

# Watching New Stars Form

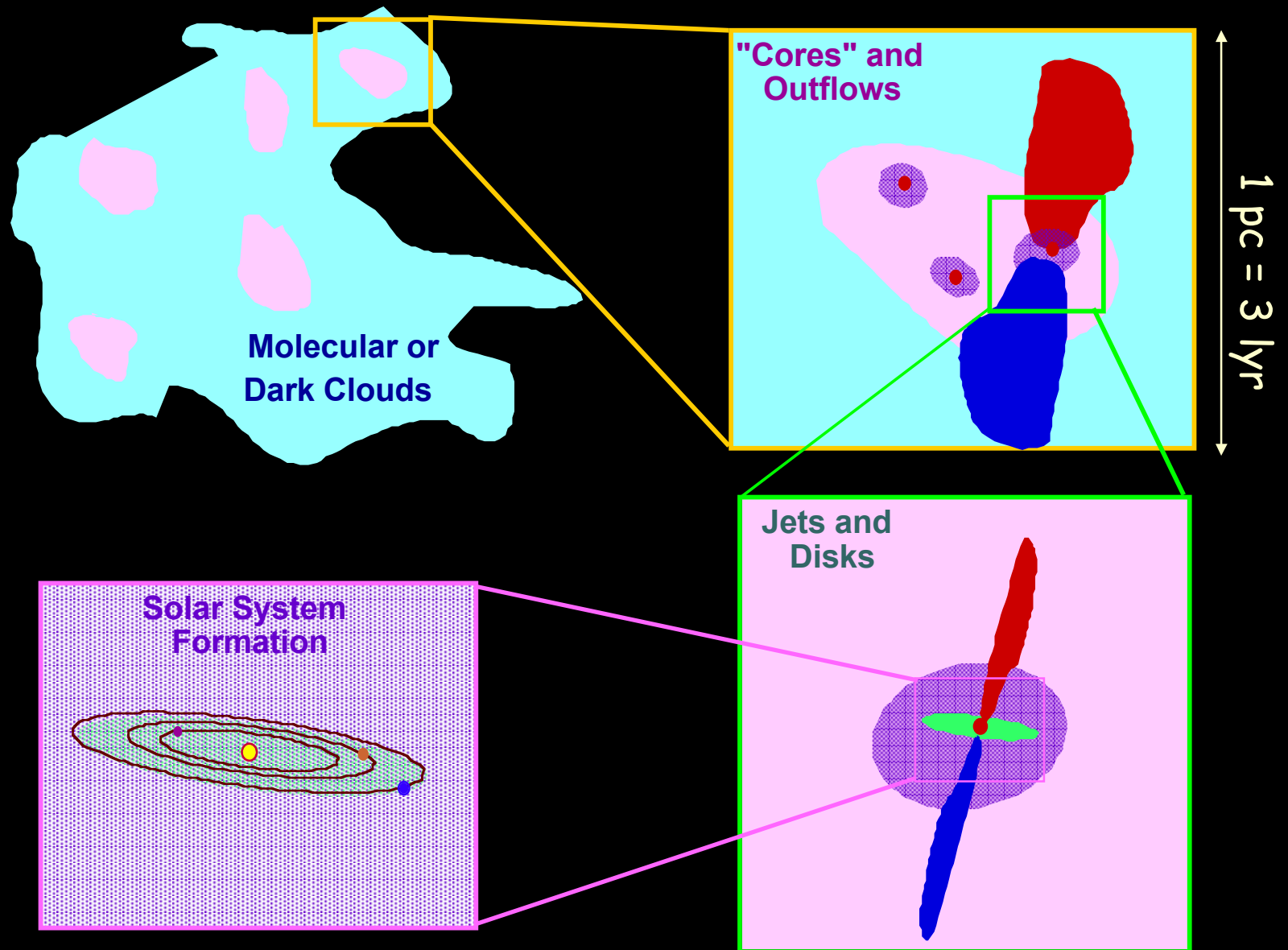
Alyssa A. Goodman

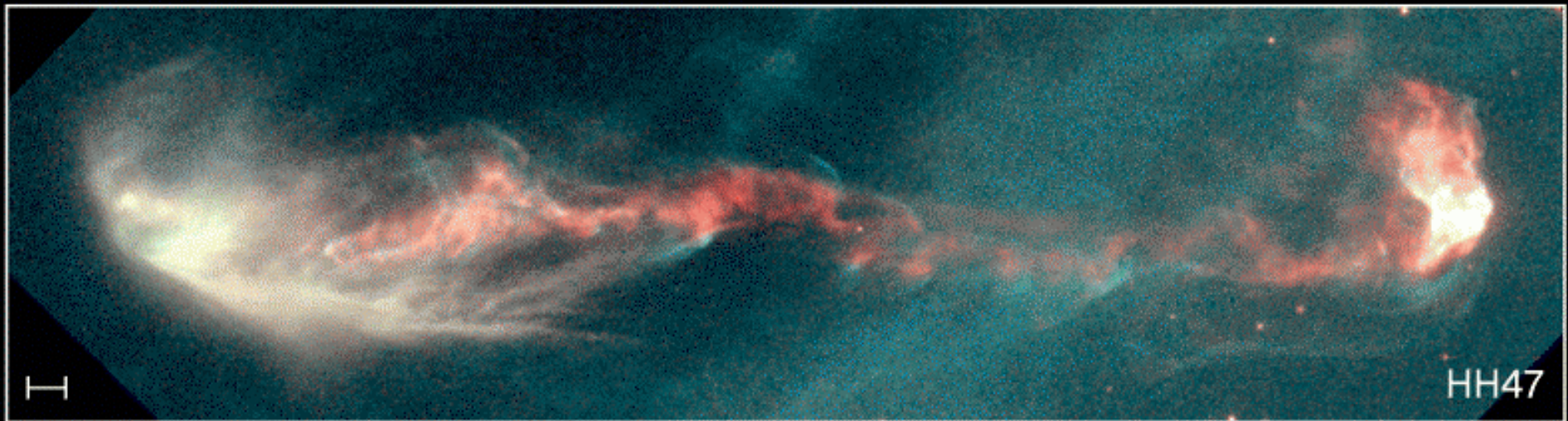
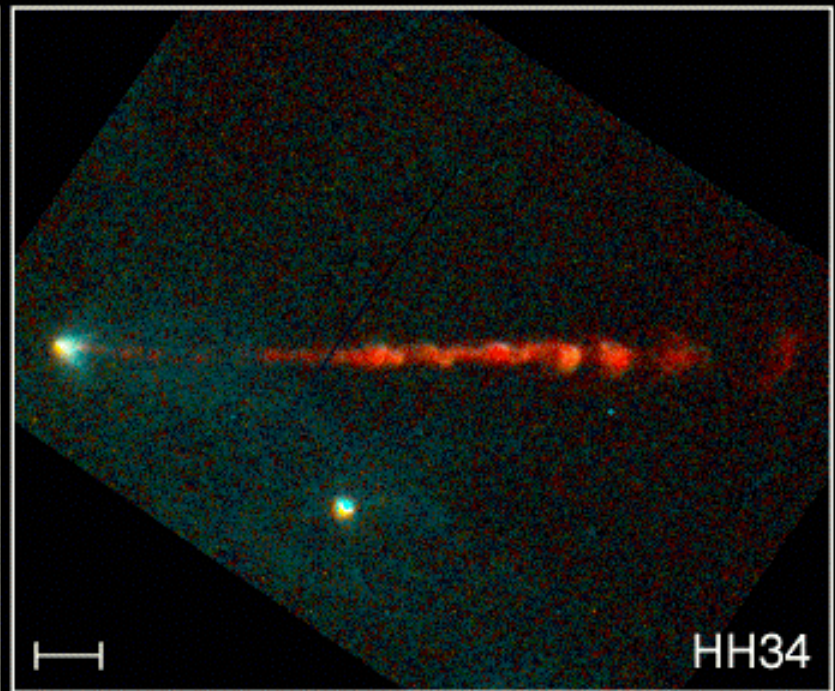
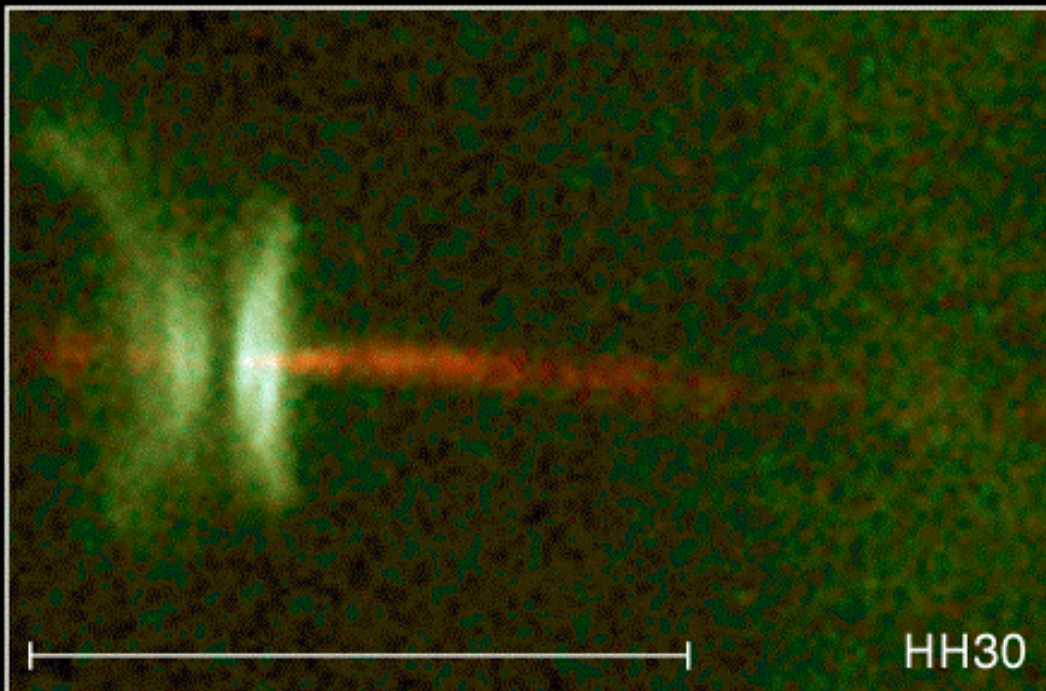
*Harvard University*

*Department of Astronomy*

[cfa-www.harvard.edu/~agoodman](http://cfa-www.harvard.edu/~agoodman)

