GG Tau A:
Morphology and kinematics, gas and dust inside the cavity, rings and gaps

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CONTENT

Introduction

GG TAU

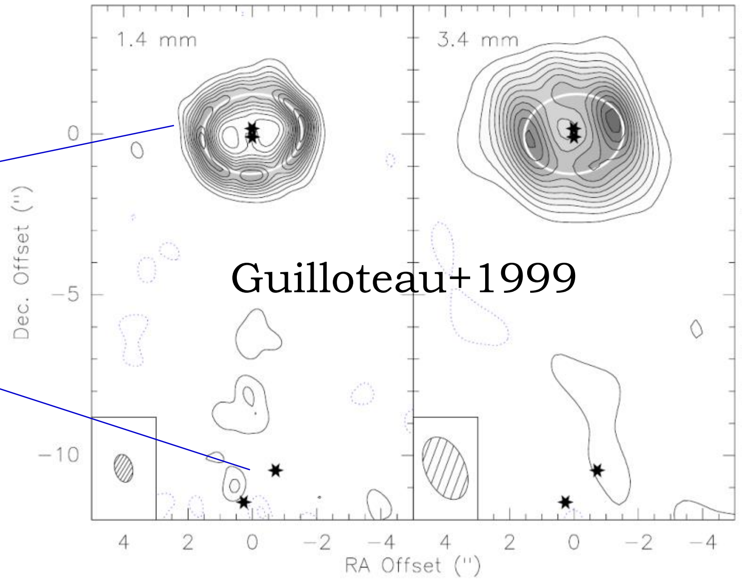
140 pc, 2-3 Myr

GG Tau A (a binary, 0.26" or 38 au - 1.3 M_{sun})

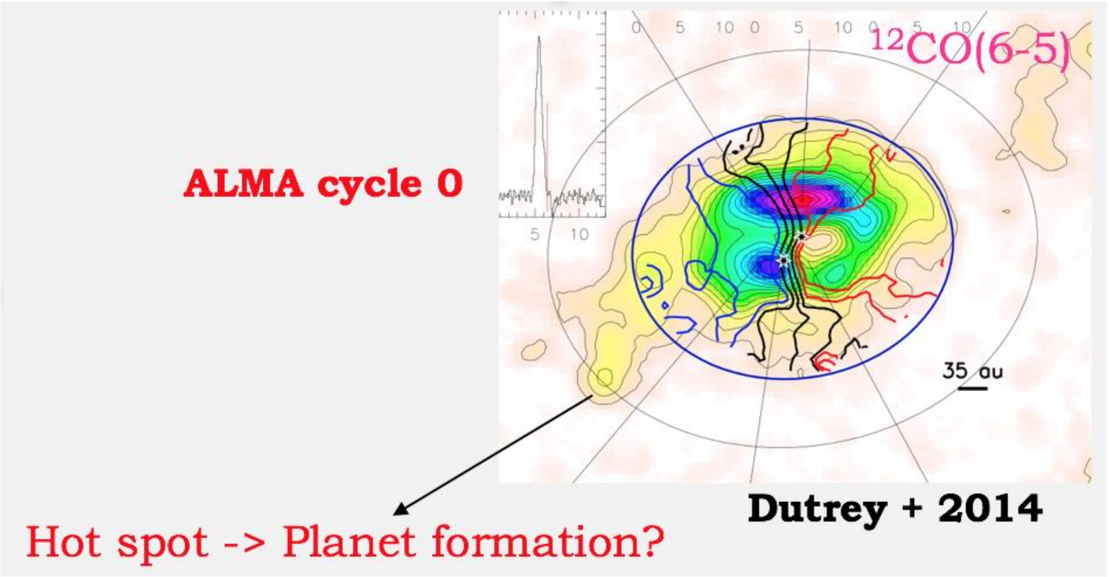
GG Tau A/B (10" or 1400 au)

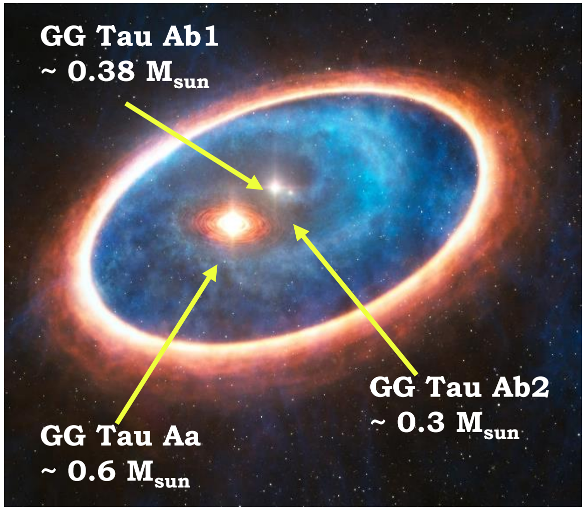
GG Tau B (a binary, 1.4" or 180 au – 0.17 M_{sun})

