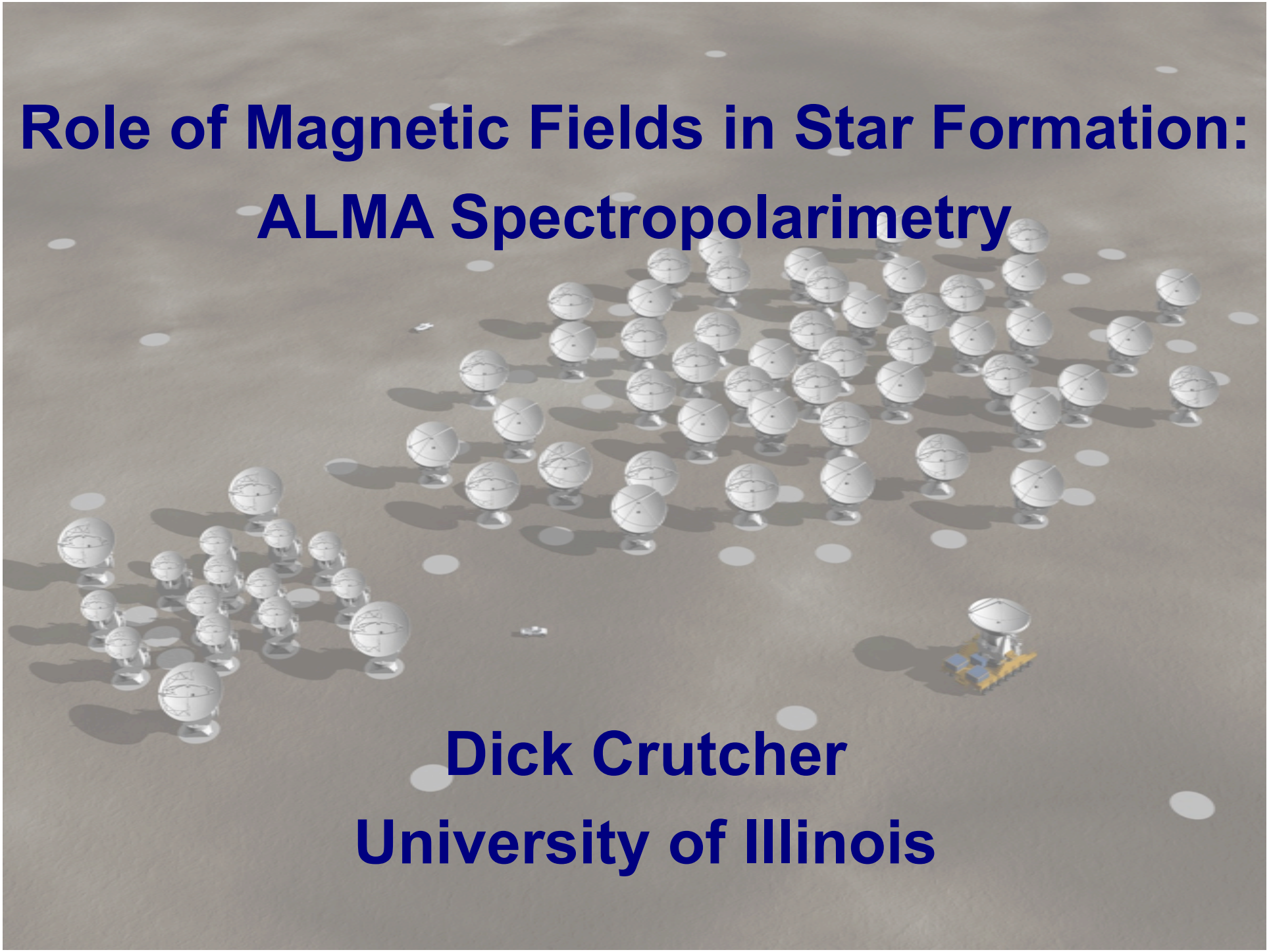
Role of Magnetic Fields in Star Formation: ALMA Spectropolarimetry