# What we (think we) understand





# Jets from Young Stars

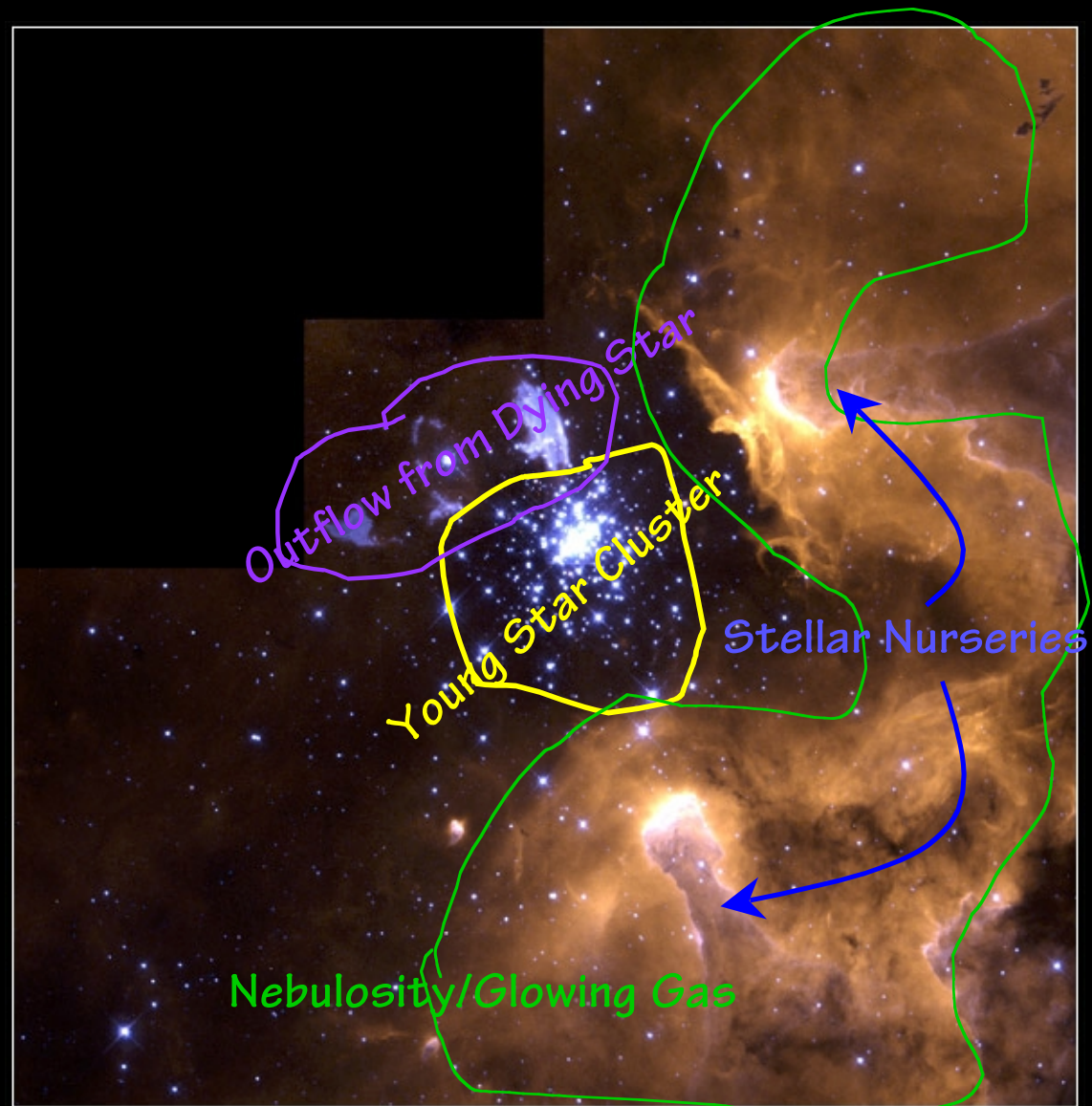
HST · WFPC2

PRC95-24a · ST ScI OPO · June 6, 1995

C. Burrows (ST ScI), J. Hester (AZ State U.), J. Morse (ST ScI), NASA



# The Cycle of Star Birth & Death



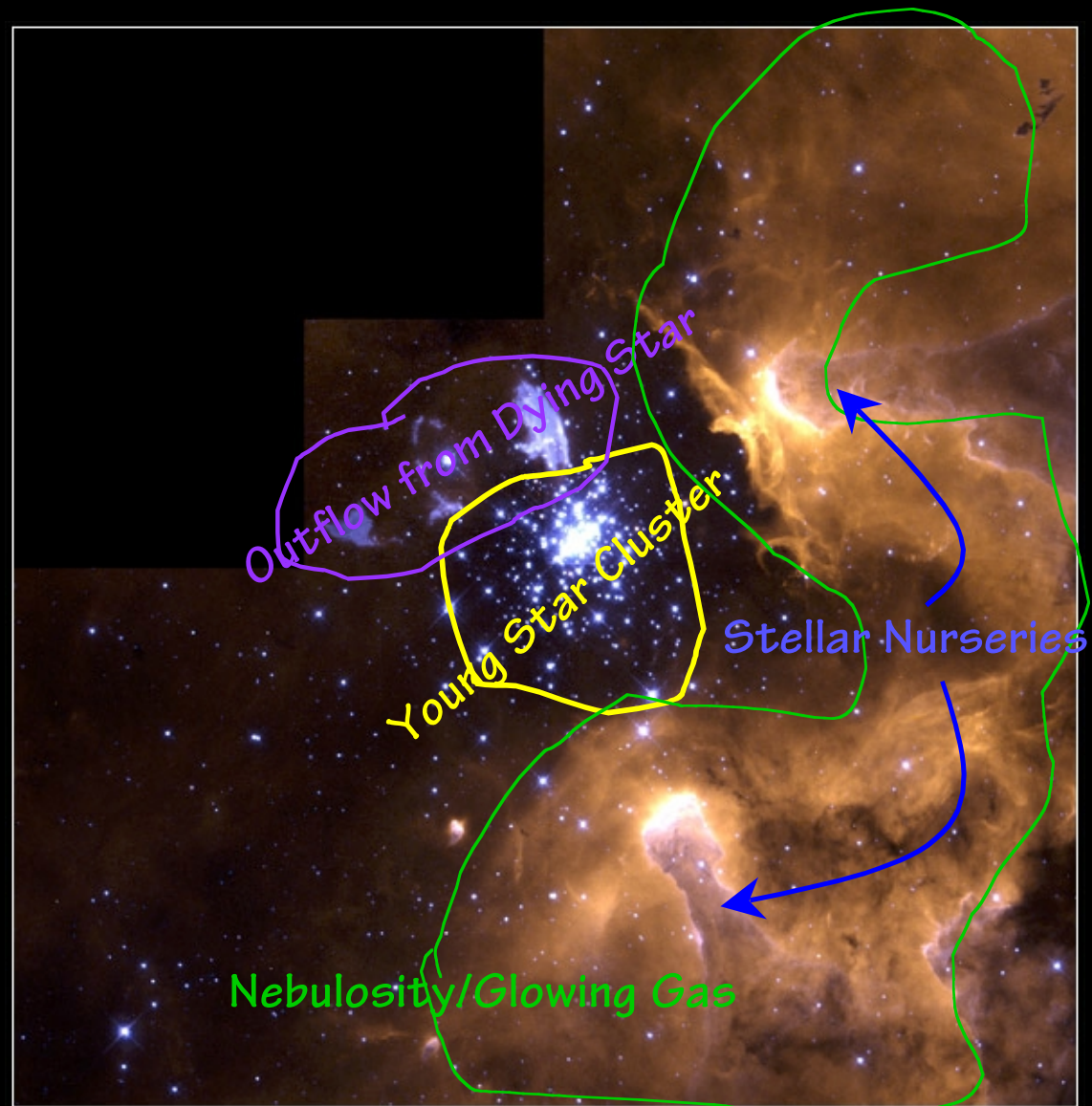
**NGC 3603**

**HST • WFPC2**

PRC99-20 • STScI OPO • June 1, 1999

Wolfgang Brandner (JPL/IPAC), Eva K. Grebel (Univ. Washington),  
You-Hua Chu (Univ. Illinois, Urbana-Champaign) and NASA

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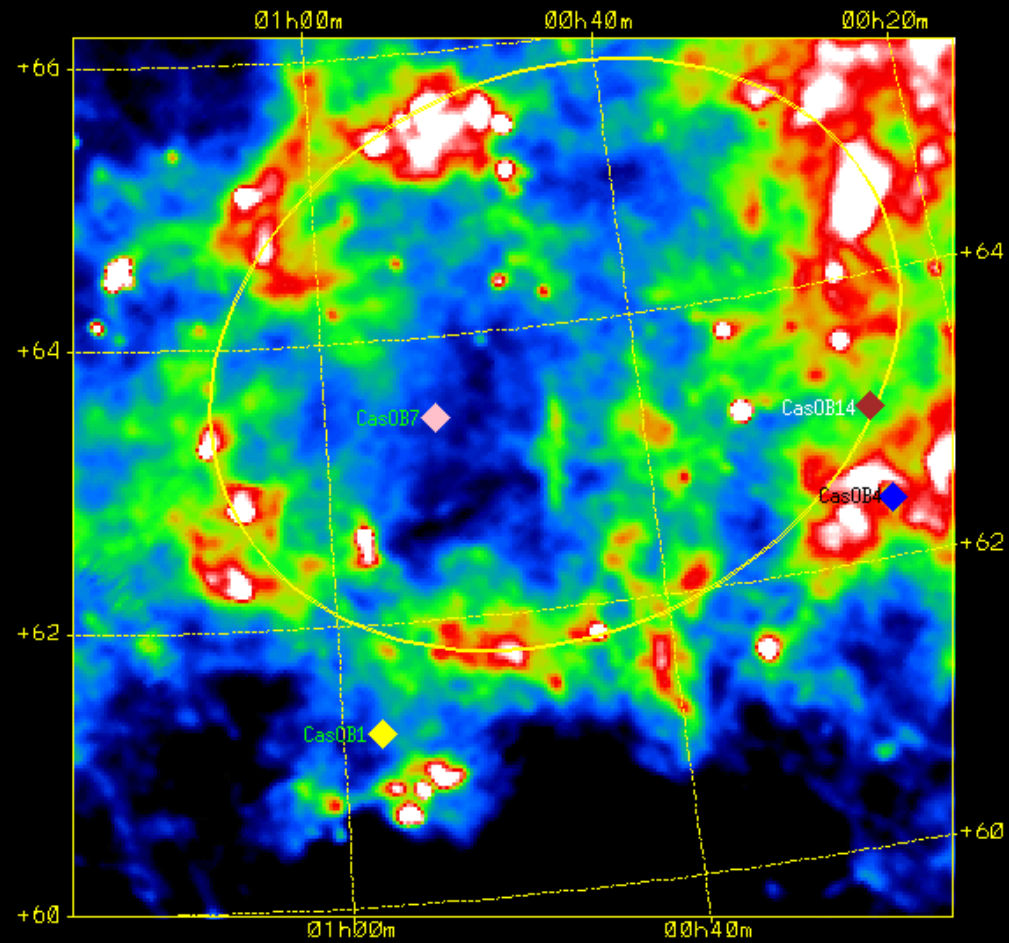
**NGC 3603**

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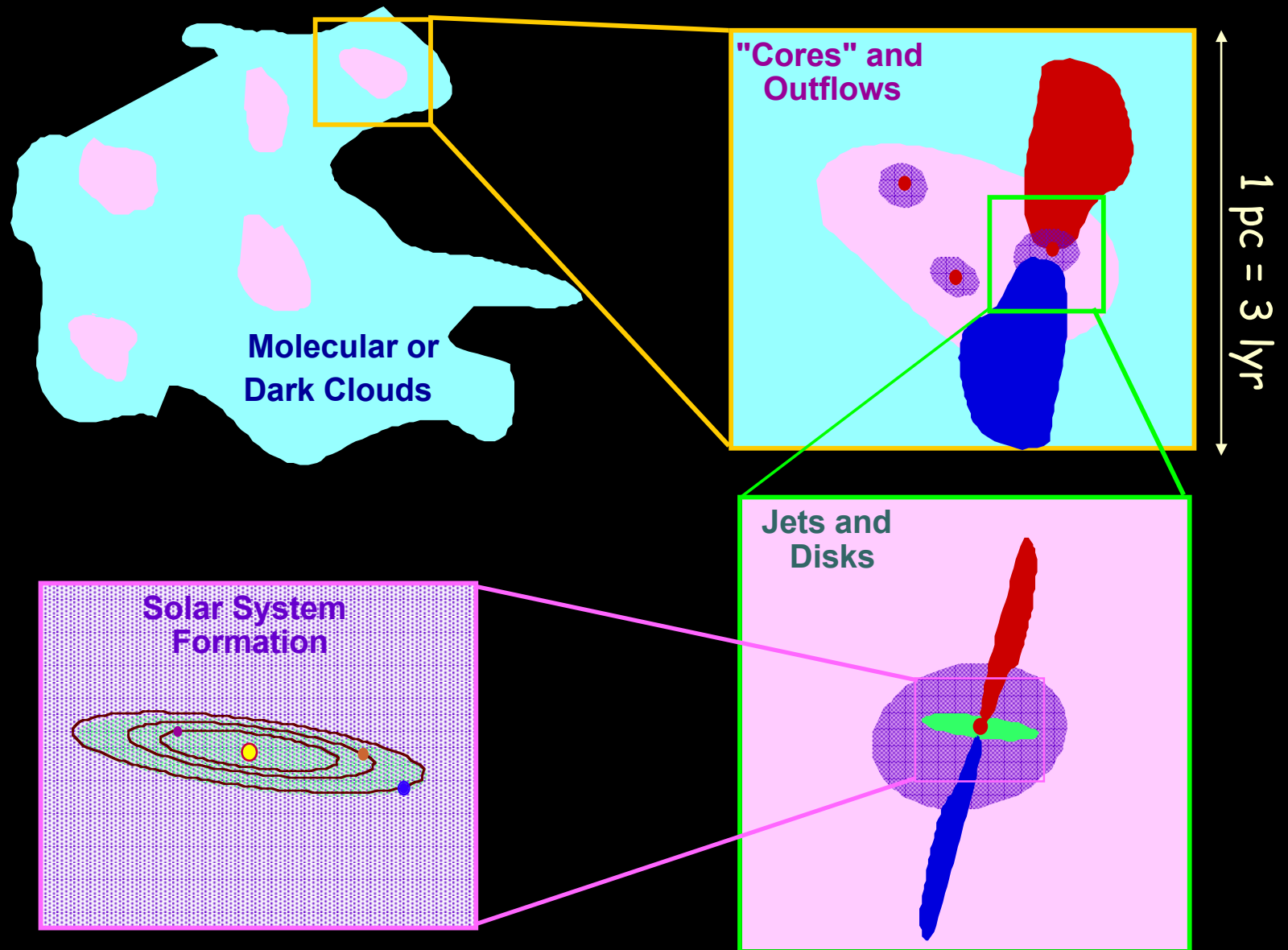
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# Some Molecular Clouds "Created" by Supernovae



