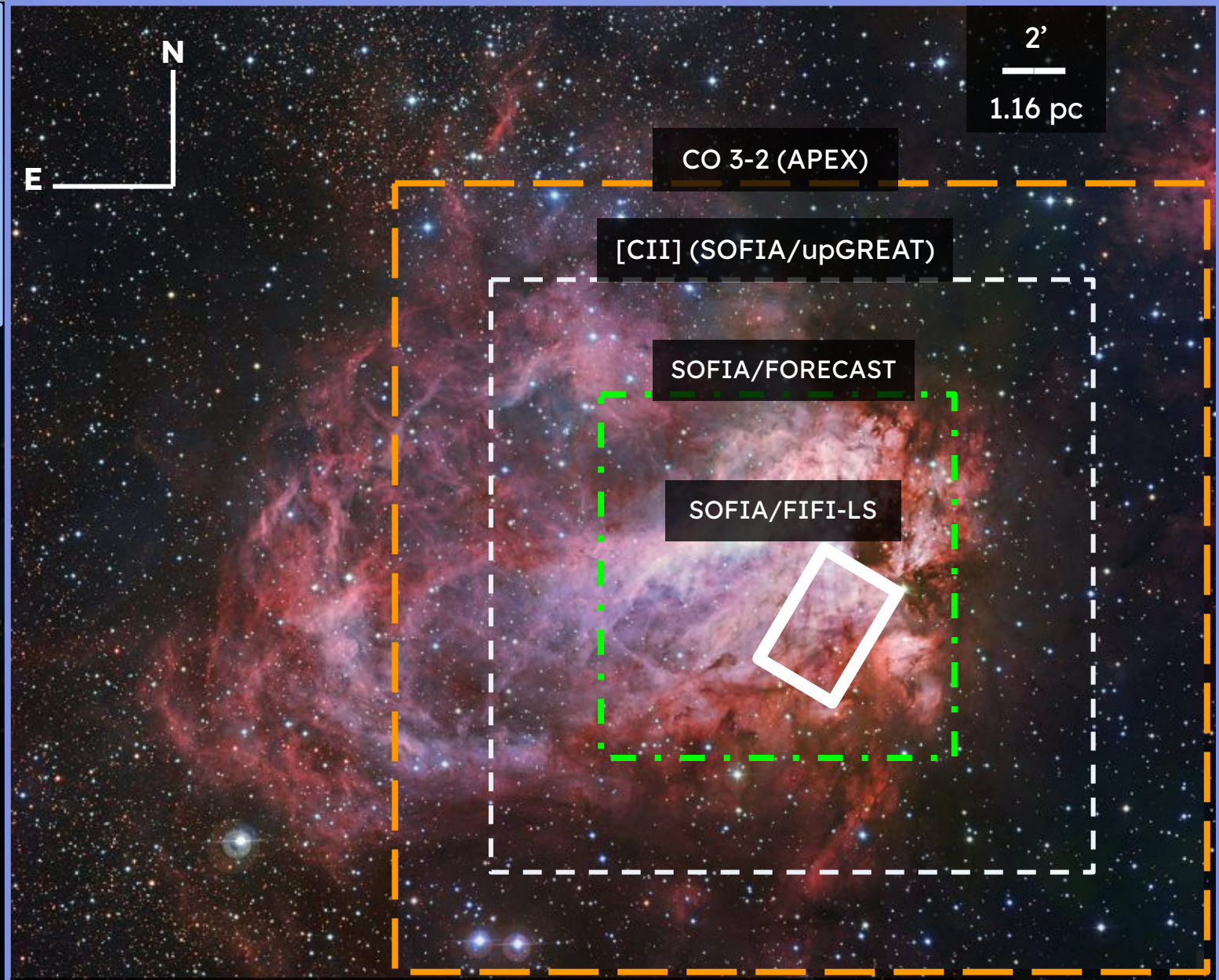
# COMPLEX GAS DISTRIBUTION IN THE EXTENDED CII & CO 3-2 MAPS OF M17


**Parit Mehta[1]**

**Ph.D. Candidate**

**Collaborators:** Jürgen Stutzki[1], Cristian Guevara[1], Nicola Schneider[1], Rolf Güsten[2], Slawa Kabanovic[1]

[1] Institute for Astrophysics, University of Cologne
[2] Max Planck Institute for Radio Astronomy, Bonn


*Frames*: Extent of new large-scale maps
*Background*: Optical image of the M17 nebula by MPG/ESO La Silla Observatory.

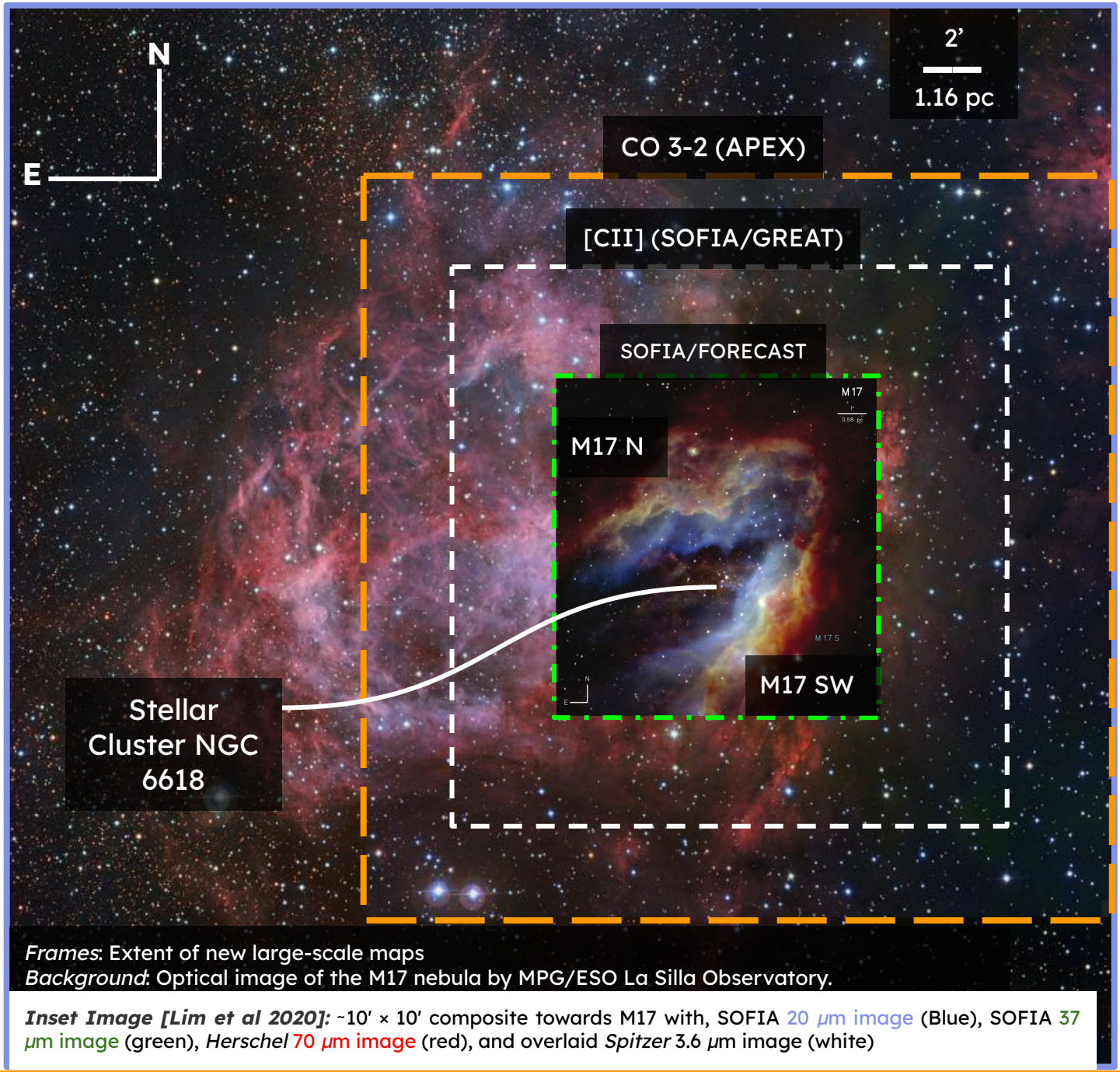
# WHAT WE SHALL TALK ABOUT

- Introducing M17
  - Historical Context
  - SOFIA FEEDBACK Legacy Program
- Why are we interested?
- Insights from the SOFIA and APEX data
- Summary

# INTRODUCING M17

- One of the **brightest** and **most massive** star forming regions in the Milky Way
- **Stellar Cluster: >100 OB stars** in **Av>10** gas (Hoffmeister et al. 2008)
- Other properties (Schneider et al. 2020):

| | |
|---|---|
| Total Mass | ~ $10^5$ $M_\odot$ |
| **Distance** | ~1.9 kpc |
| LSR Velocity | 22 km/s |




*Frames*: Extent of new large-scale maps
*Background*: Optical image of the M17 nebula by MPG/ESO La Silla Observatory.

***Inset Image [Lim et al 2020]:*** ~10′ × 10′ composite towards M17 with, SOFIA 20 μm image (Blue), SOFIA 37 μm image (green), *Herschel* 70 μm image (red), and overlaid *Spitzer* 3.6 μm image (white)

# HISTORICAL CONTEXT

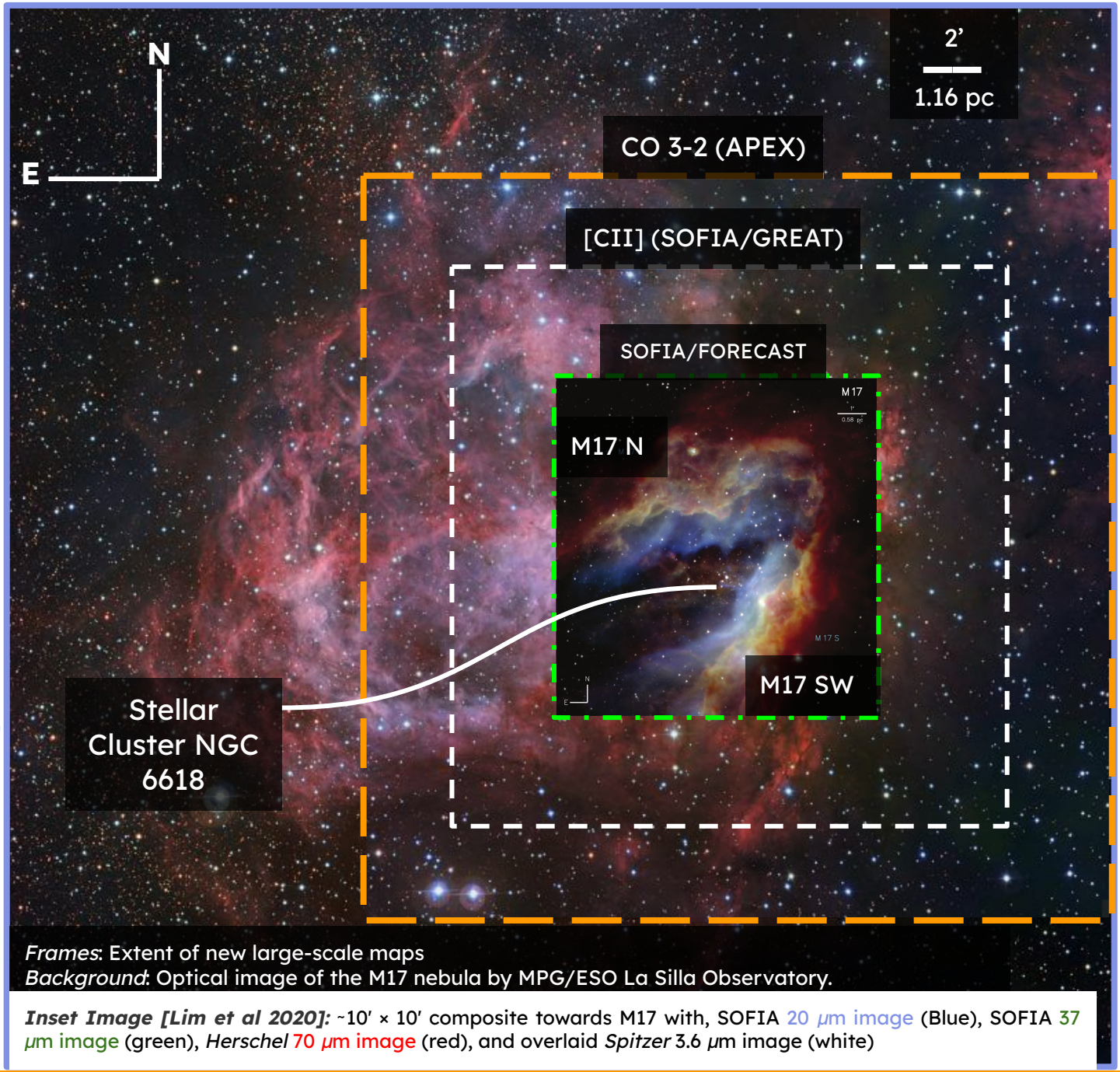
- **Extensively studied in CO** (from Lada 1976 onwards)
- **One of the first sources** ever to be observed in [CII] (Russell et al. 1980)

**M17-SW**

- **Clumpy** (Stutzki et al. 1988, 1990, Meixner et al. 1992)
- **Self-absorption** in [CII] confirmed (Guevara et al. 2020) - deep integrations in single pointings
- **Cross-calibration** - FIFI-LS [CII]-map agrees with upGREAT [CII] (Klein et al. 2023)

**M17-N**

- Lower $H_2$ column densities and $C^{18}O$ line-widths (Wilson et al. 2003)
- **Before FEEDBACK, no high spatial and velocity resolution** [CII] **data available**



