SMA Observations of the Circumstellar Disk of AB Aurigae

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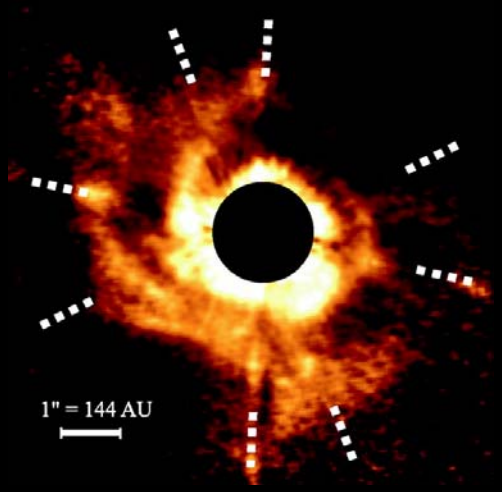
2005/3/7 Pasadena

Introduction
Circumstellar Disk of AB Aur

- AB Aurigae
  - Herbig Ae star (A0 Ve; Distance: 144pc; 2.5 M_{sun})
  - Age: 2~5 Myr old



- Previous Observations
  - ^{13}CO (2-1): OVRO
    (~4" in Mannings 1997; 2"×1.7" in Corder 2005)
    - Keplerian Rotating Disk
  - Optical: HST (Grady 1999)
    - N-S asymmetric structure
  - Near-IR: 1.6 μm Subaru coronagraphic image (Fukagawa 2004; afternoon session today)
    - Spiral-like structure

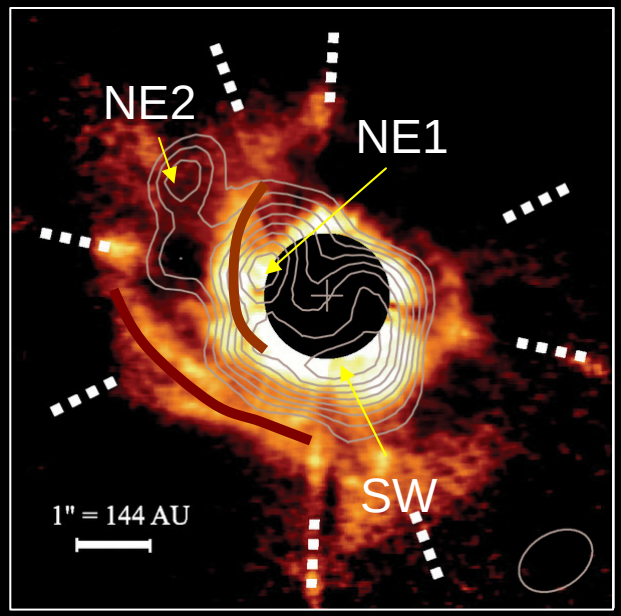
- SMA (Sub-Millimeter Array) Observations
  - **^{12}CO (3-2)** and **345 GHz dust continuum**
  - 3 tracks of different array configurations to achieve ~1"×0.7" spatial resolution
  - Velocity resolution of CO (3-2) observation: 0.17km/s

Outline

- Continuum emission at 345 GHz (0.85mm)
  - Dust disk has complex structure (three distinct peaks)
  - Does not peak at stellar position
  - Two peaks may coincide with most prominent spiral arm in Subaru image
  - Other peak between 2 arms
- Molecular gas (^{12}CO (3-2))
  - Gas disk has complex structure (two distinct peaks)
  - Main peak at stellar position
  - Secondary peak coincides with most prominent spiral arm
  - Rotation about disk minor axis; but more complex motion
  - Evidence for non-Keplerian rotation

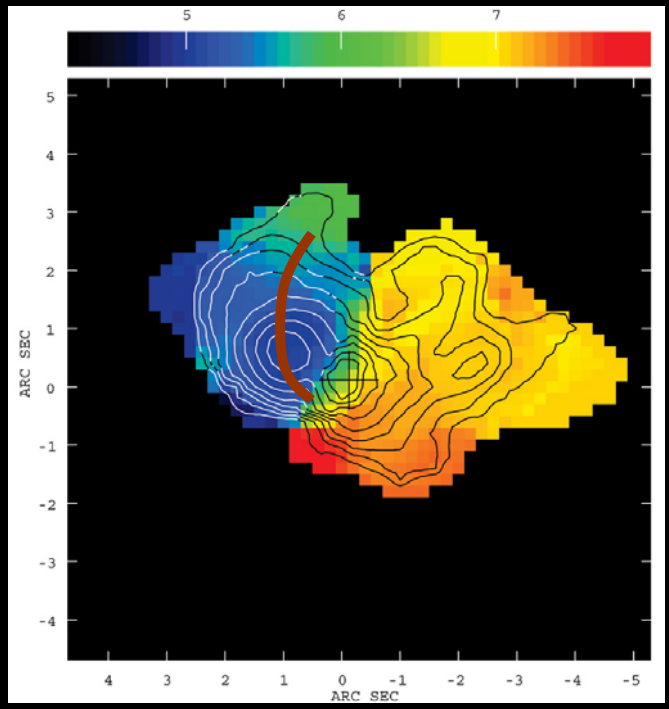
Dust Continuum at 345 GHz

- Global properties:
  - Size: 450 AU × 280 AU; PA: 48.526°
  - Disk mass (gas + dust): 0.0079 M_{sun} (T~40K, κ~ 0.0285 $cm^2\ g^{-1)}$
- Structures:
  - NE-SW elongation
  - Emission does not peak at the center
  - 3 peaks –
    - NE1 (>10σ), 140AU from center
    - NE2 (>5σ), 370AU
    - SW (>10σ) , 100AU
  - There is connection between NE1 & NE2
  - SW may coincide with inner region of most prominent spiral arm NE1 may also coincide with same spiral arm (but with slight displacement)
  - NE2 located between two prominent arms



