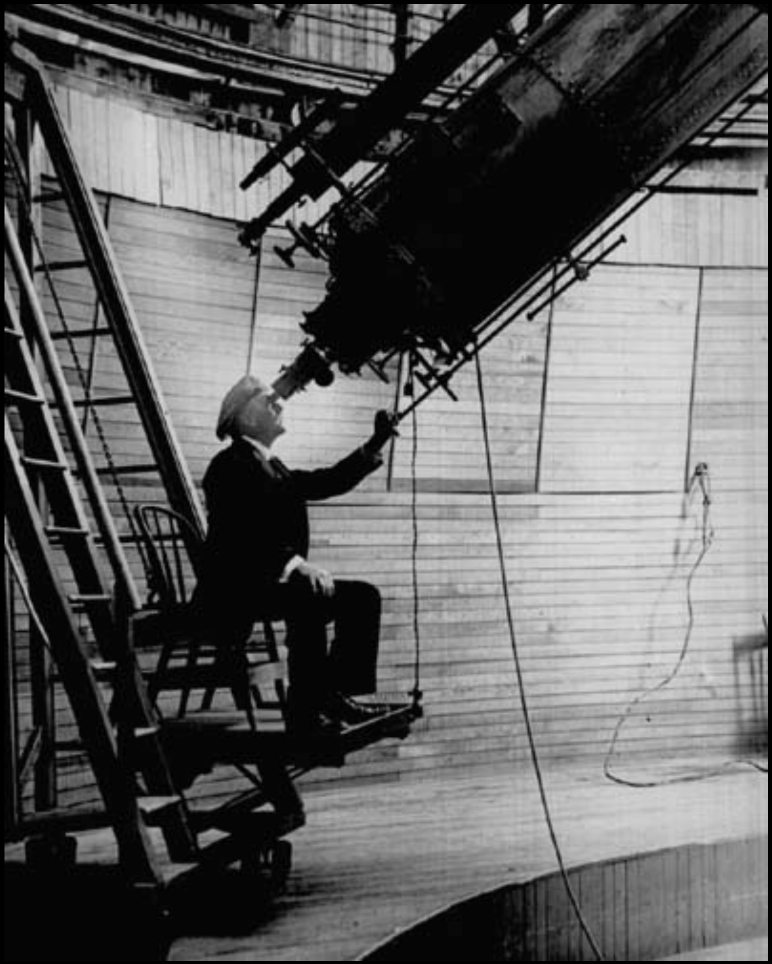
Star Birth at an Extreme: The Shrinking Womb

Deidre Hunter

Lowell Observatory

Civil Air Patrol, June 28, 2014

Lowell Observatory has a rich scientific history.



Percival Lowell observing Mars at the
24-inch refracting (Clark) telescope

Lowell Observatory today

Image: Len Bright

4.3-meter Discovery Channel Telescope

Mars Hill

Visitor Center

Anderson Mesa: NPOI, 1.8 m, 1.1 m, 0.8 m, LONEOS schmidt

Titan Monitoring Telescope

Lowell Observatory today

Scientific staff---
- 14 active PhD astronomers
- 1 assistant research scientist
- 2 post-docs
- 1 pre-doc
- seasonal undergraduates
- several research assistants

Inner Solar System
- Asteroids, comets

Outer Solar System
- Pluto, KBOs, outer planet seasons, weather on Titan

Exoplanets
- Searches, star-planet interactions

Low mass stars
- Atmospheres, formation and evolution

Intermediate mass stars
- Long term variability of solar-type stars, binary star masses, circumstellar disk evolution, fundamental properties

