大質量星形成とホットコア

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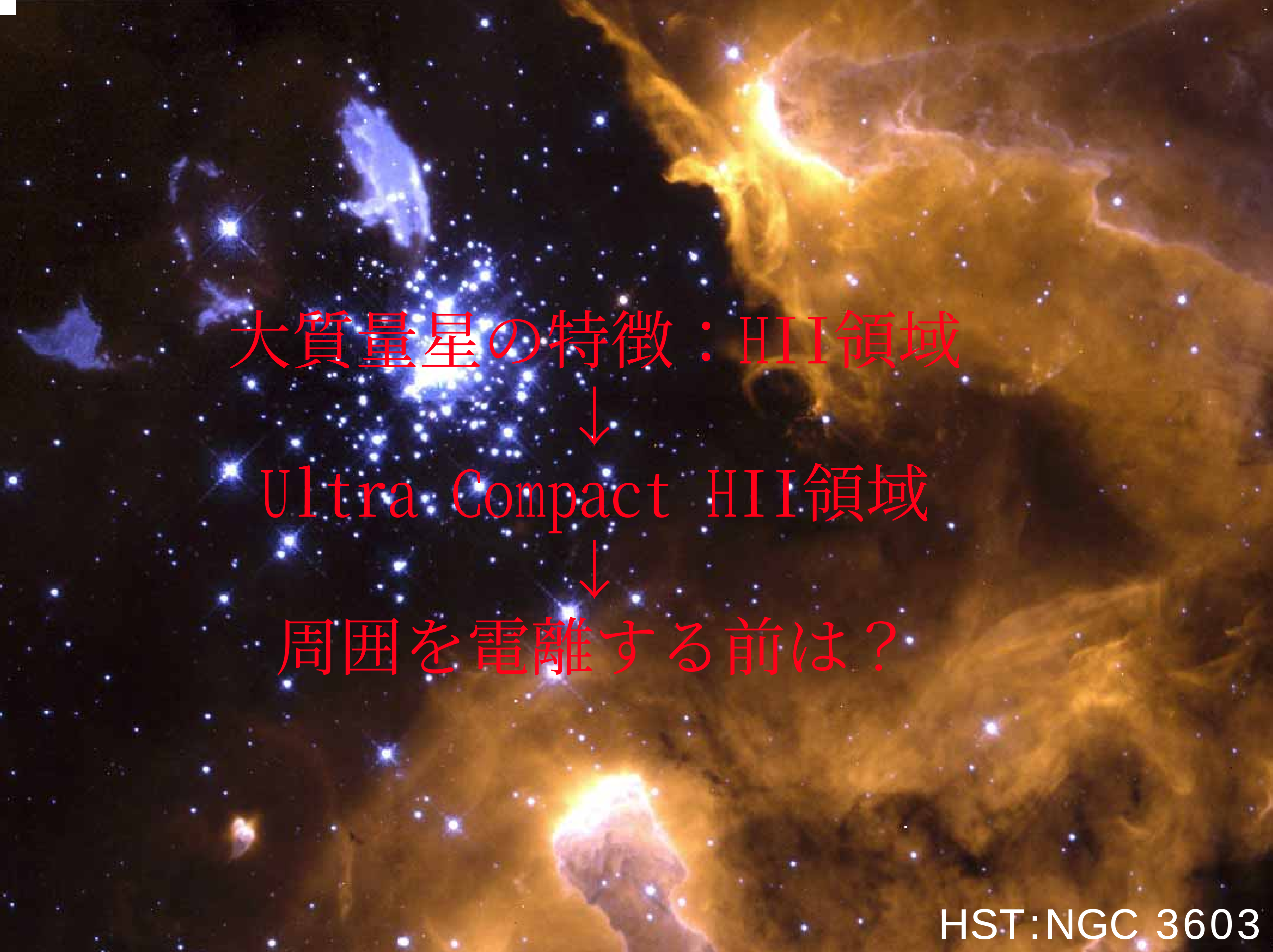
大質量星形成はサブアークセカンドでどのように見えるか？

hot core段階より後の問題について
W49Aを中心に考える


大質量星の特徴：HII領域
↓
Ultra Compact HII領域
↓
周囲を電離する前は？
HST:NGC 3603

爆発的星形成領域

銀河系内

W49A，W51A，　SgrB2など

O型星が20-50-個

ほぼ同時期に形成される領域がある。

↓

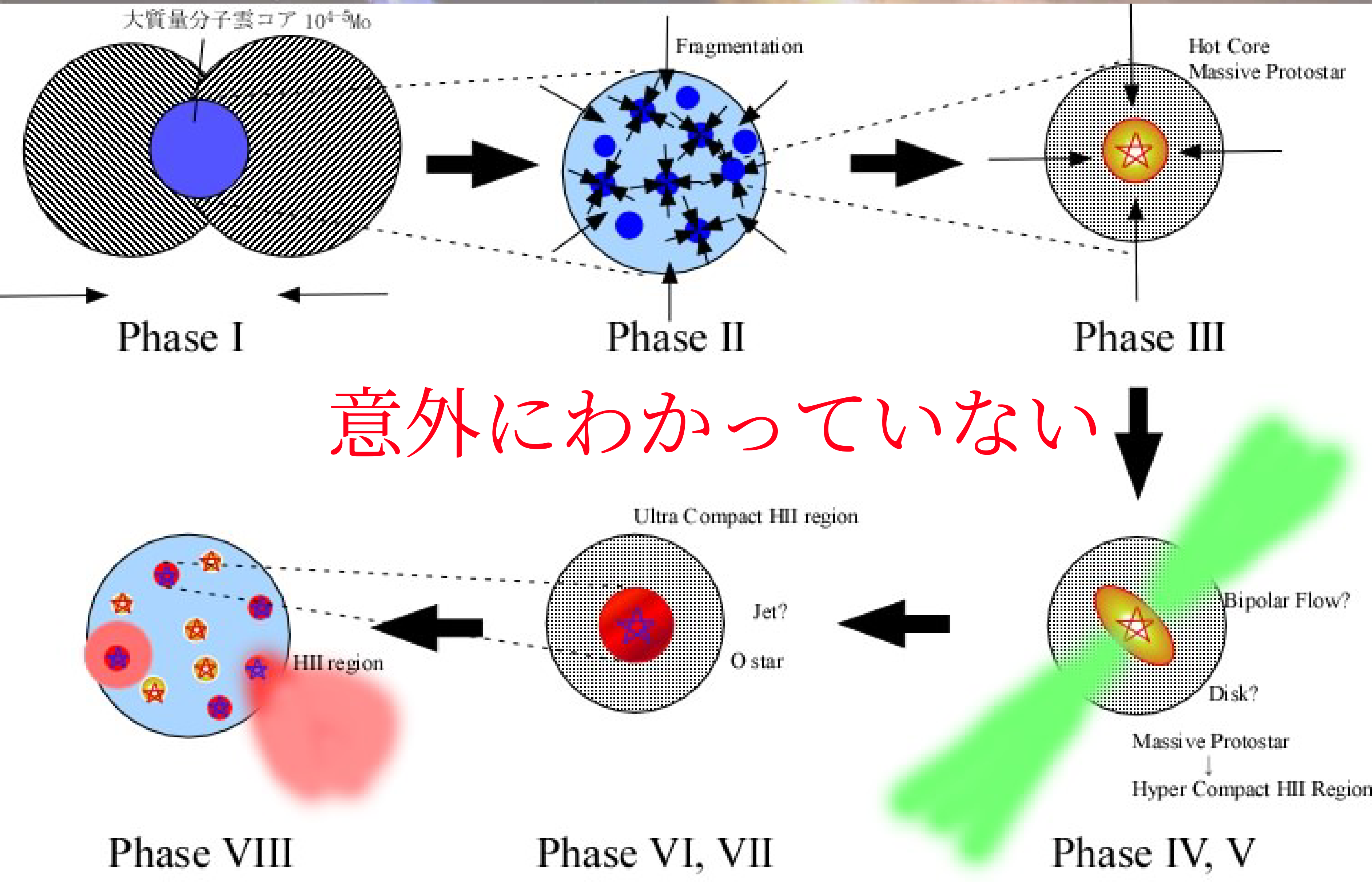
数pc以内に10^4-10^5M_{sun}のガス

↓

大質量分子雲コア(力学的に不安定)

（どうやってできたか？分子雲どうしの衝突が有力）

爆発的星形成のシナリオ



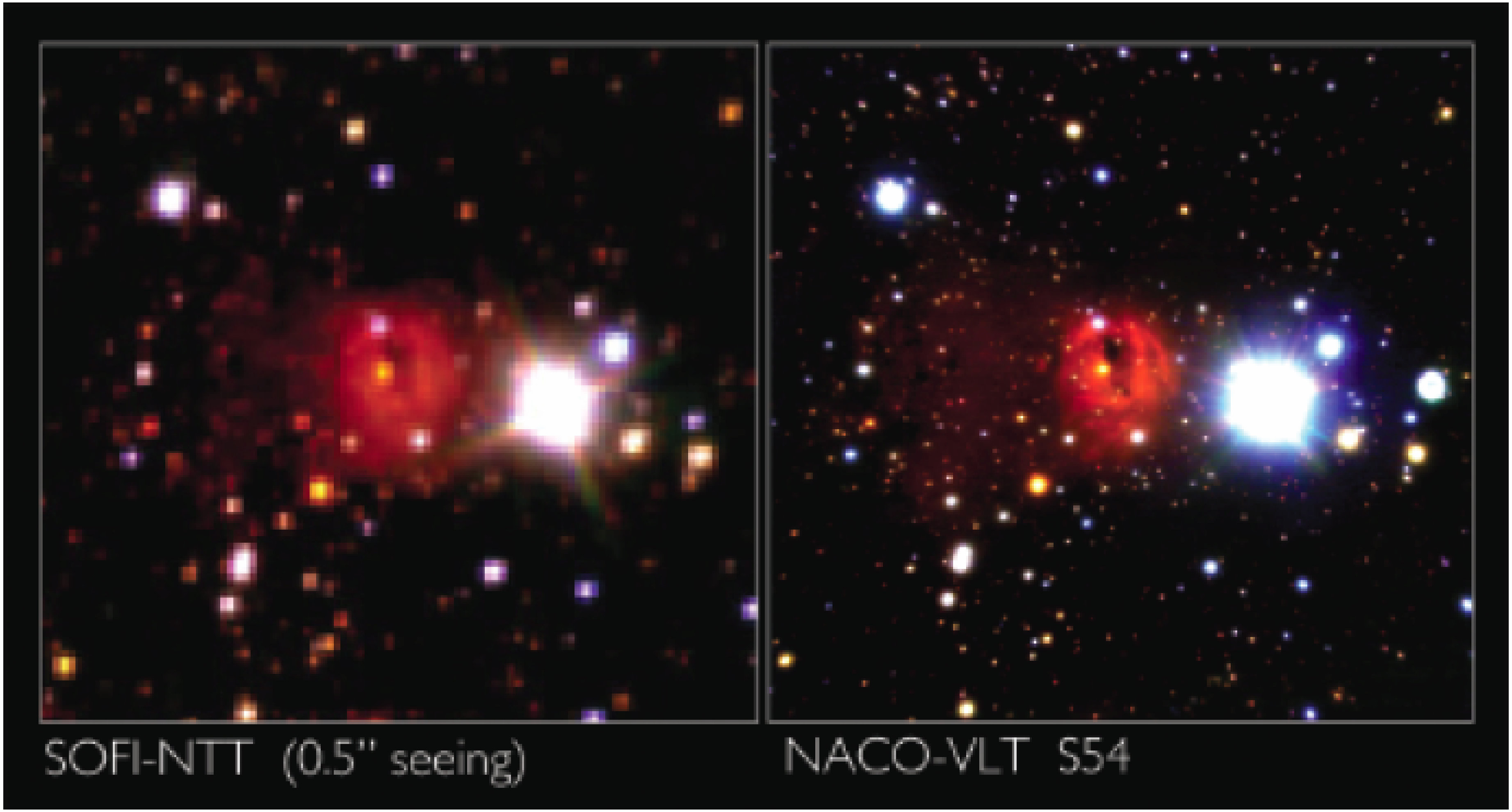


Figure 6: SOFI and NACO JHK$_s$ colour composites of the only compact HII region that is accessible to NACO using natural guide stars. The object in the centre of the compact HII region is a newborn ~80 $M_\odot$ star candidate. Through comparison with models (Freyer et al. 2003) we estimate the age of the HII region to be remarkably young: $4 \cdot 10^4$ yr. This is a very young massive star caught in the rare act of passing from the ultracompact to compact HII region stage.

