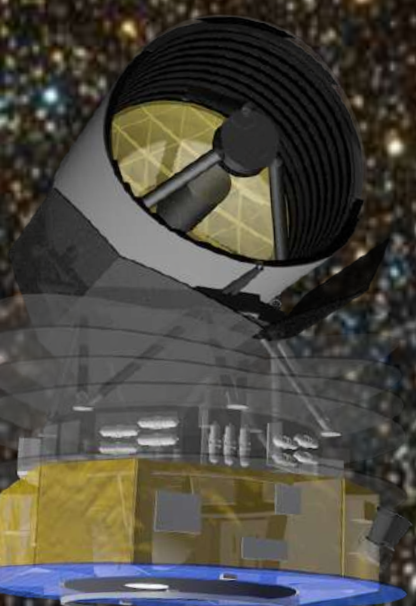
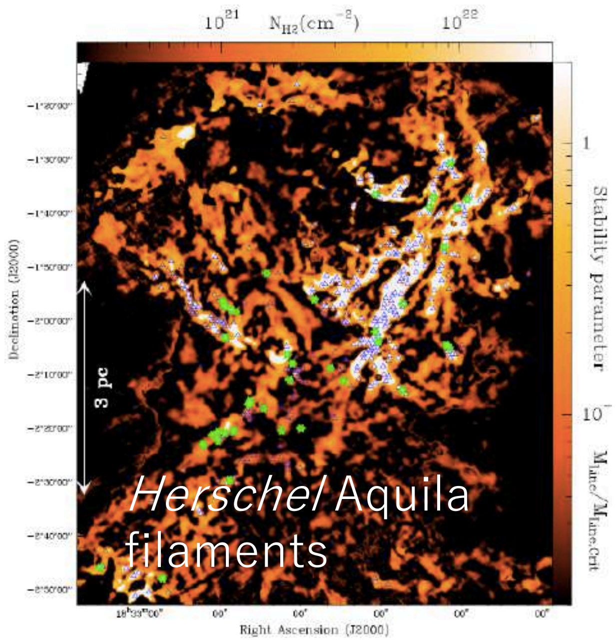
宇宙赤外線望遠鏡 SPICA による分子雲磁場の観測と星形成機構



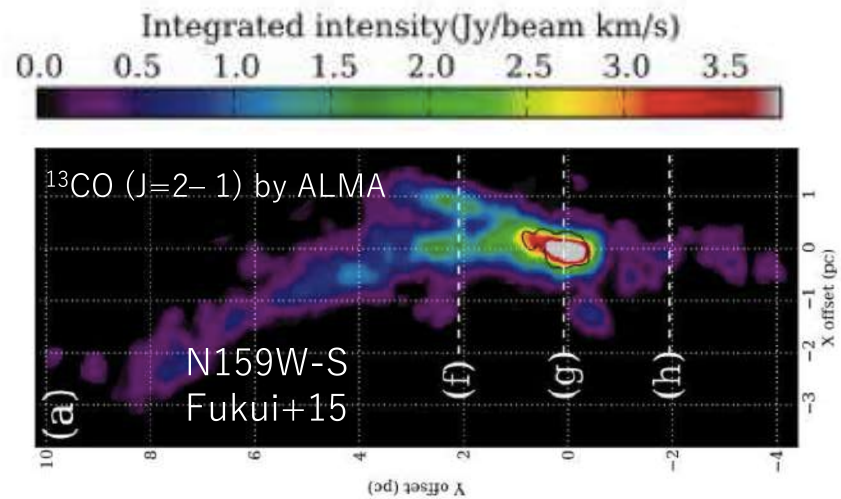
島尻芳人（NAOJ）

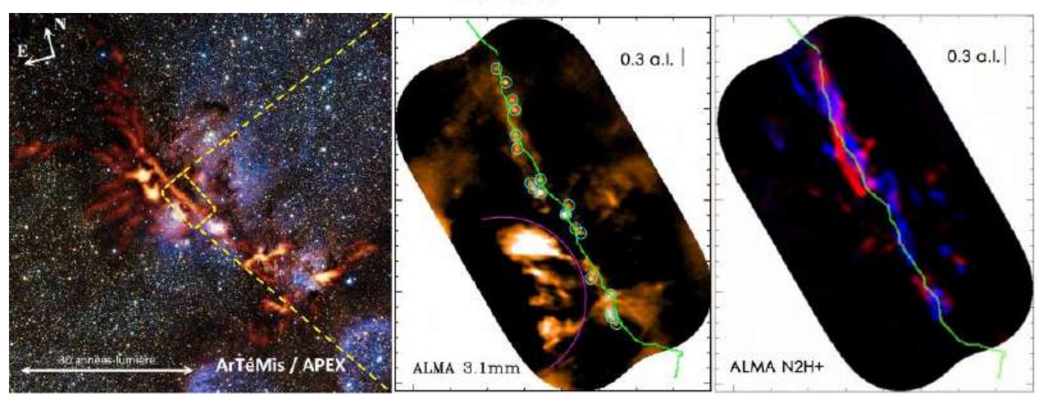
Star formation in dense filaments

- ✓ Filamentary structure is ubiquitous (Andre+10, Men'shchikov+10).
- ✓ Most prestellar cores are in the filament, suggesting the filament is the main site of the star formation (Andre+10, Konyves+15, Konyves+19).
- ✓ Even massive stars are suggested to be formed via filaments(Peretto+13, Fukui+14, Shimajiri+19).