High mass stars
- Evolution

Nearby Galaxies
- Dwarf galaxies, disk dynamics

A bird's eye view of star formation

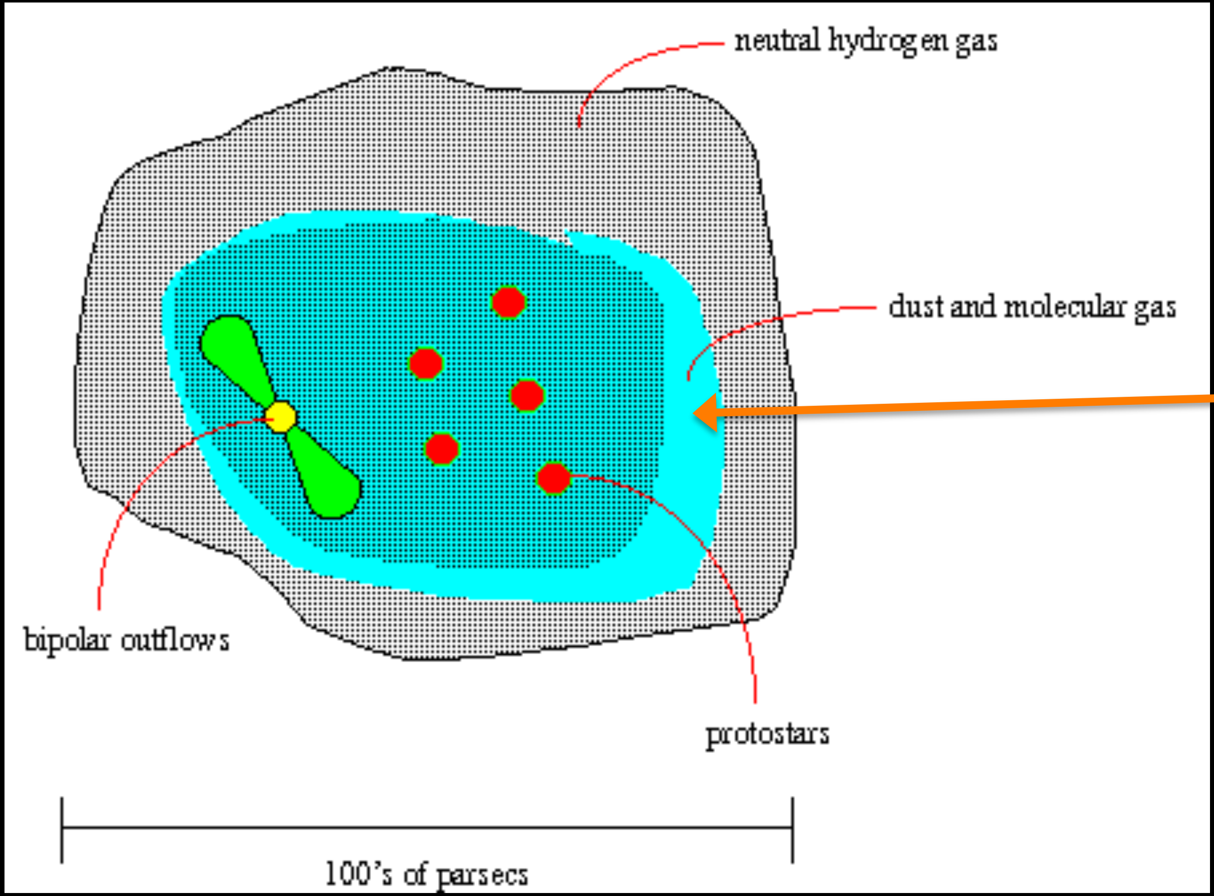
Stars form from clouds of gas.

- Between the stars is a very tenuous gas.
- Because galaxies are so big, there is a lot of mass in interstellar gas.
- Originally the gas was just Hydrogen, 8% Helium

Orion Nebula

Schoening/NOAO/AURA/NSF

Molecular clouds form from atomic clouds



H_2 traced by CO

http://abyss.uoregon.edu/~js/ast122/lectures/lec22.html

Stars form in “dense” molecular clouds – the womb

HST image,Hubble Heritage Team (STScI/AURA)/NASA

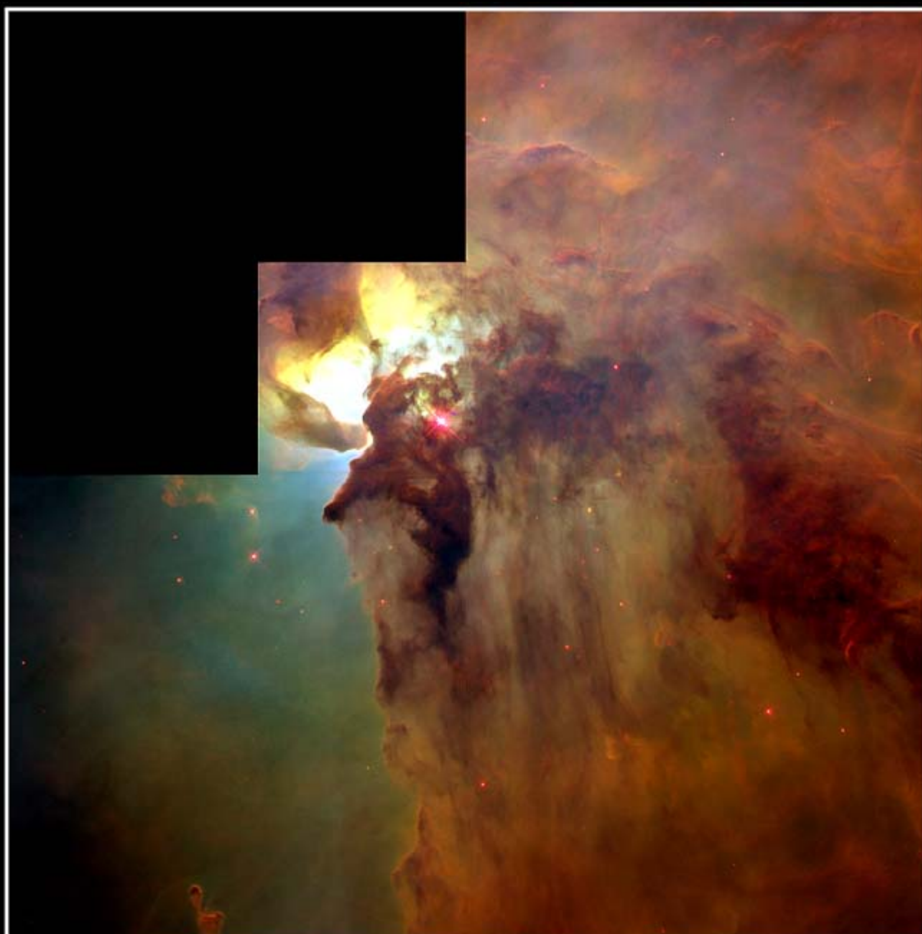
Protoplanetary Disks HST • WFPC2
Orion Nebula