Alves et al. (2003)

HCHII, UCHII, HII領域

大質量星の形成：10^4年程度

Accretion Rate ～ $10^{-2} M_{sun} yr^{-1}$

UCHI

電

寿

HCHI

寿命：意外に短い？

素朴？
異なる
メカニズムがある？

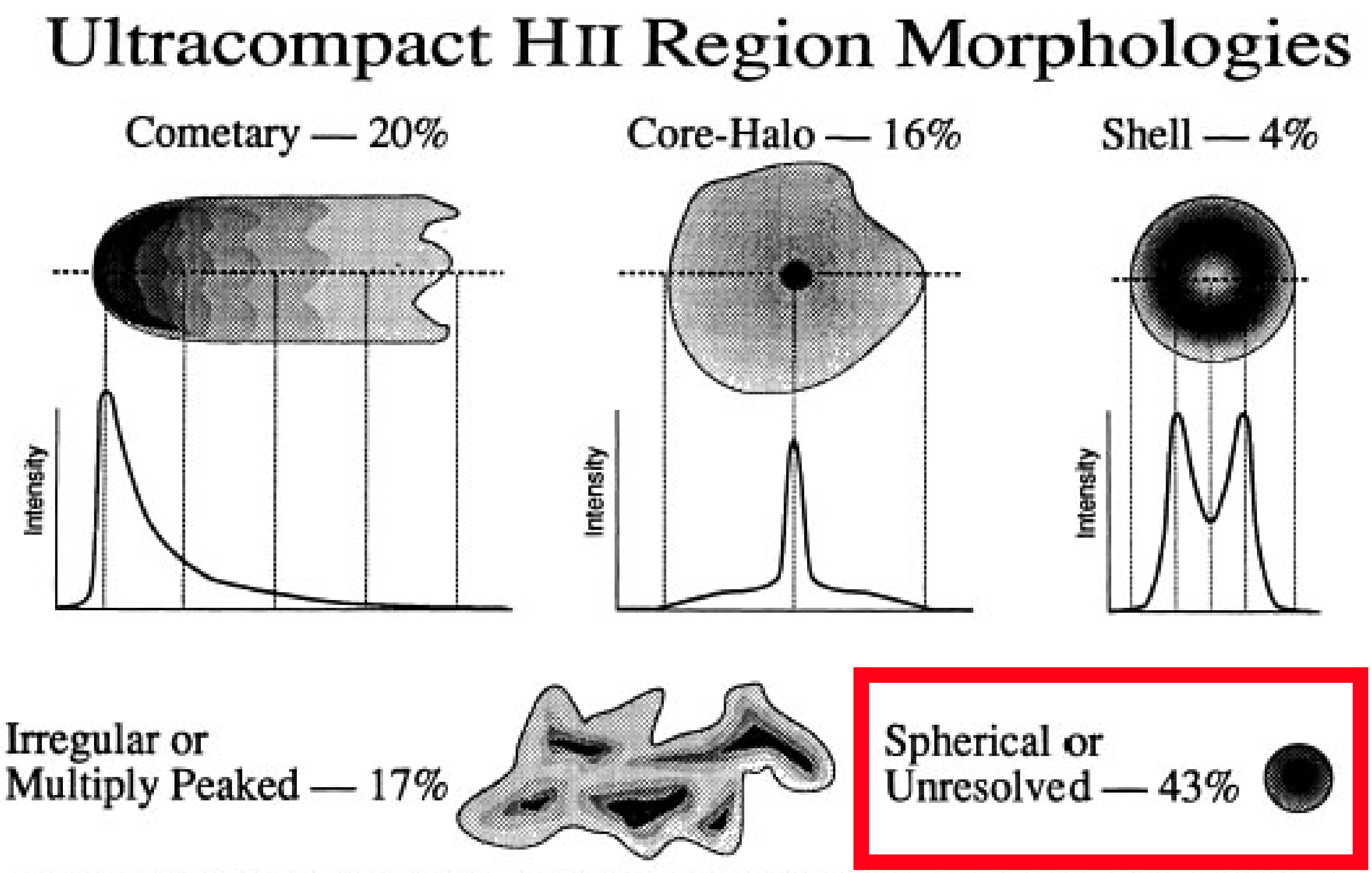
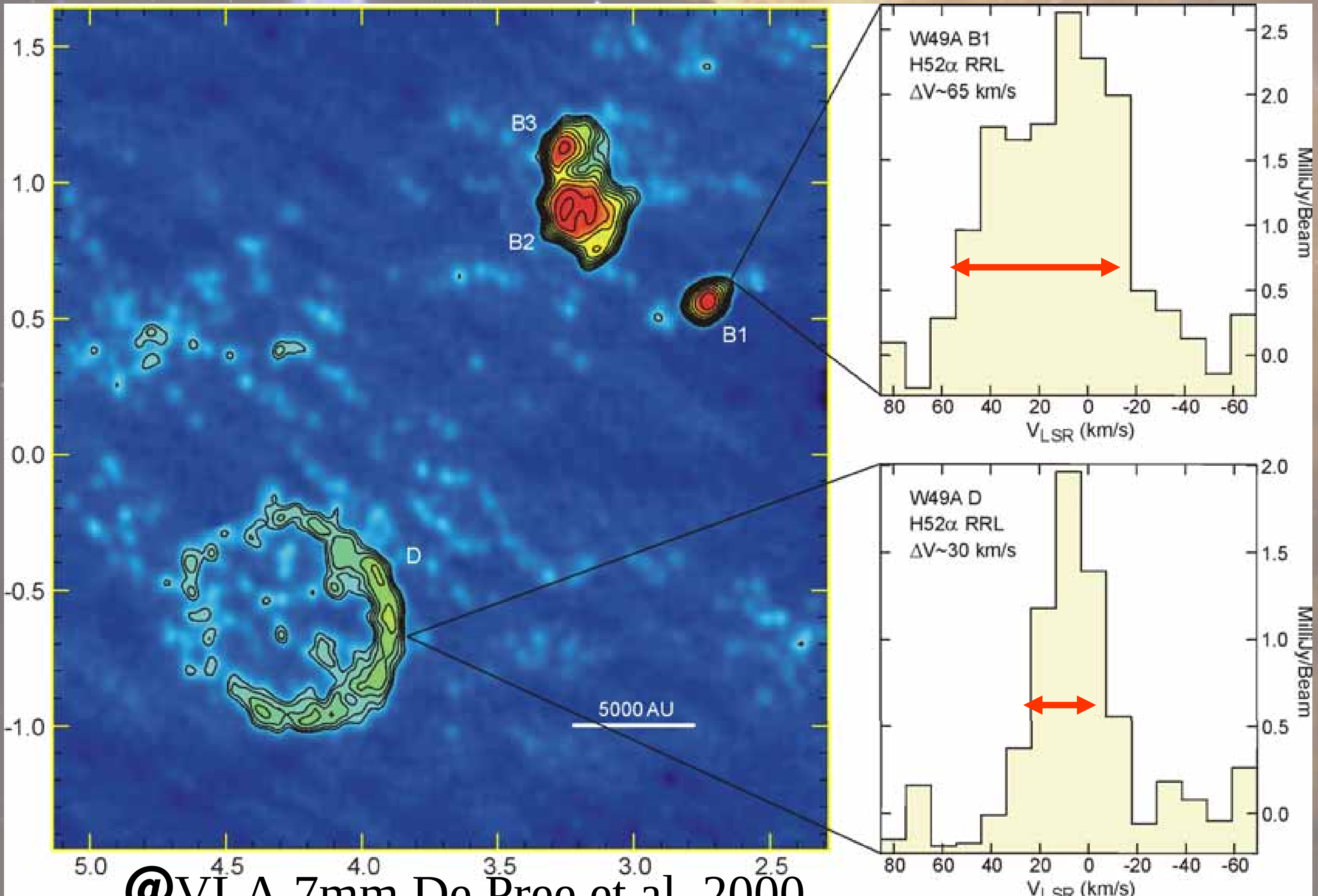


FIG. 143.—A schematic of the basic ultracompact H II region morphologies seen in these high-resolution VLA observations. The spatial resolution was ~0.″4, and structures larger than ~10″ were not well imaged. Percentages give the relative numbers of sources in each class; the total sample contained 75 objects. Some of the spherical or unresolved sources may show different structures when observed at higher angular resolution, and a few may be cometary sources viewed along their axis of symmetry. The appearance of a source may change with the wavelength of observation: the central cavities seen in the cometary and shell-shaped sources will not be seen at wavelengths where the gas is optically thick.

