HST MEASURES OF MASS ACCRETION RATES IN THE ORION NEBULA CLUSTER

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OUTLINES

1. HST Treasury program on the ONC
2. Methods to estimate L_{acc}
   - 2CD (U-band excess)
   - Hα luminosity
3. Results
   - M_{acc} vs age
   - M_{acc} vs M_*
   - Dependence on both age and M_*

HST Treasury Program on the ONC

- Cycle: 13
- GO10246
- Year: 2004-2005
- Orbits: 104
- P.I.: Robberto
- Instruments:
  - ACS (B,V,Hα,I,Z)
  - WFPC2 (U,B,Hα,I)
  - NICMOS (J,H)
- Parralel observations:
  - WFI(U,B,V,Hα,I,TiO)
  - ISPI (J,H,K)

Credits: NASA, ESA, M. Robberto

HST Treasury Program on the ONC

Science team:

M. Robberto (STScI, PI), D. Soderblom (STScI), C. R. O'Dell (Vanderbilt), L. A. Hillenbrand (Caltech), M. Simon (Stony Brook), E. D. Feigelson (Penn State), J. Najita (NOAO), K. G. Stassun (Vanderbilt), J. Stauffer (JPL-Caltech), M. Meyer (ETH), J. Krist (JPL), N. Panagia (STScI), M. Romaniello (ESO), F. Palla (Arcetri), I.N. Reid (STScI), P. McCullough (STScI), R. Makidon (STScI), N. Da Rio (ESA), M. Andersen (ESA).

STScI team:

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Graduate students:

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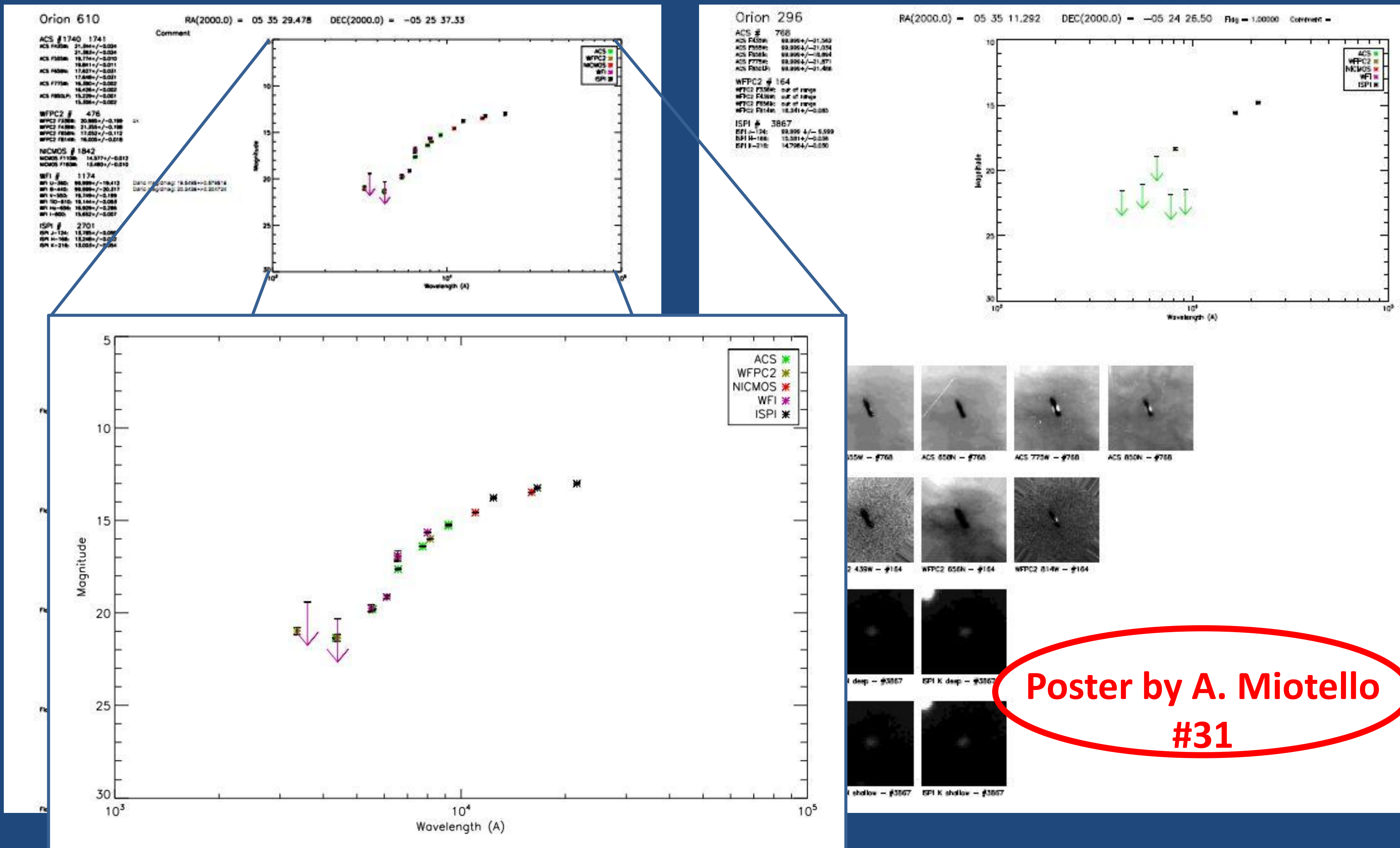
Recent papers:

