The physical structure of high-mass protostellar envelopes

Floris van der Tak

SRON
Netherlands Institute for Space Research

university of groningen

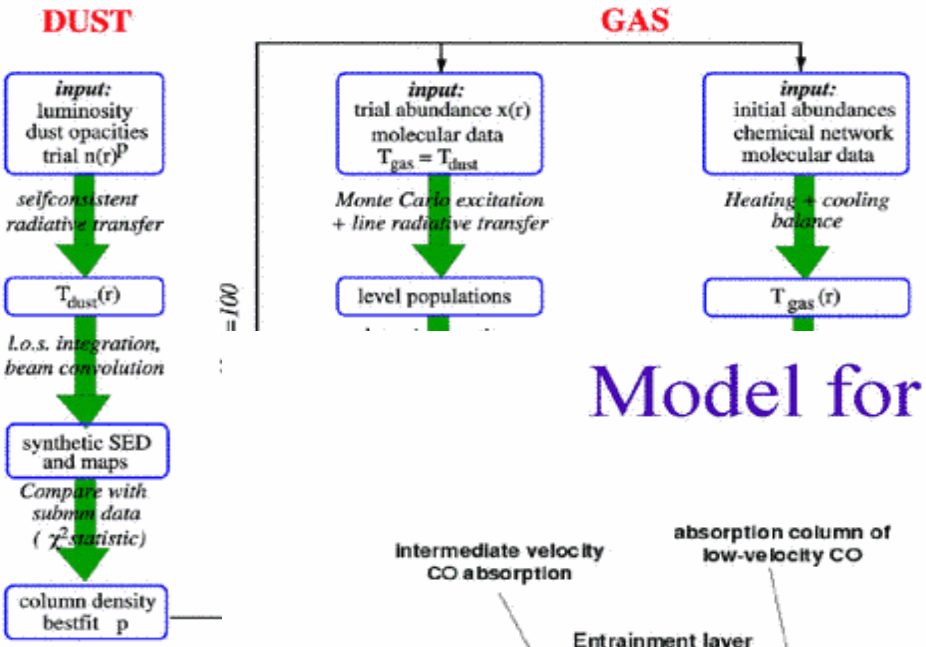
Netherlands Organisation for Scientific Research