若いUCHII
or HCHII

Wood and Churchwell (1987)

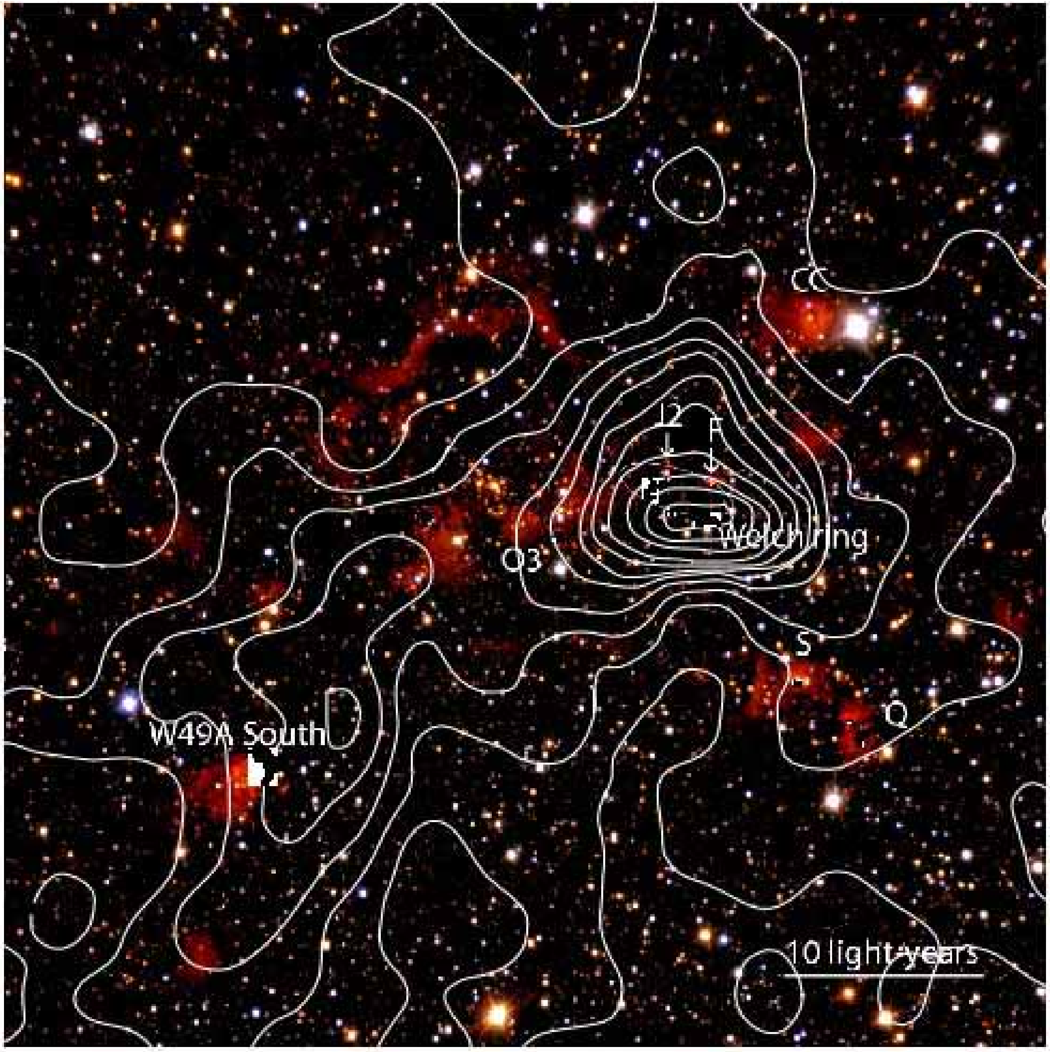
Broad Line Recombination Object (BRLO)



@VLA 7mm De Pree et al. 2000

NIR（星）（Alves et al. 2003)の分布と分子雲（^{13}CO：Miyawaki)の分布

大質量分子雲コア内は吸収が深くて見えない
→電波連続波



Colour Composite of W49A
(NTT + SOFI)

ESO PR Photo 21a/03 (22 July 2003)

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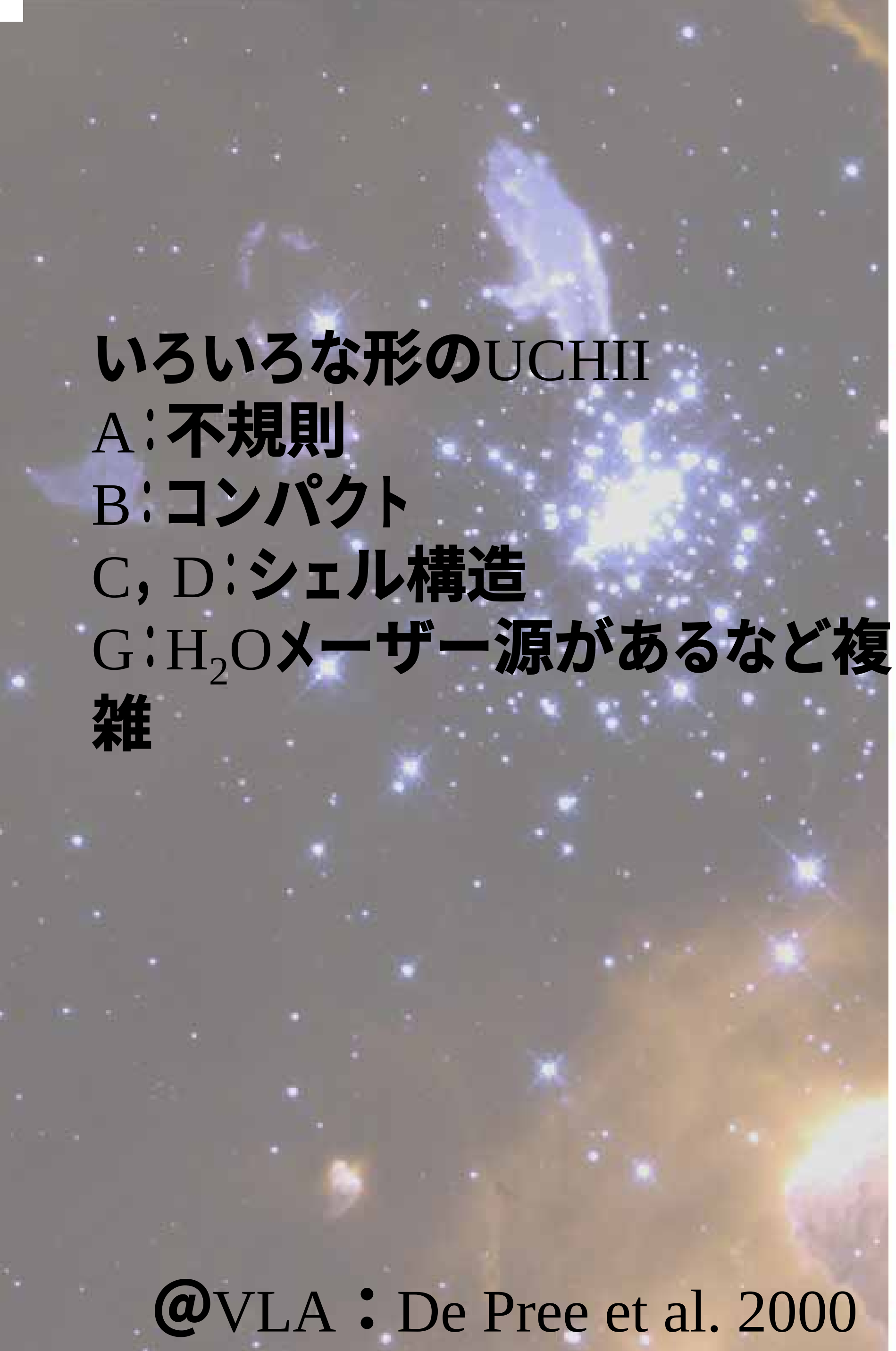