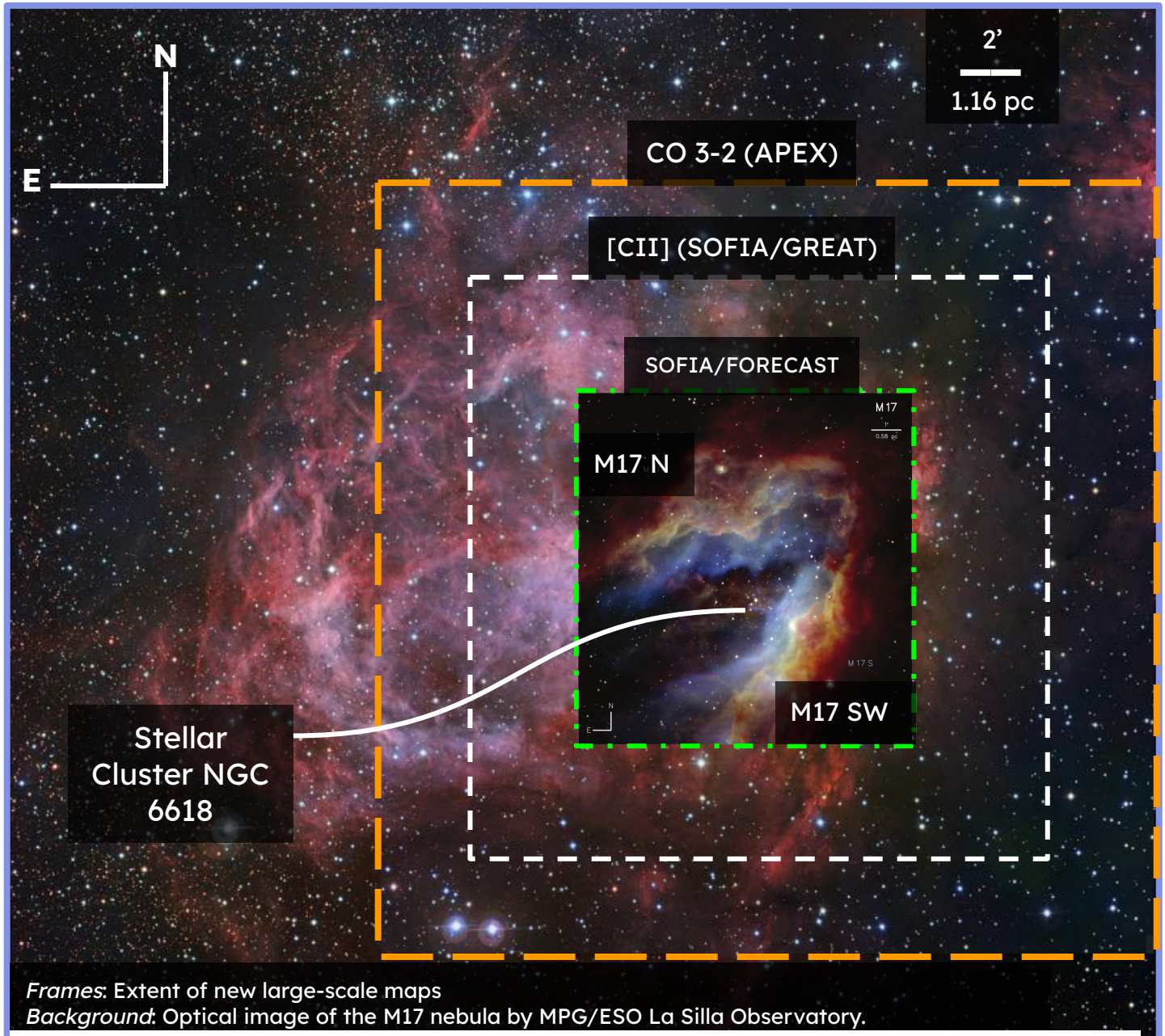

*Frames*: Extent of new large-scale maps
*Background*: Optical image of the M17 nebula by MPG/ESO La Silla Observatory.

***Inset Image [Lim et al 2020]:*** ~10′ × 10′ composite towards M17 with, SOFIA 20 $\mu$m image (Blue), SOFIA 37 $\mu$m image (green), *Herschel* 70 $\mu$m image (red), and overlaid *Spitzer* 3.6 $\mu$m image (white)

# AIMS OF ANALYSIS: EXTENDED MAPS

**M17 morphology:** **What can we say about the large-scale structure of [CII] and CO 3-2 emission in M17?**

**CII intensity:** **How do optical depth effects or self-absorption arising from multiple surfaces along the line of sight impact the estimation of CII column densities on a large scale?**




*Frames*: Extent of new large-scale maps
*Background*: Optical image of the M17 nebula by MPG/ESO La Silla Observatory.

***Inset Image [Lim et al 2020]:*** ~10′ × 10′ composite towards M17 with, SOFIA 20 $\mu$m image (Blue), SOFIA 37 $\mu$m image (green), *Herschel* 70 $\mu$m image (red), and overlaid *Spitzer* 3.6 $\mu$m image (white)


Publications of the Astronomical Society of the Pacific, 132:104301 (19pp), 2020 October https://doi.org/10.1088/1538-3873/aba840


# FEEDBACK: a SOFIA Legacy Program to Study Stellar Feedback in Regions of Massive Star Formation

N. Schneider[1], R. Simon[1], C. Guevara[1], C. Buchbender[1], R. D. Higgins[1], Y. Okada[1], J. Stutzki[1], R. Güsten[2], L. D. Anderson[3], J. Bally[4], H. Beuther[5], L. Bonne[6], S. Bontemps[6], E. Chambers[7], T. Csengeri[6], U. U. Graf[1], A. Gusdorf[8], K. Jacobs[1], M. Justen[1], S. Kabanovic[1], R. Karim[9], M. Luisi[3], K. Menten[2], M. Mertens[1], B. Mookerjea[10], V. Ossenkopf-Okada[1], C. Pabst[11], M. W. Pound[9], H. Richter[12], N. Reyes[2], O. Ricken[2], M. Röllig[1], D. Russeil[13], Á. Sánchez-Monge[1], G. Sandell[14], M. Tiwari[9], H. Wiesemeyer[2], M. Wolfire[9], F. Wyrowski[2], A. Zavagno[13], and A. G. G. M. Tielens[9,11]
[1] I. Physik. Institut, University of Cologne, Zülpicher Str. 77, D-50937 Cologne, Germany; nschneid@ph1.uni-koeln.de
[2] Max-Planck Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany
[3] Department of Physics and Astronomy, West Virginia University, Morgantown WV 26506, USA
[4] Center for Astrophysics and Space Astronomy, University of Colorado, Colorado 80309, USA
[5] Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany
[6] LAB, University of Bordeaux, CNRS, B18N, F-33615 Pessac, France
[7] USRA/SOFIA, NASA Ames Research Center, Moffett Field, CA 94035-0001, USA
[8] LPENS, LERMA, Université PSL, CNRS, Sorbonne Université, Université de Paris, Paris, France
[9] Department of Astronomy, University of Maryland, College Park, MD 20742, USA
[10] Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400005, India
[11] Leiden Observatory, Leiden University, PO Box 9513, 2300 RA Leiden, The Netherlands
[12] Institute of Optical Sensor Systems, DLR, Rutherfordstr. 2, D-12489 Berlin, Germany
[13] Aix Marseille Université, CNRS, CNES, LAM, Marseille, France
[14] Institute for Astronomy, University of Hawaii, 640 N. Aohoku Place, Hilo, HI 96720, USA
*Received 2020 May 26; accepted 2020 July 20; published 2020 September 16*

## FEEDBACK

- **SOFIA legacy program using upGREAT on board SOFIA**
  - **Velocity-resolved** emission of **[CII] 158µm at 14.1”** and **[OI] 63µm at 6.3”**
  - Sources**: 11 galactic high mass SFRs**
  - **M17** map: approx. **11x12 sq. pc**

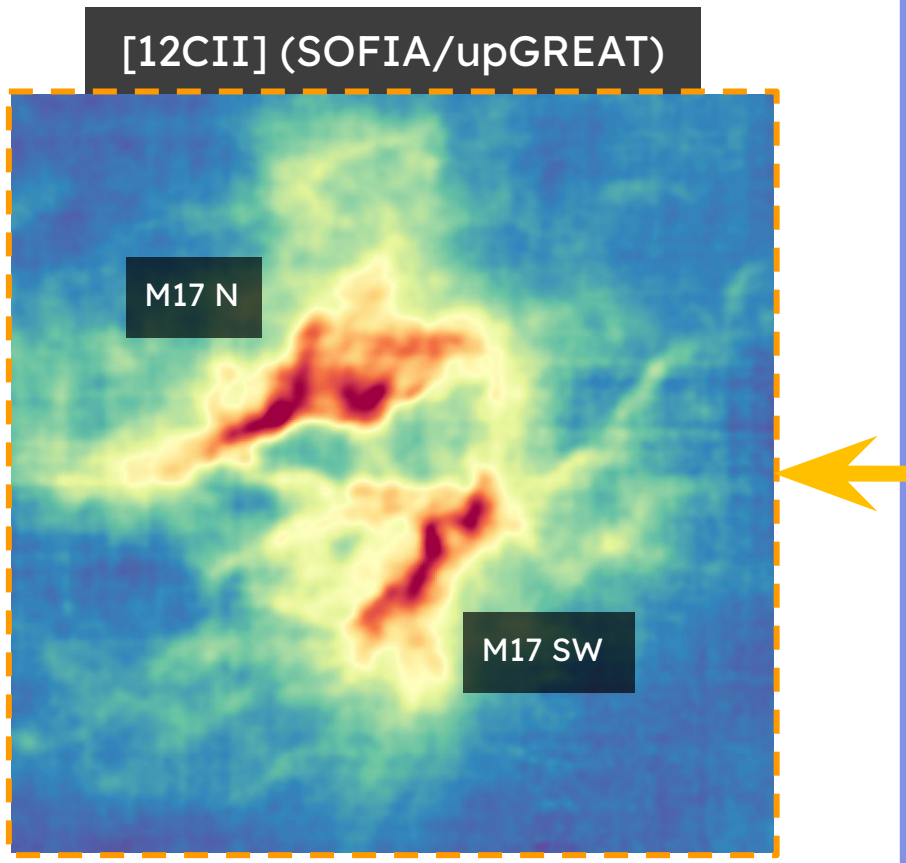
- **Complementary data:**
  - **Velocity resolved 12CO and 13CO (J=3-2)** emission from **APEX**
  - other CO and C line-datasets available

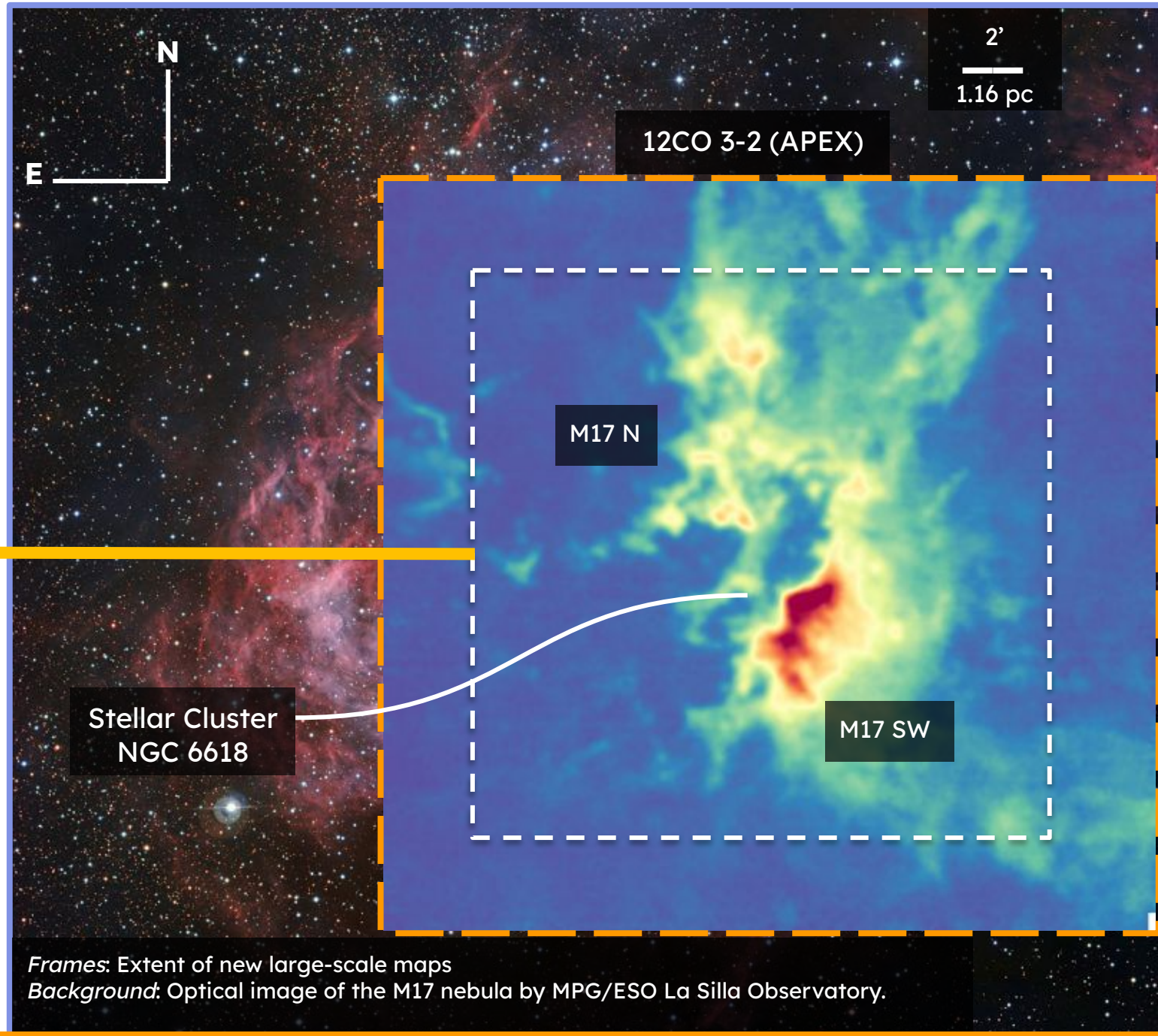
# 11 FEEDBACK SOURCES COVER VARYING COMPLEXITIES

**RCW 120**
**FUV Source: 1 O-Star**
**Spherical Geometry**

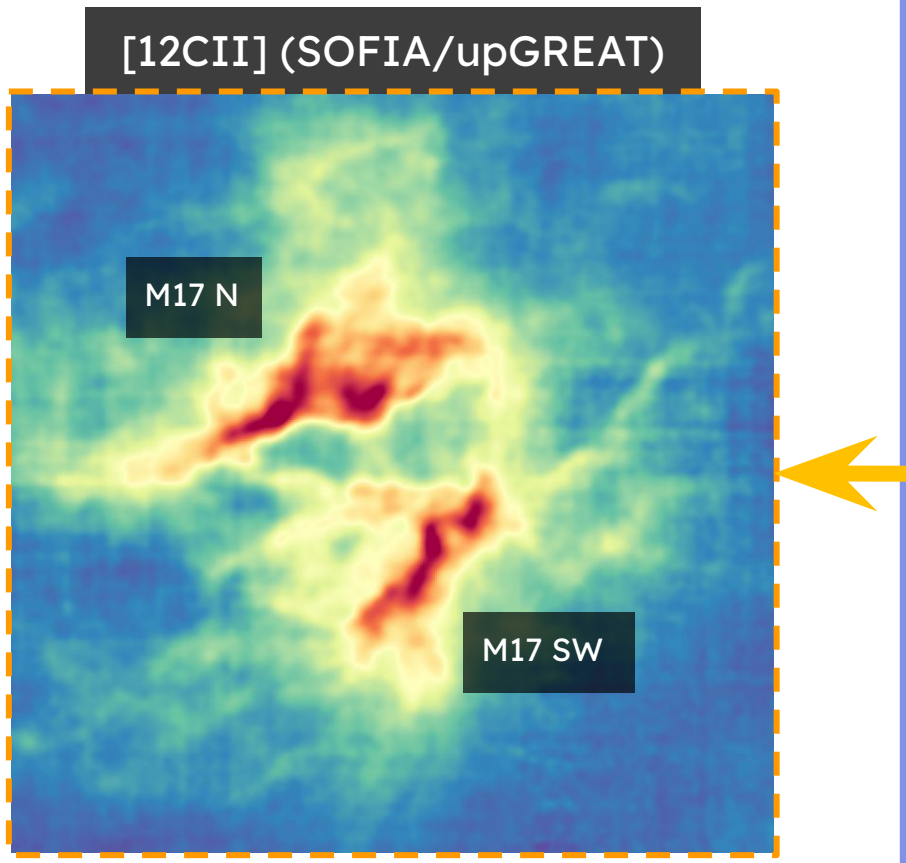
**M17**
**FUV Source: >100 OB-Stars**
**Complex Geometry**