PRC95-45b • ST ScI OPO • November 20, 1995
M. J. McCaughrean (MPIA), C. R. O'Dell (Rice University), NASA

The "Black Cloud" B68
(VLT ANTU + FORS1)

ESO PR Photo 20a/99 (30 April 1999)

The process of star formation is inefficient: 50-95% of the gas is leftover.



Lagoon Nebula • M8 HST • WFPC2

PRC96-38a • ST ScI OPO • January 22, 1997
A. Caulet (European Southern Observatory) and NASA

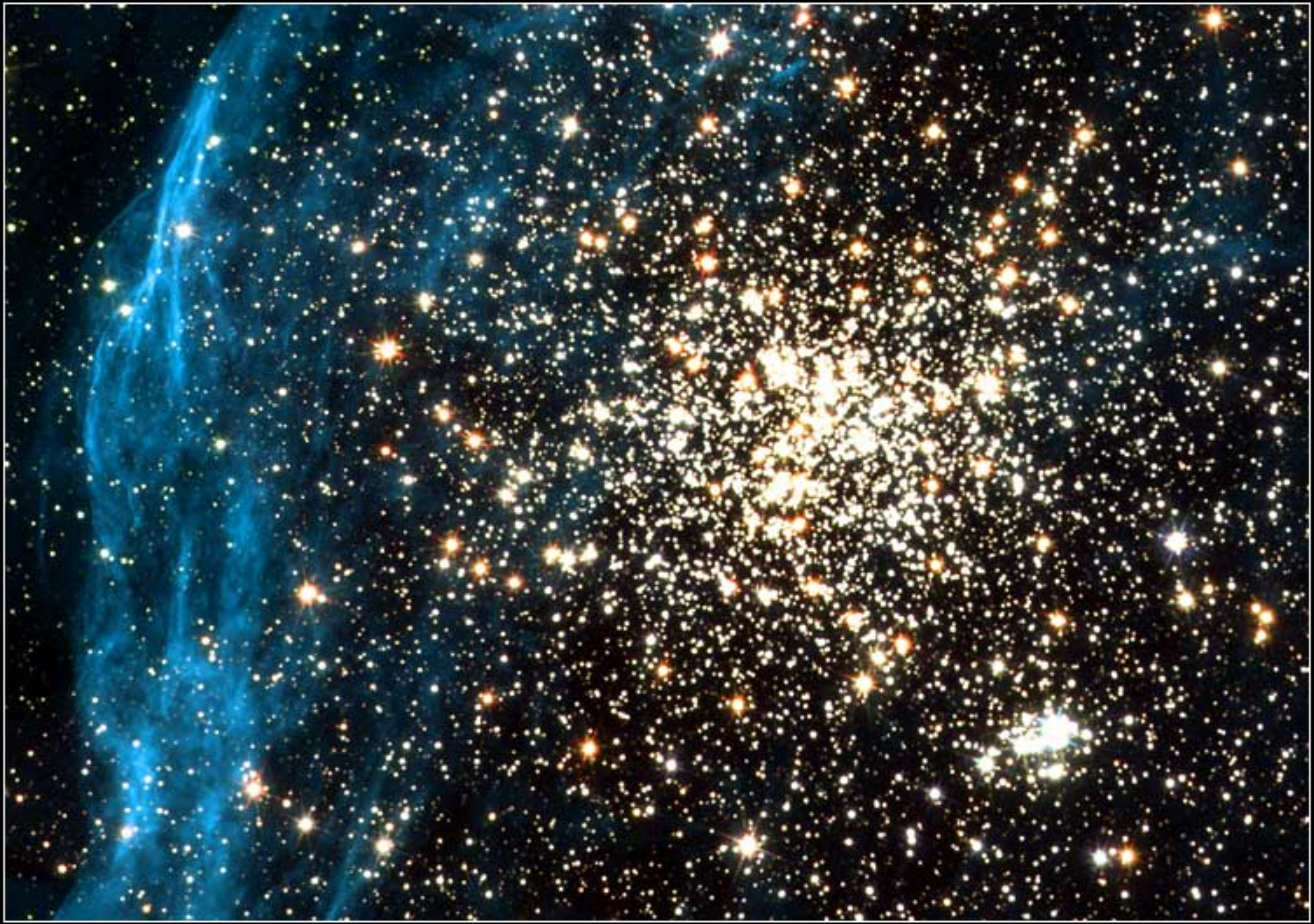
Sharp, REU program/NOAO/AURA/NSF

Massive stars break up their molecular cloud.