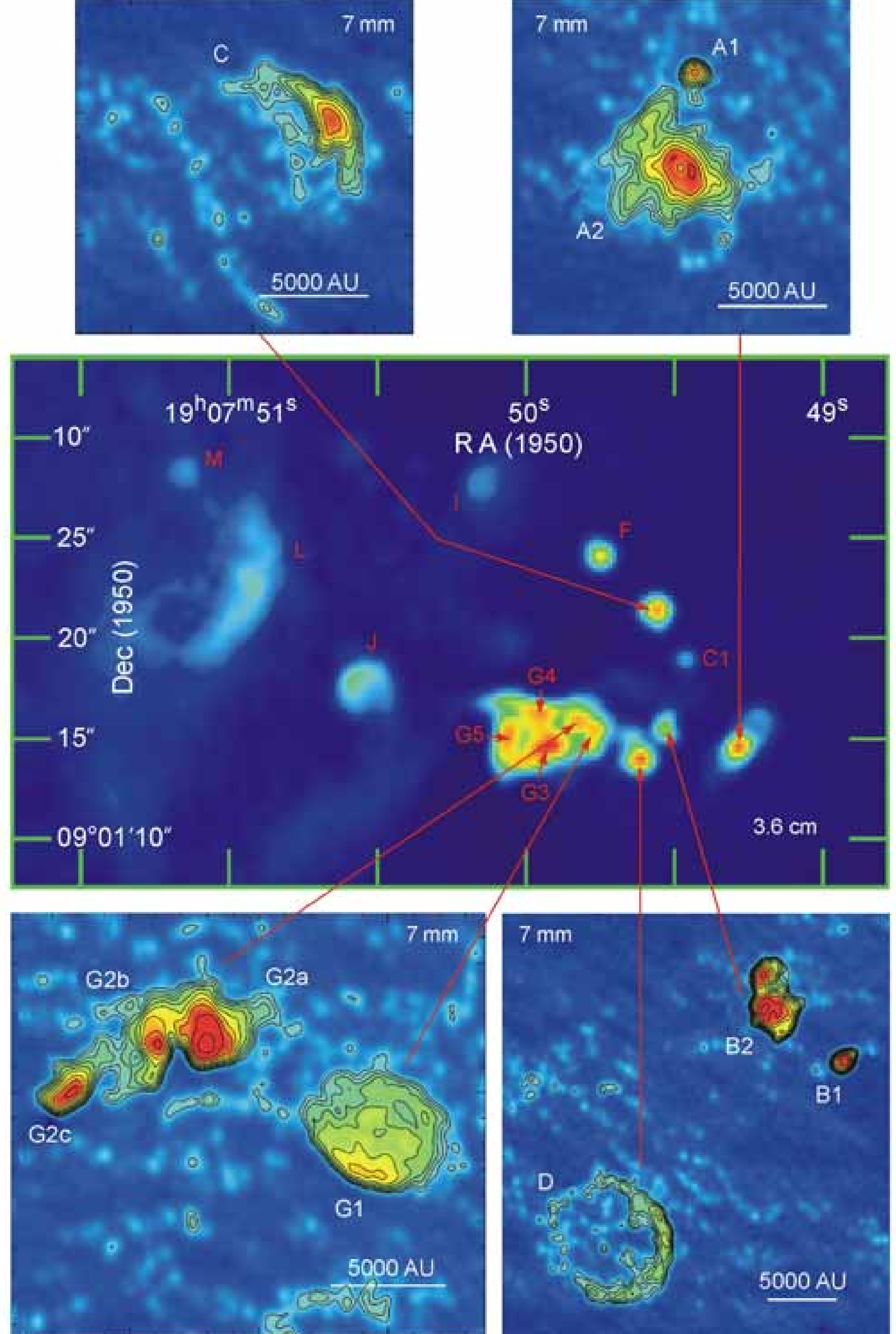
いろいろな形のUCHII

A：不規則

B：コンパクト

C, D：シェル構造

G：H_2Oメーザー源があるなど複雑



@VLA：De Pree et al. 2000

RAINBOWによる観測

SO（2_1-1_1）86 GHzによるW49Nの観測

空間分解能：1.8”×1.5”（P.A.=-85°）

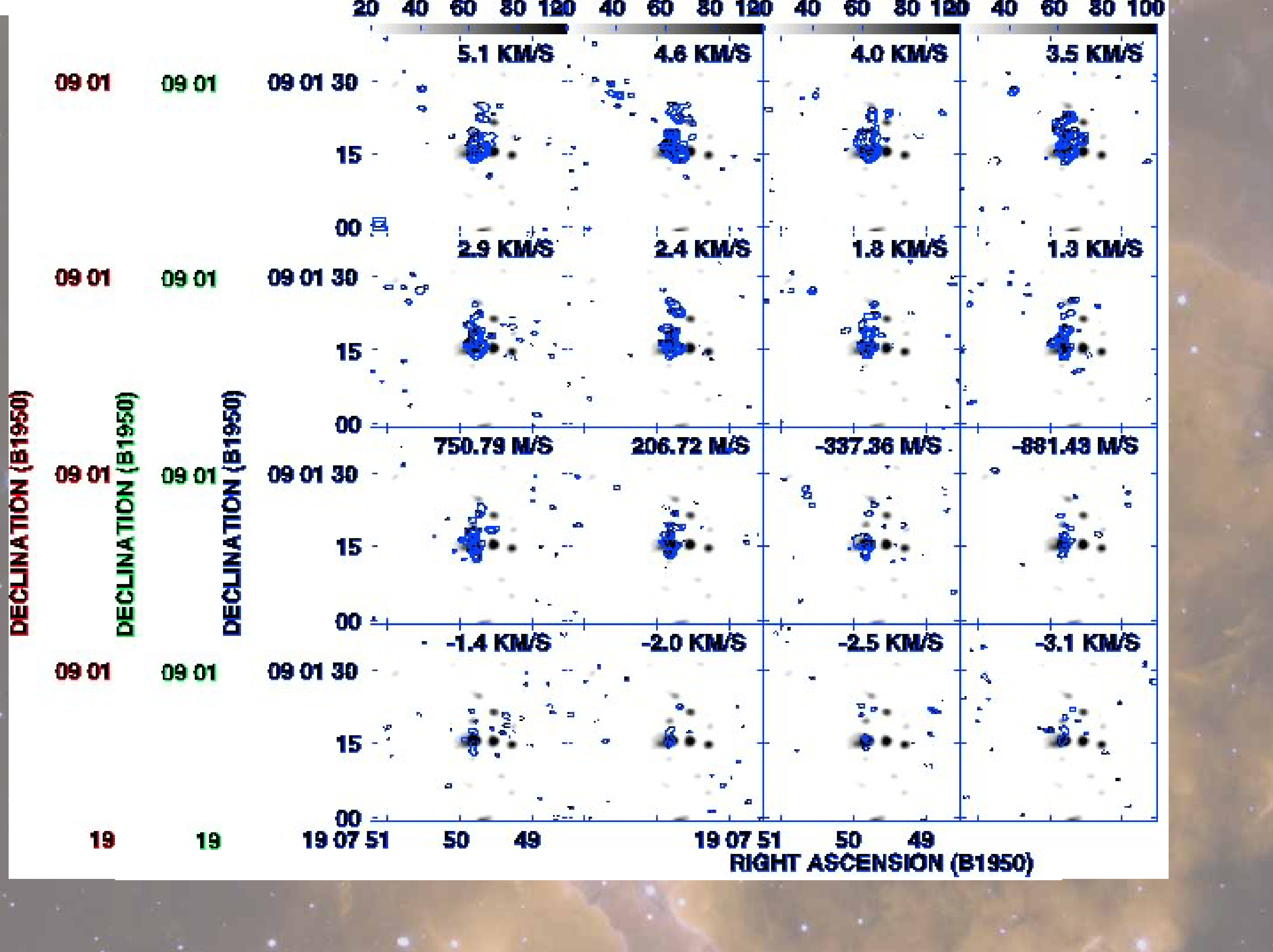
速度分解能：FX:～0.5kms^{-1} (5ch平均)

距離　12kpc

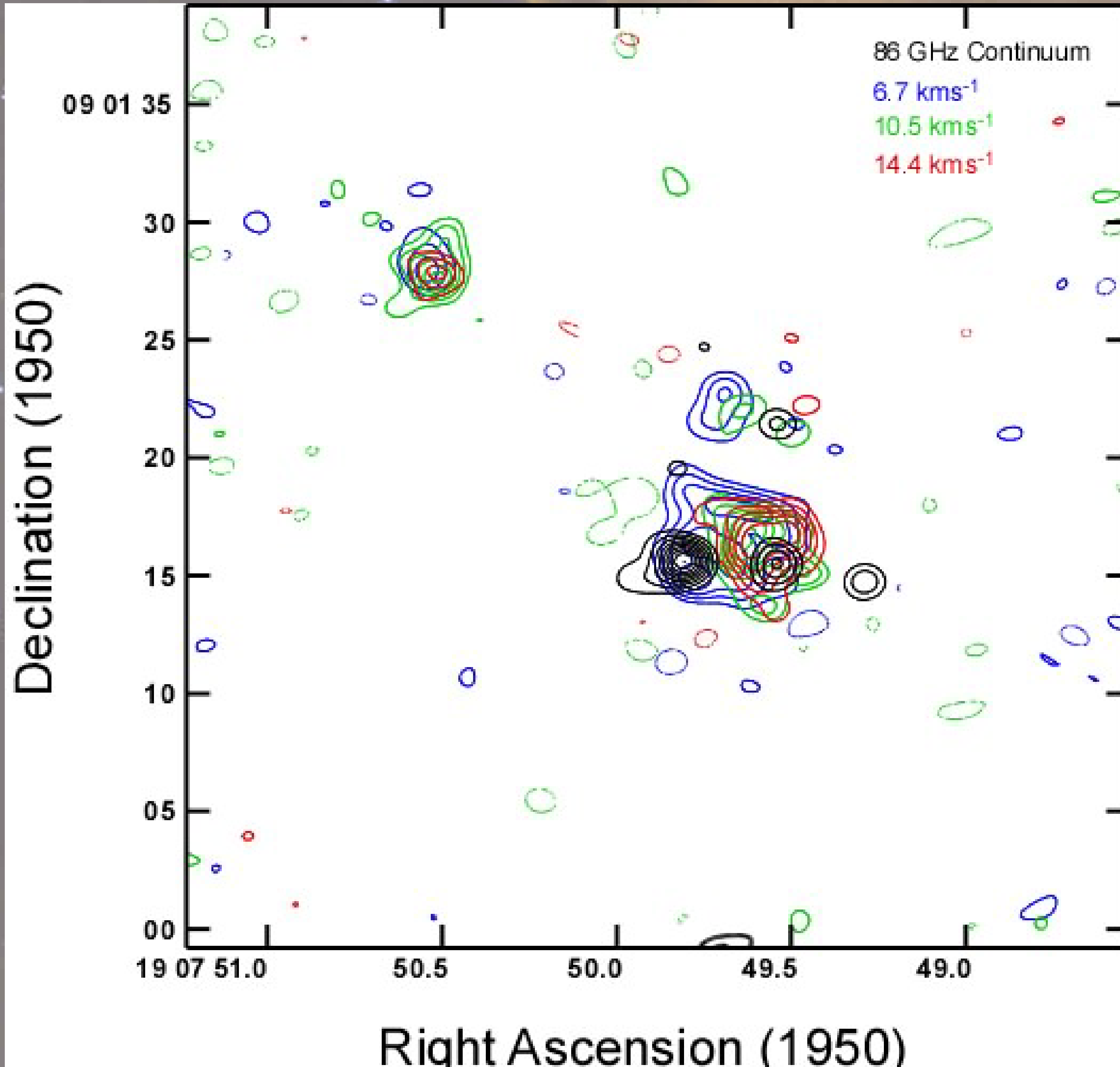
UWBCのUSBでCS(J=2-1)を同時観測

→UCHIIを持たないコアの同定可能？

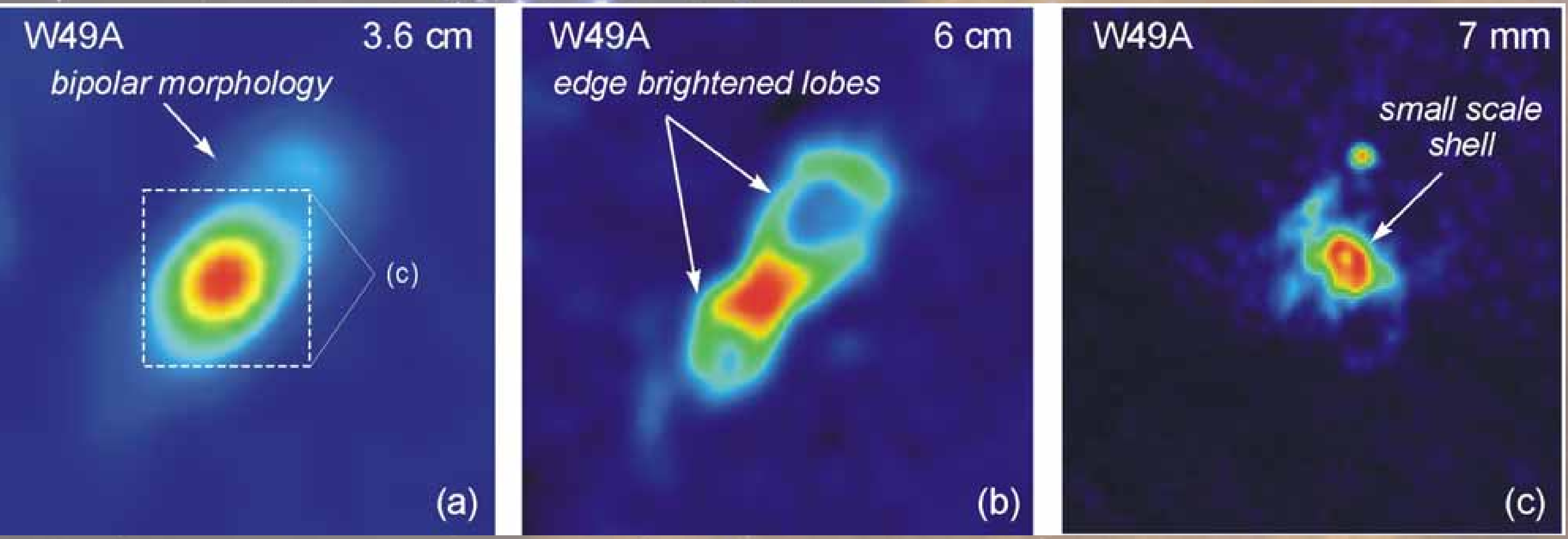
UCHIIでは吸収があることも



20 40 60 80 120 40 60 80 120 40 60 80 120 40 60 80 100
5.1 KM/S
4.6 KM/S
4.0 KM/S
3.5 KM/S
2.9 KM/S
2.4 KM/S
1.8 KM/S
1.3 KM/S
750.79 M/S
206.72 M/S
-337.36 M/S
-881.43 M/S
-1.4 KM/S
-2.0 KM/S
-2.5 KM/S
-3.1 KM/S
09 01 30
15
00
09 01
19
19 07 51
50
49
DECLINATION (B1950)
RIGHT ASCENSION (B1950)


