Identifying the youngest HII regions in the Large Magellanic Cloud

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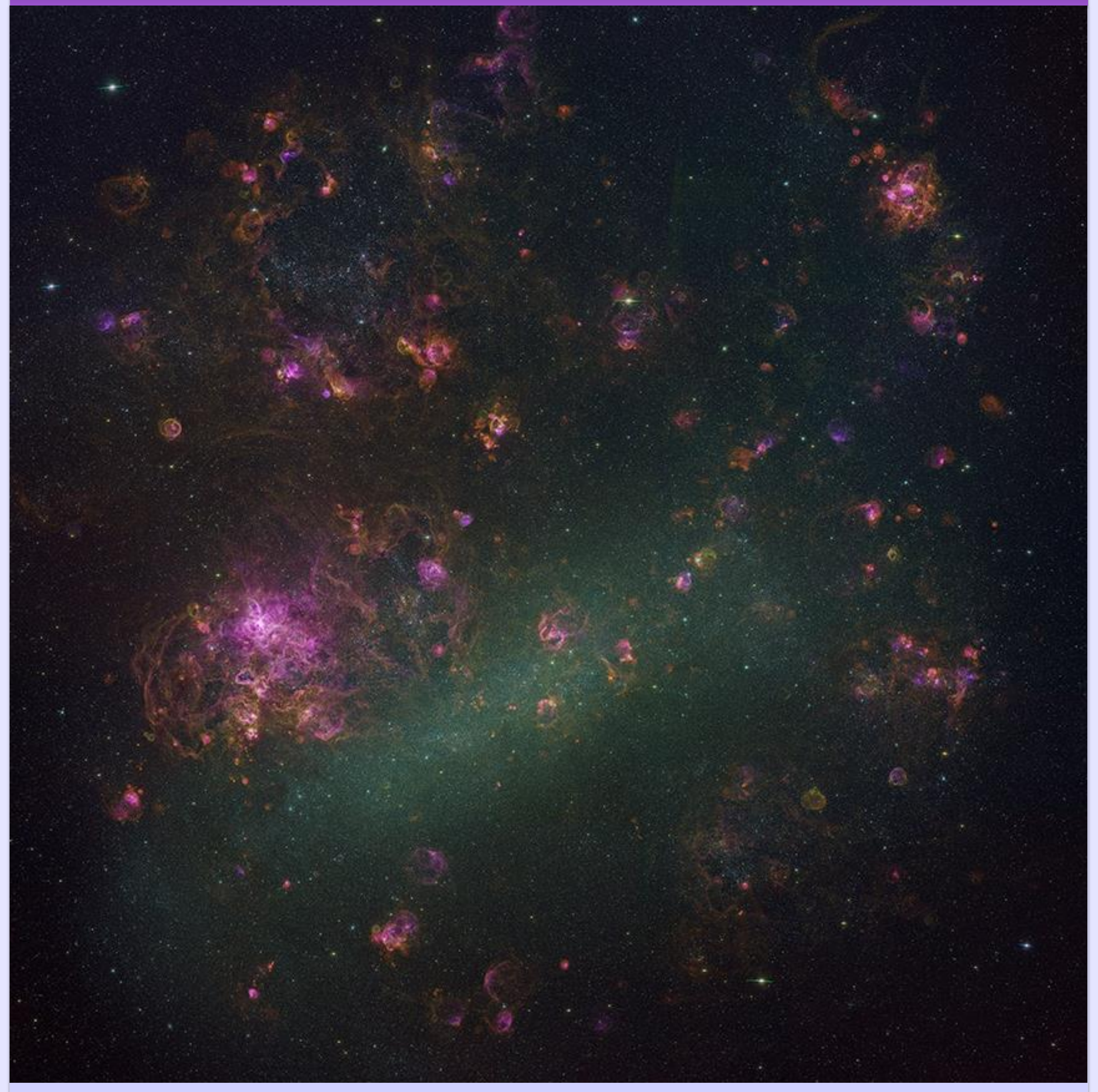
Introduction



Massive stars are known to play an important role in energizing the interstellar medium; however, their formation mechanism is still not well understood. In this study, we have identified compact HII regions around massive young stellar object so that follow-up observations can be made to study how massive stars are formed and how they affect the dynamics of the ambient cloud material in their early lifetime.