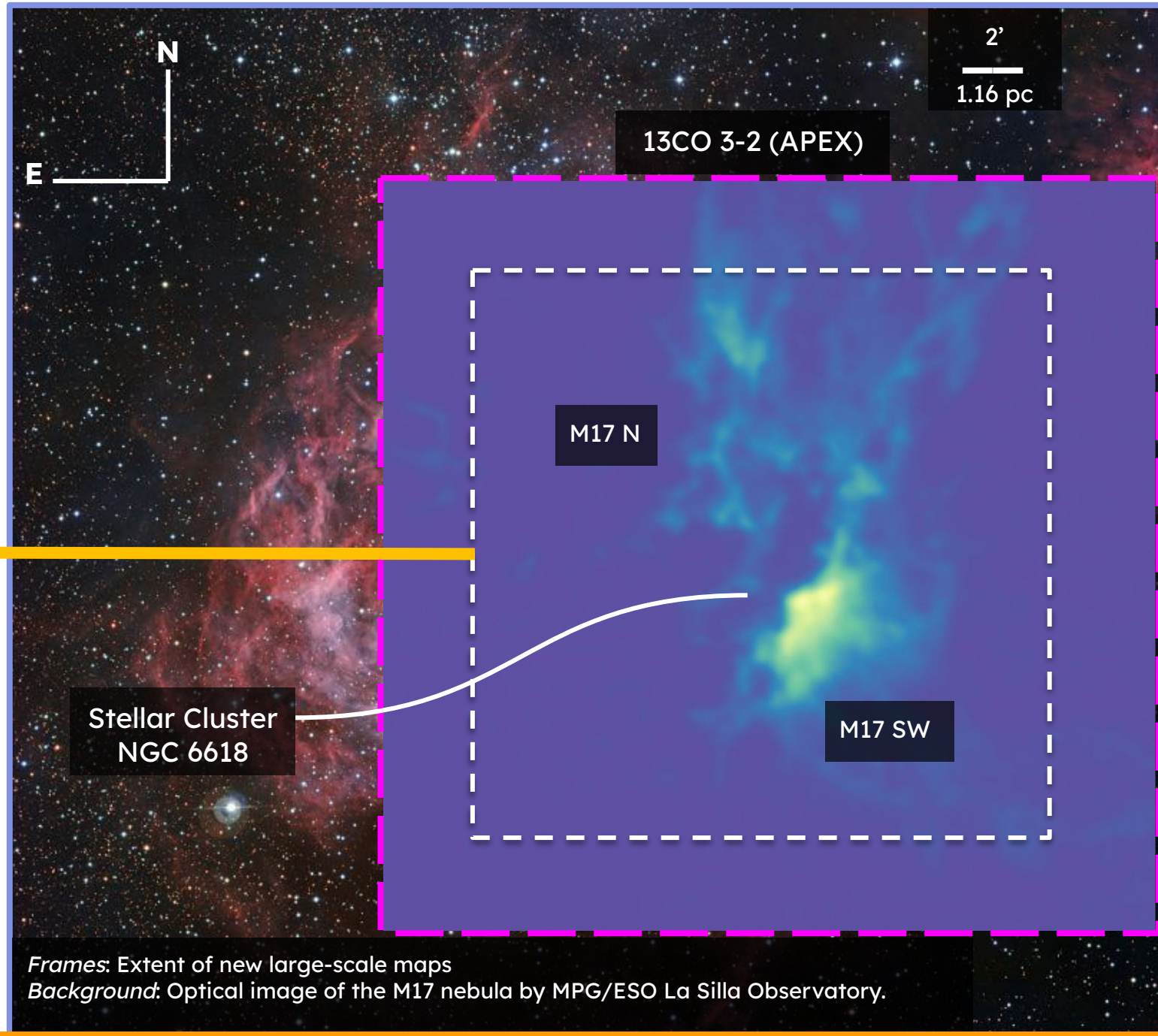
# NEW EXTENDED MAPS OF M17



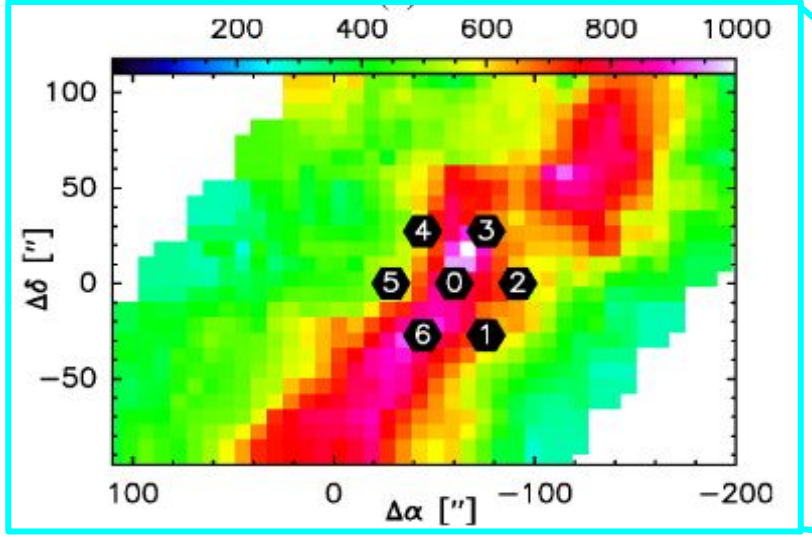
# NEW EXTENDED MAPS OF M17

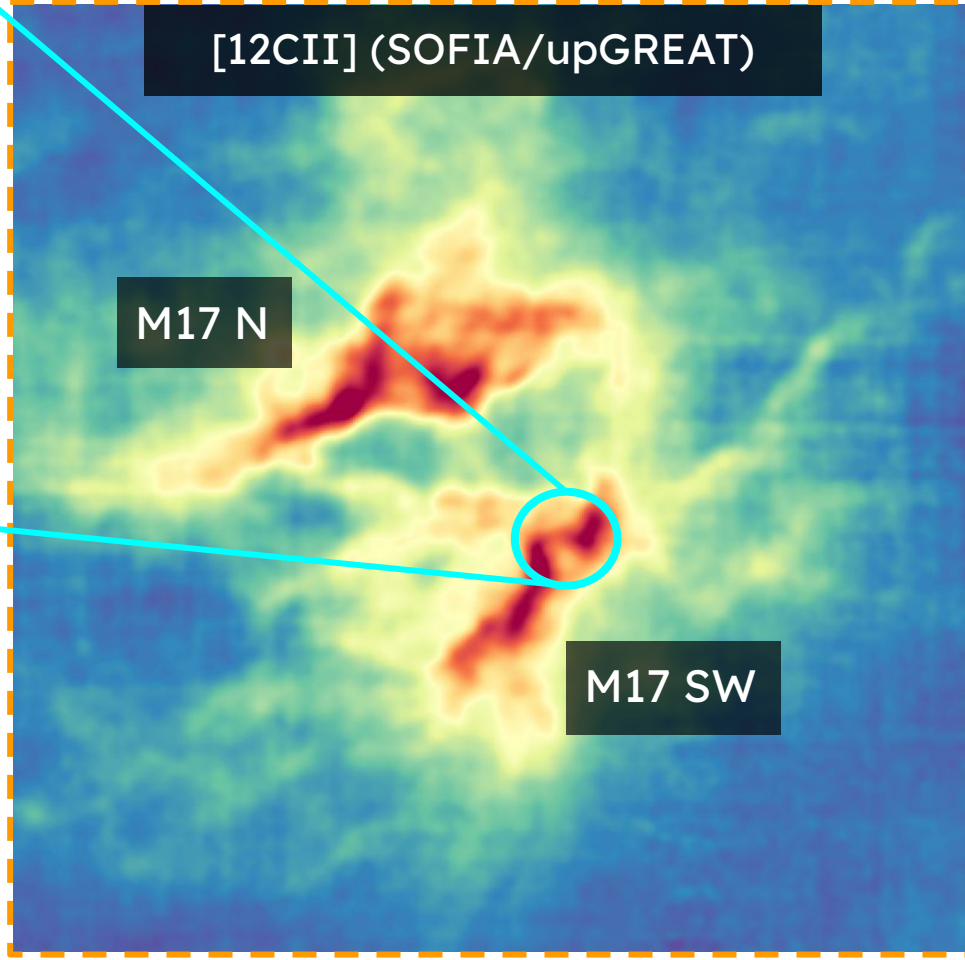


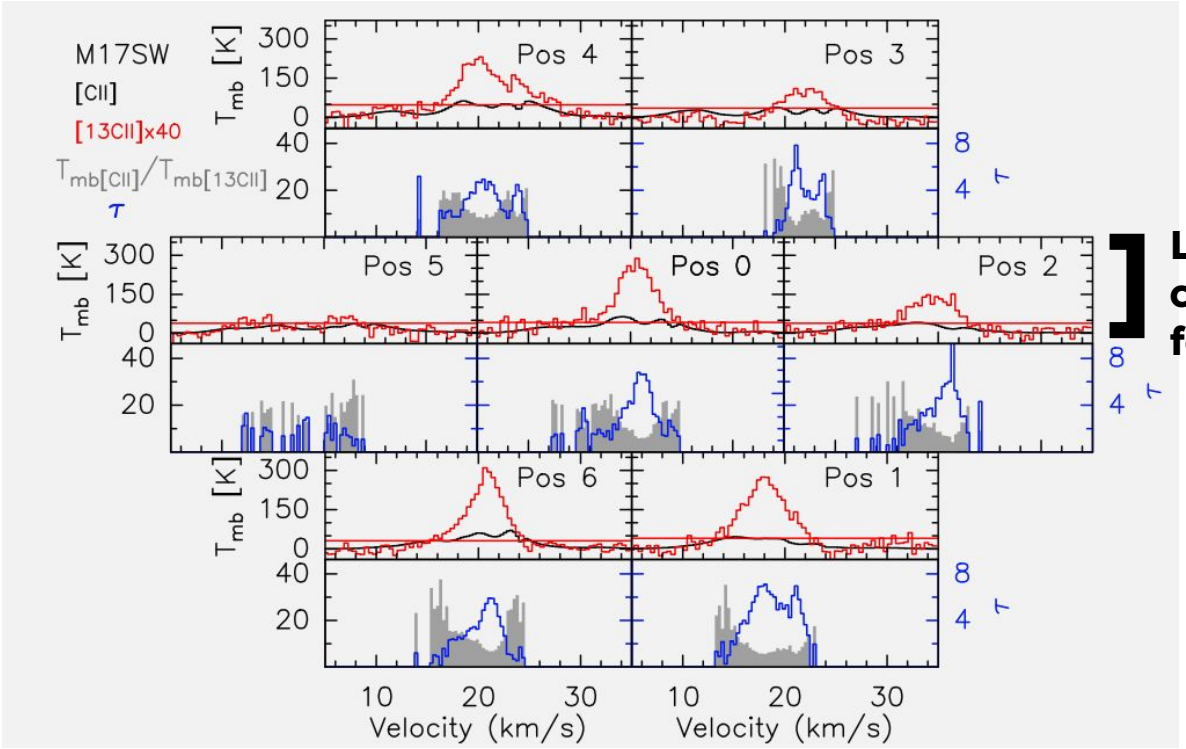



# PROBING OPTICAL DEPTH EFFECTS USING ISOTOPOLOGUES

**[Guevara et al. 2020]**



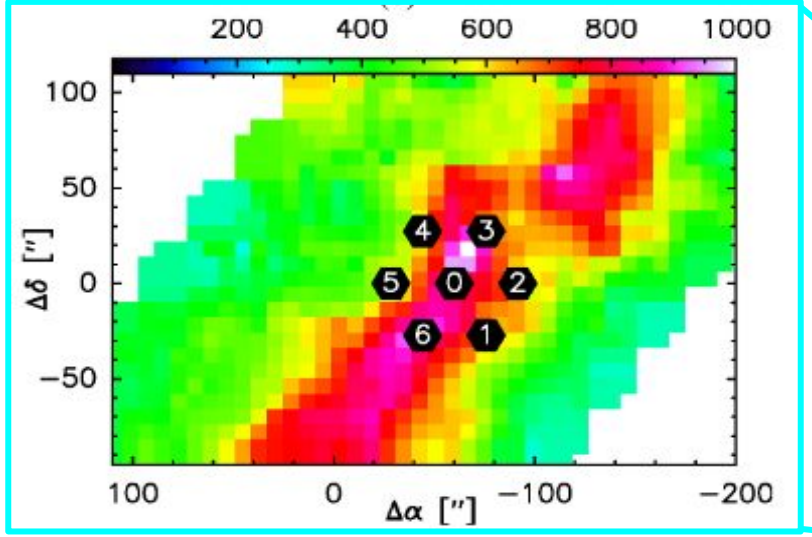



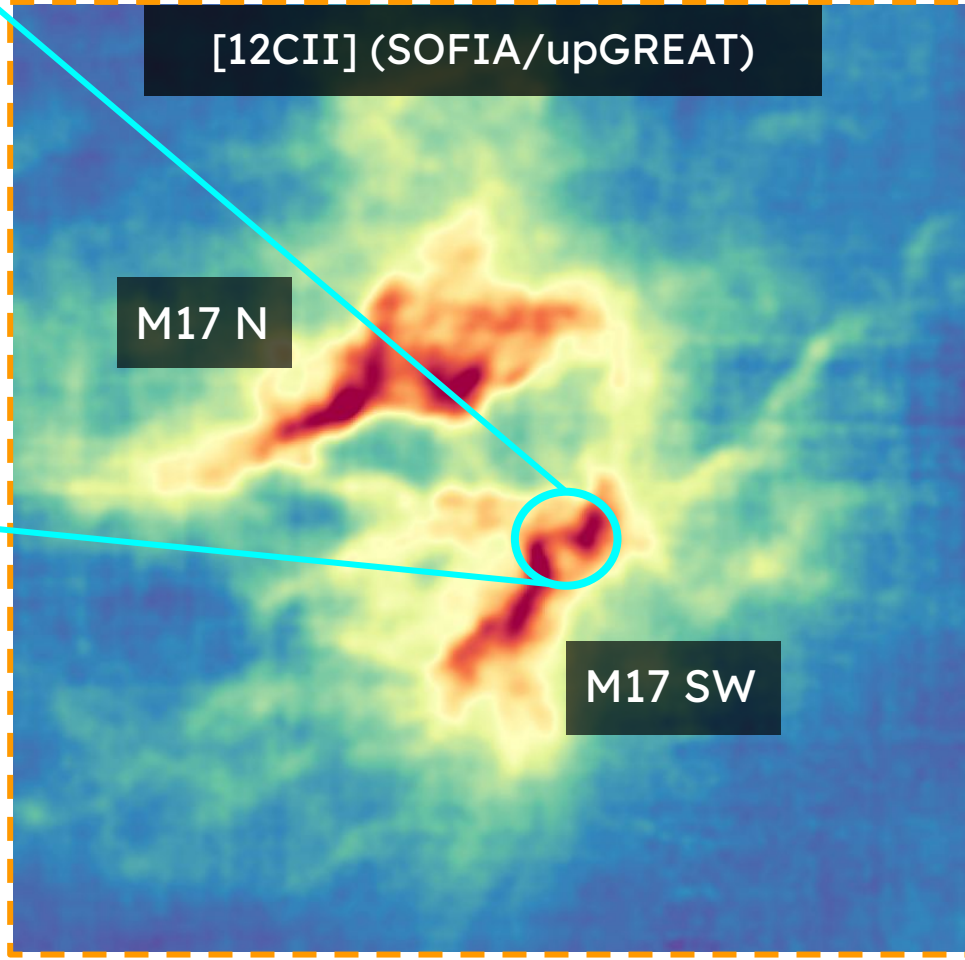



