The First Unbiased Radio Emission Line Survey of the Protoplanetary Disk Orbiting LkCa 15

Kristina M. Punzi
Rochester Institute of Technology

Joel H. Kastner (RIT, Laboratory for Multiwavelength Astrophysics)
Pierre Hily-Blant & Thierry Forveille (IPAG, Grenoble, France)
G. Germano Sacco (INAF, Arcetri Observatory, Florence, Italy)

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Pre-MS Star Environment

Proto-planetary disk

Proto Sun

Radial mixing

Comet formation region

Near-IR: continuum + atomic and molecular lines

Mid-IR: dust continuum + molecular lines

(Sub)millimeter: dust continuum + molecular rot-lines

Hot ionized region
Warm molecular region
Cold midplane
Outer disk

0.03 AU 0.1 .. 1 AU 10 AU 100 AU

http://astrobiology.gsfc.nasa.gov/mandell/images/mandell/disk_comet_nebula.jpg
Motivation for Unbiased Molecular Line Surveys of Protoplanetary Disks

- Yield a complete census of bright molecular emission lines
- Determine physical conditions, chemistry in regions undergoing buildup, orbital migration of planets
- Understand pre-MS stellar UV, X-ray radiation as potential drivers of disk gas heating, chemistry
- Pathfinder for disk structure & excitation
LkCa 15

- ~3-5 Myr old
- K5 star
  - $L = 0.74 \, L_\odot$
  - $M = 1.0 \, M_\odot$
- Taurus star-forming region
  - $D \sim 140 \, \text{pc}$
- Transition disk with dust depleted cavity & possible proto-planet...

Image: Karen L. Teramura, UH IfA

Image: Kraus & Ireland, 2011
mm-wave Spectroscopy with the IRAM 30 m
IRAM 30 m Telescope (≈1.3 mm) Spectrum of LkCa 15
IRAM 30 m Telescope (~1.3 mm) Spectrum of LkCa 15

• Full detection of hyperfine structure of CN (2-1) & C₂H (3-2)

• Potential molecular tracers of disk irradiation
Optical Depth Approximations

- $\tau_{13\text{CO}} \sim 0.3$
  - $R = (\text{CO}:\text{C}^{18}\text{O})/(\text{CO}:^{13}\text{CO}) \rightarrow ^{13}\text{CO}:\text{C}^{18}\text{O}$
  - Adopt isotopic abundance ratio, $X=7$
    - $^{12}\text{C}:^{13}\text{C} \sim 68$ (Milam et al. 2005)
    - $^{16}\text{O}:^{18}\text{O} \sim 480$ (Scott et al. 2006)

- $\tau_{\text{CO}} \sim 18.7$
  - $\tau_{12\text{CO}} \approx 68\tau_{13\text{CO}}$
Conclusions

- LkCa 15 is a rich molecular disk
- High-energy (FUV, X-ray) radiation from central T Tauri star important to disk gas chemistry, physical conditions
  - CN, C₂H
- Unbiased survey offers direction for future interferometric (e.g., ALMA) studies
- Imaging of molecules will tell us where certain species reside in the disk, which will lead to:
  - A better understanding of disk structure, temperature, chemistry, excitation