天体物理研究室（A研）ガイダンス

NANTENグループ編

主に銀河系内と近傍銀河の分子雲の観測的研究

NANTEN2とその他の望遠鏡を使います

ALMAを使った研究についてはYouTube動画：国立天文台講演会『アルマ望遠鏡で探る星と惑星の誕生』もご覧ください。
https://www.youtube.com/watch?v=9mg7dcxZ7WA

立原研悟

NANTEN
Submillimeter Observatory

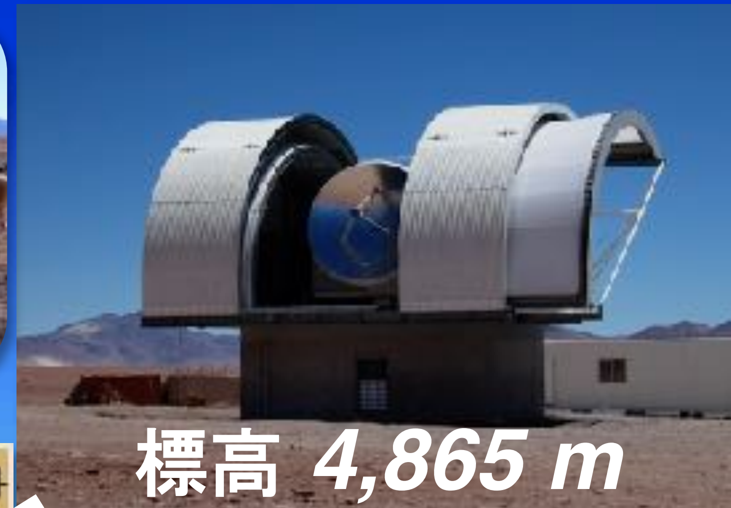
アタカマの夜空

ALMAをはじめ、多くの望遠鏡が設置されている
世界最高の観測条件（高い標高・大気の透明度・晴天率）
NANTEN2は名古屋大学が所有・維持管理

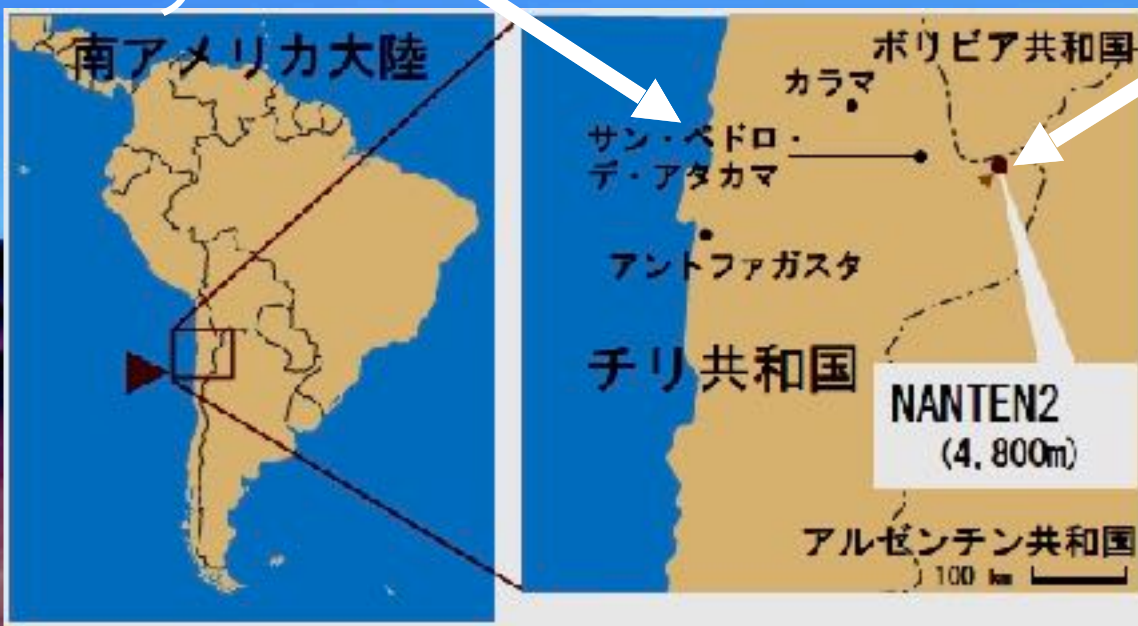
NANTEN2はどこにある？

ベースキャンプ

NANTEN2 付近

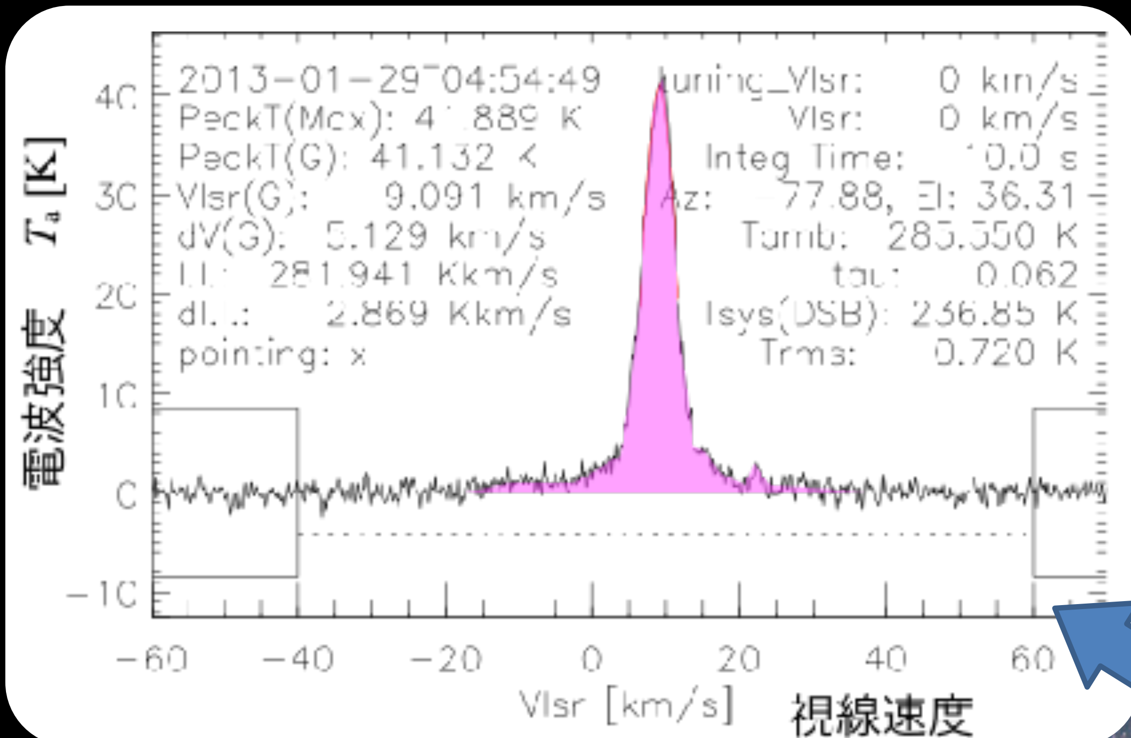


