Mapping the 36 GHz Methanol Masers

Hannah Seyb

Vincent Fish

QuickTime™ and a
decompressor
are needed to see this picture.

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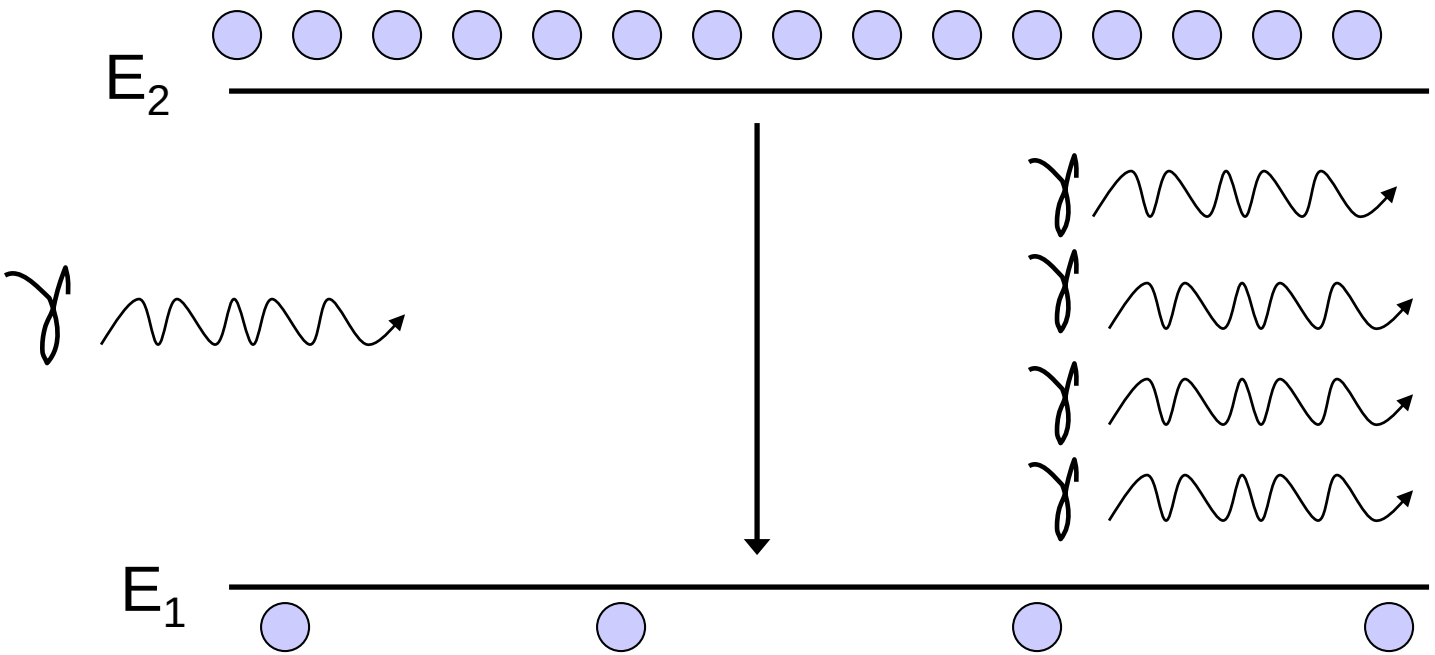
What is to come:

- Background
  - What are astrophysical masers?
  - Methanol masers
- Data Collection
- Data Reduction
- Analysis
- Conclusions/Discussions
- Questions

What is a Maser?

- **M**icrowave **A**mplification by **S**timulated **E**mission of **R**adiation
- Population inversion
  - More molecules in upper energy states
- Exponential amplification of transitioning molecules

What does this look like?