Some historical context

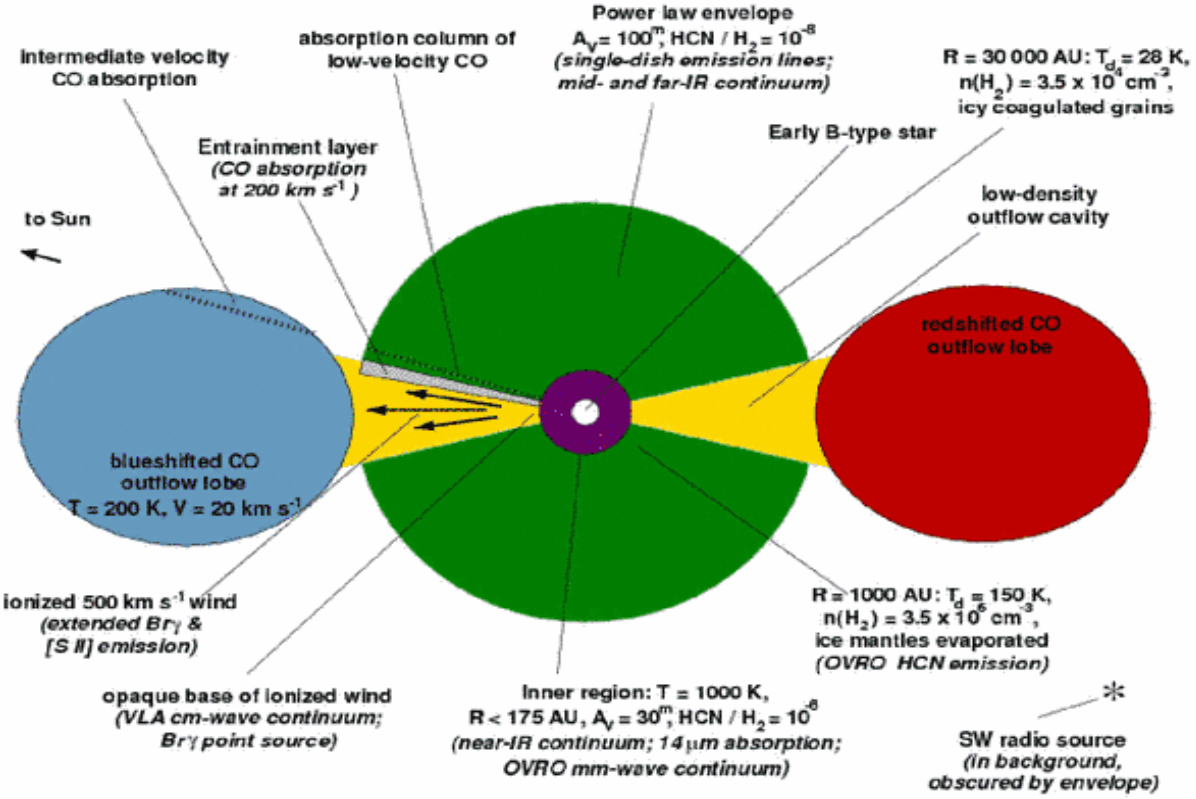
- Early 1990's: need description of protostellar envelopes
  - compare with collapse models (SIS, logatrope, ...)
  - estimate molecular abundances (evolution)
  - J-dependent T_{ex} suggests power law structure
- Neal's approach: bet on two horses
  - Molecular lines: Yangsheng W., Shudong Z., John C., ...
  - Dust continuum: Paul H., Harold B., Antonella N., James di F.
  - uncertainties: which molecule / which opacity
- In 1996, we combined the two schools using:
  - Monte Carlo codes (MC, HST)
  - submm cameras: SHARC, SCUBA
  - ISO mission: limit on CO ice in (AF)GL 2591
  - Collection of molecular data (LAMDA precursor)

Modeling approach

OH5



Model for AFGL 2591



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Some follow-ups

- Physical structure
  - Apply measured beam shape: Kaisa M.
  - Extend to low-mass objects: Yancy S. / Jes J.
  - Extend to later stages of HMSF: Jenny H.
- Chemical structure: from abundances to profiles
  - Couple to chemical network: Ronald S. / Steve D.
  - empirical profiles (jump/drop): CH_3OH, HCN, SO_2 ...
  - use HCO^+/CO ratio to estimate ζ