Dick Crutcher
University of Illinois

Observational Techniques

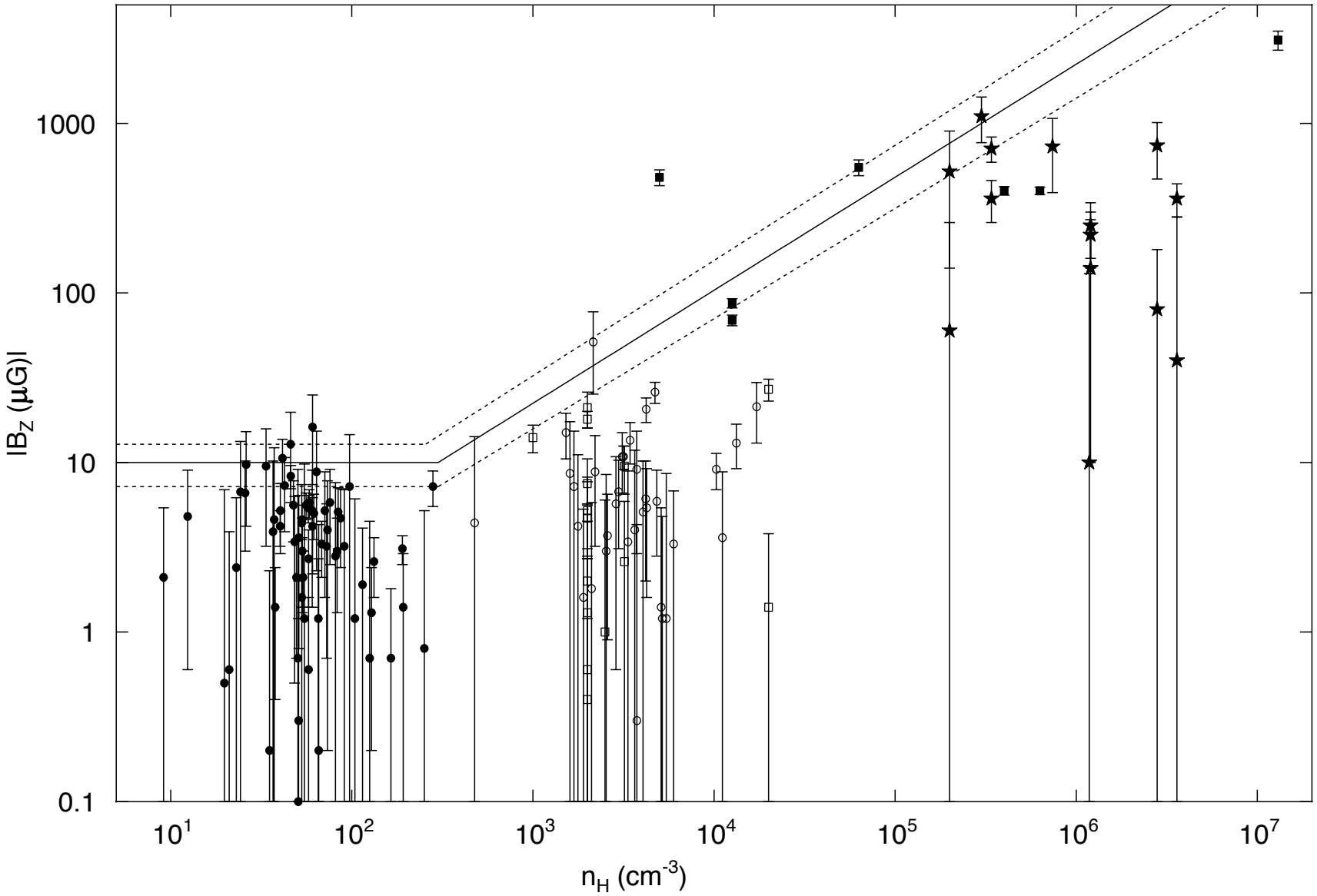
1. Polarization of emission from paramagnetic grains
   - linear polarization ➔ B(plane of sky) morphology

3. Zeeman effect
   - spectral-line circular polarization ➔ B(line of sight) magnitude & direction

species	line frequency (GHz)	density sampled (cm^{-3})
H I	1.4	$10^0 – 10^2$
OH	1.6	$10^2 – 10^4$
C_2H	87	$10^5 – 10^6$
CN	113	$10^5 – 10^6$

