

The First Young Moving Groups*

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** See reviews by, e.g., de la Reza et al. (2001, in "Young Stars Near Earth" proceedings), Zuckerman & Song (2004, Ann. Rev. A&A), Torres et al. (2008, in "Handbook of Star Forming Regions")*

TW Hya:

classical T Tauri star without a birthplace

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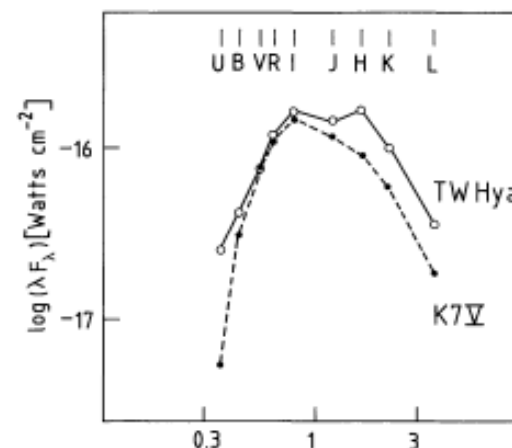
TW Hya: a T Tauri star far from any dark cloud*

S. M. Rucinski¹ and J. Krautter²

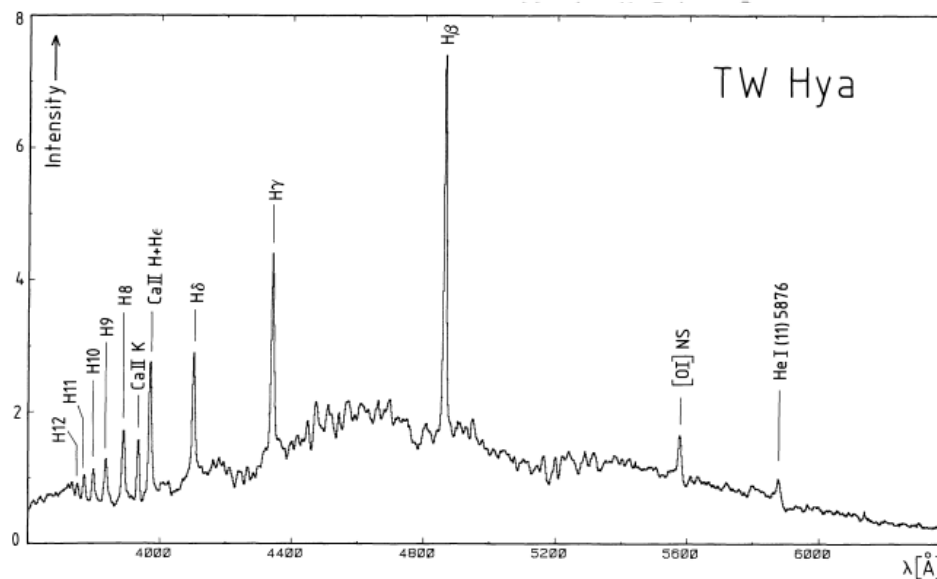
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Received October 22, accepted December 14, 1982



Henize (1976), Herbig (1978), and Rucinski & Krautter (1983) share credit for putting this seminal nearby, young star/disk system “on the map”