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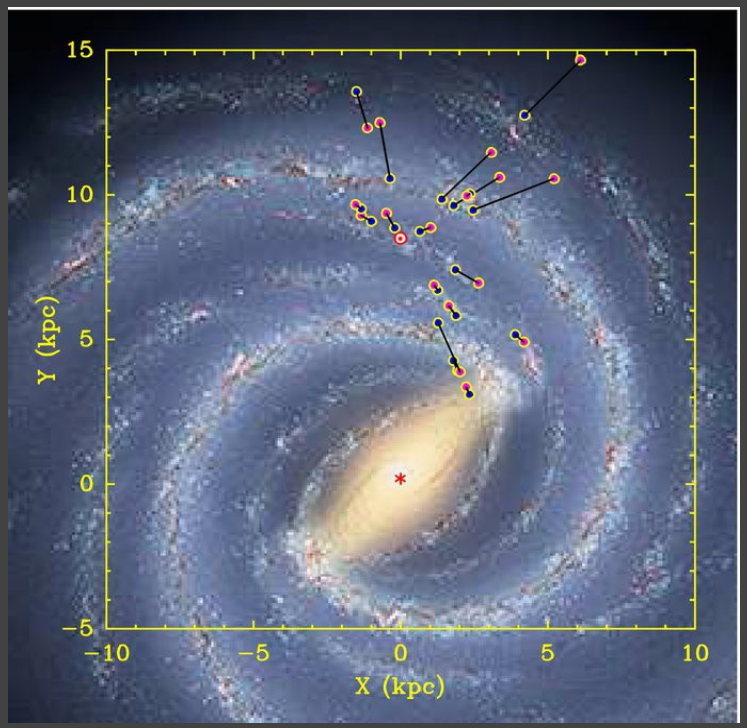
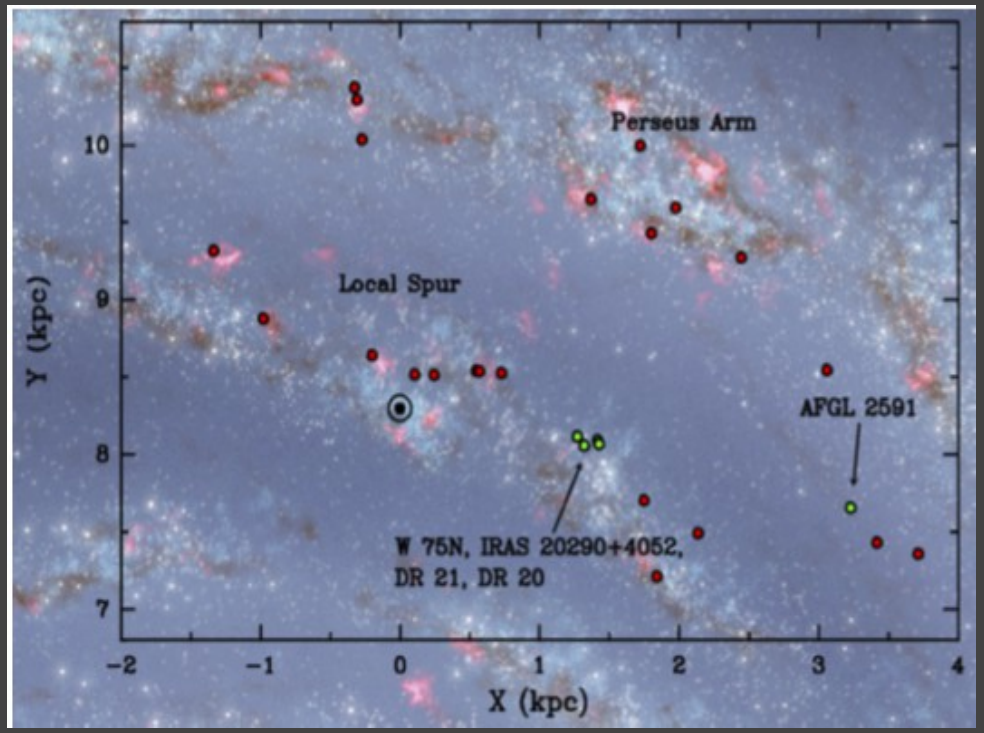
Development 1: Parallax-based distances

- Precision to 0.1 kpc or better
  - often revised: AFGL 2591 (1 – 3.3), W33A (3.7 – 2.4)