標高 4,865 m

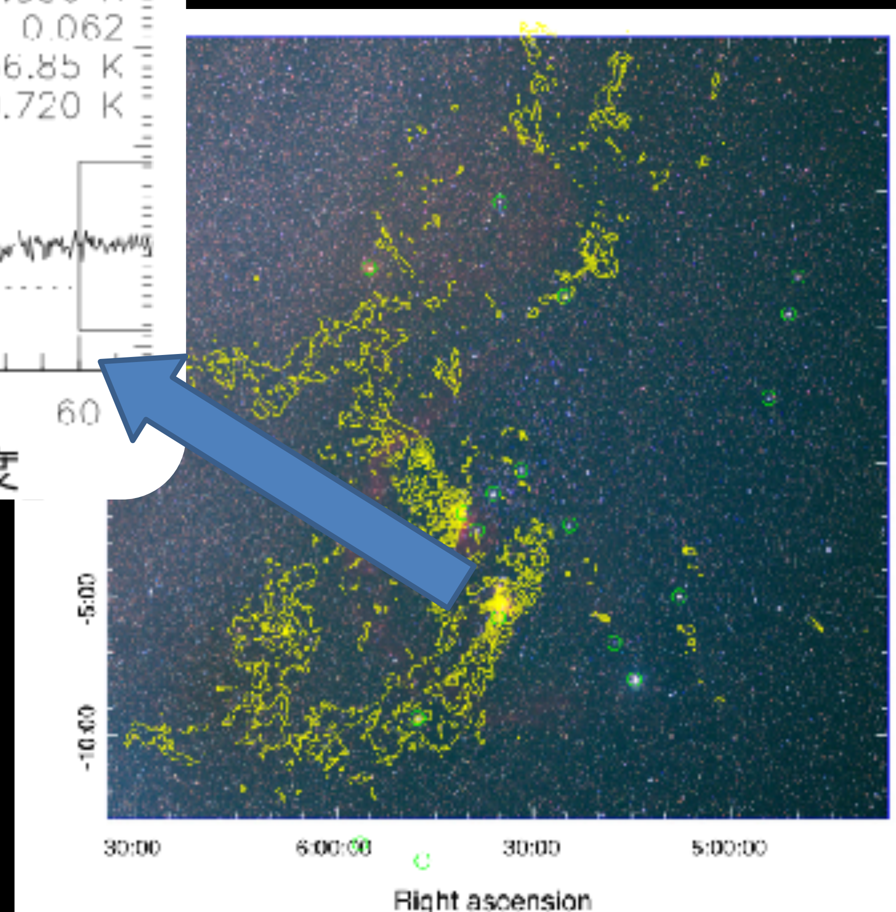


装置の立ち上げ中。
キャビンの中はとても
息苦しいです・・・

一酸化炭素のスペクトル



オリオン大星雲

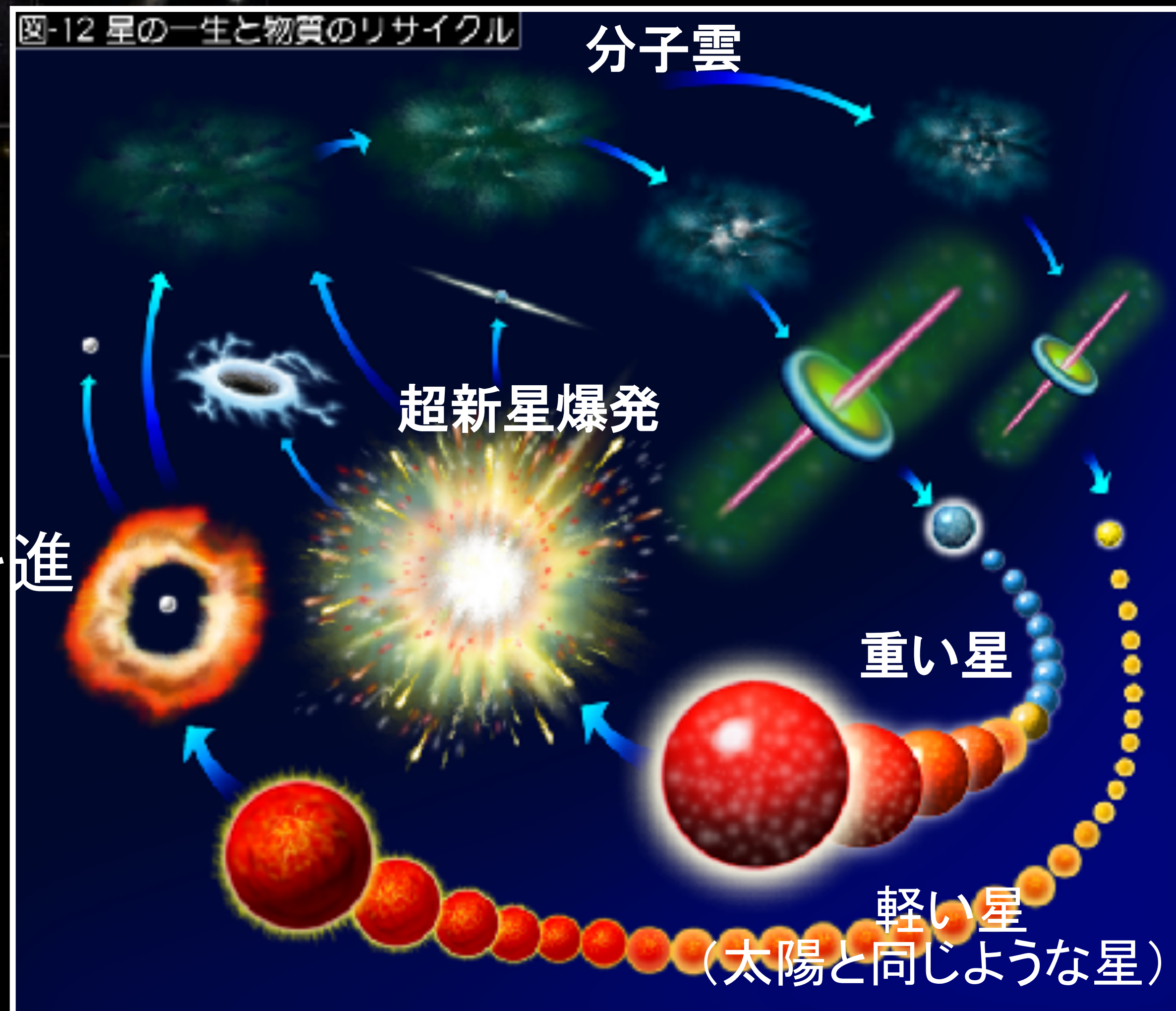


分子ガスの質量・密度・温度・
運動がわかる

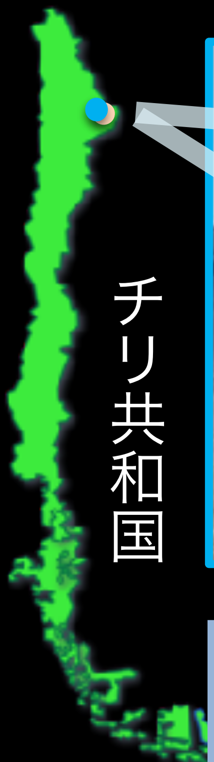
銀河と星の進化と物質循環

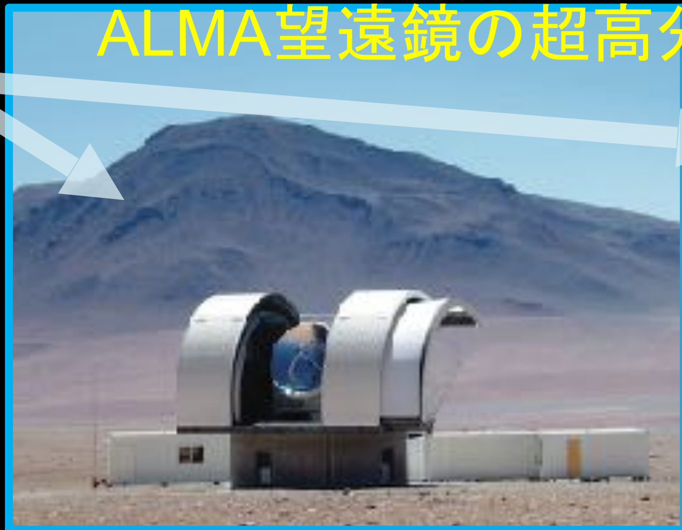
合体成長する銀河

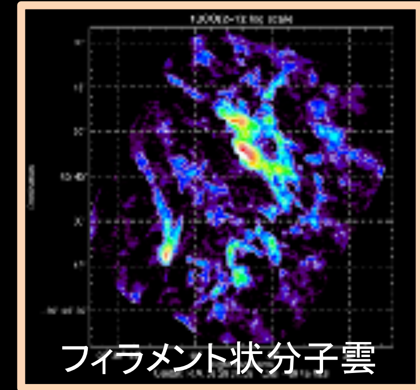
星の誕生と死が物質を進化させる（重元素汚染）



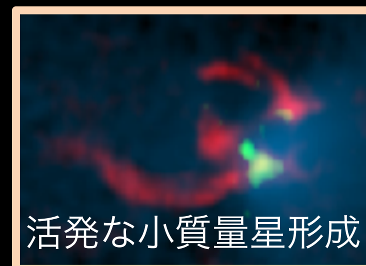
NANTEN2による超広域サーベイから ALMA望遠鏡の超高分解能な観測へ



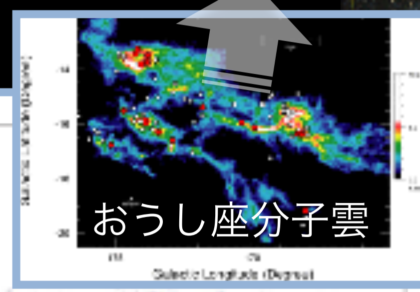


