SMA Collaborations

Qizhou Zhang

- Partnership with ASIAA
  - Joint time allocation committee to review proposals
  - Contribute to general operating cost and technical support
- Collaboration with Nanjing University, China
- Potential collaboration with Purple Mountain Observatory, China on wSMA

Limited partnership with Nanjing University (2014 – 2022)

- Scientific Cooperation Agreement signed between SAO – NUSASS (Nanjing University School of Astronomy and Space Science) for a limited partnership that allows access of SMA observing time
- First agreement in Dec. 2014
- Extended in Nov. 2016
- Extended again in Nov. 2017 for period 2018 - 2022

Cygnus-X survey

Surveys of Clumps, Cores, and Condensations in Cygnus-X

Keping Qiu (NJU), Yue Cao (NJU), Yuwei Wang (NJU), Qizhou Zhang (CfA), Junhao Liu (NJU), Bo Hu (NJU)

Project Overview:

Cygnus-X is the most massive and active high-mass star-forming complex at a distance less than 3 kpc from the Sun (Motte et al. 2007, 2017). We are performing comprehensive surveys of Clumps, Cores, and CoNdenSations in cygnUS-X (CENSUS, PI: K. Qiu), dedicated to a systemic study of the hierarchy of molecular cloud structures and high-mass star formation in the complex. **The SMA survey, which is the central part of the project, has been conducted in the 1.3 mm waveband with the Subcompact, Compact, and Extended configurations. So far we have completed most of the SMA observations with more than 200 hours of observing time.**

The scientific goals of this project are:

- to constrain the initial conditions of high-mass star formation by revealing how pc-sized massive molecular clumps form in giant molecular clouds, how they fragment to form ~0.1 pc massive dense cores (MDCs), and how MDCs further collapse and fragment into ~0.01 pc prestellar and protostellar condensations;
- to understand to what extent high-mass protostars acquire mass in a way similar to their low-mass counterparts through an unbiased survey of a large sample of outflows, rotational toroids and disks within a single molecular cloud complex.

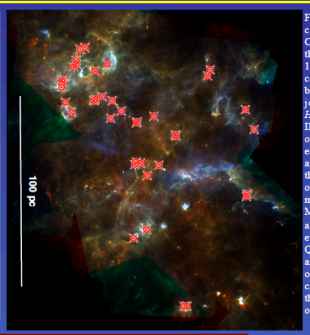
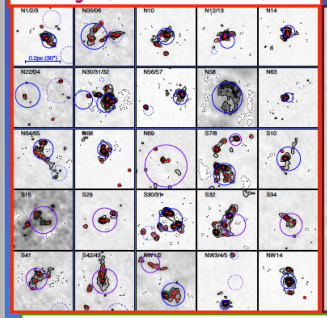
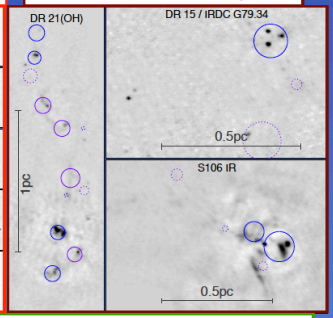


Figure 1 — Pseudo three-color image of the Cygnus-X complex, with the Herschel 500 μm, 160 μm, and 70 μm maps coded in red, green, and blue, respectively. By jointly analyzing the *Herschel*, JCMT, and IRAM 30m observations of the dust continuum emissions, we identify and characterize more than 40 MDCs with sizes of order 0.2 pc and masses of ~20 to 1000 $M_\odot$. These MDCs cover a broad range of evolutionary stages (Cao, Qiu, et al., submitted), and provide targets for our SMA survey. Red circles and crosses mark the 38 fields covered by our SMA survey.

SMA single-field observations of MDCs



SMA mosaic observations of MDCs



SMA single-field observations of MDCs around the Cygus-X OB2 association

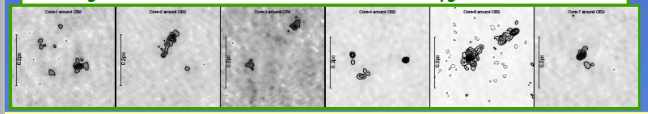


Figure 2 — SMA 1.3 mm continuum observations of the MDCs in Cygnus-X. The data reveal the fragments of the MDCs with a linear resolution of ~0.01 pc. *Upper Left*: SMA single-field observations of the MDCs. We follow Motte et al. (2007) for the nomenclature of the MDCs. *Upper Right*: SMA mosaic observations of the MDCs embedded within remarkable pc-sized clumps. Solid circles approximately show the sizes and locations of the MDCs. Dashed circles depict dense cores with masses less than 20 $M_\odot$. *Lower*: SMA observations of the MDCs newly identified around the Cygnus-X OB2 association. A detailed analysis of the fragmentation of the MDCs based on the continuum maps is ongoing. We find that most MDCs fragment into a few to more than 10 condensations, but there are also a very few MDCs remaining singly peaked down to a size scale of 0.01 pc. Moreover, statistically, the fragmentation level dose not appear to correlate with properties of the MDCs (Qiu et al., in prep.).

Remarks:

We are completing an SMA survey of the Cygnus-X complex, and the ongoing analysis provides these preliminary results:

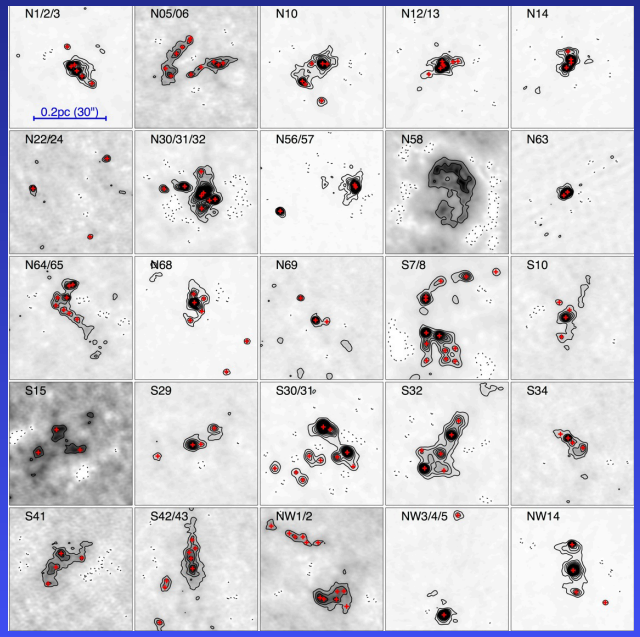
- We detect ~0.01 pc fragments toward more than 90% of the MDCs, and find that the fragmentation of the MDCs cannot be understood as thermal Jeans or turbulent fragmentation.
- We detect high-velocity outflows in the SMA+JCMT CO maps in more than 90% of the MDCs; though most outflows are bipolar and/or collimated, only a few of them are associated with rotational structures seen in typical "disk-tracing" spectral lines, suggesting that (pseudo)disks around high-mass protostars are mostly smaller than 1000 AU.
- We find that expanding HII regions, strong UV radiation, and stellar winds are very inefficient in triggering nearby high-mass star formation.

Poster: Qiu +

Cygnus-X survey

- Investigate cloud collapse and fragmentation → stellar cluster
- Explore chemical diversity and evolution in protostellar cores
- 47 pointings (including data from SMA archive), subcompact and extended configurations

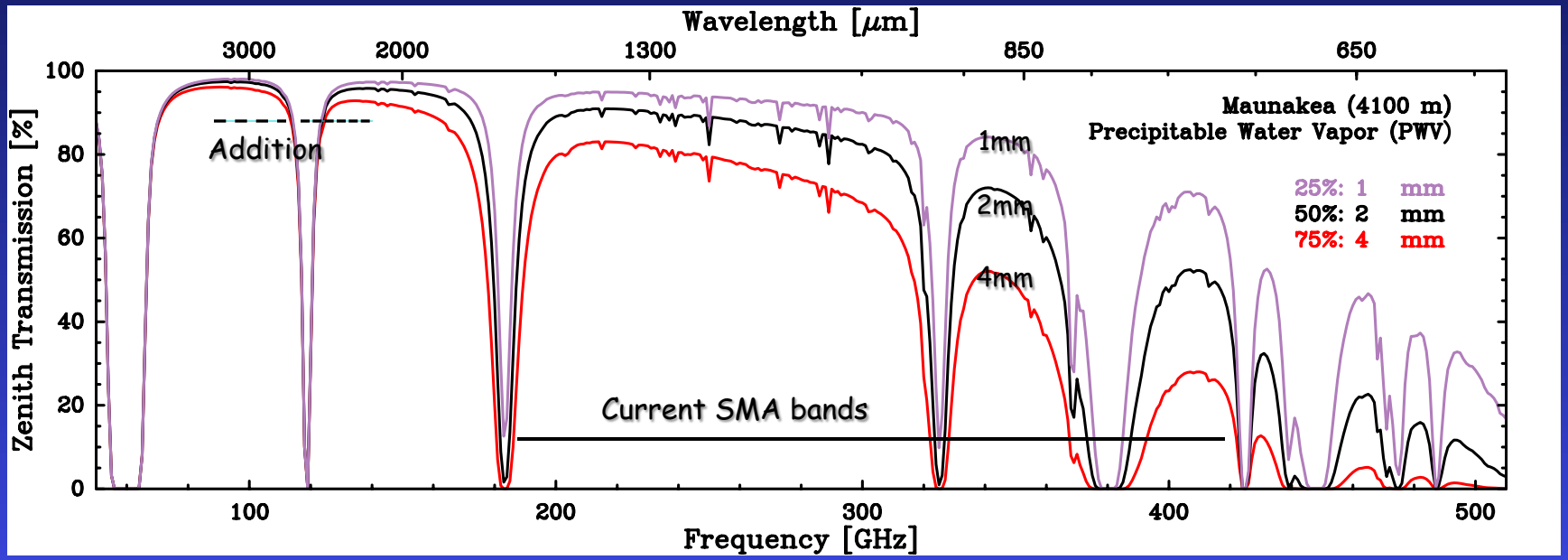
1.3mm continuum (PI: Qiu)



Interest from PMO for 3mm-band RX

- Purple Mountain Observatory of Chinese Academy of Sciences expressed interest to build a set of 3mm-band guest receivers for the wSMA
- Preliminary discussions between SMA – PMO since April 2018 about technical feasibility
- PMO will hold meetings to gauge community interest in China
- Small group (Paine, Radford, Oberg and Zhang) at CfA to explore its feasibility