Reid et al 2009, Rygl et al 2012, Immer et al 2013

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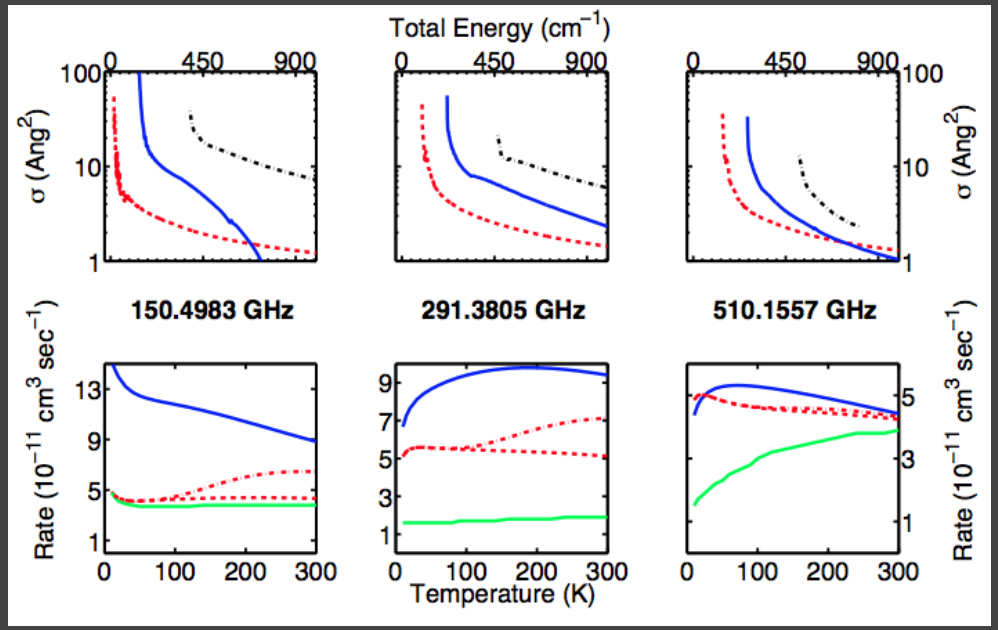
Development 2: Collisional rate coefficients

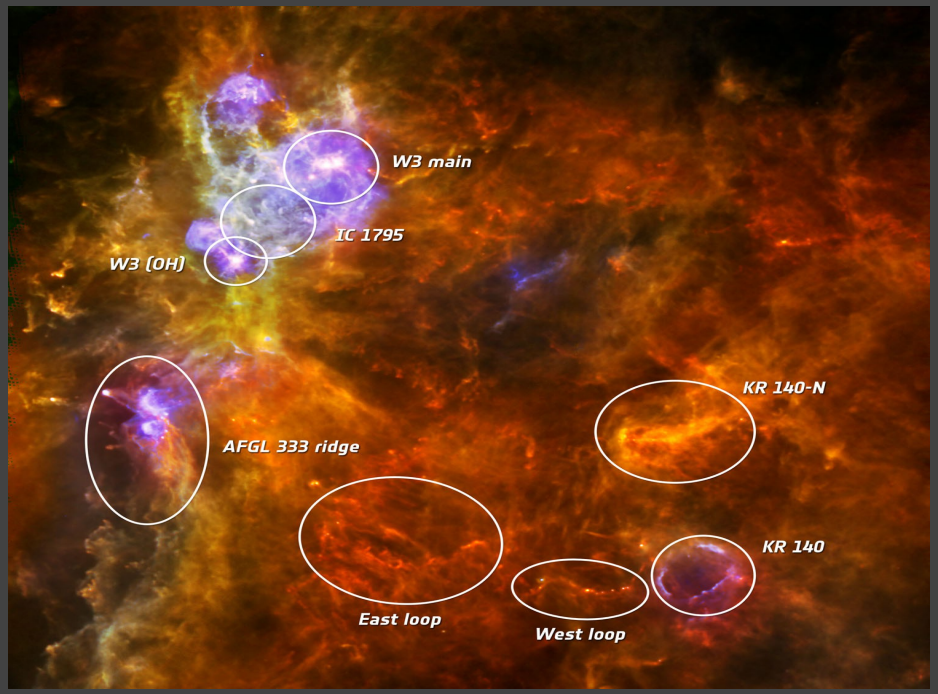
- Huge improvement in computing power since 2000
  - standard with H_2 = 3-10x higher than He
  - o/p resolved
  - hyperfine structure (HCN, CN, ...)
  - isotopes (HDO, ND, ...)
  - experimental tests