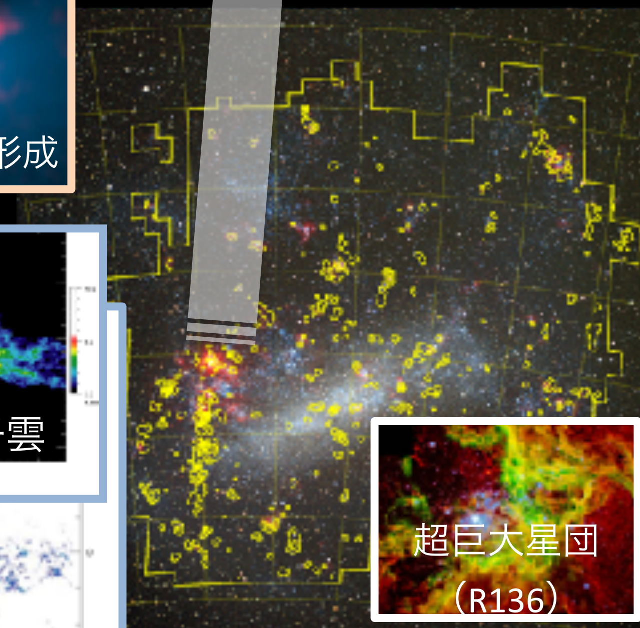


大マゼラン雲における
大質量星形成を解明

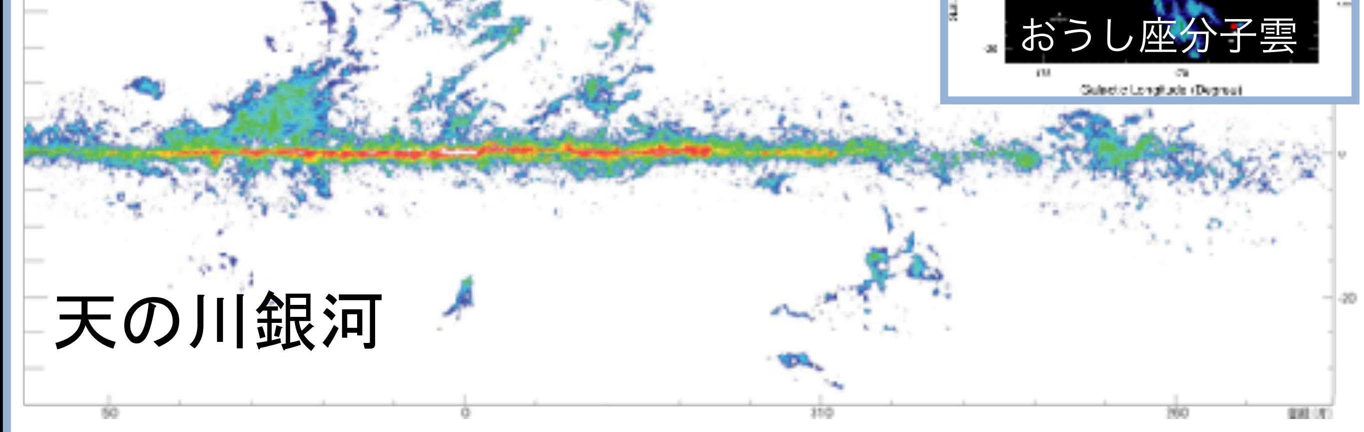


天の川銀河と大マゼラン雲の
分子雲を探査
大質量星を含む巨大星団の形成

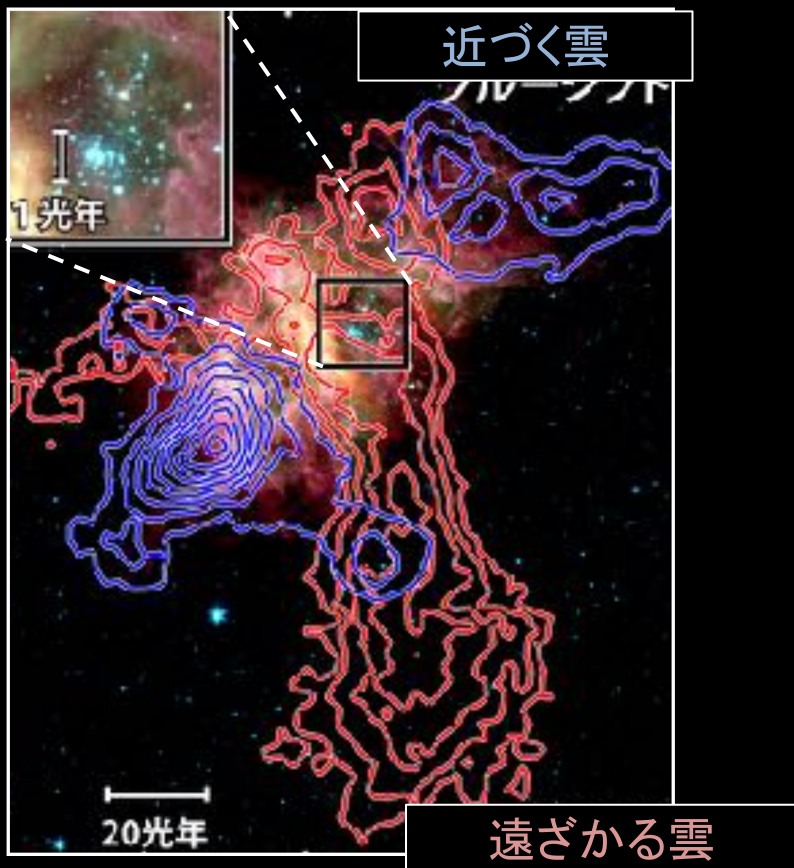




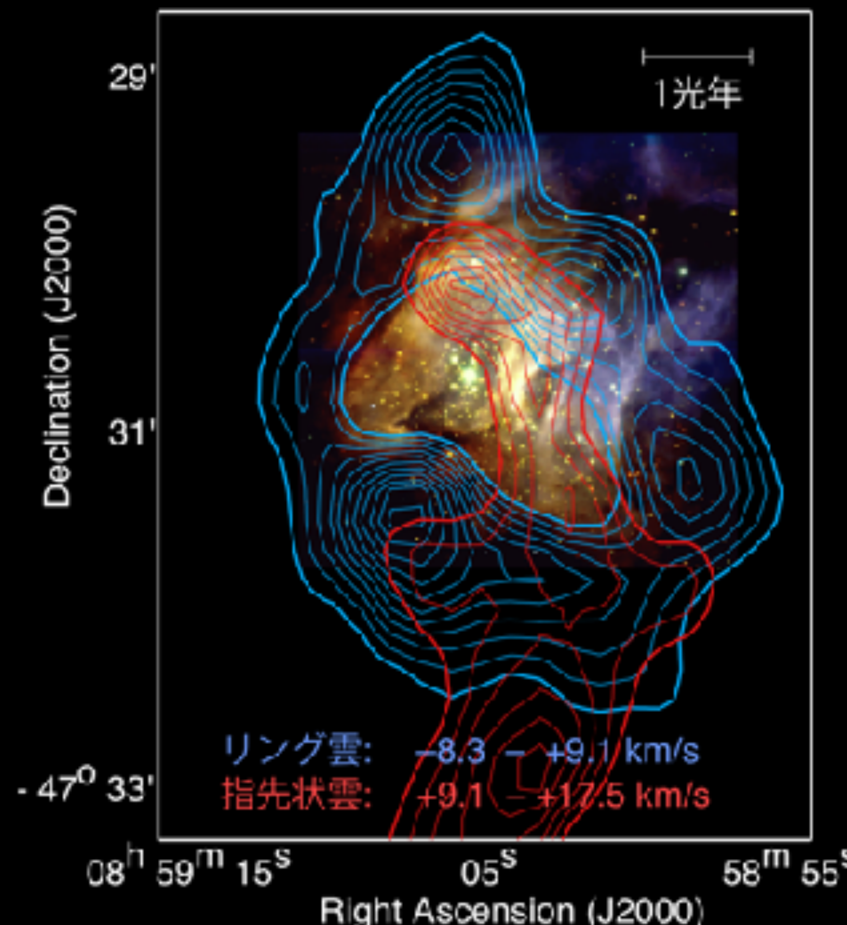
大マゼラン雲



主な研究トピック1. 大質量星形成

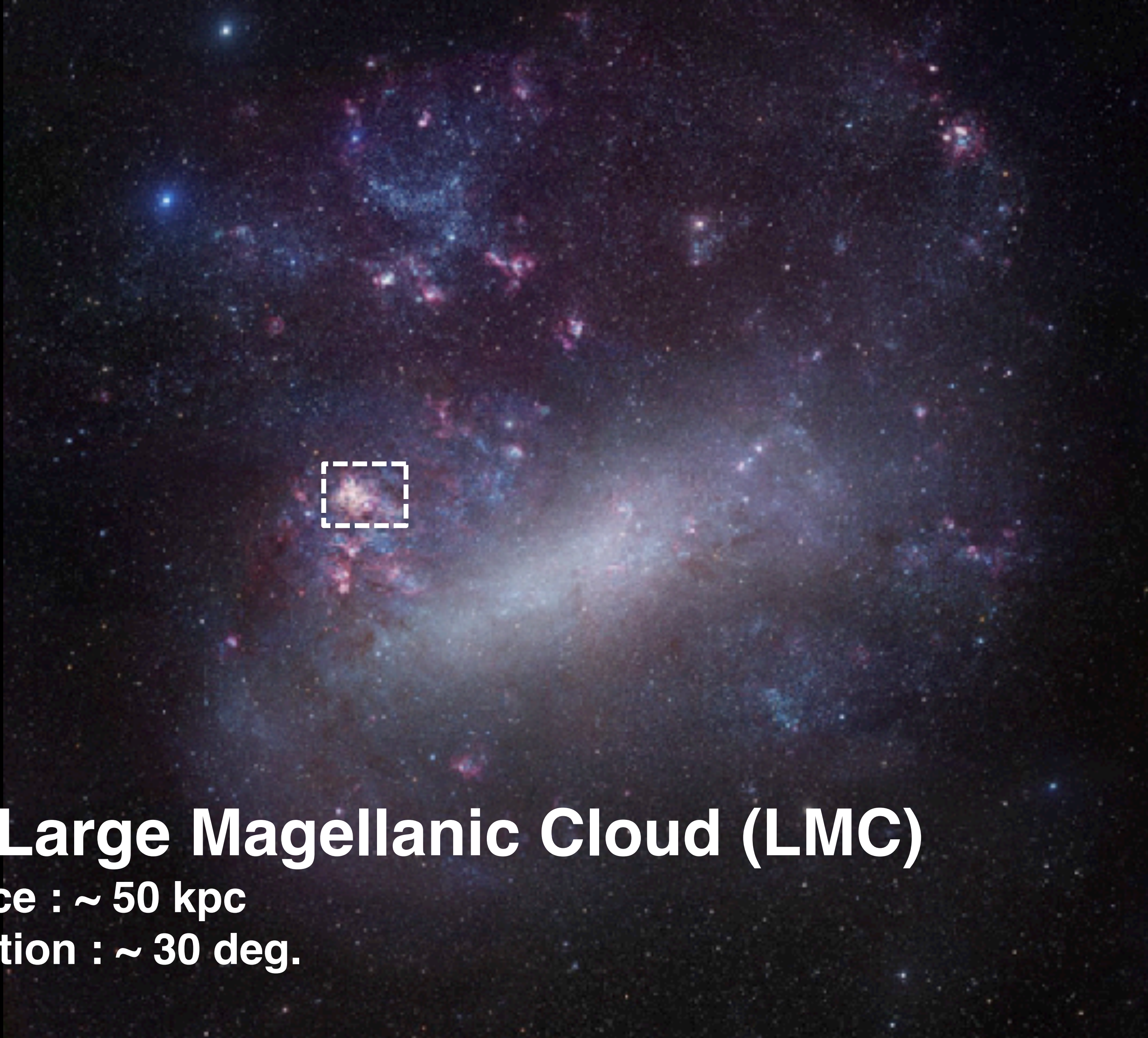


巨大星団形成領域
Westerlund 2

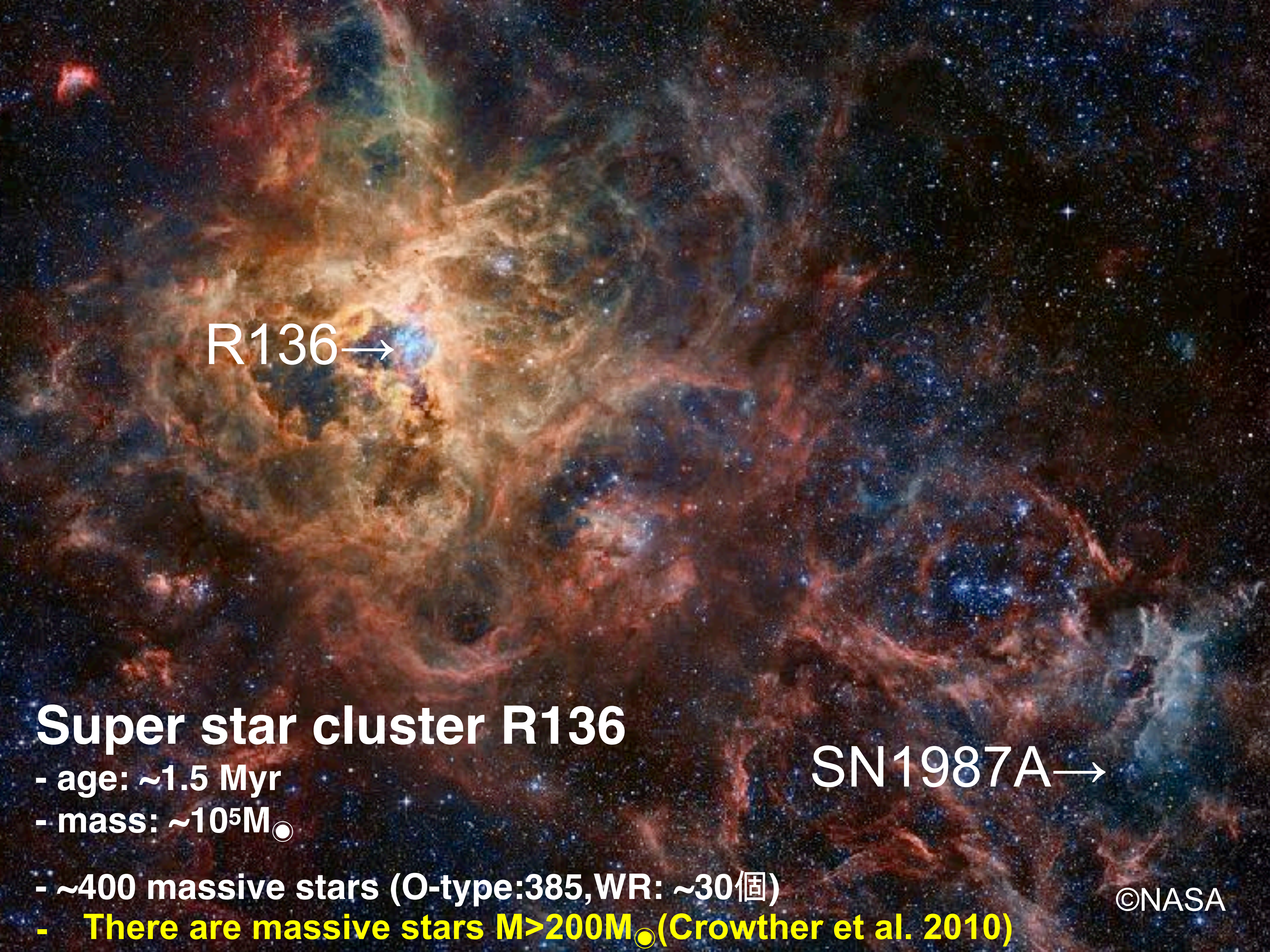


RCW 38

ALMAで見た巨大星団の誕生



The Large Magellanic Cloud (LMC)
distance : ~ 50 kpc
Inclination : ~ 30 deg.

