The Disk and Jet of the Classical T Tauri Star AA Tau

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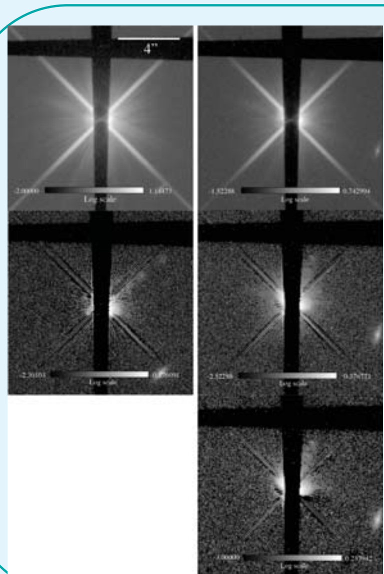
Abstract

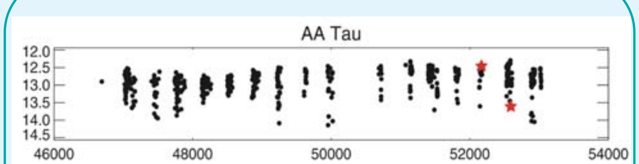
Previous studies of the classical T Tauri star AA Tau have interpreted the UX Orionis-like photopolarimetric variability as being due to a warp in the inner disk caused by an inclined stellar magnetic dipolefield. We test that these effects are macroscopically observable in the inclination and alignment of the disk. We use the HST/STIS coronagraphic detection of the disk to measure the outer disk radius and inclination, and find that the inner disk is both mis-inclined and misaligned with respect to the outer disk. AA Tau drives a faint jet which is also misaligned with respect to the projection of the outer disk minor axis. The jet is also poorly collimated near the star. The measured inclination, 71±1°, is above the inclination range suggested for stars with UX Orionis-like variability, indicating that dust grains in the disk have grown and settled toward the disk midplane.



PSF subtraction was used to remove dirffaction spikes and instrumentally scattered star-light from STIS coronagraphic data taken on Sept. 2001 and Aug. 2002

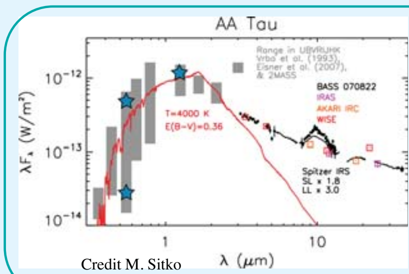
After subtraction, the disk and A chain of Herbig-Haro knots Are visible in the 2001 data (left), but better revealed in the 2002 data (right). The Field of view is 12" on a side In the detector frame.

A roll-difference image provides the best imaging of the disk.



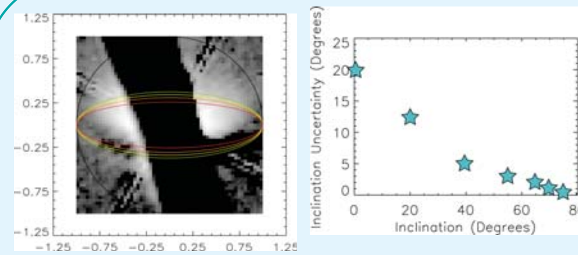
Credit: Grankin et al. (2007)

The scale factors derived when we subtracted the PSF template star data from observations from our late-type star PSF library can be combined with V magnitudes for the PSF stars from Simbad to give us V magnitudes for AA Tau with a typical uncertainty of 0.1 mag. The earlier STIS observation was obtained near maximum light, while the 2nd observation was at minimum light for 2002, when compared with photometry from Grankin et al. (2007).



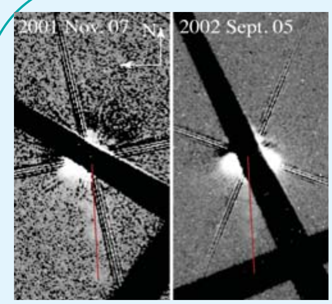
Credit M. Sitko

AA Tau has a variable SED (Cox et al. 2013). Blue stars show the positions of the HST STIS and NICMOS corona-graphic images. Non- or marginal detections are at maximum light, while the firm detection is near minimum light. Given the periodic minima in AA Tau, future high contrast imagery might best be obtained at minimum light.



Left) Fitting the dark lane at the midplane of AA Tau's disk to a grid of circles viewed at different inclinations from pole-on yields i=71±1° for the outer disk. Right) The uncertainty in inclination measurements for a 1" radius disk seen by STIS is a strong function of inclination.

Our measured inclination for AA Tau differs by 4° from the inclination found for the inner disk (i=75°, O'Sullivan et al. 2005), is in agreement with the inclination inferred from stellar rotation and v sin i (i=70±10°, Bouvier et al. 2003). The disk major axis is along PA=97±2°, 7° different from predictions from linear polarimetry by Ménard et al. (2003).



Jet-driving PMS stars typically have The jet PA 90° from the disk semi-major axis. The Jet PA in AA Tau Is along 183±1°, 86° from the disk semi-major axis. The jet is poorly collimated with an opening half angle of 17° within 3" of the star.

We do not clearly see a counterjet, either in the STIS images or in Goddard Fabry-Pérot data from 2005, but the counterjet is clearly visible in imaging and long-slit spectroscopy from 2012.

AA Tau does not lie in a region of obvious optical nebulosity (below, left), but does lie in a filament of cold dust which is more extended to the north of the star IRAS (blue=12 microns, green=60 microns, red=100 microns. Field of view 1° on a side). This suggests that the counterjet non-detection is due to an extinction gradient.

IRAS data for the vicinity of AA Tau indicate that the star lies in or near a molecular cloud filament (left). In the course of the past year, AA Tau has undergone a prolonged deep minimum, thought to be due to foreground material (V. Grinin, priv. comm).

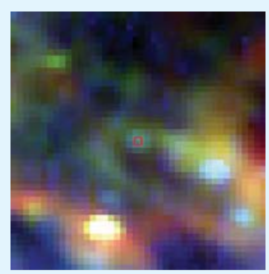
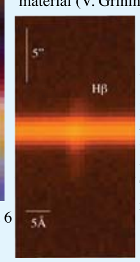


Image generated using HerschelSpot 6



A long slit spectrum from 2012 Dec. shows that in Hβ the brightest part of the jet extends 4" south of the star (PA 183°), while the counterjet can be traced only 2" N of the star. The star is embedded in reflection nebulosity which was not apparent in 2005.

Conclusions

- AA Tau has a disk extending 1.15" (156 AU) and viewed at 71°±1° from pole-on. The outer disk is misaligned with respect to the inner disk by 4° (O'Sullivan et al. 2005), providing independent verification of the warp in the disk.

- AA Tau is an UXOR. The best disk visibility is at minimum optical/NIR light, when the inner disk partially occults the star.

- The jet is poorly collimated compared to other single T Tauri stars and is also slightly misaligned with respect to predictions based on polarimetric data (Ménard et al. 2003). The absence of an extended counter-jet may reflect an extinction gradient to the north of AA Tau.

- For more details, see Cox et al. 2013, ApJ 762, 40

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