



The Spitzer Cygnus-X Legacy Survey

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and
The Cygnus-X Legacy Team

Cygnus-X Legacy Team

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Summary

- Cygnus-X is an extremely active region of massive star formation, at 1.7 kpc it is the nearest and largest within 2 kpc
- With this survey, we can study the evolution of high-mass protostars, and the associated low mass star formation in a massive molecular cloud/OB complex
- Spitzer IRAC & MIPS (24, 70 μm) unbiased survey covers ~25 sq. deg. region
 - MIPS similar to MIPS GAL in depth, coverage, & processing
 - IRAC: 3x12s HDR frames: (10x GLIMPSE), sensitive to young stars $<1M_{\odot}$
- Status:
 - MIPS observations completed, IRAC 95% done, rest next week
 - Data reduction and analysis in progress, generating catalogs and improved images
 - First products release in Feb. 2009 – MIPS, 2MASS, part of IRAC
- For more info: <http://www.cfa.harvard.edu/cygnusX>

The Cygnus-X Region

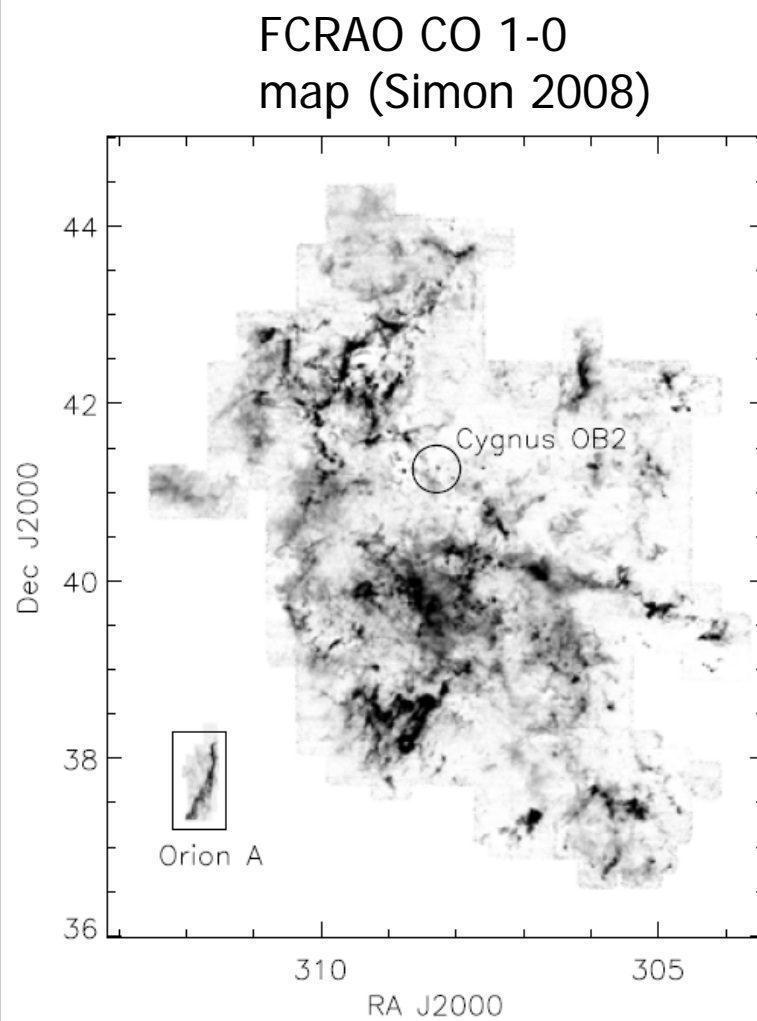
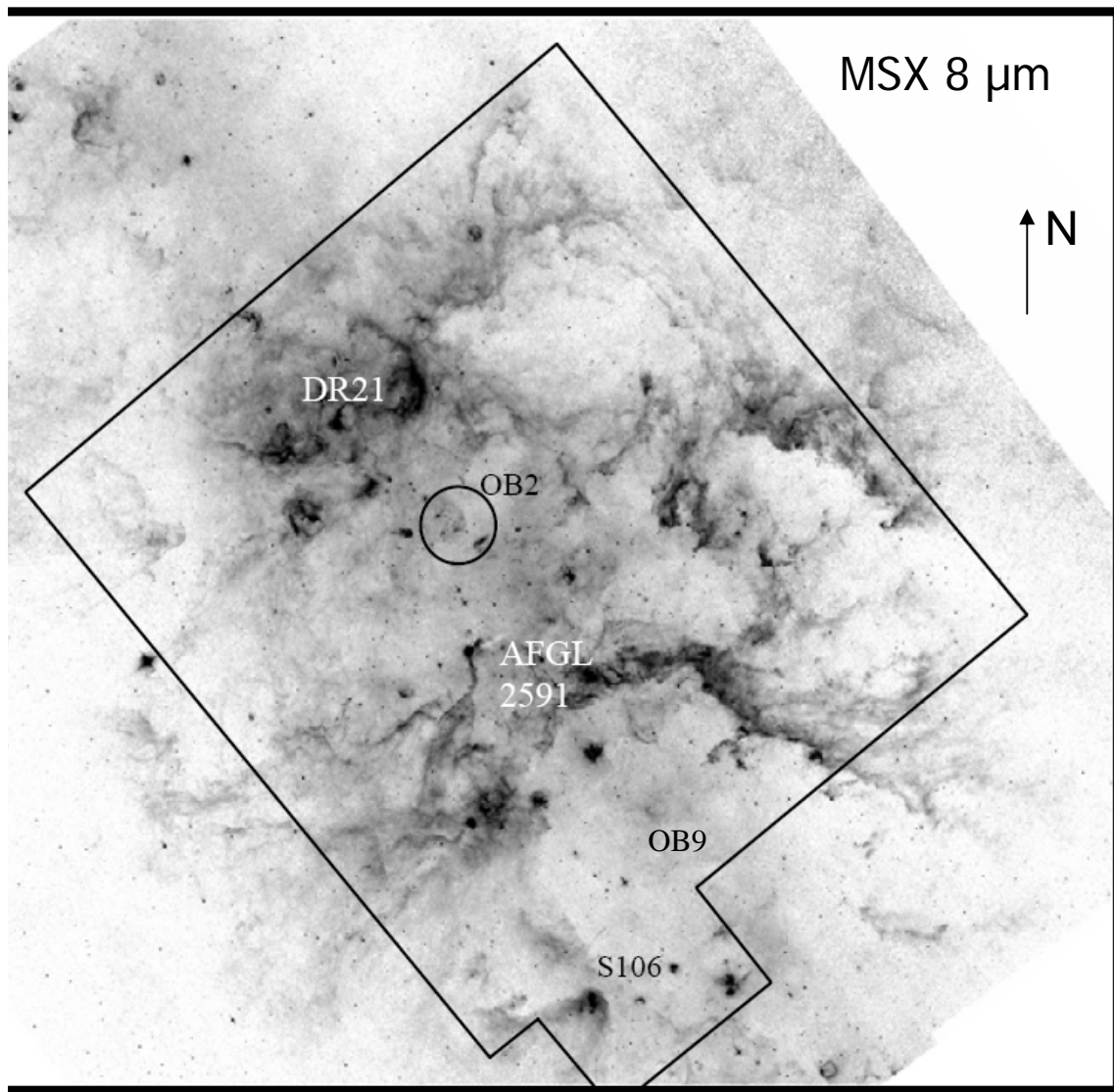
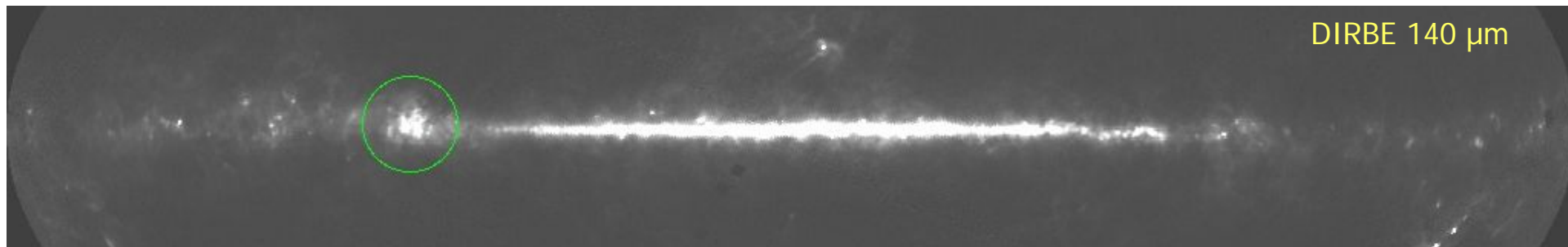
- Cygnus-X is one of the brightest regions of the sky at all wavelengths
- One of the richest known star formation regions in the Galaxy.
 - It contains as many as 800 distinct HII regions,
 - a number of Wolf-Rayet and OIII stars and
 - several OB associations.
- The association near the center of the complex, Cygnus OB2, was identified optically and known to be large
 - 2MASS observations indicated that Cygnus OB2 contains 2600 ± 400 OB stars and ~ 100 O-stars
 - total stellar mass that could be as high as $10^5 M_{\odot}$ (Knödlseeder 2000)
- A large fraction of stars form in these types of massive clusters

The Cygnus-X Region (cont.)

- Long argued to be superposition of a number of regions along spiral arm tangent
- Schneider et al. (2006, 2007): made a detailed comparison of ^{13}CO $2\rightarrow 1$ and $1\rightarrow 0$ emission along with MSX images
 - Molecular clouds in the regions form connected groups
 - Cyg OB2 and OB1/OB9 associations directly heat the molecular material in Cygnus-X
 - Concluded the majority of the sources in the region are at the same distance as the OB associations, 1.7 kpc
- Cygnus-X is a 200pc diameter, $3\cdot 10^6 M_{\odot}$ complex
- Largest OB complex known within 2 kpc

The Cygnus-X Legacy Survey

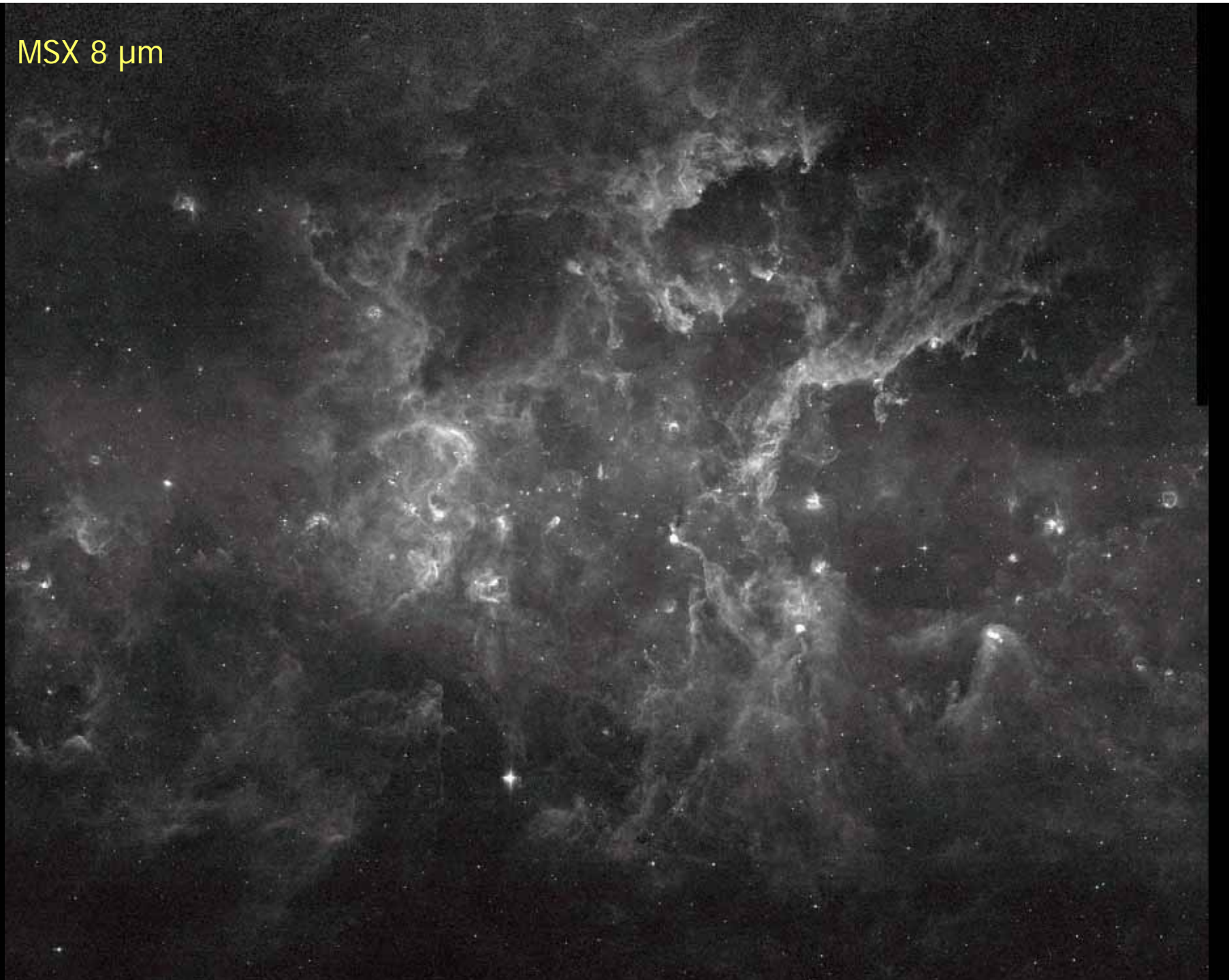
- Cygnus-X differs from other Spitzer surveys of nearby low-mass star forming regions (c2d, Gould's Belt, Orion surveys):
 - Very active high-mass star formation in Cygnus-X, as demonstrated by the existence of 40 massive protostars in regions such as DR21, DR21(OH), W75N, and AFGL 2591
 - The mass of the complex ($\sim 3 \cdot 10^6 M_{\odot}$) is significantly larger than other nearby molecular clouds with OB associations such as:
 - Orion A ($10^5 M_{\odot}$; Bally et al 1987),
 - M17 ($3 \times 10^5 M_{\odot}$; Elmegreen et al. 1979) or
 - Carina ($2 \times 10^5 M_{\odot}$; Schneider & Brooks 2004)
 - Most stars may form in complexes like Cygnus-X