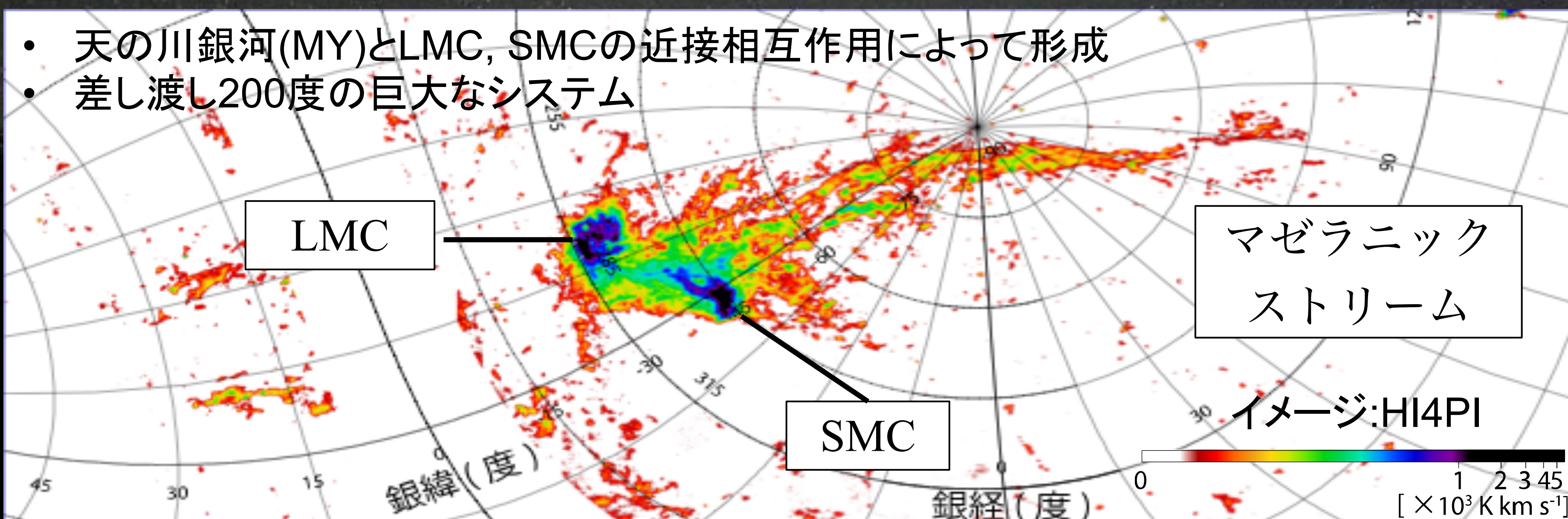


Super star cluster R136

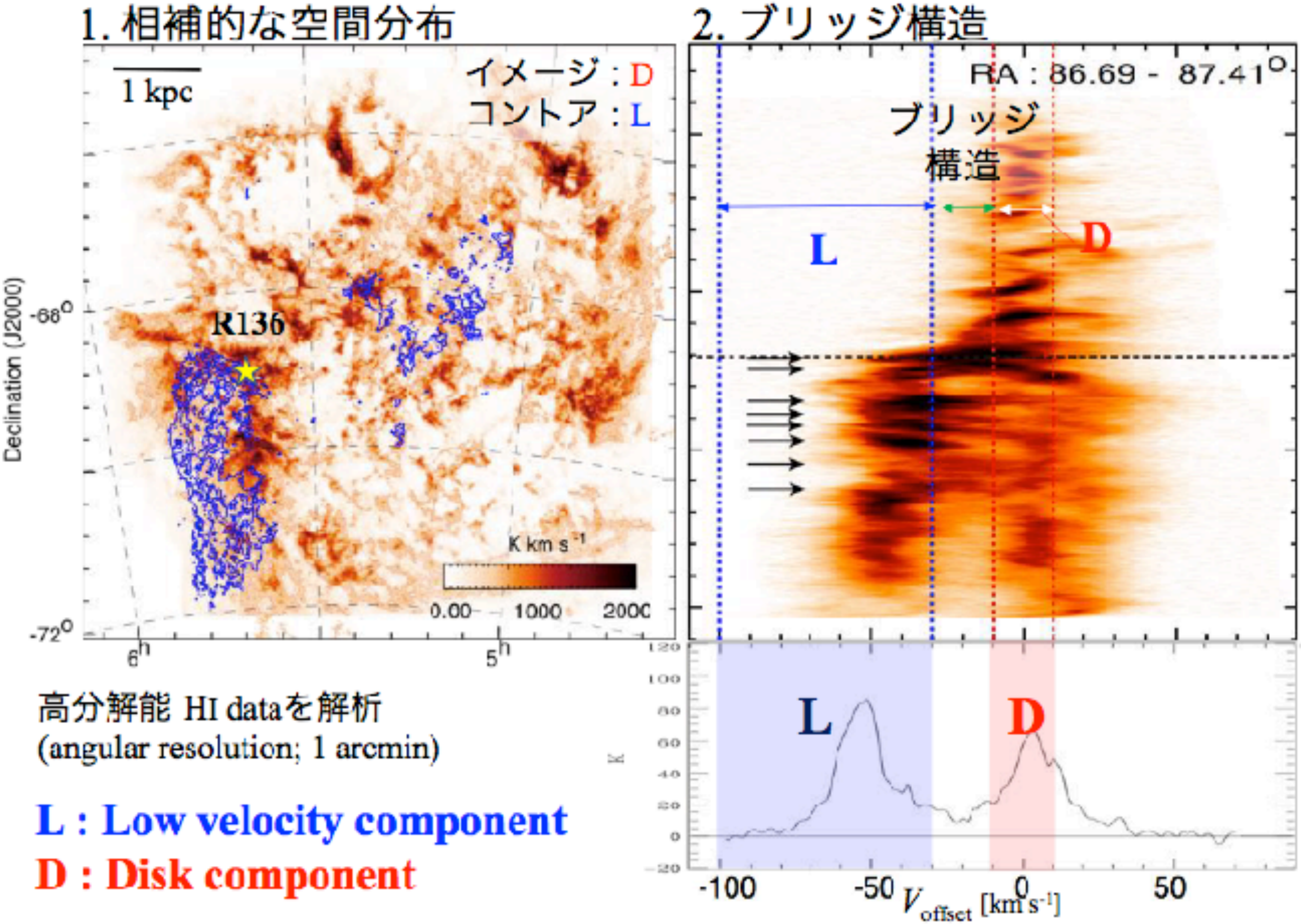
- age: ~1.5 Myr
- mass: ~$10^5 M_{\odot}$
- ~400 massive stars (O-type:385,WR: ~30個)
- There are massive stars $M>200M_{\odot}$ (Crowther et al. 2010)