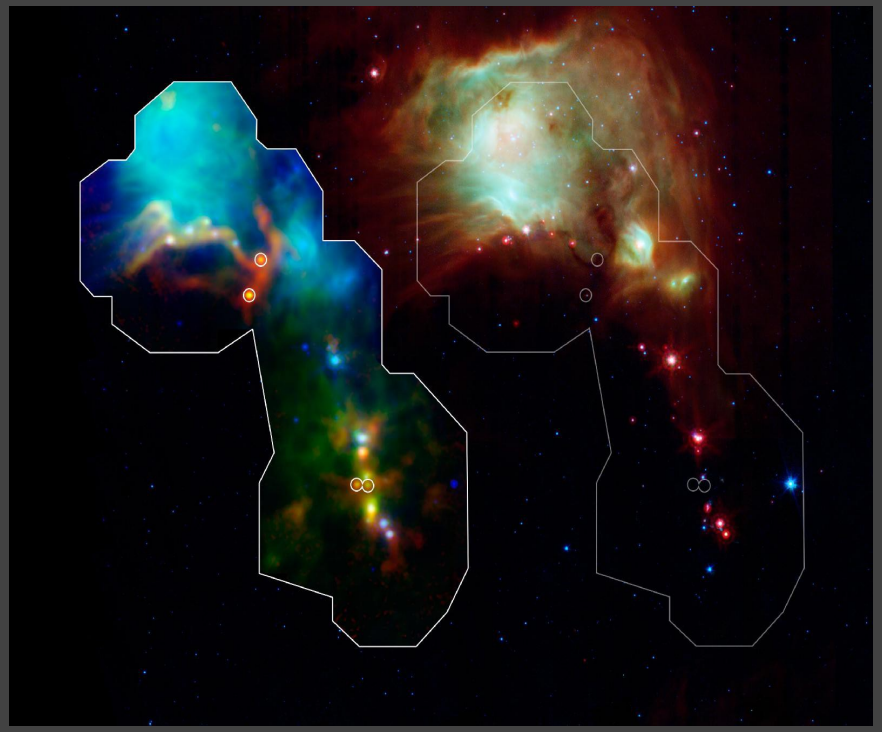


H_2CO-H_2 vs -He: Wiesenfeld & Faure 2013

Development 3: High resolution in far-IR

- Before: IRAS, ISO, KAO points in ~1' beam
  - Now: PACS images at ~10'' resolution
  - Disentangle binaries etc





