Maser Studies

Theory view

- Saturation and competitive gain
- Redistribution versus saturation
- Radiation statistics: Gaussian?
- Mode coupling
- Polarization
- OAM content?
- Inverse problem: lines to $n, T, T_d, \Delta v$

Tool view

- Distances: phase lag & various parallaxes
- B field: Zeeman splitting & polarization
- Small-scale kinetic tracers of disc/outflow
- Cosmological variation of fundamental constants?
- Inverse problem

Molecular Data for Modelling

- Molecular energy levels and associated quantum numbers: all that may be 'reasonably' populated
- Transition strengths or Einstein A-values for electric dipole transitions between these levels
- Collisional rate coefficients for maser molecule + (usually) H_2, in ortho- and para-forms, but also He and sometimes H atoms, electrons
- Pack all into a convenient data file, usually in the RADEX format: part A, levels; part B, radiative transitions; part C, rate coefficients

Example: Water Lines for ALMA

- o-H_2O: 411 levels, 7597 radiative transitions
- p-H_2O: 413 levels, 7341 radiative transitions
- Complete to $5000cm^{-1}$ (7194K)
- ALI radiative transfer with line overlap
- Separate water spin species
- Levels: Tennyson et al. (2001JPCRD..30..735T)
- A-values: Barber et al. (2006MNRAS.368.1087B)
- Collisional data for H_2+H_2O: Faure & Josselin (2008A&A...492..257F) – uses extrapolations
- RADEX file from Leiden database