→ typical of T Tauri binary systems



GG TAU A - a triple system itself,
cavity of 190 au, i~ 37°, PA ~8°



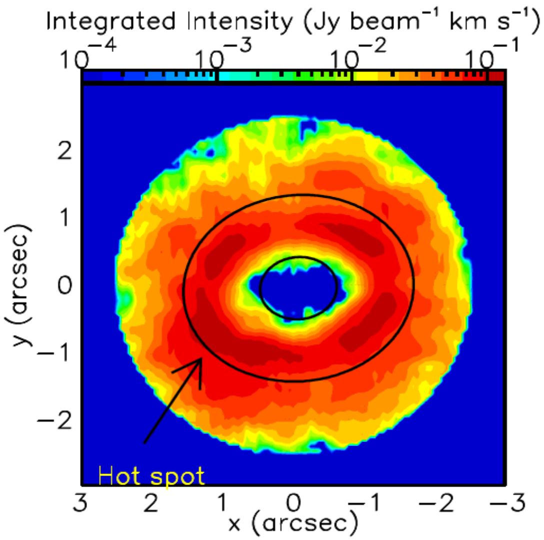


Morphology? Kinematics? Planet formation in multiple stellar system?

Morphology and kinematics

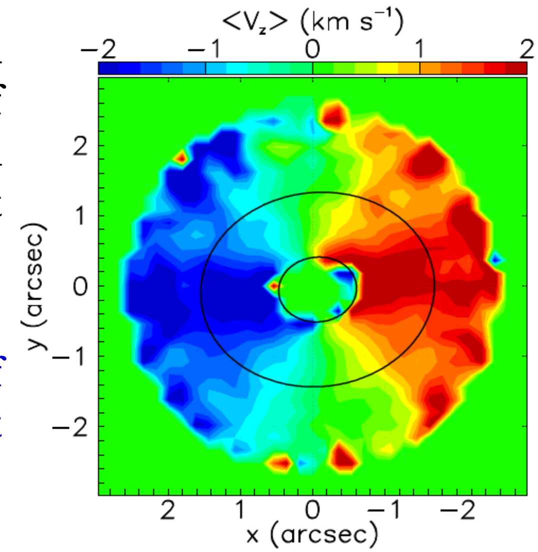
$^{13}CO(3\text{-}2)$ emission

General Features

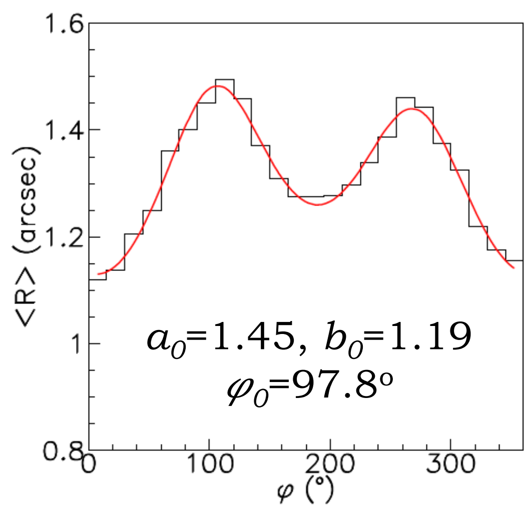


The map of the integrated intensity shows a clear ring of gas surrounding the central stars (similar to the dust morphology).

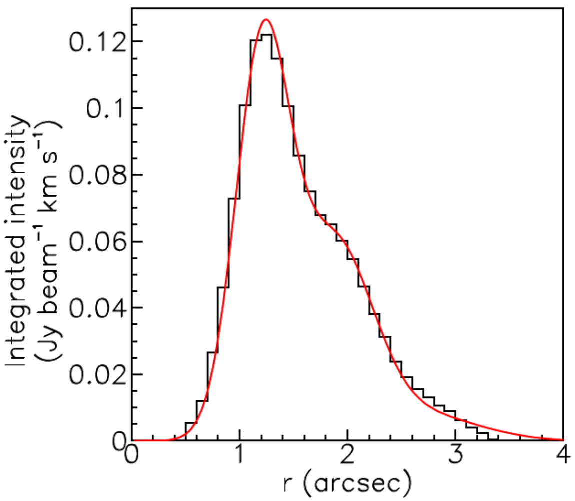
It displays no central emission, with an abrupt inner cut-off at 1 arcsec and no significant emission inside r<0.54 arcsec.