Rivera-Ingraham et al 2013, Stutz et al 2013

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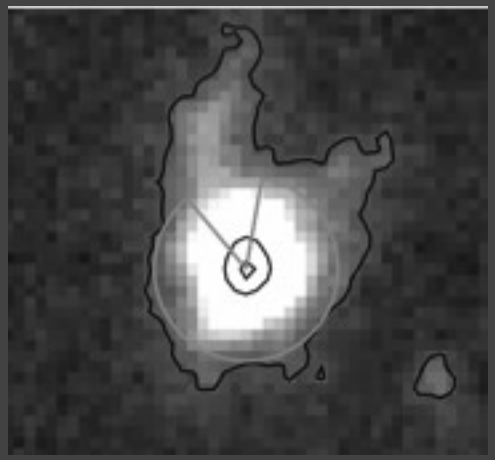
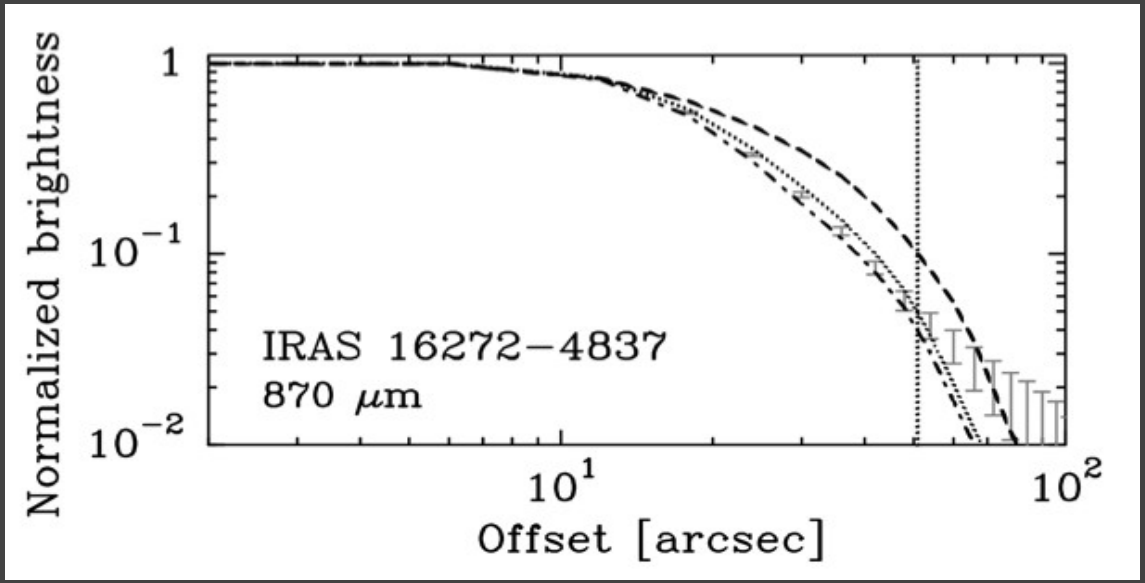
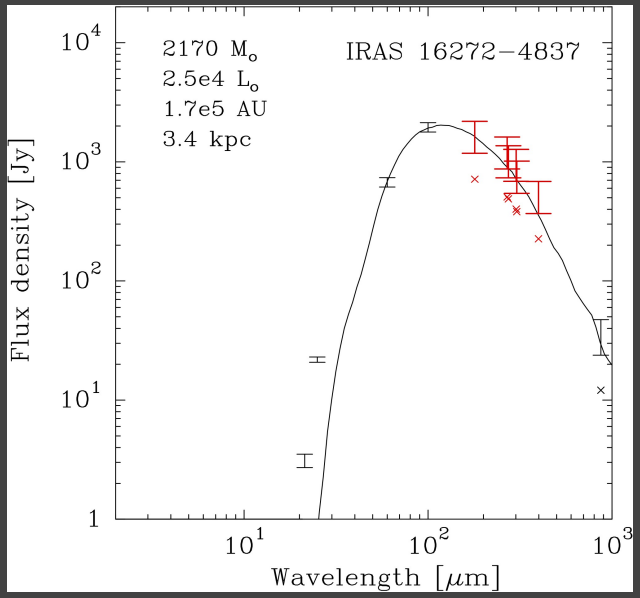
Pure continuum models of high-mass envelopes

- Far-IR SED: Luminosity & mass
  - Submm images: Size & density structure
  - Use lines for kinematics & chemistry