Astrophysical Masers

- Masers that naturally occur in space
- Emitted radiation has same energy as difference between two states
- Common types:
  - Water: H_2O
  - Hydroxyl: OH
  - Formaldehyde: H_2CO
  - Methanol: CH_3OH

Methanol (CH_3OH) Masers

- Many different transitions result in masers
- Locations:
  - Star-forming regions
  - Supernova Remnants
  - Galactic Center
- Two different types:
  - Class I
  - Class II

Class I

- Excited by shocks
- Along outflows from continuum sources
- Common transitions:
  - J_0-$(J-1)_1$ A^+ series
    - 7_0-6_1 at 44.070 GHz
  - J_2-$(J-1)_1$ E series
    - 5_2-5_1 at 24.959 GHz
    - 6_2-6_1 at 25.018 GHz
  - J_{-1}-$(J-1)_0$ E series
    - 4_{-1}-3_0 at 36.169 GHz

Class II

- Located near continuum sources
- Ultra Compact HII regions
- Common transitions:
  - $(J\text{-}1)_1\text{-}J_0$ A^+ series
    - $5_1\text{-}6_0$ at 6.7 GHz
  - E series
    - $2_0\text{-}3_{-1}$ at 12.2 GHz
- Some have shared energy states with class I masers, so they cannot occur at same locations
  - 44 GHz and 6.7 GHz

What can CH_3OH masers tell us?

- Velocity of gas
- Characteristics of gas flow
- Trace shocks
- Star formation

Source Selection and Data Acquisition

- 12 Star forming regions
- Previously detected 36 GHz CH_3OH masers
  - Haschick and Baan (1989)
  - Liechti and Wilson (1996)
  - Pretap et al. (2008)
- EVLA in D or DnC configuration
- 9 July - 15 August 2010

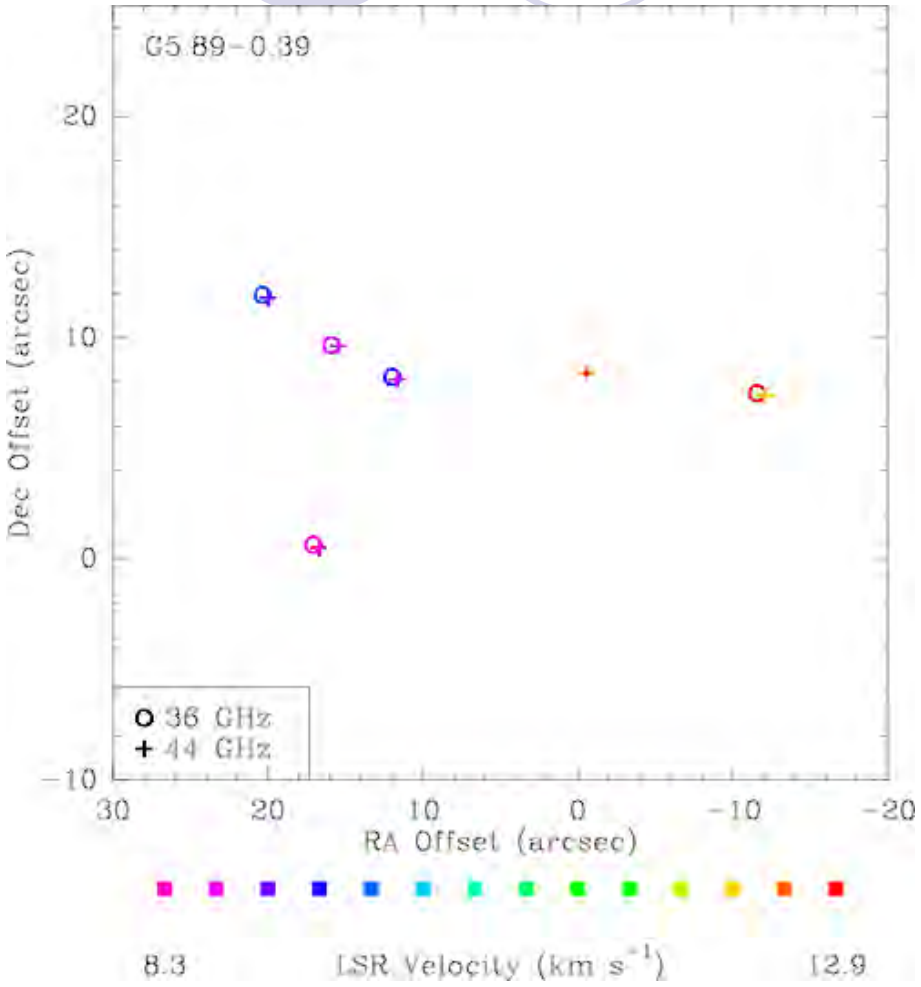
Data Reduction

- NRAO **A**stronomical **I**mage **P**rocessing **S**ystem (AIPS)
- Calibration
  - Quasars
  - Self-calibration
- Image cubes
  - Spectral channels
- Located and mapped masers