86 GHz Continuum
6.7 kms-1
10.5 kms-1
14.4 kms-1
Declination (1950)
09 01 35
30
25
20
15
10
05
00
19 07 51.0
50.5
50.0
49.5
49.0
Right Ascension (1950)

UCHIIのサブミリセコンドのイメージ



DePree 2000

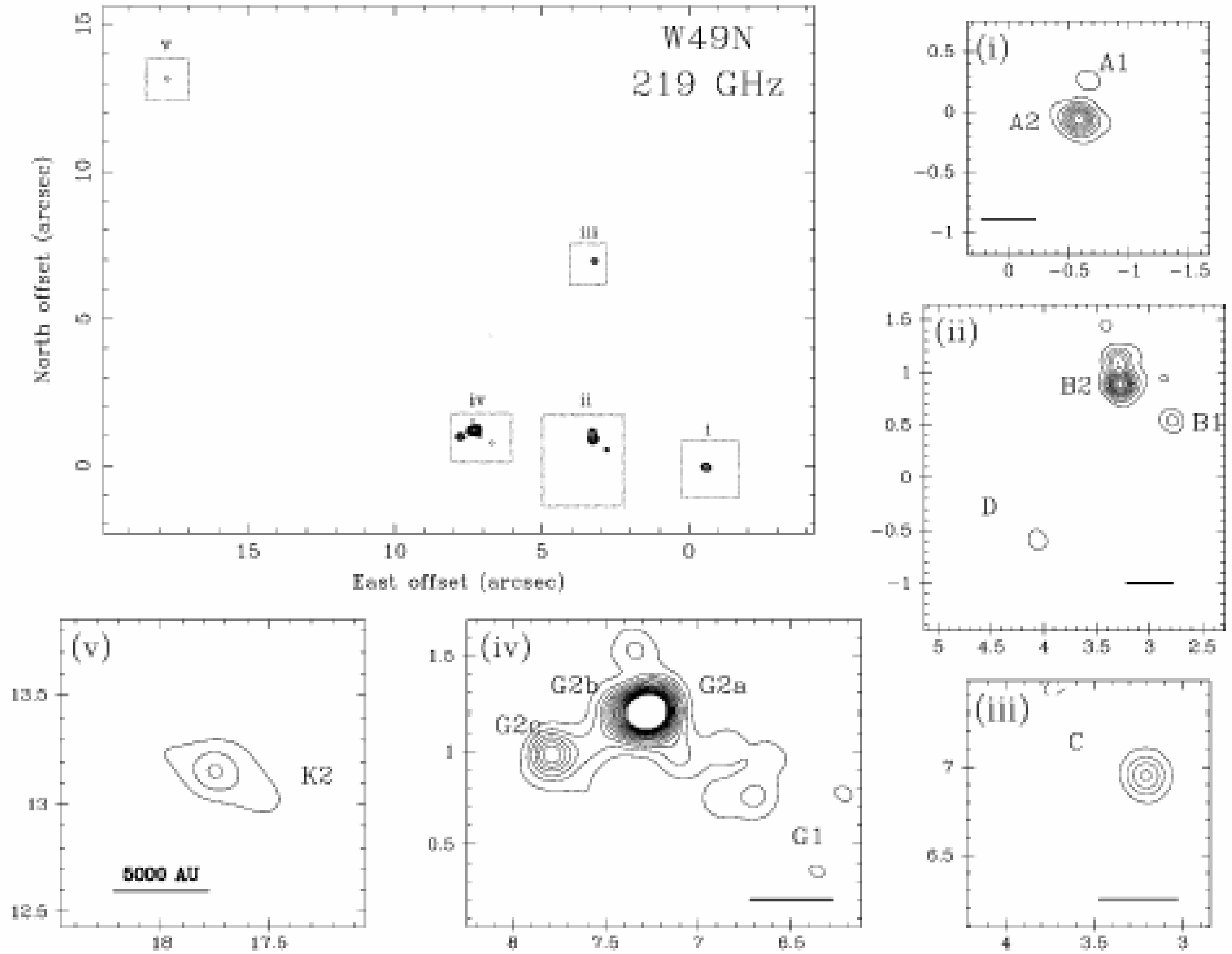
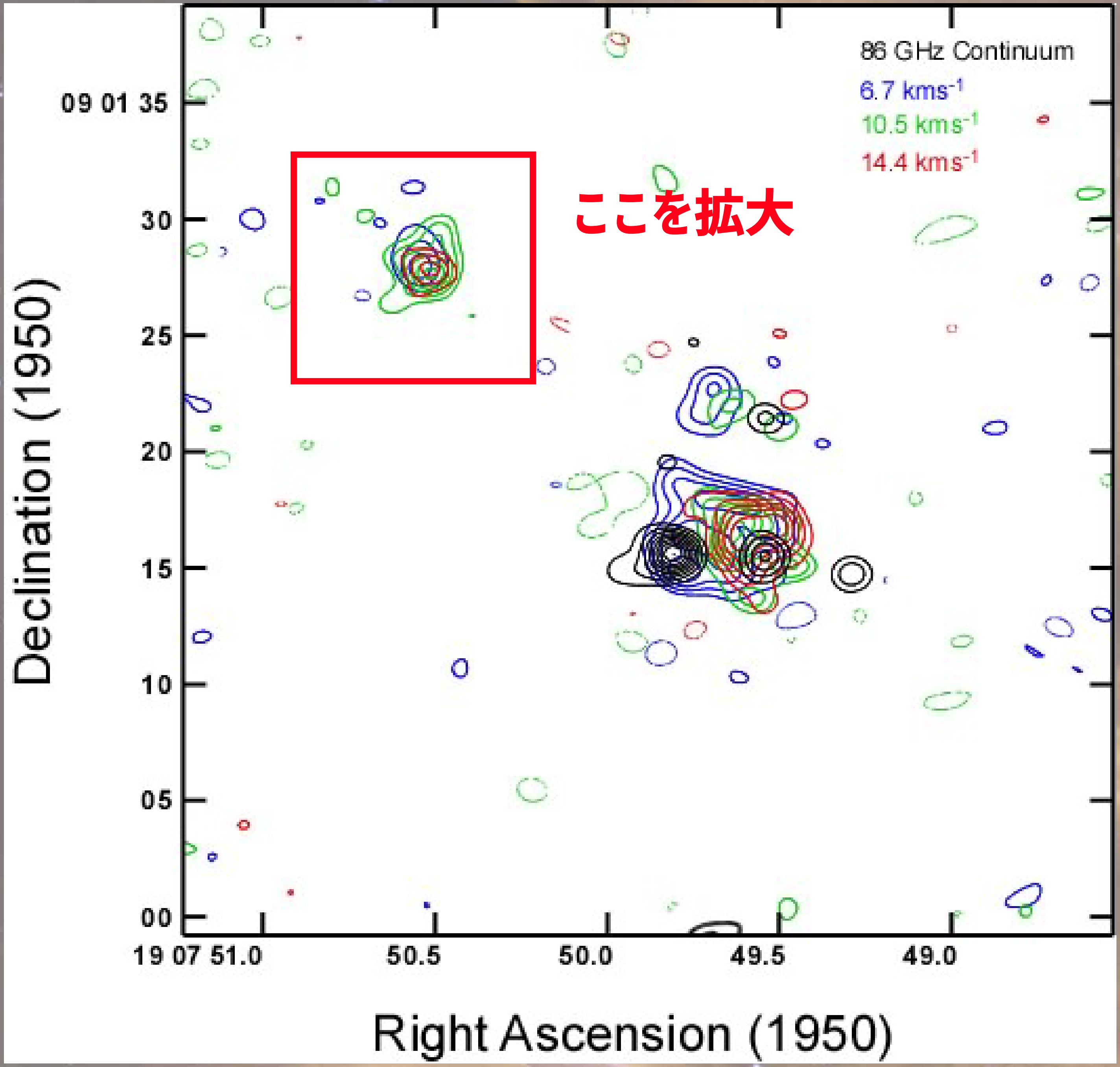
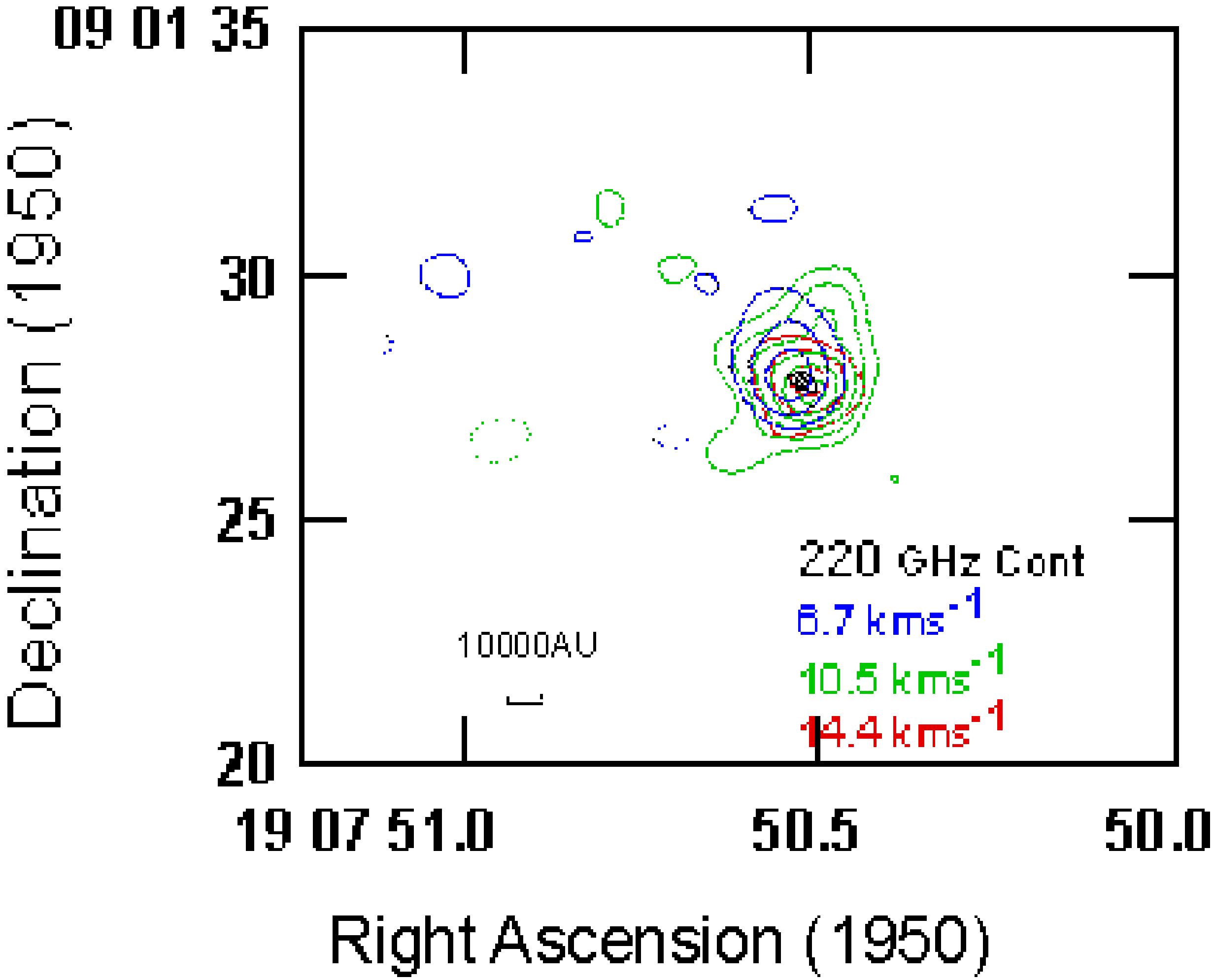