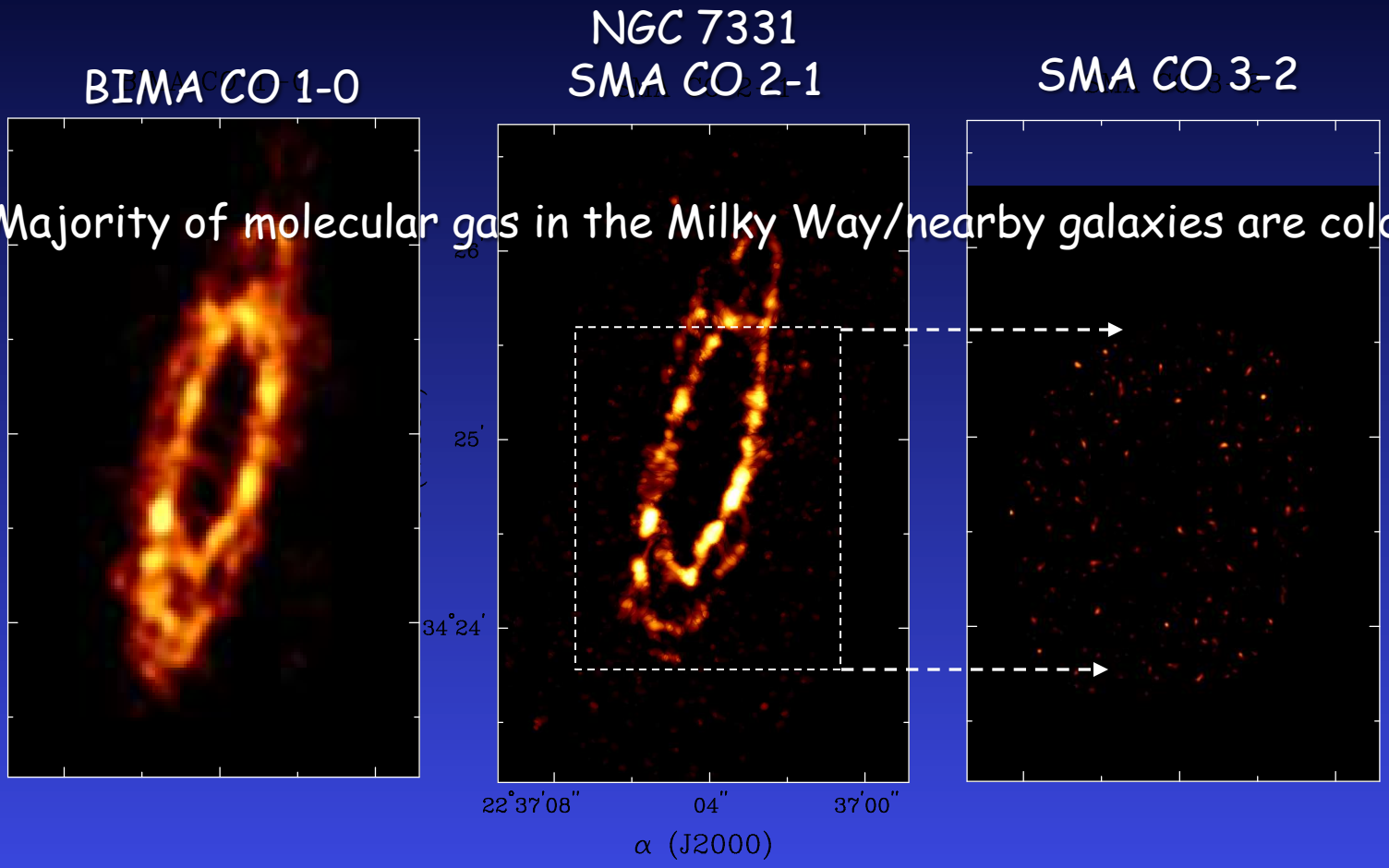
Atmospheric transmission at Maunakea



Why 3mm band?

- Science drivers
  - Access low-J molecular lines (N_2H^+/NH_2D/HCO^+/HCN/CO) to complement 230/345GHz RXs
  - Explore high-z universe via large areal surveys & spectral stacking (large BW compensates for small dishes)
  - Enable time sensitive observations in less optimal conditions
- Dual band operation through dichroic splitter