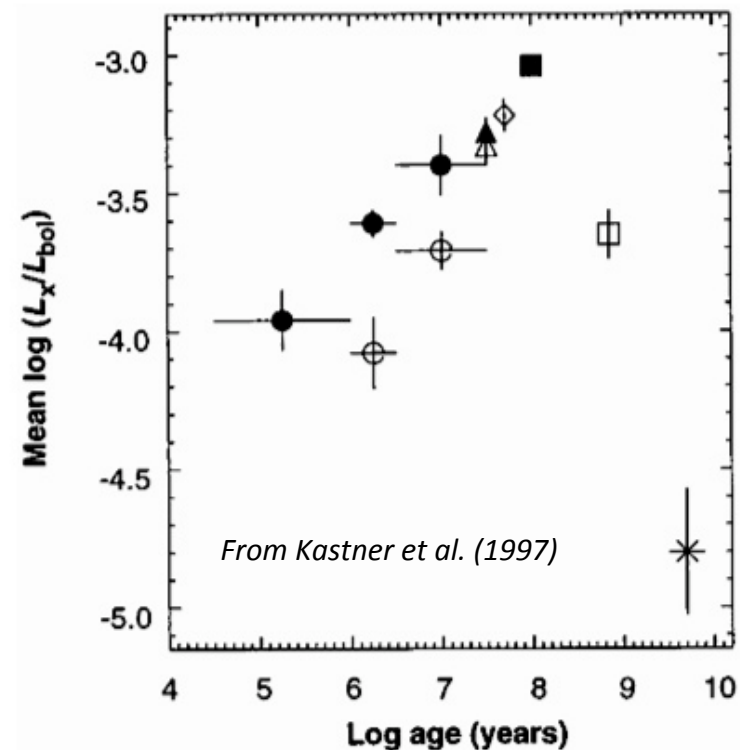


“Isolated T Tauri stars”

- de la Reza et al. (1989, ApJL) and Gregorio-Hetem et al. (1992 AJ), combining IRAS excesses w/ Li measurements, identify a handful of young stars in the general vicinity of TW Hya
 - Are these 5 stars runaways from some cloud, or were they formed in situ from a low-mass cloud?
 - How old are they?
 - Are they nearby, as suggested by their high galactic latitudes?

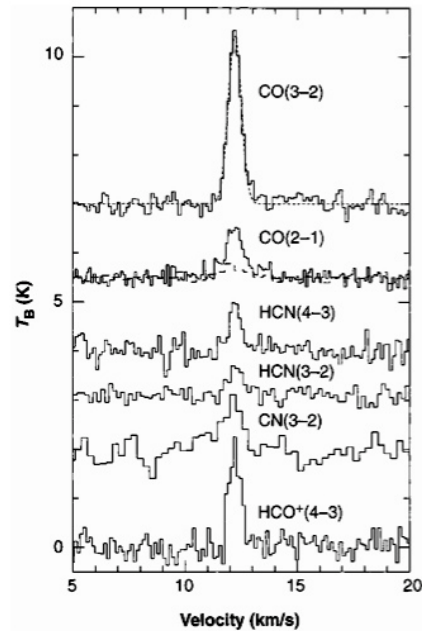
The identification of the TW Hya Association: The “nearest [known] region of recent star formation”

- RASS X-ray data demonstrates these 5 stars are indeed young & nearby (Kastner et al. 1997, Science)
 - Evidence that all 5 are near peak L_X/L_{bol} for K&M stars
 - => not as young as cloud-embedded TTS
 - yet have strong Li
 - => age constrained at ~10-20 Myr
- D estimates then follow
 - all 5 are all ~50 pc distant
 - Hipparcos confirms D's of ~50 pc to TW Hya & HD 98800
- Over the next 10+ years, the candidate membership of the TWA would increase to >30 stars, and age estimates would converge on ~8 Myr...