100  $\mu\text{m}$  Dust Emission in Cassiopeia  
*Tóth et al. 1995*

# What we (think we) understand

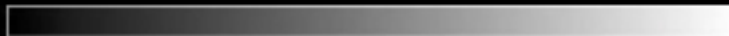
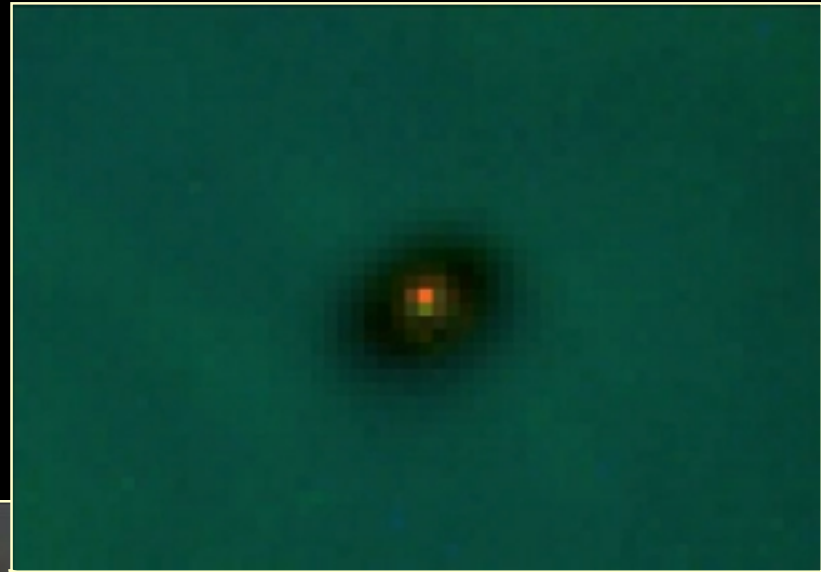




# The Orion Nebula

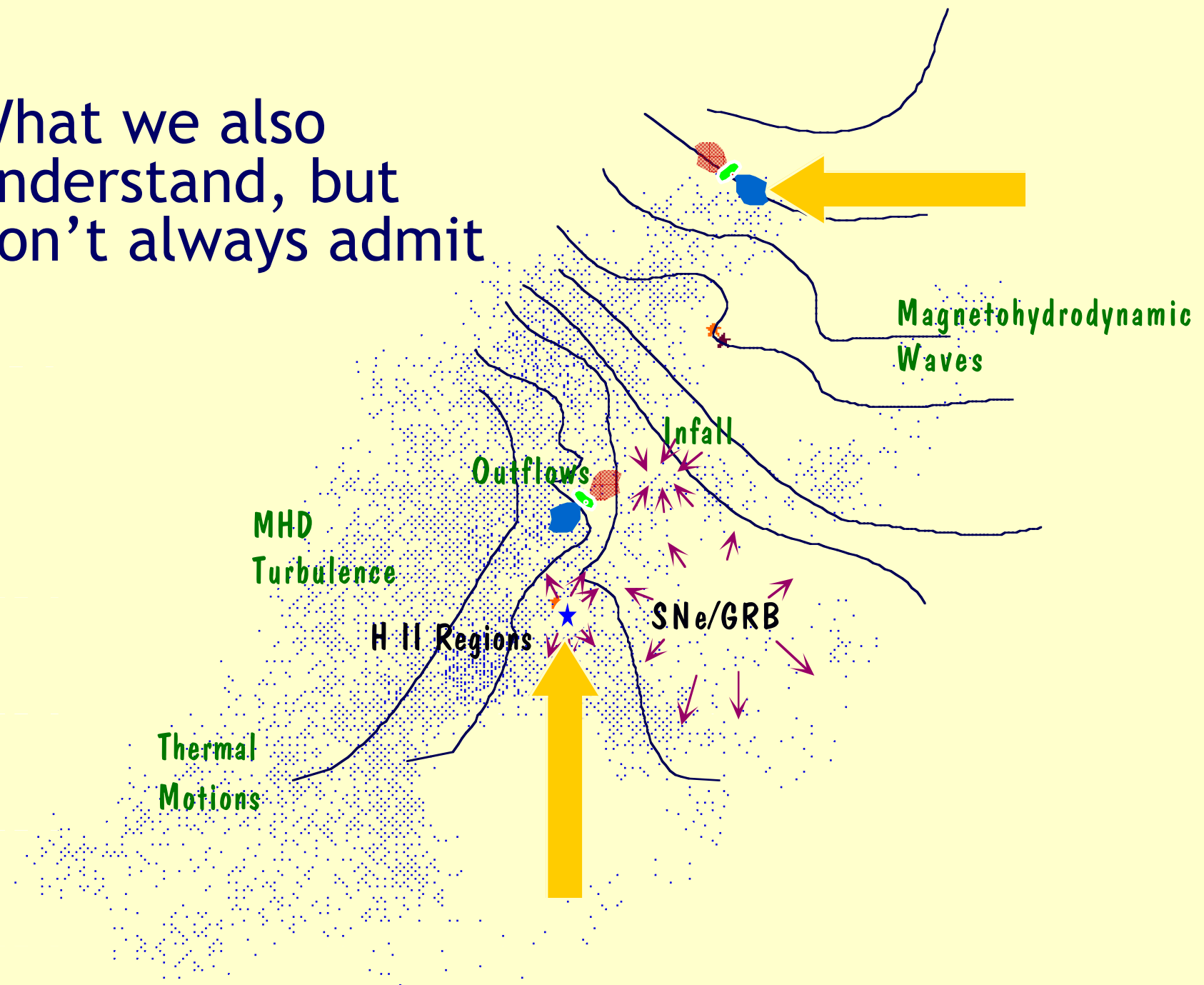


Hubble Space Telescope  
Wide Field Planetary Camera 2





What we also understand, but don't always admit



“Dust,  
Not Holes”

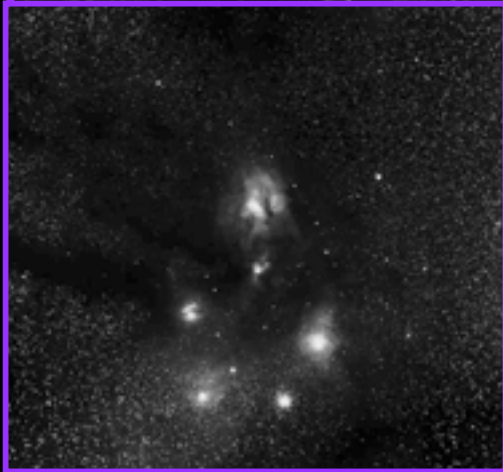
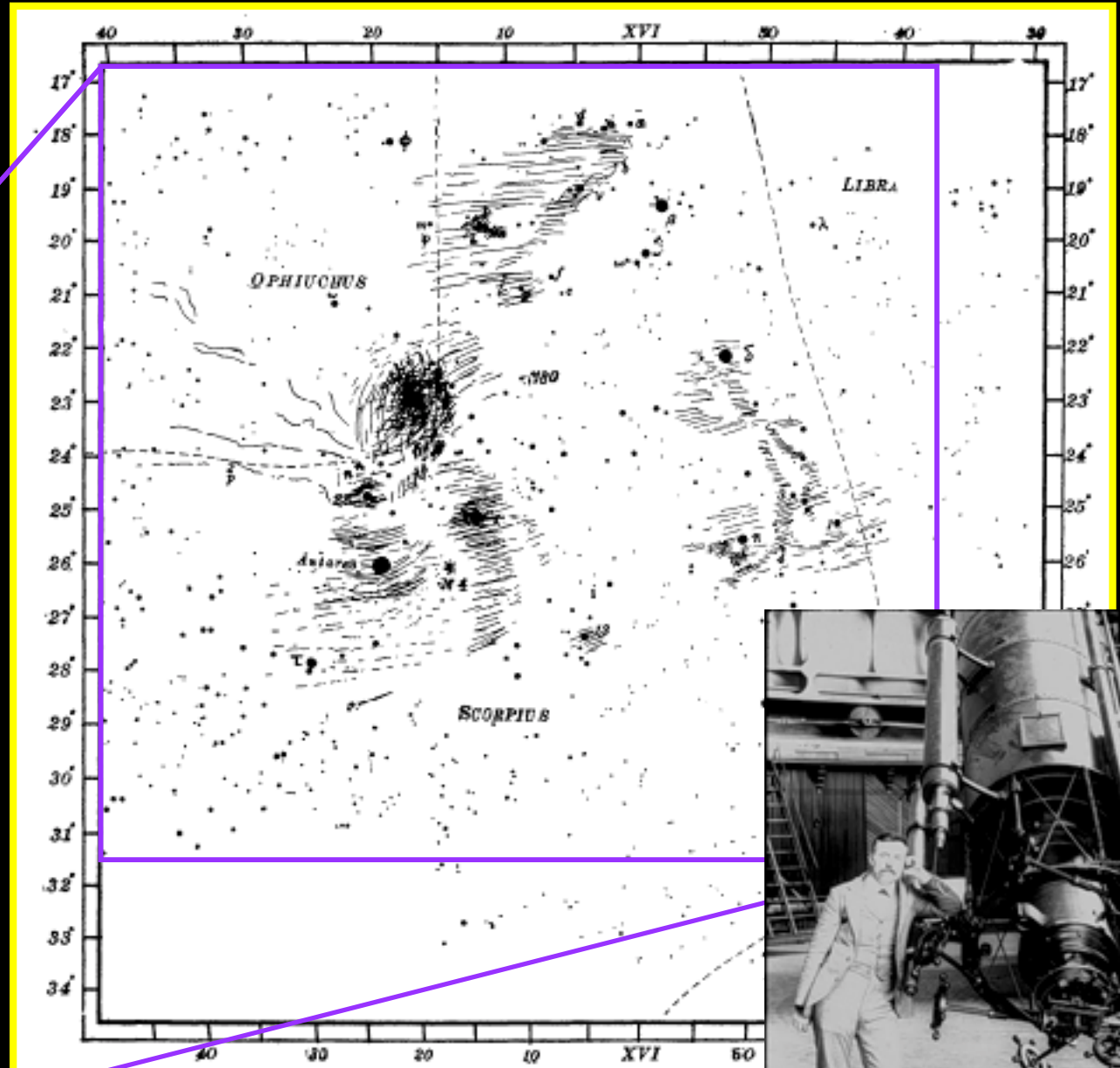
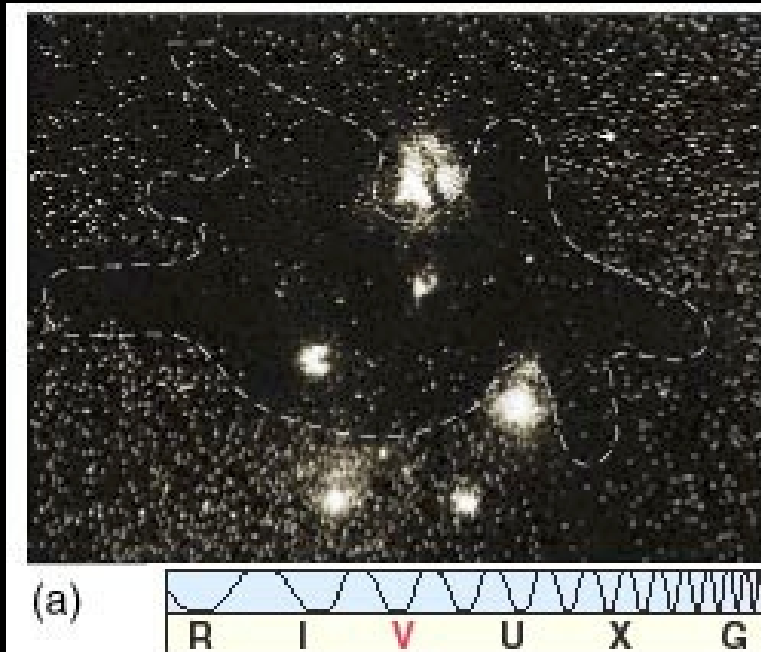
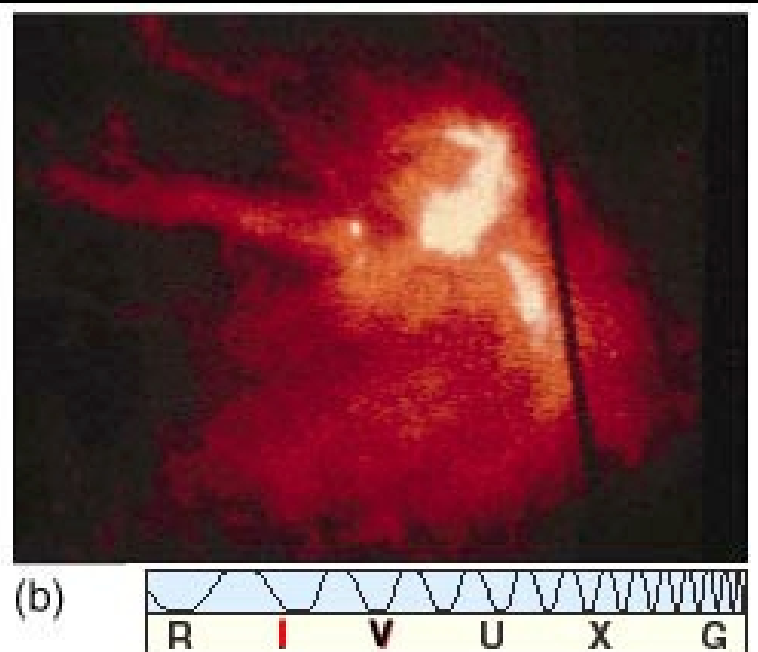