Excitation & H_2 mass in galaxies

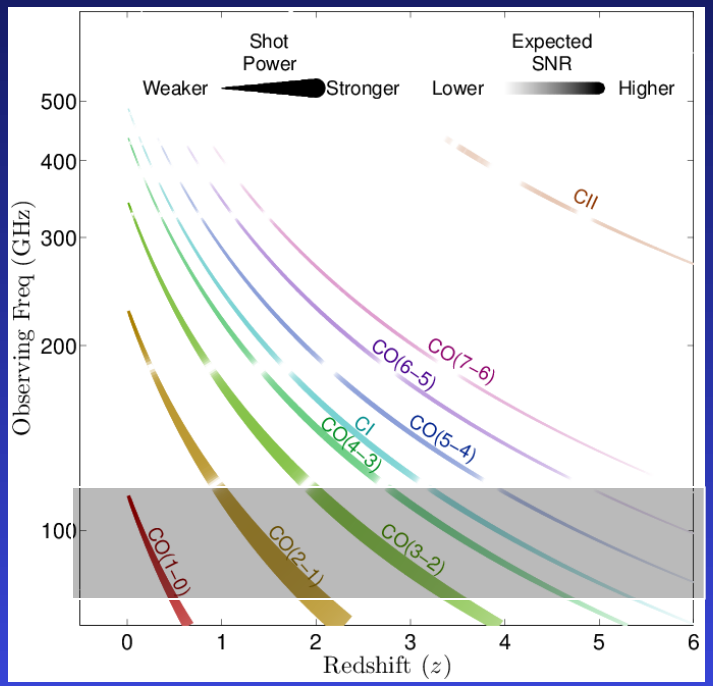


Majority of molecular gas in the Milky Way/nearby galaxies are cold

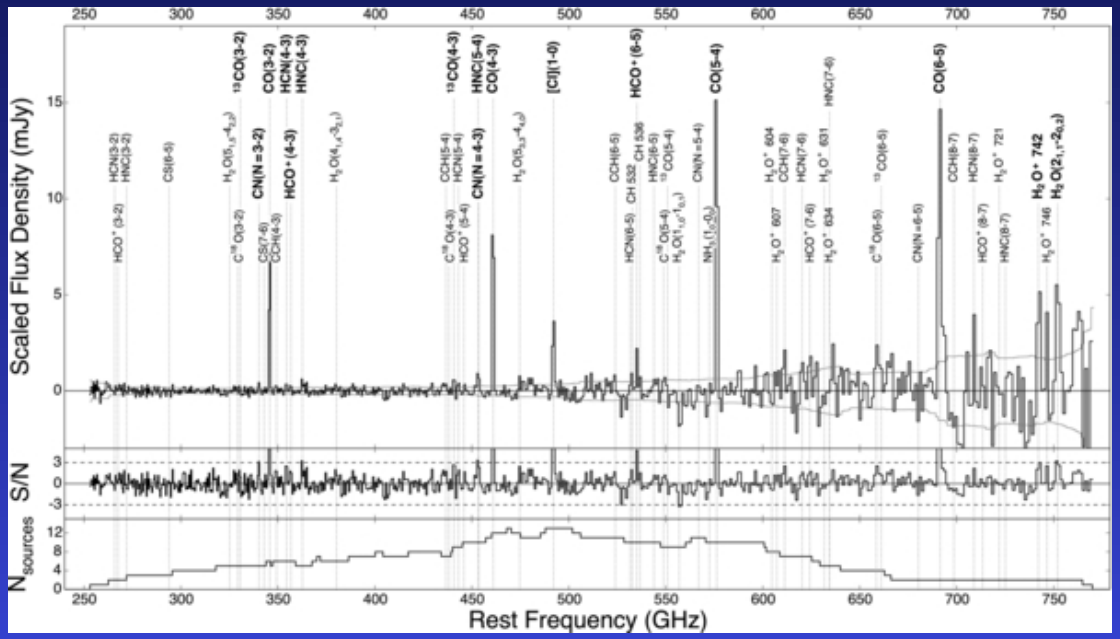
Courtesy Petitpas

Hi-z galaxies

Observing freq ~ z



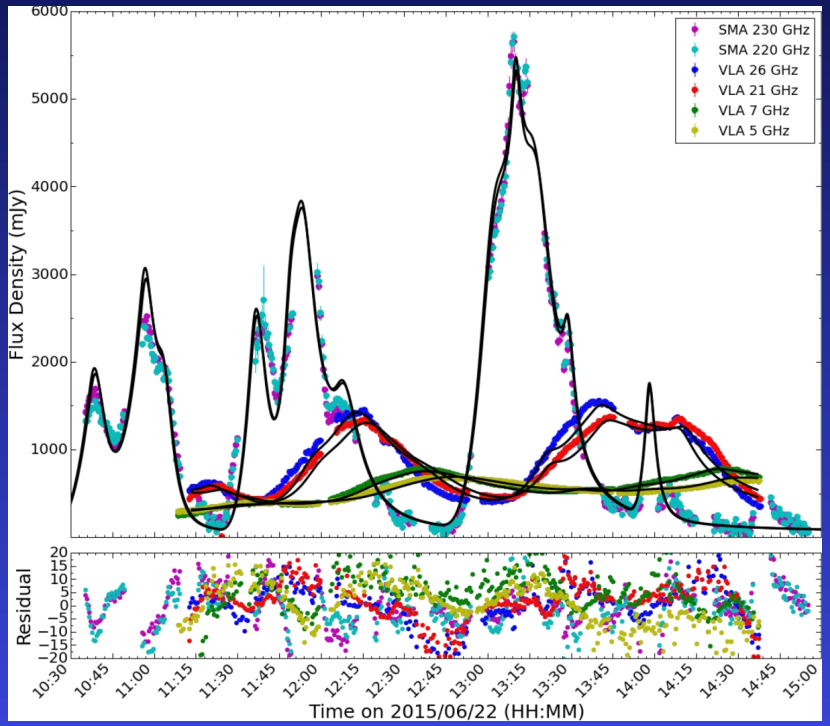
Courtesy Keating



Spilker+ 2014

Time domain astronomy

Black hole X-ray binary V404 Cyg



Tetarenko+ 2017, Gurwell's poster

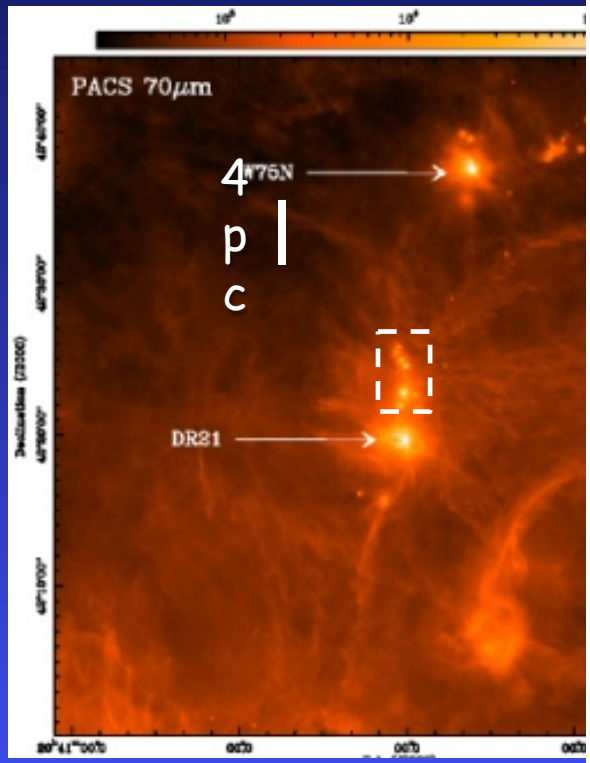
A 3mm band:

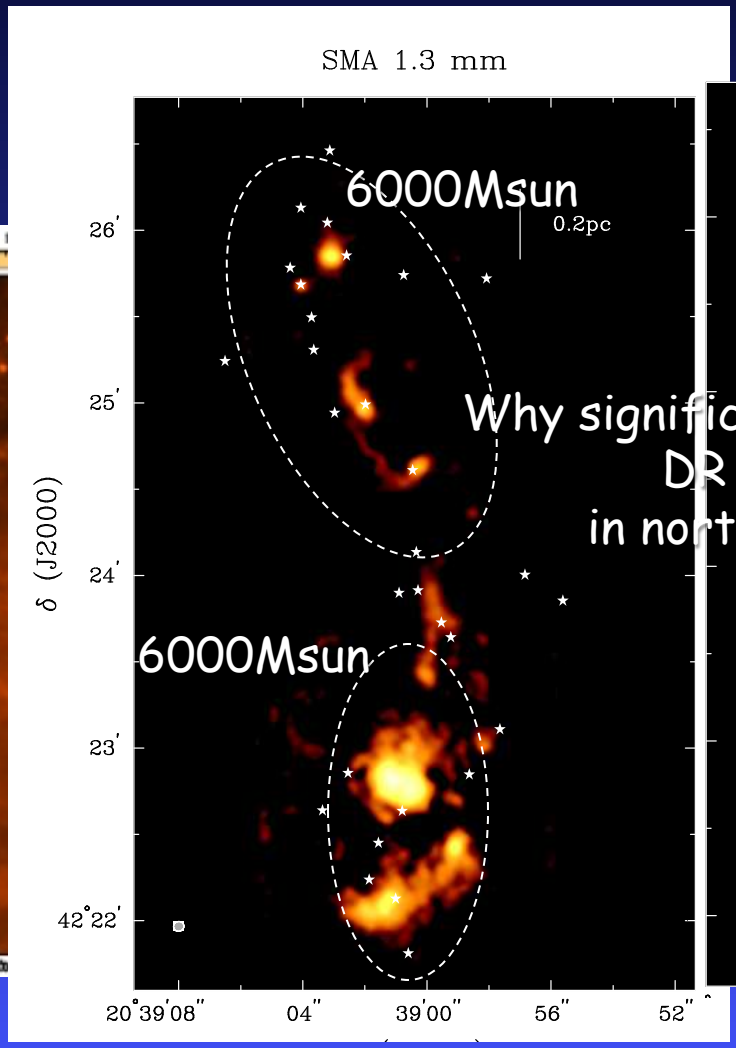
Enable time sensitive observations in less optimal conditions