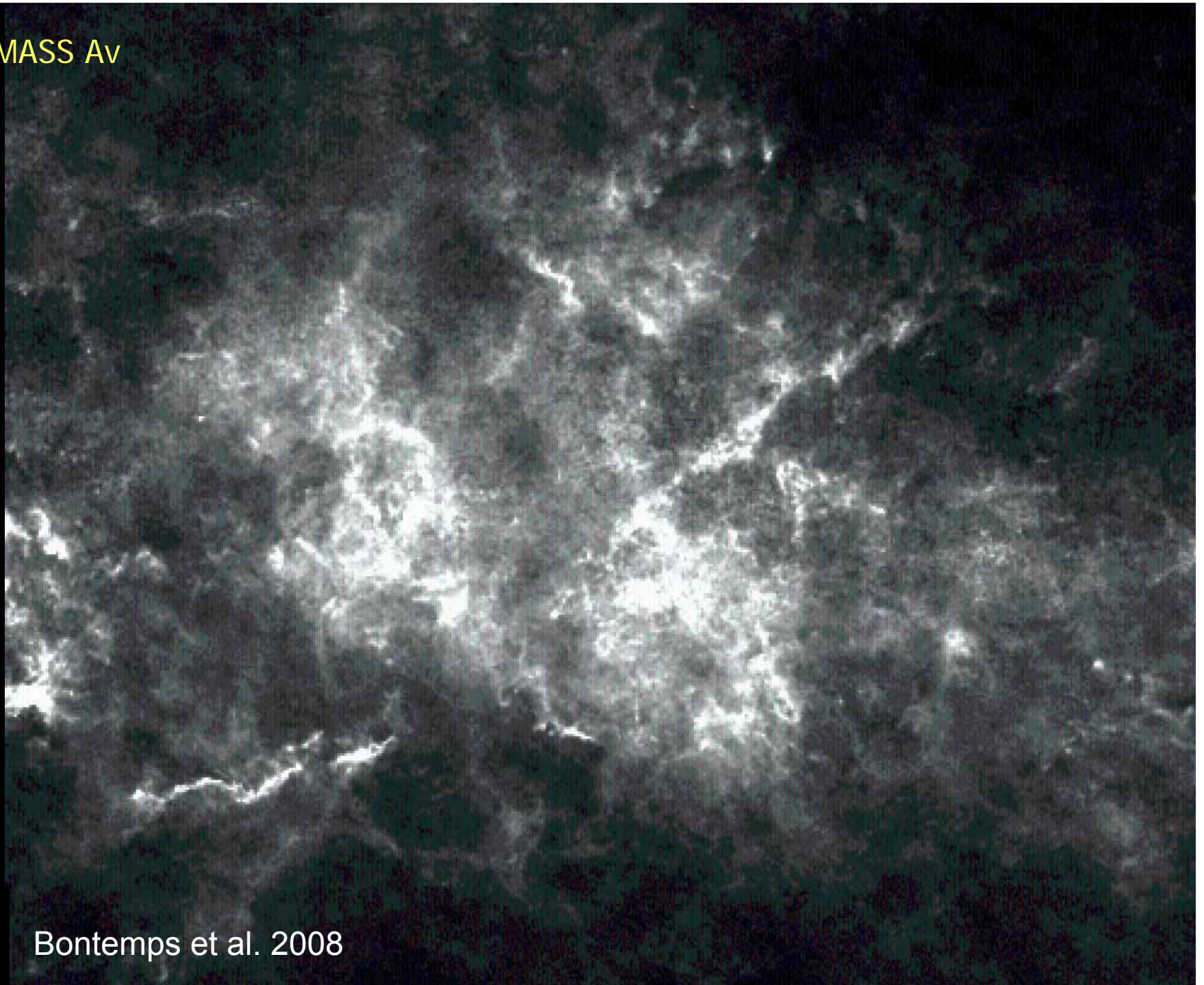
Goals of Cygnus-X Legacy Survey

- Analyze the evolution of high-mass protostars with a large, statistically robust sample at a single distance
- Study the role of clustering in high-mass star formation
- Study low-mass star formation in a massive molecular cloud complex dominated by the energetics of ~ 100 O-stars
- Assess what fraction of all young low-mass stars in the nearest 2 kpc are forming in this one massive complex
- Provide an unbiased survey of the region and produce a legacy data set for use with future studies (e.g., JWST, Herschel)

MSX 8 μm



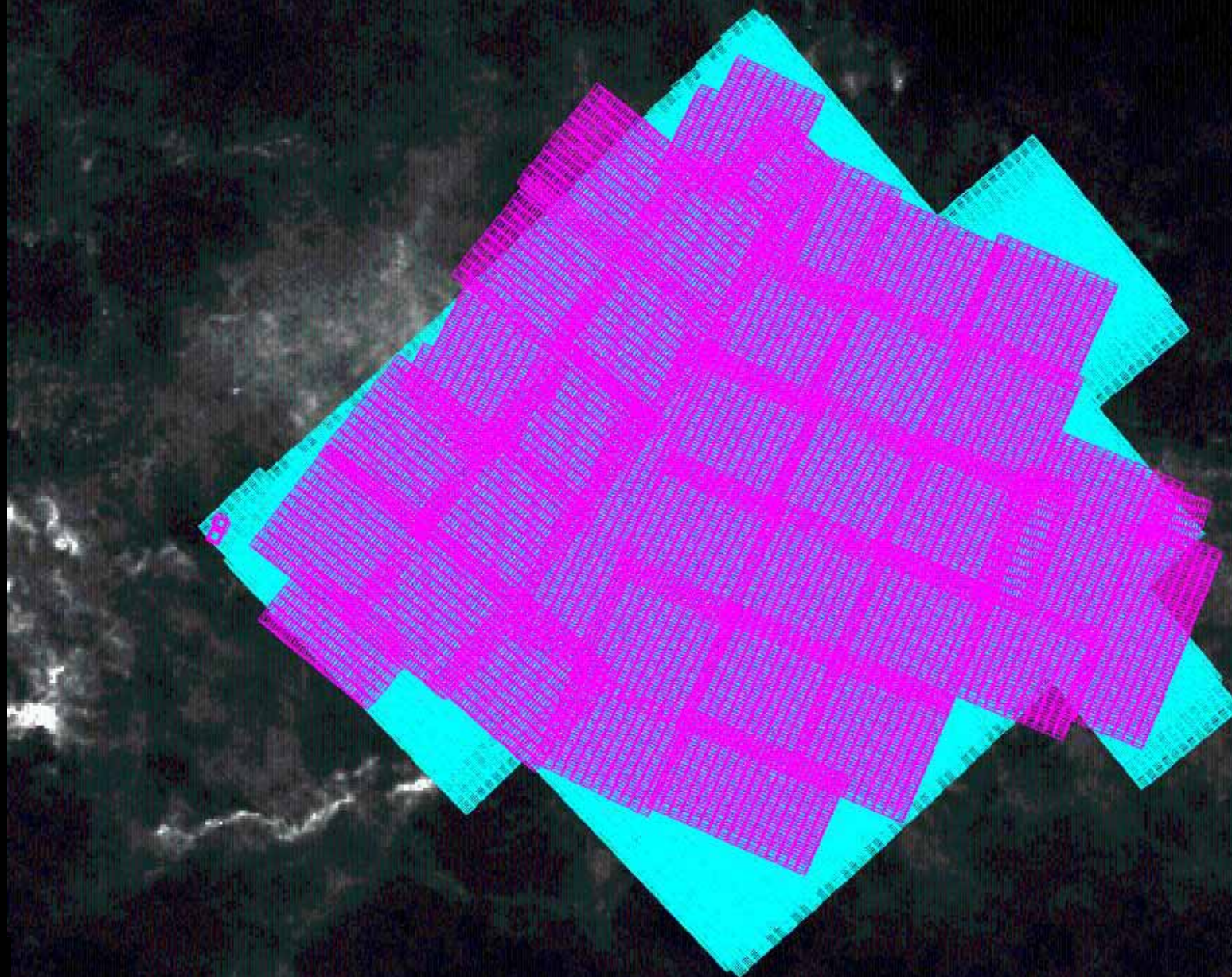
2MASS Av



Bontemps et al. 2008

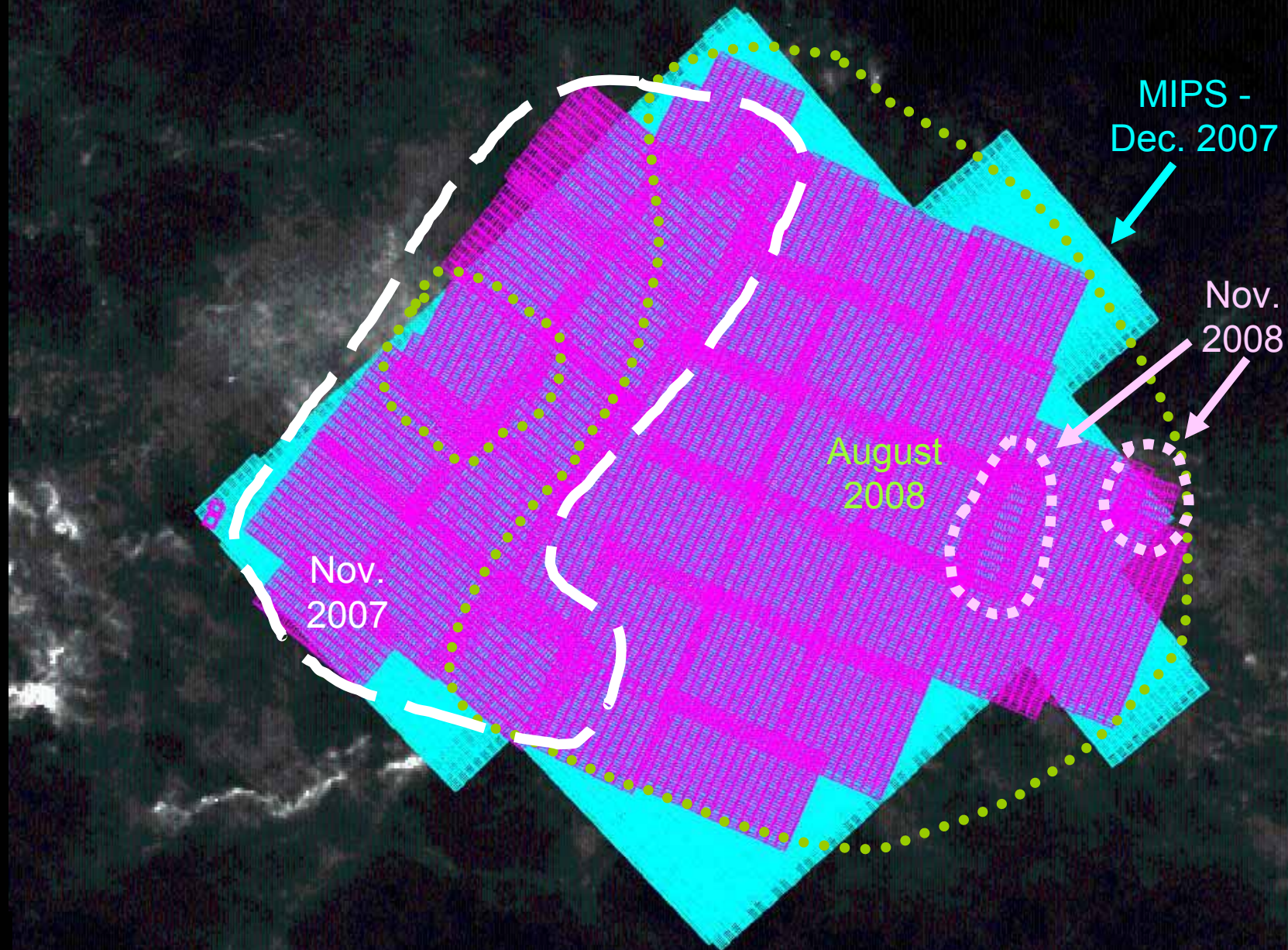
2MASS Av

Cygnus-X Survey AORs (4.5 & 24 μm)



2MASS Av

Cygnus-X Survey AORs (4.5 & 24 μm)



Data processing status

- MIPS

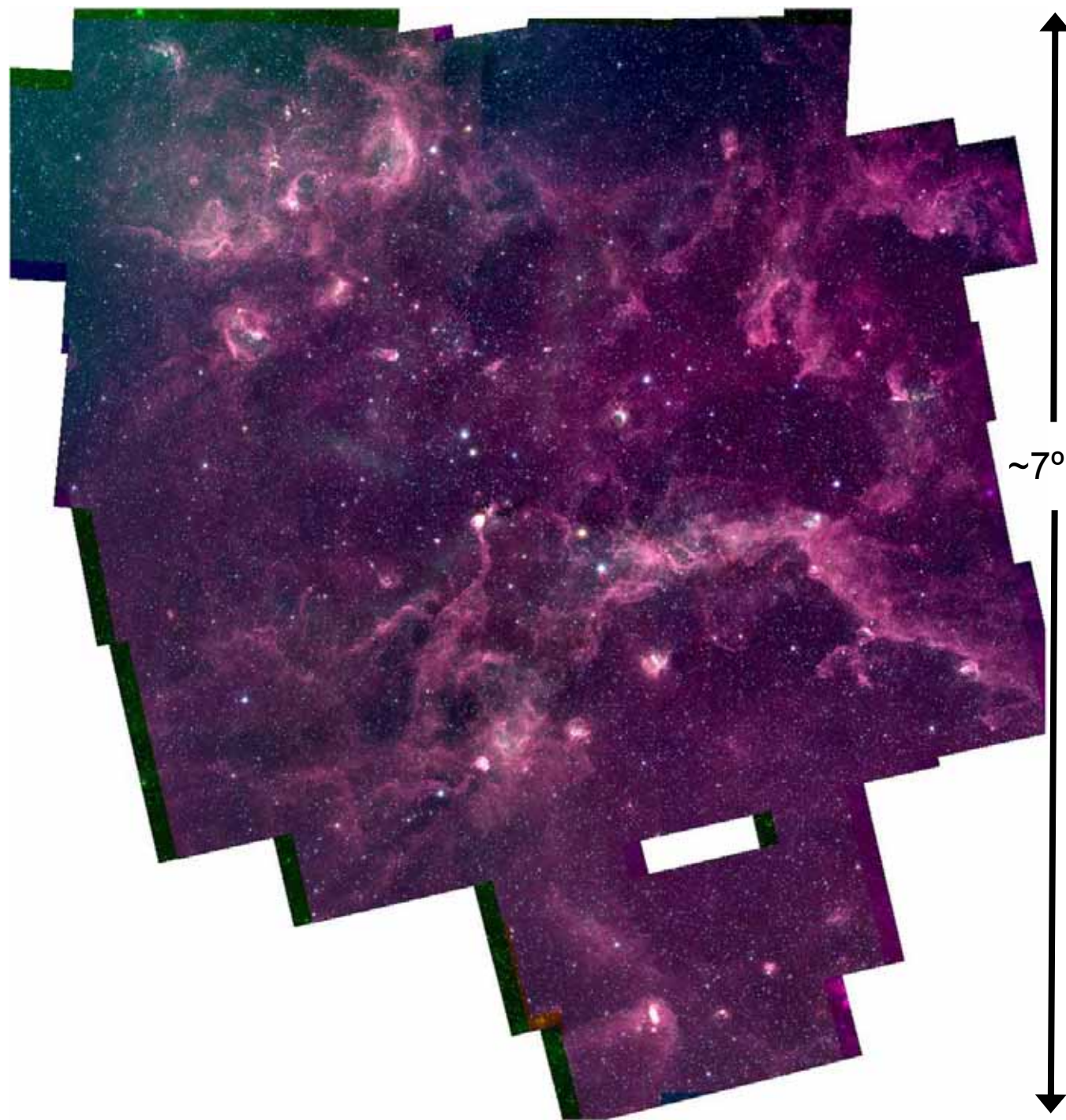
- Observations completed Dec. 2007
- Similar to MIPS GAL data processing
- 24 μm data images completed, initial point source extraction and catalogs produced
- Further effort on saturated sources
- 70 μm reduction in progress – working on destriping methods