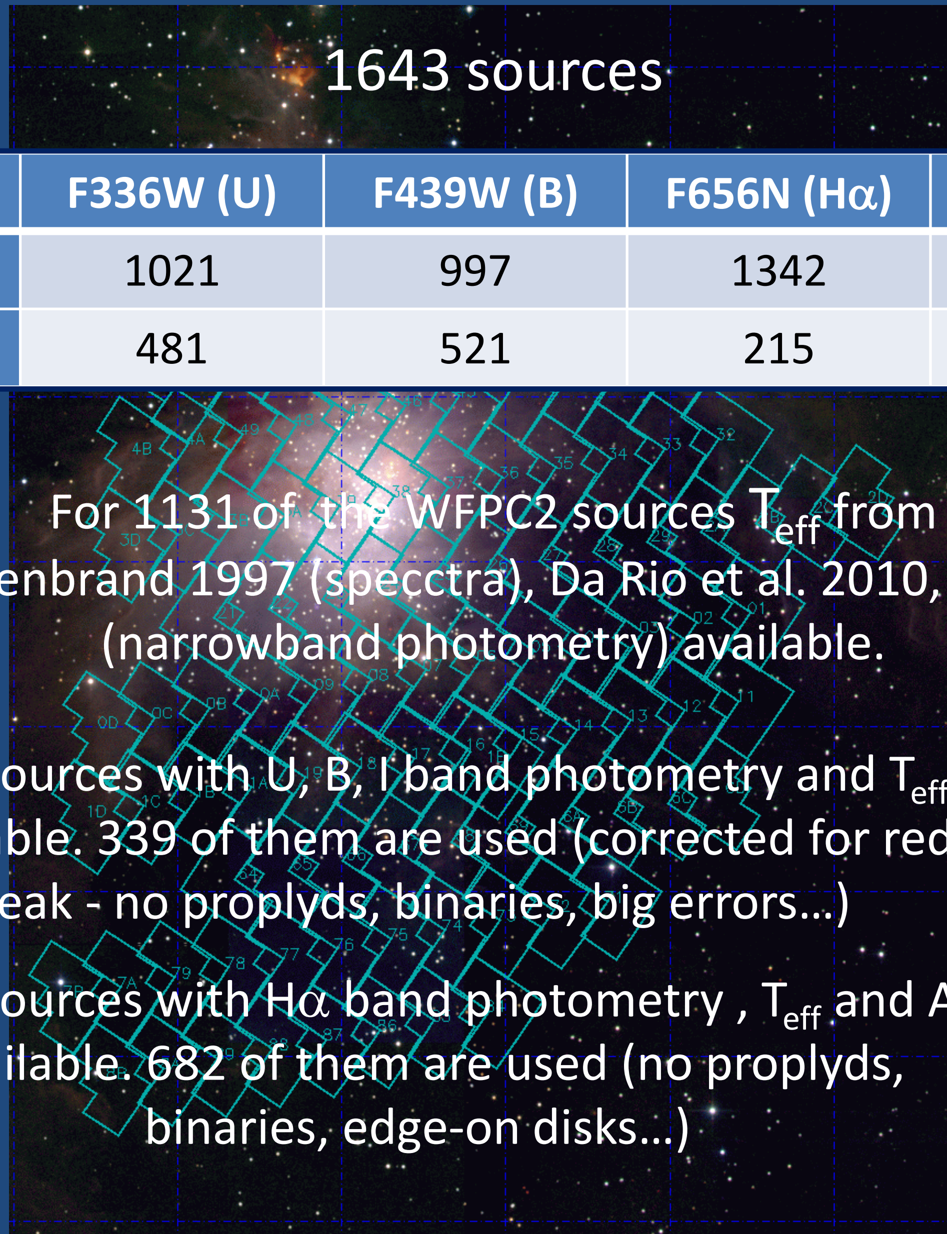
Andersen et al. 2011, A&A, 534:10; Reggiani et al. 2011, A&A, 534:83

HST Treasury Program on the ONC - Atlas



Poster by A. Miotello #31

WFPC2 dataset



1643 sources

	F336W (U)	F439W (B)	F656N (Hα)	F814W (I)
Detected	1021	997	1342	1610
Upper limit	481	521	215	11

For 1131 of the WFPC2 sources T_{eff} from Hillenbrand 1997 (specctra), Da Rio et al. 2010, 2011 (narrowband photometry) available.

439 sources with U, B, I band photometry and T_{eff} available. 339 of them are used (corrected for red leak - no proplyds, binaries, big errors…) ⇒ 2CD

1027 sources with Hα band photometry , T_{eff} and A_V available. 682 of them are used (no proplyds, binaries, edge-on disks…) ⇒ $L_{H\alpha}$

Method

Two Colors Diagram

UBI Diagram (2CD) with:

- Atmosphere Models (Allard et al.2010)

  Empirically calibrated

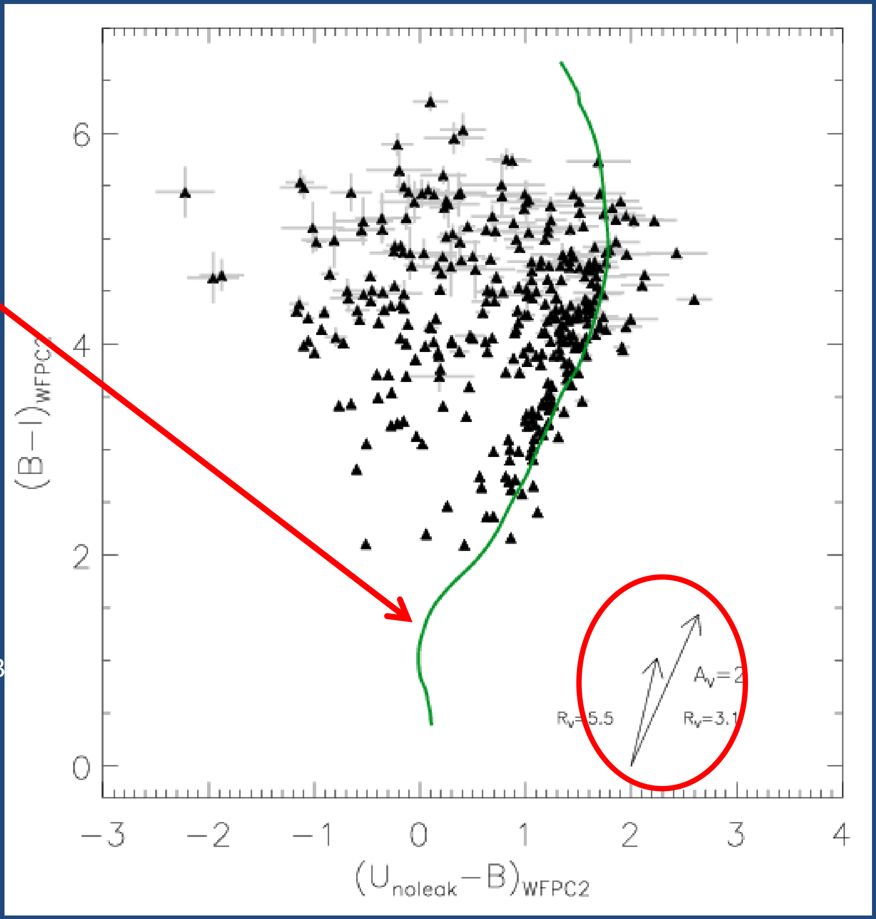
- Extinction law (Cardelli et al. 1989)

  $R_V = 3.1$

- Accretion spectrum (Calvet et al. 1998)
  - 75% optically thick emission (blackbody at 8000K)
  - 25% optically thin emission (HII region with $n=10^4$ cm^{-3}

  + HII region (magnetospheric emission)