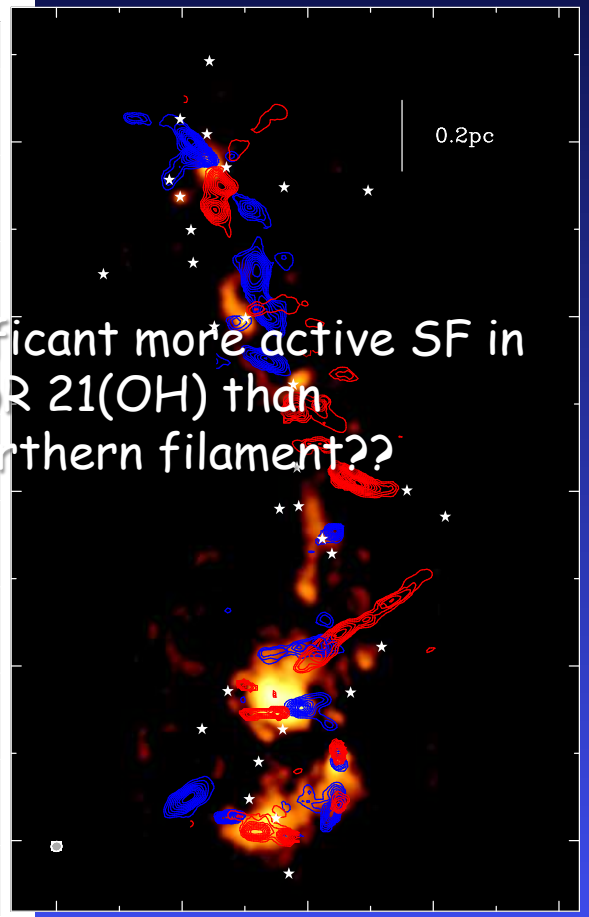
Multi-frequency observations

- 3mm RX is one of the several ideas for the wSMA guest receiver slot
- We are at very early stage of a feasibility study, would love to hear Committee's advise