マゼラニックシステム

- 天の川銀河(MY)とLMC, SMCの近接相互作用によって形成
- 差し渡し200度の巨大なシステム



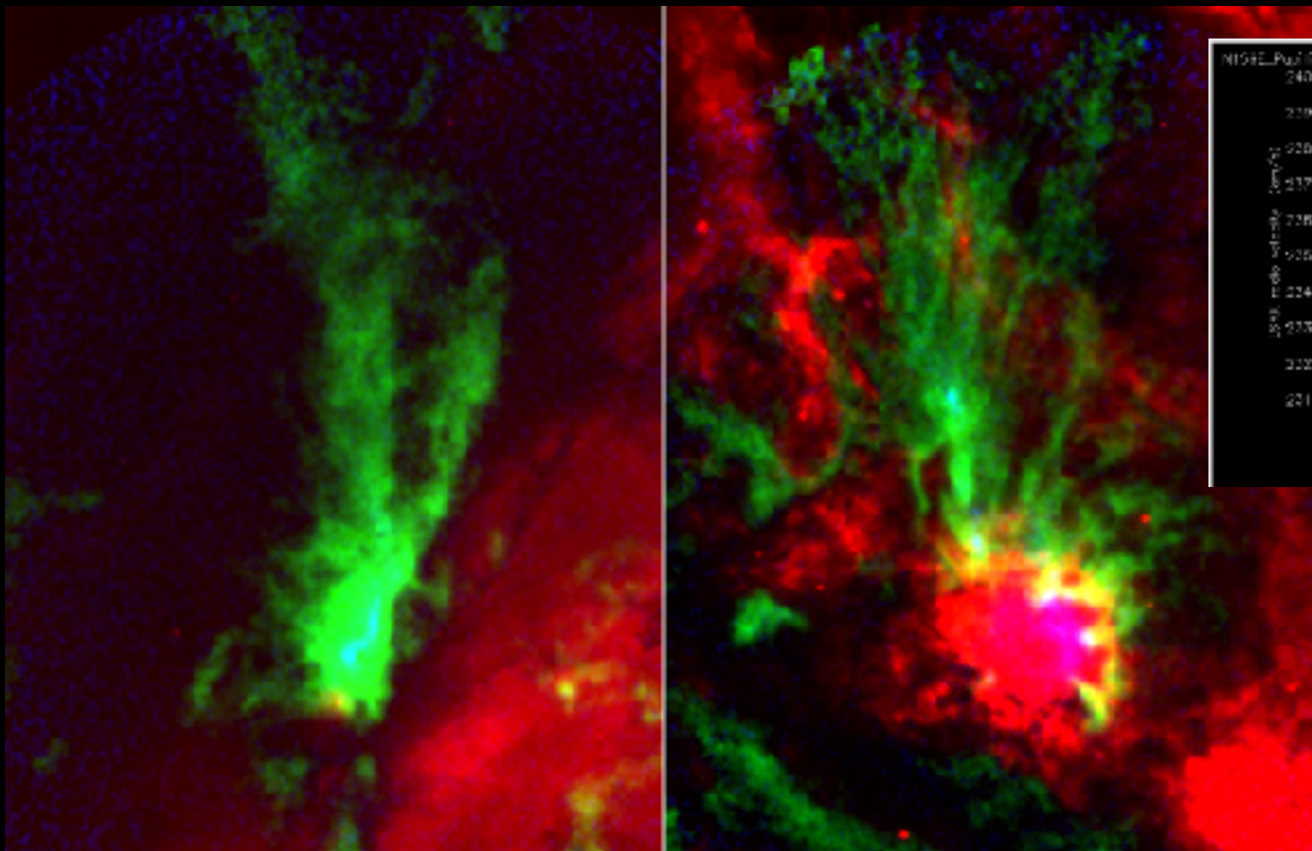
Super Star Cluster R136形成モデル

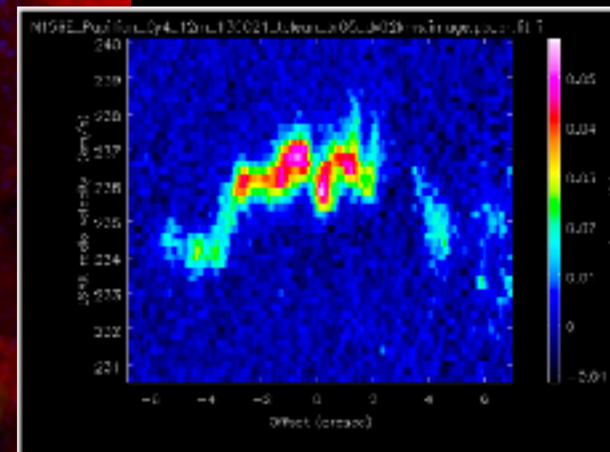


高分解能 HI dataを解析
(angular resolution; 1 arcmin)

L : Low velocity component
D : Disk component

巨大なフィラメント状分子雲

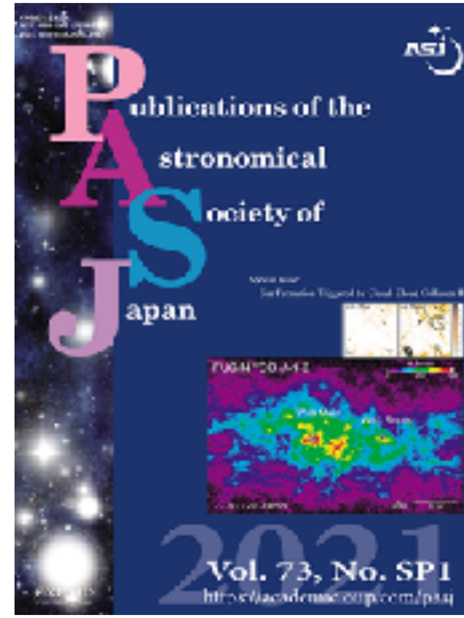




R: HST 656nm (Hα)
G: ALMA: 13CO (2-1)
B: ALMA 1.3

記者発表

- 学会誌に特集号として２１篇の論文を発表
- 国立天文台・大阪府立大とともに記者発表

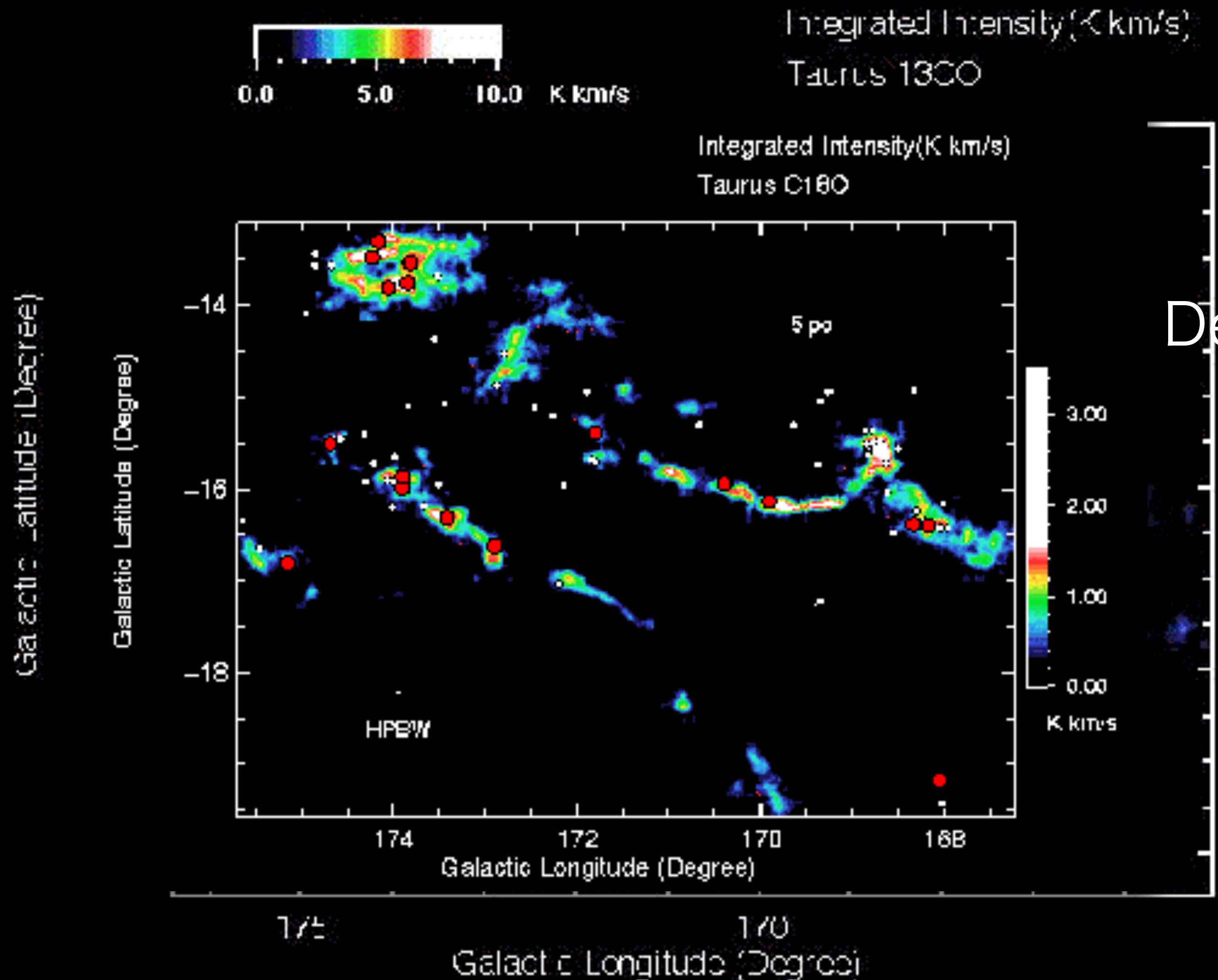


- https://www.nagoya-u.ac.jp/about-nu/public-relations/researchinfo/upload_images/20210310_sci1.pdf
- https://news.mynavi.jp/article/20210311-1795118/
- https://www.astroarts.co.jp/article/hl/a/11894_starformation
- https://scitechdaily.com/star-formation-is-triggered-by-collisions-of-gas-clouds-in-space/

主な研究トピック2：小質量星形成

- 太陽系はどのように誕生したのか？
- 宇宙のほとんどの星は太陽と同程度かそれ以下の軽い星
- 近い分子雲が誕生の現場

おうし座分子雲の分子雲コア

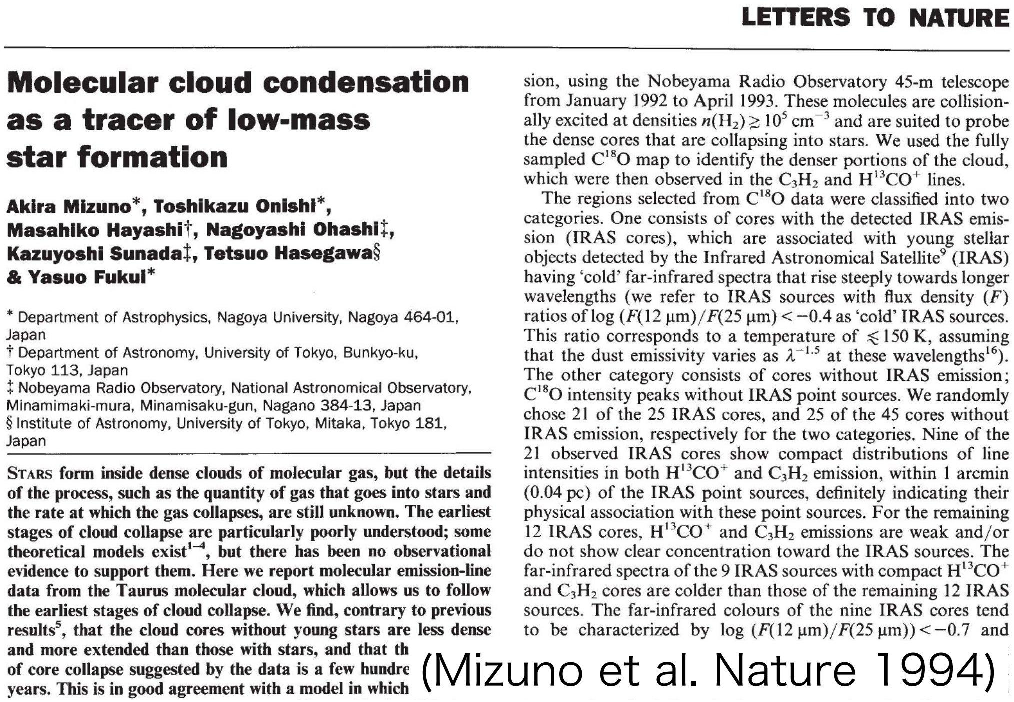


Dense cores

Onishi+ 1996

Mizuno+ 1995

高密度分子雲コア「星の卵」の検出



LETTERS TO NATURE

Molecular cloud condensation as a tracer of low-mass star formation

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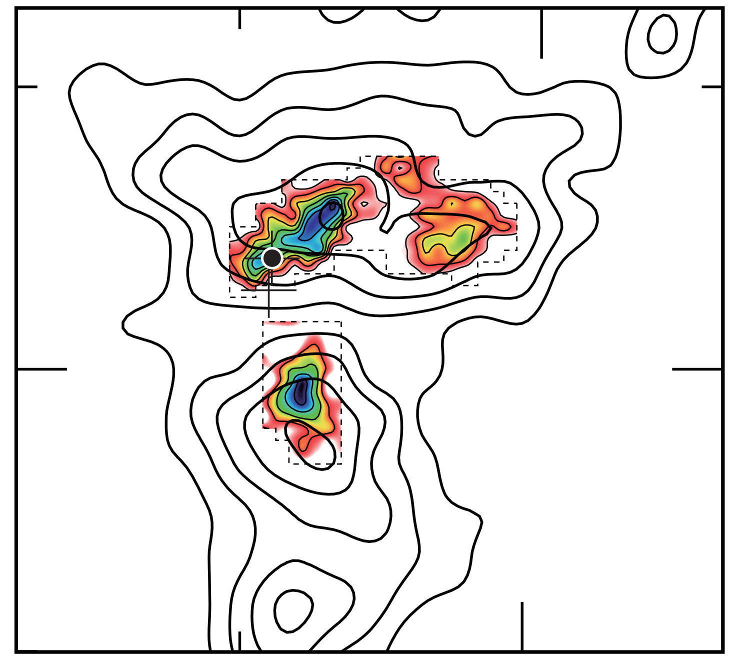
† Department of Astronomy, University of Tokyo, Bunkyo-ku, Tokyo 113, Japan
‡ Nobeyama Radio Observatory, National Astronomical Observatory, Minamimaki-mura, Minamisaku-gun, Nagano 384-13, Japan
§ Institute of Astronomy, University of Tokyo, Mitaka, Tokyo 181, Japan