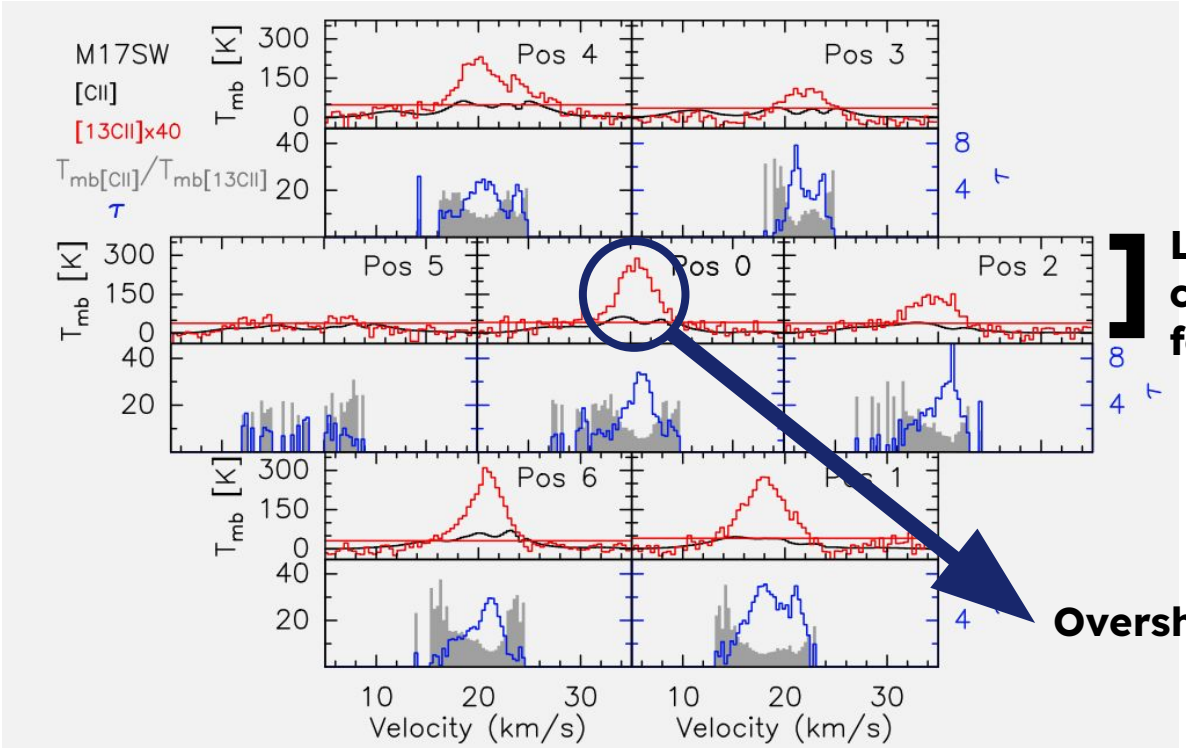

**Line-shape comparison for all 7 pixels**

# PROBING OPTICAL DEPTH EFFECTS USING ISOTOPOLOGUES

**[Guevara et al. 2020]**



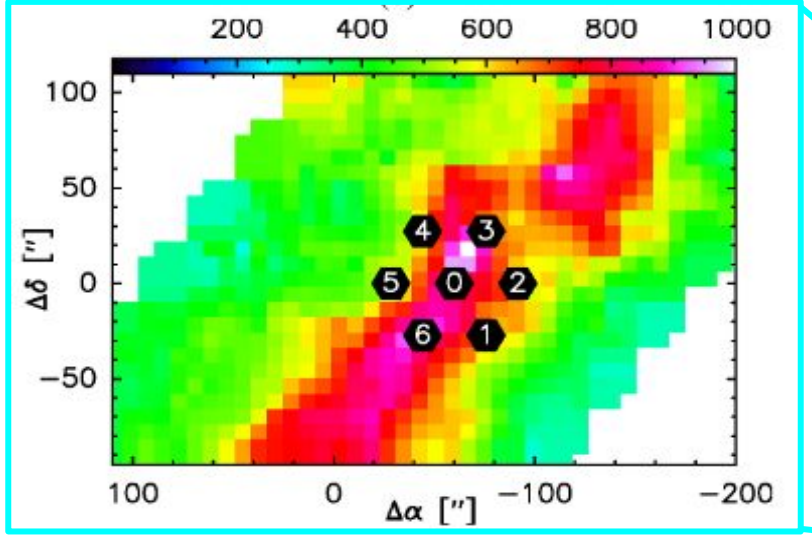



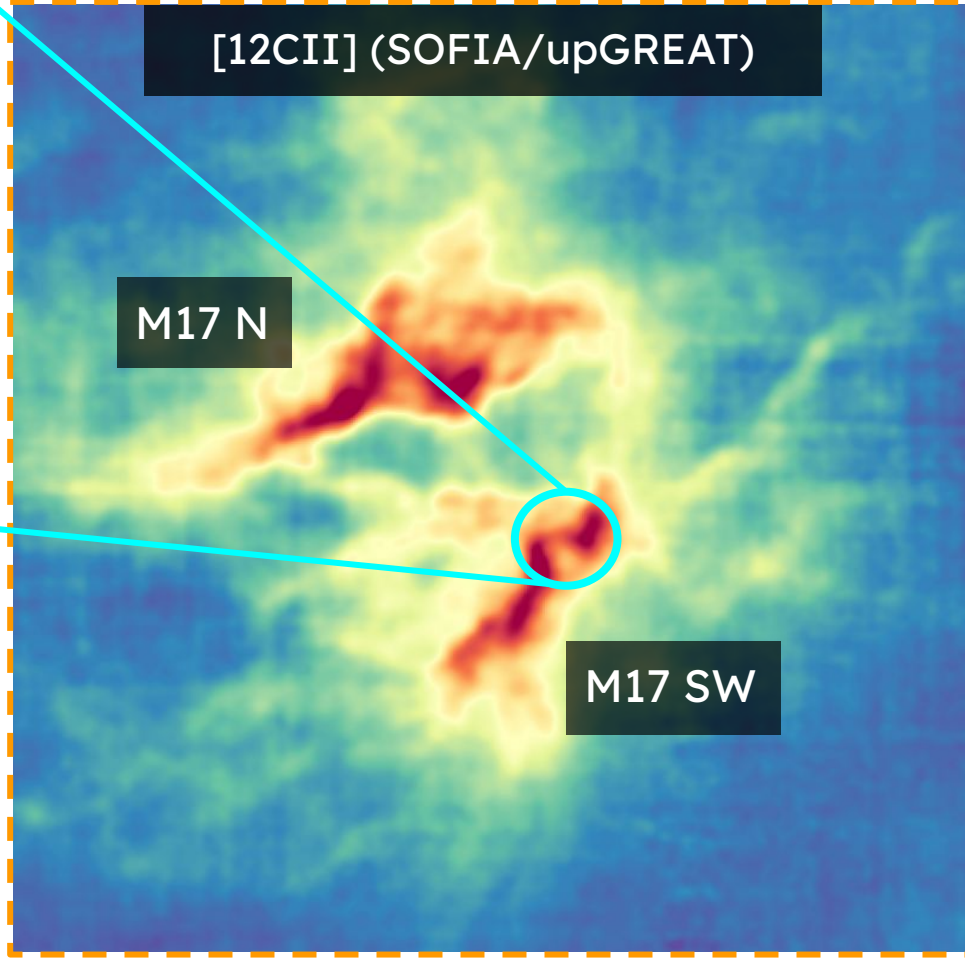

**Line-shape comparison for all 7 pixels**

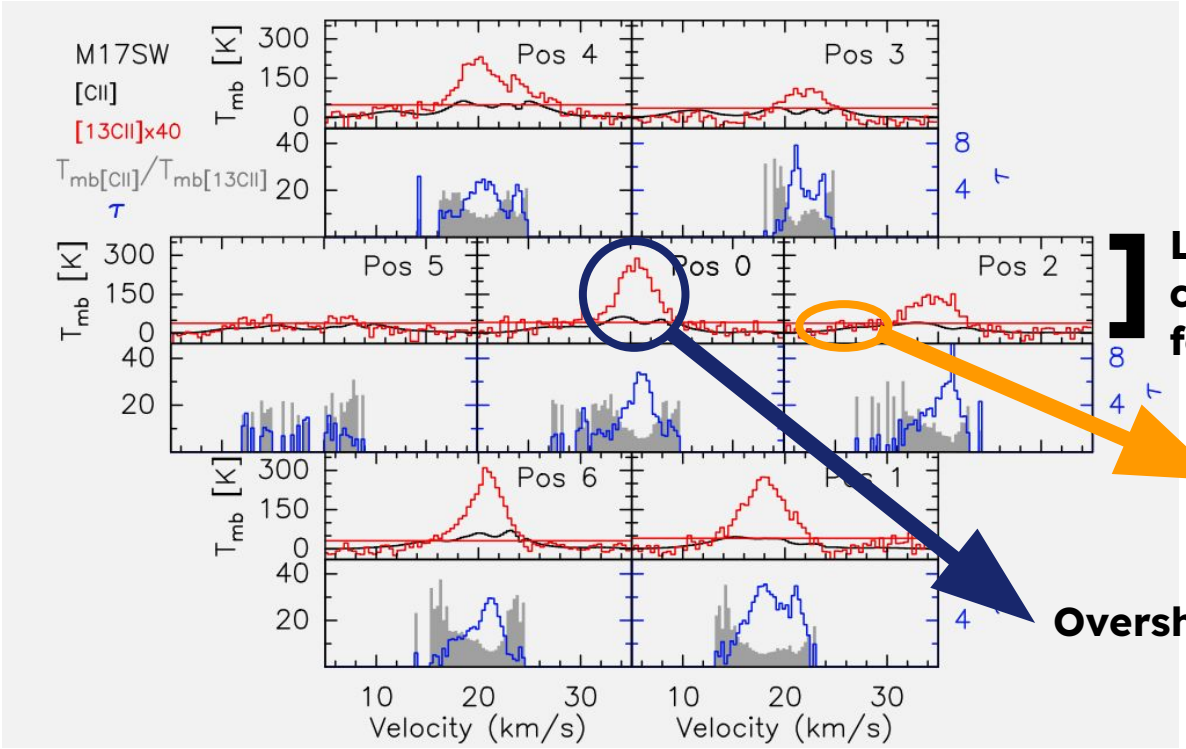
**Overshoot of [13 CII] peaks where [12 CII] dips**