FvdT, L. Chavarría et al 2013

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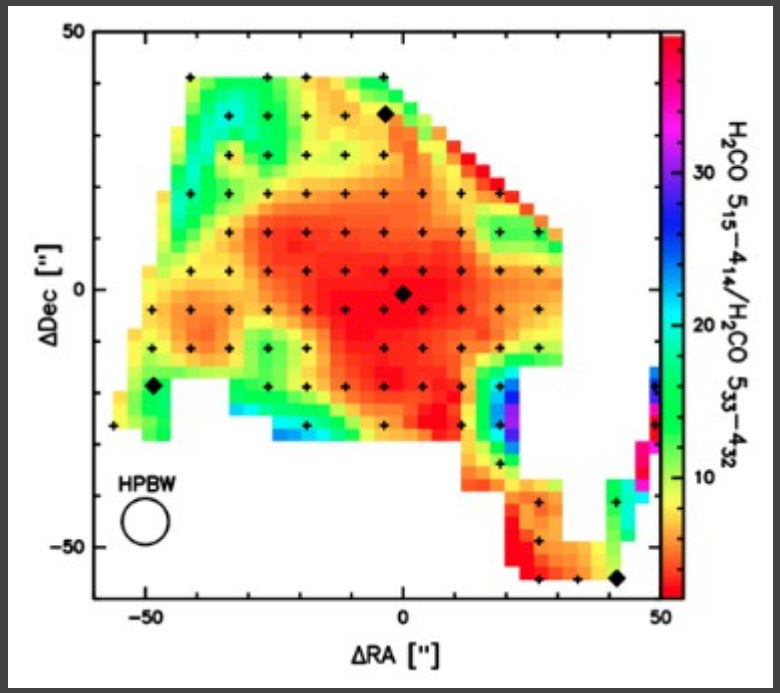
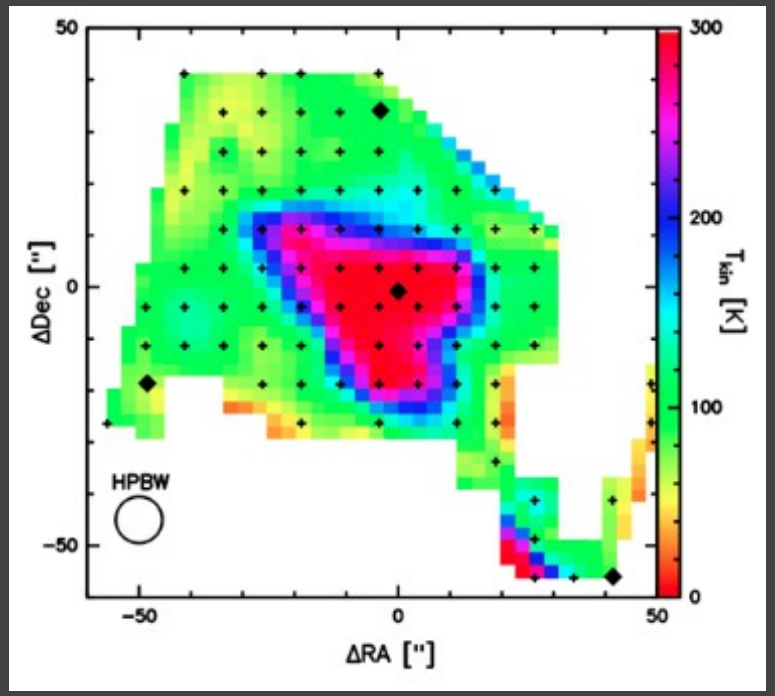
The next step: An engine to process ...

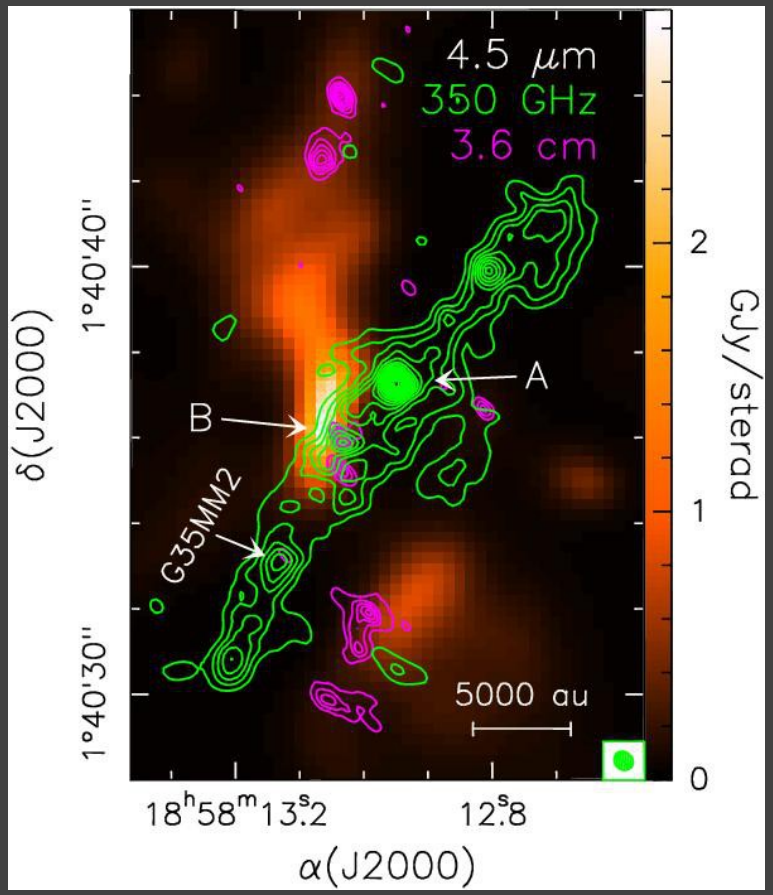
- Automated data fitters
  - crucial for large data streams
  - currently limited to Radex-type models ...