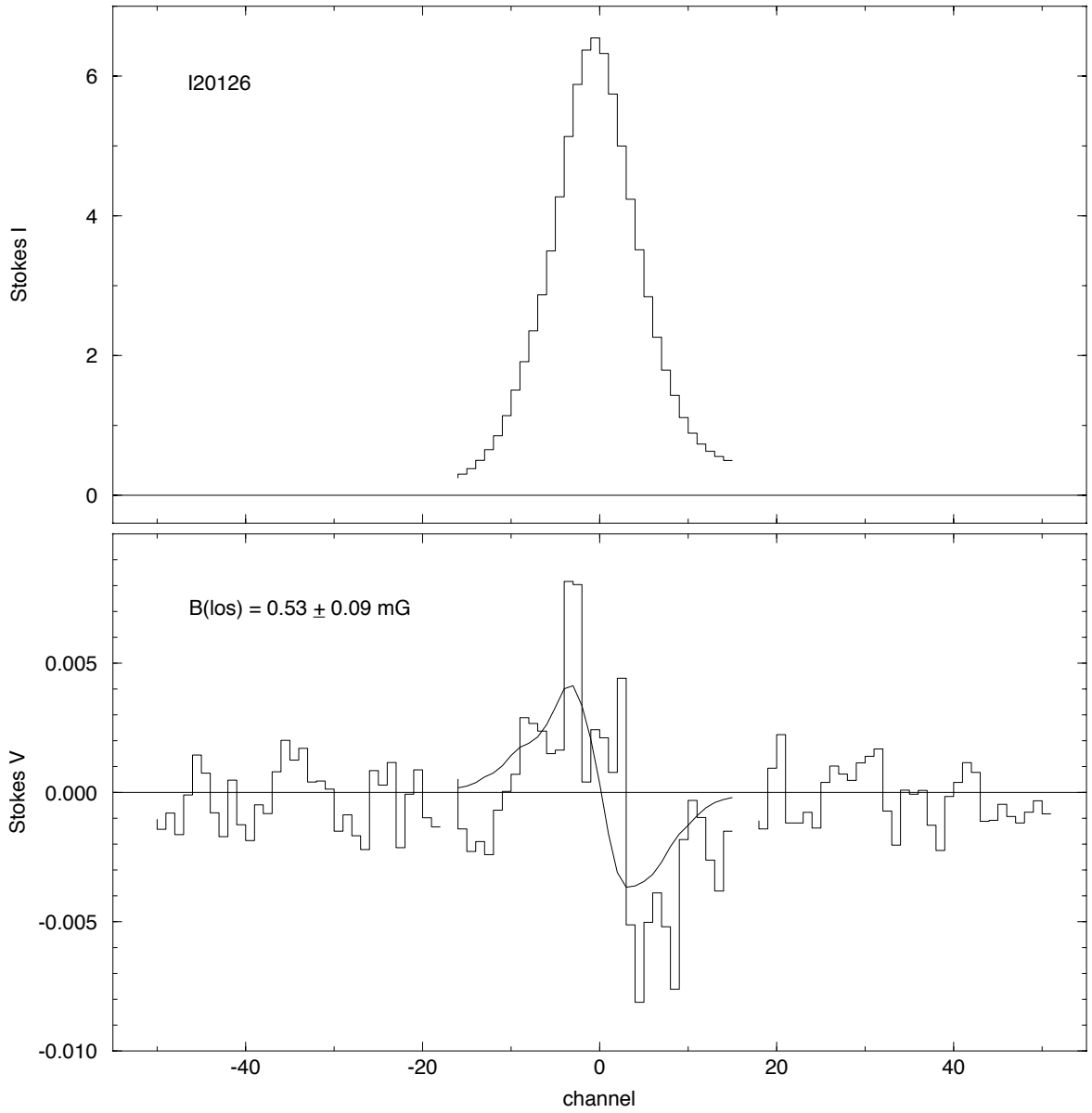
5. Goldreich-Kylafis effect
   - spectral-line linear polarization ➔ B(plane of sight) morphology
   - effect requires $\tau \sim 1$, anisotropic radiative excitation dominates collisional excitation
   - CO 1-0 & 2-1 detected.
   - other species and transitions would sample other densities