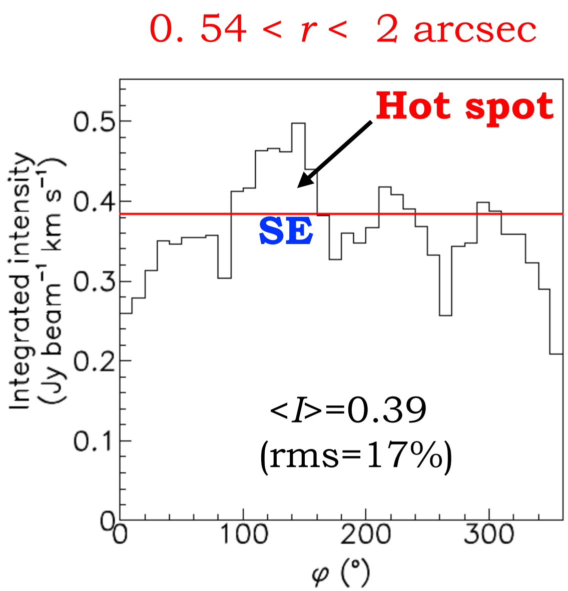
The aspect ratio corresponds to a tilt $\theta=\cos^{-1}(1.45/1.19)=35°$ with respect to the sky plane of a circular ring



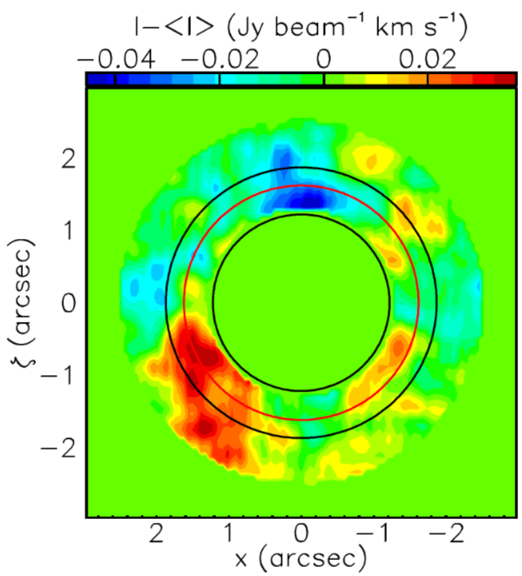
The velocity map displays a clear velocity gradient along the major axis of the ellipse, as expected from rotation of the tilted disc about its axis.



r-dependence of the integrated intensity in the disc plane is well described by the sum of 3 Gaussians.



φ-dependence of integrated intensity in the disc plane show an uniform distribution over the disc circumference.