Q&A

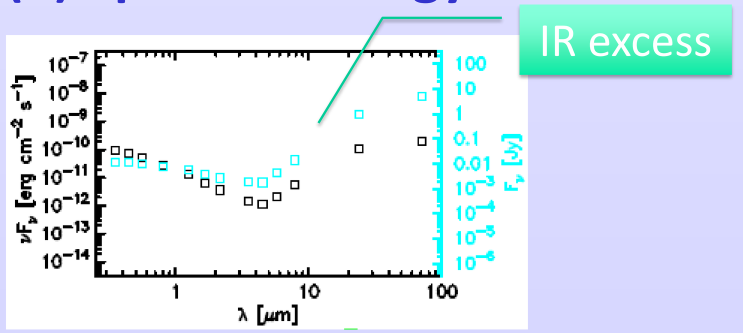
Q: What is an **HII region**?
A: A large, low density cloud photo-ionized by massive stars.
Q: Why survey the **Large Magellanic Cloud**?
A: The known common distance (50kpc) ensures an unambiguous sample.

More questions? Write them down!

Selecting YSO candidates with compact HII region

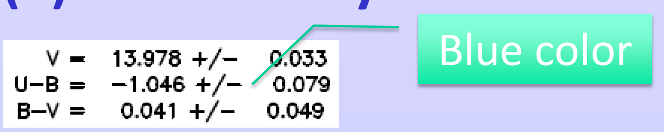
What we were looking for was compact HII regions around massive young stellar objects (MYSOs). Below are the criteria we want our YSO candidates to meet:

(1) Spectral energy distribution with an infrared (IR) excess



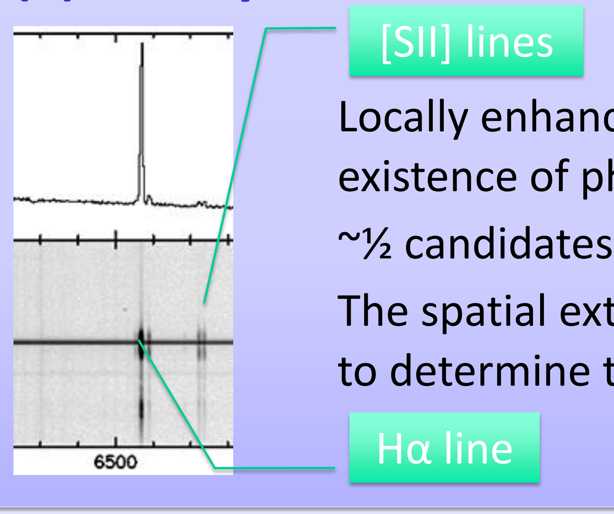
An IR excess suggests the existence of surrounding material. Using Spitzer SAGE survey of the LMC and complementary optical and near-IR images ~270 MYSO candidates was identified.