Star formation in Cygnus-X

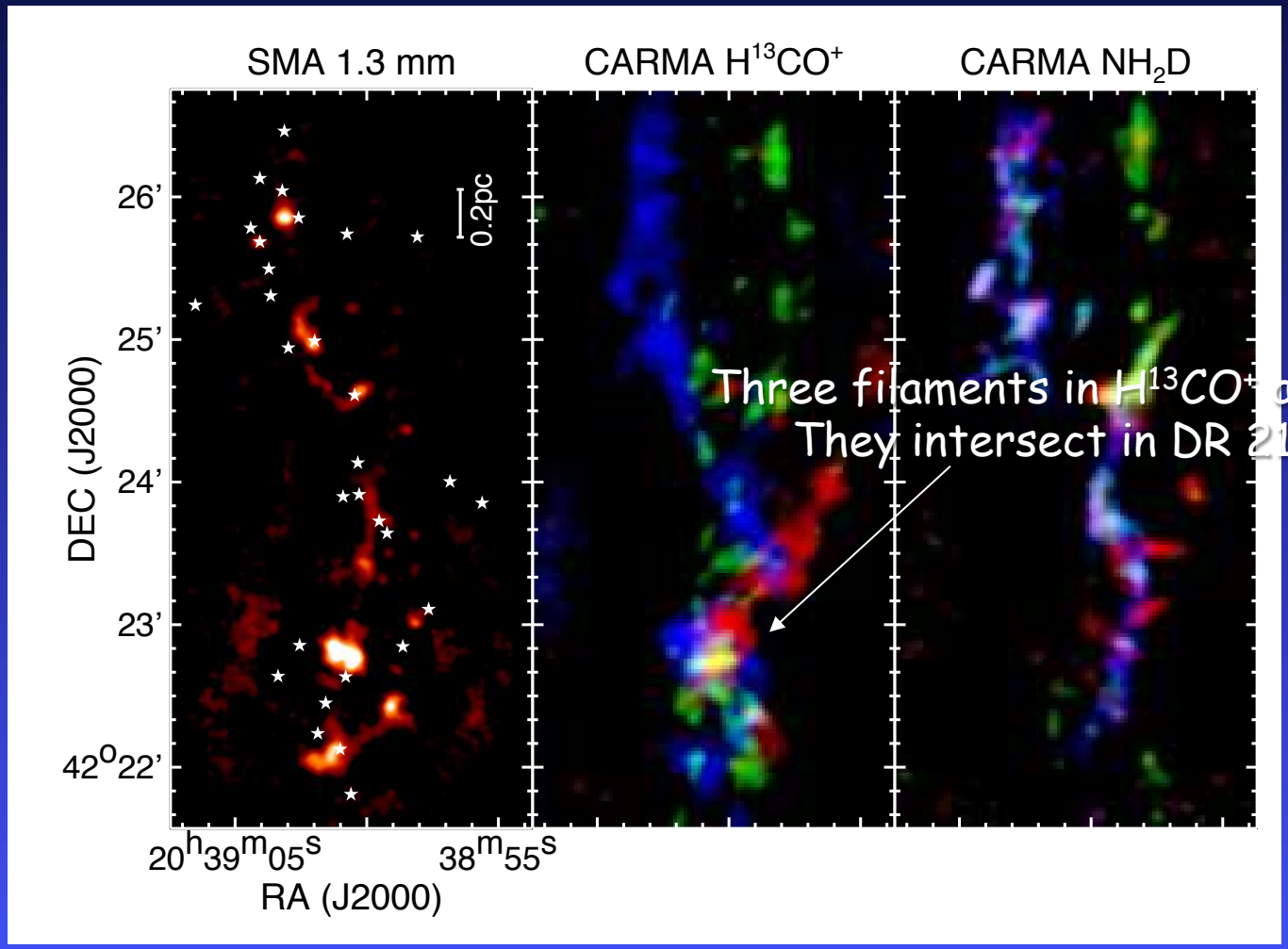




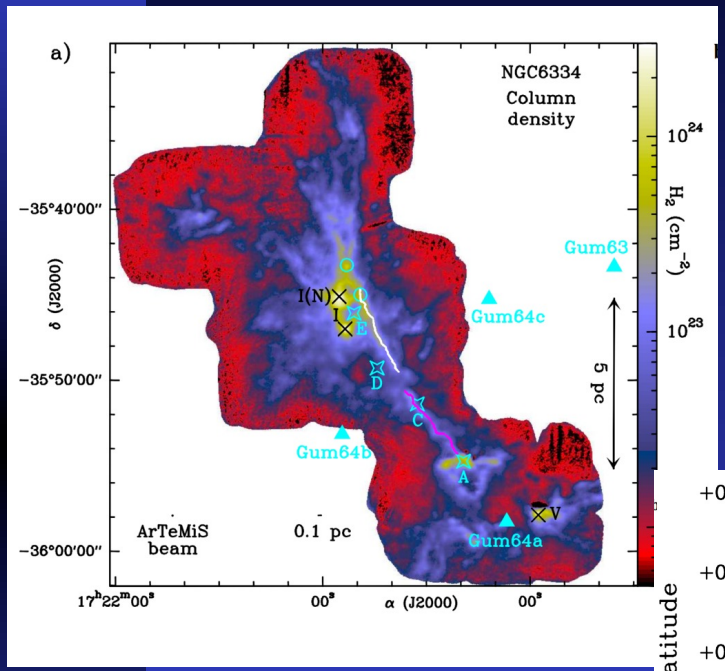


Why significant more active SF in DR 21(OH) than in northern filament??