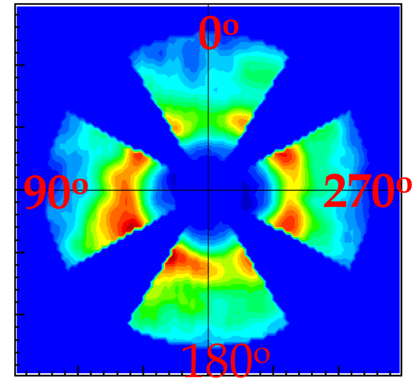


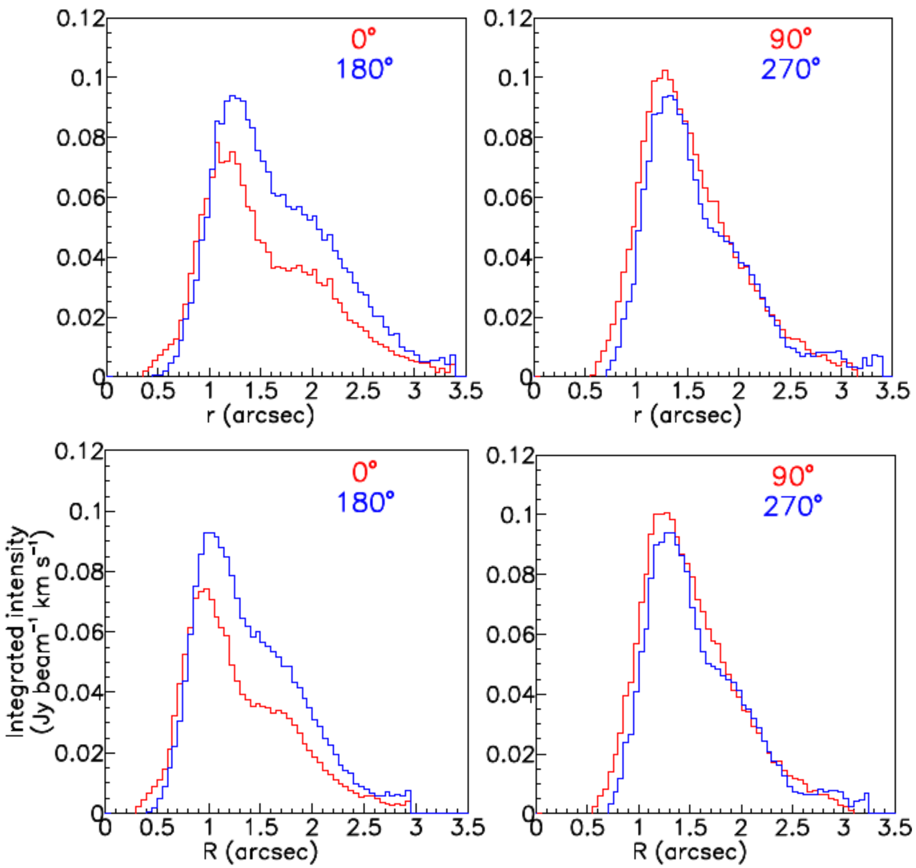
The map in the disc plane of the difference between the measured integrated intensity and its value at the same value of *r* gives strong evidence for an **excess associated with the hot spot** and for a **northern depression** of similar amplitude.

Estimate of the disc thickness

In the optically thin approximation, the effect of disc thickness essentially cancels on the major axis (90° and 270°); on the minor axis (0° and 180°), it scales with the product of the disc thickness by the sine of the tilt angle.

We estimate the thickness of the disc by comparing the value of the smearing of the inner edge of the disc map near the major axis of the ellipse with its value near the minor axis.

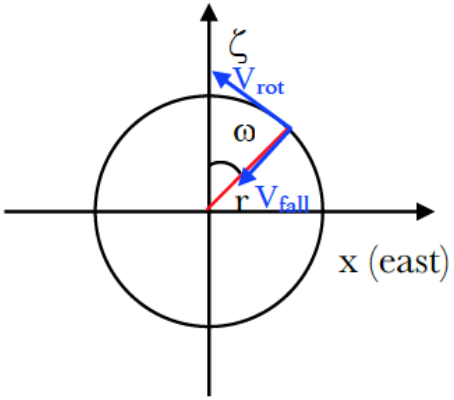




To 95% confidence level we obtain an upper limit of 0.24 arcsec (34 au) for the scale height *H(r)* at *r*=1 arcsec (140 au) where the Keplerian velocity is ~3 kms^{-1}; at 30 K, the sound velocity is 0.5 kms^{-1} and hydrostatic equilibrium implies

H(r) = 0.5/3 = 0.17 arcsec compared with the 0.24 arcsec obtained above.

Gas kinematics and line width



In the disc plane (x, ζ)

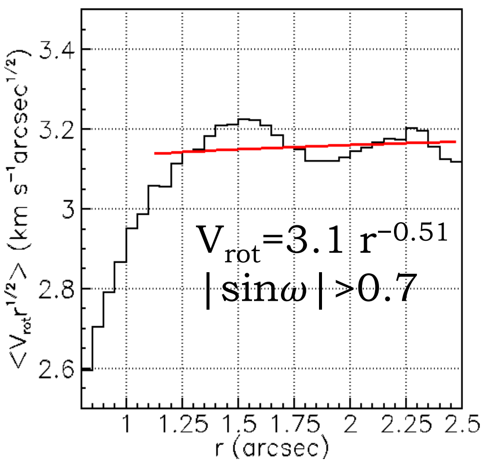
$$V_z = \sin\theta\,(V_{rot}\sin\omega - V_{fall}\cos\omega)$$