Current Observational Status



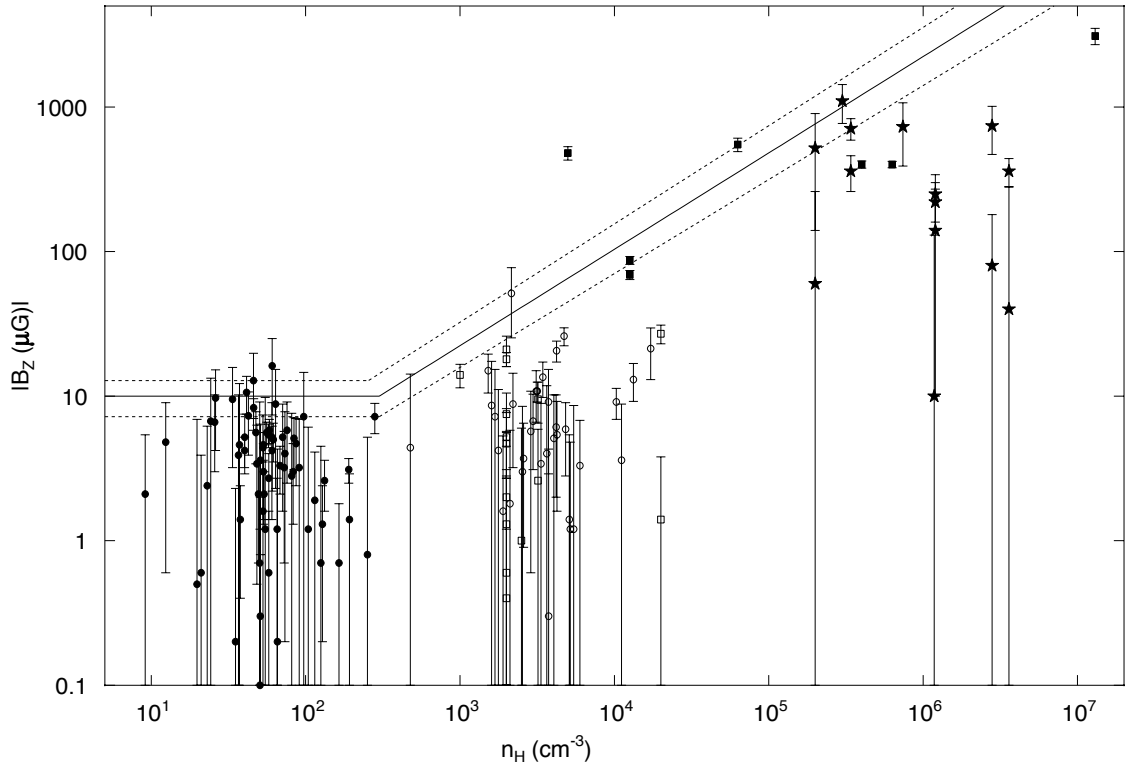
Crutcher, Wandelt, Heiles, Falgarone, Troland 2010

Current Observational Status



Falgarone et al 2010

Current Observational Status



1. PDF of B(total) inferred from observed PDF of B(line of sight)
   - B(total) ~ uniformly distributed between 0 & B(max)
   - <M/Φ> supercritical by ~ factor of 3
   - many, many molecular clouds are highly supercritical
   - Ambipolar diffusion cannot be **THE** star formation driver
2. $B \sim \rho^{2/3}$
   - scaling implied by ~ isotropic collapse

