Spectral Line VLBI

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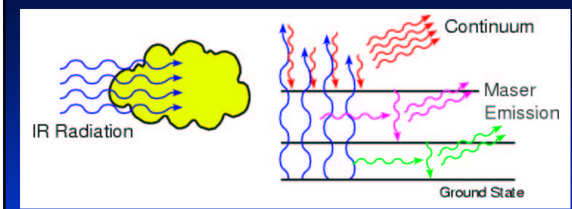
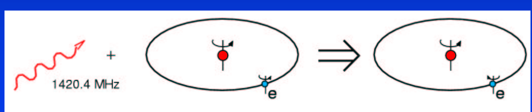
Spectral Line Sources

- VLBI → High brightness temperatures
- Masers:
  - → Galactic
    - OH, H_2O, SiO, CH_3OH
  - → Extragalactic
    - OH, H_2O
- Extra-galactic HI absorption





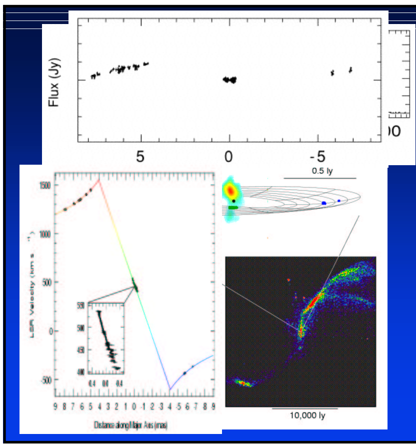
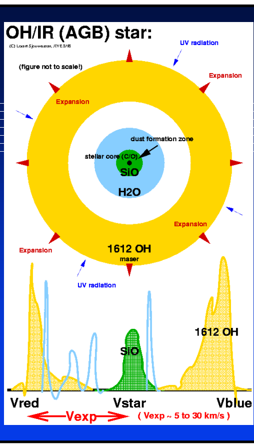


Image courtesy of Lincoln Greenhill, CfA VLBI Group

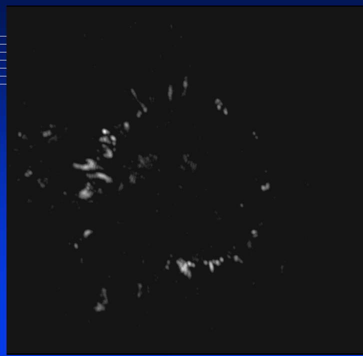
See also:

Hernstein etal, 1999, *Nature*, **400**, 539

Miyoshi etal, 1995, *Nature*, **373**, 127

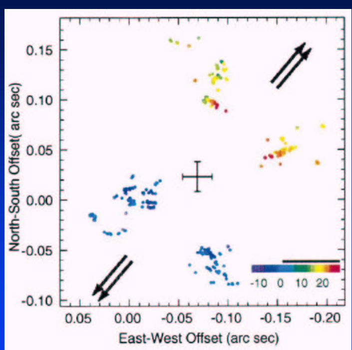


SiO masers in TX Cam

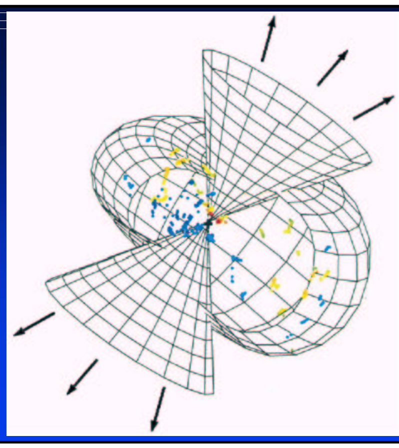


Movie courtesy of Phil Diamond, Jodrell Bank

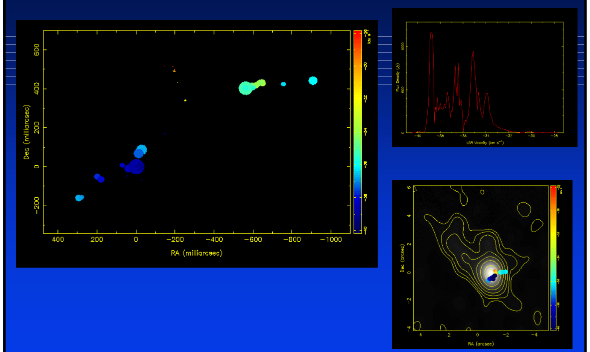
SiO masers in Orion BN/KL

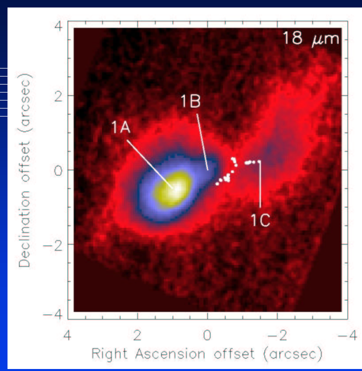


Greenhill etal, 1998, *Nature*, **396**, 650



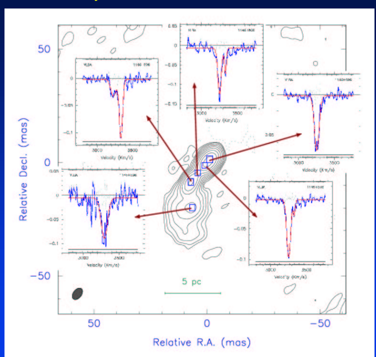
6.7-GHz methanol in G339.88-1.26



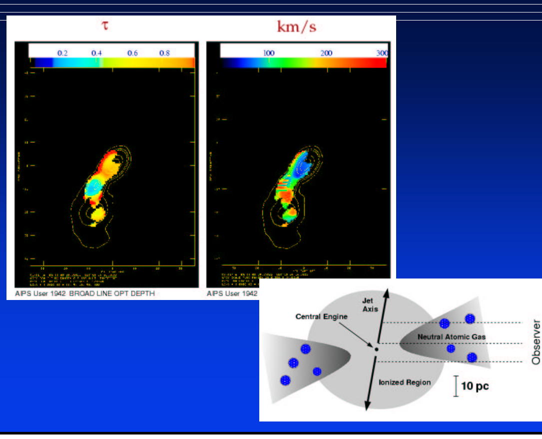


De Buizer etal, ApJ *In press*

HI absorption towards NGC 3894



Peck & Taylor, 2000, EVN Symposium 2000

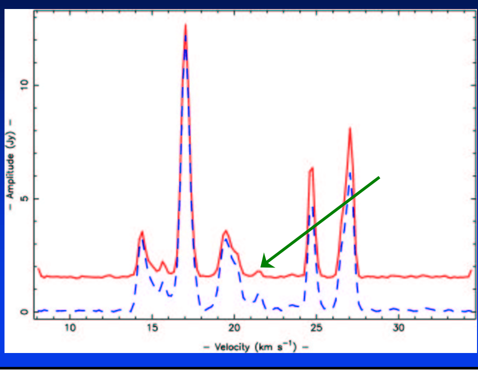


Spectral Line Correlation

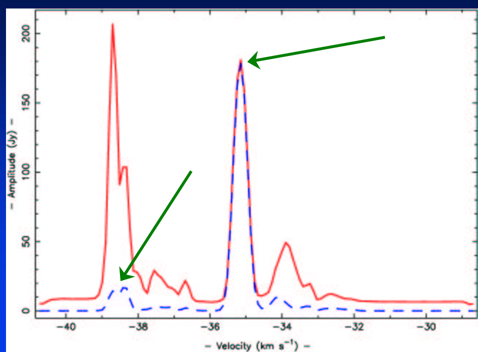
- Modern digital correlators intrinsically spectral line
- Spectral resolution function bandwidth & number of lags (or size of FFT)
- Maser components are very narrow
  - → High spectral resolution is needed