Low J molecular lines are crucial

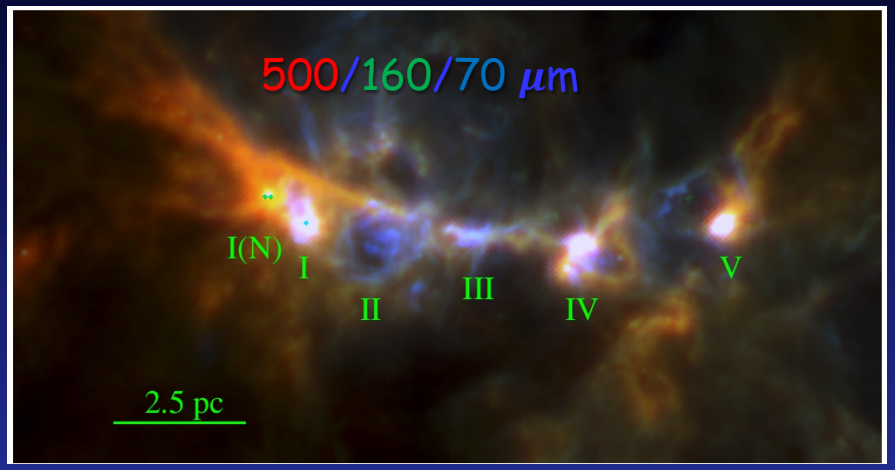


NGC 6334

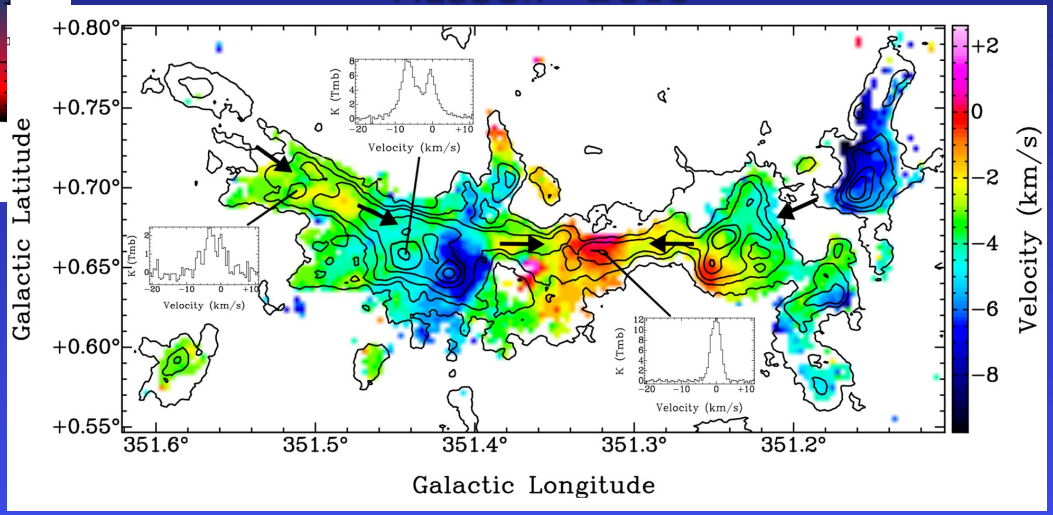


Column density derived from ArTéMiS and Herschel 350 μm

Andre+ 2016

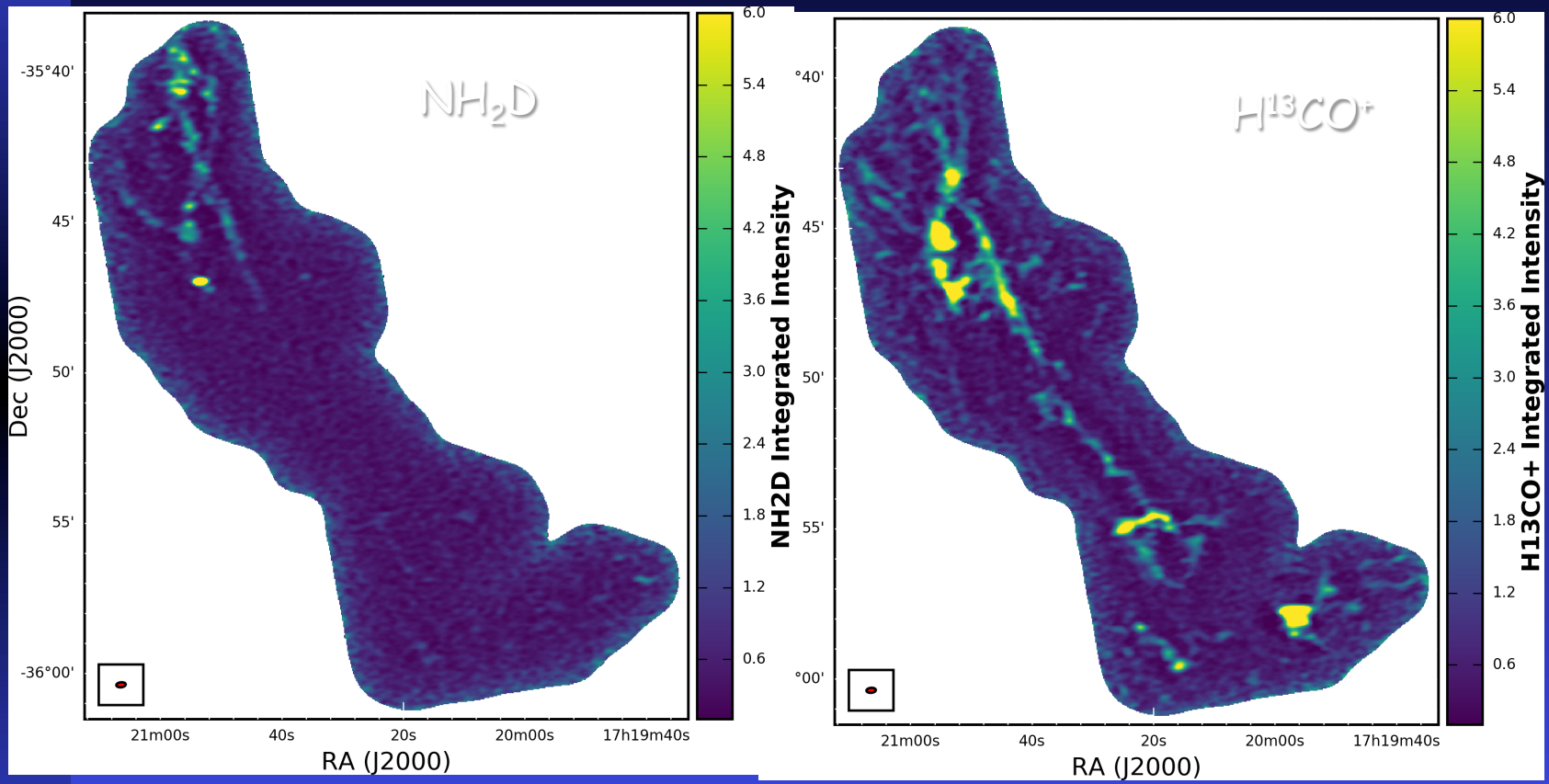


Russeil+ 2013



Zernickel+ 2013: HCO^+ 3-2

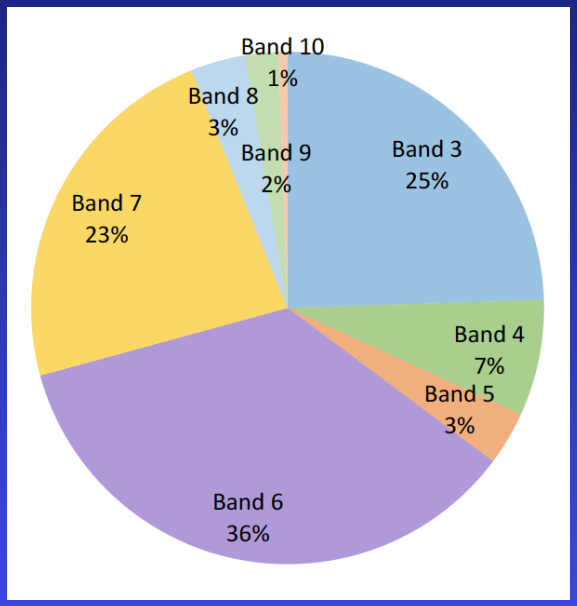
NGC 6334 imaged with ACA