- IRAC

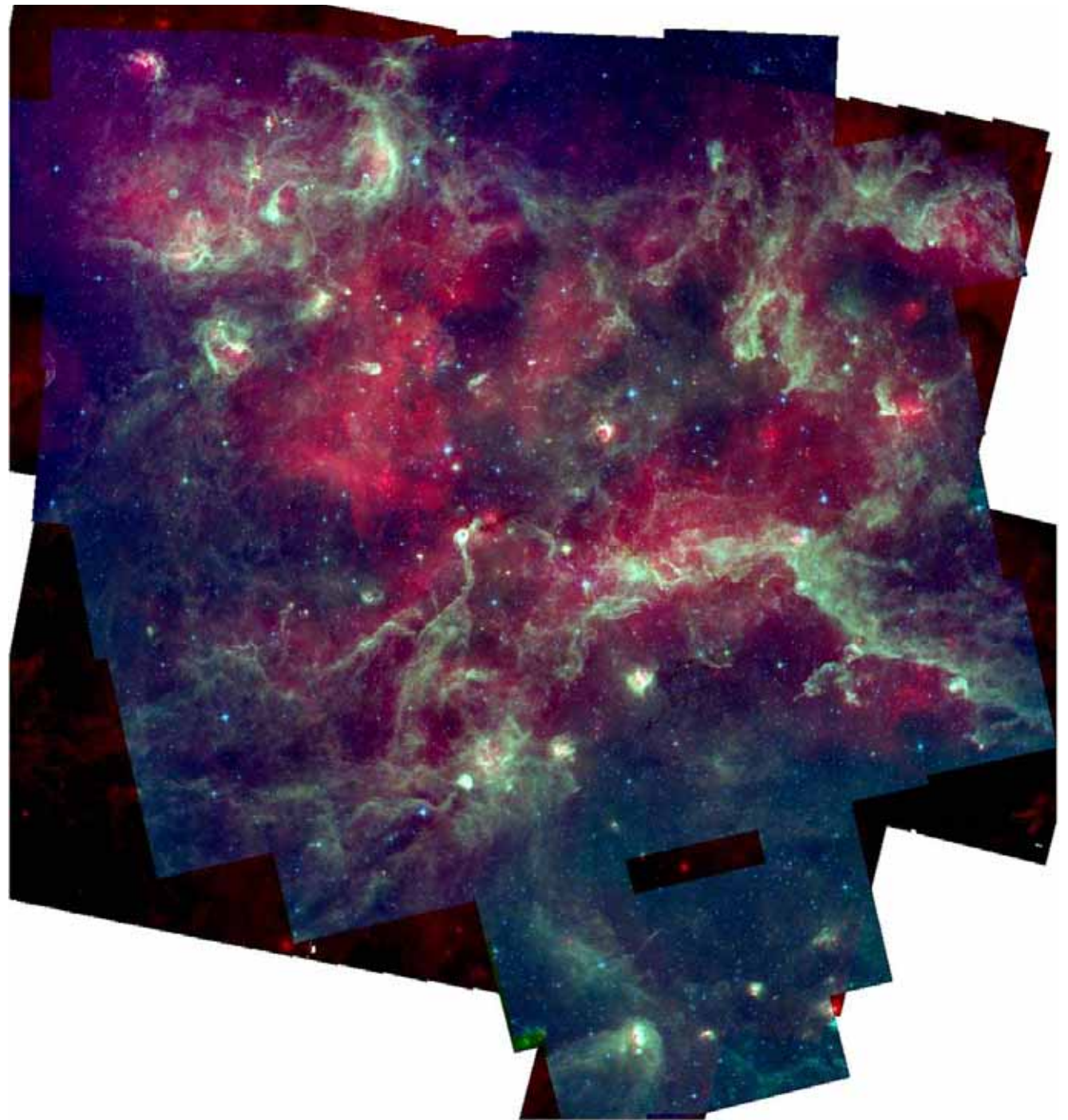
- Observations 95% complete, final frames next week
- S18 BCDs used, further artifact corrections applied, HDR frames used to maximize dynamic range
- Initial pass completed, catalogs and mosaics produced
- Will reprocess Nov 2007 data when S18 products available for better muxbleed correction

- First release of catalogs and images scheduled to be delivered to IRSA in February 2009

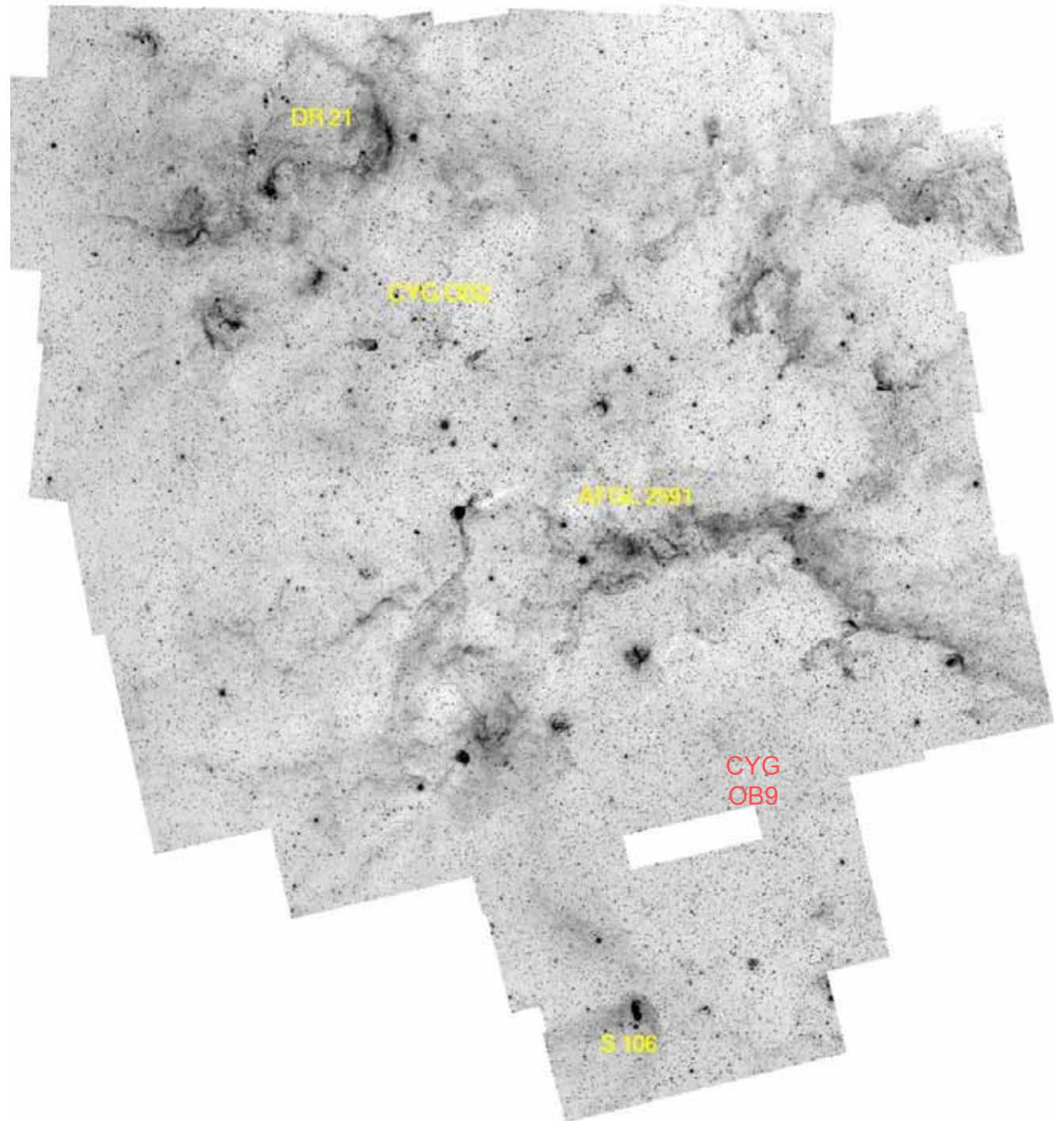
Blue: IRAC 3.6 μm
Green: IRAC 4.5 μm
Red: IRAC 5.8 μm



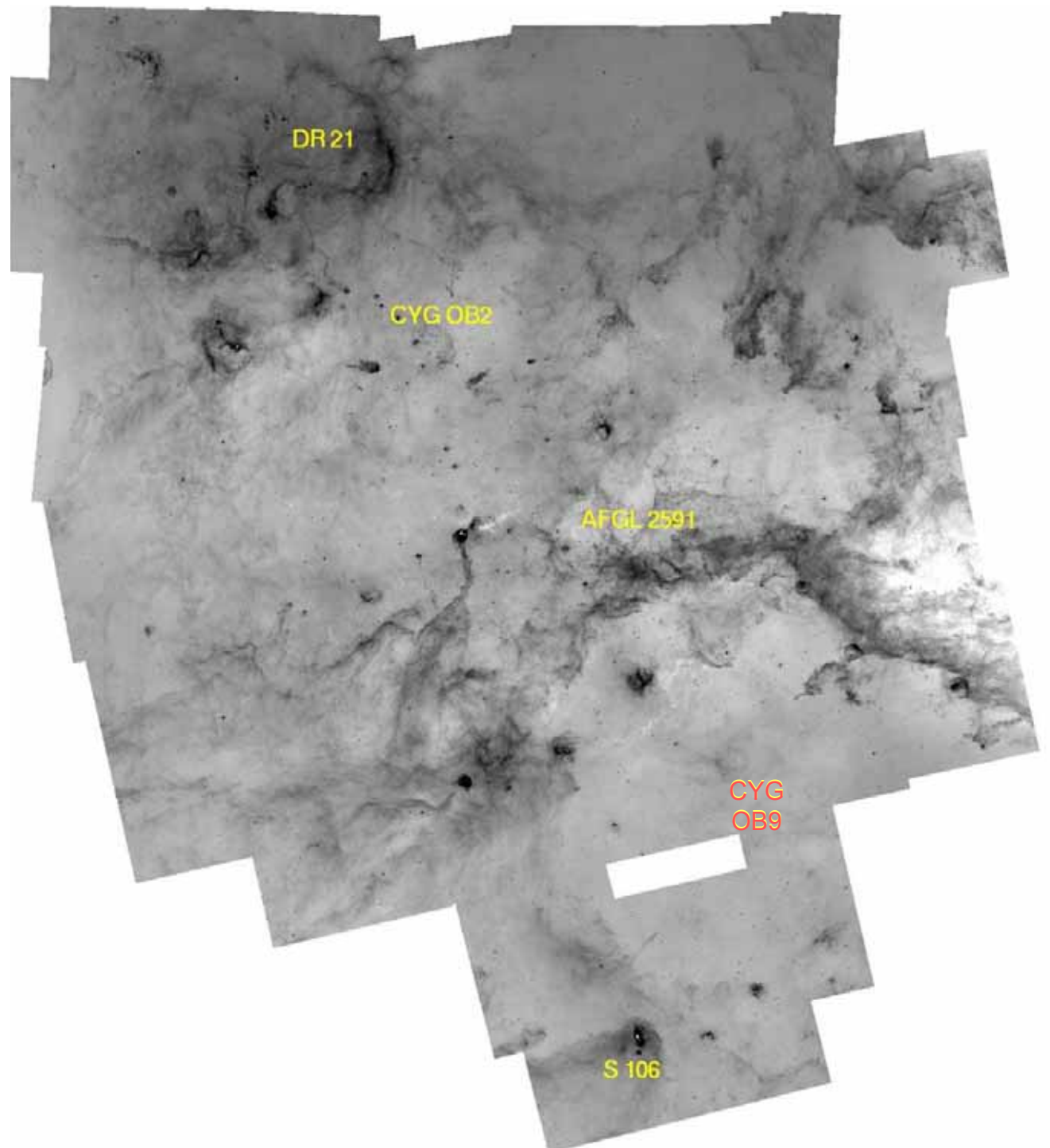
Blue: IRAC 3.6 μm
Green: IRAC 5.8 μm
Red: MIPS 24 μm



