Class 0/I Protostars & Triggered Star Formation in NGC281

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Thesis:

Do differences in star formation triggers produce different protostars?

Motivation, Methodology:

A variety of trigger mechanisms are seen to cause the onset of star formation (SF) in the Galaxy.
Larson, R.B. 2003, Rept. Prog. Phys, 66, 1651

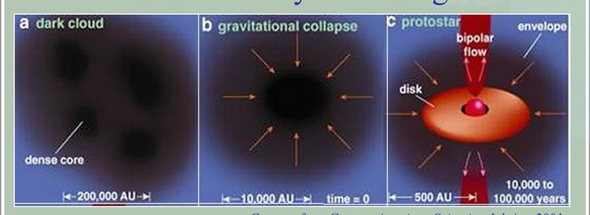
NGC 281 is an unusual case in which two separate triggers appear to be responsible for SF in the same cloud.
Guetter & Turner 1997, AJ, 113, 6.

We used Herschel to map NGC 281 in the far-IR (70, 100, 160 μm).

Herschel observations allow us to identify and measure brightnesses of the youngest protostars

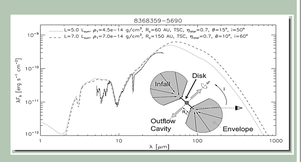
Star Formation:

In the earliest stages of their development, stars are enshrouded by dust and gas.



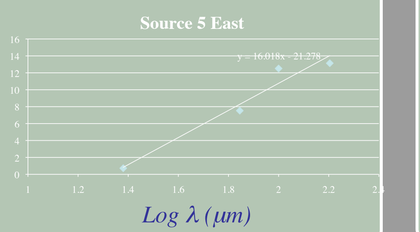
Cartoon from Greene, American Scientist, Jul-Aug 2001

The youngest protostars are most easily identified in the far-IR and sub-mm because the bulk of their emission is in those wavelengths.



Model SED with peak at 70 μm and protostar geometry Credit: Elise Furlan

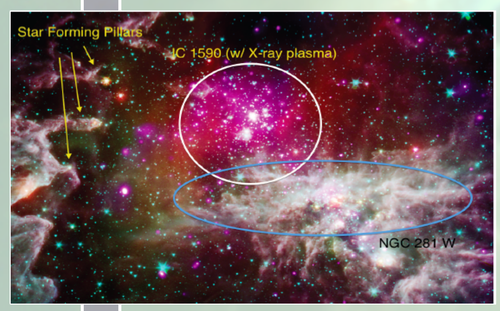
Typical source SED in NGC 281 *Rising SEDs towards the mid-IR mean our sources are at class 0 or 1 stage*



East: Star formation is thought to be triggered by Radiation Driven Implosion (RDIs, *Megeath & Wilson 1997, AJ, 114, 3*).

- 70 visual candidates
- 31 after further vetting

Final Results
- 8 Yes sources
- 23 Maybes

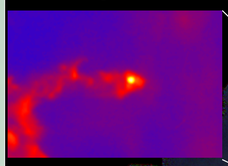


NGC 281 as seen in X-ray and infrared.

NGC 281: A Tale of Two Populations

East

A typical source:
- cocoon-like envelope
- aligned along filament or pillar

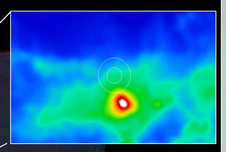


Source ID and Photometry

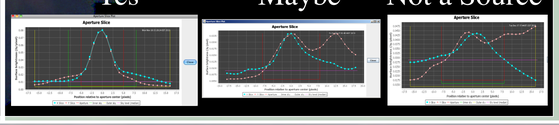
Visual identification from 24, 70, and 100 micron FITS images along with values of full-width half maxima (FWHM) and x-y aperture slices from photometry data led to the determination of a select group of protostar candidates in each region.

West

A typical source:
- located along ionization front



Combined PACS 70 (blue), 100 (green) and 160 (red) micron image of NGC 281 from Herschel



West: Star formation is triggered by lateral compression of gas.

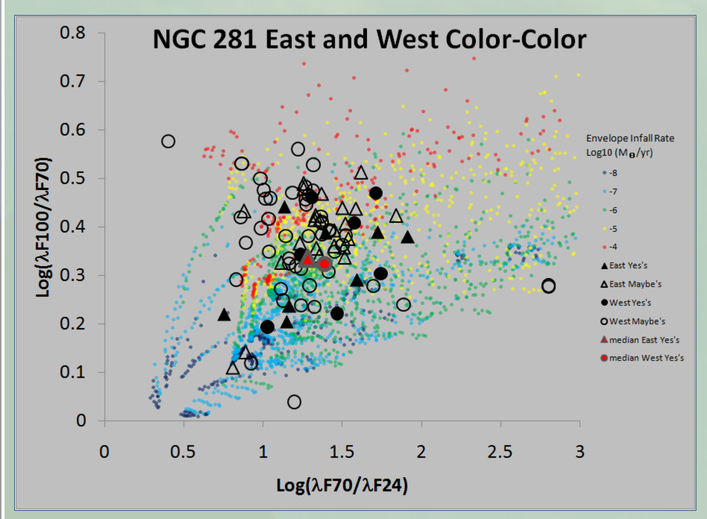
- 118 visual candidates
- 58 after further vetting

Final Results
- 7 Yes sources
- 51 Maybes

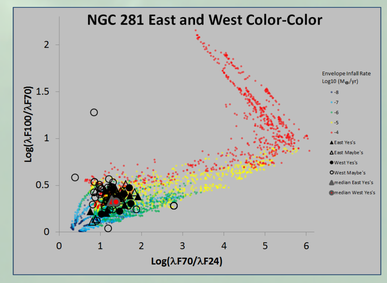
Photometry Details:

We were limited to aperture photometry only.
We used the Aperture Photometry Tool .
http://www.aperturephotometry.org
We cannot reliably determine backgrounds for 160 μm channel with aperture photometry.
Consequently, 160 μm photometry was dropped from further analysis.

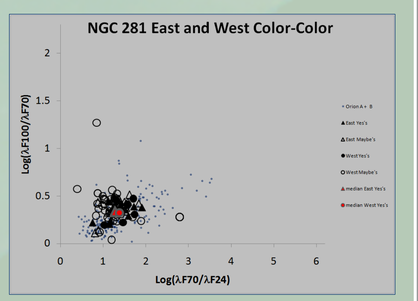
Results:



The East and West populations occupy the same region of the color-color plot. A lack of difference may signify lack of evolutionary differences in the accretion rates, or ages of the two groups.



Comparison of NGC 281 protostars with a grid of radiative transfer models based on physical characteristics of protostars.
Both East and West protostars have mass infall rates consistent with model values less than 10^{-5} $M_\odot$/yr. No protostars are unambiguously consistent with high mass infall rates.



Both East and West sources are bluer than protostars found in the prolific star-forming region of the Orion Nebula.

Conclusions:

East and West side comparison
- We did not find any systematic differences in proto-stellar populations between the East and West groups.
- However, our experiment is sensitive only to the high-luminosity protostars. Differences may yet exist in the low luminosity protostars.

Comparison to models and Orion A&B.
- Protostars in NGC 281 appear to have low mass infall rates, and are bluer than protostars in Orion.

- We offer three scenarios to explain these results:
- Protostars in NGC 281 are at a later evolutionary stage compared to those in Orion.
- It is possible that only the lowest luminosity proto-stars (not detected here) are at an earlier evolutionary state compared to Orion and the models.
- Protostellar evolution is faster in NGC 281 compared to Orion.