- Galactic masers typically 1-20”
  - → Short integration time (Time Smearing)
- Hanning smooth
- Scalar and vector averaging:
  - → Scalar - Noise bias
  - → Vector - Small synthesised beam

ATCA Data (6.7 GHz Methanol)



VLBI Data (12.2 GHz Methanol)



Calibration

- Basically the same as for continuum
  - → Estimate time dependent antenna Tsys
  - → Estimate residual delay and rate
- Also correct for bandpass

Assume time and frequency corrections are independent

Bandpass Calibration

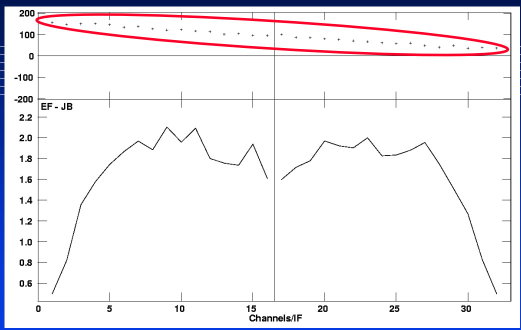
- Need relatively strong continuum source
- Must observe at same frequency
- Can use auto-correlations, but cannot correct phase
- Cross-corr allow phase correction
  - → Need enough S/N on calibrator
  - → Need to fringe fit first

Amplitude Calibration

- Can do normal Tsys calibration
- Optionally, use auto correlations:
  - → Gives very good results (in principle)
  - → Corrects for pointing errors at telescope
  - → Only gives relative calibration
    - Depends on amplitude calibration of template spectrum

Fringe Fitting

- Need to estimate residual delay and rate
- Residual rate seen as slope of phase in time (in both frequency and lag domain)
- Residual delay seen as shift in lag domain, so a slope of phase across the bandpass in the frequency domain



- Measure residual delay by measuring phase slope
- Only a couple of channels per feature for spectral line
  - → Cannot measure residual delay
- Continuum delay calibrator must be observed every hour or so
- Residual rates obtains from a bright spectral feature

Doppler Correction

- Each station at different velocity
- Need to correct to standard rest frame
- Observe at fixed frequency
- Fringe rotation at correlator does some
- Further velocity correction in software
  - → Application depends critically on design of correlator

Self-calibration

- Many separate components at different velocities and position
- Cannot selfcal data set as a whole
- Cannot run self cal on each frequency channel separately
- Selfcal strong (compact) feature and apply calibration to rest of channels

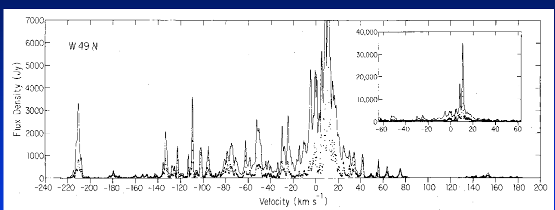
Continuum Subtraction

- No need for Galactic masers
- Do after all calibration for HI absorption
  - → Image negative hole in image
  - → POSSM plots show as emission

Imaging

- Nothing special but…
  - → Large maps with many frequency points yields large data cubes

Water masers in W49N



Walker etal 1982, ApJ

Fringe Rate Mapping

- Galactic masers sometimes large (>10”)
  - → Often many sources in beam
- Wide velocity width
  - → Large data cube
- Use fringe rate mapping to find where emission is
- Also gives absolute position
- FRMAP in AIPS tricky to use

Scheduling

- ~~Choose enough bandwidth for velocity coverage~~
- Calculate required spectral resolution
  (Allow for Hanning smoothing)
- Find correct velocity (and ref frame!)
- Find close (enough) delay calibrator
- Choose a strong bandpass calibrator
- Turn off phasecal!
- Consider over sampling