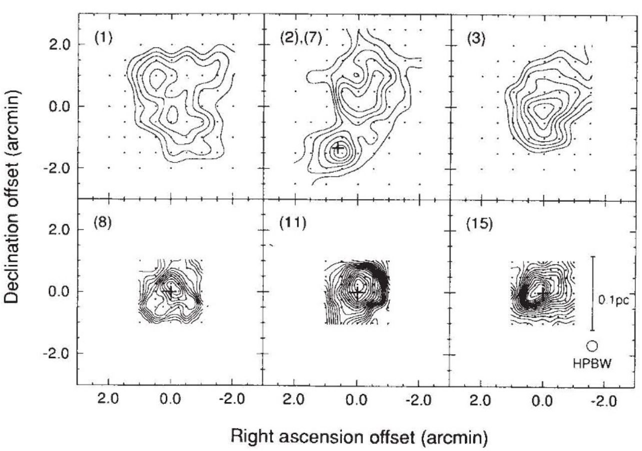
STARS form inside dense clouds of molecular gas, but the details of the process, such as the quantity of gas that goes into stars and the rate at which the gas collapses, are still unknown. The earliest stages of cloud collapse are particularly poorly understood; some theoretical models exist[1–4], but there has been no observational evidence to support them. Here we report molecular emission-line data from the Taurus molecular cloud, which allows us to follow the earliest stages of cloud collapse. We find, contrary to previous results[5], that the cloud cores without young stars are less dense and more extended than those with stars, and that th[...] of core collapse suggested by the data is a few hundre[...] years. This is in good agreement with a model in which

sion, using the Nobeyama Radio Observatory 45-m telescope from January 1992 to April 1993. These molecules are collisionally excited at densities $n(H_2) \gtrsim 10^5$ cm^{-3} and are suited to probe the dense cores that are collapsing into stars. We used the fully sampled $C^{18}O$ map to identify the denser portions of the cloud, which were then observed in the C_3H_2 and $H^{13}CO^+$ lines.

The regions selected from $C^{18}O$ data were classified into two categories. One consists of cores with the detected IRAS emission (IRAS cores), which are associated with young stellar objects detected by the Infrared Astronomical Satellite[9] (IRAS) having 'cold' far-infrared spectra that rise steeply towards longer wavelengths (we refer to IRAS sources with flux density (F) ratios of $\log(F(12\ \mu m)/F(25\ \mu m)) < -0.4$ as 'cold' IRAS sources. This ratio corresponds to a temperature of $\lesssim 150$ K, assuming that the dust emissivity varies as $\lambda^{-1.5}$ at these wavelengths[16]). The other category consists of cores without IRAS emission; $C^{18}O$ intensity peaks without IRAS point sources. We randomly chose 21 of the 25 IRAS cores, and 25 of the 45 cores without IRAS emission, respectively for the two categories. Nine of the 21 observed IRAS cores show compact distributions of line intensities in both $H^{13}CO^+$ and C_3H_2 emission, within 1 arcmin (0.04 pc) of the IRAS point sources, definitely indicating their physical association with these point sources. For the remaining 12 IRAS cores, $H^{13}CO^+$ and C_3H_2 emissions are weak and/or do not show clear concentration toward the IRAS sources. The far-infrared spectra of the 9 IRAS sources with compact $H^{13}CO^+$ and C_3H_2 cores are colder than those of the remaining 12 IRAS sources. The far-infrared colours of the nine IRAS cores tend to be characterized by $\log(F(12\ \mu m)/F(25\ \mu m)) < -0.7$ and

(Mizuno et al. Nature 1994)





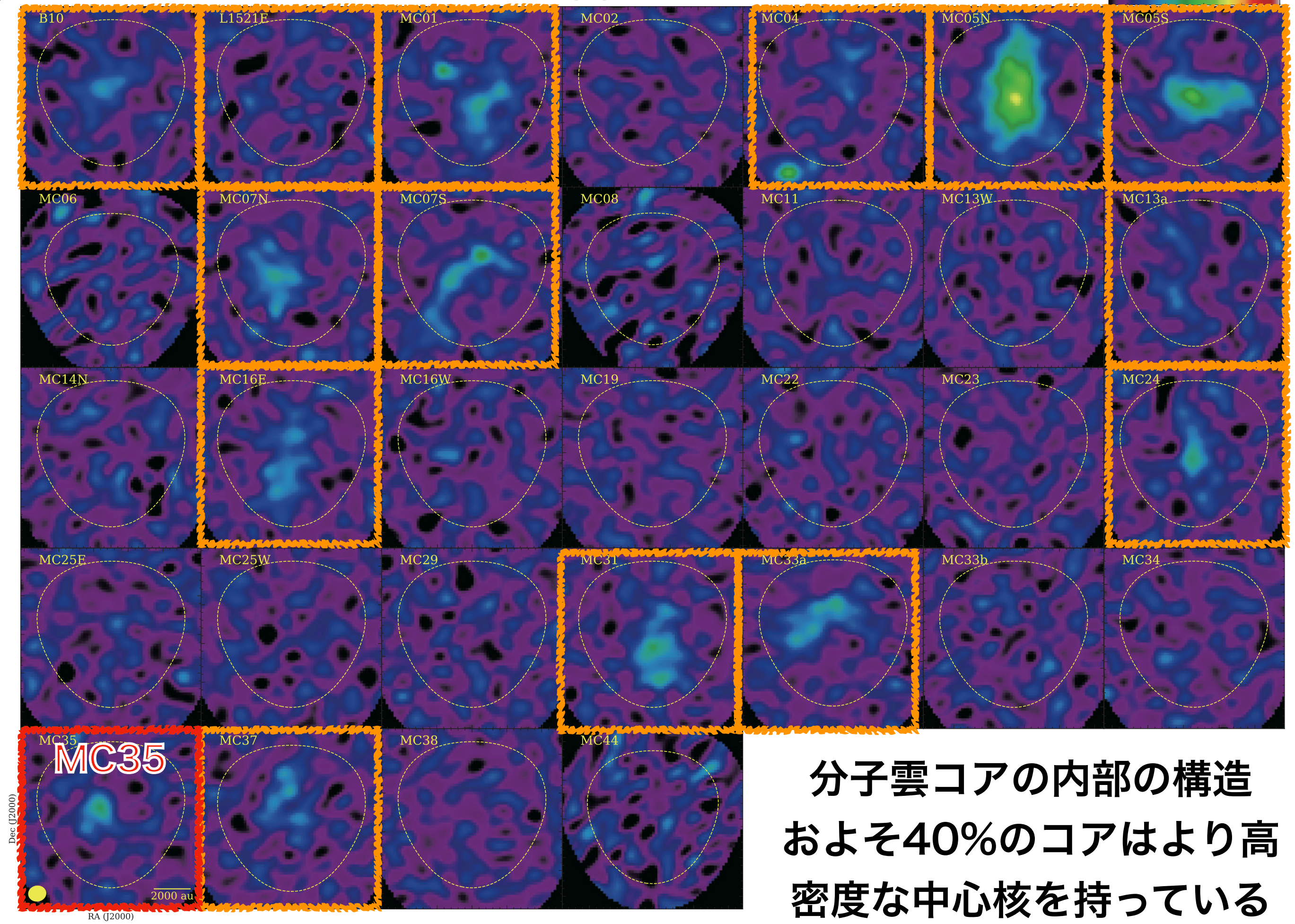
55 eggs were discovered in Taurus (Onishi et al. 2002)

ALMA望遠鏡によるサーベイ

- Atacama Compact Array (ACA) by Japan
- Good surveyor
- 39 dense cores in Taurus from Onishi's catalog

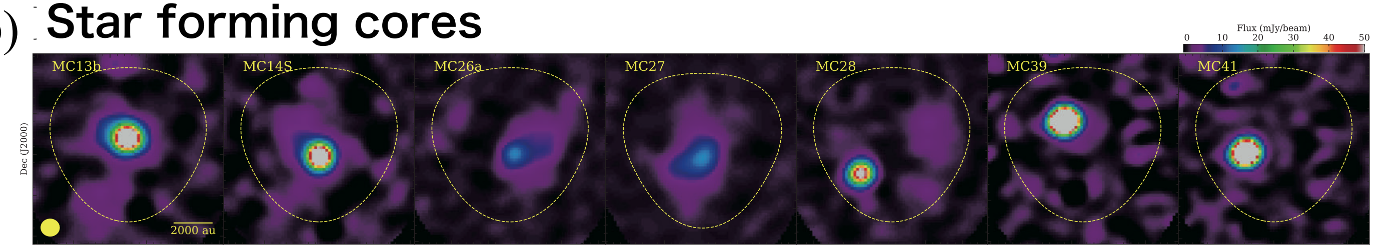
ALMAの観測結果

(a) Starless cores (stellar eggs)