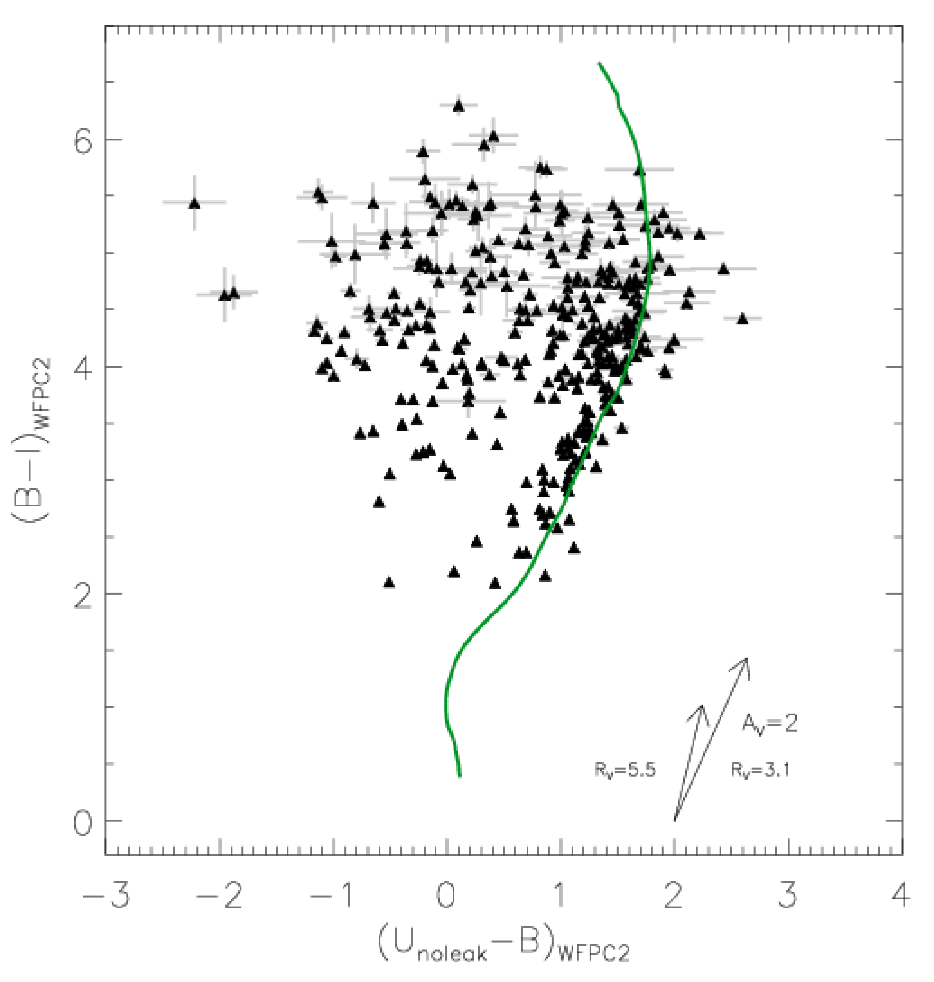
  (more important for low accretion rates)



Manara et al., 2011, in prep.

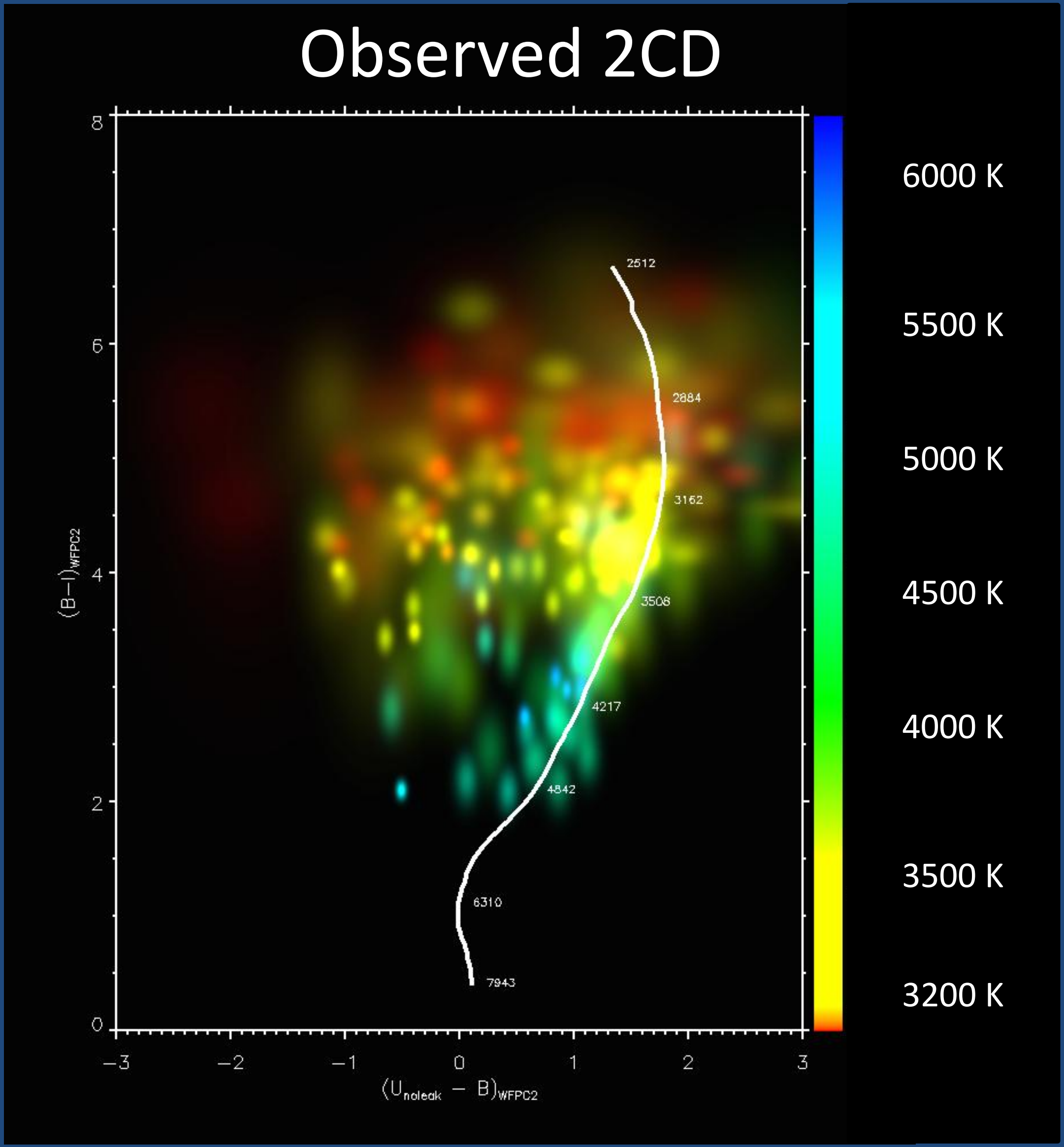
Two Colors Diagram – Accretion Spectrum

Observed 2CD



Manara et al., 2011, in prep.