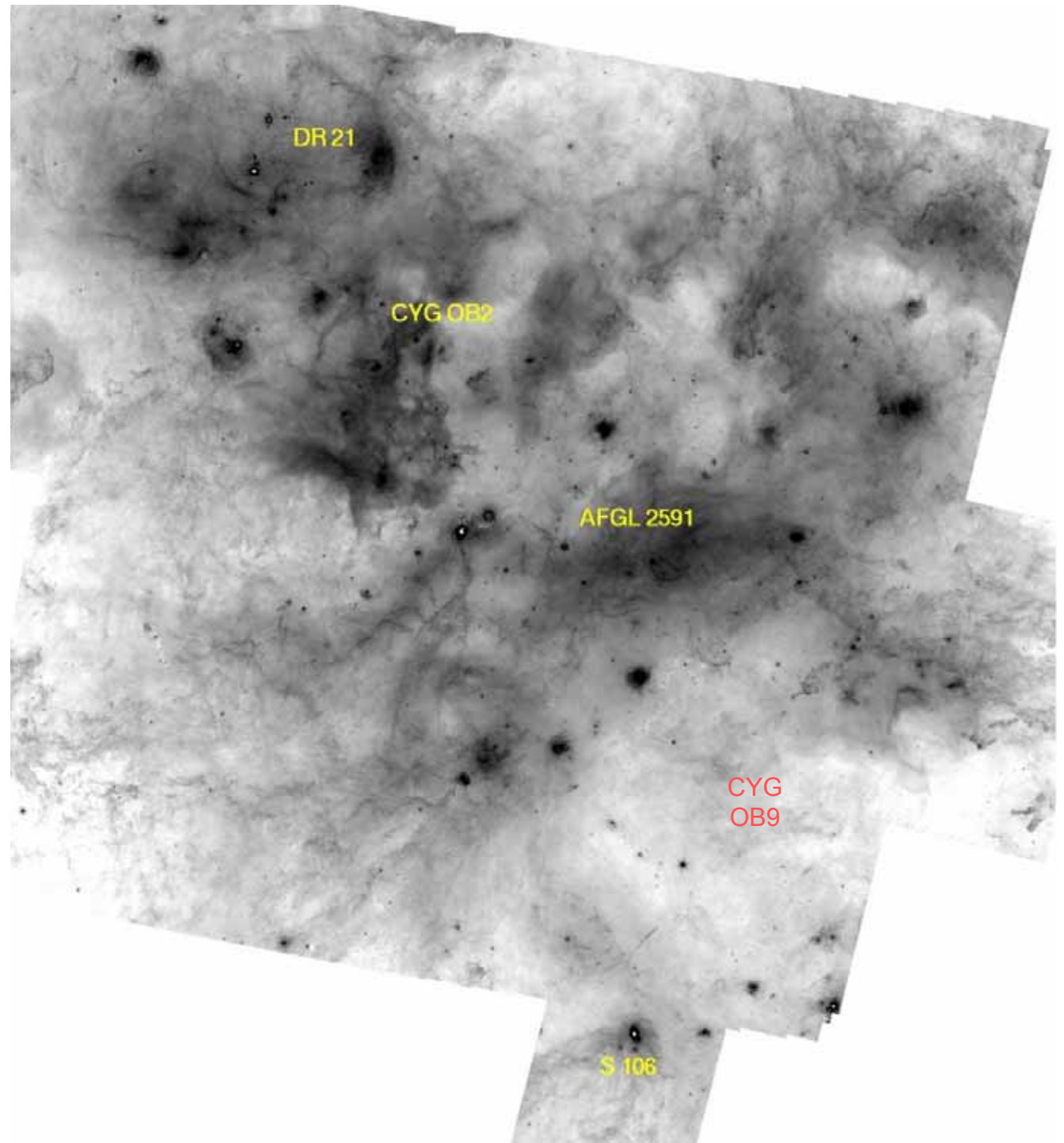
IRAC 3.6 μm



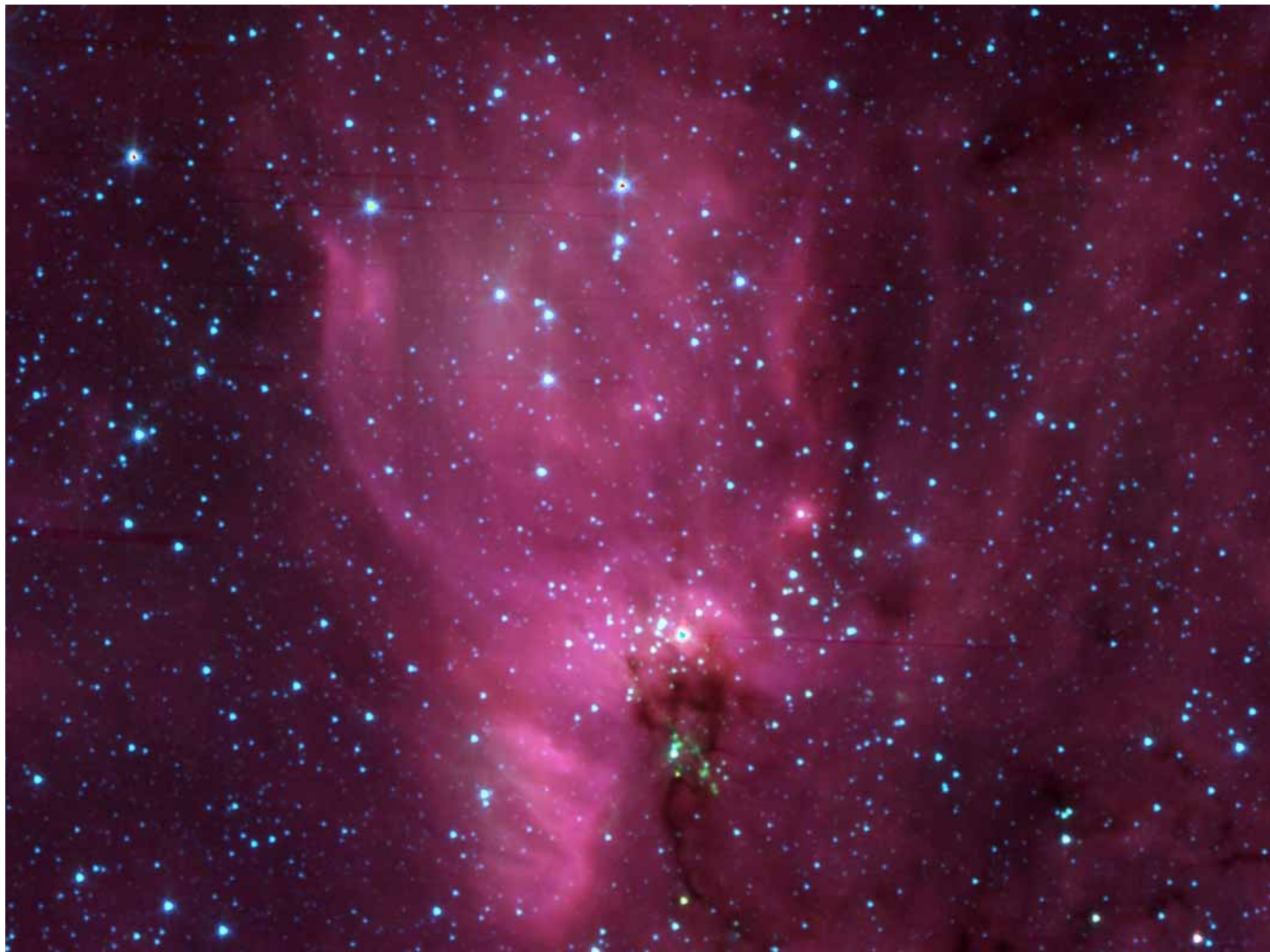
IRAC 8 μ m



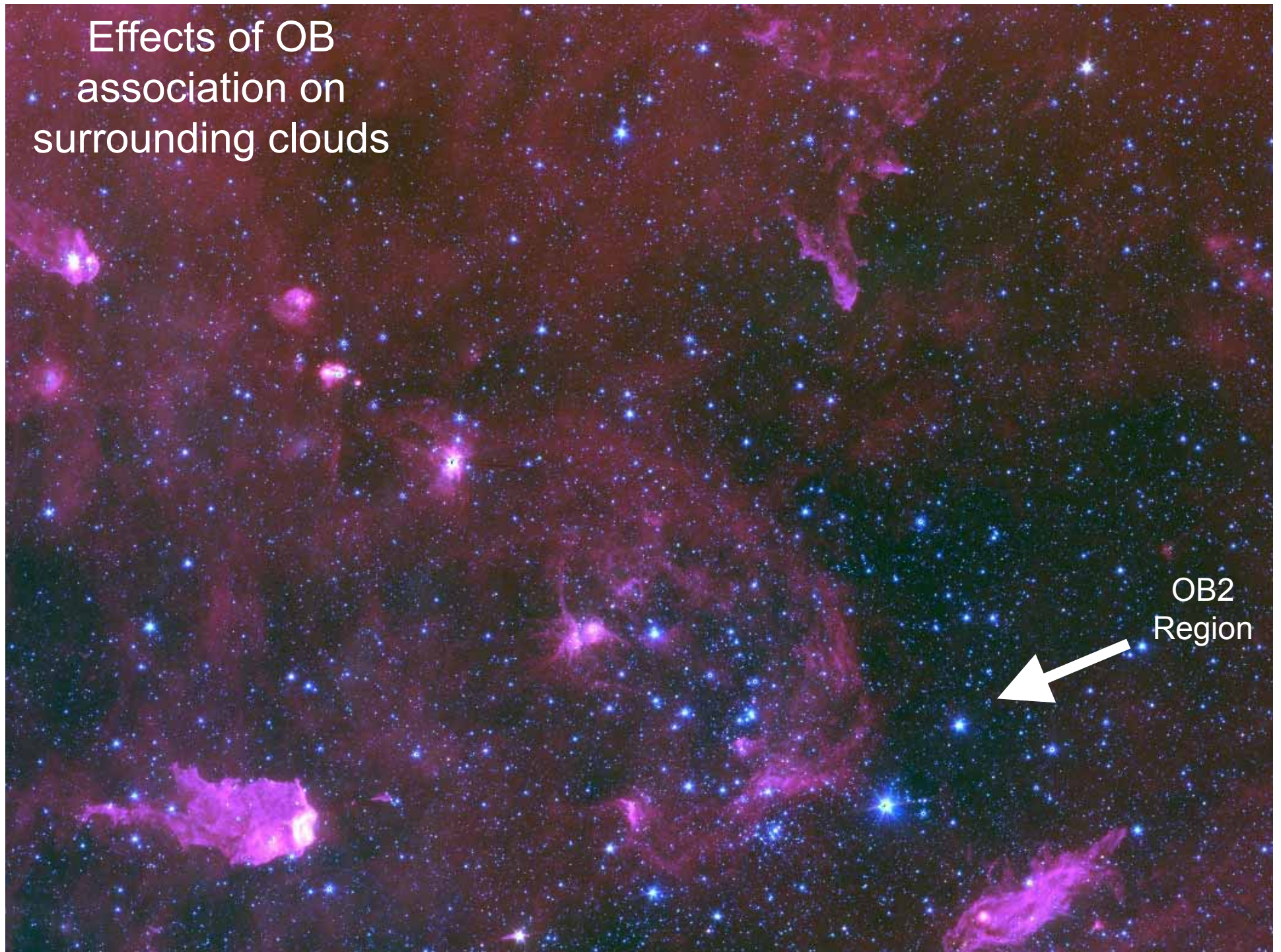
MIPS 24 μm





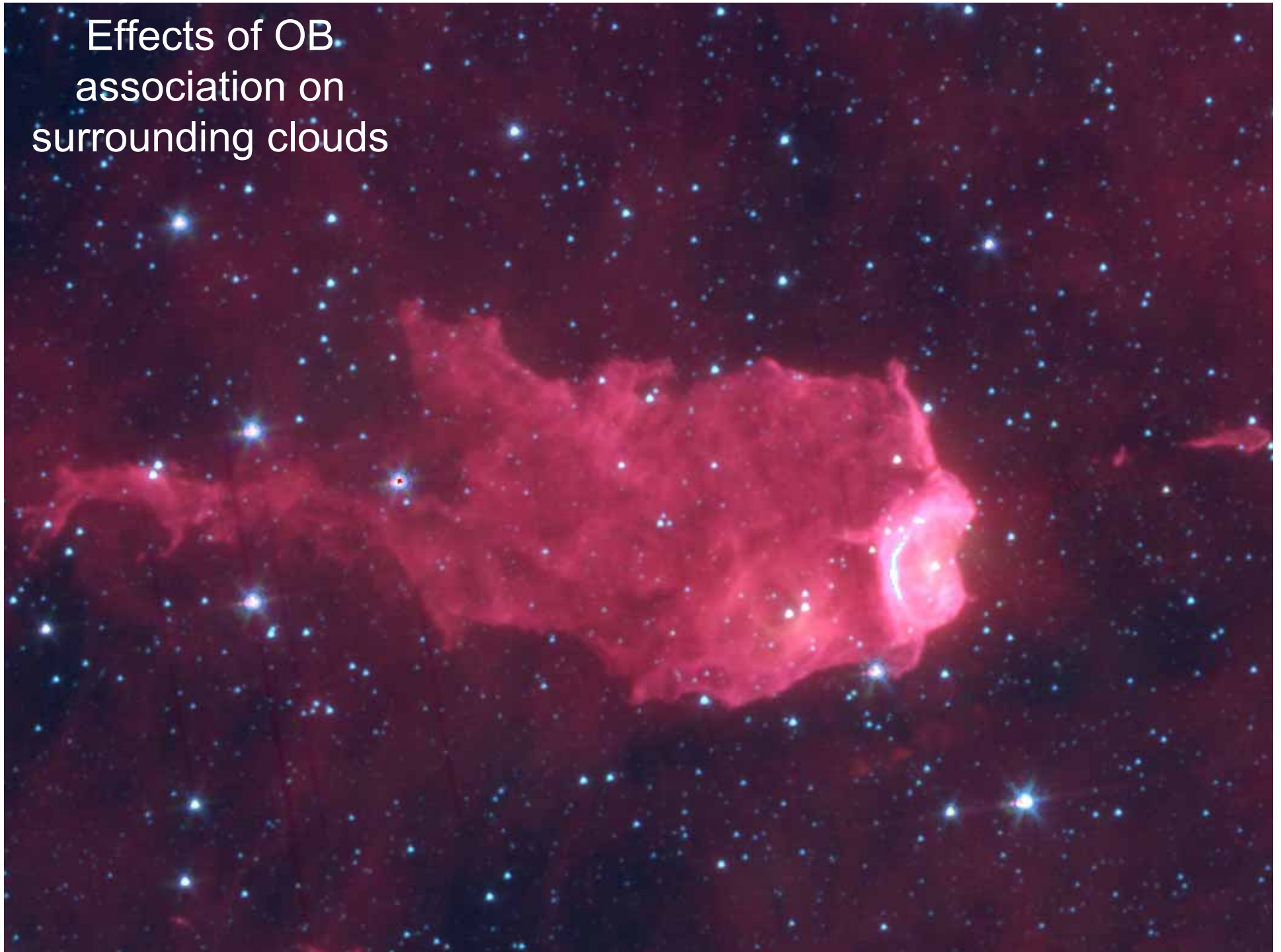


Effects of OB
association on
surrounding clouds

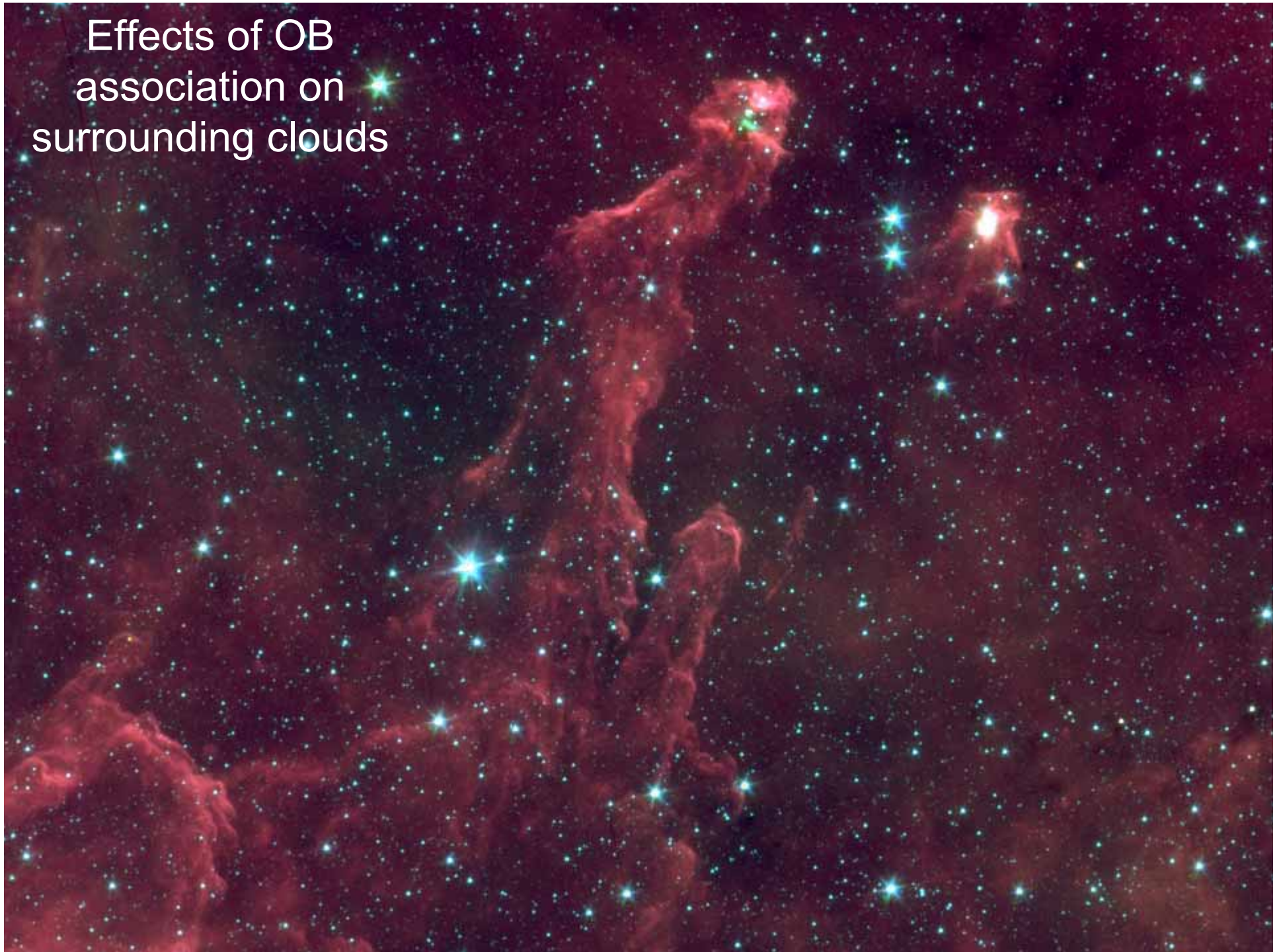


OB2
Region

Effects of OB
association on
surrounding clouds



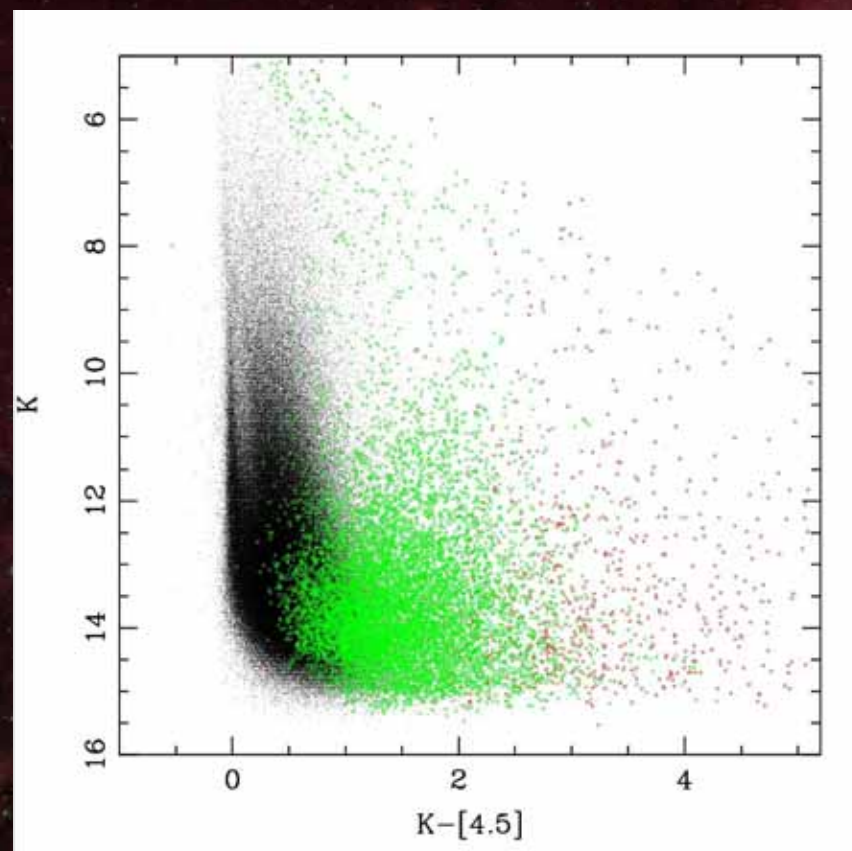
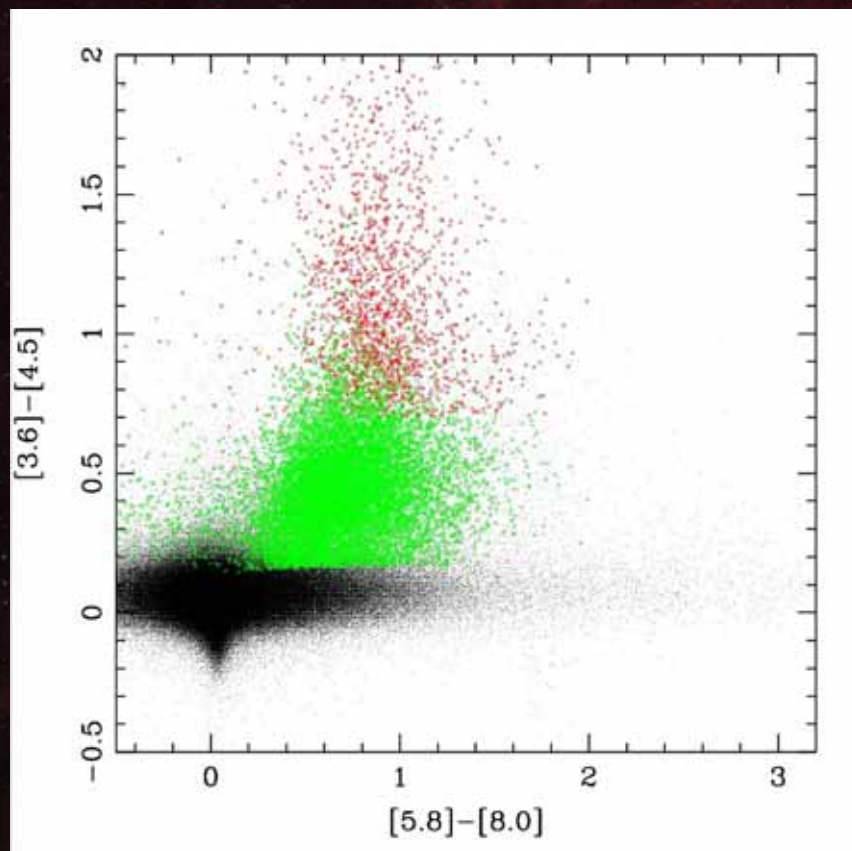