Nebula N83B (NGC 1748) in the Large Magellanic Cloud **HST**

NASA, ESA, and M. Heydari-Malayeri (Observatoire de Paris, France) • STScI-PRC01-11

A massive star cluster in the LMC



NGC 1850 • Star Clusters in the Large Magellanic Cloud **HST** • WFPC2

NASA, ESA and M. Romaniello (European Southern Observatory) • STScI-PRC01-25

Formation of the molecular cloud depends on dust and heavy elements

- As a shield: Protect the molecules from dissociation by UV radiation from stars
- As a coolant: Remove energy so that a cold, dense cloud can form

But in the early universe the first stars formed from H+He only.
They slowly polluted the universe with dust and heavier atoms.
But not all galaxies are as polluted as the Milky Way.

Dwarf galaxies as nearby sites of star birth at low abundances

Young dwarf galaxy?

But what are dwarf irregular galaxies?

Dwarf Irregular galaxies are irregular.

DDO 63

Hunter & Elmegreen, Lowell 1.1 m

Dwarf galaxies are tiny.

M74
Boroson/AURA/NOAO/NSF

DDO 75: A dwarf galaxy
Hunter & Elmegreen, CTIO 0.9 m

Dwarf galaxies are faint.

Leo T

Irwin et al. 2007

Leo T is comparable in brightness to a large star cluster that contains several million stars.

Dwarf galaxy abundances are low.

DDO 75

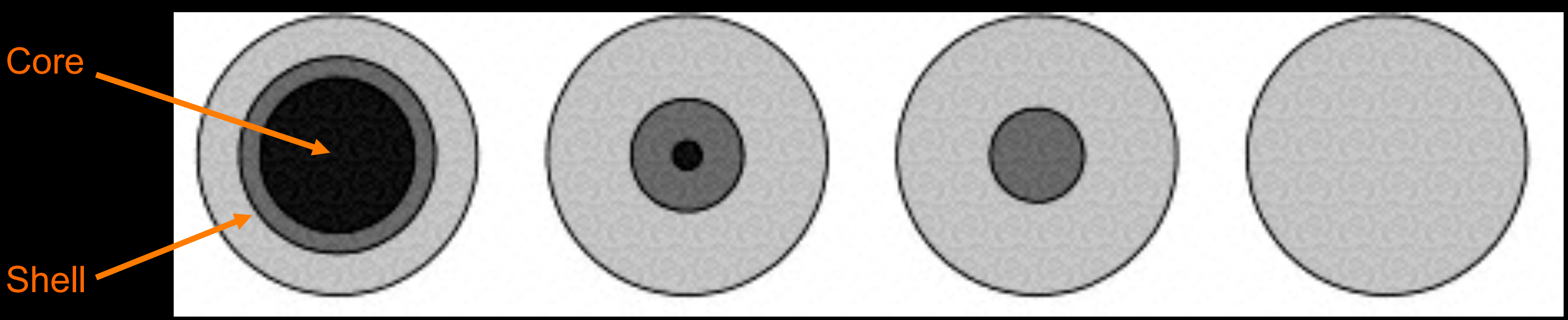
Hunter & Elmegreen, CTIO 0.9 m

- Low in heavy elements
    - Down to 1/60th solar
- Low in dust

Star forming clouds at low abundances

Consequence of low abundances: change in structure of molecular cloud

Theory



Bolatto et al. 1999

Core usually traced by CO.
Shell bright in [CII]λ158 μm.

Collaborators

Phil Cigan (New Mexico Tech) - PhD dissertation on *Herschel* observations
Celia Verdugo (Univ of Chile) – Master's student worked on APEX observations

Elias Brinks (Univ Hertfordshire)
Bruce Elmegreen (IBM T J Watson Research Center)
Monica Rubio (Univ of Chile)
Caroline Simpson (Florida International University)
Lisa Young (New Mexico Tech)

Shrinking CO core means they are harder to detect: CO “detection barrier” of 20%×solar abundance