^{12}CO (3-2) Emission

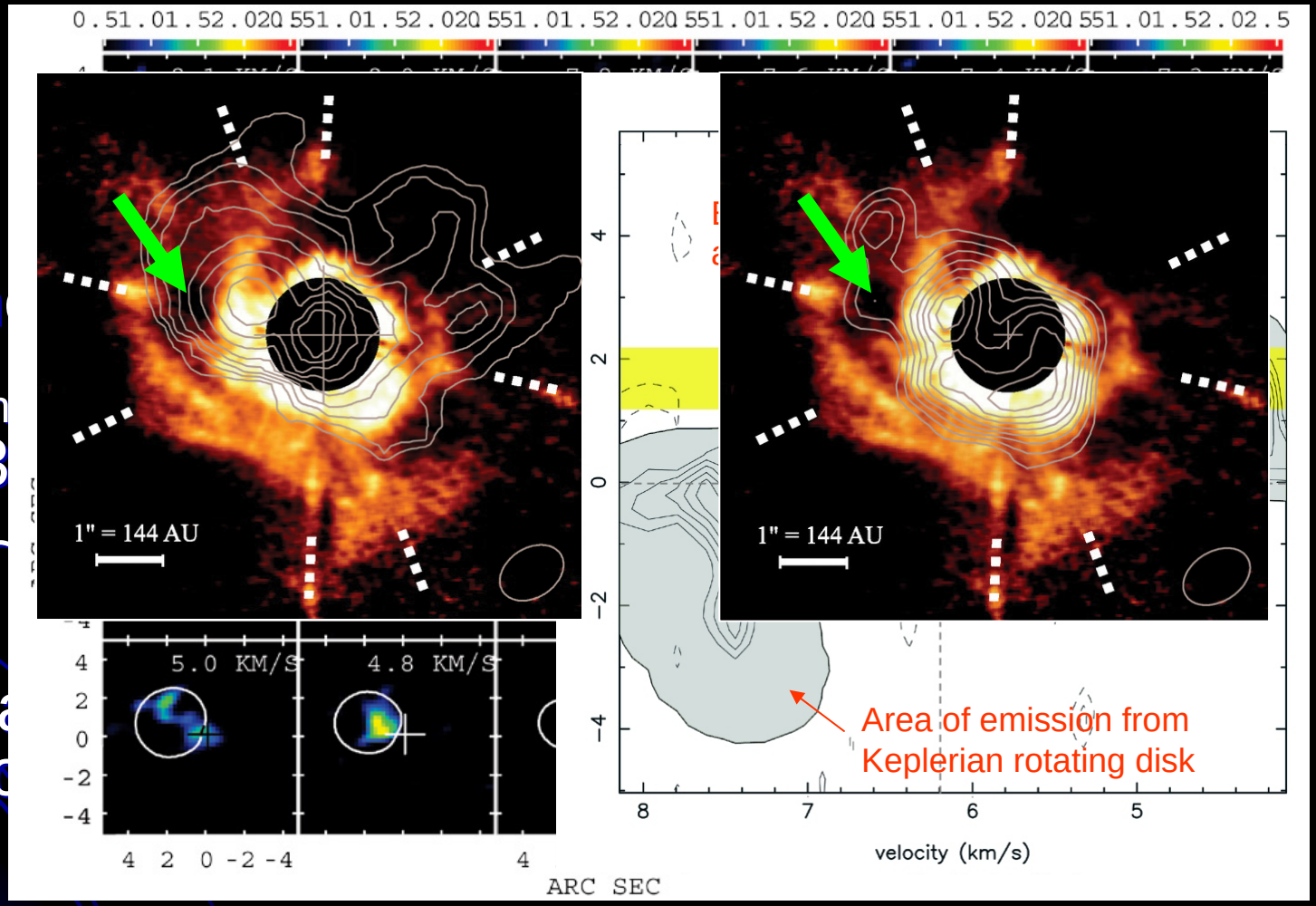
- Global properties:
  - Main peak at stellar position
  - Secondary peak coincides with most prominent spiral arm (does not coincide with any dust peaks)
  - Largest velocity gradient along major axis → rotation
  - Velocity gradients also along minor axis → non-circular motion



Color: Mean velocity
Contour: Integrated intensity

Deviation from Keplerian Rotation

- Model
  - Disk
- Param
  - M_{cen}
  - i ~ 3
  - PA ~
- Kinema
  connec



Yellow arrows indicates the deviation from Keplerian motion.

Disk dynamics

- Excitation of complexity on the disk
  - Gravitational instability

$$Q = \frac{c_s \kappa}{\pi G \Sigma}$$

    - For axisymmetric disk, $1.5 \leq Q \leq 2.0$ (Nelson et al. 1998), the spiral structure can be produced and sustained
    - In AB Aur case, Q?
      - Q ~ 2 to 17 (Fukagawa 2004)
      - T ~ 40 K, Σ~1.19 g/cm^2, Q ~ 13
      - T ~ 15 K, Σ~0.84 g/cm^2, Q ~ 2
  - Other possibilities
    - Giant planet at 250AU to excite the 2 main spiral arms
    - Encounter with other stars

Summary

- Dust disk
  - Complex structure (3 distinct peaks)
  - Not centrally peaked
  - Two brightenings coinciding with most prominent spiral arm
  - Another brightening between two spiral arms
- Molecular gas disk [^{12}CO (3-2)]
  - Complex structure (2 distinct peaks)
  - Main peak at stellar position
  - Secondary peak coincides with most prominent spiral arm
  - Most of emission consistent with Keplerian rotation
  - Non-Keplerian rotation between two most prominent spiral arms