CHART OF THE GREAT NEBULOUS RE

# Time Showed Barnard was Right!



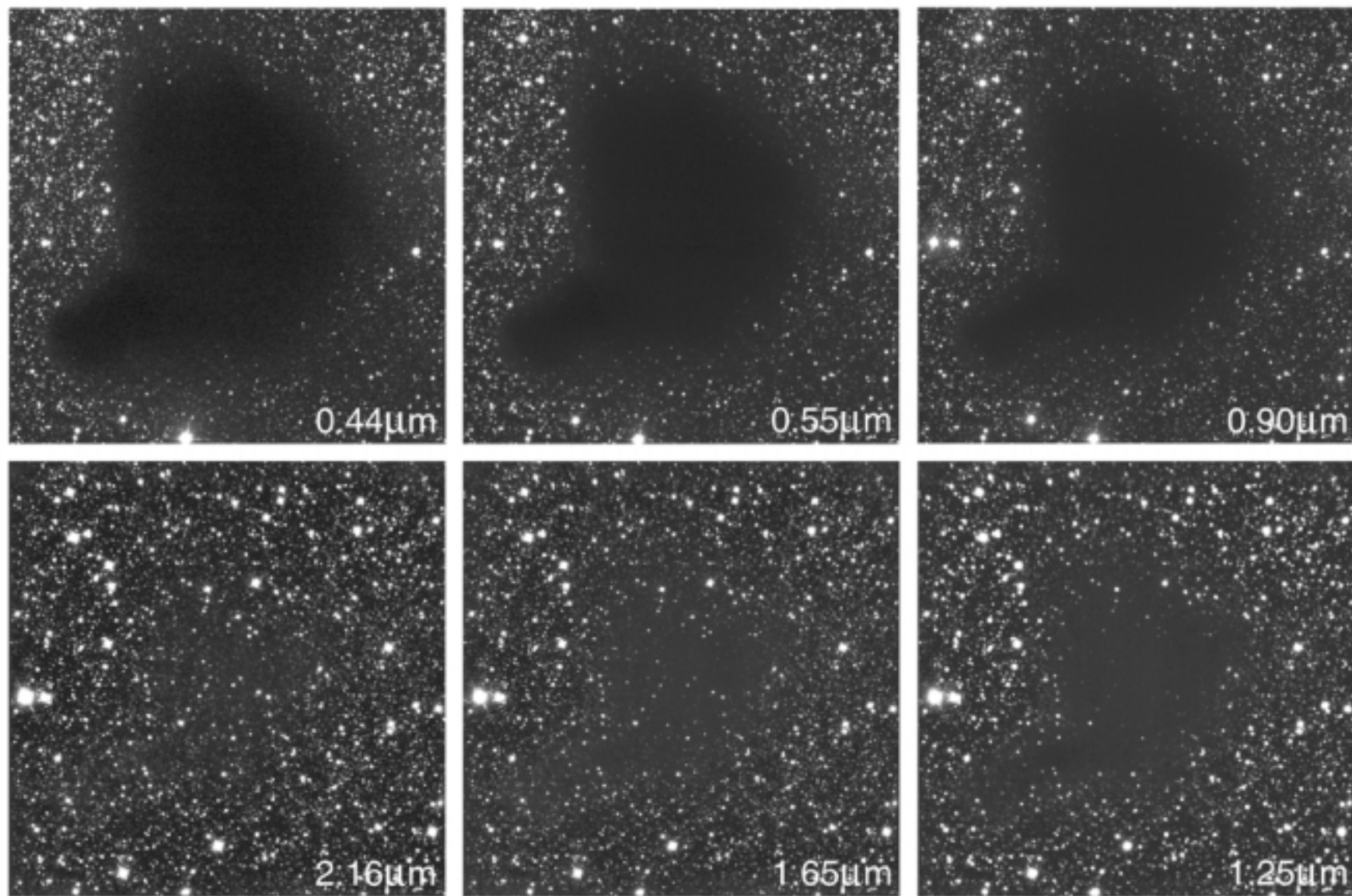
Barnard's Optical  
Photograph of Ophiuchus



IRAS Satellite Observation,  
1983

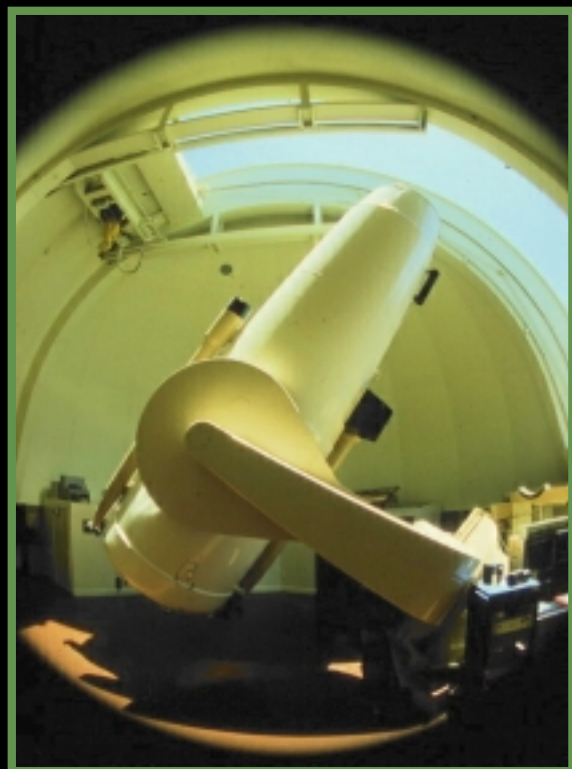
Remember: Cold (10K) dust glows, like a blackbody, in the far-infrared.



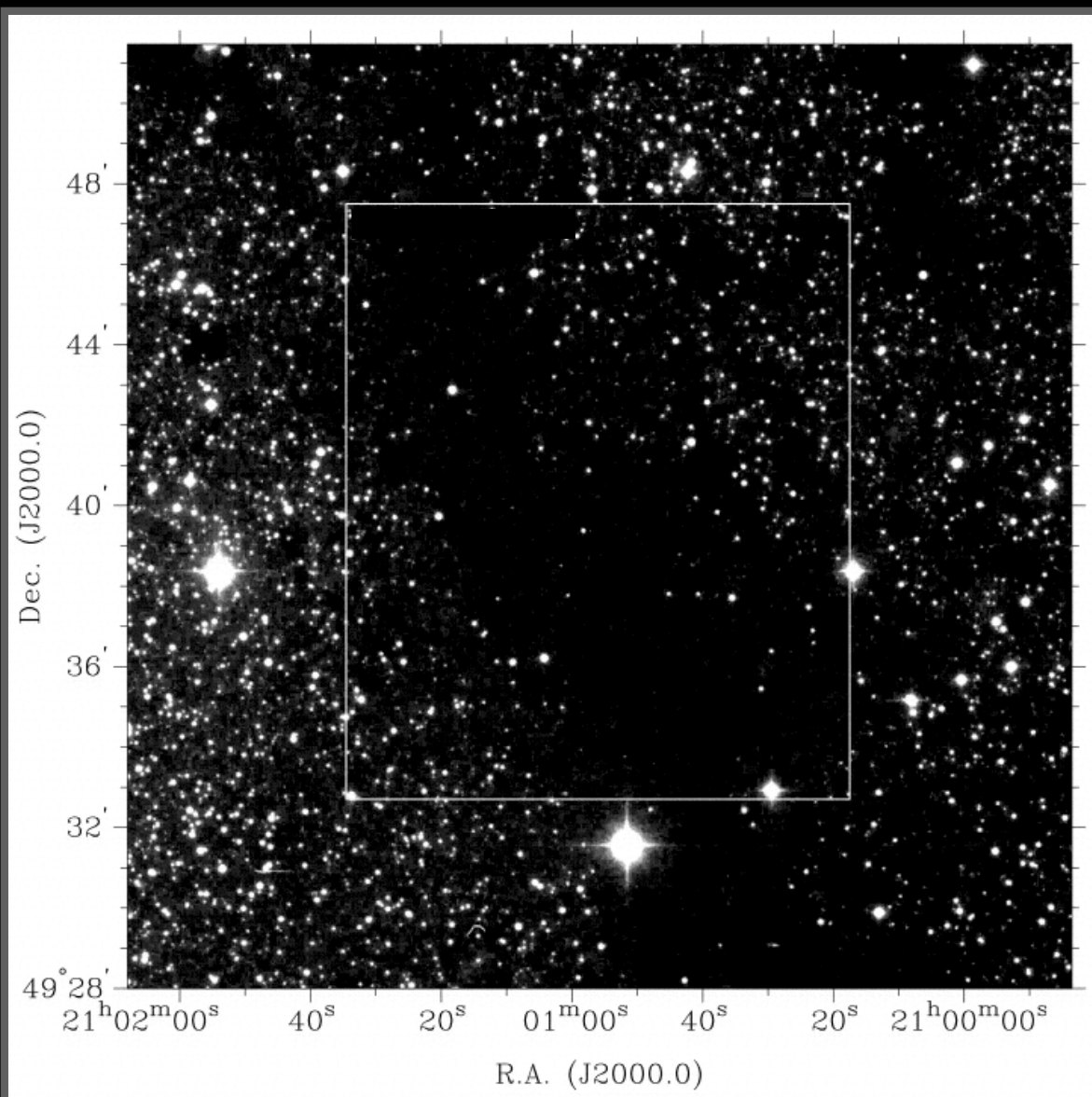


The Dark Cloud B68 at Different Wavelengths (NTT + SOFI)