Konyves+15





Shimajiri+19b

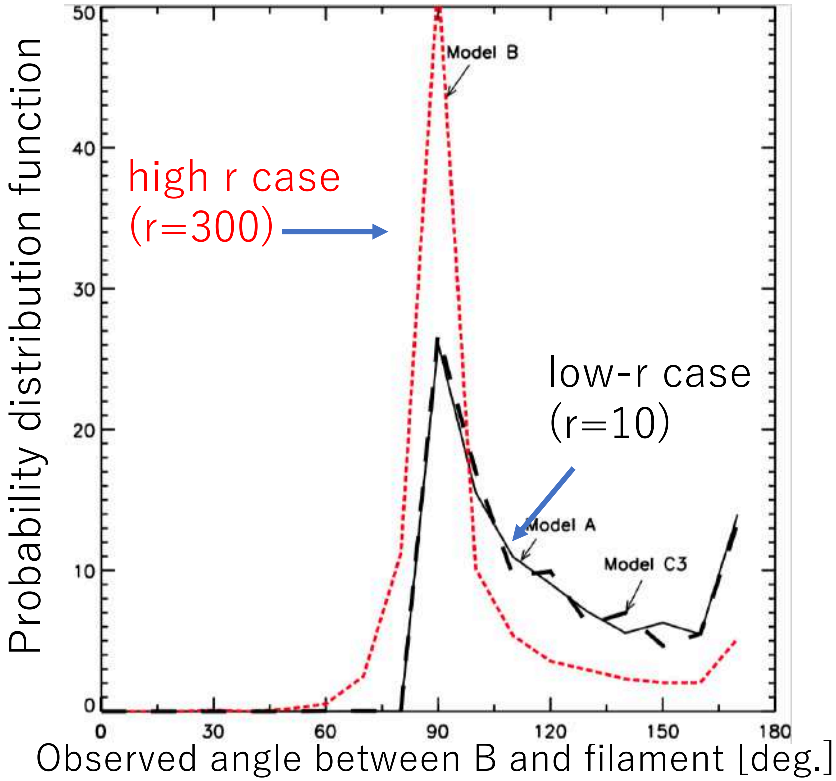
Importance of polarization observations toward filaments

Many theoretical scenarios have been proposed

- ✓ Gravitational insta. of molecular sheet (e.g., Nagai+98)
- ✓ Turbulent sheet-sheet collision (e.g., Padoan 00)
- ✓ MHD shock compression (Inoue & Fukui 13; Vaidya+13)

How can we distinguish these scenarios?

- ✓ High-r suggests that the filaments are formed through gravitational process.
- ✓ Low-r filaments can be formed through non-gravitational processes, which haven't been reached to gravitationally-critical line-mass.



Polarization observations are crucial!!

See also Z233c (T. Inoue)

Revealing the filament formation in low star-forming regions

Herschel

- ✓ Omnipresence of the filamentary structure in any given molecular clouds (Andre+10, Arzoumanian+11, Palmeirim+13)

Molecular line observations with the ground-based telescopes

- ✓ Provided the kinematic evidence of the filament formation paradigm (Hacar+13, Arzoumanian+13, Shimajiri+19a)

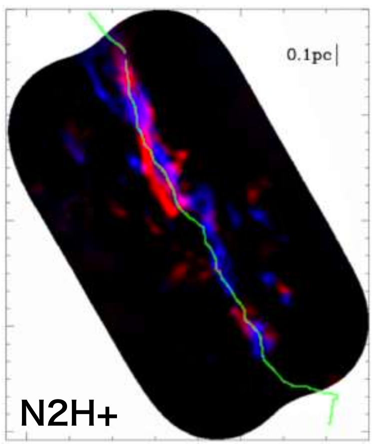
Polarization observations with the ground-based telescopes

- ✓ Large programs such as BISTRO (SCUBA2pol/JCMT) and B-FUN(NIKA2pol/IRAM30m) are on going to reveal the B-fields on the filament. Now, mosaic observations with the ALMA are also feasible. These observations will provide us more insight.

Next step should be to investigate the universality of the filament formation paradigm. For this purpose, the observations toward the massive star-forming regions are crucial.

Revealing the filament formation in massive star-forming regions with SPICA?