# PROBING OPTICAL DEPTH EFFECTS USING ISOTOPOLOGUES

**[Guevara et al. 2020]**



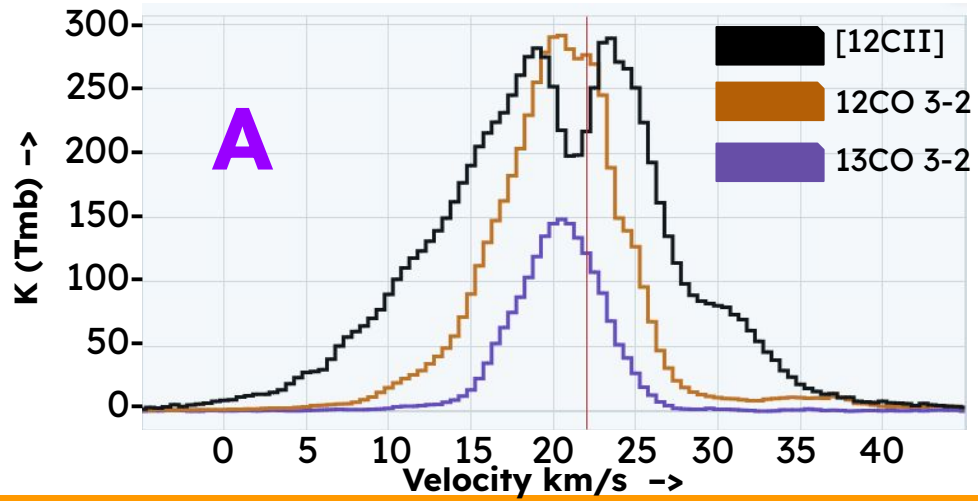



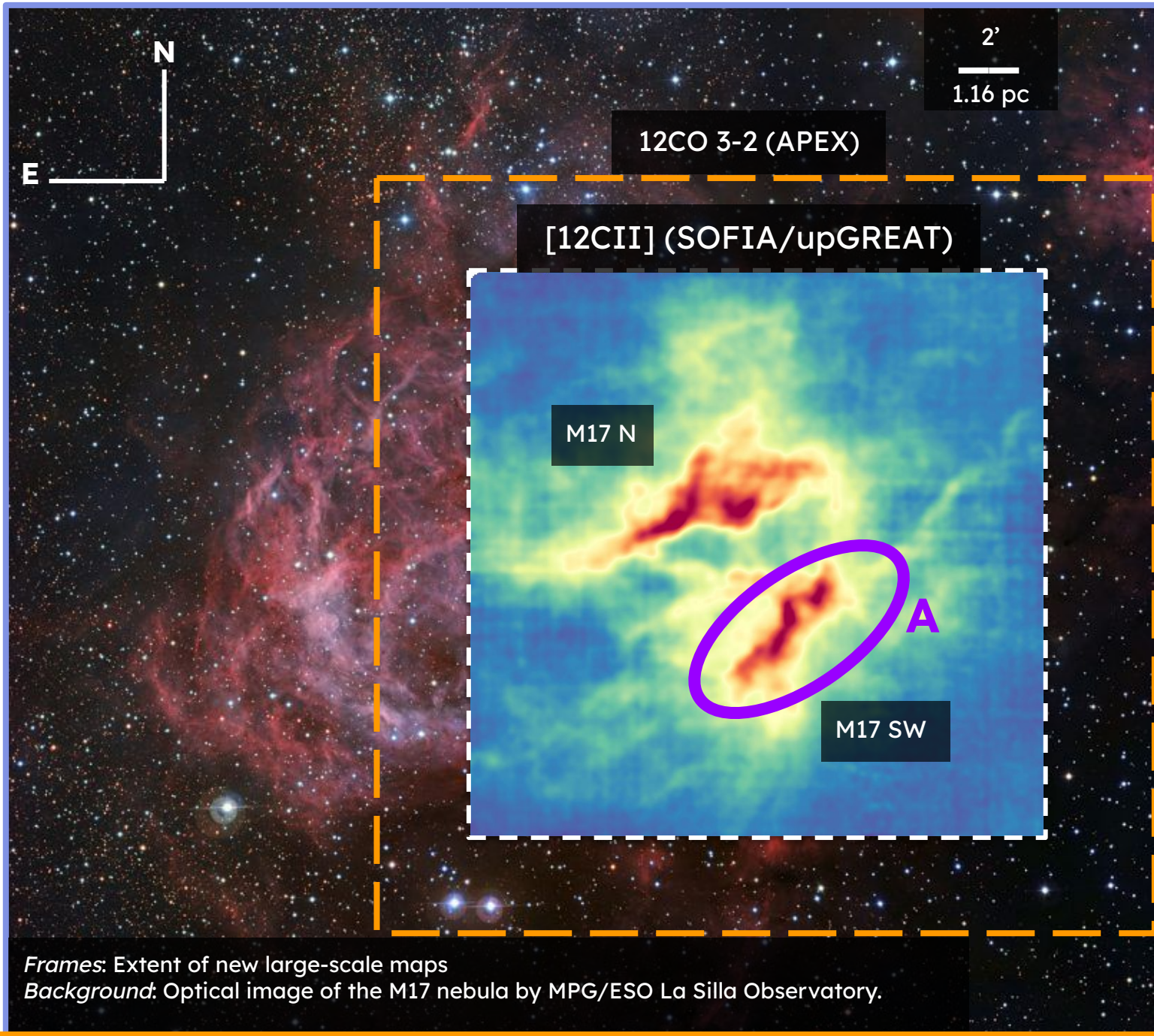

**Line-shape comparison for all 7 pixels**

**Abundance ratio from optically thin line wings**

**Overshoot of [13 CII] peaks where [12 CII] dips**

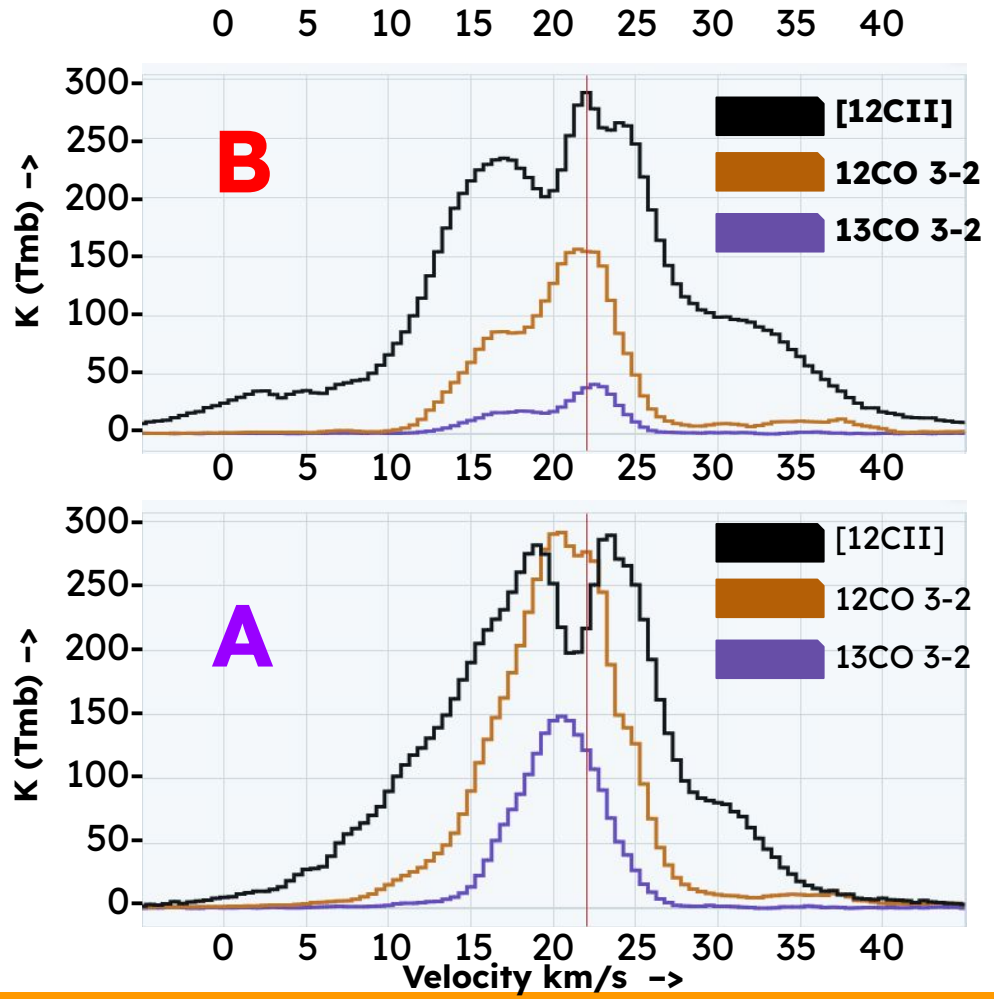
# AVERAGED CO 3-2 SPECTRA ON LARGE SCALES IN M17

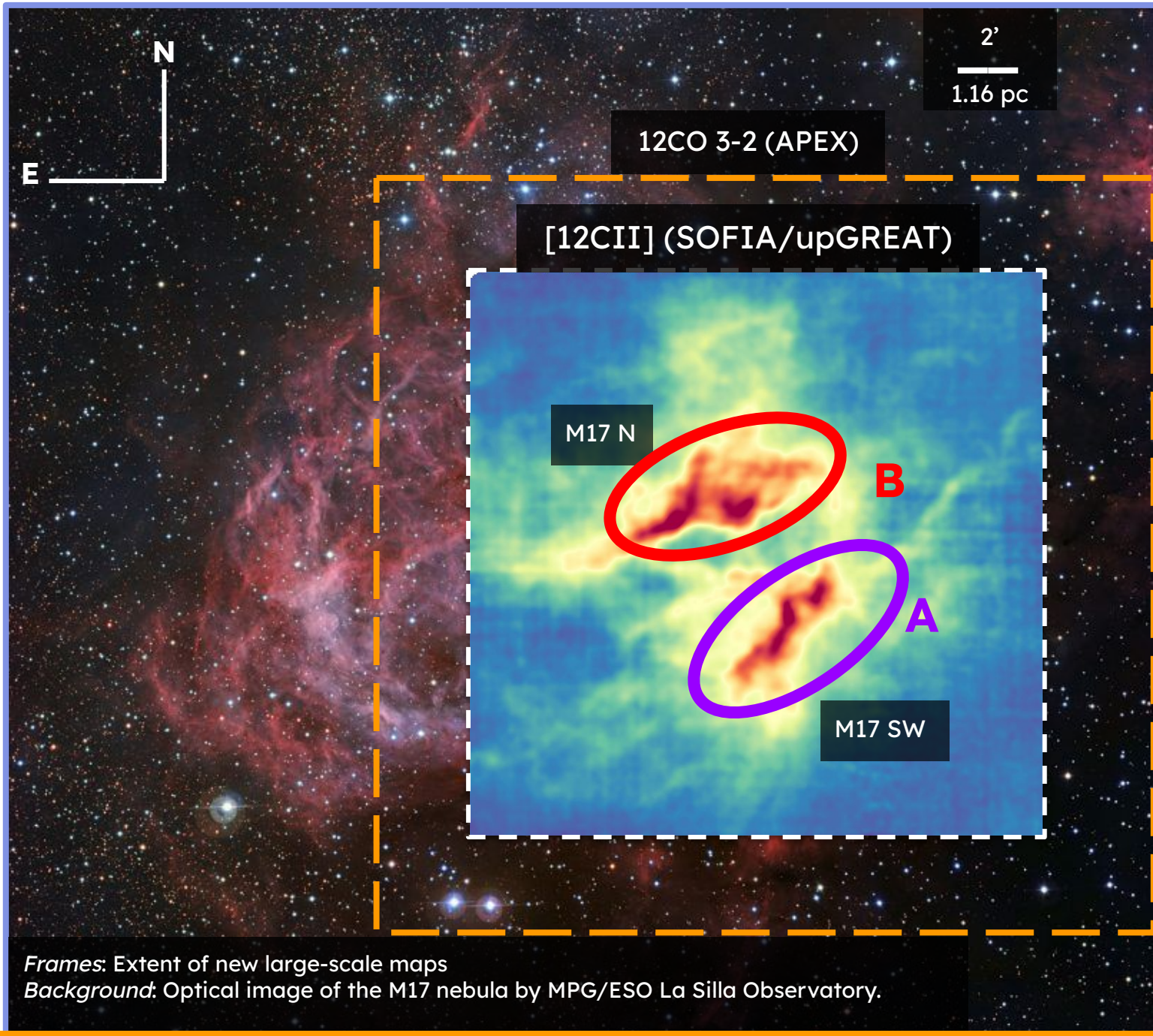


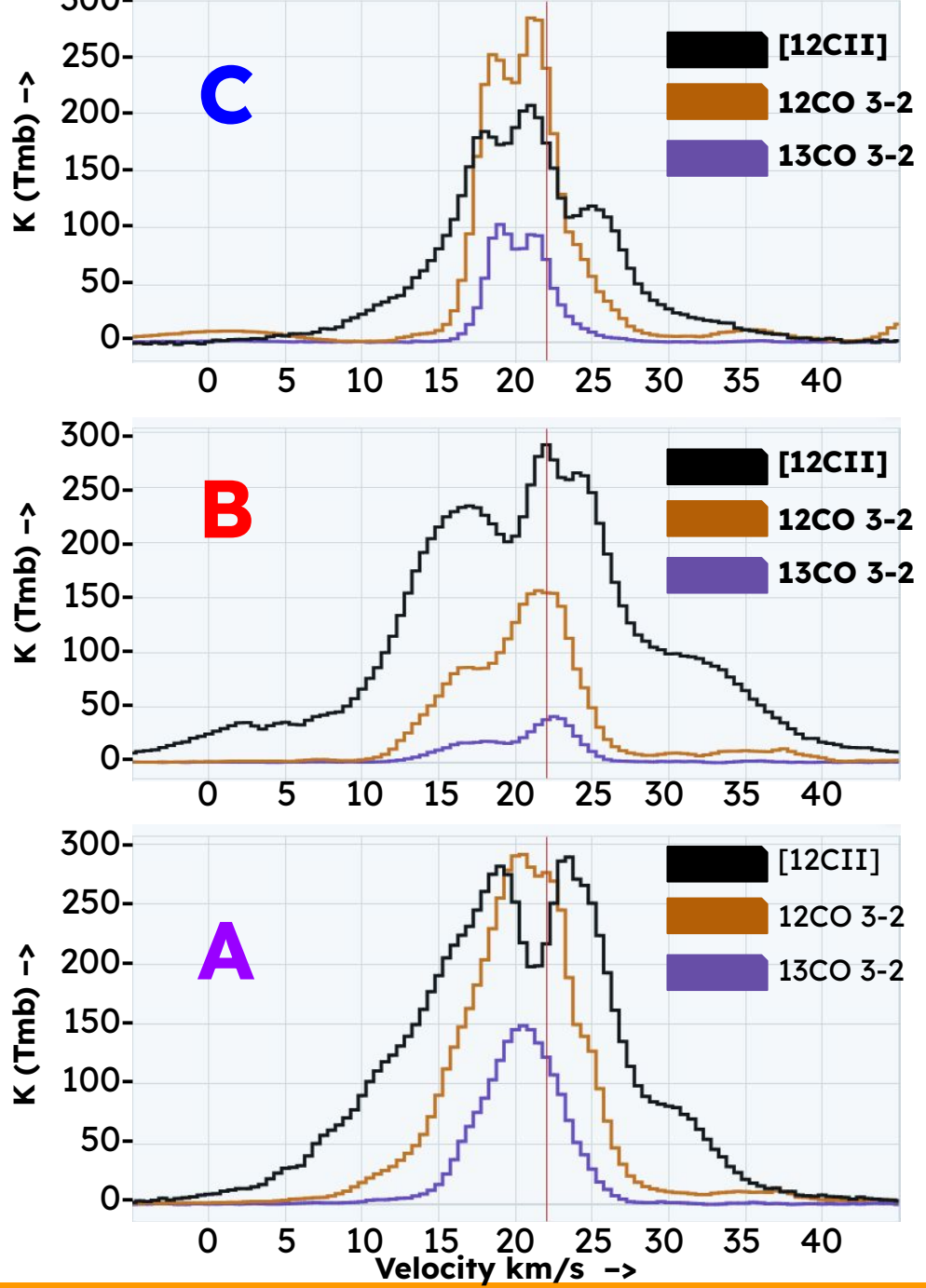

*Frames*: Extent of new large-scale maps
*Background*: Optical image of the M17 nebula by MPG/ESO La Silla Observatory.

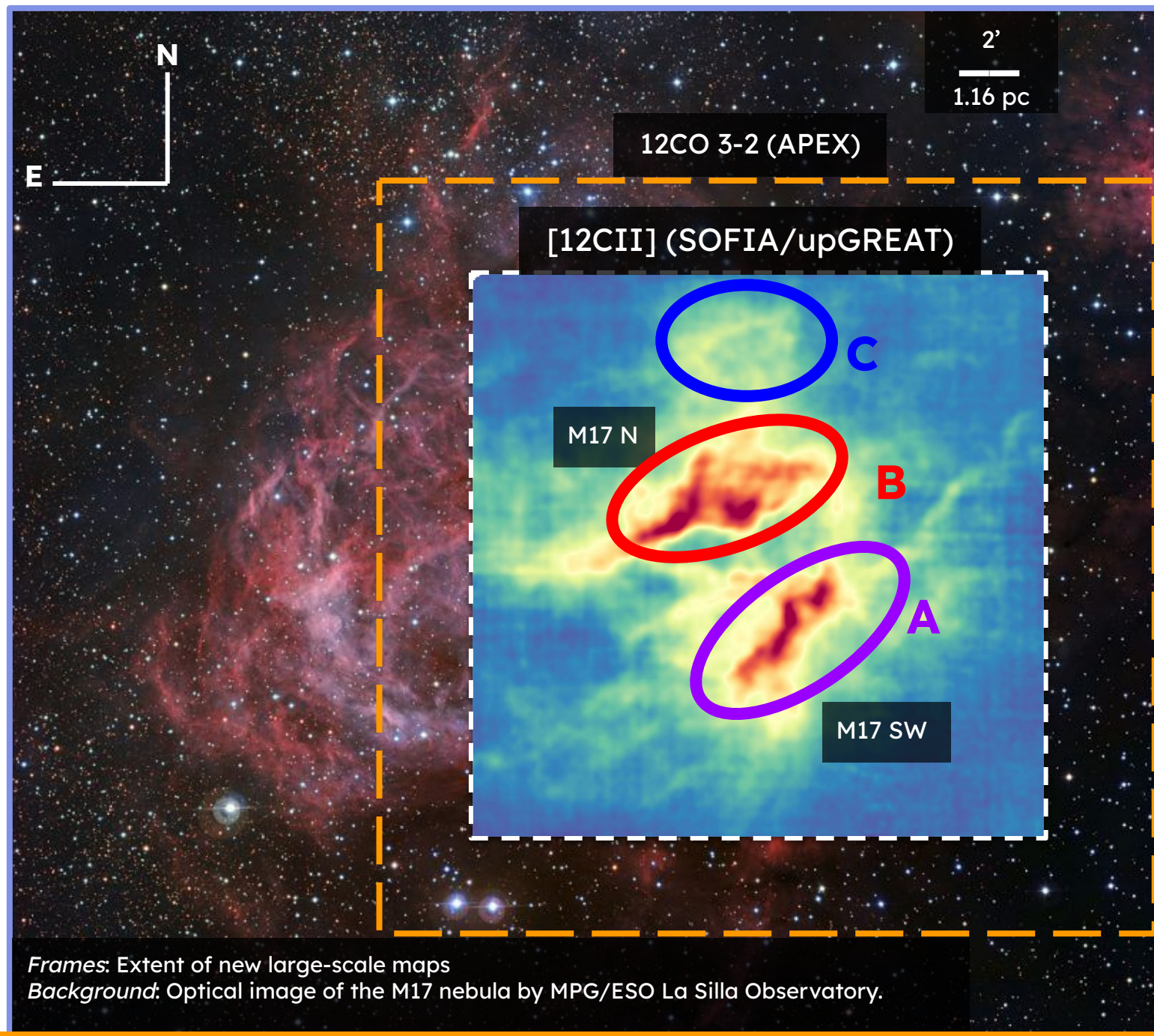
# AVERAGED CO 3-2 SPECTRA ON LARGE SCALES IN M17