# Dust, not Holes

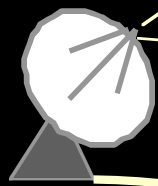


The Oschin telescope,  
48-inch aperture wide-field  
Schmidt camera at Palomar

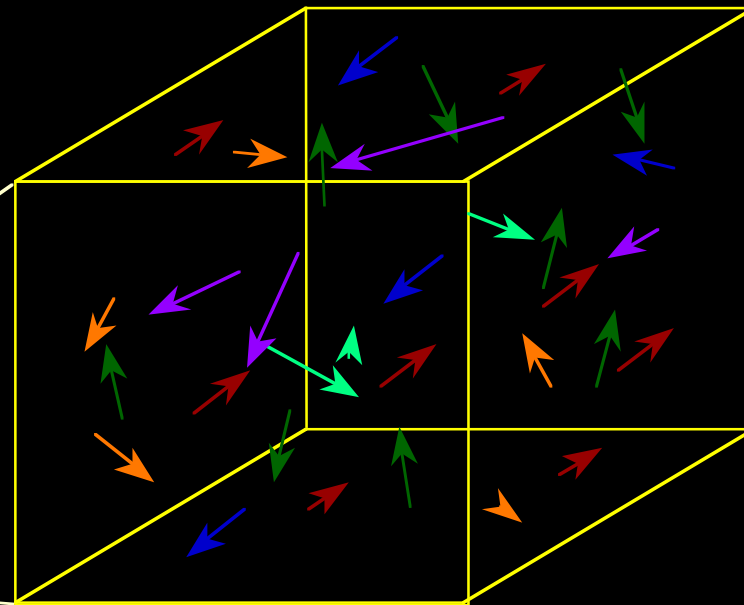


Red Plate, Digitized Palomar Observatory Sky Survey

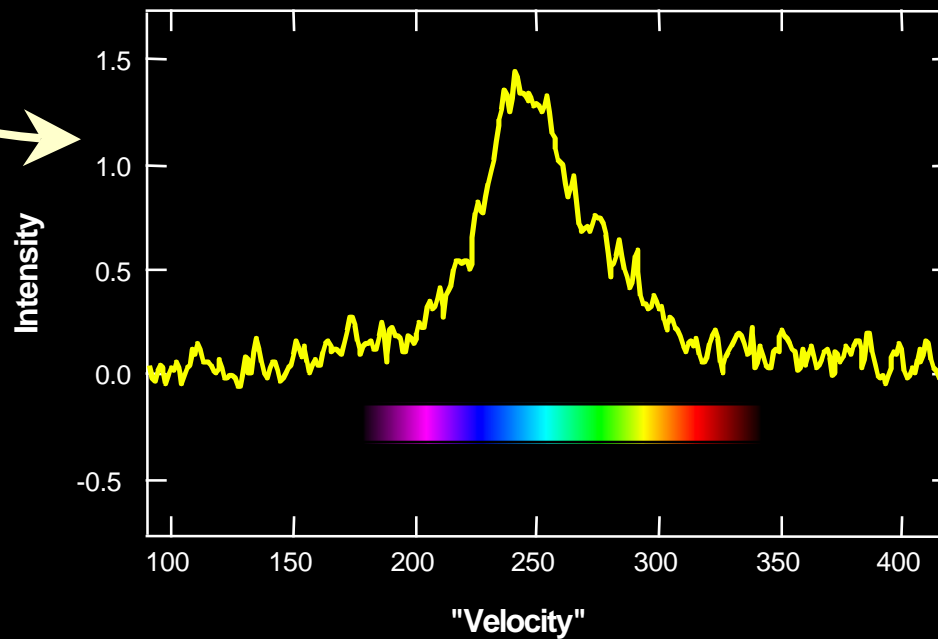
# Tutorial: Velocity from Spectroscopy



Telescope +  
Spectrometer



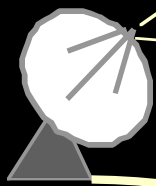
Observed Spectrum



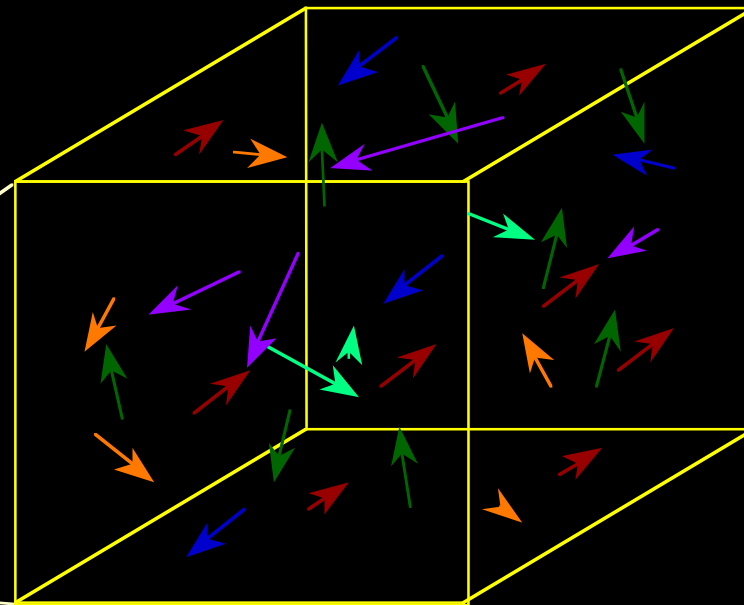
All thanks to *Doppler*



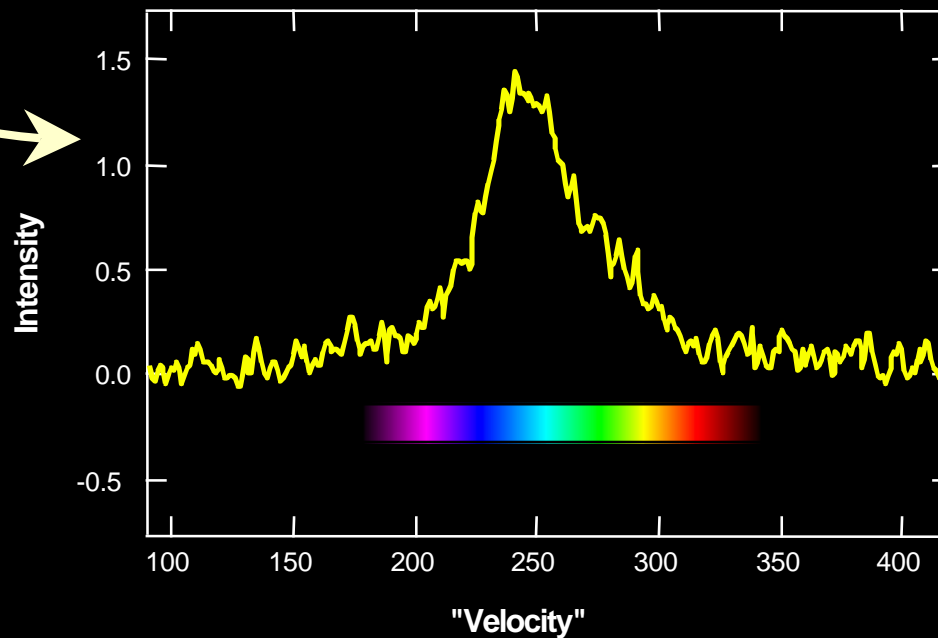
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Spectrometer

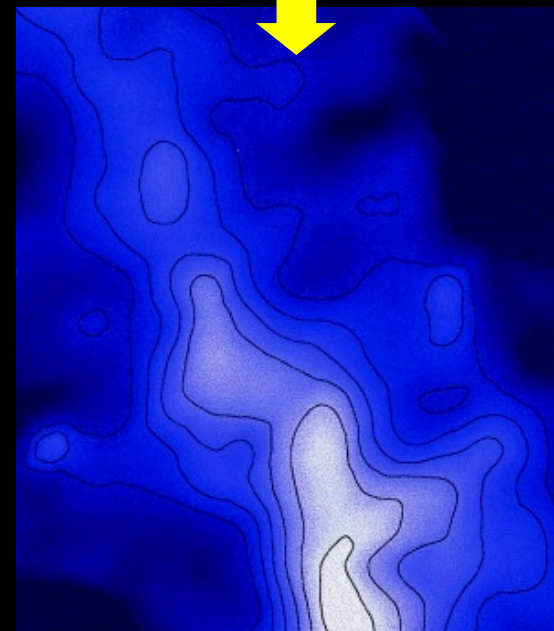
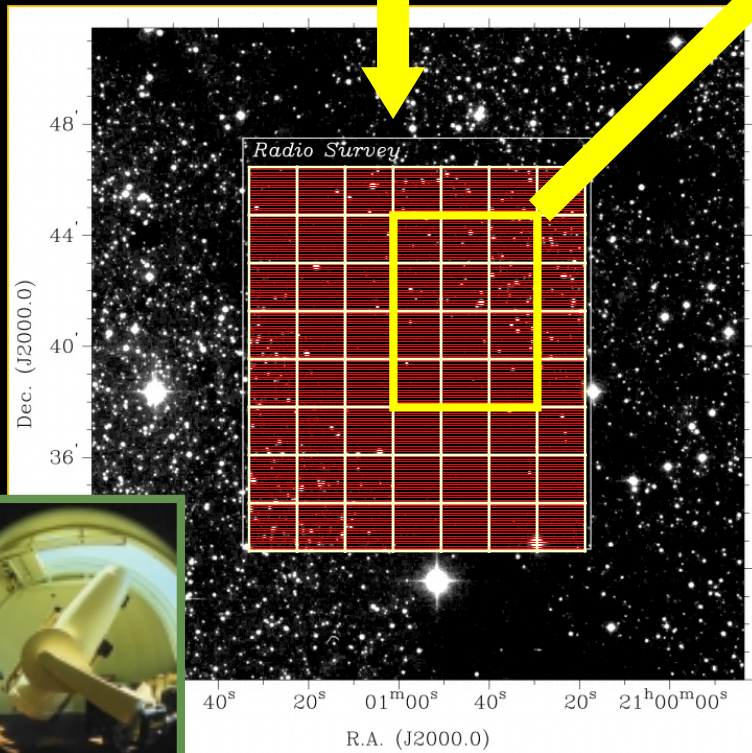
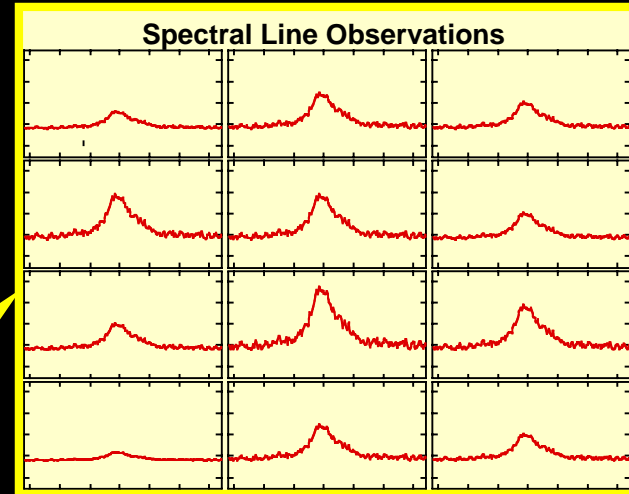