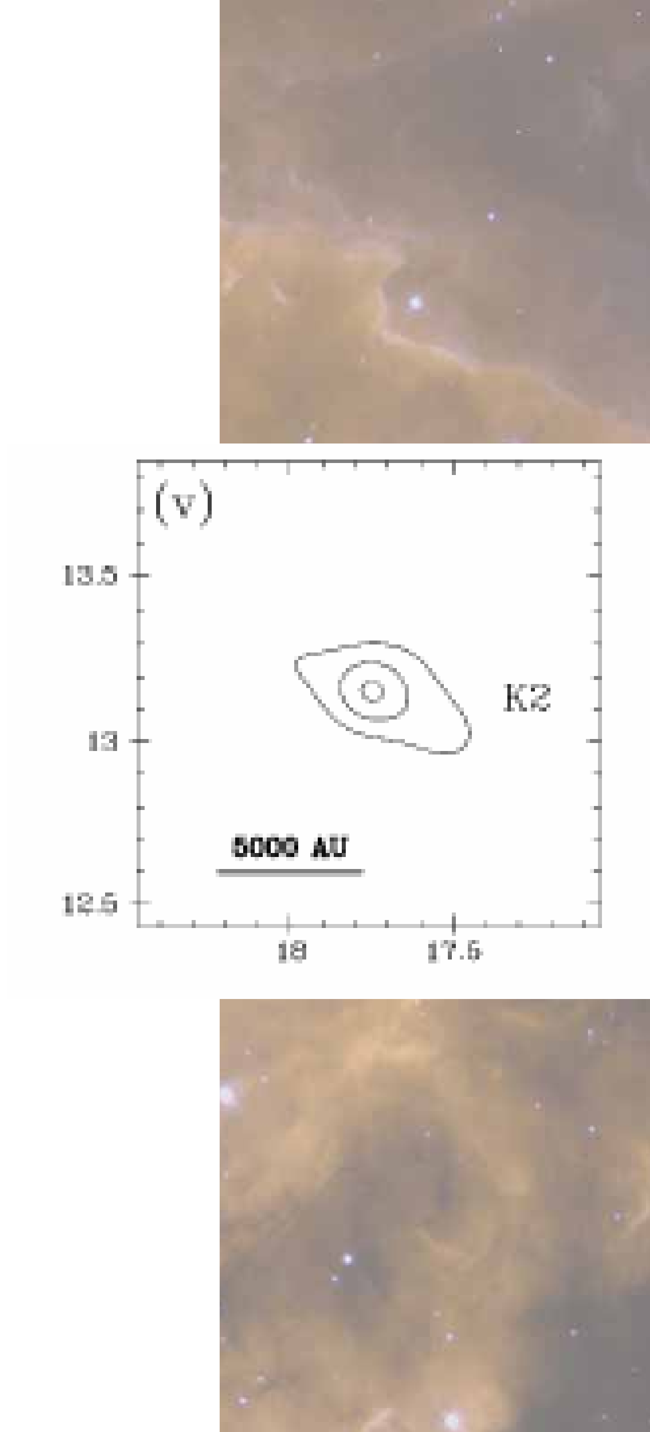
FIG. 1.—*Upper left*: BIMA 1.4 mm continuum image of the W49N core with 0."18 resolution (2000 AU). The boxes labeled with roman numerals indicate the regions displayed in the surrounding panels. *Panels* (i)–(v): Close-up views of the 1.4 mm emission from the ultracompact H II region complexes and the newly identified dust peak K2. The lowest contour and contour interval is 15 mJy beam^{-1}. The scale bar in each panel represents 5000 AU.

Wilner et al. 2001


86 GHz Continuum
6.7 kms-1
10.5 kms-1
14.4 kms-1
ここを拡大
09 01 35
30
25
20
15
10
05
00
Declination (1950)
19 07 51.0
50.5
50.0
49.5
49.0
Right Ascension (1950)



09 01 35
30
25
20
Declination (1950)
19 07 51.0
50.5
50.0
Right Ascension (1950)
10000AU
220 GHz Cont
6.7 kms⁻¹
10.5 kms⁻¹
14.4 kms⁻¹



(v)
13.5
13
12.5
18
17.5
K2
5000 AU

Ori KLでは

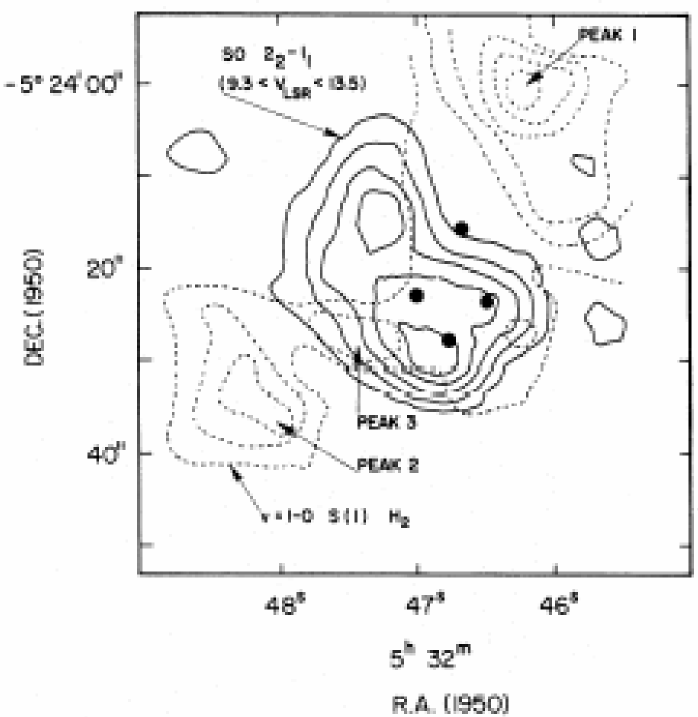


FIG. 4.—A map of the SO emission in the velocity interval 9.3–13.5 km s^{-1} (contour interval 10 K), superposed on a map of the $v = 1$–0 $S(1)$ line of H_2 (Beckwith *et al.* 1978). The H_2 and SO emission are strongly anticorrelated.

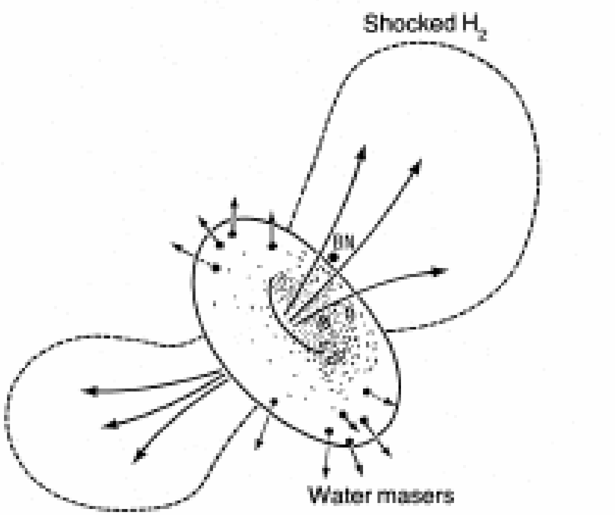
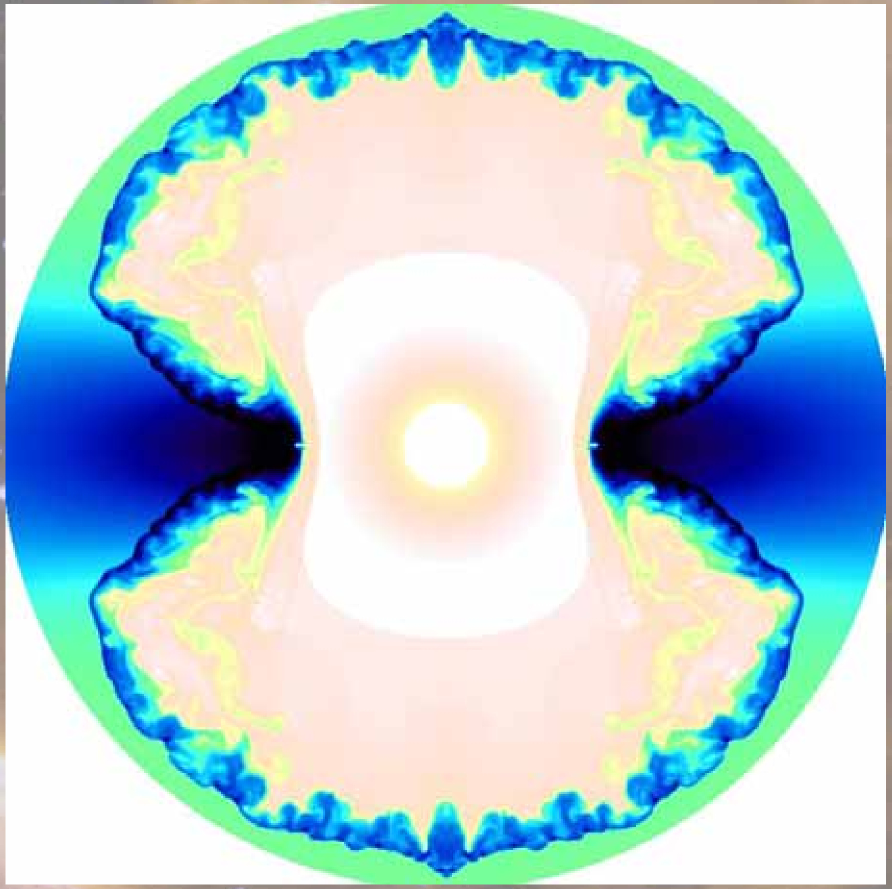


FIG. 5.—A model for the KL region. Outflow from a central source (possibly IRc2) pushes into the Orion molecular cloud. SO emission arises from an expanding doughnut of gas which has been compressed and accelerated by the outflow. H_2O masers are clustered near the NE and SW edges of the doughnut, where the flow plows into the densest portions of the ambient cloud. To the NW and SE, the cloud density falls more rapidly, the flow velocity is higher, and H_2 emission is strongest. Infrared sources line the hole of the doughnut, but are obscured toward the E by the SO emitting material. BN lies well away from the center of the flow.