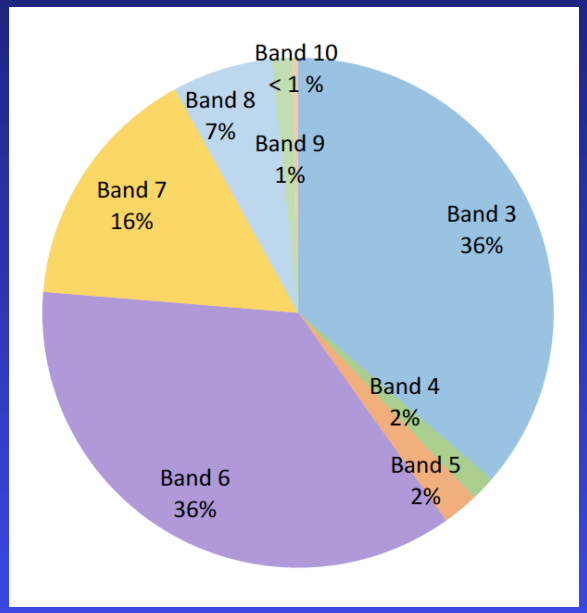
Storm+

ALMA Cycle 6 Stats: Time requests

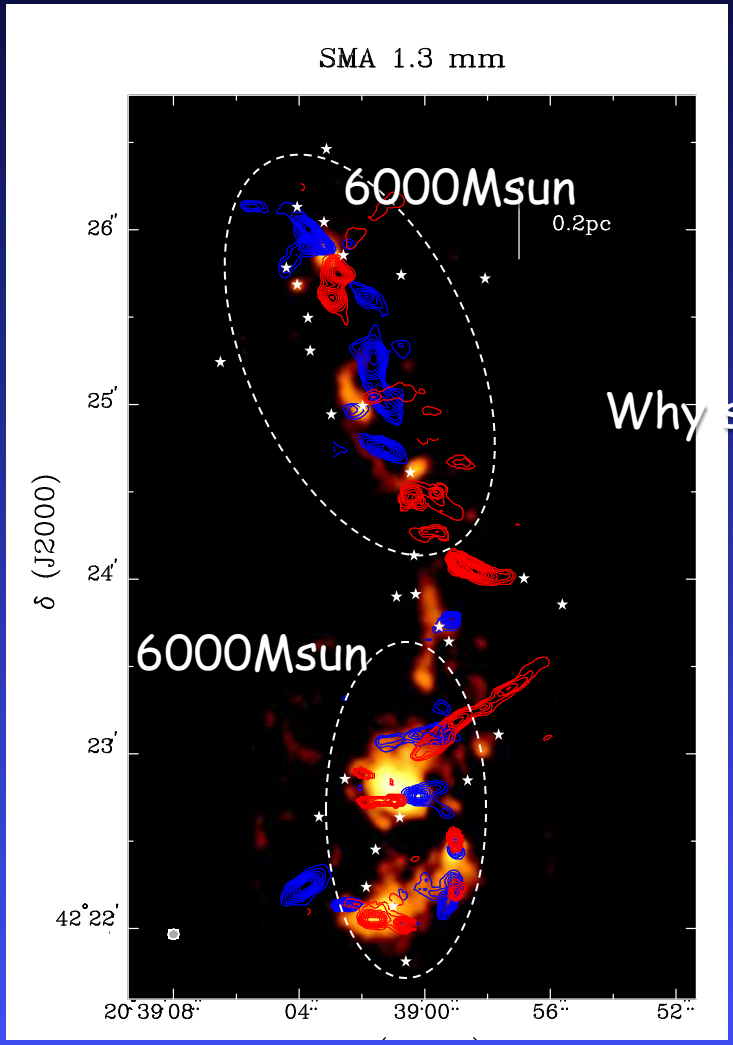
12-m Array



7-m Array

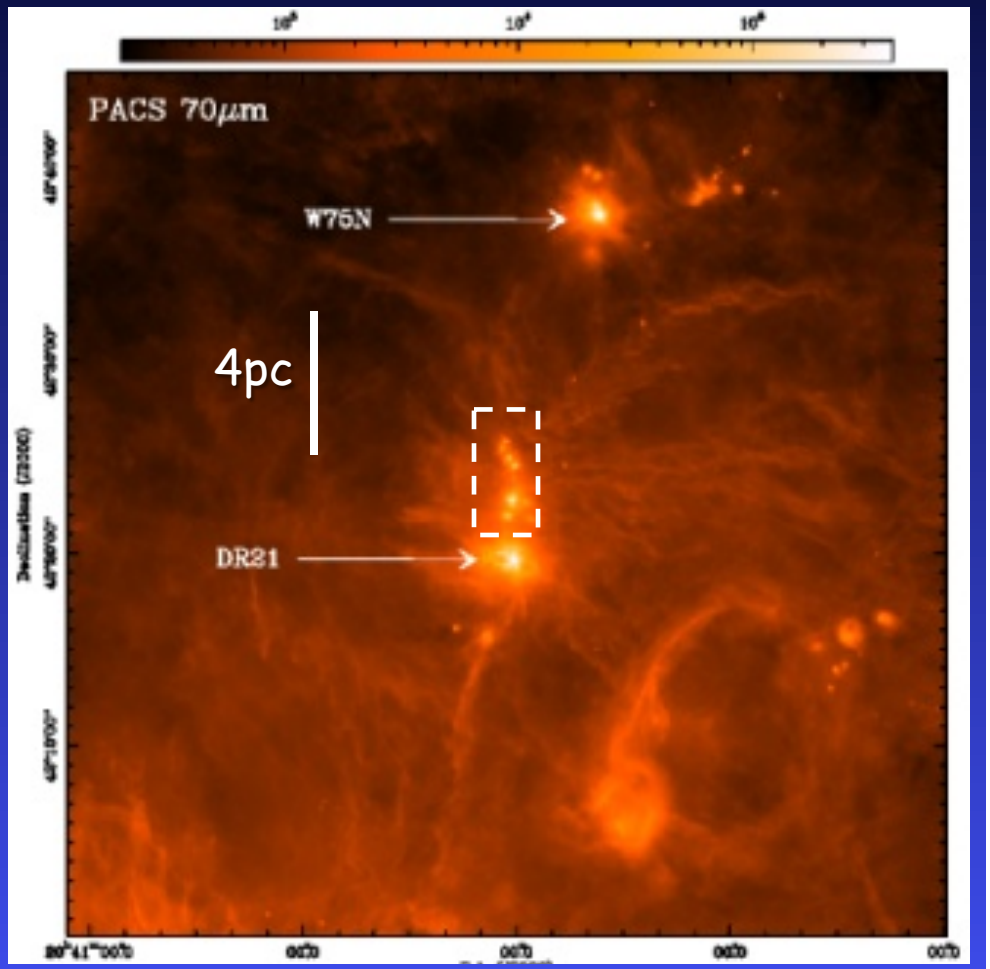


Star formation in Cygnus-X



Why significant more active SF in DR 21(OH) than in northern filament??

Star formation in Cygnus-X



Hennemann et al. 2012