Observed Spectrum

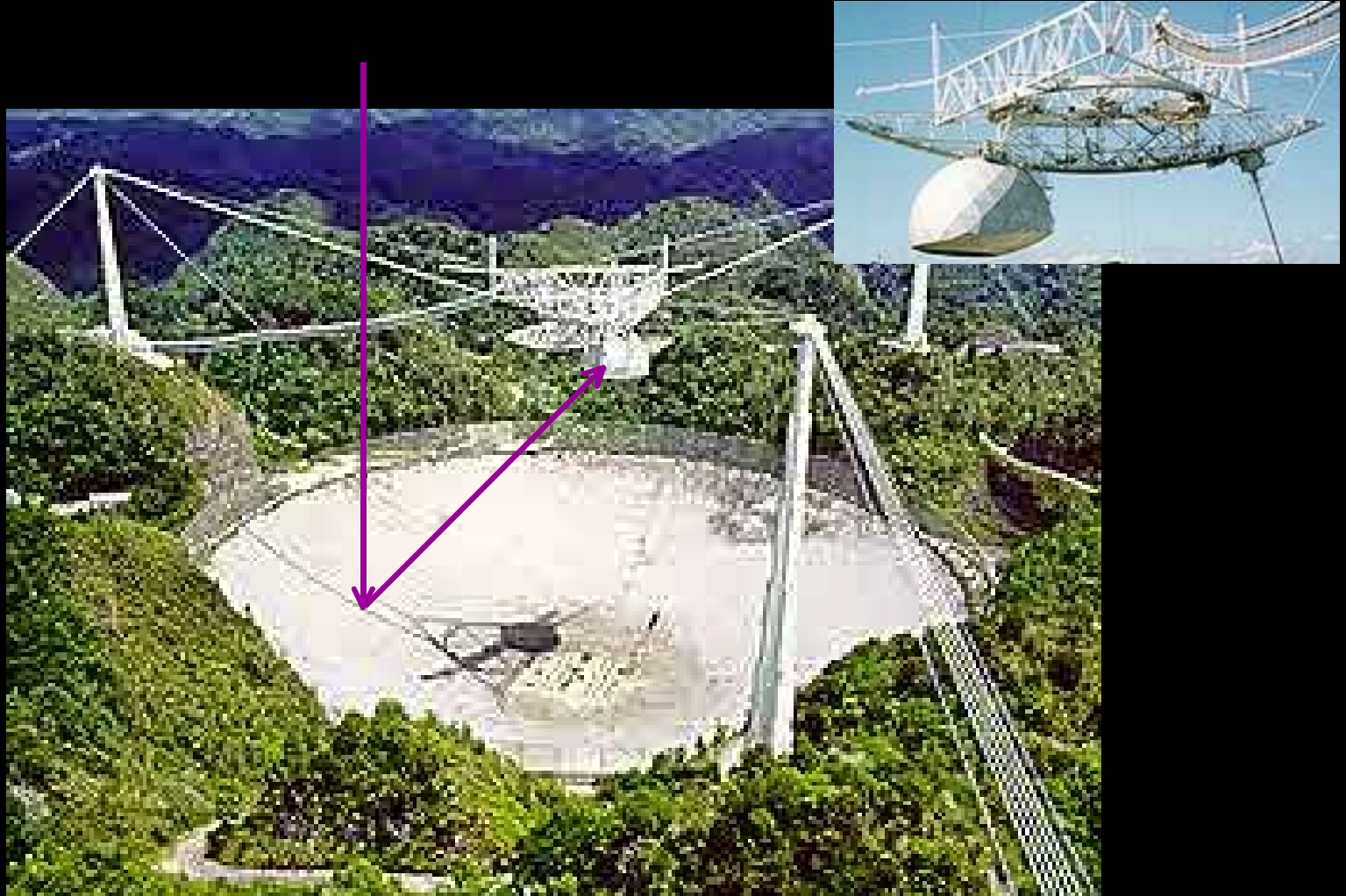


All thanks to *Doppler*

# My Main Line of Work: Radio Spectral-line Observations of Interstellar Clouds

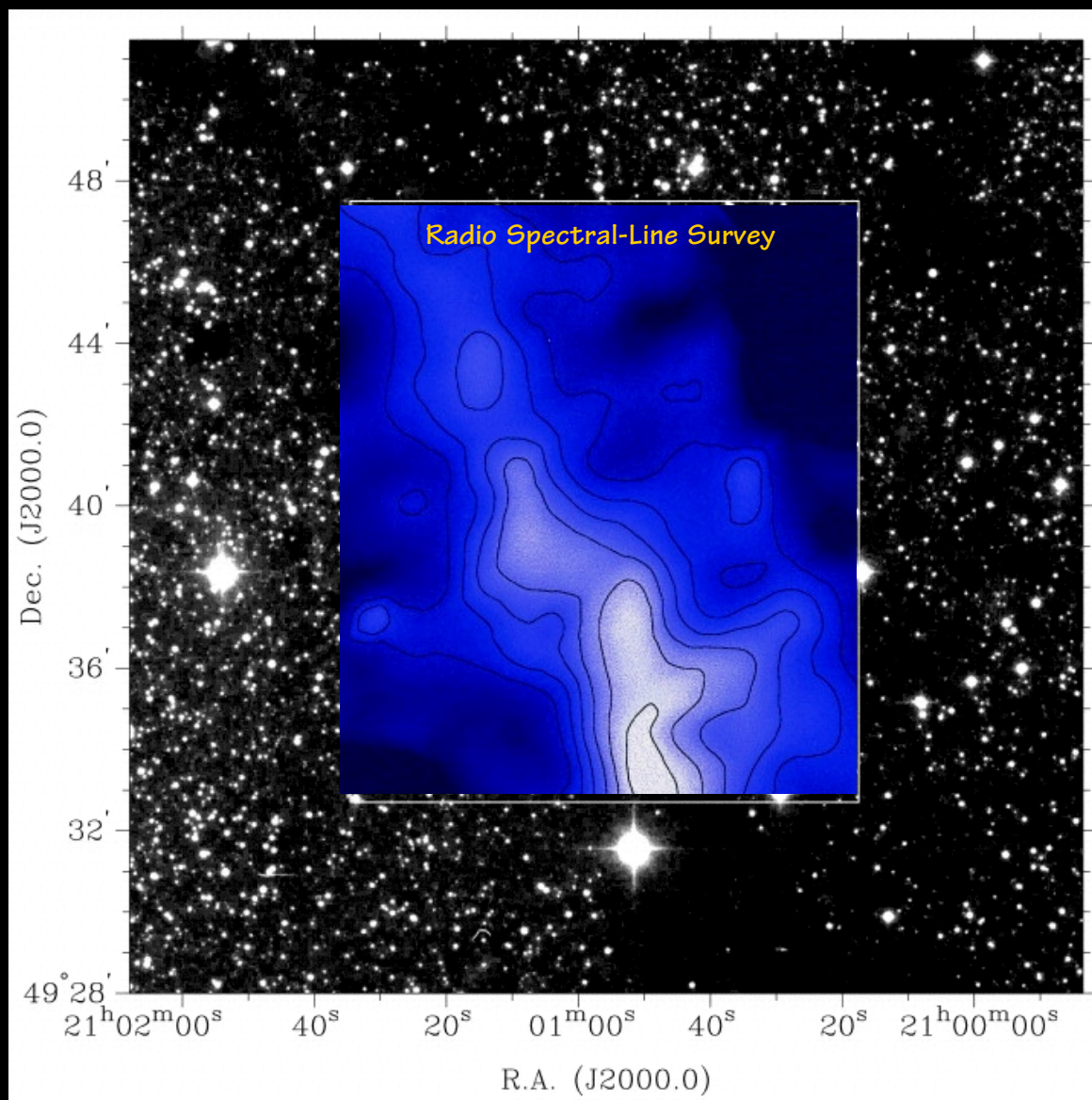


# The 1000-ft Telescope at Arecibo, PR





# Radio Spectral-line Observations of Interstellar Clouds

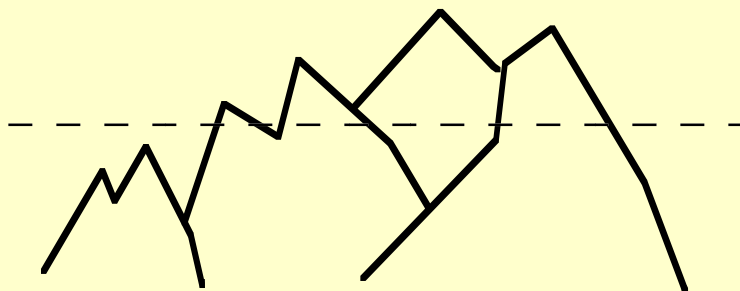
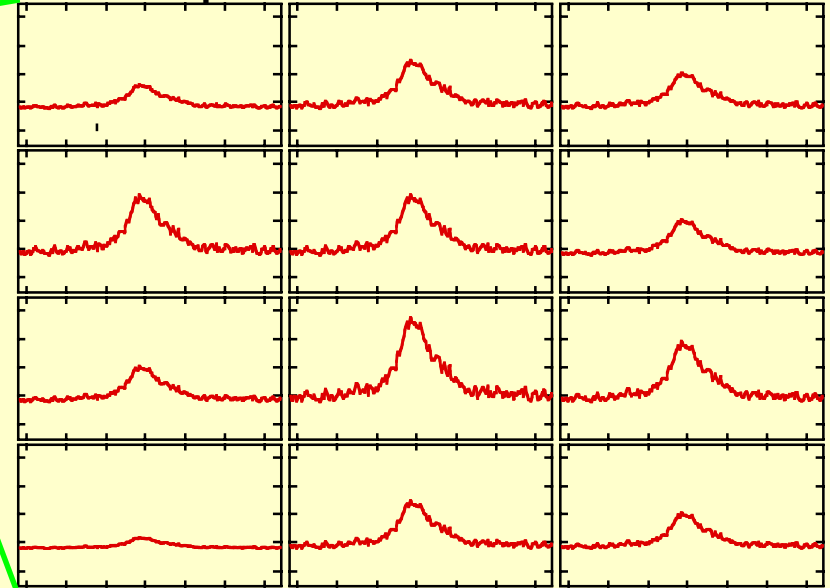




# Velocity as a "Fourth" Dimension



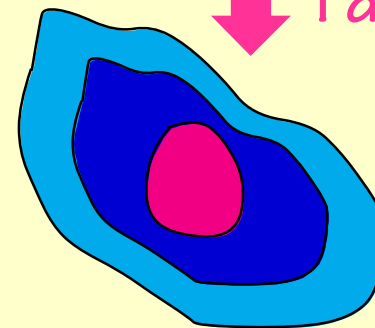
Spectral Line Observations



Mountain Range

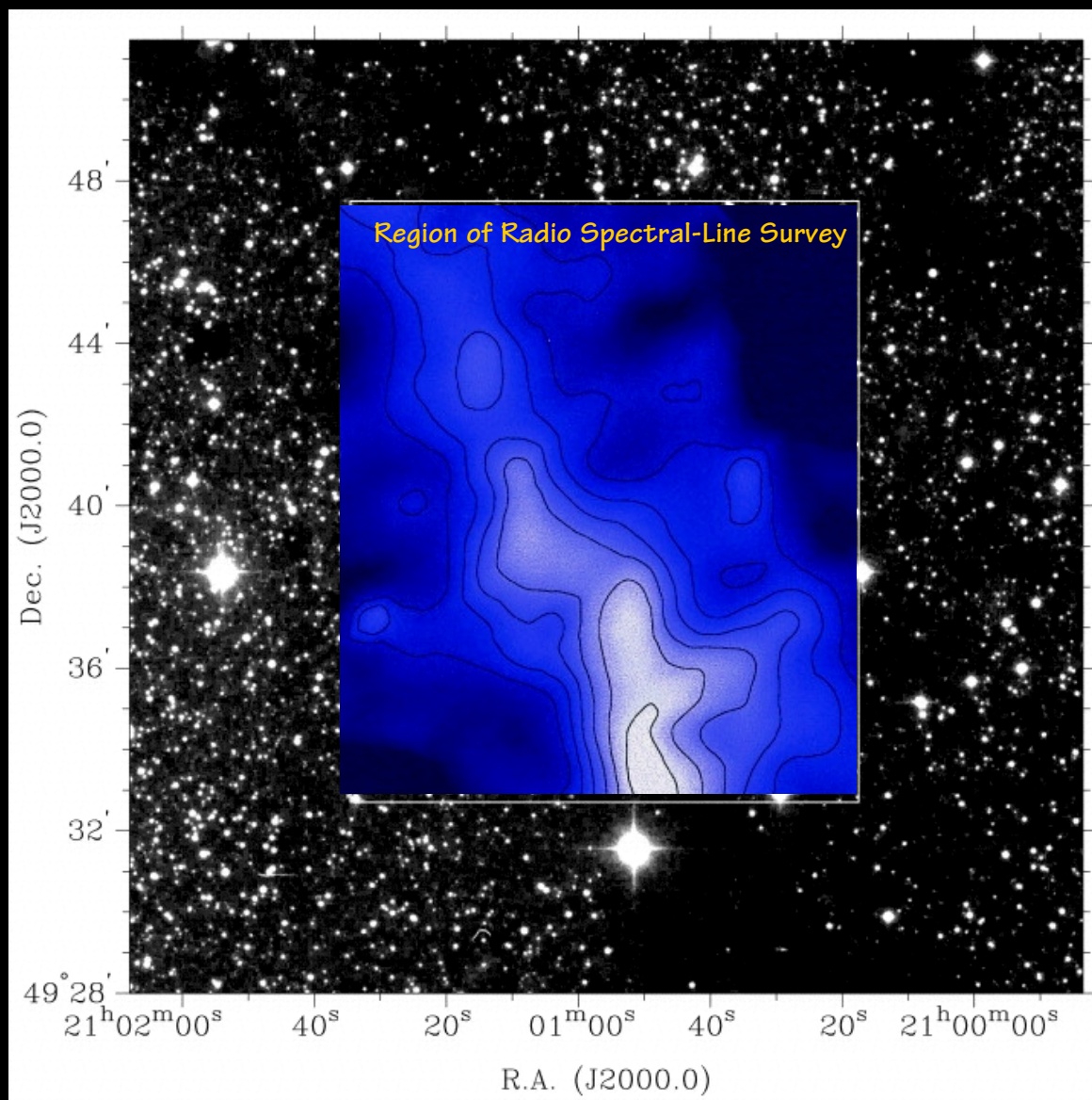


No loss of information

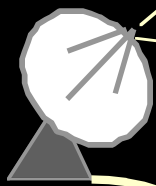


Loss of 1 dimension

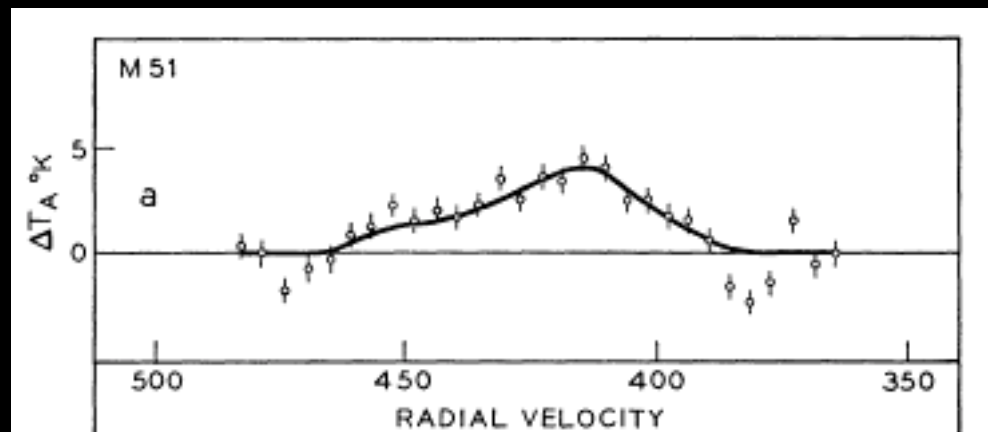
# “Integrated Intensity Map”