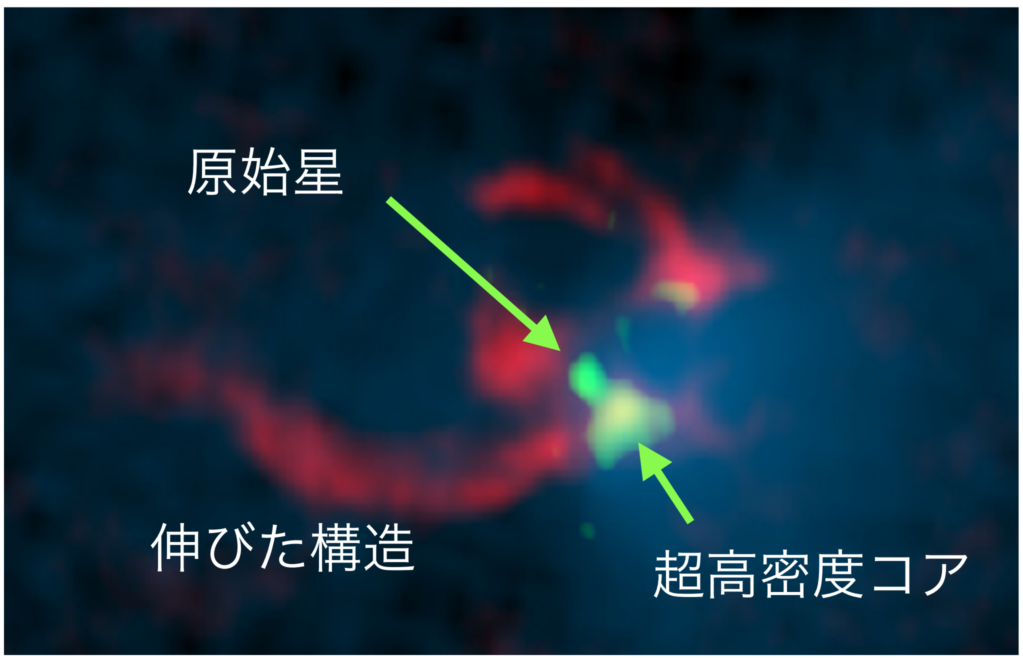
分子雲コアの内部の構造
およそ40%のコアはより高
密度な中心核を持っている

(b) Star forming cores

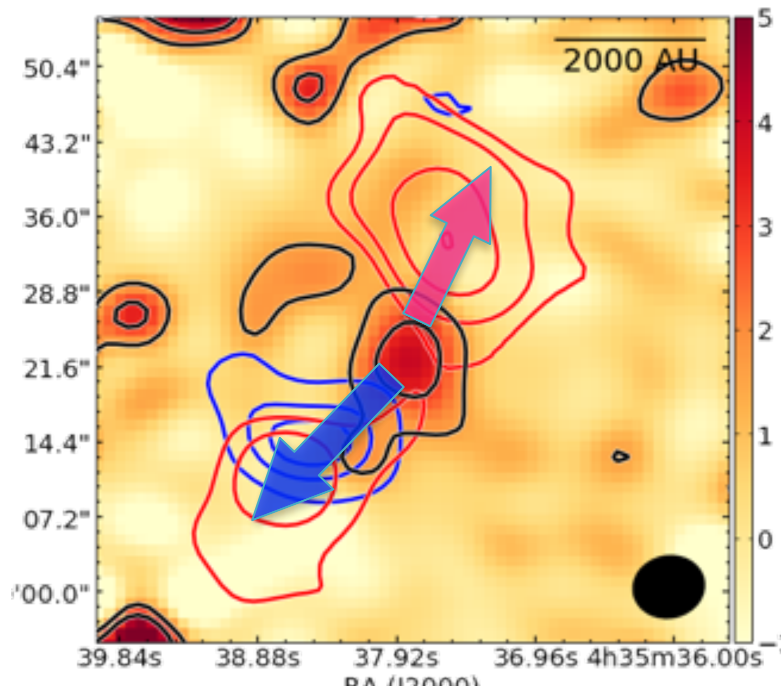


分子雲コアの不思議な内部構造

- 単純なガス球ではない
- 複数の塊に分裂して、それらがダイナミックに運動？
- これまで見えなかった天体から分子流が吹き出している？



Tokuda et al. 2014



Fujishiro et al. 2020

記者発表

- ２篇の論文が米国学会紙に掲載
- 大阪府立大・国立天文台ALMAプロジェクトとともに記者発表
- 名古屋大学 https://www.nagoya-u.ac.jp/about-nu/public-relations/researchinfo/upload_images/20200807_sci1.pdf
- 国立天文台 https://alma-telescope.jp/news/press/taurus-202008

日本経済新聞
https://www.nikkei.com/article/DGXMZO62498050R10C20A8CE0000/

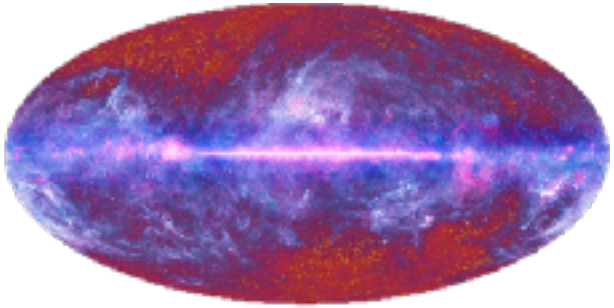
アストロアーツ
https://www.astroarts.co.jp/article/hl/a/11432_taurus

マイナビニュース
https://news.mynavi.jp/article/20200814-1223233/

日本の研究.com
https://research-er.jp/articles/view/91080

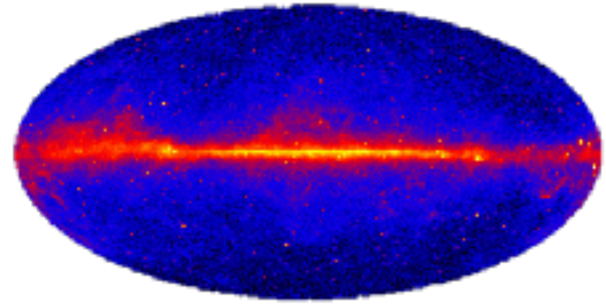
ALMA Observatory
https://www.almaobservatory.org/en/press-releases/stellar-egg-hunt-with-alma-tracing-evolution-from-embryo-to-baby-star/