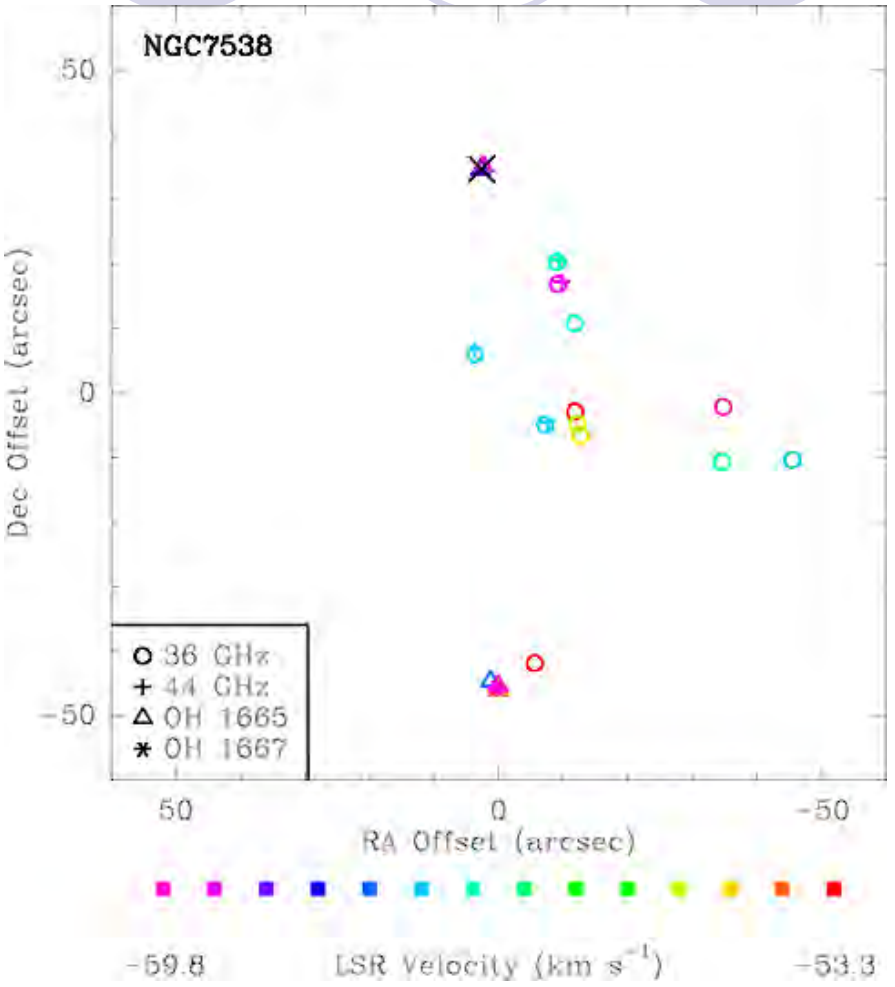
Data Analysis

- Velocity
  - Fixed sky frequency: 36.169265 GHz
  - Convert to LSR velocities
    - NRAO Online Dopset Tool
- Mapped along with other transitions
  - 44 GHz
    - Verify various models (temperature and density dependency)
    - Commonalities in excitation conditions