V_{fall} (level <~9%) can be neglected

$$V_{rot} = V_z(\sin\theta\,\sin\omega)^{-1}$$

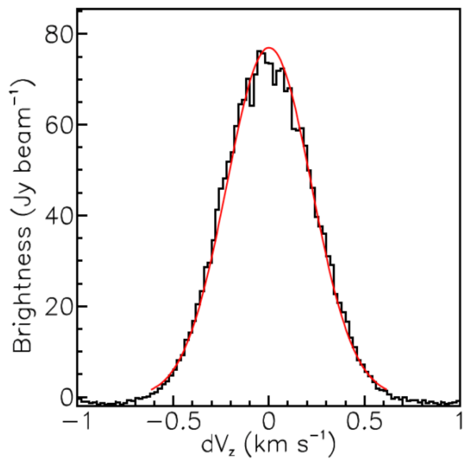
V_{rot} becomes trivially singular along the ζ axis.

We need to require $|\sin\omega|>0.7$ when calculating V_{rot} which we find of the form $V_{rot}=3.1\ r^{-0.51}$ km s^{-1}



In each pixel we define dVz as the difference between V_z and its mean value in the pixel. A Gaussian fit to the measured distribution gives σ_{Vz}=0.23 km s^{-1}.

$$\sigma_{Vz}=\sqrt{\sigma_K{}^2+\sigma_I{}^2+(\sigma_T\sigma_\tau)^2}$$



σ_K: Keplerian shear, **~ 0.09 km s^{-1}**

σ_I: Instrumental resolution, **0.09 km s^{-1}**

σ_T: Thermal broadening, possibly including a turbulence contribution, and opacity broadening, σ_τ, **~0.15 km s^{-1}** (T=18K, τ =10)

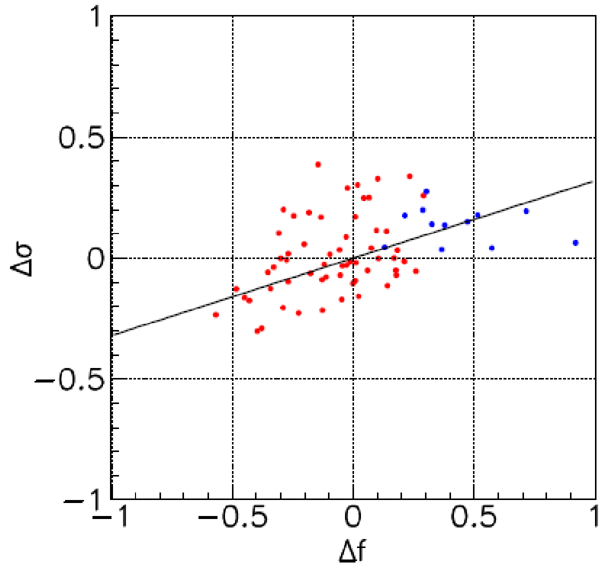
σ_{Vz} = 0.20 km s^{-1} expected, compare with 0.23 measured

σ_{Vz}= **0.26 km s^{-1}** in 1.3<*r*<1.7 arcsec

σ_{Vz}= **0.18 km s^{-1}** in 2.1<*r*<2.3 arcsec

Suggesting an increase of the temperature and opacity (*T*, *τ*) towards the stars, from (18K, 5) at *r* ~2.2 arcsec to (36K, 10) at *r* ~1.5 arcsec (meaning **0.18** and **0.25** kms^{-1})

Δ_σ=0.32 Δf



Significant correlation is observed between fluctuations of the line width and of the integrated intensity.

N. T. Phuong et al., 2017 (submitted to RAA)

Summary

Evidence for rotating gas and concentric/coplanar dust rings is obtained

A 95% CL upper limit of 0.24 arcsec (34 au) is placed on the disc scale height at a distance of 1 arcsec (140 au) from the central stars

Evidence for Keplerian rotation of the gas disc is presented, the rotation velocity reaching 3.1 kms^{-1} at 1 arcsec from the stars, and a 99% CL upper limit of 9% is placed on a possible in-fall velocity relative contribution.

Variations of the intensity across the disc area are studied in detail and confirm the presence of a hot spot in the south-eastern quadrant. Other significant intensity variations, in particular a depression in the northern direction, are also revealed.

Contributions from temperature/opacity, Kepler shear and spectral resolution account well for the observed line width, which is found to be independent from ω and to increase as r decreases, suggesting the presence of a radial temperature/opacity gradient from (18K, 5) at 2.2” to (36K, 10) at 1.5” in excellent agreement with observation.

New observations with angular resolution of 30 au show optimistic prospects to reveal detail features.

Thank you for your attention!