Effects of OB
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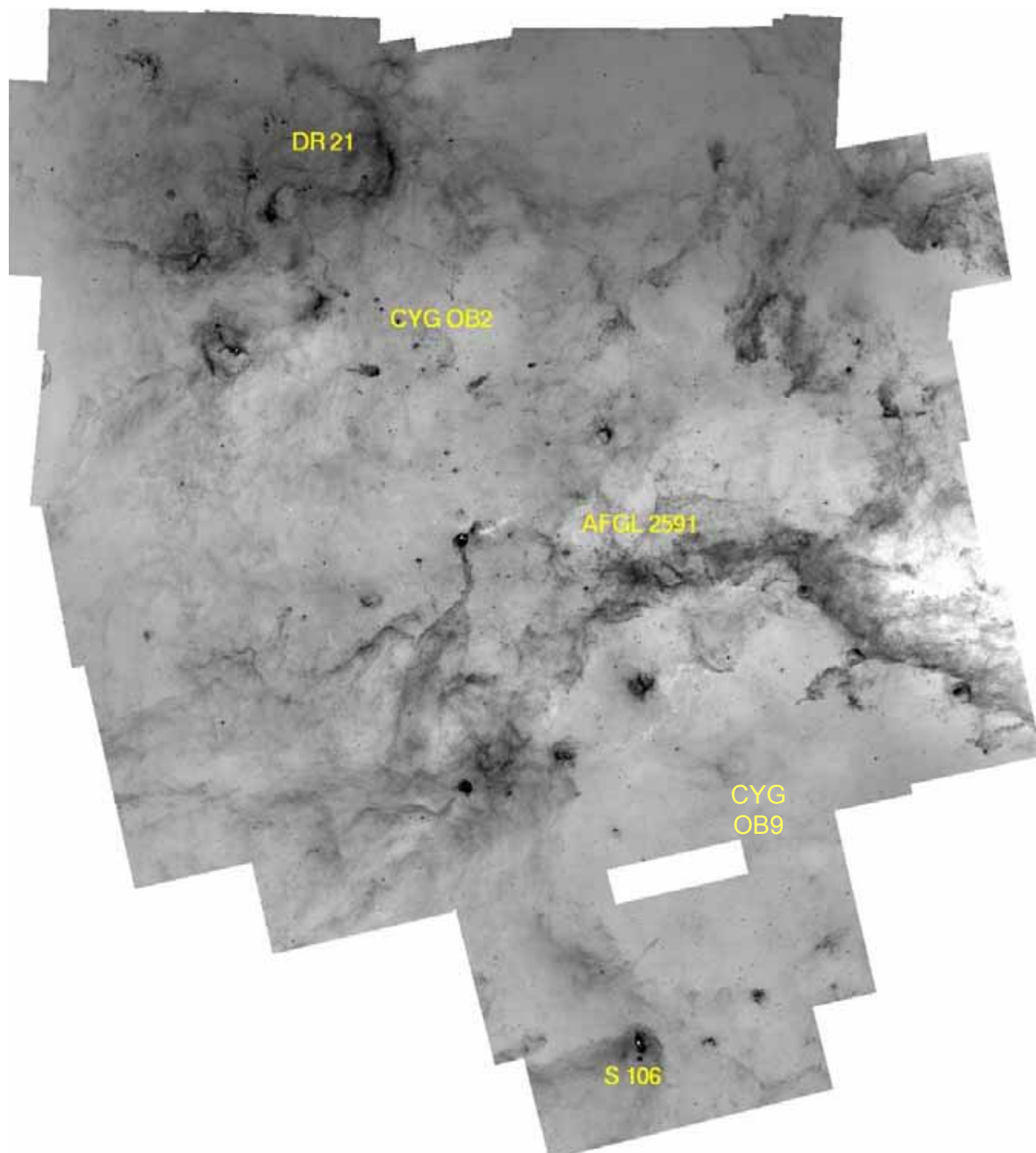
Source Classification Results

- The following slides show the distribution of classes of objects, based on the 2MASS/IRAC/MIPS photometry and methods detailed in Gutermuth et al. (2008)
- 3.8 million Spitzer sources in the initial catalog
- YSOs identified:
 - 875 deeply embedded sources
 - 1635 class I
 - 12726 class II