APEX – sub-millimeter telescope in the Atacama Desert

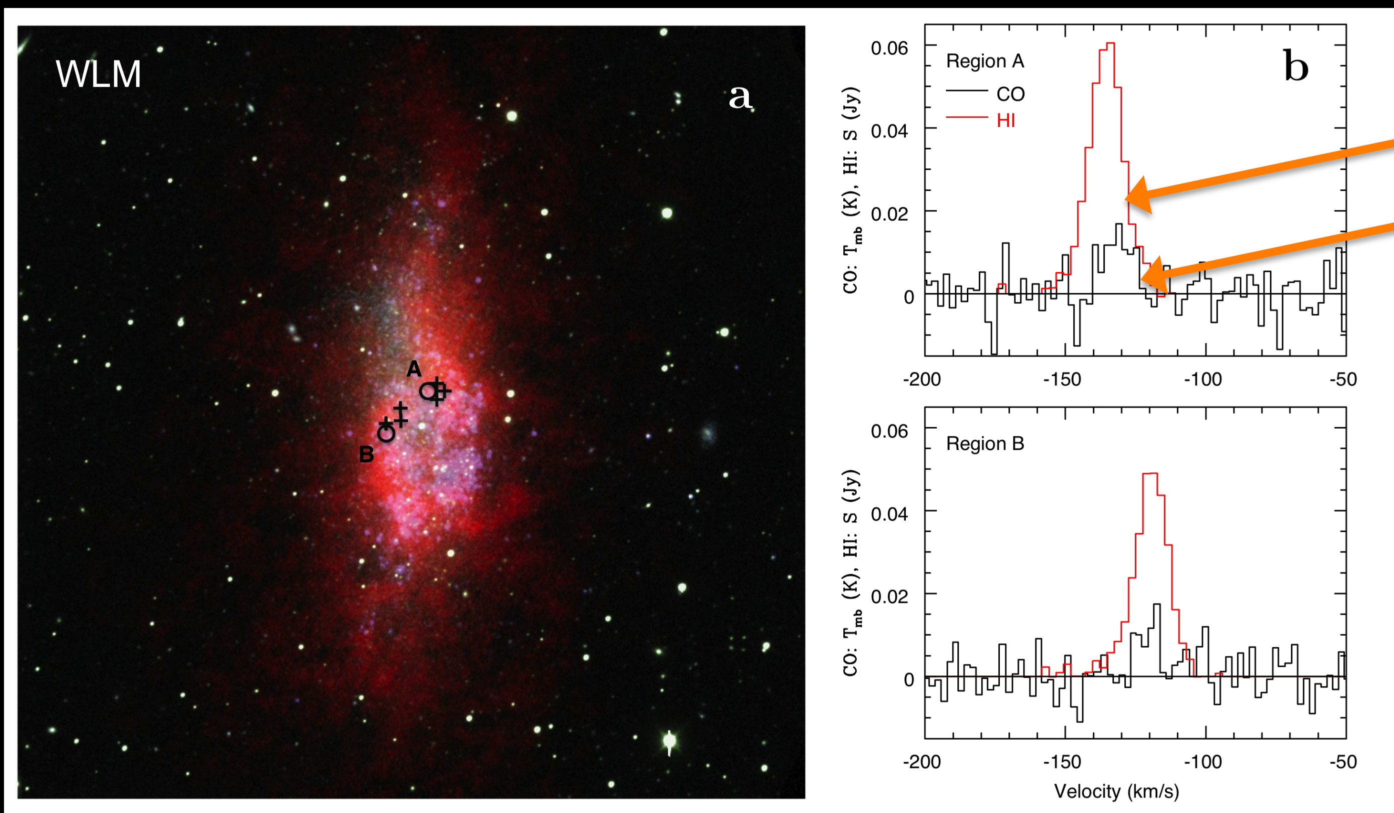
CO (3-2)

Beam of 18” = 290 light years at WLM (87 parsecs)

Bérengčre Parise

We detected molecules in the most heavy element poor galaxy ever!