# 1957 H I Spectroscopy



Telescope +  
Spectrometer

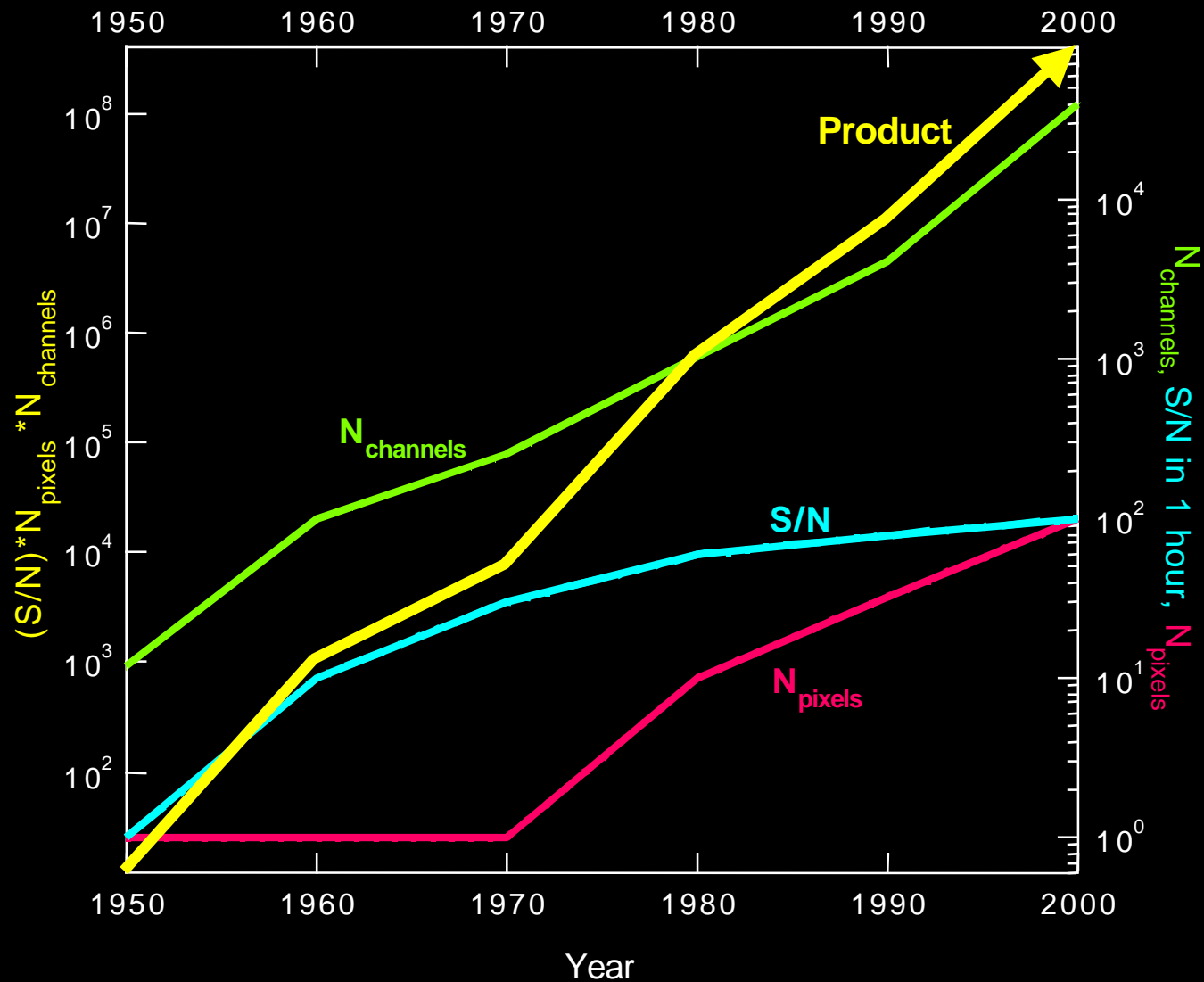


All thanks to *Doppler*

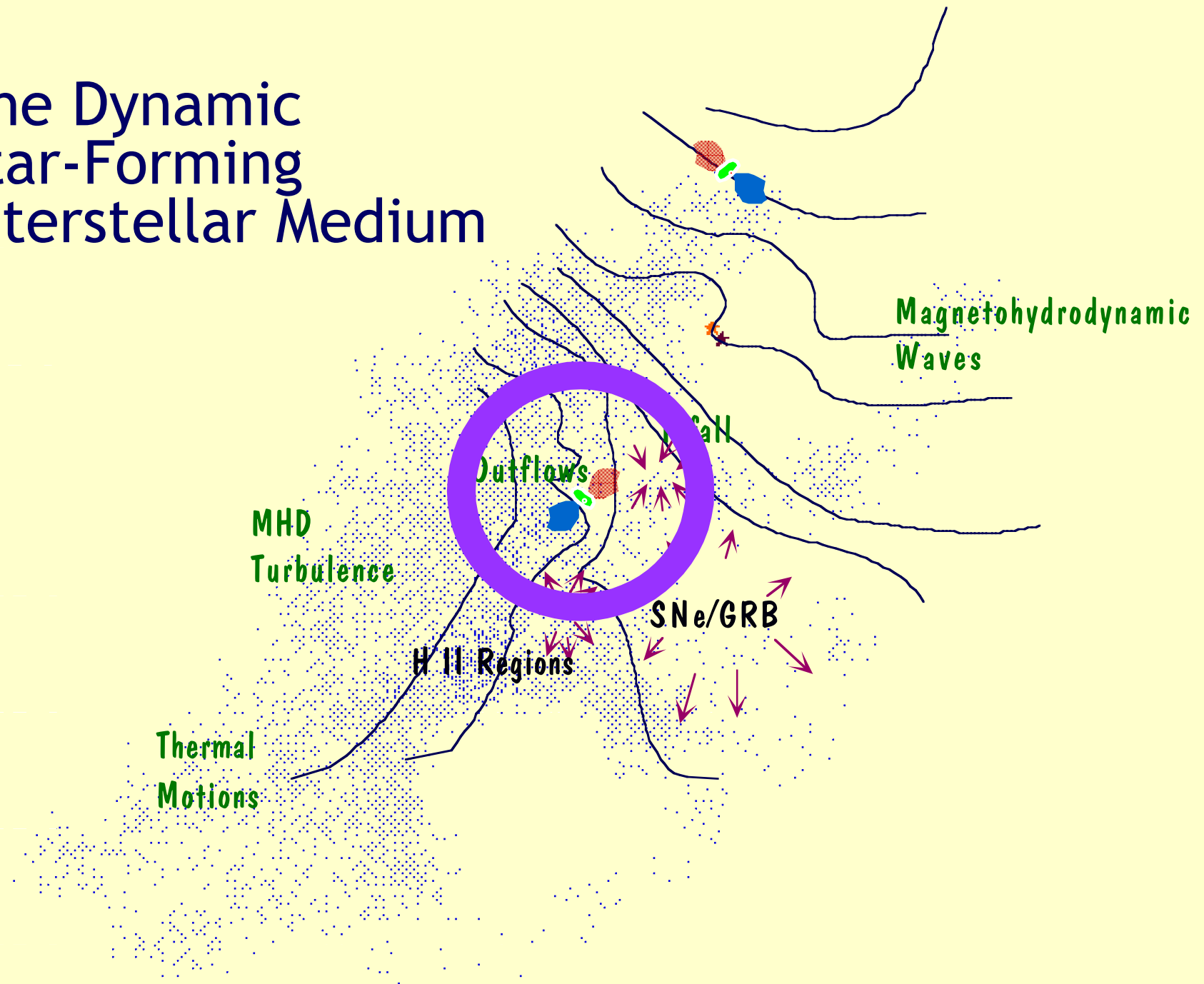
H I Spectrum of the Galaxy M51  
from Agassiz Station, *Heeschen 1957*



# Learning More from "Too Much" Data



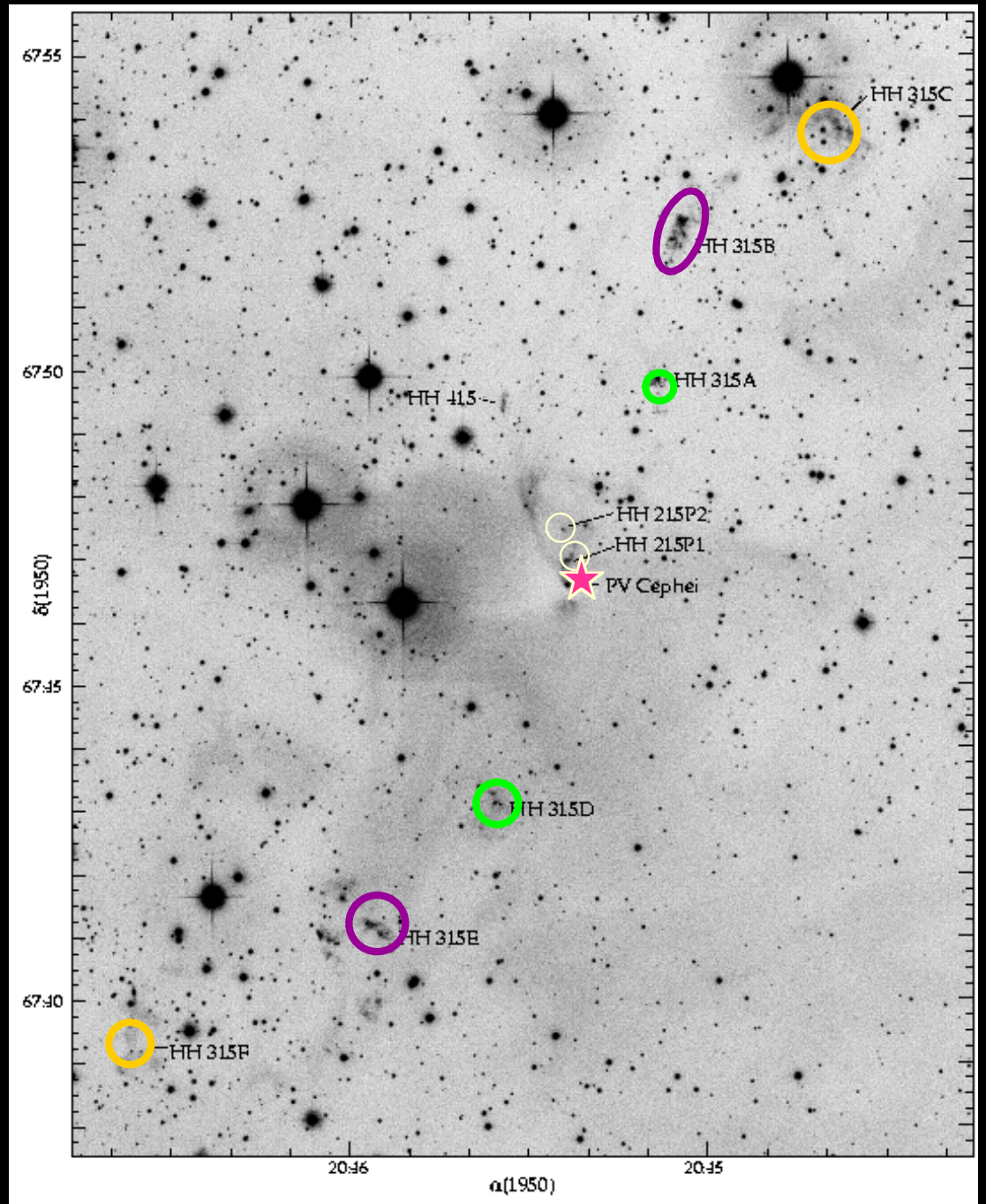
# The Dynamic Star-Forming Interstellar Medium