Source Classification Results

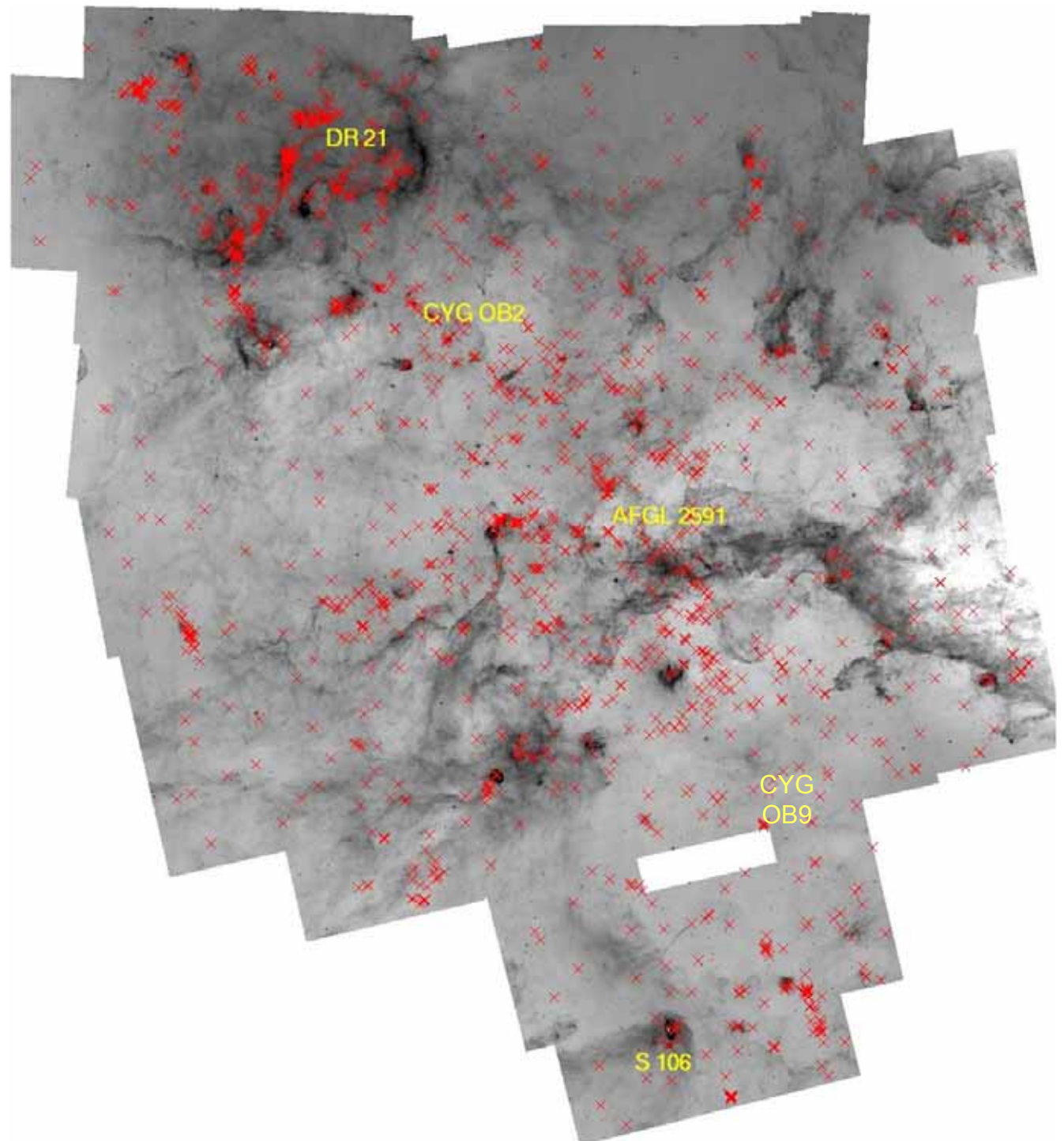


IRAC 8 μ m



IRAC 8 μm

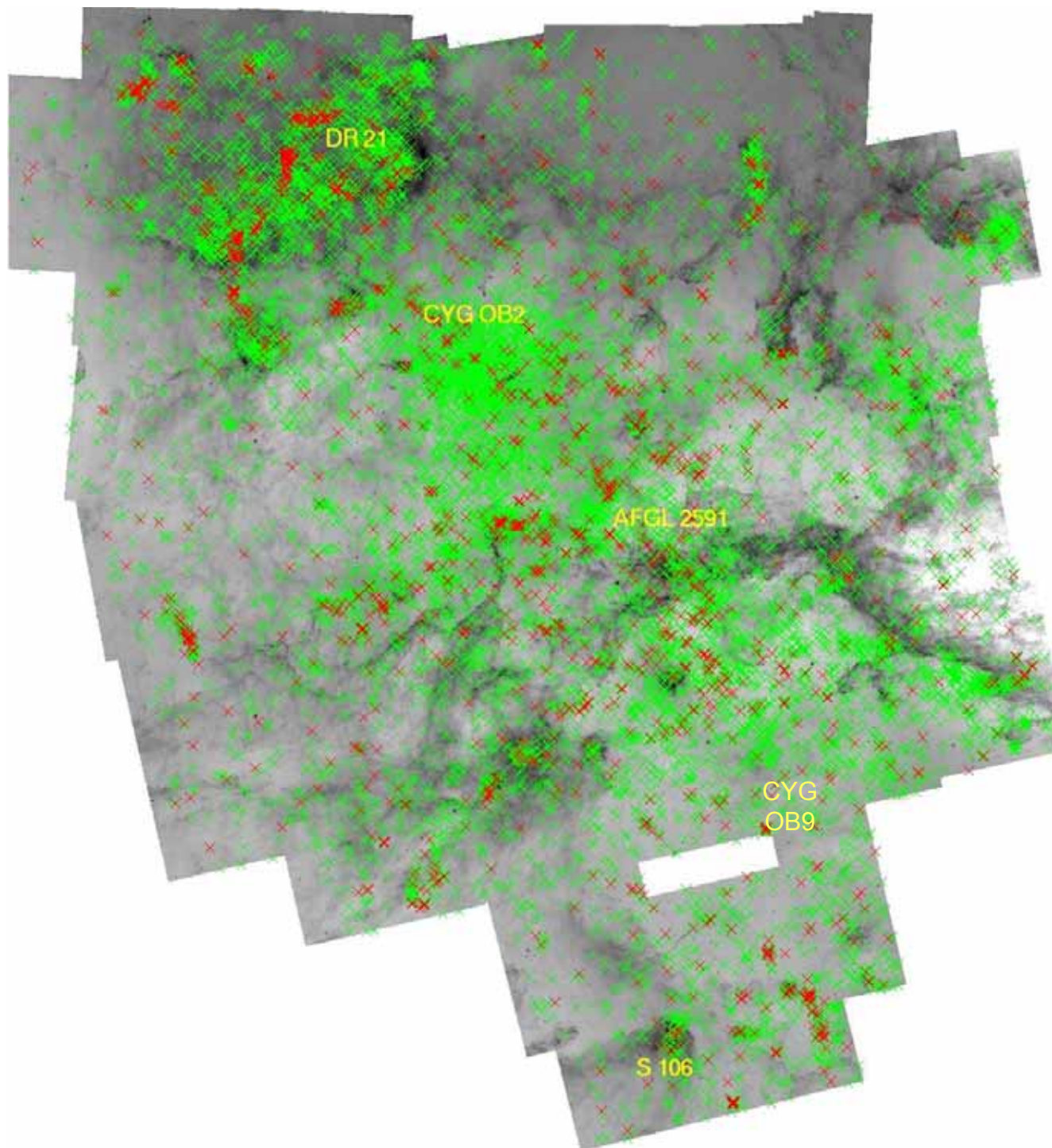
Class I - Red



IRAC 8 μ m

Class I – Red

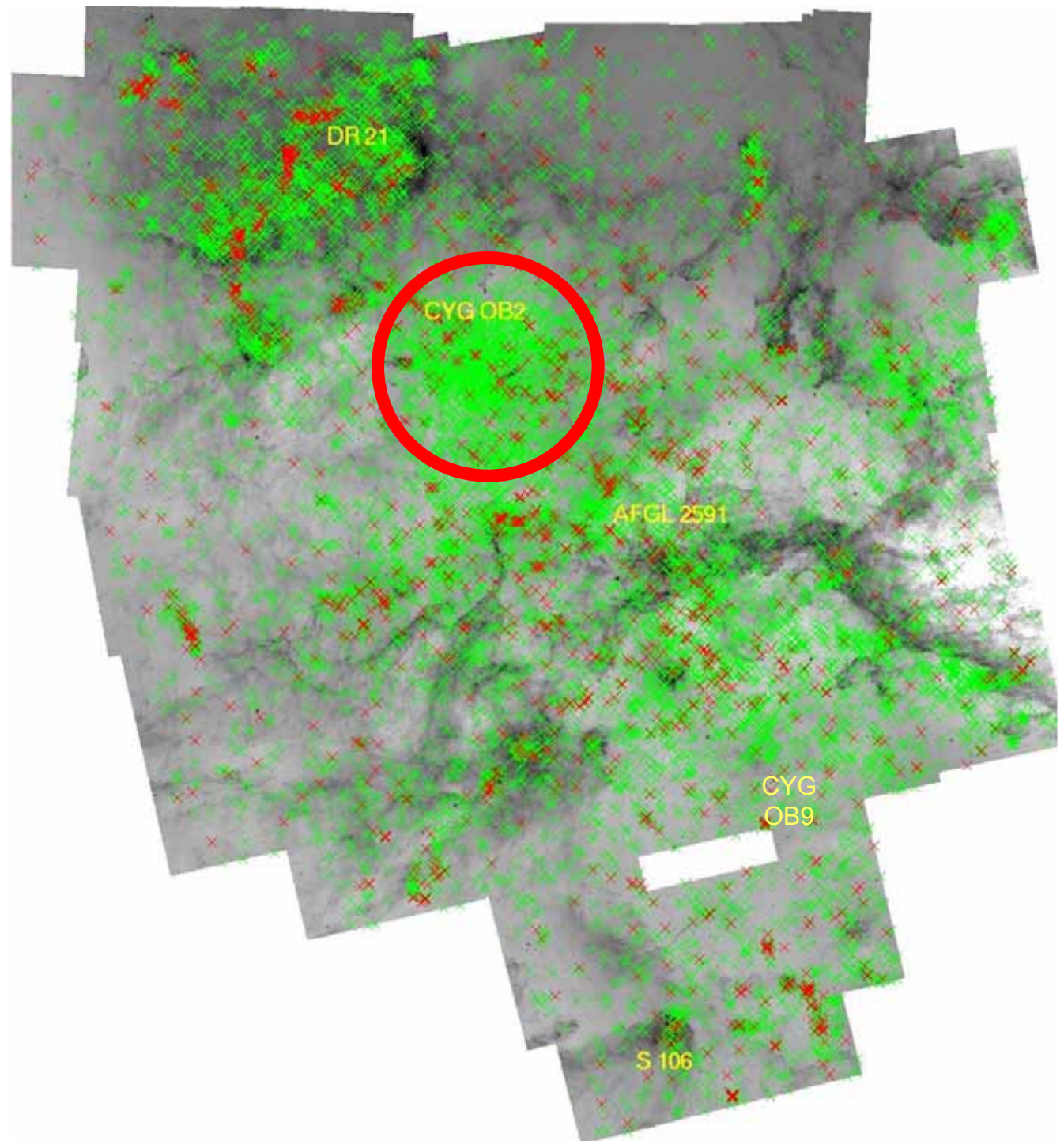
Class II – Green



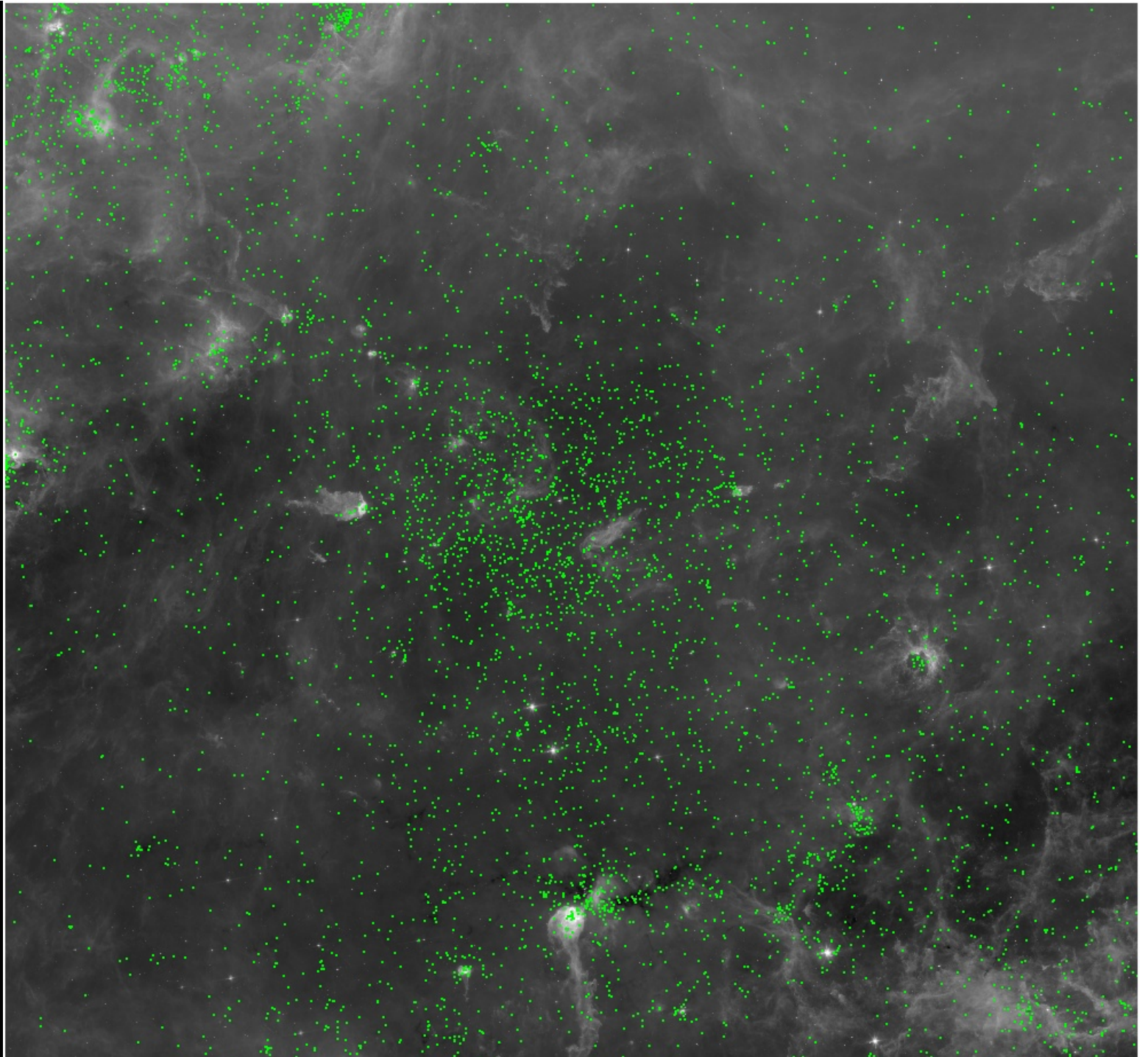
IRAC 8 μm

Class I – Red

Class II – Green

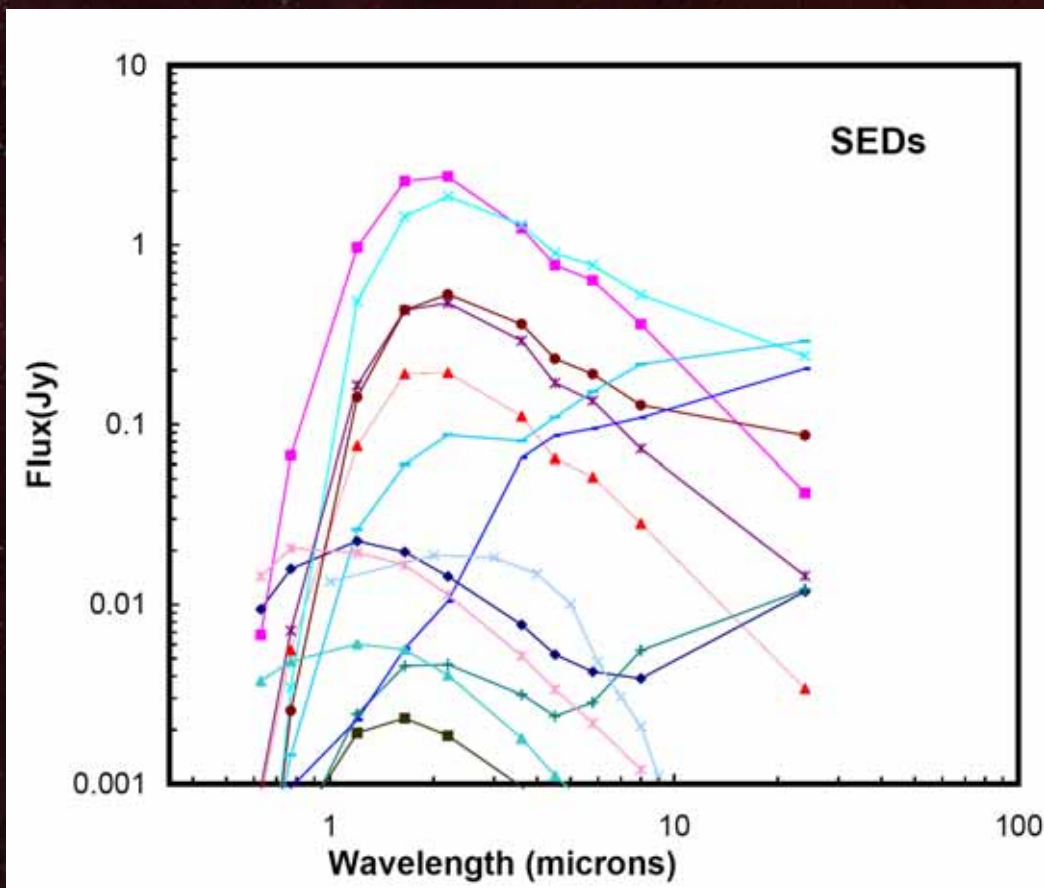


Class II
objects
near
Cyg
OB2