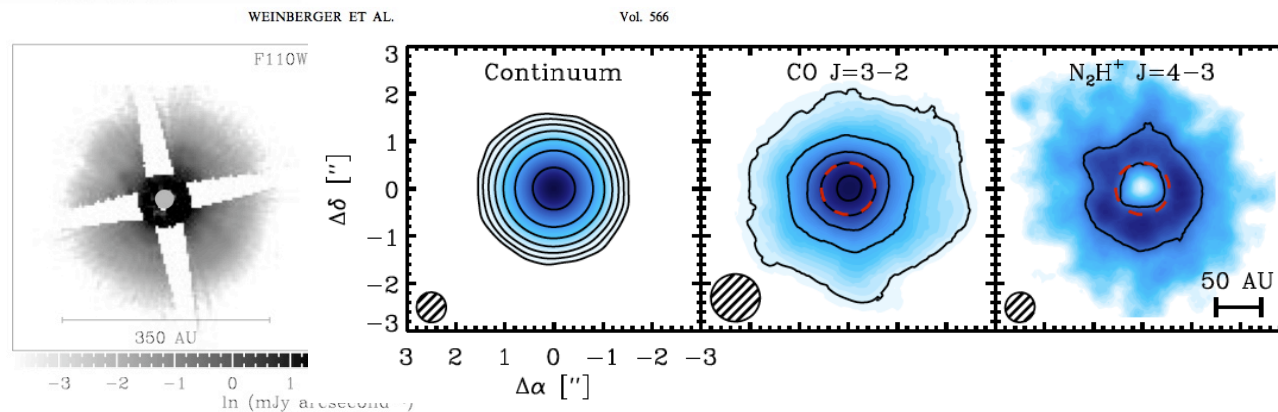
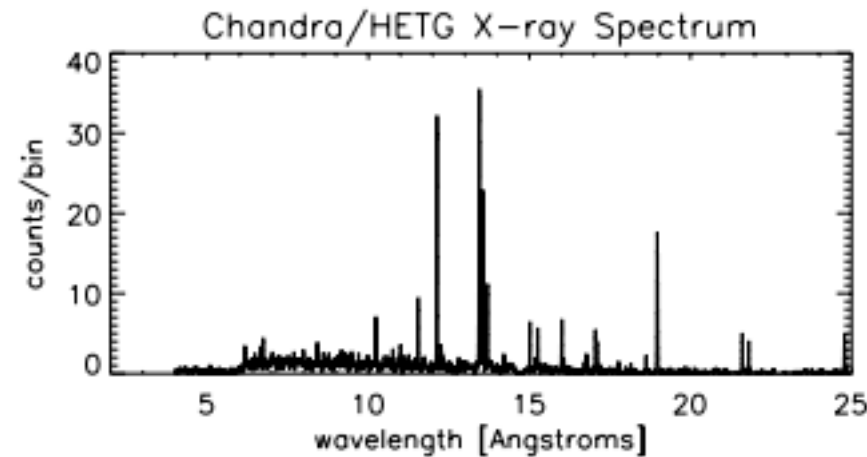
...while TW Hya has become the “Crab Nebula”* of late-stage pre-MS accretion and protoplanetary disk evolution studies

* w/ apologies/thanks to David Wilner



Left: molecular line spectrum of TW Hya, from Kastner et al. (1997)

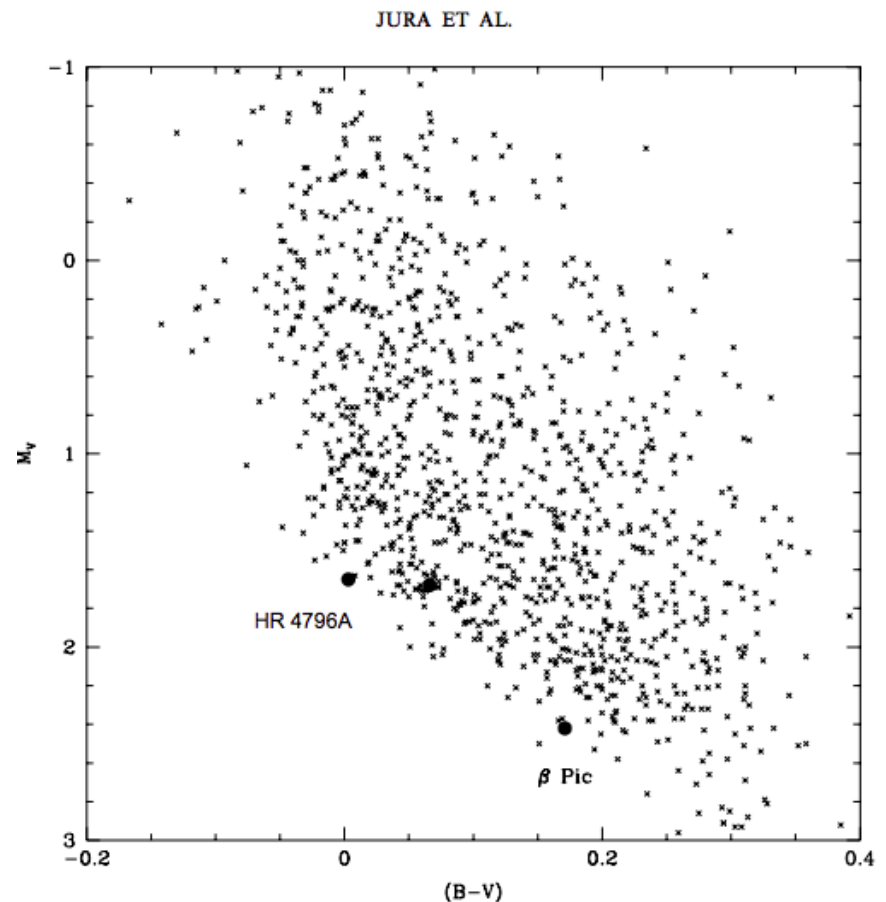
Above: Chandra X-ray spectrum, from Kastner et al. (2002)