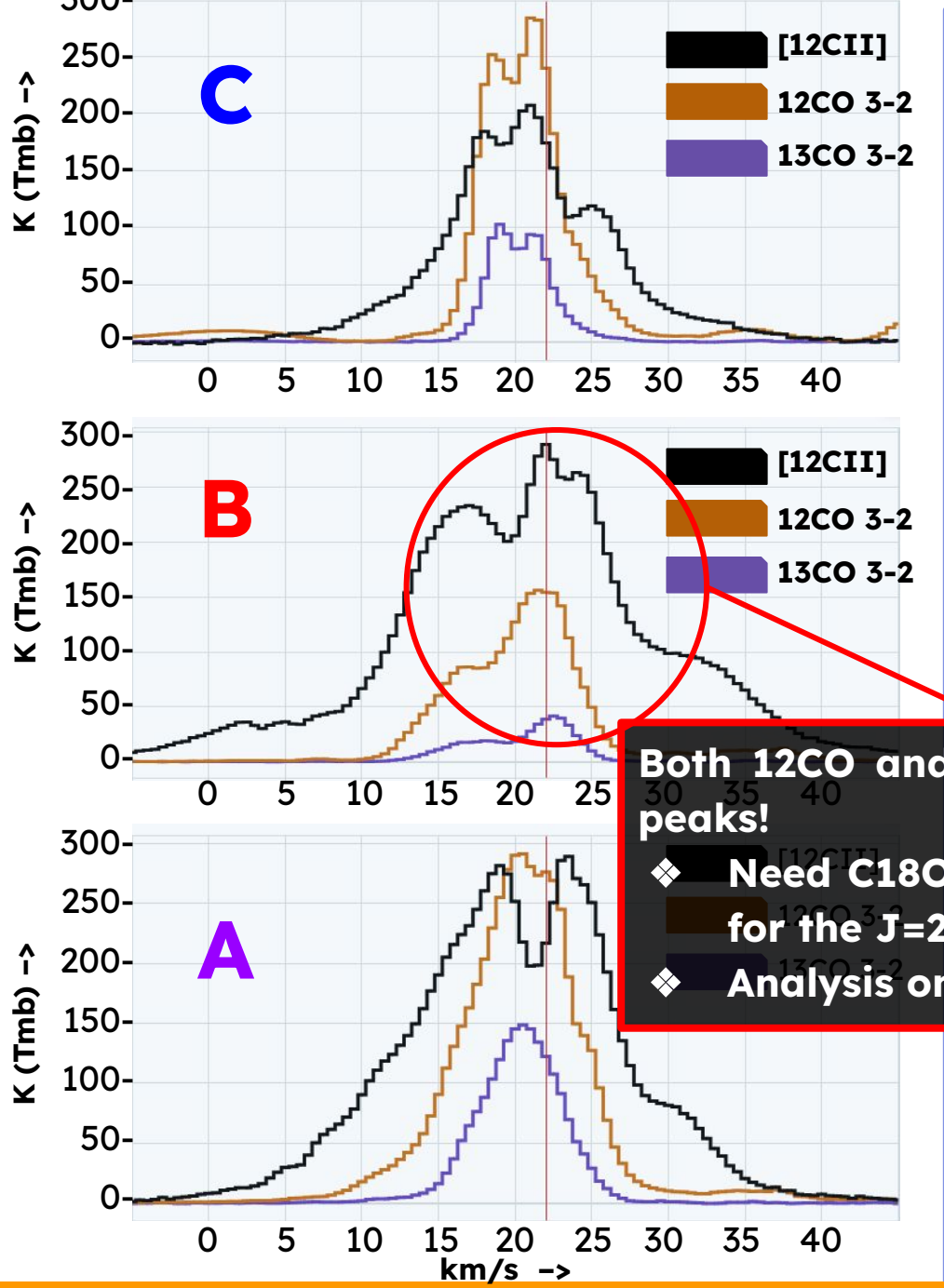




*Frames*: Extent of new large-scale maps
*Background*: Optical image of the M17 nebula by MPG/ESO La Silla Observatory.




*Frames*: Extent of new large-scale maps
*Background*: Optical image of the M17 nebula by MPG/ESO La Silla Observatory.



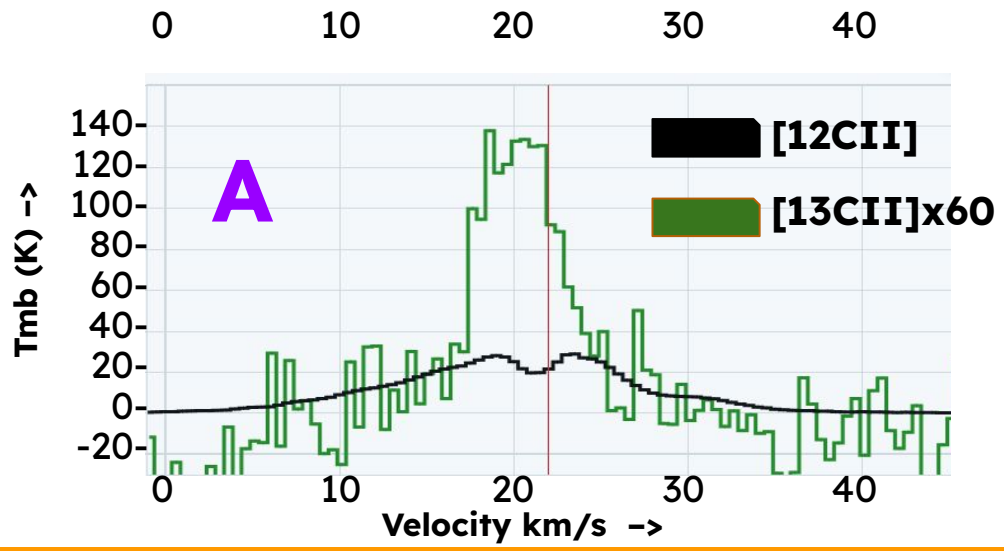

**Both 12CO and 13CO have double peaks!**

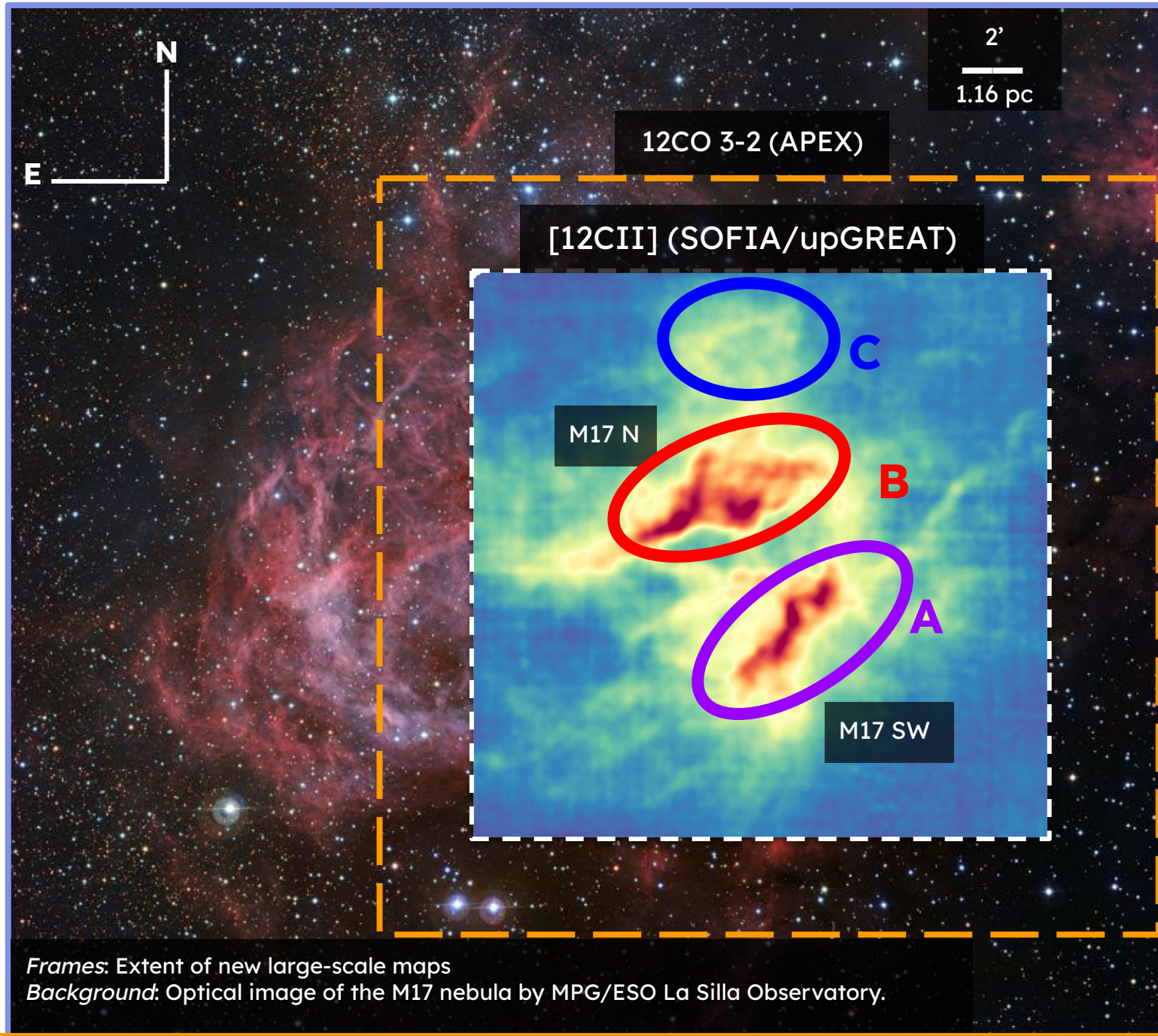
- Need C18O, but only available for the J=2-1 transition
- Analysis ongoing!

N
E
2’
1.16 pc
12CO 3-2 (APEX)
[12CII] (SOFIA/upGREAT)
C
M17 N
B
A
M17 SW

*Frames*: Extent of new large-scale maps
*Background*: Optical image of the M17 nebula by MPG/ESO La Silla Observatory.

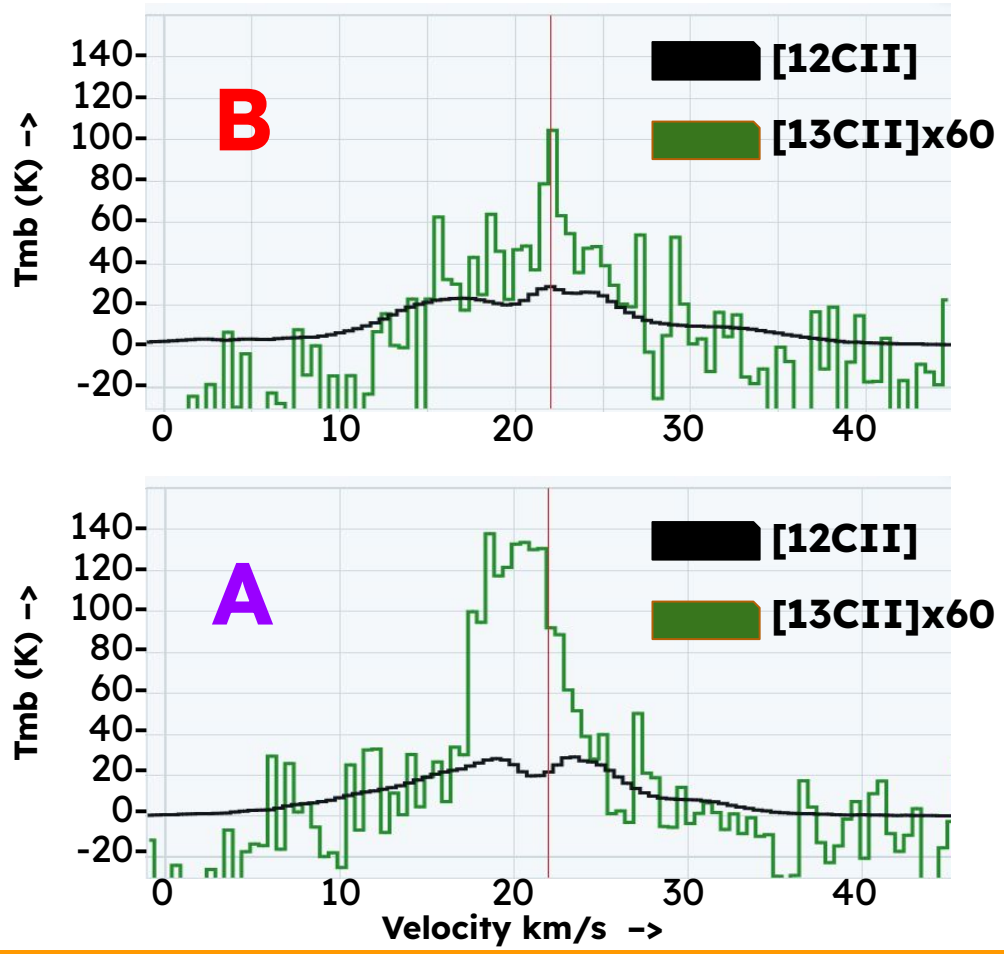
# AVERAGED CII SPECTRA ON LARGE SCALES IN M17