Crutcher, Wandelt, Heiles, Falgarone, Troland 2010

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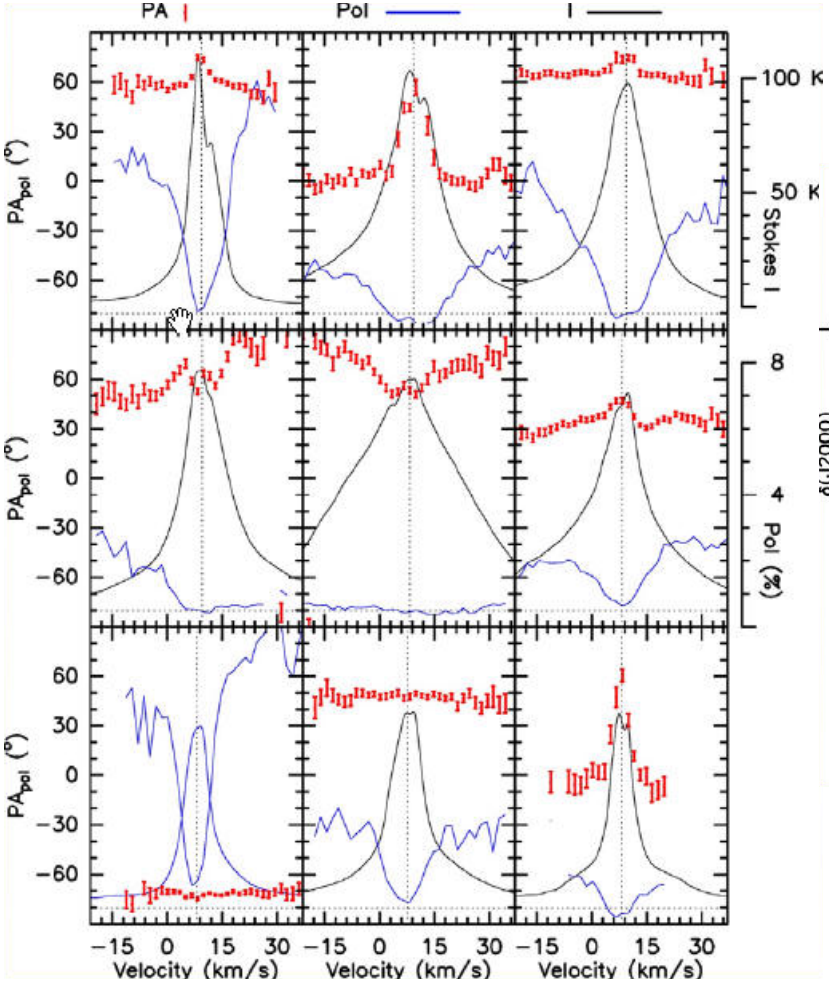
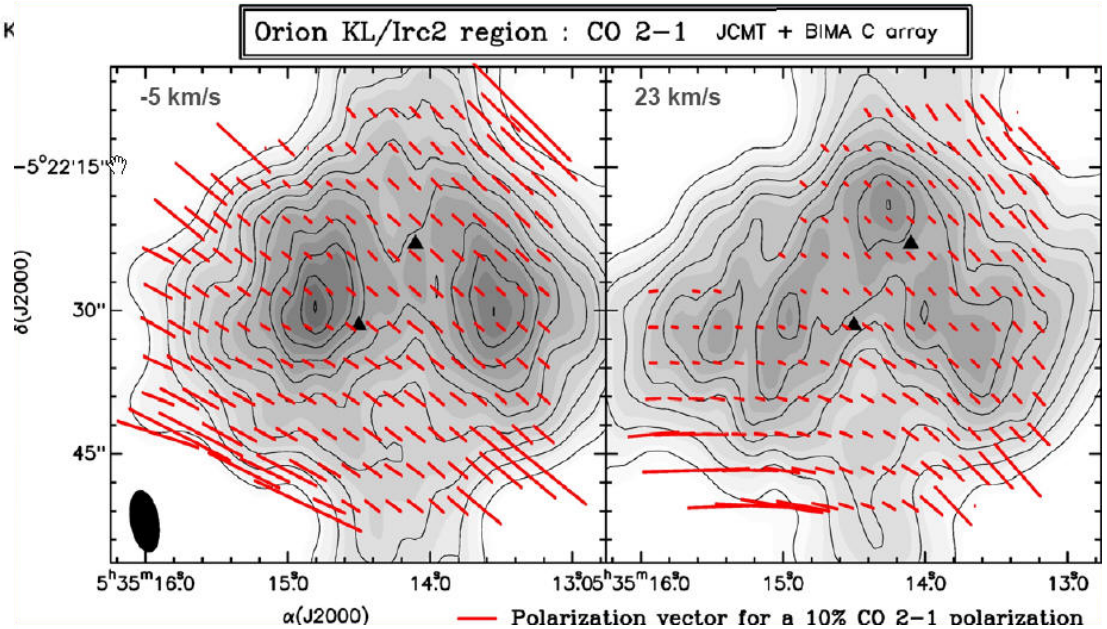
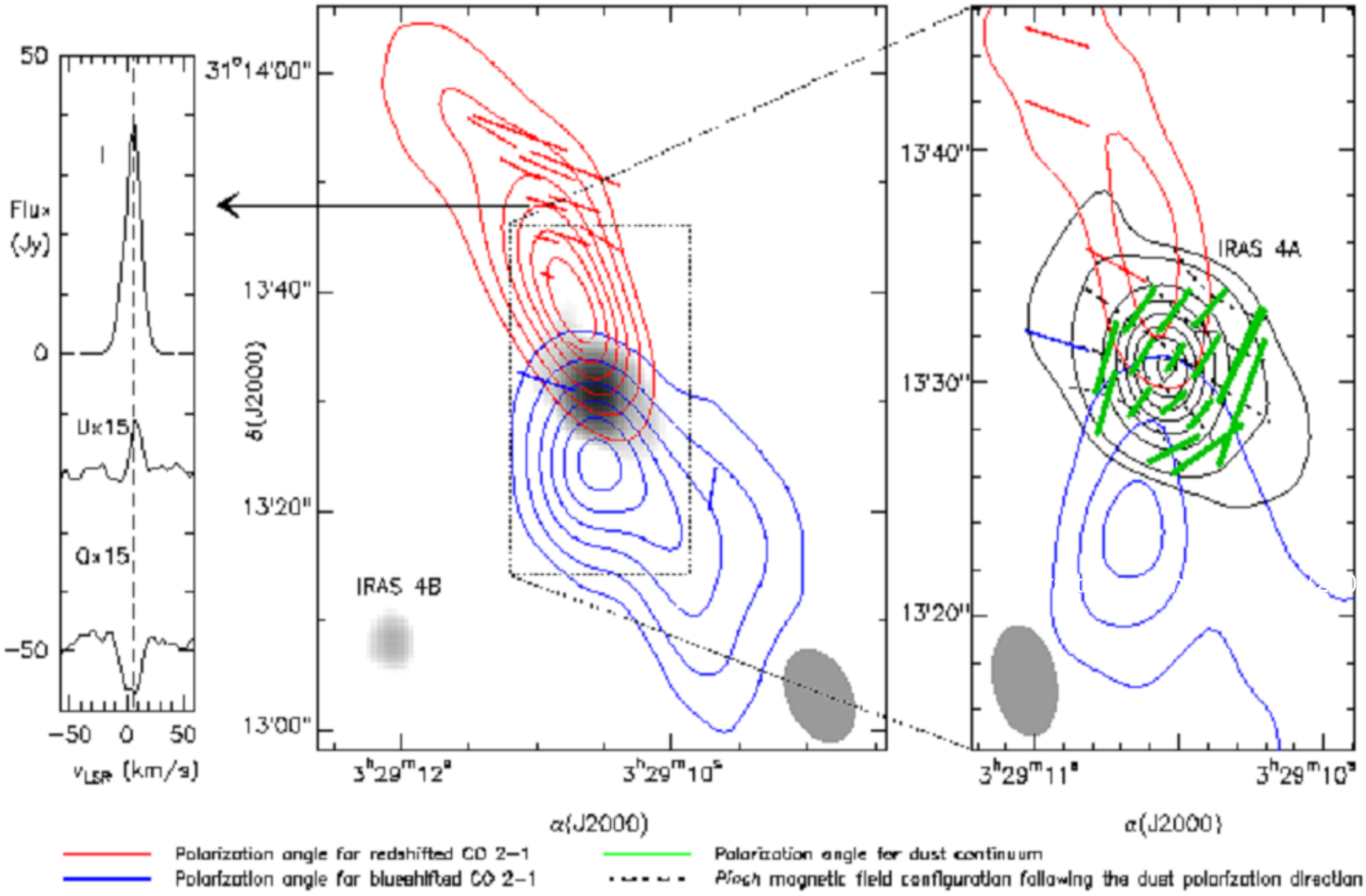