Left panel: HST imaging of TW Hya disk in scattered light (Weinberger et al. 2001); remaining 3 panels: ALMA & SMA mm-wave imaging (Qi et al. 2013)

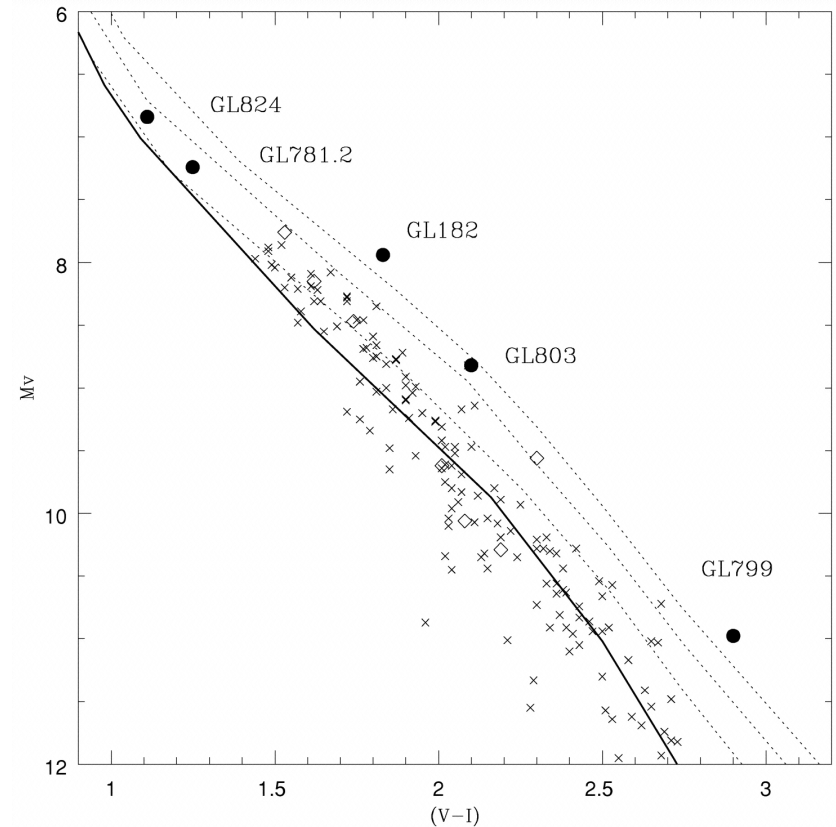
The “young association” link between HR 4796A and β Pic

- Jura et al. (1998 ApJ): large IR-excess A stars HR 4796A, β Pic, and 49 Cet are all underluminous for their colors (T_{eff} 's)
 - Stauffer et al (1995) had previously determined an age of 8 ± 2 Myr for HR 4796A from isochronal age of its M-type comoving companion
 - Jura et al.: HR 4796AB might be part of the TWA
 - later confirmed by Webb et al. (1999)
- Implies that β Pic & 49 Cet are also ‘young’ (Jura et al. 1998)...do they also have comoving, low-mass “friends”?