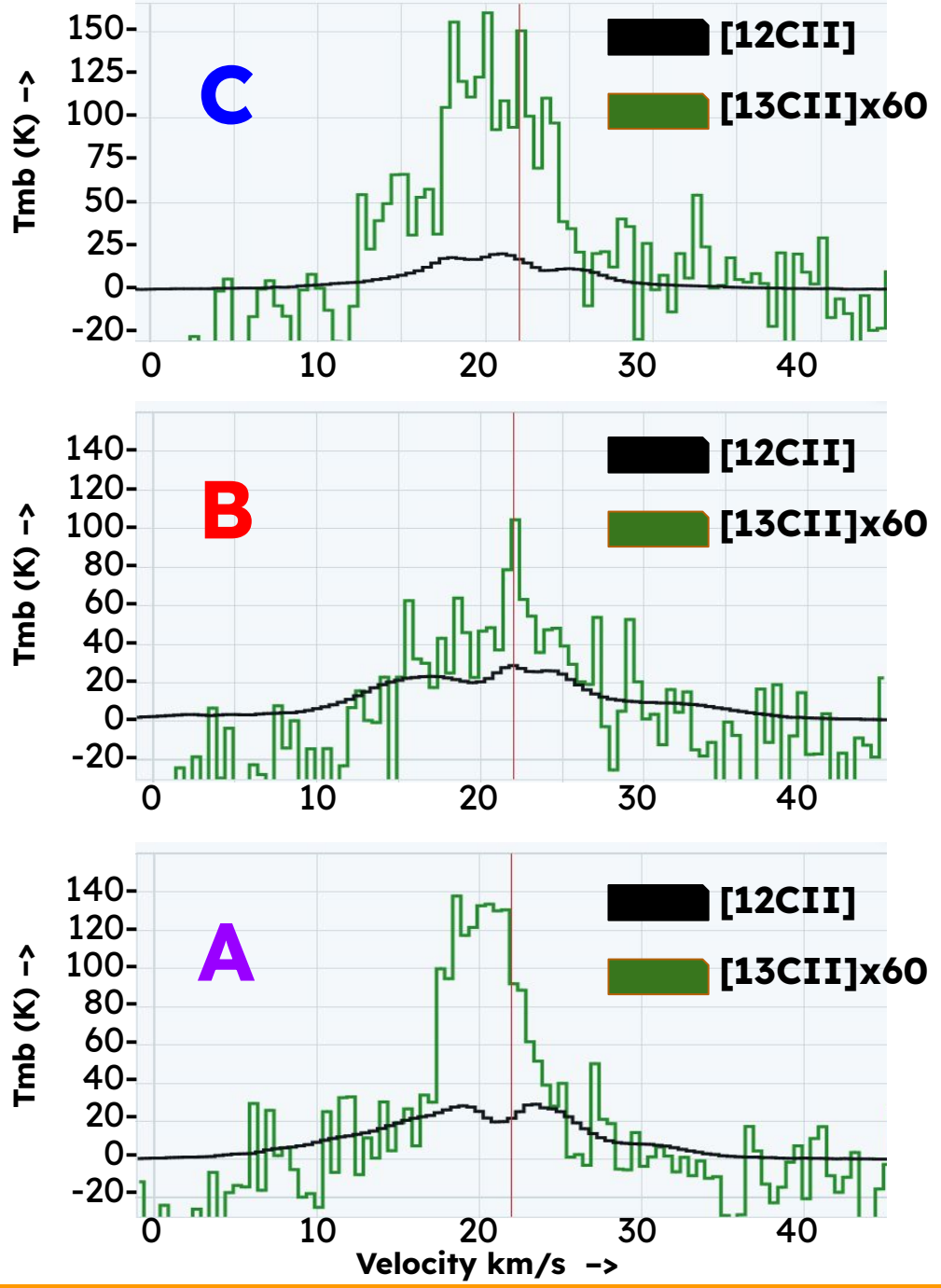



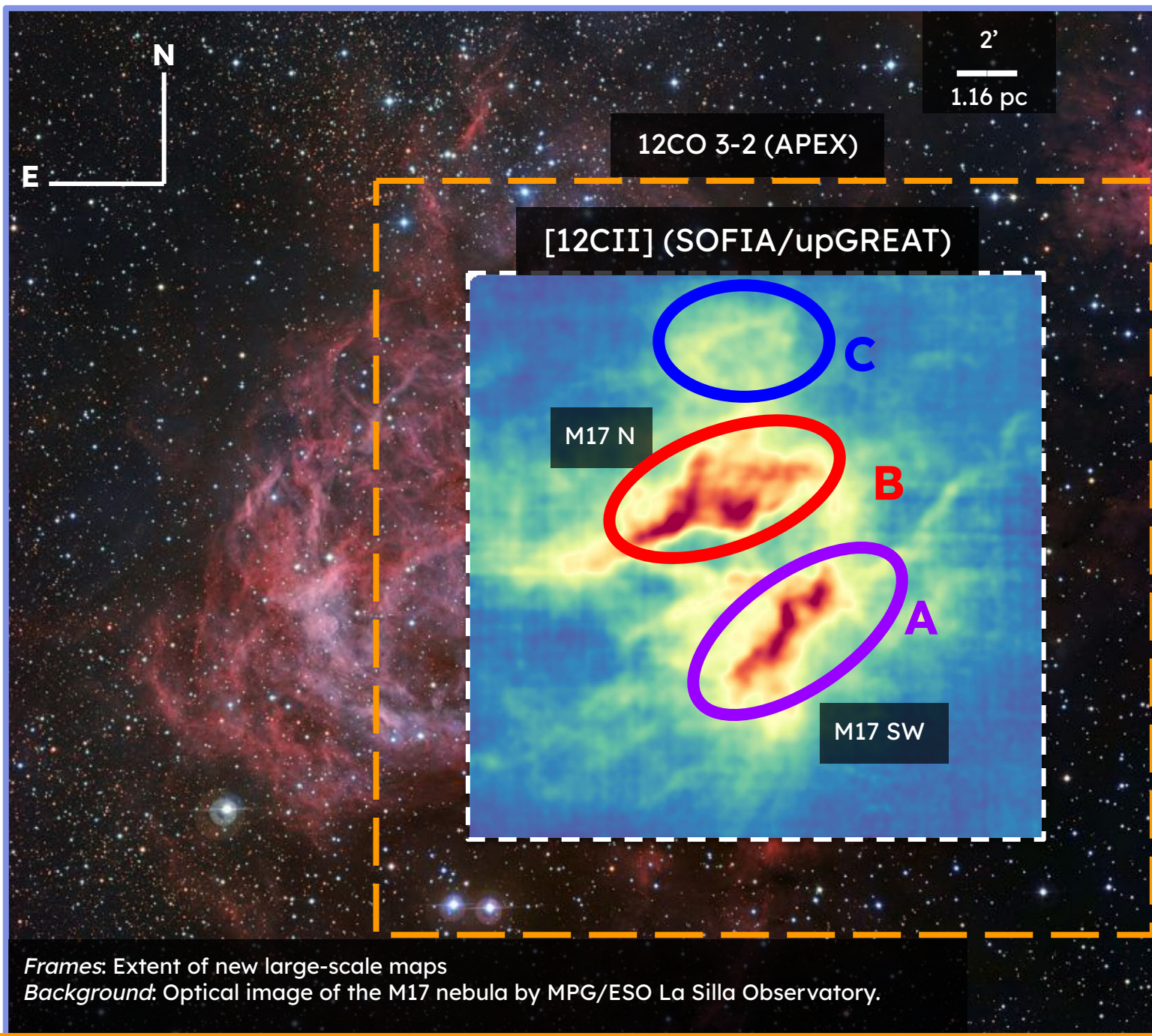

*Frames*: Extent of new large-scale maps
*Background*: Optical image of the M17 nebula by MPG/ESO La Silla Observatory.

# AVERAGED CII SPECTRA ON LARGE SCALES IN M17

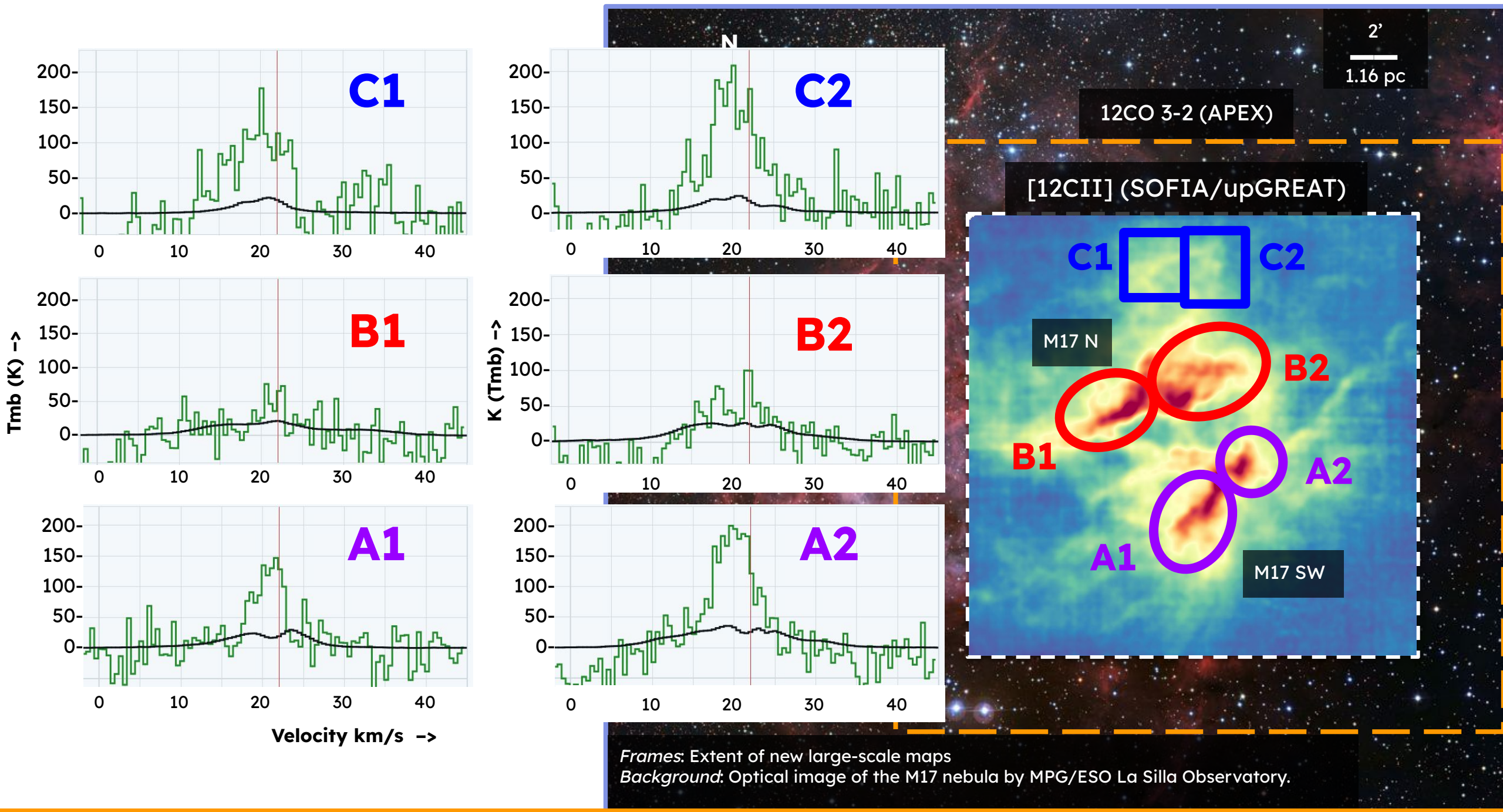



*Frames*: Extent of new large-scale maps
*Background*: Optical image of the M17 nebula by MPG/ESO La Silla Observatory.



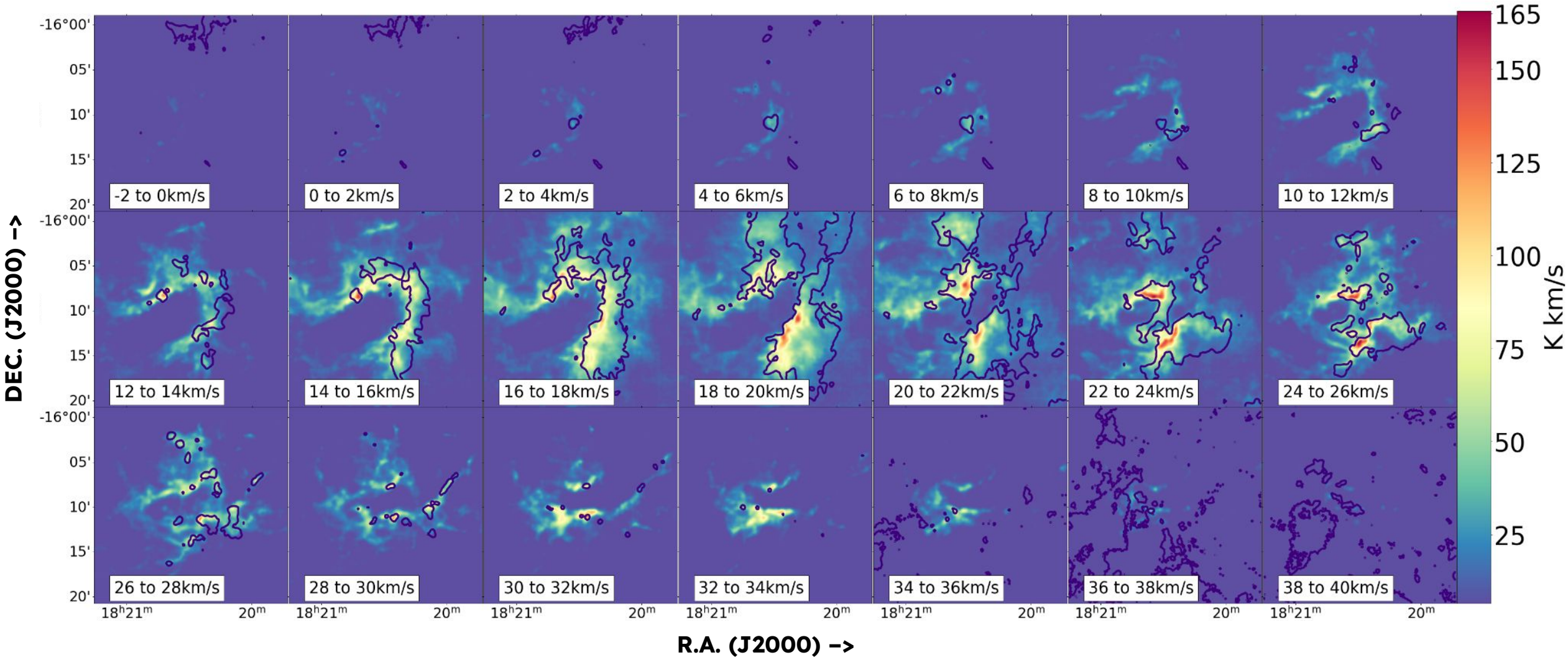




*Frames*: Extent of new large-scale maps
*Background*: Optical image of the M17 nebula by MPG/ESO La Silla Observatory.


C1
C2
B1
B2
A1
A2
Tmb (K) ->
K (Tmb) ->
Velocity km/s ->
N
2'
1.16 pc
12CO 3-2 (APEX)
[12CII] (SOFIA/upGREAT)
M17 N
M17 SW
*Frames*: Extent of new large-scale maps
*Background*: Optical image of the M17 nebula by MPG/ESO La Silla Observatory.