# “Giant” Herbig-Haro Flows: PV Ceph

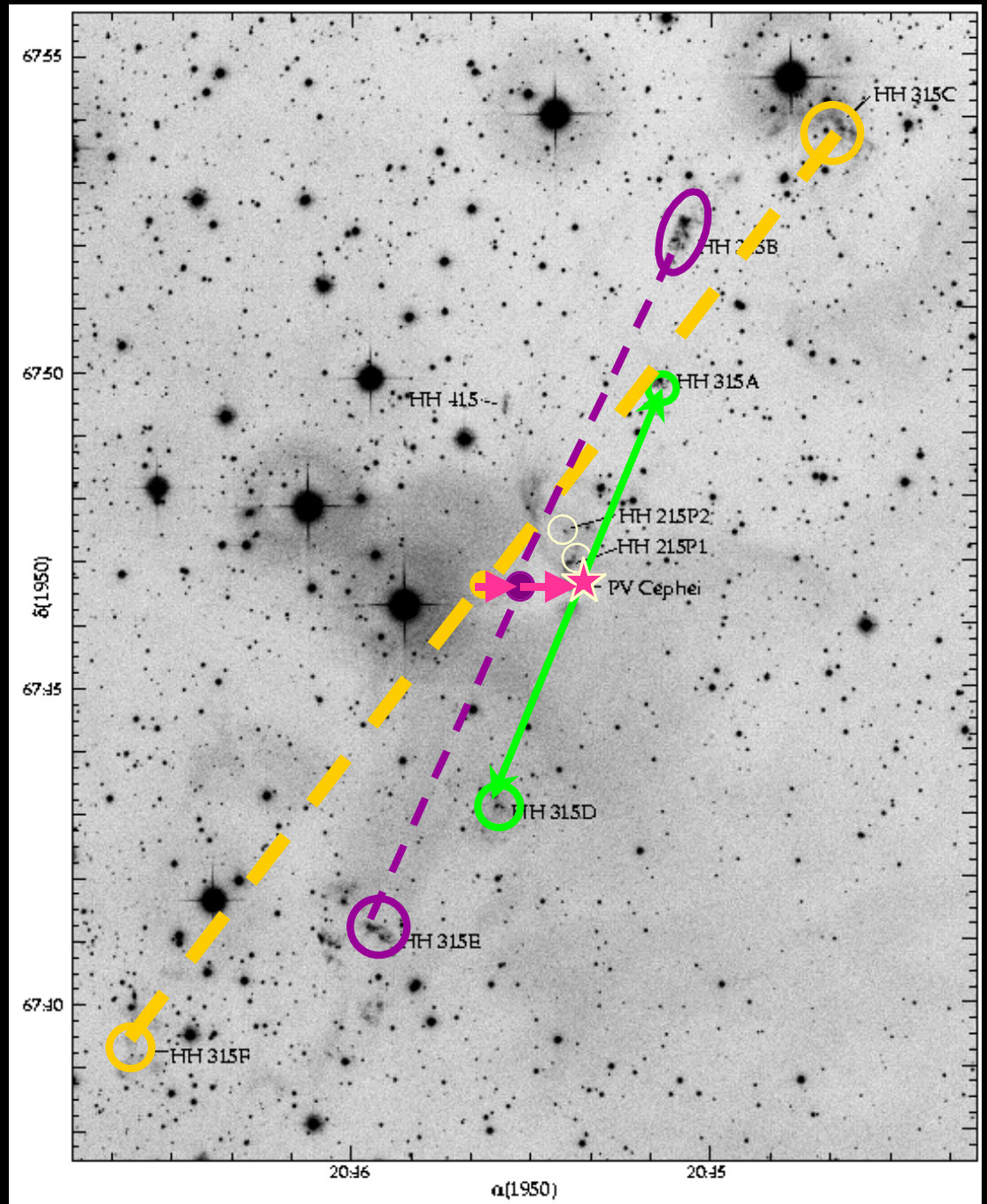
1 pc

*Reipurth, Bally & Devine 1997*



A New  
Proposal:  
Episodic  
ejections  
from  
precessing or  
wobbling  
moving  
source

*Required motion of 0.25 pc  
(e.g. 2 km s<sup>-1</sup> for 125,000 yr)*



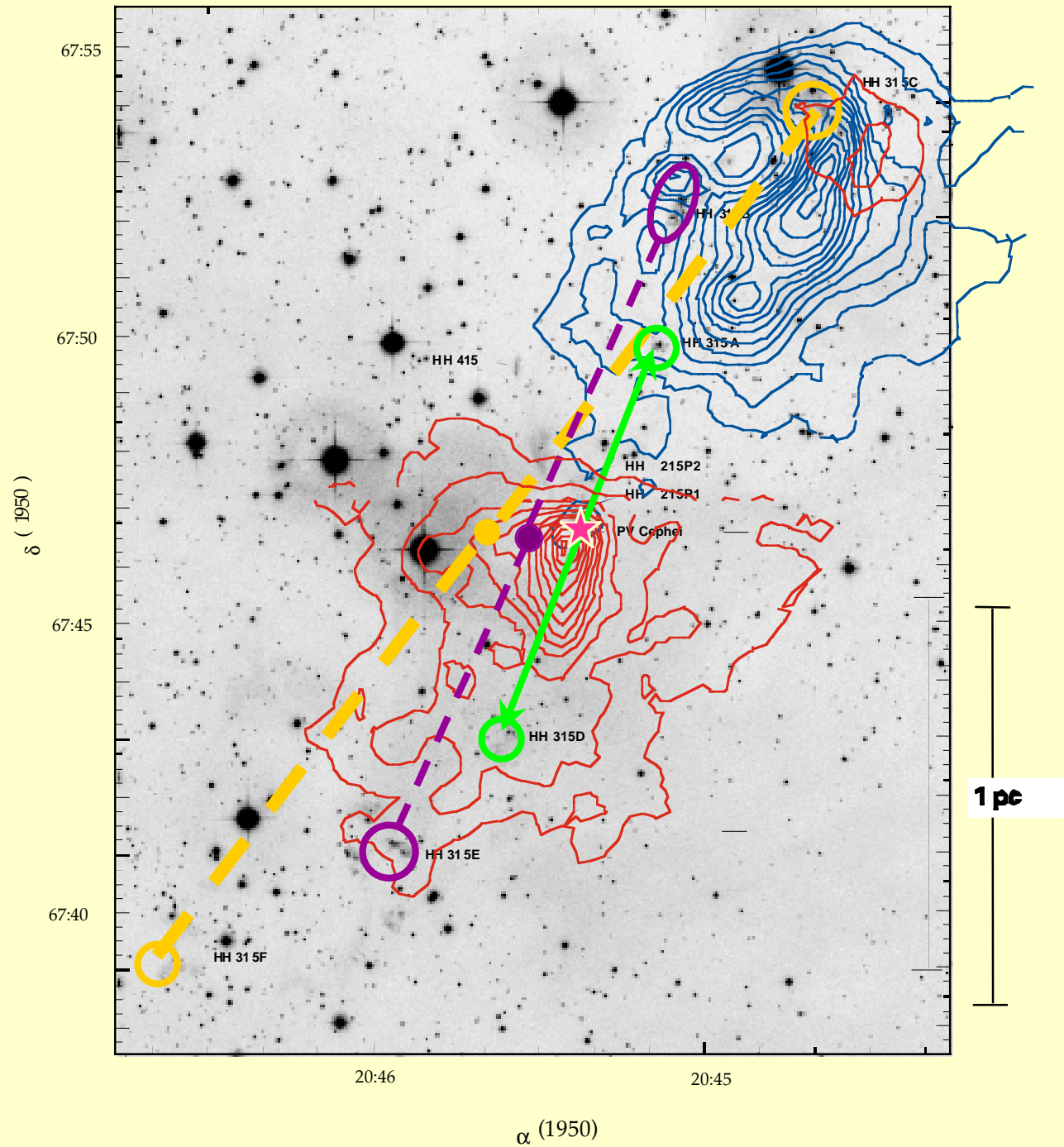


# PV Ceph

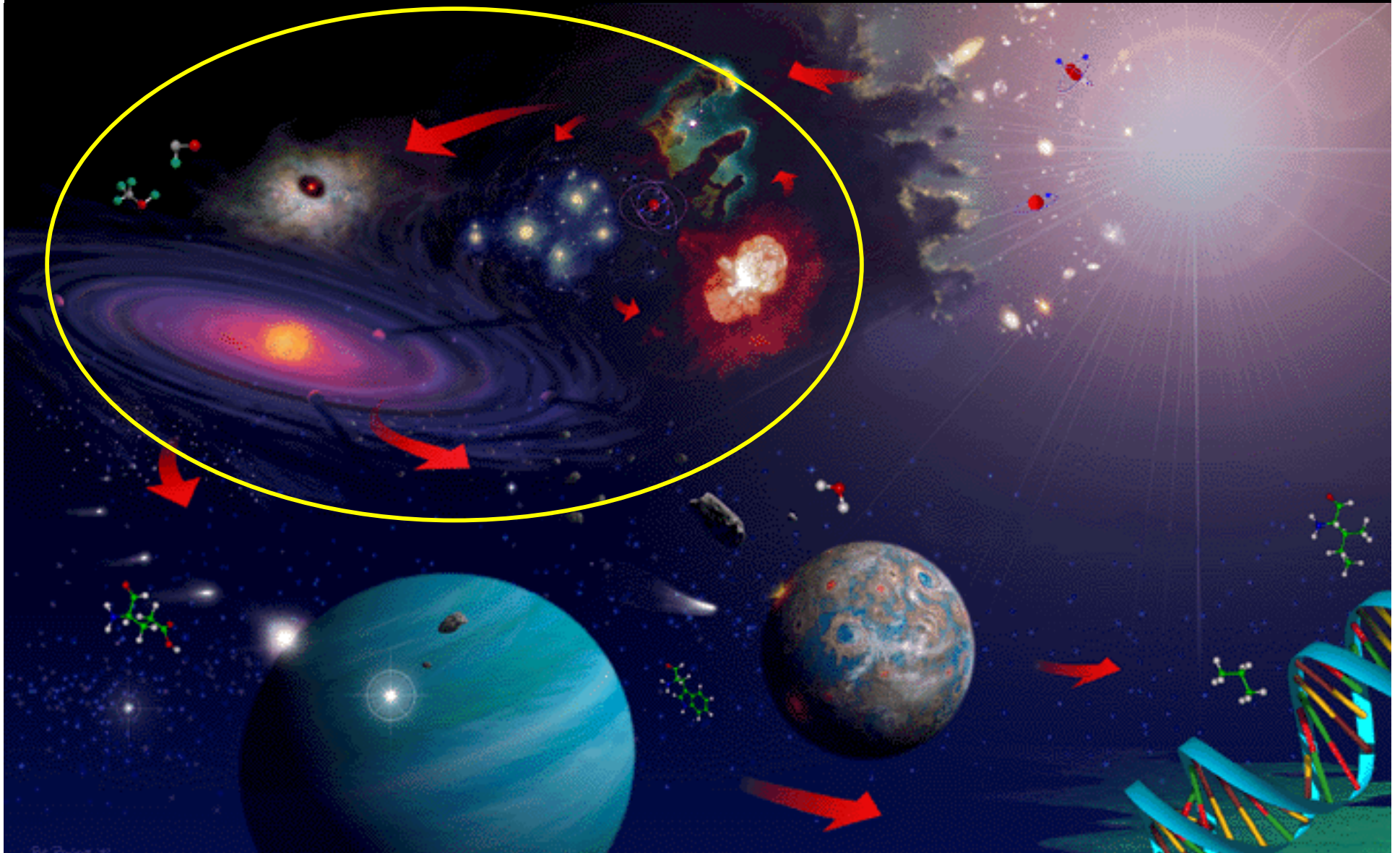
$^{12}\text{CO}$  (2-1) OTF  
Map from **NRAO 12-m**

Red: 3.0 to 6.9  $\text{km s}^{-1}$   
Blue: -3.5 to 0.4  $\text{km s}^{-1}$

*Arce & Goodman 2001*



# NASA's Origins Program



# More Questions?

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