Plambeck et al. 1982

シミュレーション

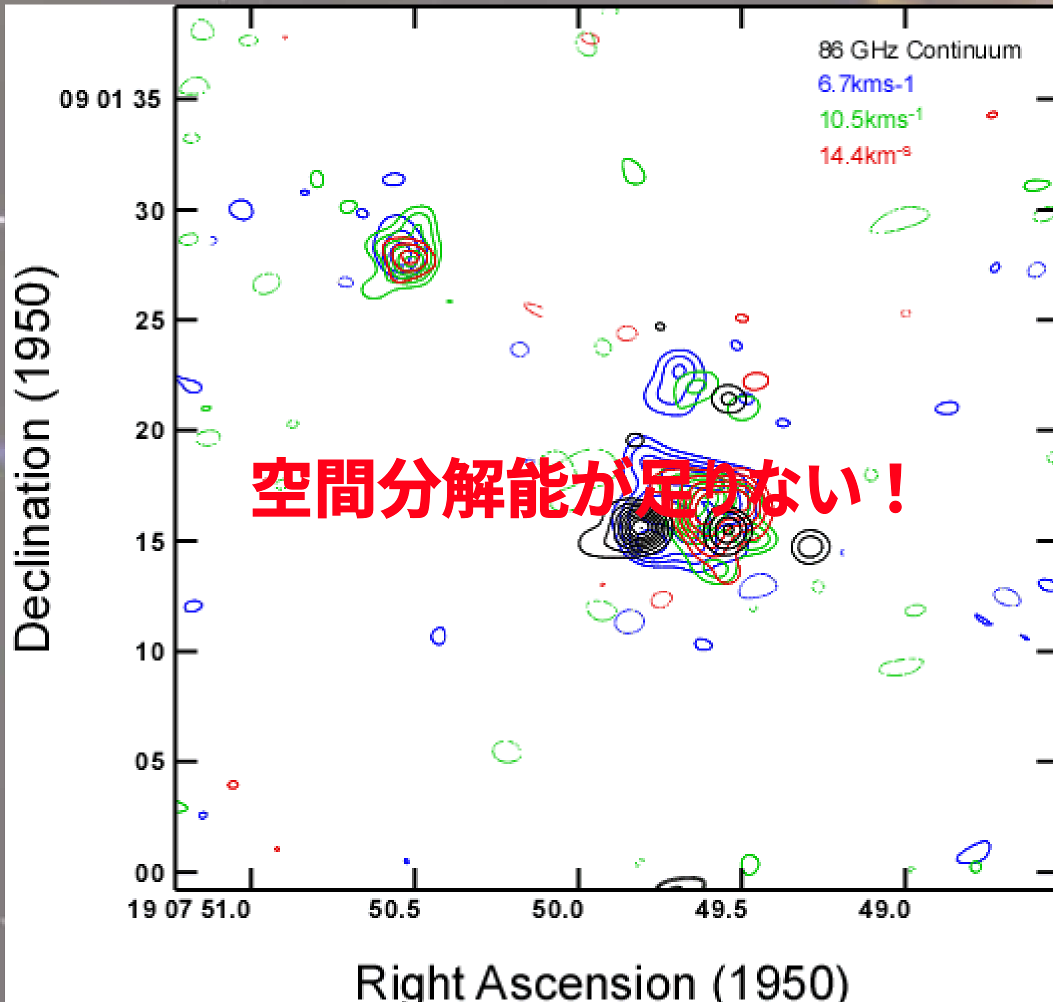
- DePreeらはUCHIIの数値シミュレーションと連続波による観測を進行中



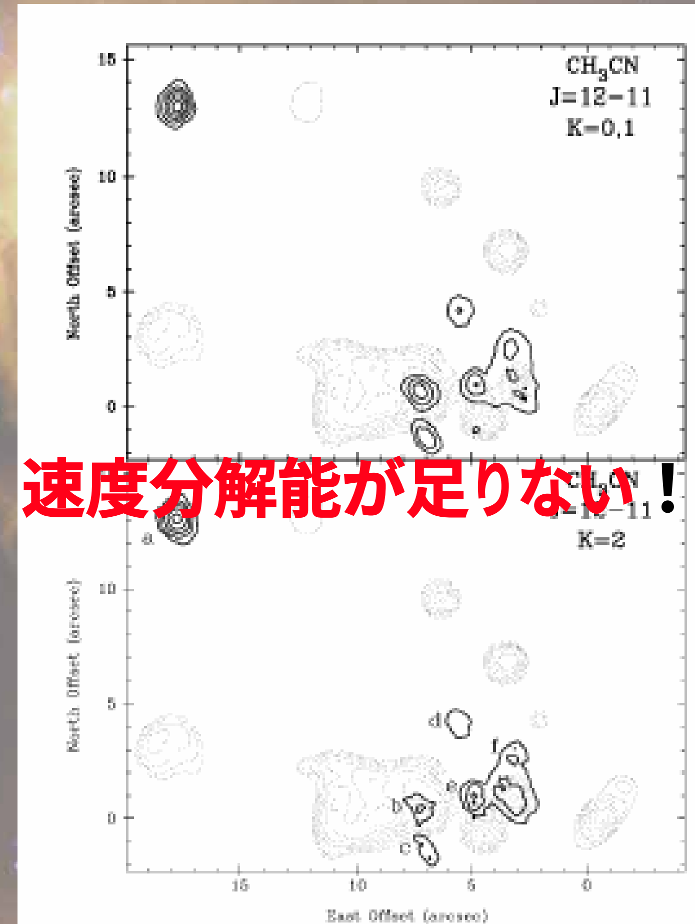
ホットコアと分子

Wilner et al. (2001)
 hot core/UCHII=6/12 50%
 →25-100%
  hot coreの寿命≦UCHIIの寿命（10^{4-5}年）と推定
 (Kurtz et al. 2000)

しかし，SOでは多くのhot coreがあるようである
（hot coreを探すのにSOは適切な分子か？）
 →10^{4-5}年より長い?
  あるいはもっと多くの星形成が進行中？



SO(86GHz)