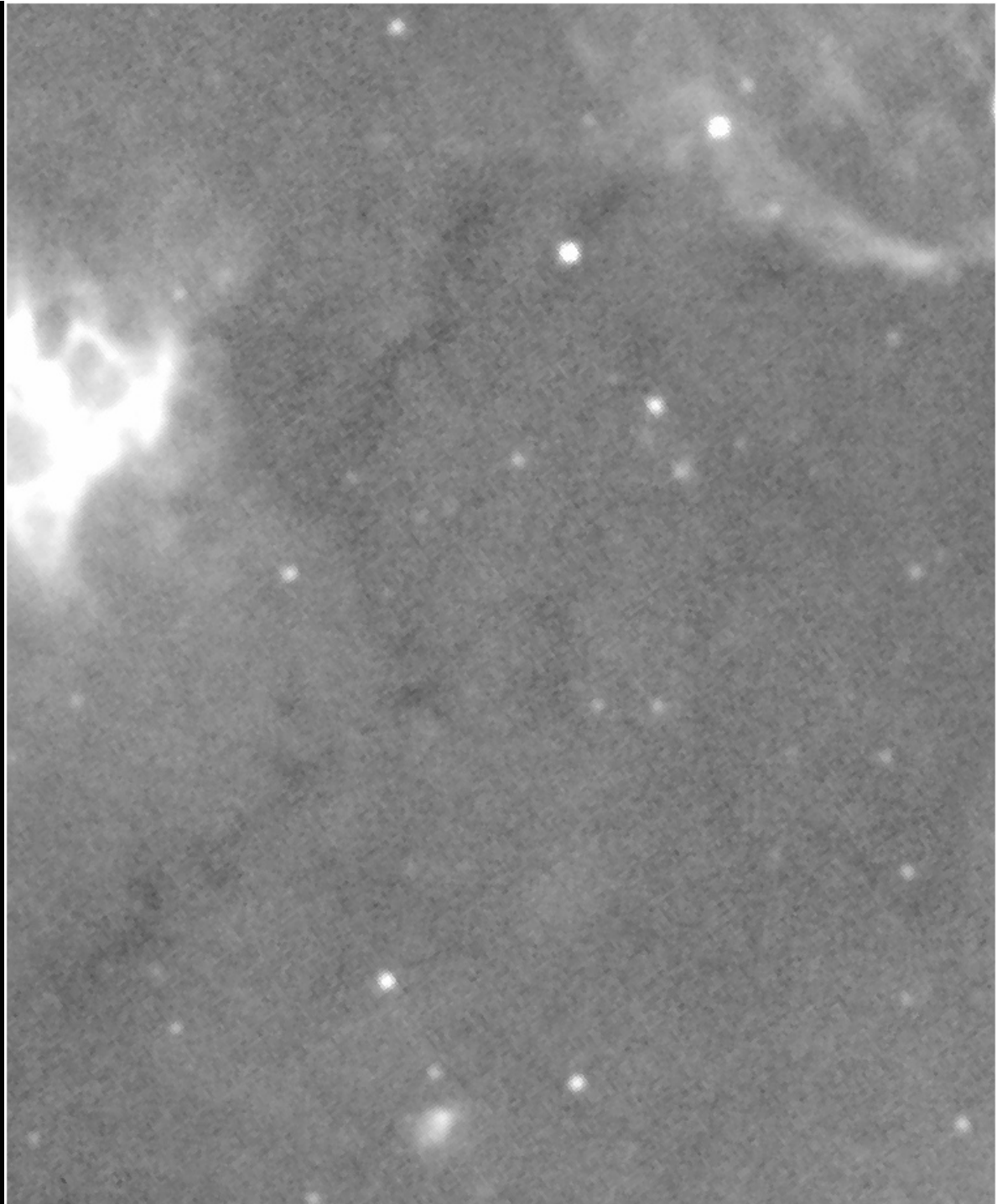
SEDs –

- Can assemble SEDs of objects from optical through mm range
 - IPHAS r' , i'
 - 2MASS J , H , K
 - IRAC 3.6, 4.5, 5.8, 8 μm
 - MIPS 24, 70 μm
 - 350 μm SHARC
 - 1.2 mm MAMBO-2
- Eventually will have:
 - UKIDSS JHK
 - Herschel 75-520 μm
 - SCUBA2 850 μm



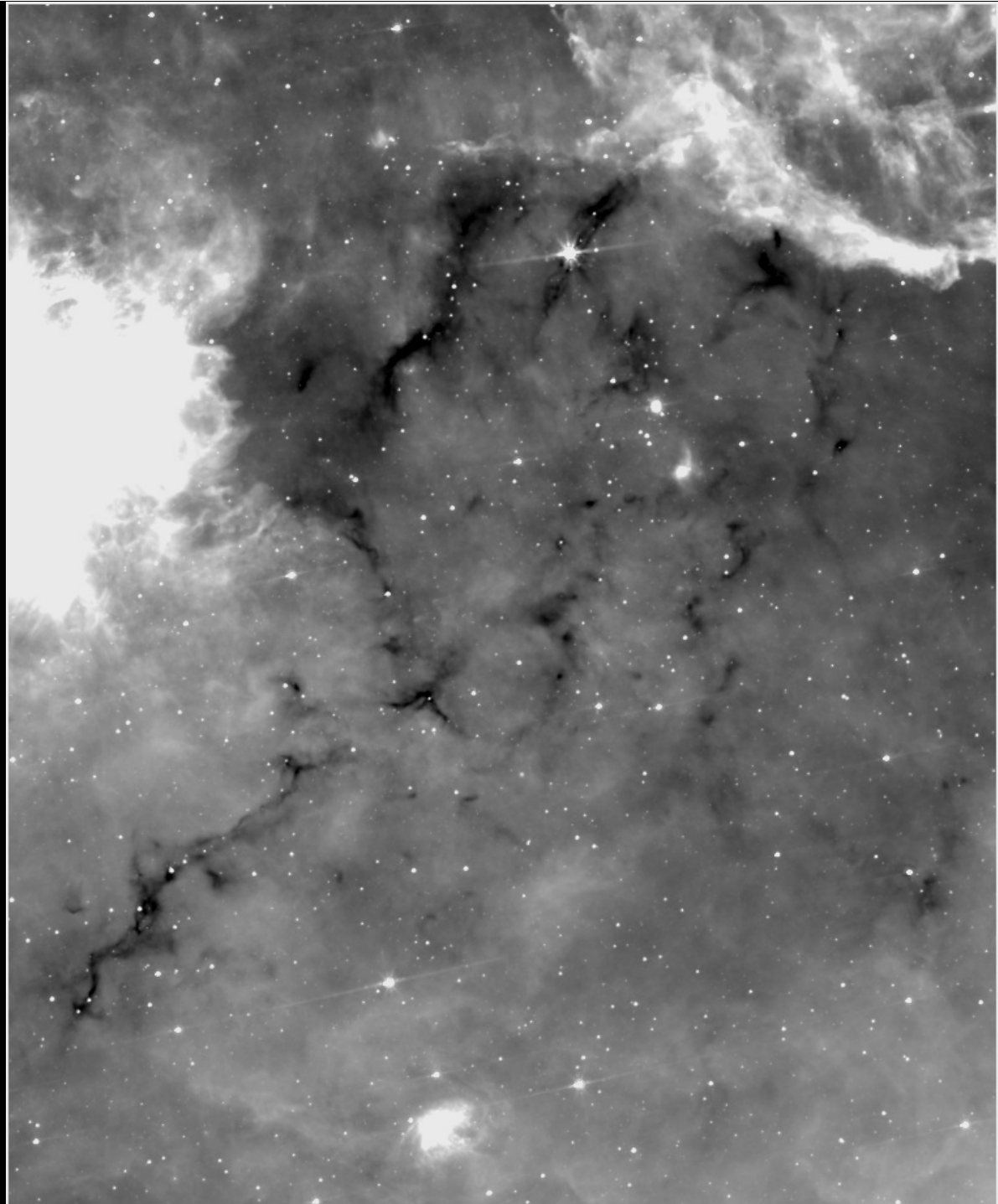
IRDCs – “IR-Dark Clouds”

MSX
8 μ m



IRDCs – “IR-Dark Clouds”