Two Colors Diagram – Accretion Spectrum



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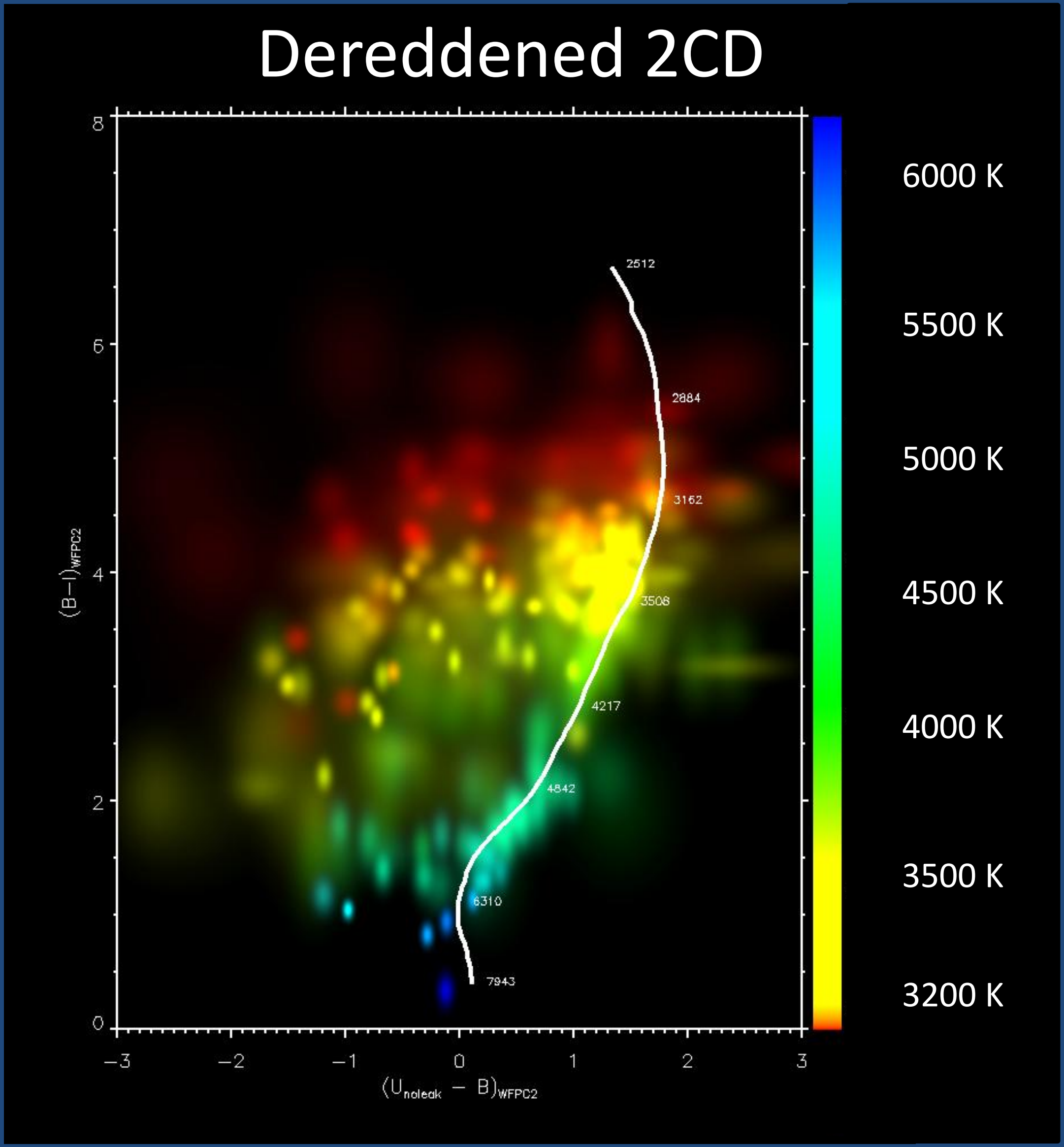
Two Colors Diagram – Accretion Spectrum



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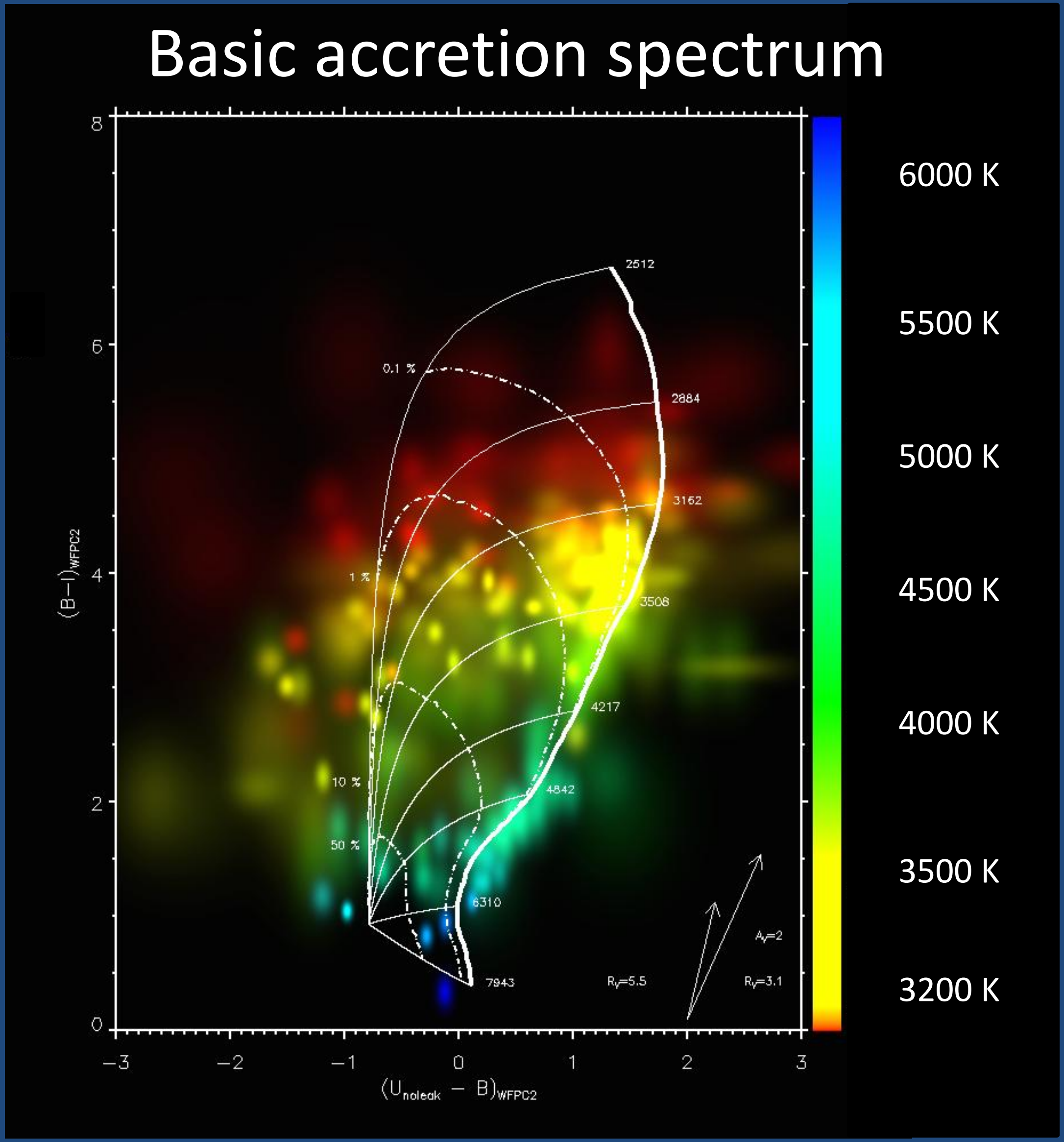
Two Colors Diagram – Accretion Spectrum