主な研究トピック3. 超広域分子雲探査

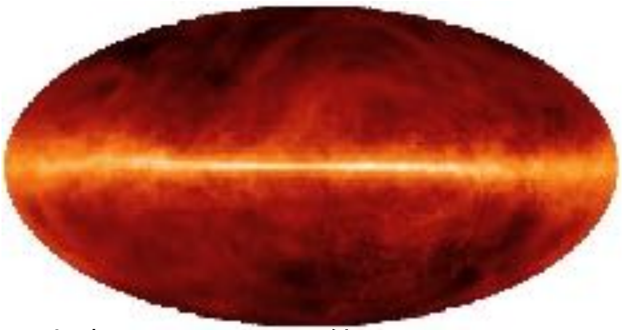


サブミリ波：Planck衛星

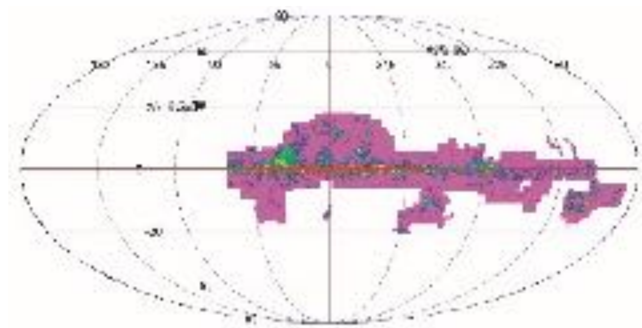
赤外線：あかり衛星



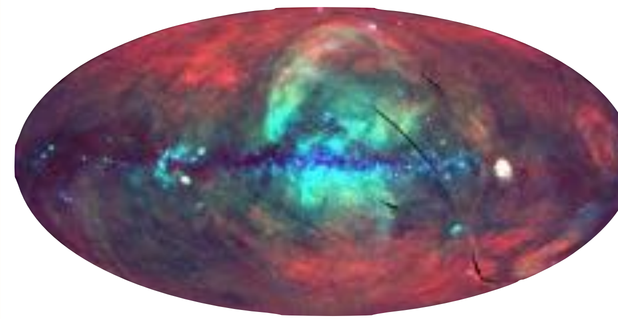
ガンマ線：Fermi衛星



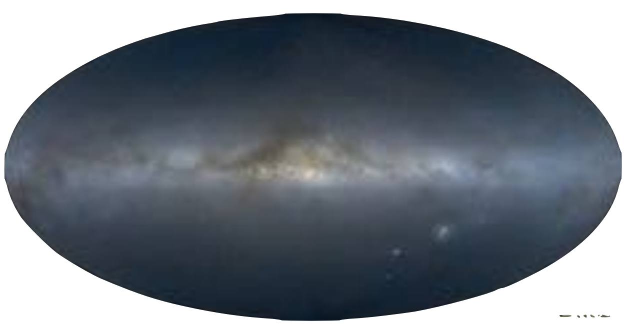
水素原子：Parkes他



分子雲：なんてん



X線：ROSAT



可視光：星 GAIA他

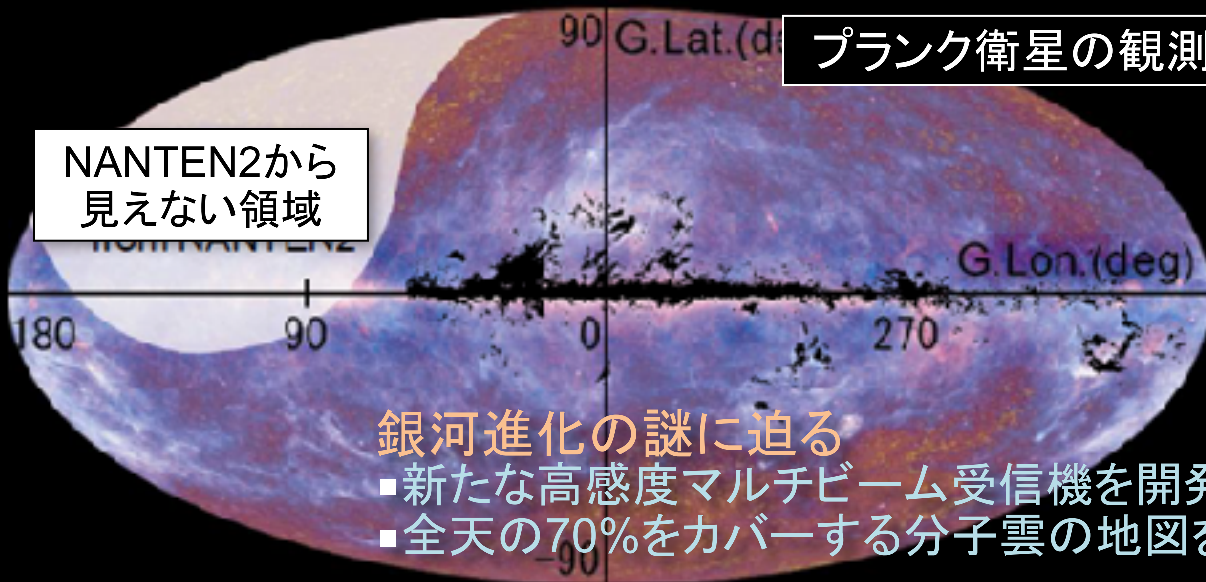
星間物質は原子ガス・分子ガス・ダストからなる

これらのうち、分子雲のみ全天マップが未だ存在しない

銀河面から離れた場所にも分子ガスは結構ある

チリから観測できる全天に渡る分子雲の地図を作りたい

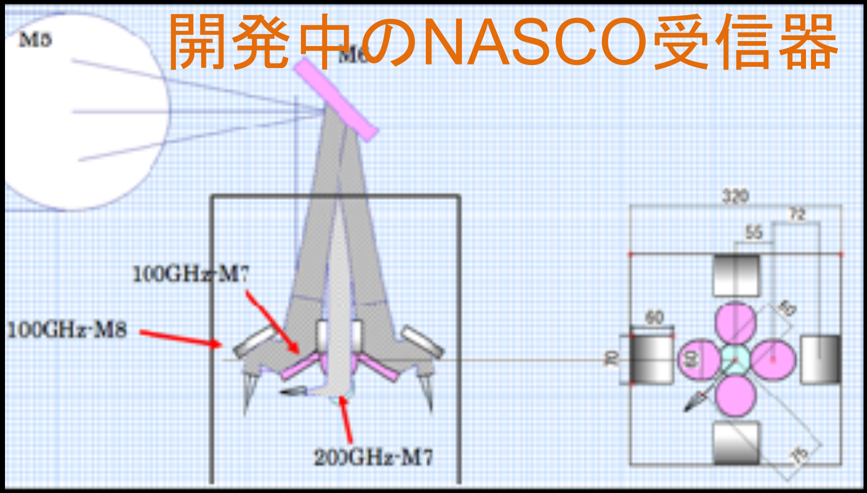
NANTE2 Super CO Survey as Legacy (NASCO)計画

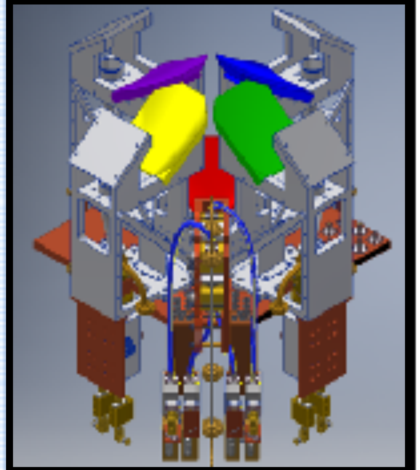


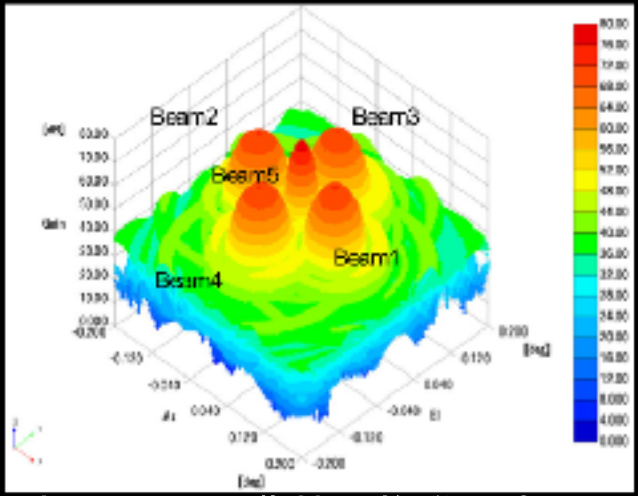
銀河進化の謎に迫る
- 新たな高感度マルチビーム受信機を開発
- 全天の70%をカバーする分子雲の地図を作る

銀河系の分子雲の地図は不完全：新たな専用受信機が必要

開発中のNASCO受信器

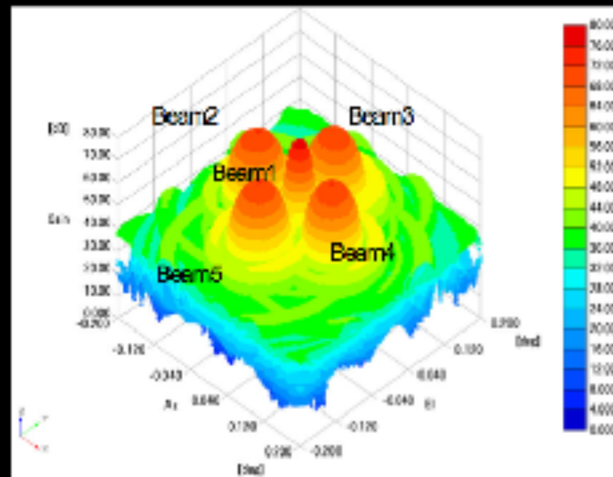


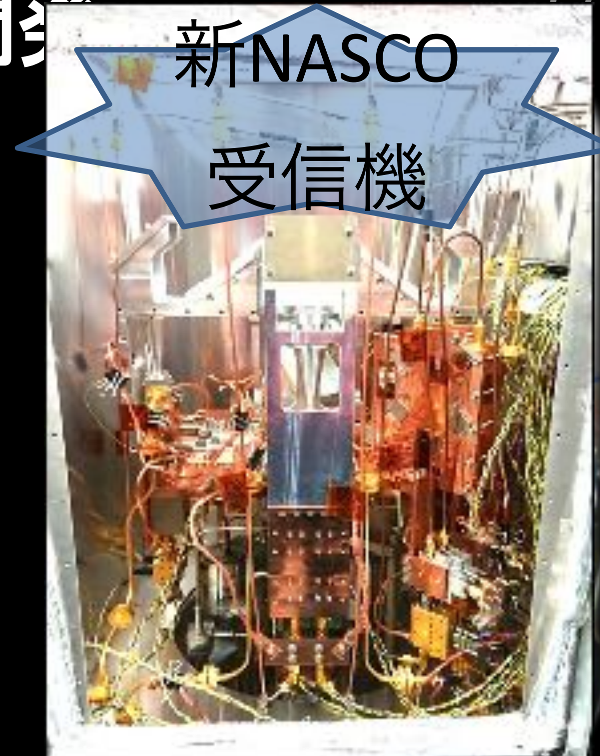


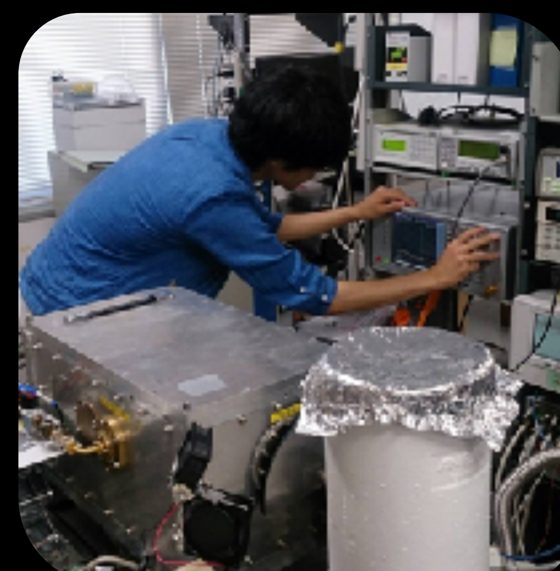


（2015年度より、科研費特別推進研究）

観測装置は自ら開発

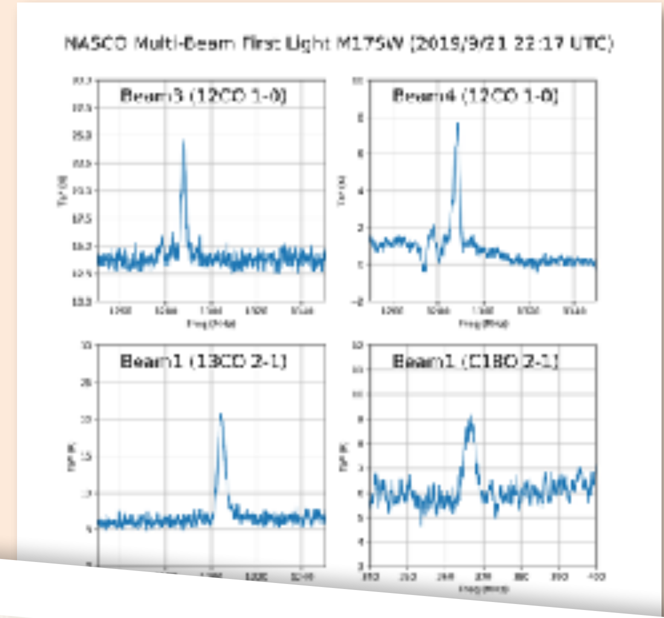


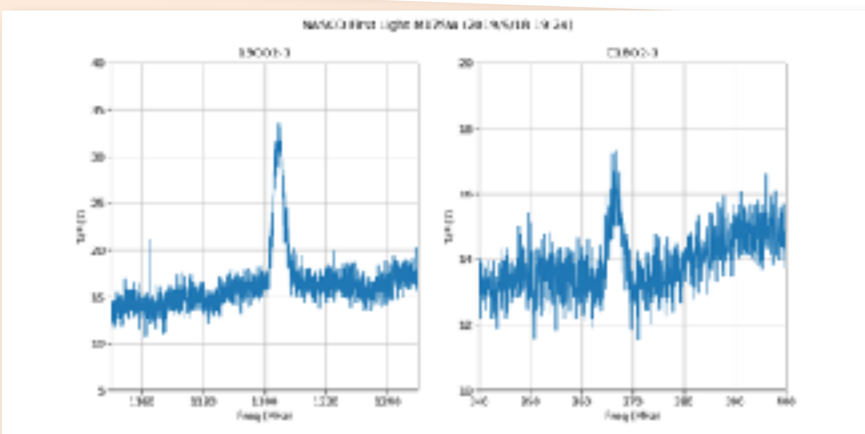




1. まずは設計
2. 自分で作れるモノは作る！
3. 実験！きちんと動くか・・・
4. NANTEN2に搭載！！

NASCO受信機ファーストライト！





物理学科のオープンキャンパス・ラボツアーの動画もご覧ください

https://nuss.nagoya-u.ac.jp/s/Pj844ipPtYdtkzN

まとめ

- 豊かな星間物質からなる銀河を一緒に探検しませんか？
- 星が誕生する瞬間を見てみませんか？
- 自分で作った装置で、はるか遠くの天体からきた信号を検出してみませんか？
- チリの満天の星空の下、一緒に研究しましょう！