- ✓ Star formation law converting from dense gas (filament) to star may be universal (Shimajiri+17)
- ✓ Filamentary structures in the massive star-forming regions may be formed via the similar process as in the low-mass star-forming regions (Shimajiri+19b)
- ✓ High-mass stars may be formed in the filament with a large Mline/NH2 (Andre+19, Fukui+19)



Shimajiri+19b

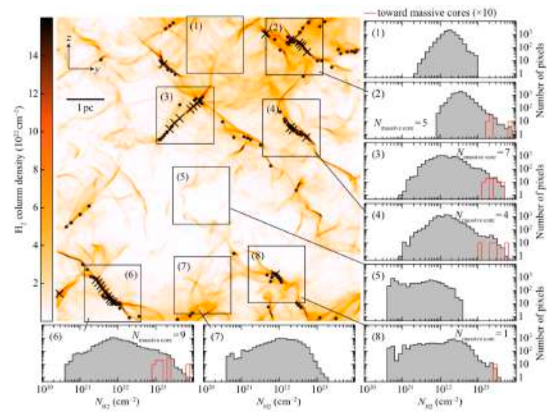


Fig. 11. Column density map of H_2 (low density gas with $< 10^4$ cm^{-3} is excluded) in the y-z plane at $t = 0.7$ Myr (top-left panel) and column density histogram in the 8 regions of 1.5 pc × 1.5 pc (panels (1) – (8)). The crosses in the top-left panel show the positions of massive cores with $M_{core} > 10\,M_{\odot}$ and $M_{core} > 10\,M_J^{eff}$, and the dots show intermediate mass cores with $M_{core} = 5 - 10\,M_{\odot}$.

Fukui+19

Direct observations are required to reveal the filament formation process in the massive star-forming regions.

(Q)Can we do with SPICA?

(A)No, since due to a lack of angular resolution

Distance to targets

To resolve the 0.1-width filament, 0.03pc-resolution is required.

<200pc
Taurus
Oph.
Cha.
Lupus
Musca
Pipe
Polaris

~200pc
Serp
Aquila
NGC1333
Perseus

400pc
Orion A&B
IC5146
CMC
Cepheus
Callback
Coroa Australis

800pc
MonR2
GGD12-15
NGC2264

1kpc
M8
NGC3576
IRAS17233-3606

~1.5kpc
RAFGL5126
RCW38
Rosette
M20
NGC6334

~2kpc
RCW116B
RCW121
RCW122
W31B
RAFGL5189
G35.20-0.74

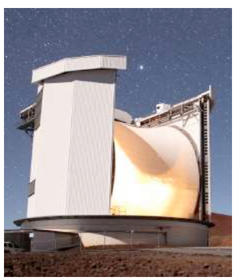
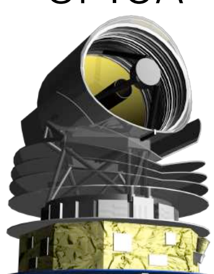
Herschel & SPICA (18”)
can resolve the filament structures

SPICA+ground-based telescope (3”)
may resolve the filament structures

SPICA (9”)
can resolve the filament structures

*High-mass star-forming region
*Low- & intermediate star-forming region

Advantages & Disadvantages of each observations

	Advantages	Disadvantages
Herschel 	Wide field High sensitivity	Low angular resolution No polarization
Ground-based telescope 	High angular resolution Polarization	Small field No extended emission
SPICA 	Wide field High sensitivity Polarization	Low angular resolution

Synergy with ground based telescope

SPICA

Extended emission

Low angular resolution

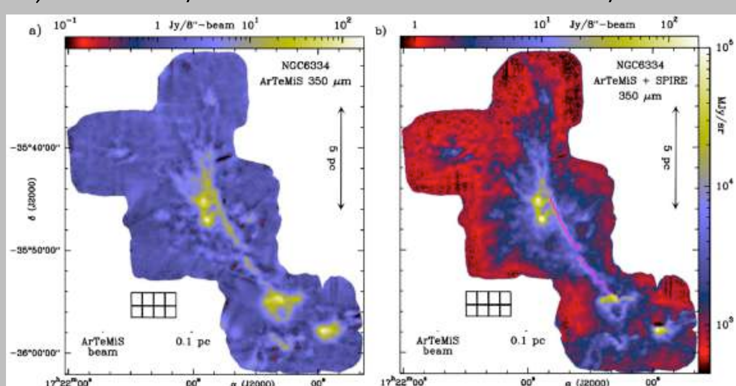
Ground-based telescope

No extended emission

High angular resolution

Improve angular-resolution by combining SPICA+ground-based telescope data

Ex) SPIRE/Herschel + ArTeMiS/APEX



Andre+16

Extended emission

&

High-angular resolution

Ex) if a copy of Safari-pol in LMT(D~50m, D_{eff}~30m), we can produce the 3”-resolution map with an extended emission.

Summary

✓SPICA B-BOP can reveal B-fields structures in molecular clouds that enable us to understand physical character of turbulence and origin of star-forming filaments in molecular clouds.

✓For the filaments, due to their narrow widths of 0.1 pc, we cannot expect increase of target number comparing with Herschel. However, we can exceed Herschel, if we combine data from SPICA and grand-based telescopes such as LMT.