Predicted Inversions: T_d=50K
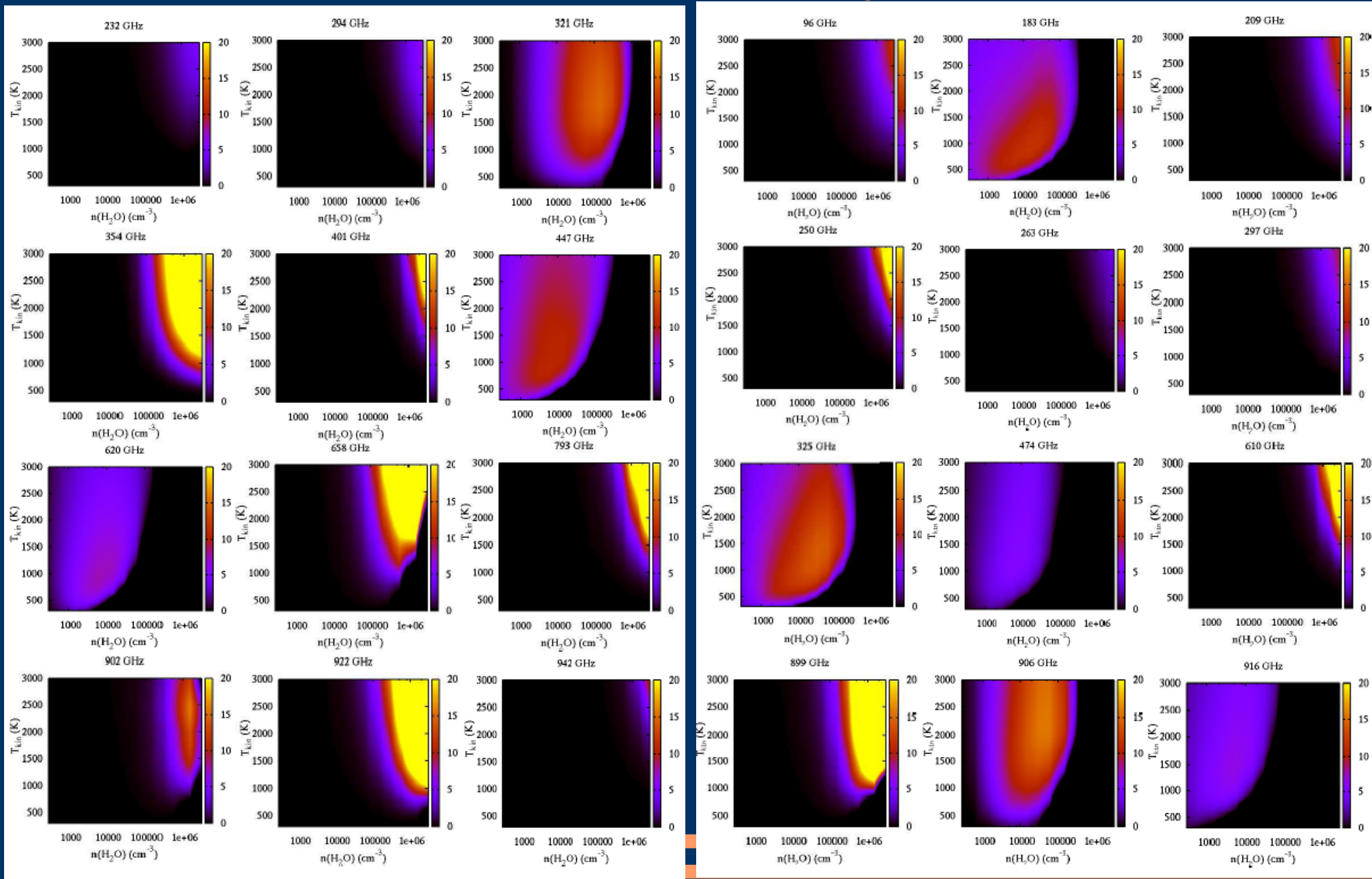
...and with lots of dust: T_d=1025K
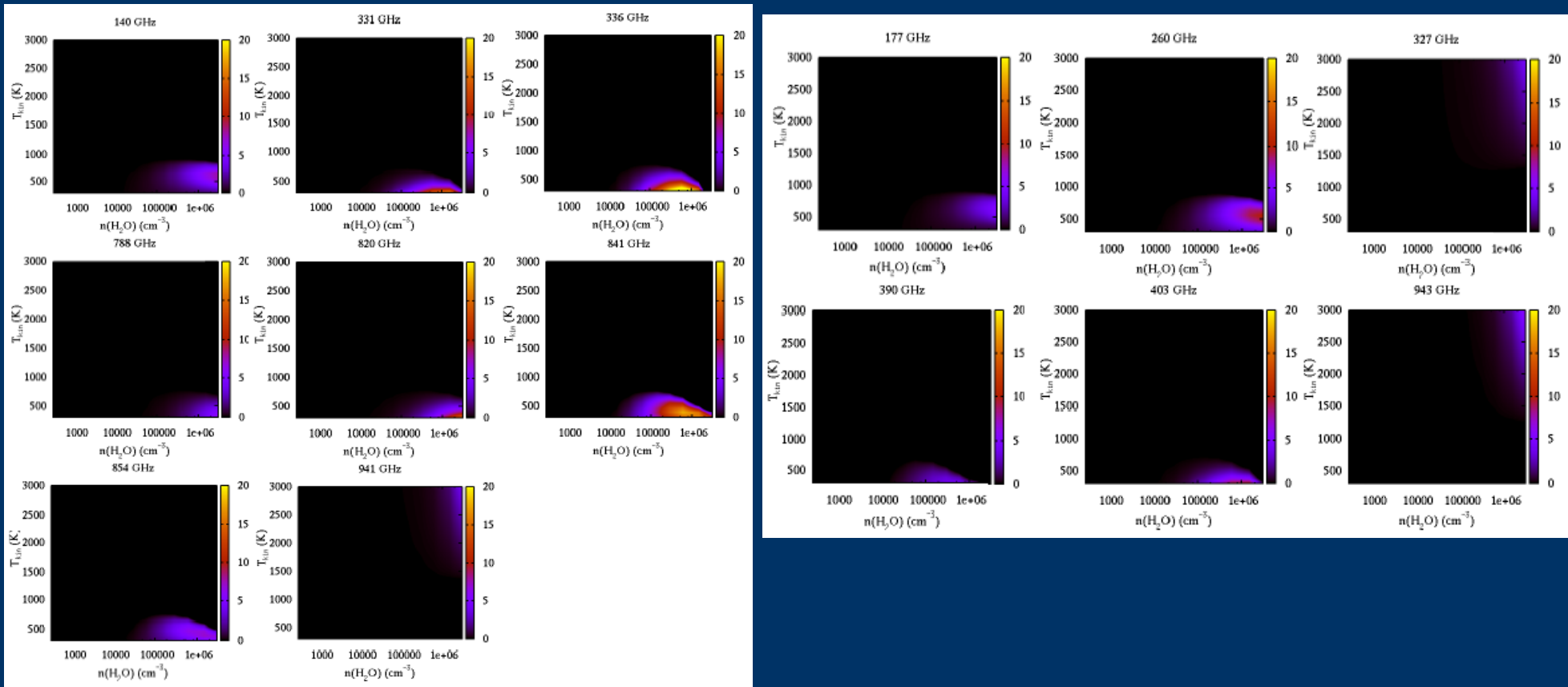
New Features

- Inversions in (0,1,0), (0,2,0), (0,0,1) and (1,0,0) vibrationally excited states
- Some fully rovibrational transitions inverted
- Extended range of T_{kin} to 3000K
- Extensive radiative pumping including line overlap: note different locus for radiatively pumped lines
- Of order 25 maser lines for each spin species of water: attempt the inverse problem?

Inverse Problem with ALMA

- 5 main unknowns: $n, T_{kin}, T_d, \Delta v, [H_2O]$, but ALMA bands 3-10 can see ~50 known & potential masers!
- Excellent 3-D resolution: angular typically < 100milliarcsec; velocity < 1km/s
- Can probably identify co-propagating masers
- Overlay pixel technique (Alain Baudry) to determine most likely values of unknowns
- It will probably never work with OH even with VLBI: too few lines; restricted bandwidth

Plans

- Similar model for formaldehyde: levels and A-values done; finish collisional data.
- SiO 3 isotopomer overlap coupled model: data being generated
- People want models with polarization...