The ID of the β PMG

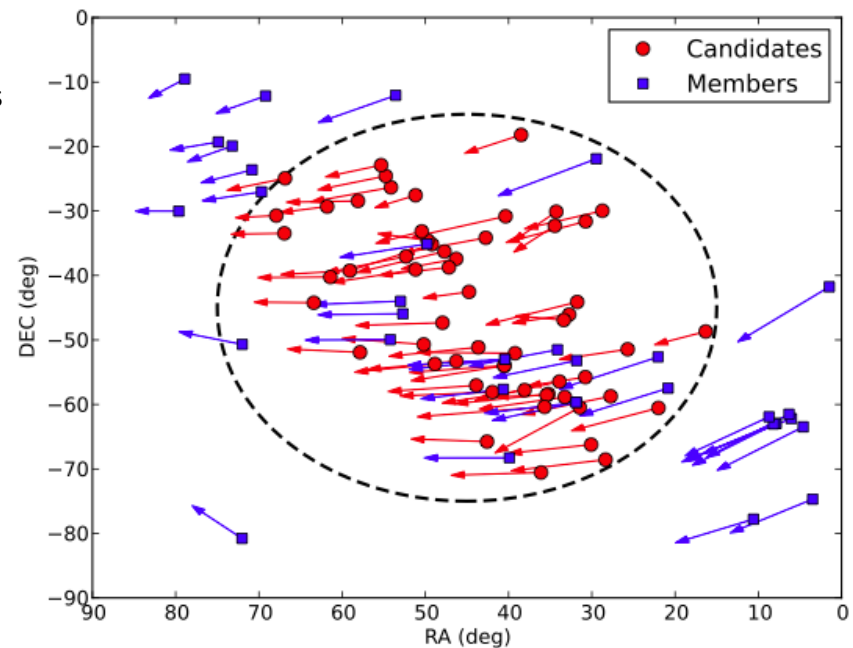
- Barrado y Navascues et al. (1999, ApJ, 520, L123): 3 M stars comoving with beta Pic
 - Labeled the “ β PMG” even though only 4 stars survive after ByN et al’s scrutiny of space motions & age diagnostics
 - Isochronal age: 20 +/- 10 Myr
- Wider availability and application of space velocities leads to ID of 17 more β PMG members (Zuckerman et al 2001)
 - “comoving, youthful group [that is] closest to Earth”
- These early β PMG studies engendered much larger efforts to ID nearby young MGs and their members



From Barrado y Navascues et al. (1999)

The Present State of the Art

- Galactic kinematics techniques (space velocity analyses) have become increasingly sophisticated
 - Song et al. (2002 & numerous other papers)
 - Torres et al. (2006, 2008)
 - Search for Associations Containing Young Stars (SACY)
 - Malo et al. (2013, 2014a,b)
 - Bayesian Analysis for Nearby Young AssociationNs (BANYAN)
- X-rays (RASS) have been superseded by UV (Galex) as a means to isolate large samples of candidate nearby, young stars
 - Rodriguez et al. (2011); Shkolnik et al. (2012)
- Combination of techniques (UV + kinematics) is particularly powerful
 - e.g., Rodriguez et al. (2011, 2013): Galex Near/Young Star Search ("GALNYSS")



From Rodriguez et al. (2013)

Identifying and age-dating NYMGs and their members: the β PMG as “litmus test”

