times 10^{15}\ \mathrm{cm}^{-2}$

〈way①〉



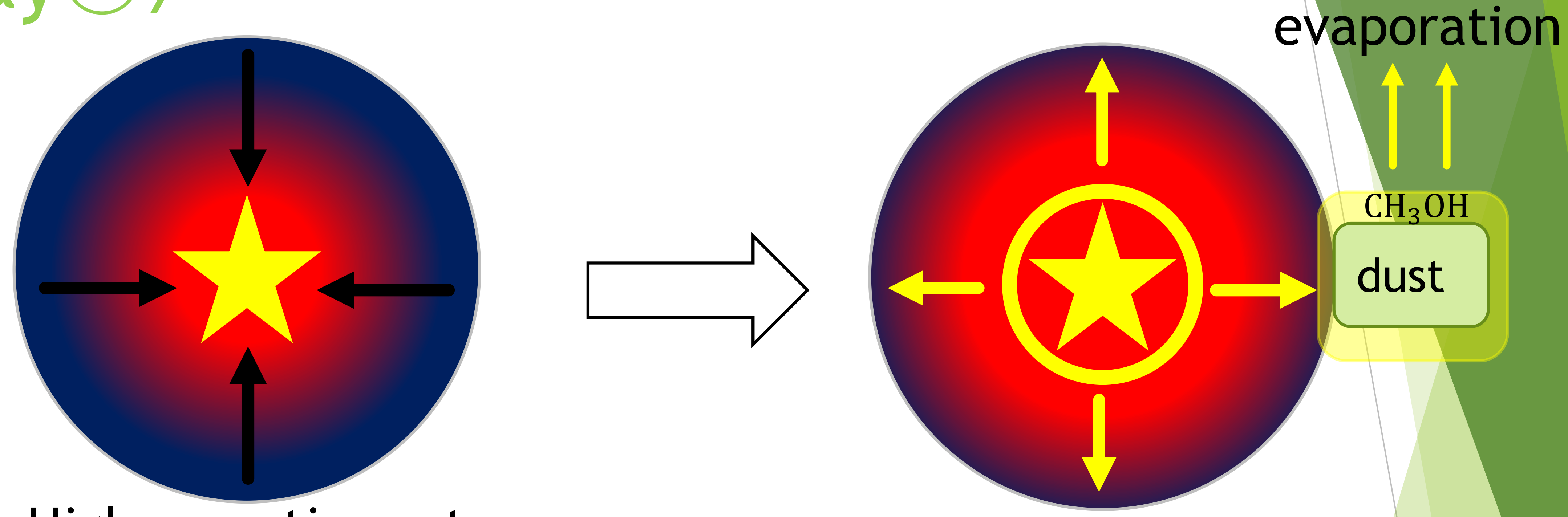
High accretion rate

⇨ Accretion flow supplies dust near the host object

⇨ Increase methanol column density by enhanced dust evaporation

⇨ Enhance maser luminosity!

⟨way②⟩



High accretion rate

⇨ High temperature near the host object by accretion luminosity

⇨ Extend heated area

⇨ Increase methanol column density by enhanced dust evaporation

⇨ Enhance maser luminosity!

Conclusion ＆ Future work ①:appearing phase of 6.7GHz methanol maser

〈prediction〉 The maser occurrence depends on the stellar age.

〈conclusion〉 The maser is associated with the active accretion phase in the early evolutionary state, although the exact stellar age cannot be determined

〈future work〉 Comparison between maser detected objects and non-detected objects for other parameters

Conclusion ＆ Future work
②:Strong correlation: maser luminosity－accretion rate

〈Question〉 A strong positive correlation between maser luminosity and accretion rate is found.
What is this?

〈hypothesis〉 High accretion rate caused higher methanol column density

〈future work〉 research correlation between methanol column density and accretion rate