(2) Photometry with U-B<0

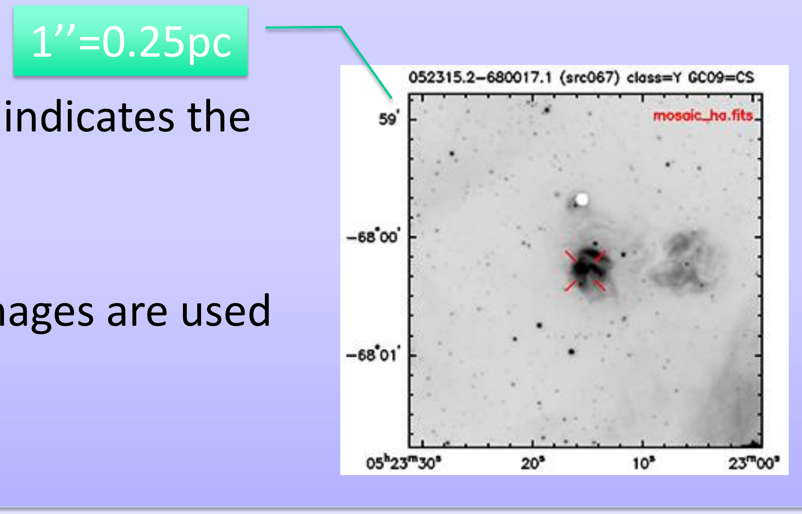


Photometry with U-B<0 suggests that the star is massive. ~70 of the MYSO candidates are blue and long-slit optical spectra were obtain for 54 of them.

(3) Locally enhanced Hα and forbidden line emission



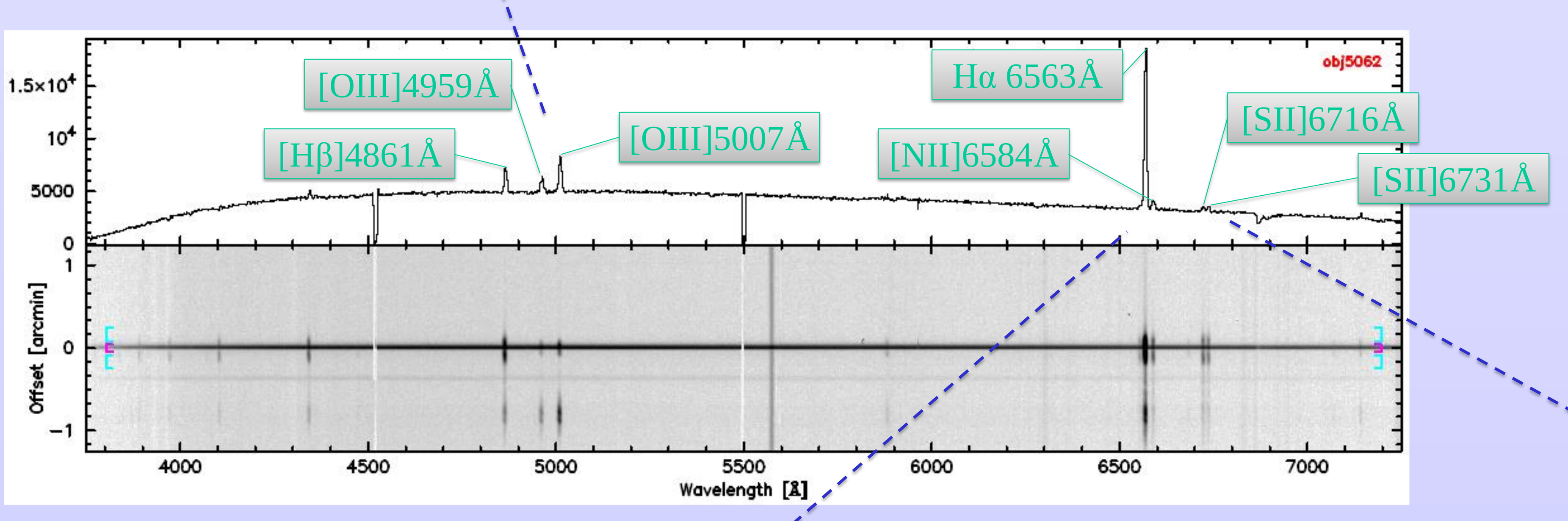
Locally enhanced Hα and forbidden line emission indicates the existence of photo-ionized gas around the star.
~½ candidates exhibit this enhanced emission.
The spatial extents of the spectral lines and Hα images are used to determine the sizes of the HII regions.