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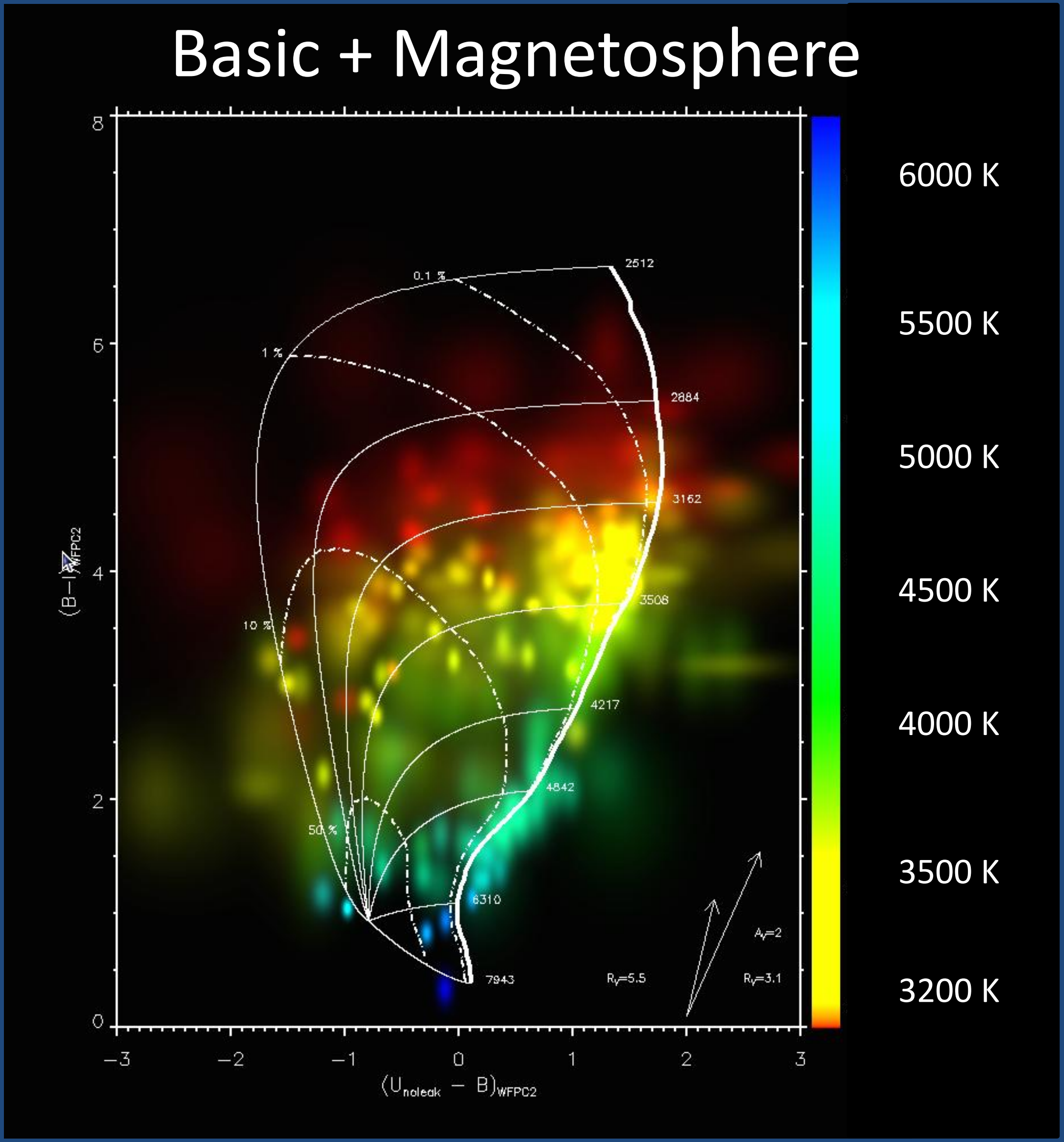
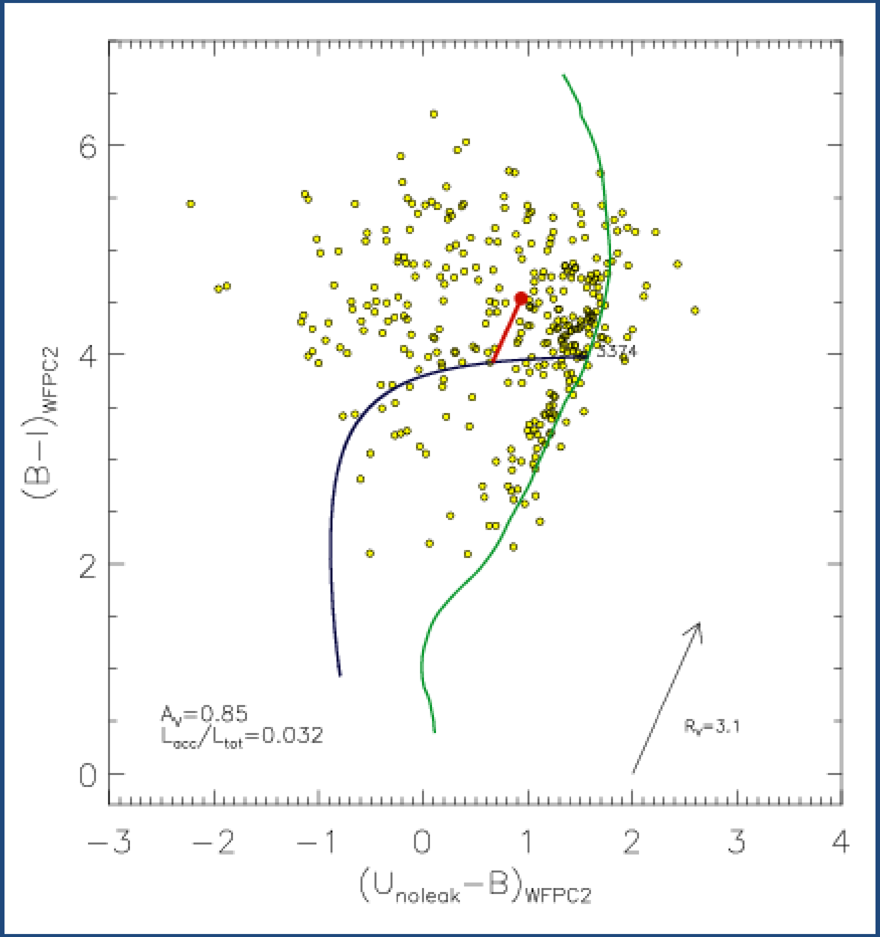