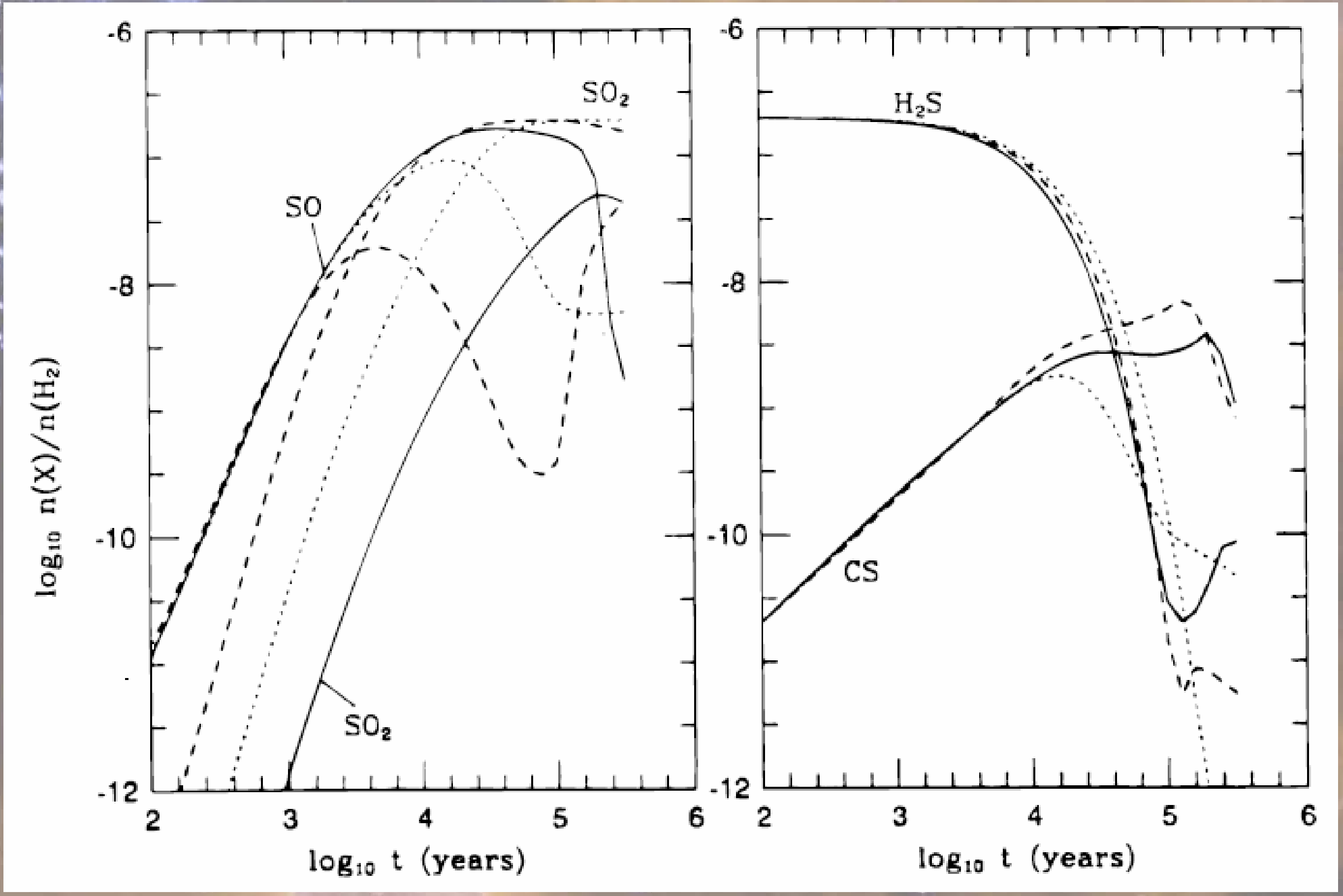


BIMA CH_3CN
Beam ~0.9”
Wilner et al. 2001

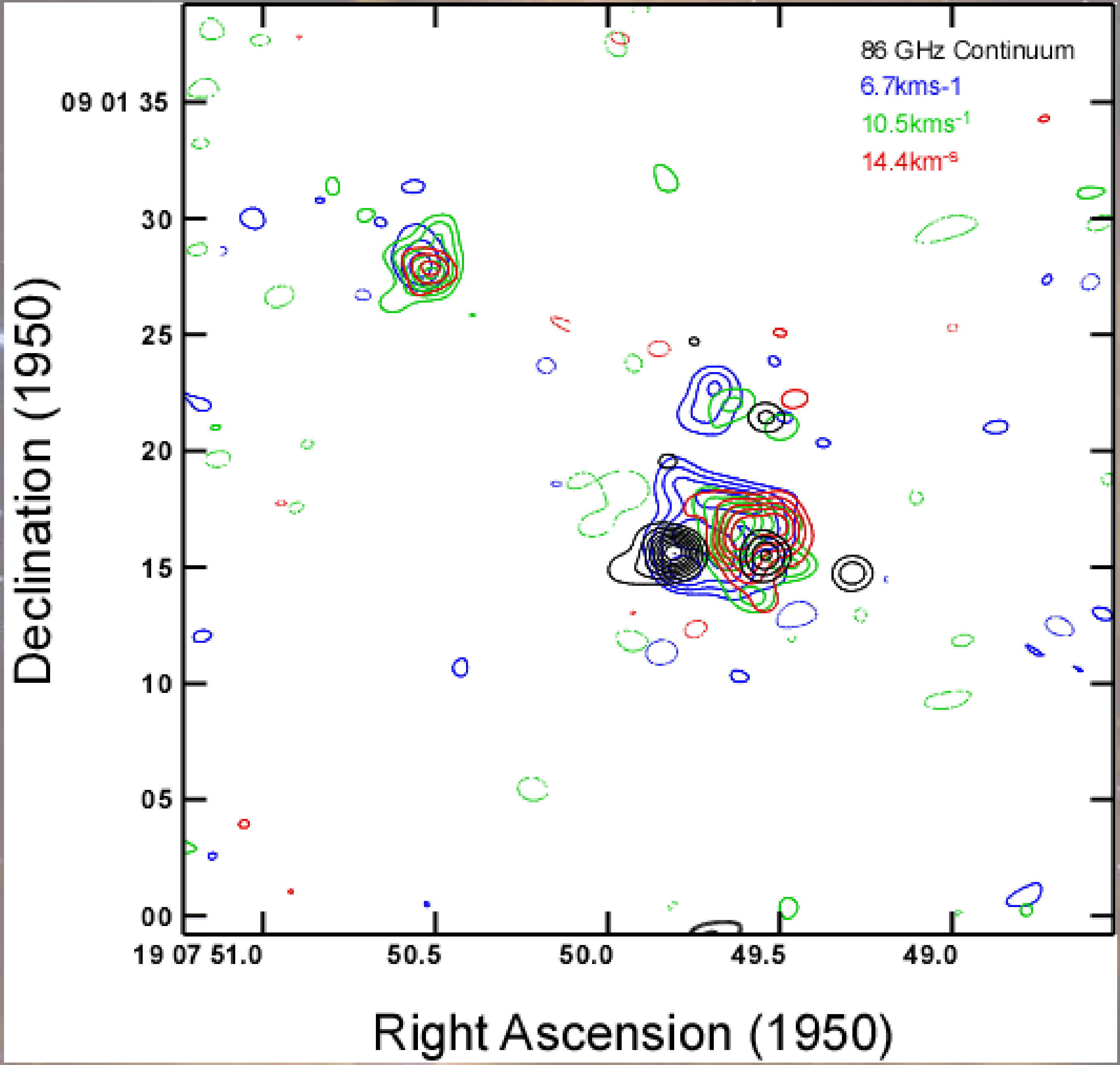
分子モデル

hot core**内の化学**

SOとSO_2
W49A方向では
プロファイル
が異なる
↓
何を意味する
（ごめんなさい用意するの忘れました）



Charnley 1997


86 GHz Continuum
6.7kms-1
10.5kms-1
14.4km-s
Declination (1950)
09 01 35
30
25
20
15
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05
00
19 07 51.0
50.5
50.0
49.5
49.0
Right Ascension (1950)

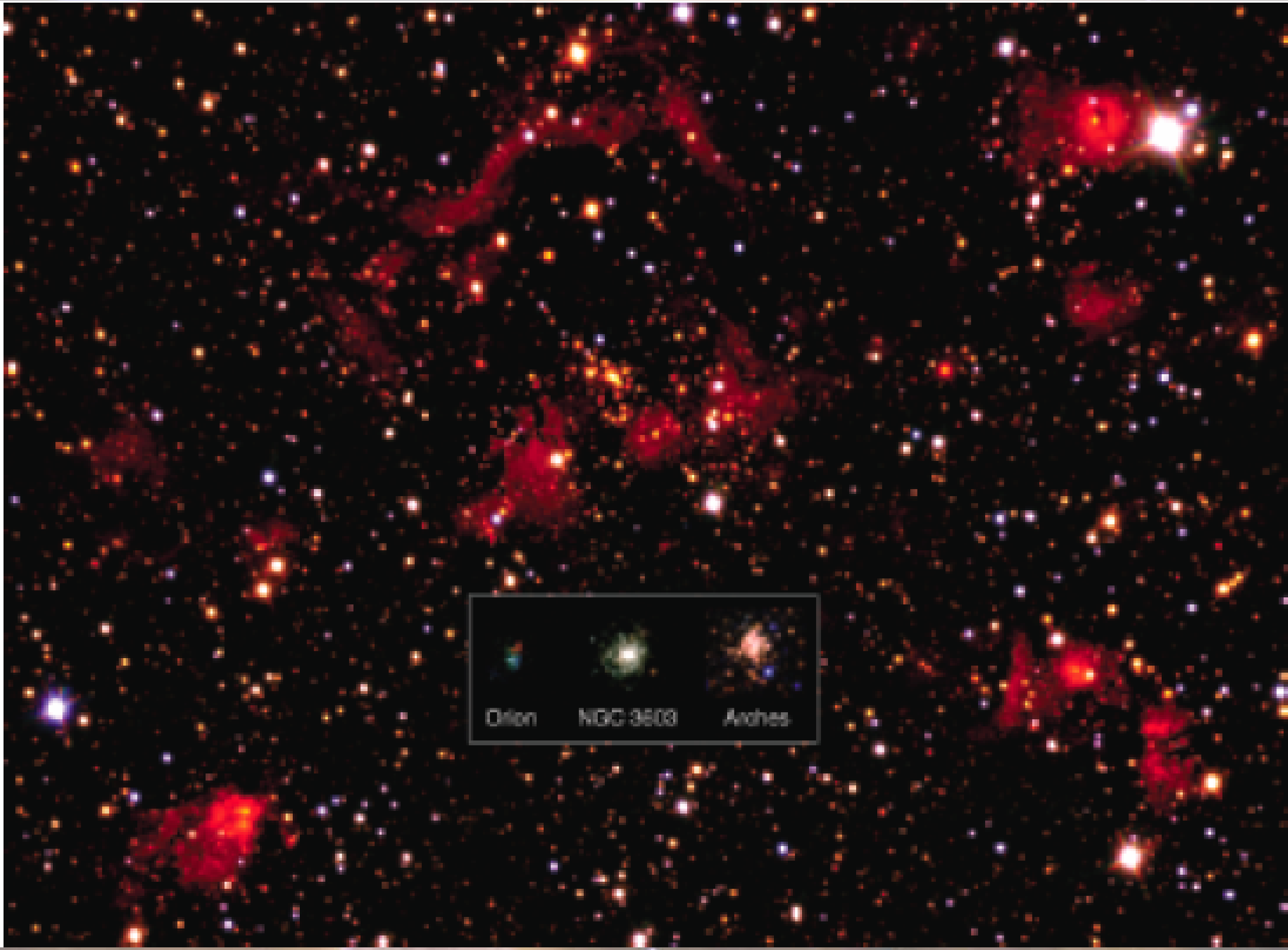
まとめ

- サブアークセコンドで銀河系内の大質量星の形成について理解できる。
- hot core と UCHIIの関係を使って，大質量星の進化がわかる。しかし，まだ不十分。
- 爆発的星形成領域での大質量星の形成過程がわかる。あと少し！

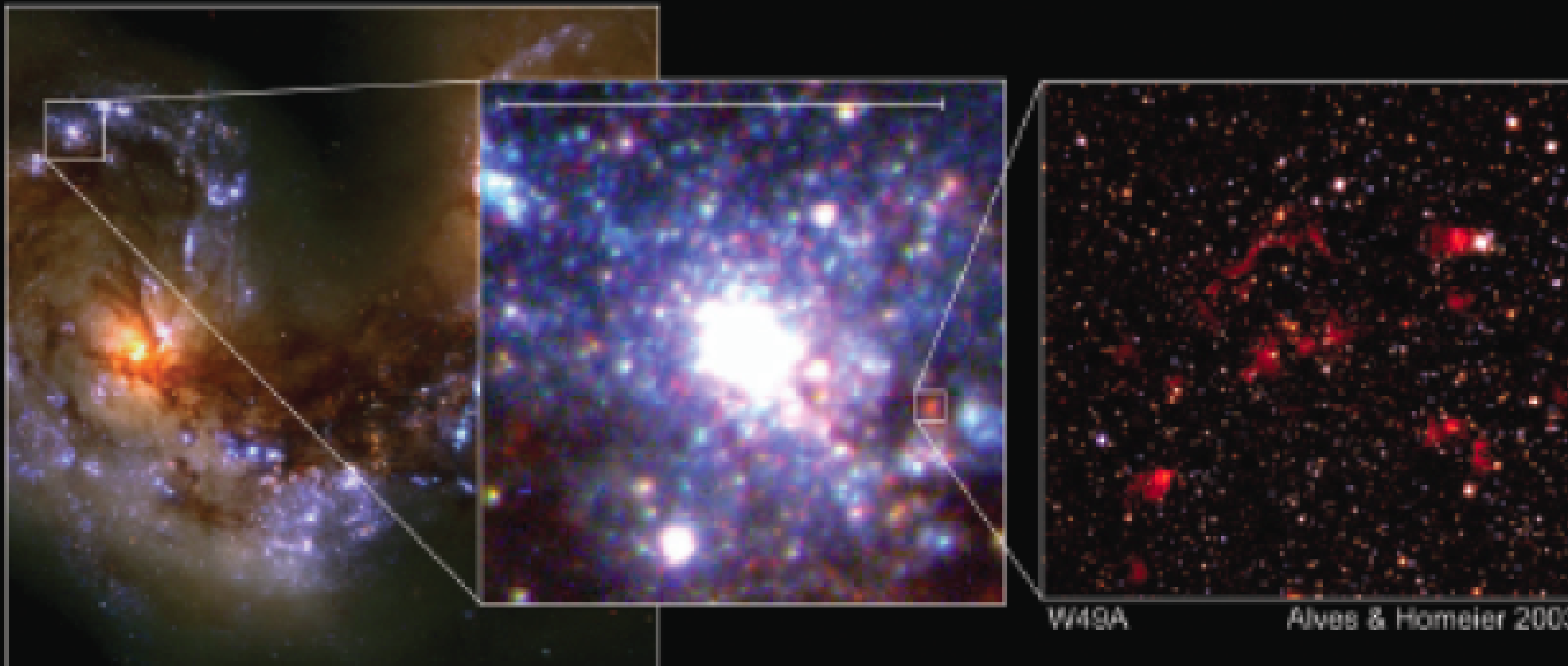
ALMAはこれらの問題を解決してくれるだろう（たぶん）。

おまけ

Figure 7: Size comparison between W49A and 1) Orion, 2) NGC 3603, and 3) the Arches cluster seen in the near-infrared as if they were located at the same distance and observed with the same instrument (SOFI on the NTT).



Alves et al. (2003)



Alves et al. (2003)

Figure 8: Size comparison between W49A and the most luminous cluster in the Antennae (starburst) galaxy. W49A is approximately an order of magnitude smaller. The luminosity comparison is not fair as the wavelengths of the two images are different (visible and near-infrared). Also, while the Antennae cluster is essentially extinction free, W49A is seen behind a wall of more than 30 mags of dust extinction.