8x lower abundances than the Sun



Atomic gas

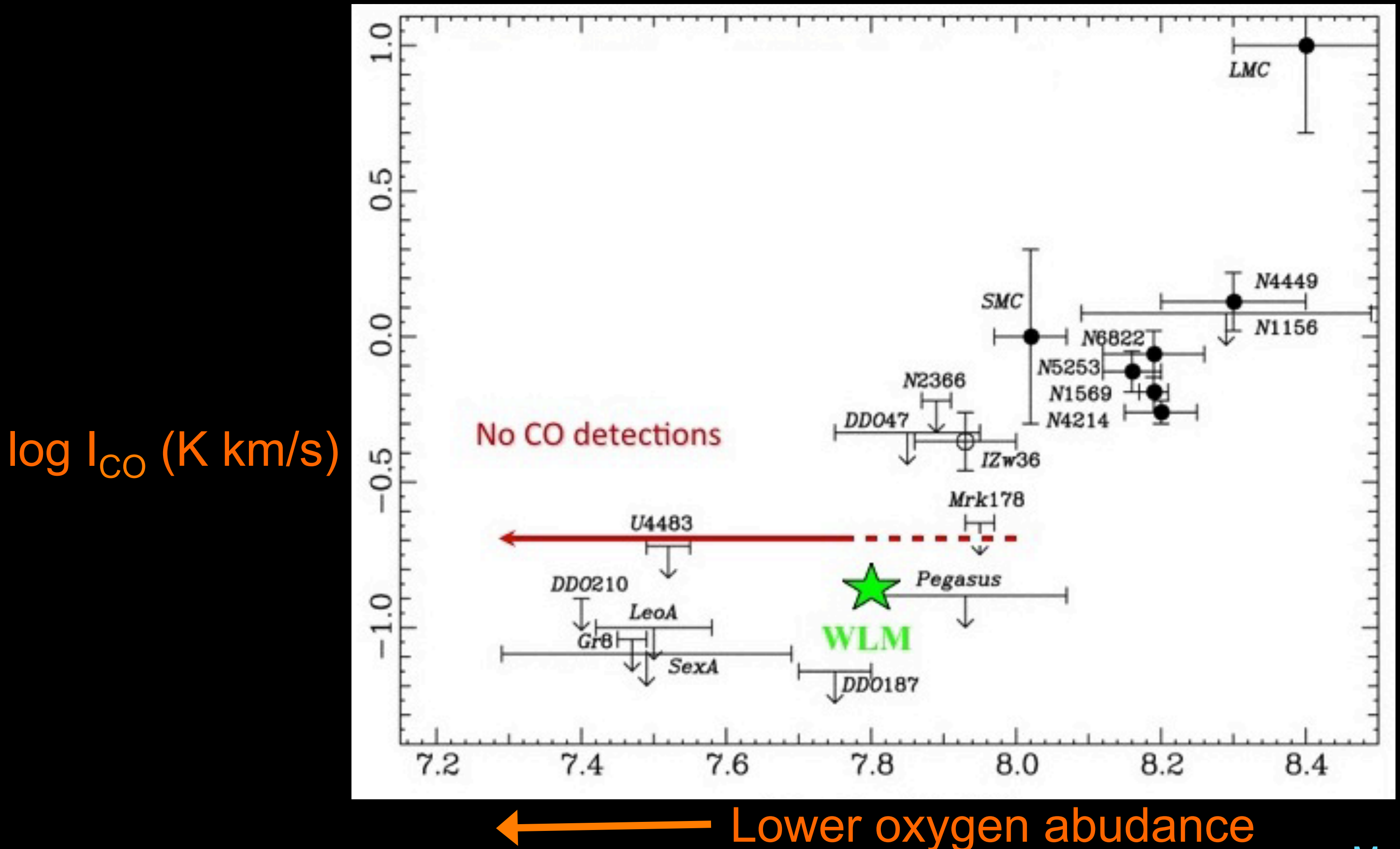
Molecular gas

Intensity of emission

Elmegreen et al. 2013

Velocity of gas

WLM detection in context



M. Rubio

Non-WLM data: Tacconi & Young 1987;
Taylor et al. 1998
WLM data: Elmegreen et al. 2013

The molecular clouds in WLM

Masses of H_2 are $1\text{-}2\times10^5\ M_\odot$

➔ Star formation is occurring in giant molecular clouds even at 13%×solar abundances.

Elmegreen et al. 2013

Herschel observations of the shells of molecular clouds in 5 abundance-poor dwarf galaxies