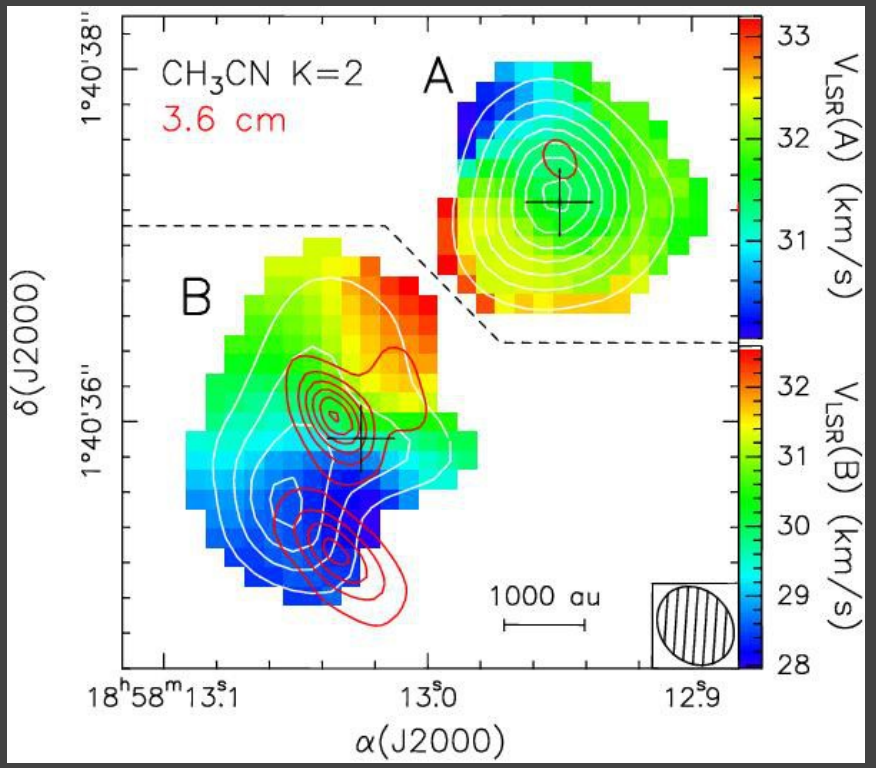


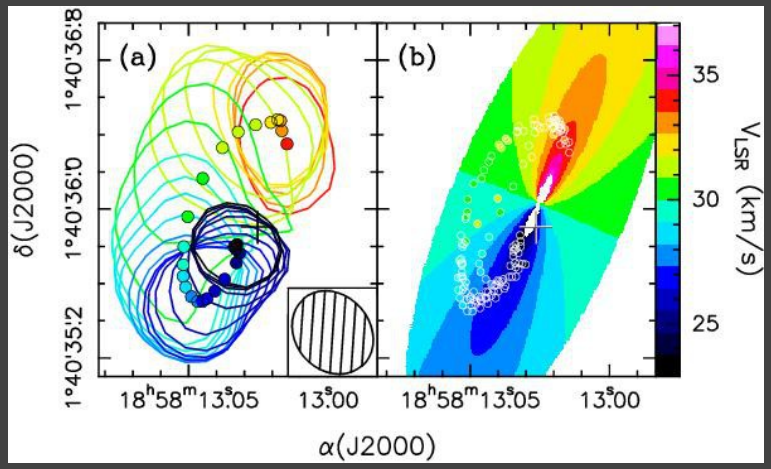


JCMT mapping of H_2CO lines in W49A: Nagy et al 2012

...the ALMA data!







Circumbinary disk in G35.20: Alvaro-Sanchez et al 2013