Manara et al., 2011, in prep.

Derivation of L_{ACC} and A_V

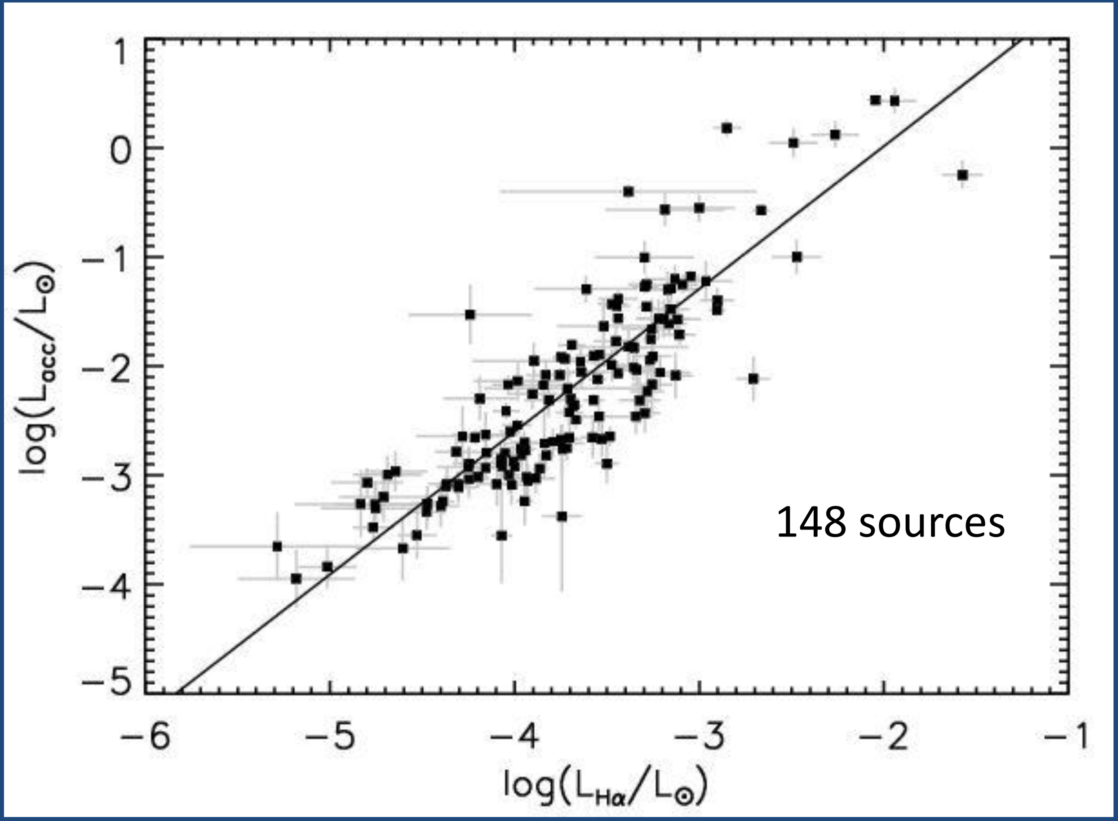


Manara et al., 2011, in prep.

The intersection of the reddening line (red) and the accretion curve (blue) determines simultaneously L_{acc} and A_V.

Estimate of L_{acc} and A_V obtained for 245 sources.