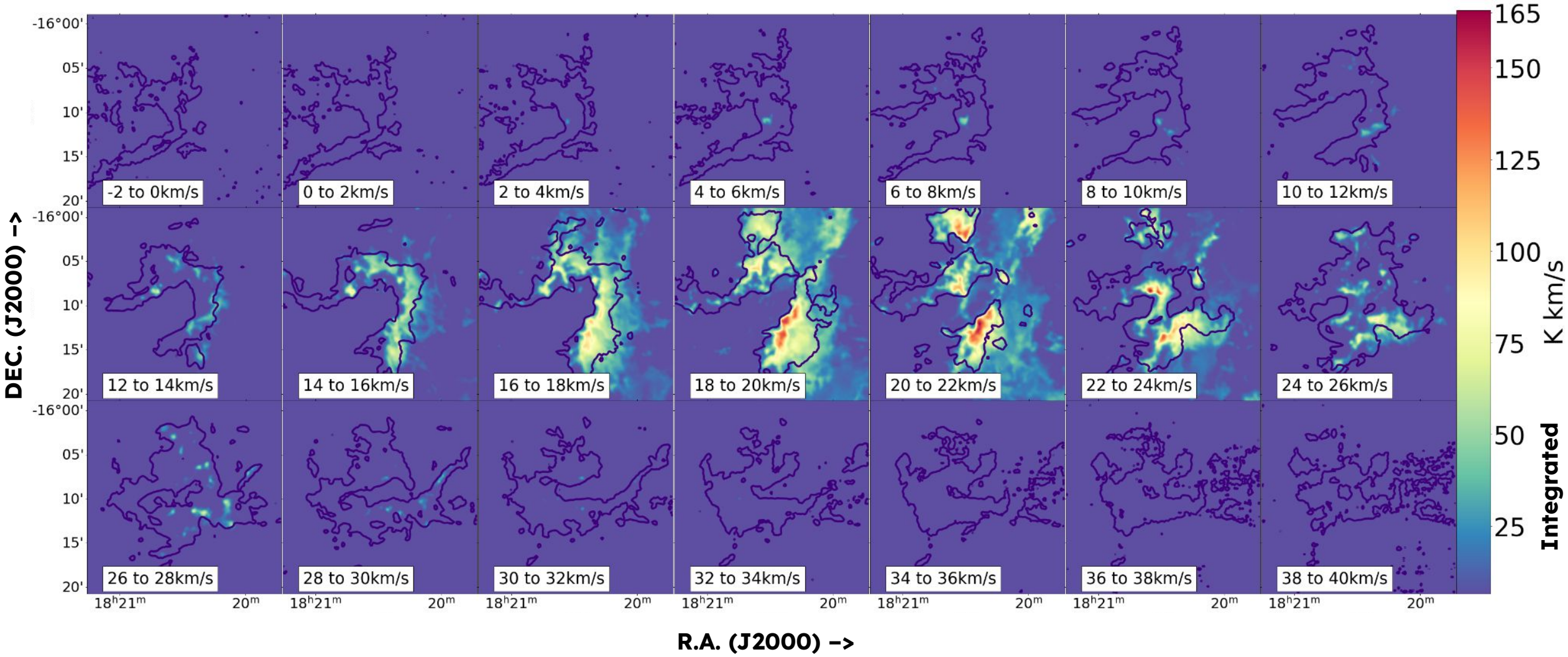
# CHANNEL MAPS

- Colored Map: **12CII**, Spatial res.: **20”**, Velocity res.: **2 km/s**
- Contours: **12CO 3-2.** Levels: **3σ**



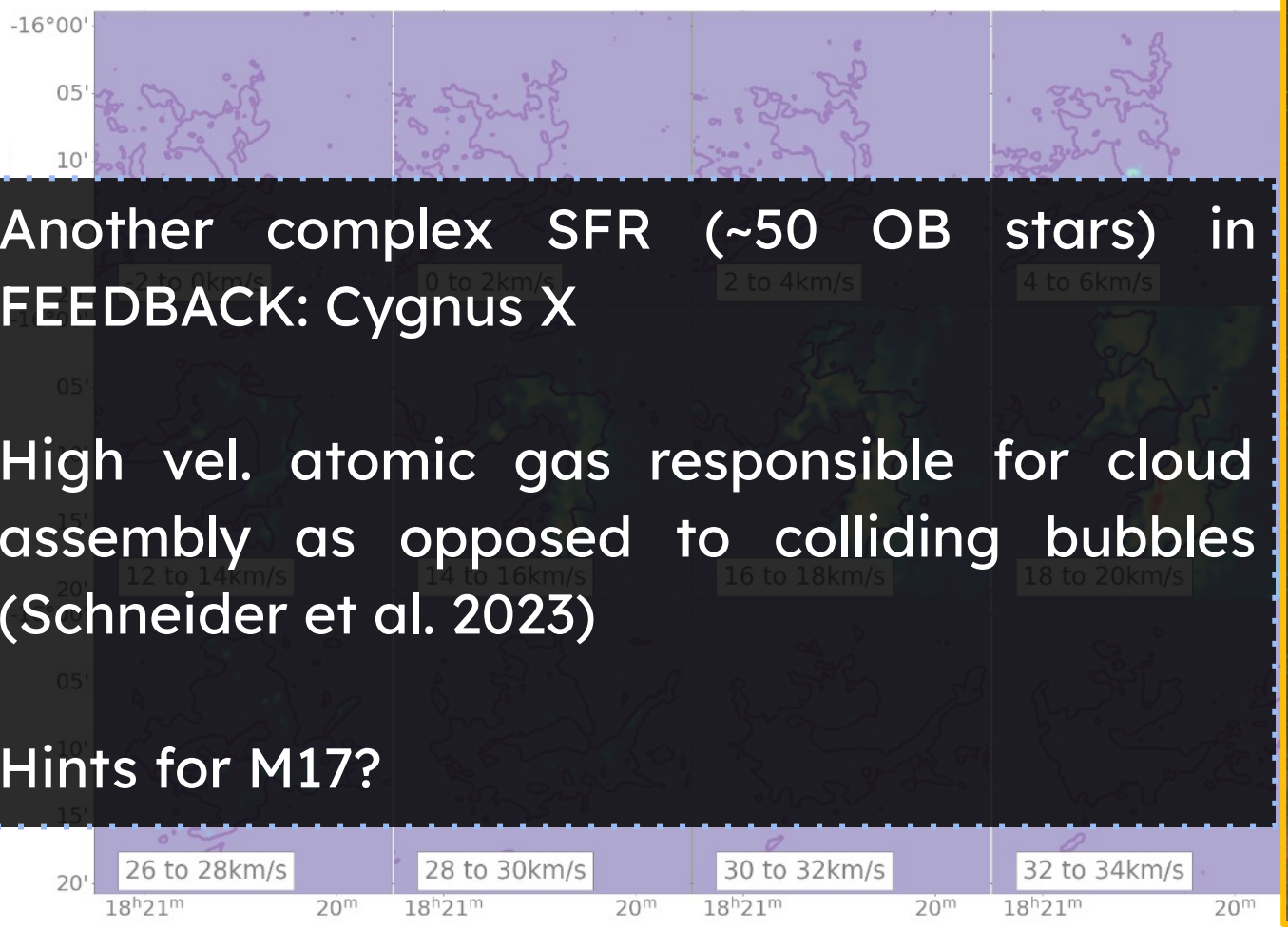
# CHANNEL MAPS

- Colored Map: **12CO 3-2**, Spatial res.: **20”**, Velocity res.: **2 km/s**
- Contours: **12CII.** Levels: **3σ**



# CHANNEL MAPS

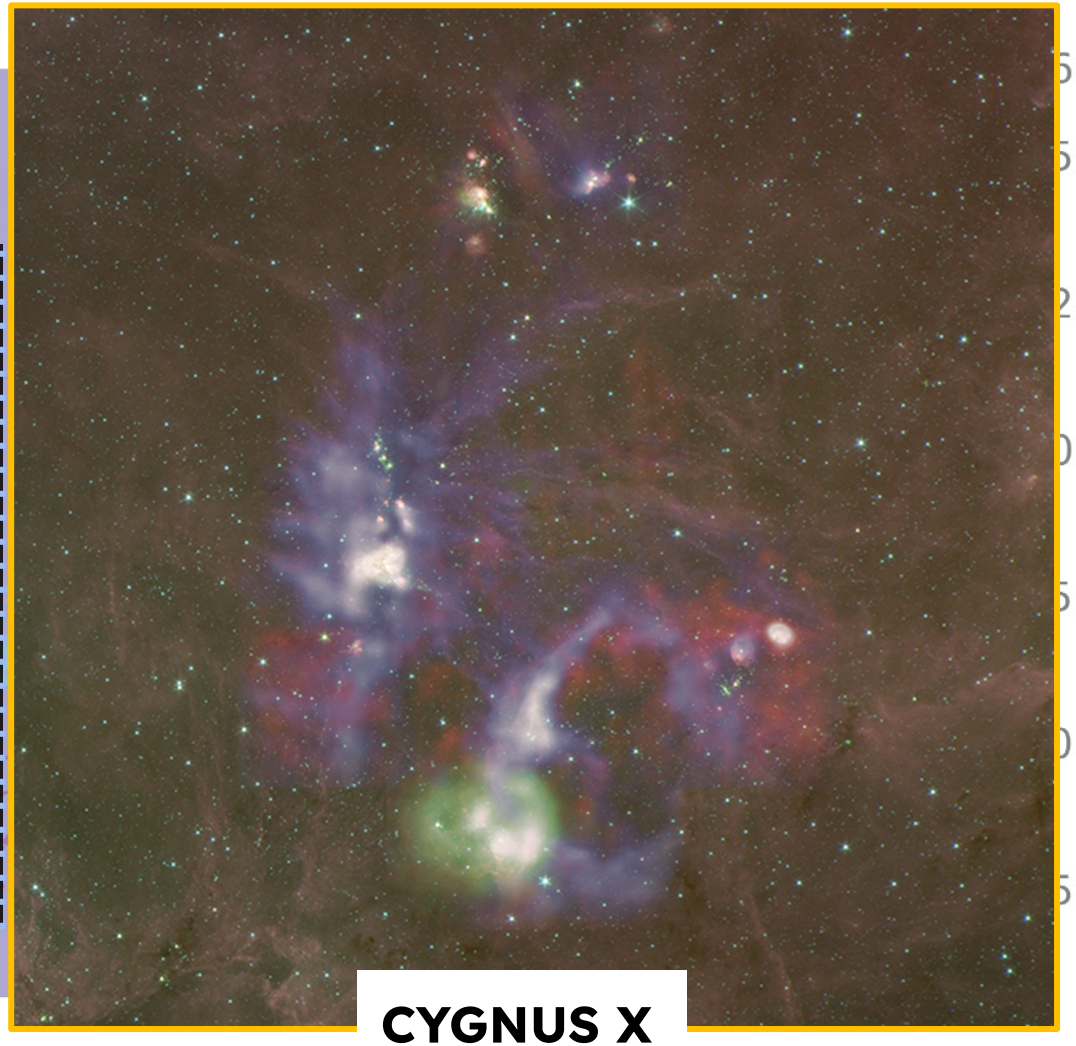
- Colored Map: **12CII**, Spatial res.: **19”**, Velocity res.: **2 km/s**
- Contours: **12CO 3-2.** Levels: **3σ**




Another complex SFR (~50 OB stars) in FEEDBACK: Cygnus X

High vel. atomic gas responsible for cloud assembly as opposed to colliding bubbles (Schneider et al. 2023)

Hints for M17?




**CYGNUS X**

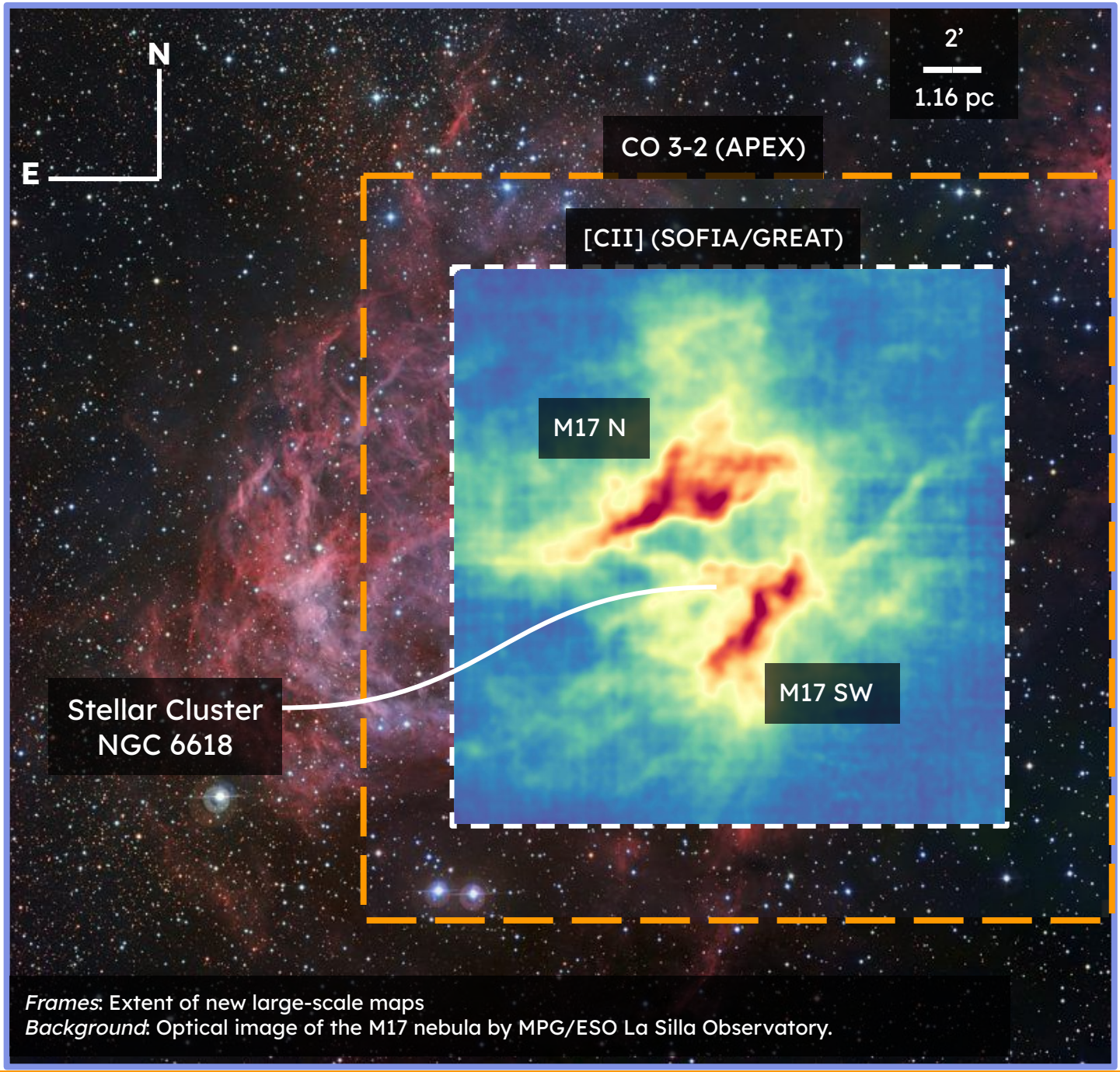
# SUMMARY

## M17 morphology:

- M17N is as bright as SW in CII, much fainter in CO 3-2
- CII has bright components in high vel. channels, where CO is below detection limit
- Filamentary structure of emission in the outskirts of M17N and M17SW

## M17 Structure:

- CO 3-2 has multiple velocity components in both isotopologues, comparison with C18O needed
- Minimal self-absorption in M17N, but the associated cloud further north (Region C) is heavily self-absorbed
- Extended areas of M17 have cold foreground in front of bright background emission in CII



## 22 April 2022


(me)

**Thank you!**