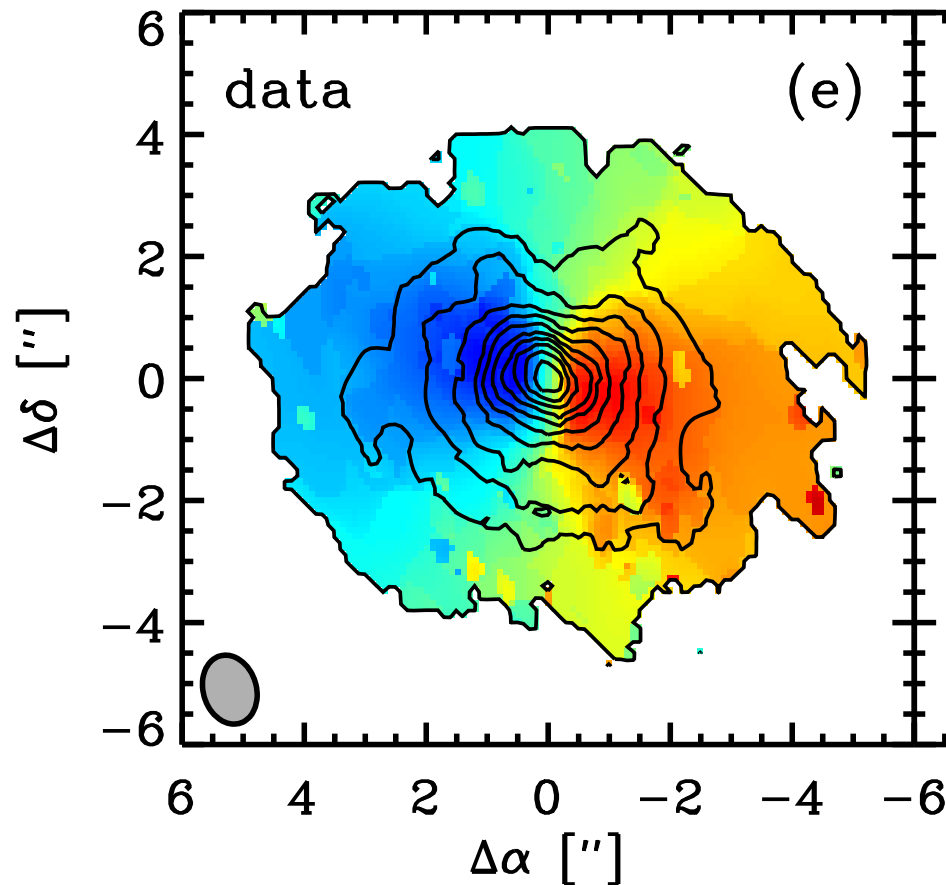
2 *Mamajek & Bell*

Table 1. Literature age estimates for the BPMG. We adopt the terms “traceback age” and “expansion age” generically for any age estimate trying to infer when an unbound group of stars was at its minimum size in the past.

Reference ...	Age (Myr)	Method ...
Barrado y Navascués et al. (1999)	20 ± 10 Myr	CMD isochronal age (KM stars)
Zuckerman et al. (2001)	12^{+8}_{-4} Myr	H-R diagram isochronal age (GKM stars) + Li depletion
Ortega et al. (2002)	11.5 Myr	Traceback age
Song et al. (2003)	12 Myr	Traceback age
Ortega et al. (2004)	10.8 ± 0.3 Myr	Traceback age
Torres et al. (2006)	~ 18 Myr	Linear expansion age
Makarov (2007)	22 ± 12 Myr	Traceback age
Mentuch et al. (2008)	21 ± 9 Myr	Li depletion
Macdonald & Mullan (2010)	~ 40 Myr	Li depletion (magneto-convection models)
Binks & Jeffries (2014)	21 ± 4 Myr	Li depletion boundary
Malo et al. (2014)	26 ± 3 Myr	Li depletion boundary
Malo et al. (2014)	21.5 ± 6.5 Myr (15 – 28 Myr)	H-R diagram isochronal age (KM stars)
This work	22 ± 3 Myr	CMD isochronal age (FG stars)
Final	23 ± 3 Myr (1σ) [± 2 Myr (stat.), ± 2 Myr (sys.)]	Li depletion boundary & CMD isochronal age (FGKM stars)

From Mamajek & Bell (2014)

Move over, TW Hya...make room for
 β PMG member V4046 Sgr



*SMA CO image of the disk orbiting V4046 Sgr
(from Rosenfeld et al. 2013)*

Young Stars & Planets Near the Sun

Zeroth Announcement

- May 11-15, 2015; Atlanta, GA (GSU campus)
 - <http://www.iau.org/science/meetings/future/symposia/1120/>
 - GSU-sponsored Symposium website coming soon
- Topics:
 1. Nearby young moving groups (NYMGs): identification, ages, origins
 2. What NYMGs teach us about early stellar evolution
 3. Dispersal of protoplanetary disks; nature & origins of debris disks
 4. How NYMGs inform us about early evolution of planetary systems
 5. Nearby young stars and planets: the likely impacts of new and future facilities
- SOC: J. Kastner & A.-M. LaGrange, co-Chairs; I. Baraffe, M. Bessell, R. Doyon, G. Herczeg, M. Ireland, R. Jeffries, M. Jardine, M. Liu, S. Metchev, D. Rodriguez, B. Stelzer, M. Tamura, C. Torres, B. Zuckerman
- LOC: S. Lepine, I. Song, R. White