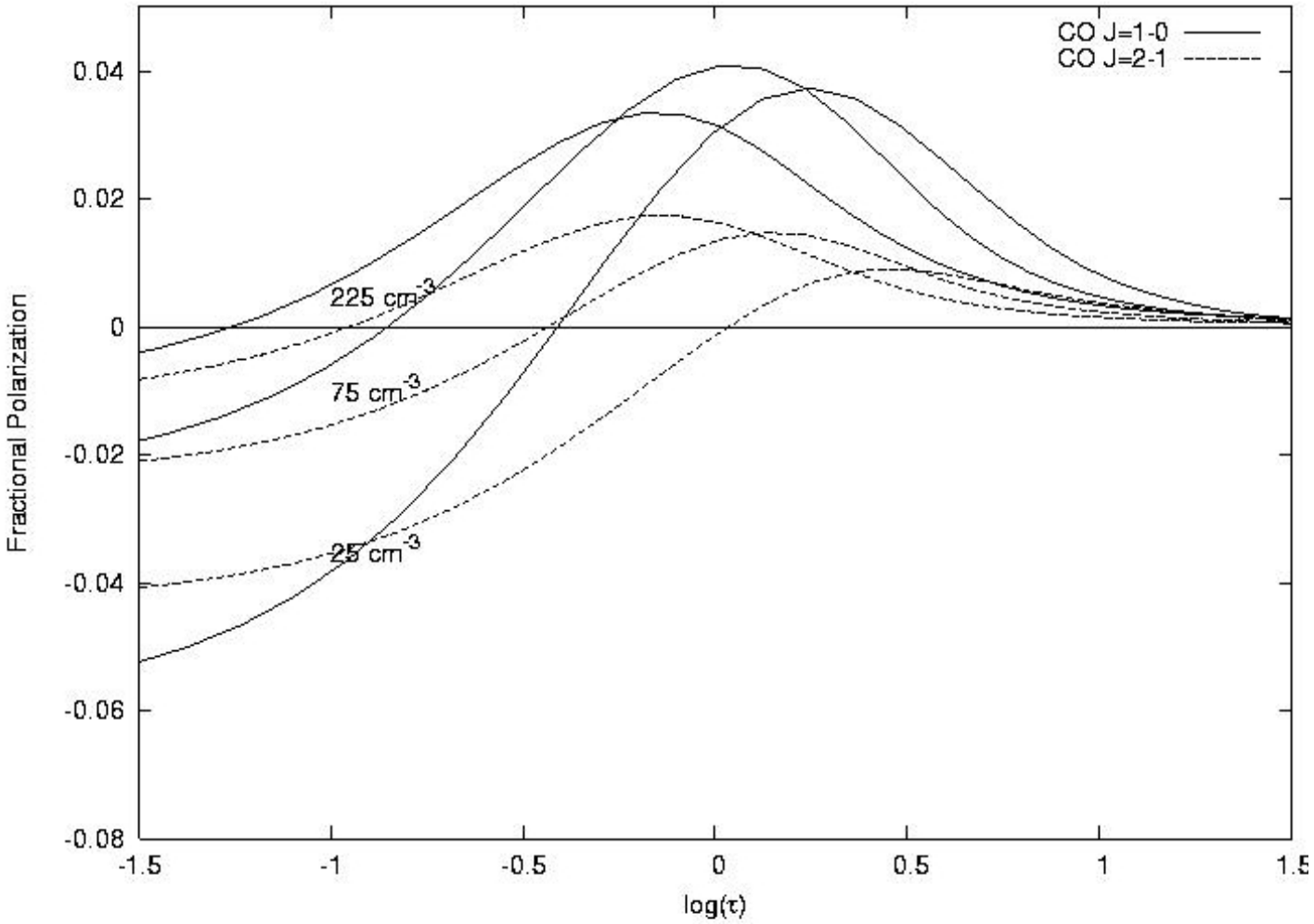
Girart, Greaves, Crutcher & Lai 2004

Current Observational Status



Girart, Crutcher, Rao 1999

Current Observational Status



Modeling Goldreich-Kylafis CO polarization

- Infer gas density and morphology of B

Cortes, Crutcher, Watson 2005

Future Spectropolarimetry with ALMA

1. Sensitivity is ***always*** the major issue in polarimetry
   - ALMA will be ***far*** more sensitive than existing interferometers and single dishes
   - ALMA will be able to observe continuum, Zeeman, and Goldreich-Kylafis polarization ***simultaneously***
   - Results will be maps of (1) plane-of-sky field morphologies averaged through clouds (dust continuum), (2) plane-of-sky field morphologies in different "onion layers" of clouds as various molecules and transitions sample different conditions via the Goldreich-Kylafis effect, (3) line-of-sight field strength maps via the Zeeman effect.

3. Future will be in modeling (not one-off measurements)
   - Models (simulations) of molecular clouds and cores will predict the continuum, Goldreich-Kylafis, and Zeeman maps produced by ALMA
   - Comparisons and model iterations will lead to a far richer and more complete understanding of the role of magnetic fields in the star formation process


That's all Folks!