Correlations with other transitions



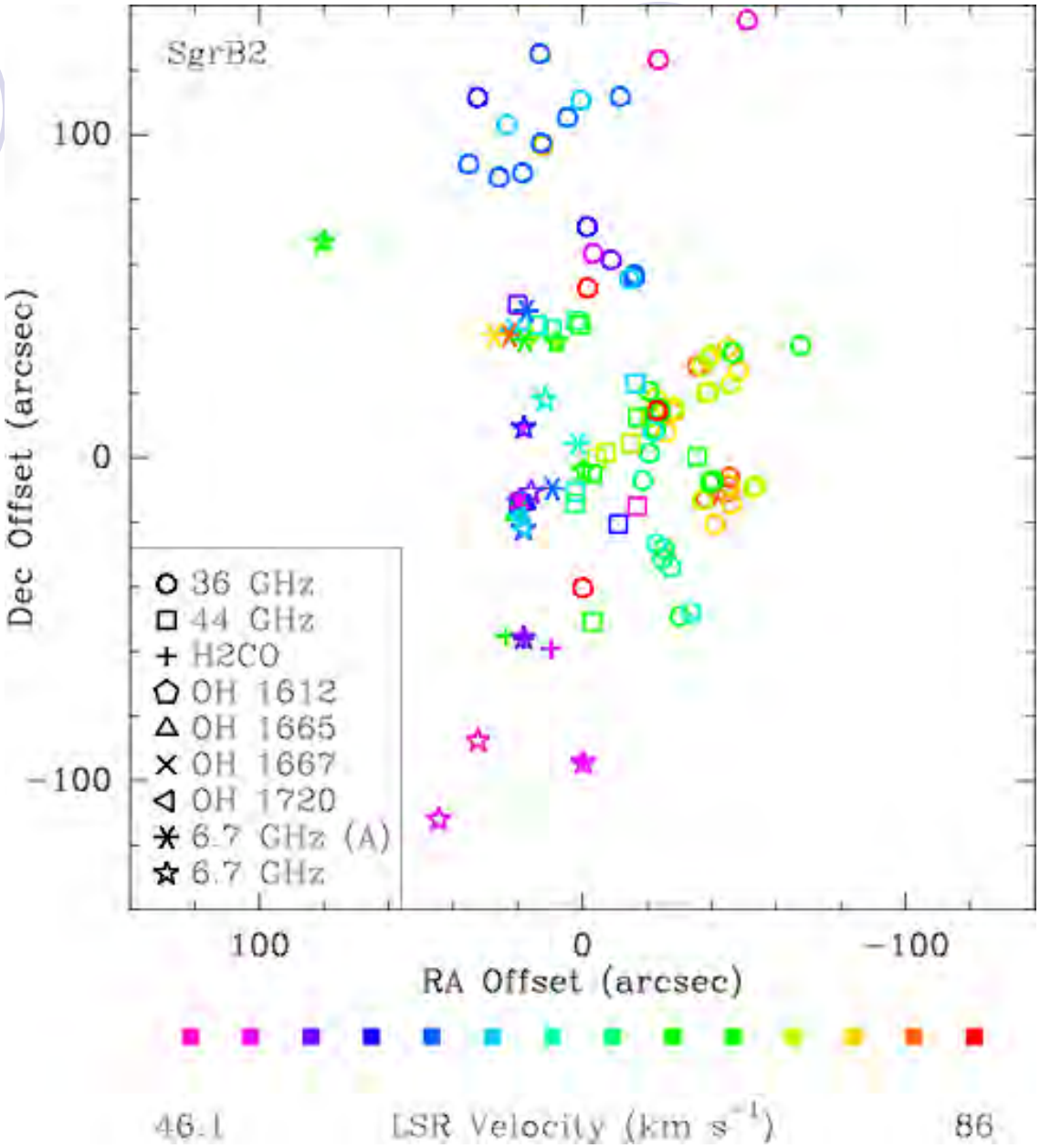
(0,0) R.A. 18:00:30.4 Dec. -24:04:00.0 (J2000)



The black “X” marks the position of a continuum source we detected. (0,0) is R.A. 23:13:45.0 Dec. 61:27:36.0 (J2000)