L_{ACC} from $L_{H\alpha}$ - calibration



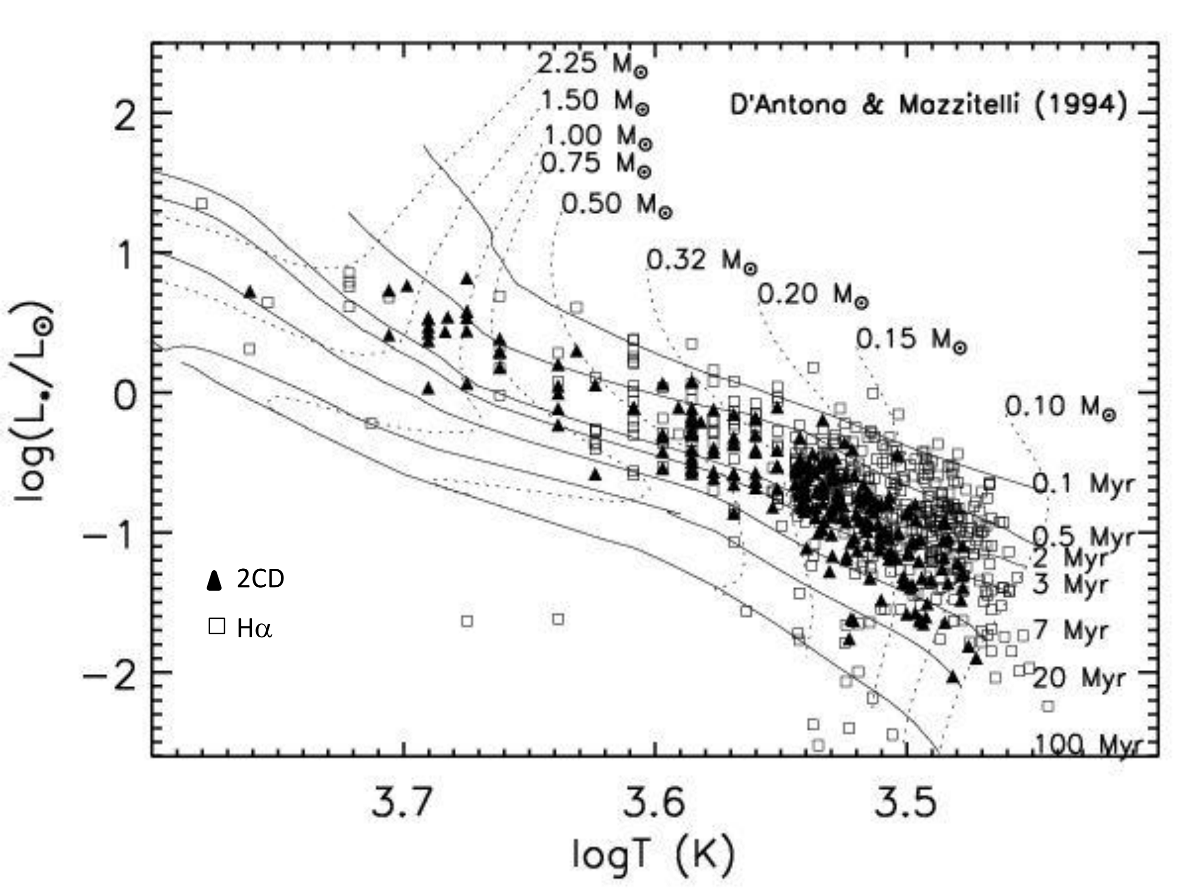
Manara et al., 2011, in prep.

Linear regression :

$$\log\left(\frac{L_{acc}}{L_{Sun}}\right) = (1.31 \pm 0.03)\log\left(\frac{L_{H\alpha}}{L_{Sun}}\right) + (2.63 \pm 0.13)$$

528 sources with L_{acc} estimated from $L_{H\alpha}$

HR Diagram – Masses – M_{acc}



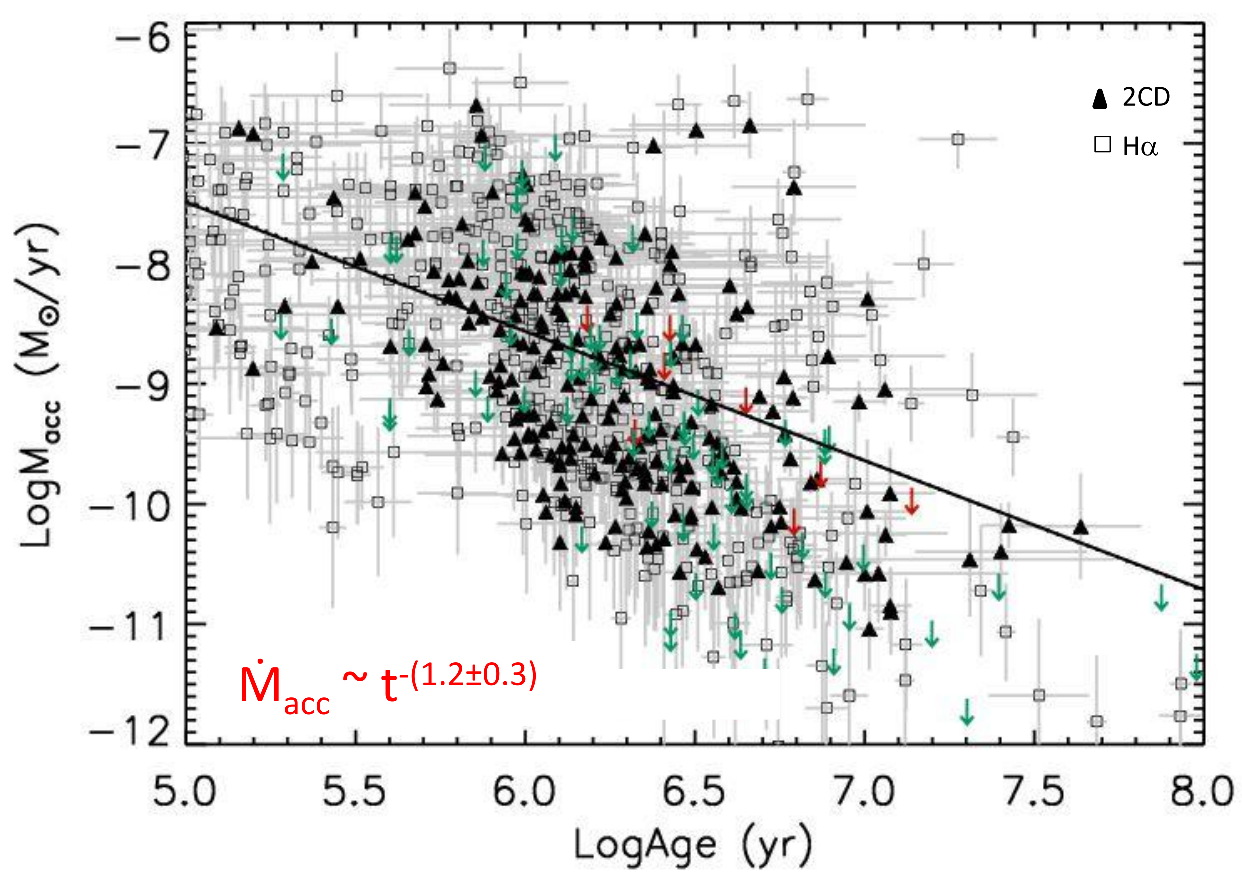
Manara et al., 2011, in prep.

$$\dot{M}_{acc} = \frac{L_{acc} R_*}{G M_*}\left(1 - \frac{R_*}{R_m}\right)^{-1}$$

Derivation of $\dot{M}_{acc}$ for 730 sources (244 with 2CD and 486 from $L_{H\alpha}$)