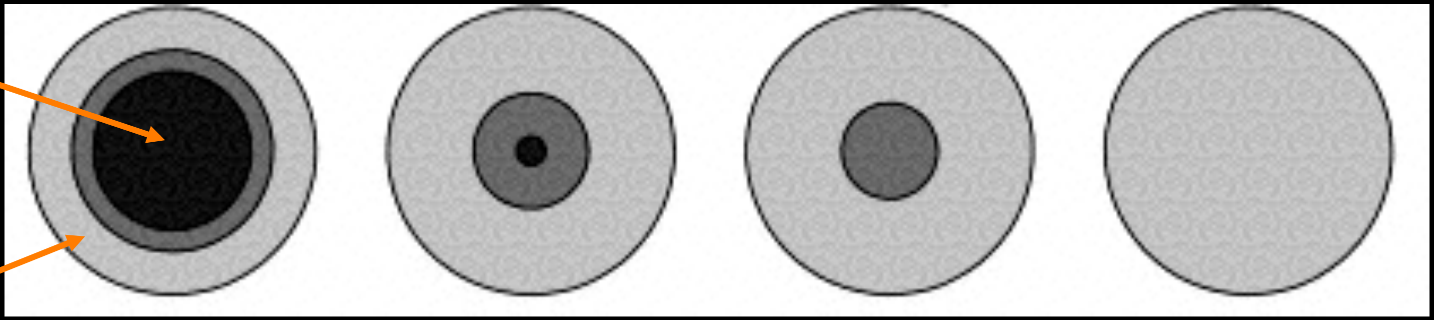
Cigan et al., in prep

Solar abundances

Theory

Very low abundances

Core



Shell

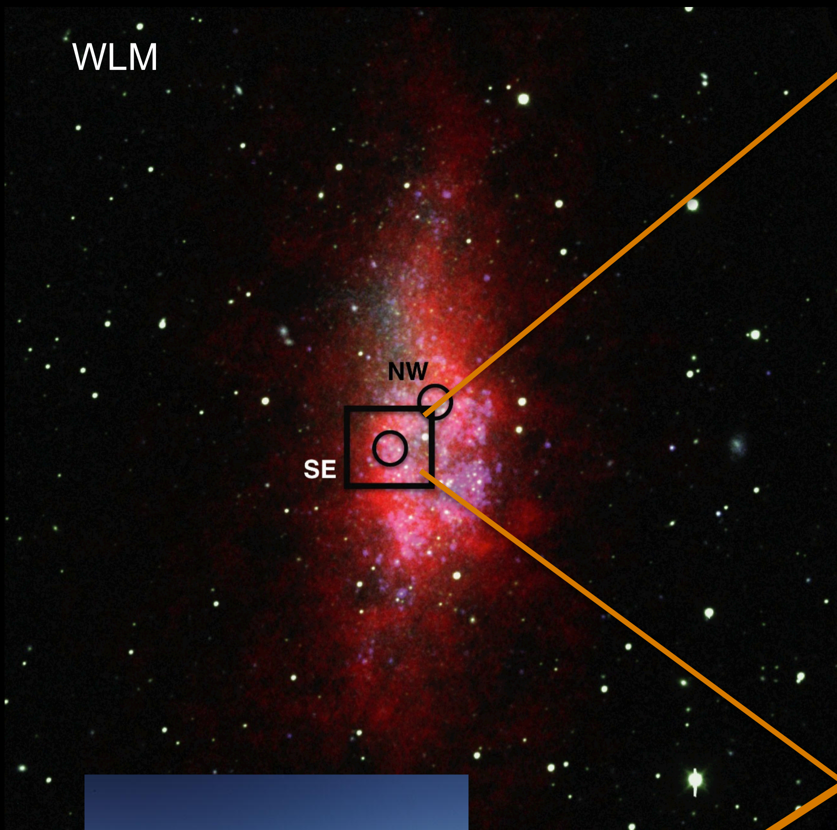
Bolatto et al. 1999

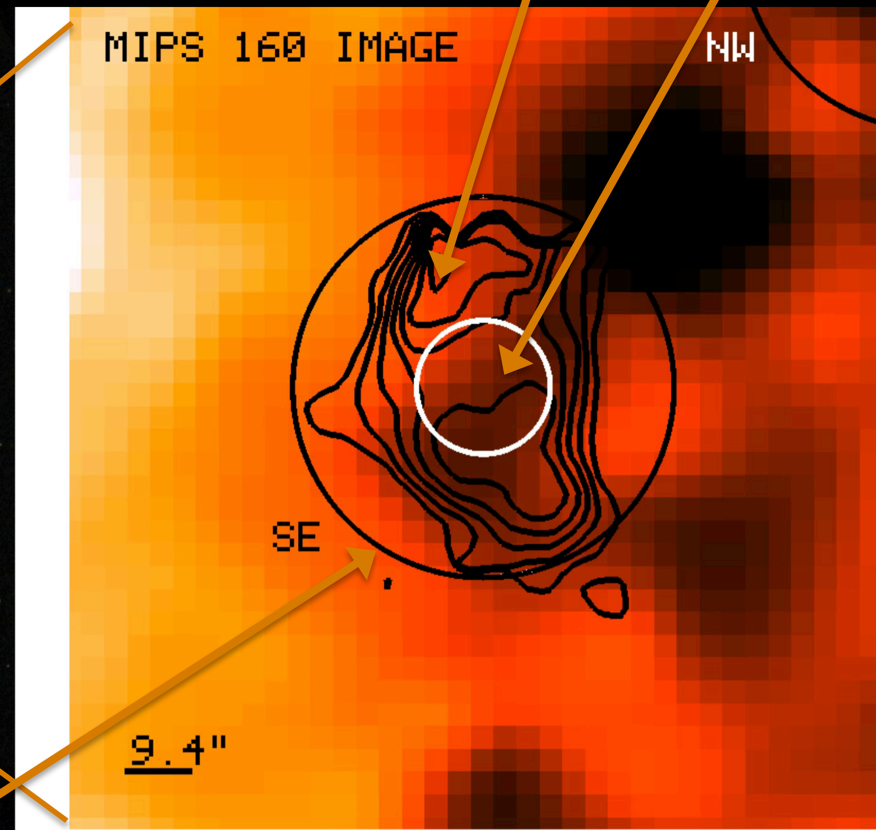
Molecular core + shell – like a baseball in a glove

Molecular cloud shell,
Observed with *Herschel*

Image: Warm dust

CO core from APEX





Region being mapped in CO with ALMA

WLM - Region B:

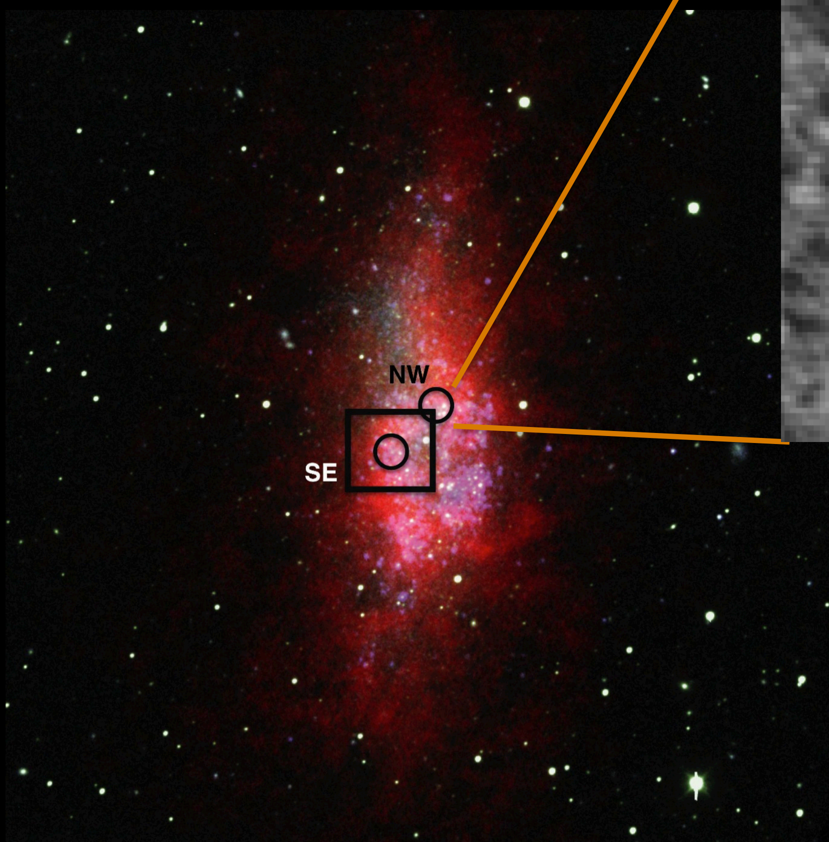
Shell annulus ≥ core diameter

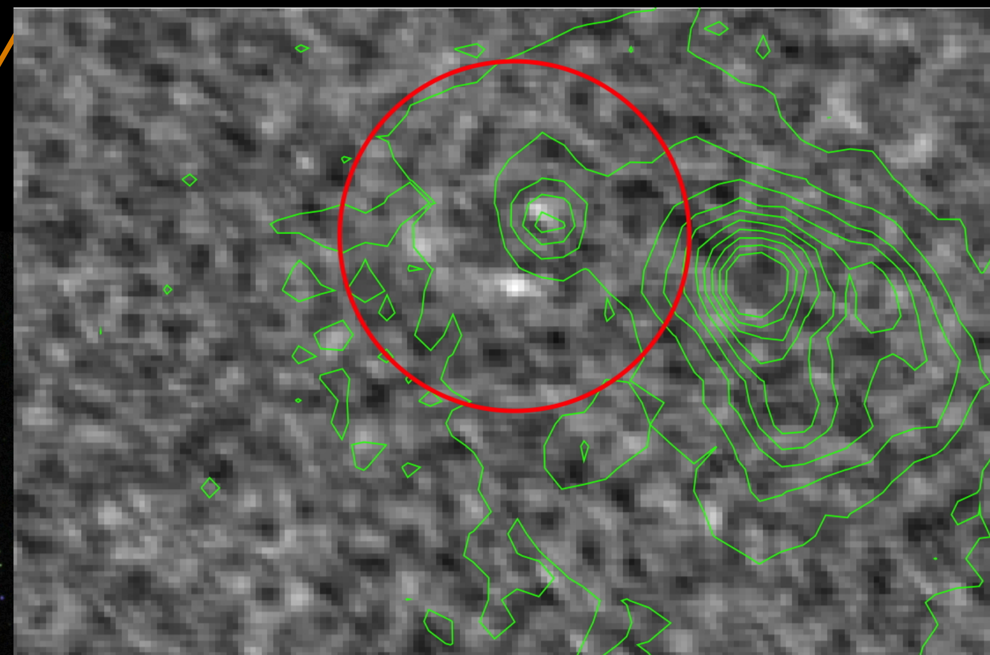
Theoretical prediction: Size of shell $\propto$ 1/abundance

➔ Molecular cloud structure at 13% of solar abundances

NW molecular cores observed by ALMA

WLM





Size ~ 1-3 arcseconds

To come…

Molecular cloud structure:

- *Herschel* images of the molecular cloud shells
- ALMA maps of the CO cores

	abundance relative to solar
WLM –	13%
DDO 155 –	10%
DDO 75 –	6%
DDO 69 –	5%

➔ How does the molecular cloud structure change with abundance?

➔ What difference does it make to the star formation?