Analyzing physical properties

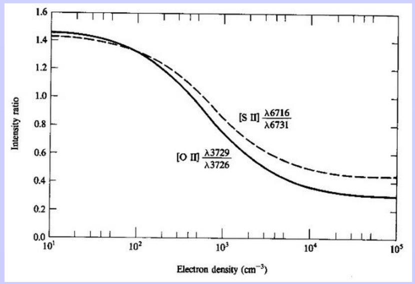
[OIII] 5007Å/Hβ
Temperature of the star

Only O stars show [OIII] emission lines as O6 stars have [OIII]5007Å/Hβ ~1
Using this as a reference, we categorized the YSO candidates into early-O, late-O and B stars.



[NII]6584Å/Hα
Nitrogen abundance and temperature of the star

Density of HII regions can be determined from [SII]6716Å/[SII]6731Å ratio.



HII regions expand as they evolve; thus, young HII regions have high densities.

In the Large Magellanic Cloud, HII regions have [NII]6584Å/Hα ~0.1
HII regions of early-O stars (hotter) have lower [NII]/Hα ratio because N is more highly ionized than N^+.

[SII]6716Å/[SII]6731Å
Electron density of the HII region

Results

	Coordinates	[OIII]/Hβ	[NII]/Hα	6716/6731	ne	HII (pc)
1	054007.2-693204.1	0.00	0.10	1.29	130	1.16
2	052340.5-680528.2	0.00	0.13	1.28	150	1.13
3	045054.5-702201.6	0.00	0.13	1.24	190	0.45
4	054233.2-690236.5	0.00	0.08	1.22	200	0.36
5	050834.7-692525.1	0.00	0.10	1.13	350	very compact
6	050941.9-712742.1	0.00	0.12	1.11	400	0.25
7	053714.0-662659.3	0.00	0.16	1.36	<100	2.13
8	052147.1-675656.8	0.09	0.14	0.84	1200	0.22
9	052757.1-672522.3	0.15	0.14	1.20	250	0.92
10	051340.9-692301.6	0.17	0.25	1.10	400	very broad
11	050439.9-705419.0	0.23	0.14	0.67	2600	0.19
12	051728.4-664307.0	0.35	0.14	0.67	2600	0.22
13	051541.4-675849.8	0.48	0.15	1.05	500	1.90
14	053945.2-694450.4	0.67	0.12	1.05	500	2.02
15	045811.7-662211.3	0.71	0.12	1.09	400	0.68
16	045454.0-692324.5	1.01	0.09	0.84	1200	2.09
17	051730.7-664337.4	1.05	0.10	0.64	3200	very compact
18	052315.2-680017.1	1.55	0.06	1.25	200	3.93
19	053827.4-690809.0	2.06	0.08	1.18	270	very broad
20	052133.2-694019.9	2.53	0.09	1.23	200	very broad
21	045426.1-691102.3	3.20	0.05	0.86		overexposure
22	053838.5-690418.3	3.24	0.04	1.10	400	very broad
23	050950.1-685349.4	3.44	0.05	1.42	<100	2.07
24	053949.2-693747.4	5.39	0.00	0.00		very broad
25	053849.8-690643.3	5.59	0.00	0.00		1.43
26	053820.7-704057.8	5.78	0.02	1.02	560	2.64
27	053909.1-690128.7	7.57	0.05	1.04	500	very broad

- Among the massive young stellar object candidates, 8 are categorized as B stars, 11 as late-O stars and 11 as early-O stars.
- The HII regions around early-O stars have the lowest [NII]/Hα ratios, which is consistent with the expectations for hot stars.
- The young compact HII regions can be diagnosed by their high densities and small sizes. Many are identified around late-O stars.
- Early-O stars in general have lower densities in their HII regions, most likely resulting from the action of the powerful stellar winds.

Conclusions

Our study has identified 12 promising MYSOs with compact HII regions. These have been included in a proposal requesting Hubble Space Telescope imaging observations. The high-resolution images will reveal the morphology of the HII regions and whether low-mass stars are formed along with the massive stars. These results will allow us to study the formation mechanism of massive stars and how they interact with the ambient medium.