SgrB2

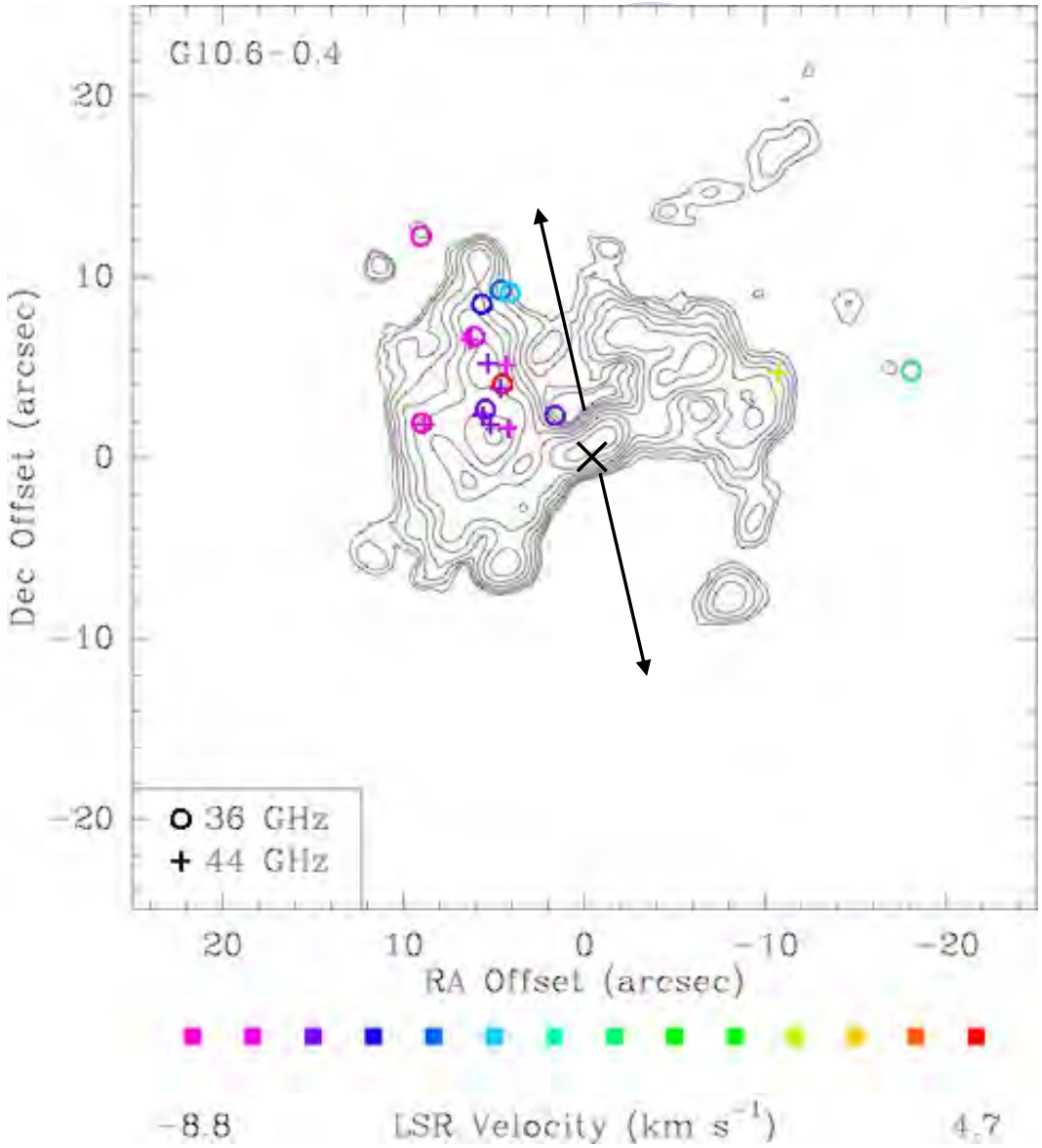
- Two pointings (SgrB2 N and M)
- Not much correlation with 36 GHz and 44 GHz



(0,0) R.A. 17:47:20.4 Dec. -28:23:05.0 (J2000)

G10.6-0.4

- Some 44/36 GHz overlap; velocity
- 36 GHz trace the eastern edge of the outflow
- Along evacuated cavity
  - NH_3 agreement
- Edge of higher density CH_3OH
- Interface of molecular material in shocked environments