IRAC
8 μ m

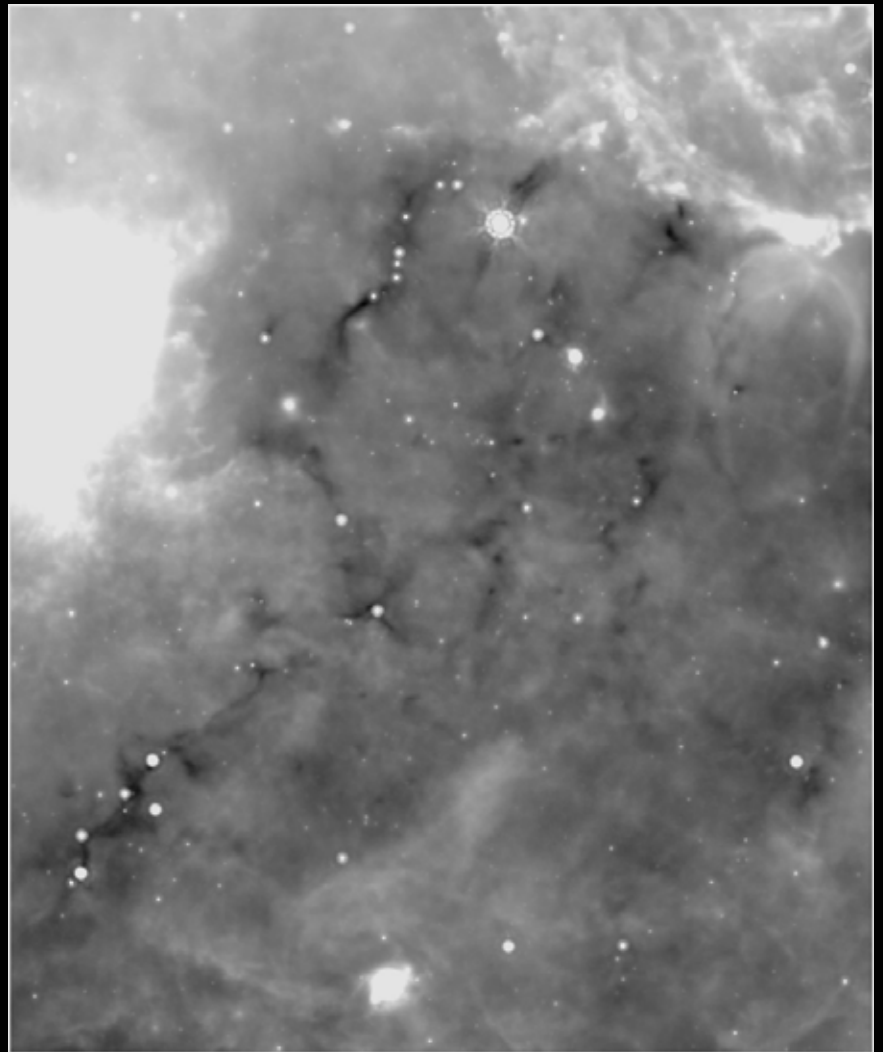


IRDCs

8 μm

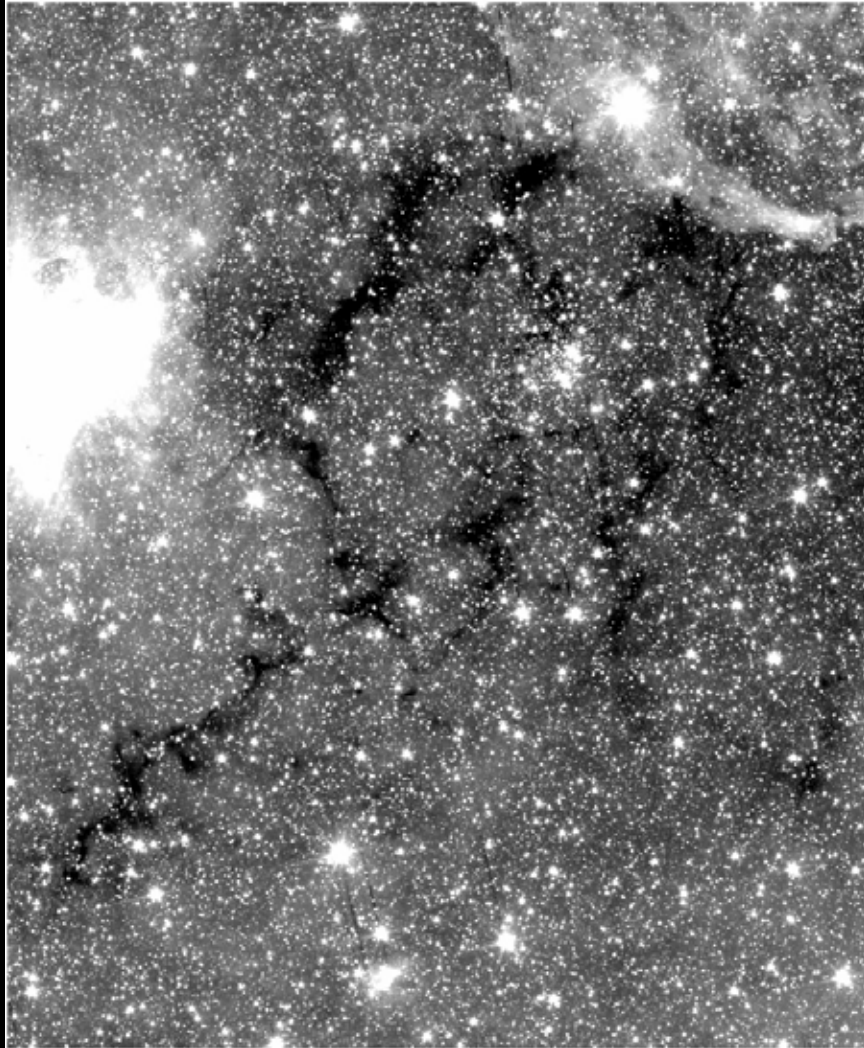


24 μm



IRDCs -

3.6 μm

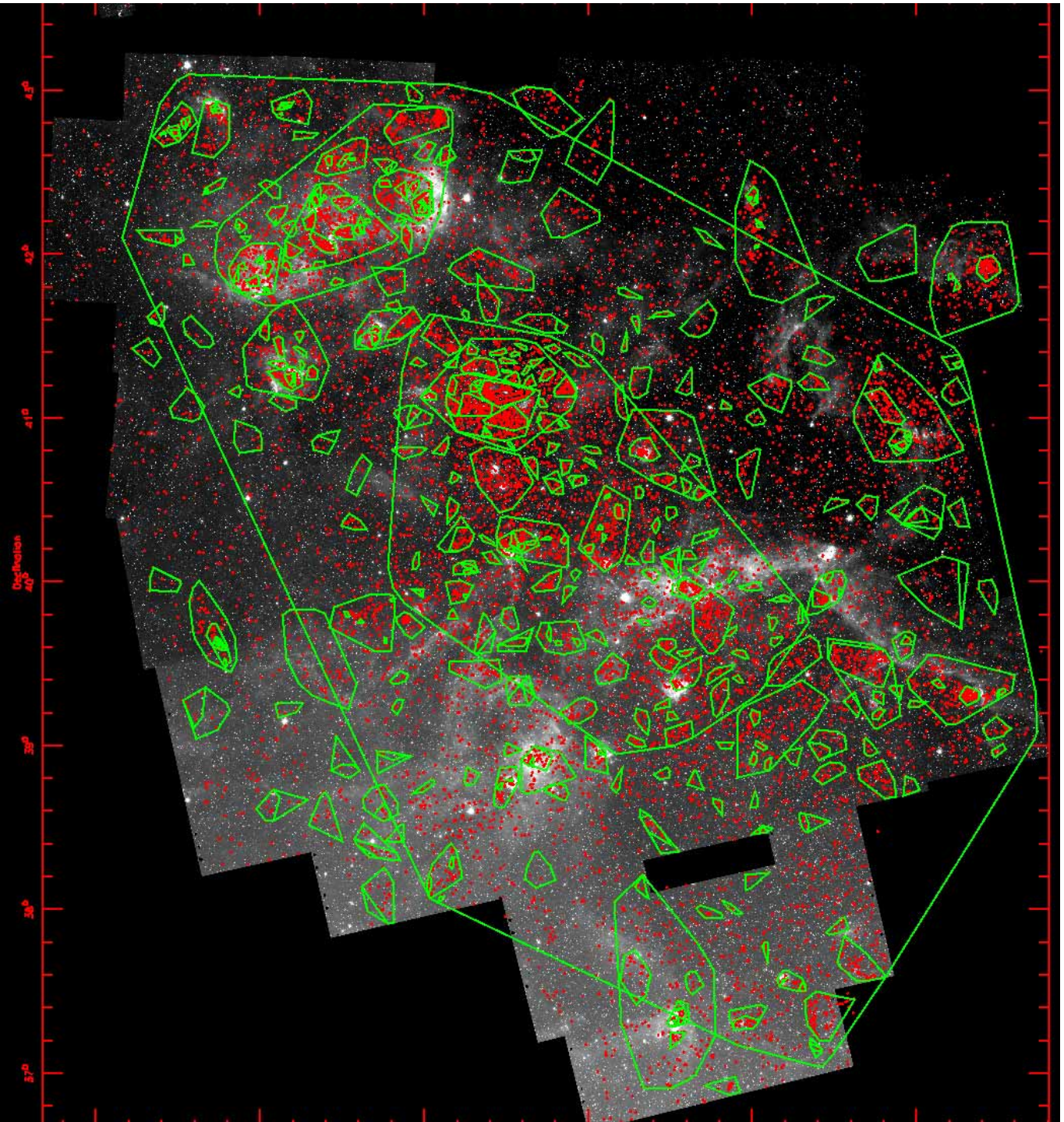


3.6 – 8 – 24 μm

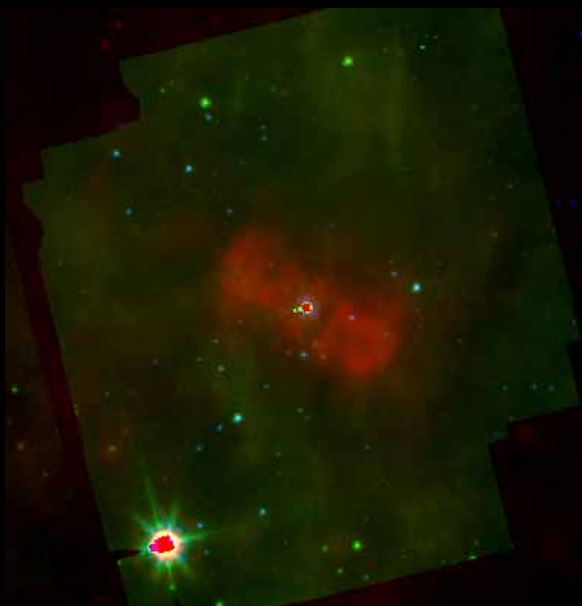


Hierarchical structure

- Finding clusters and groups in Cygnus-X
- Red dots are YSOs
- Green lines show cluster boundaries
- See analysis of other SFRs by Rob Gutermuth (poster #25)



Other objects in the survey

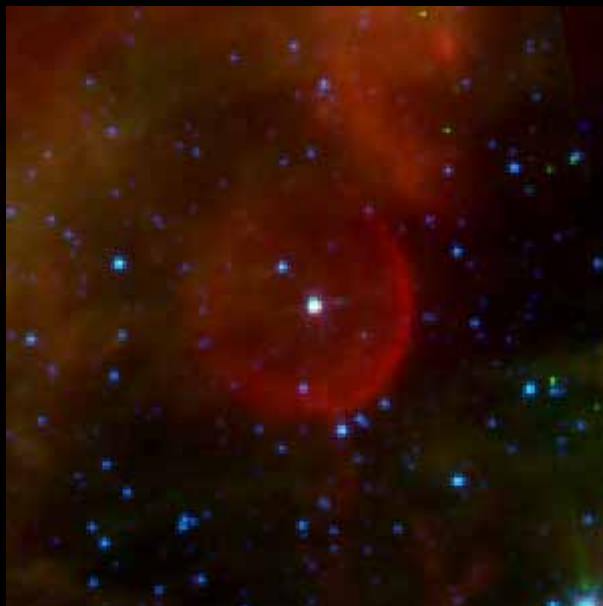


Carbon Star

BD 43+3710

3.6 – 8.0 – 24 μm

24 μm bipolar nebula

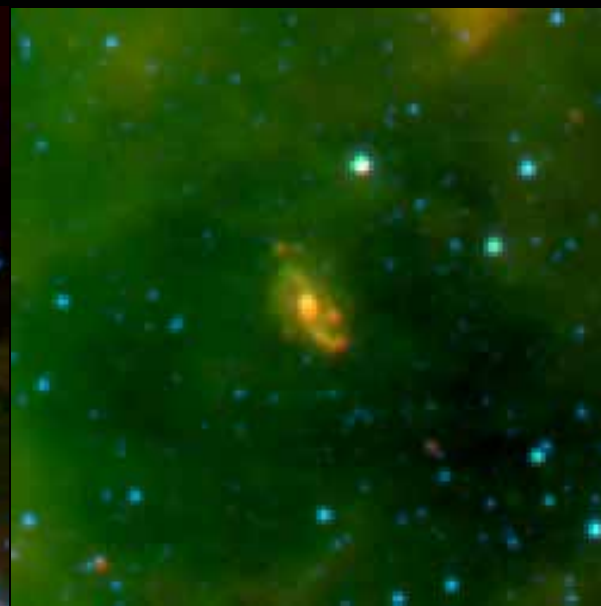


Candidate W-R star

HBHA 4202-22

3.6 – 5.8 – 24 μm

24 μm dust shell



Radio Galaxy

[H92] 32

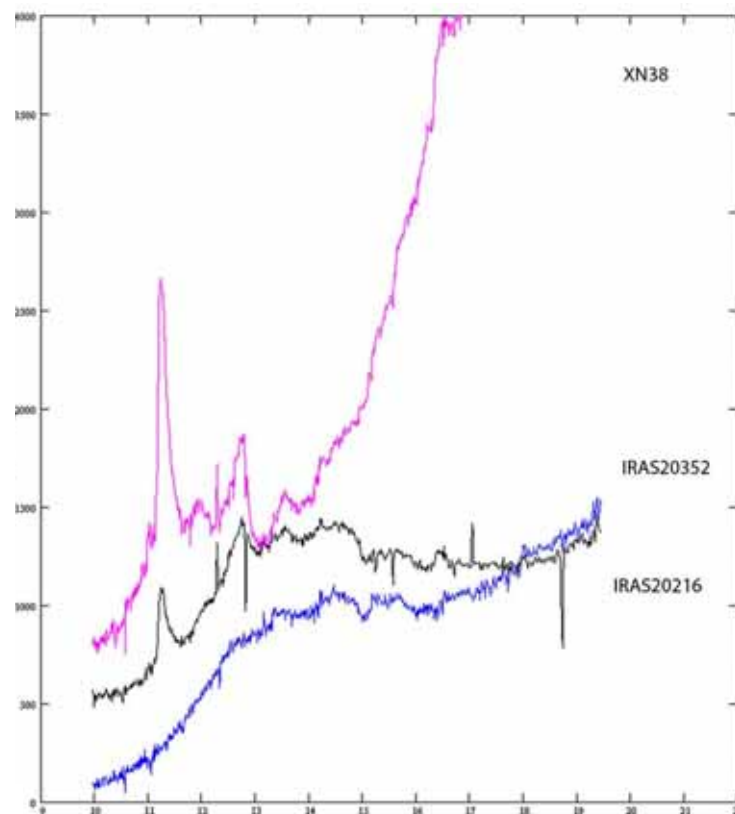
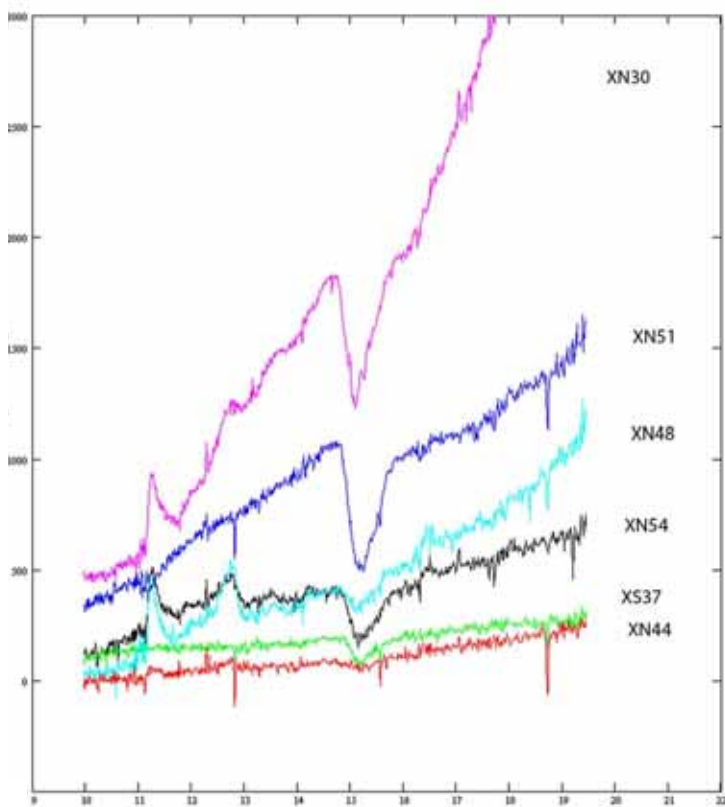
3.6 – 8.0 – 24 μm

Listed as “possible spiral” in 21cm survey

IRS Observations of Massive Forming Stars in Cygnus-X

- ~20 objects chosen for IRS spectra
 - Some are known IRAS/MSX sources
 - Also “infrared-quiet” objects not detected with IRAS but identified in MIPS 24 μm and mm observations as protostars
- IRS spectra, along with other Spitzer data, will determine characteristics of the object
 - SEDs can constrain models of protostars
 - Forbidden line emission can be used to determine stellar temperature
 - Continuum and silicate absorption depth can be used to determine mass of dust, luminosity of the objects
 - H_2 line emission from shocks

IRS SH Spectra – first results



- Fine structure lines and shocked H_2 lines present in spectra
- A range of PAH and silicate strengths observed
- CO_2 ice absorption feature near 15 μm , also seen in the DR21 spectra
 - can be modeled to extract an optical depth and corresponding A_v

Summary

- Cygnus-X is an extremely active region of massive star formation, at 1.7 kpc it is the nearest and largest within 2 kpc
- Will study evolution of high-mass protostars, and the associated low mass star formation in a massive molecular cloud/OB complex
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