CH_3OH gas flow of the J=5 transition (Liu et al., 2011). Contour levels are at at 1, $\sqrt{2}$, 2, $2\sqrt{2}$, 4, $4\sqrt{2}$, 8, and $8\sqrt{2}$ in units of Jy km/s. (0,0) R.A. 18:10:28.7 Dec. -19:55:50.0 (J2000)

Conclusions

- Correlations between 36 GHz and 44 GHz
  - 1 source had strong 36/44 overlap
  - 2 sources had moderate correlation
    - 36 GHz masers outnumber 44 GHz
  - 2 sources had only 1 overlap
    - 44 GHz outnumber 36 GHz
  - 1 source had no overlap
  - 4 sources did not have any 44 GHz data
- Density dependency

Future Work

- Find more information on sources of interest
- Gain more knowledge about:
  - Environments in which the masers are found
  - Find commonalities in the sources
  - Class I CH_3OH masers
    - Relationships between various transitions

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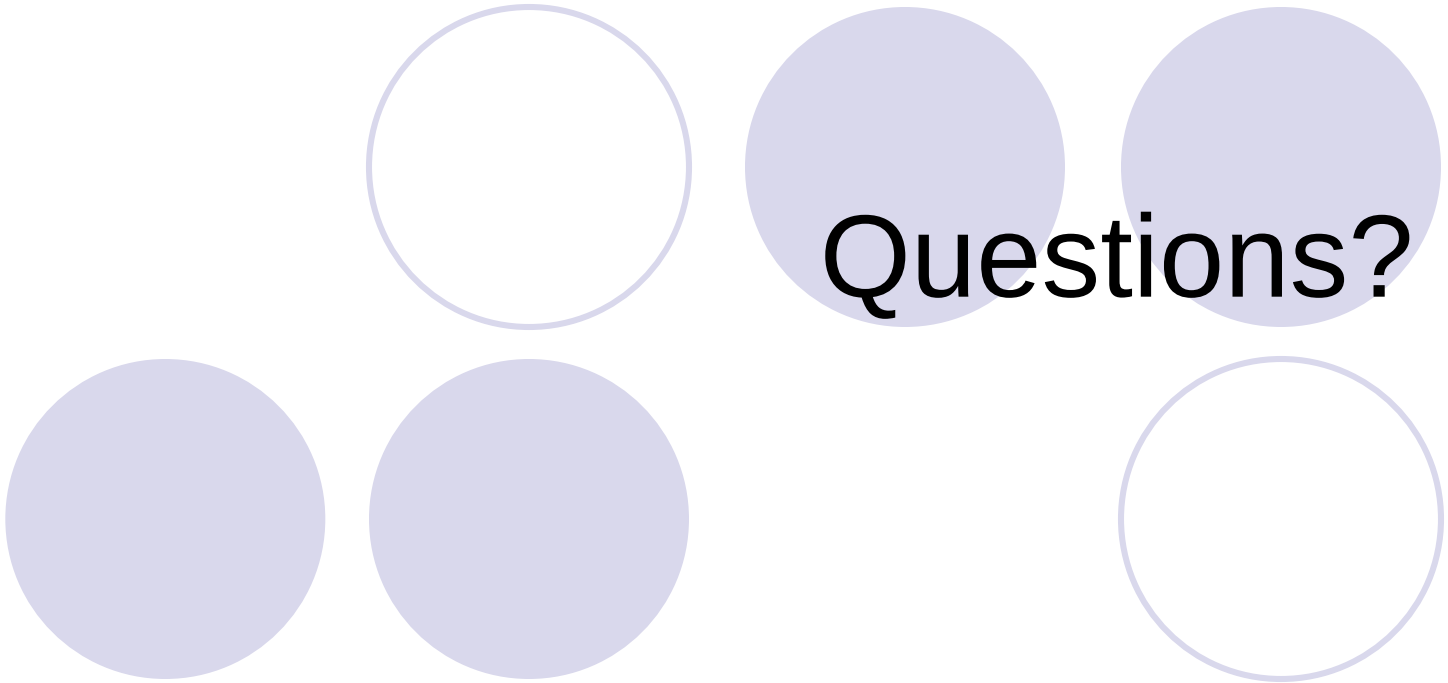
Questions?