Results

M_{acc} decreases with time

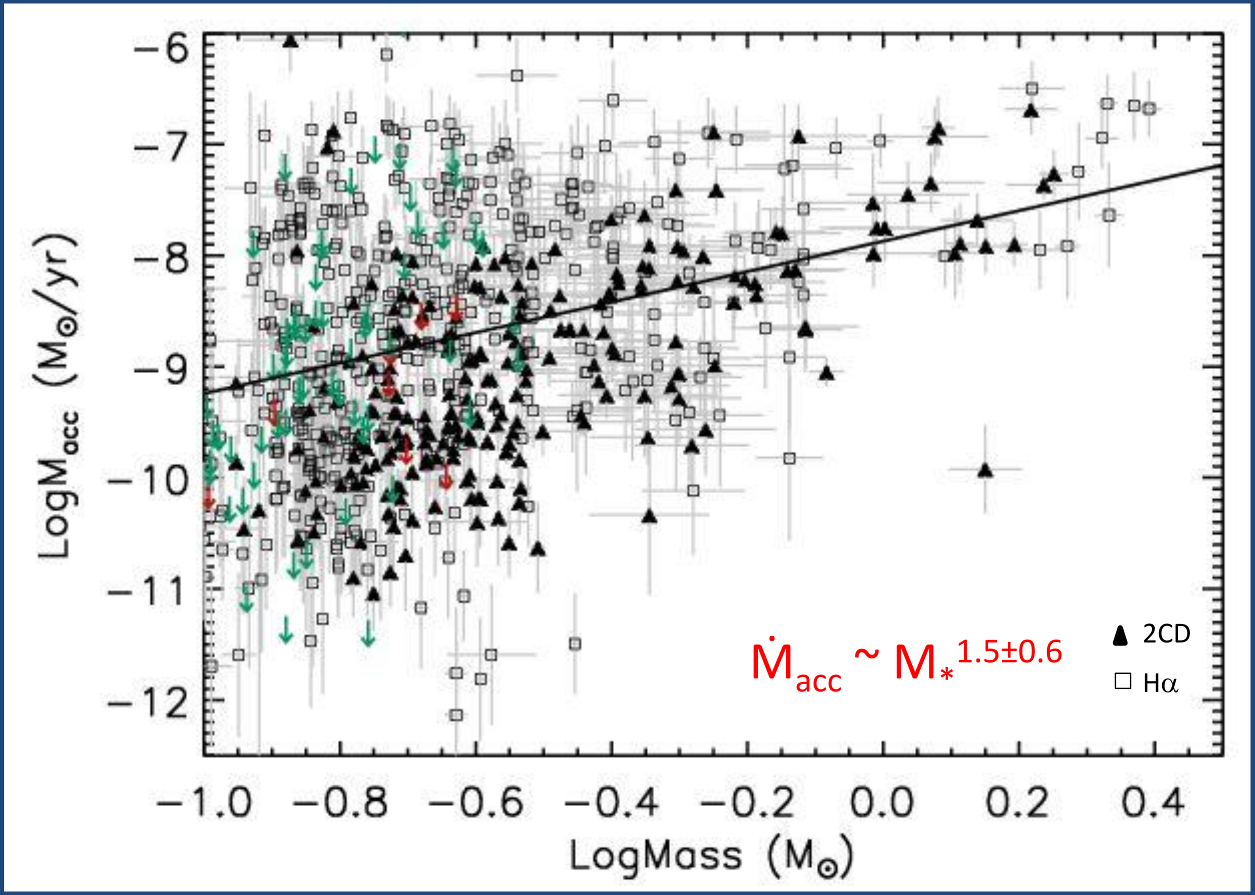


Manara et al., 2011, in prep.

$$\dot{M}_{acc} \propto t^{-\eta}$$

Hartmann et al., 1998: $\dot{M}_{acc} \sim t^{-1.5}$

M_{acc} increases with M_{star}



Manara et al., 2011, in prep.

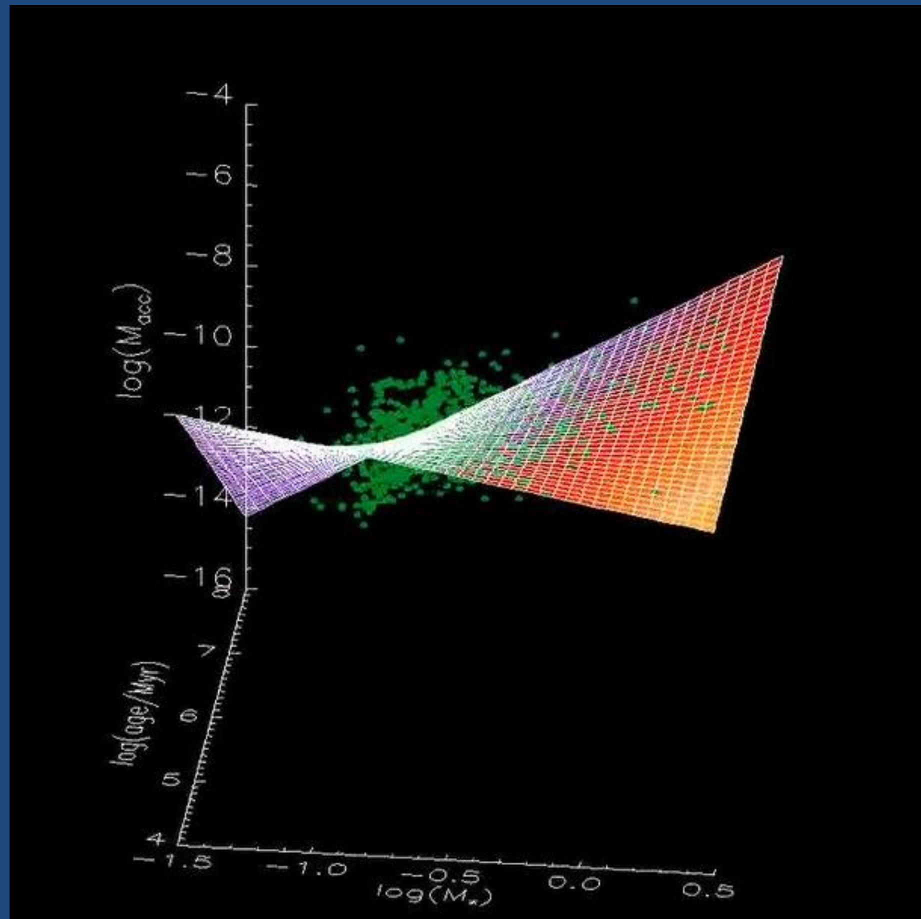
Muzerolle et al., 2003: $\dot{M}_{acc} \sim M_*^2$

Natta et al., 2006: $\dot{M}_{acc} \sim M_*^{1.8\pm0.2}$

Rigliaco et al., 2011: $\dot{M}_{acc} \sim M_*^{1.6\pm0.4}$

M_{acc} depends on age & M_{star}

log M_{acc}

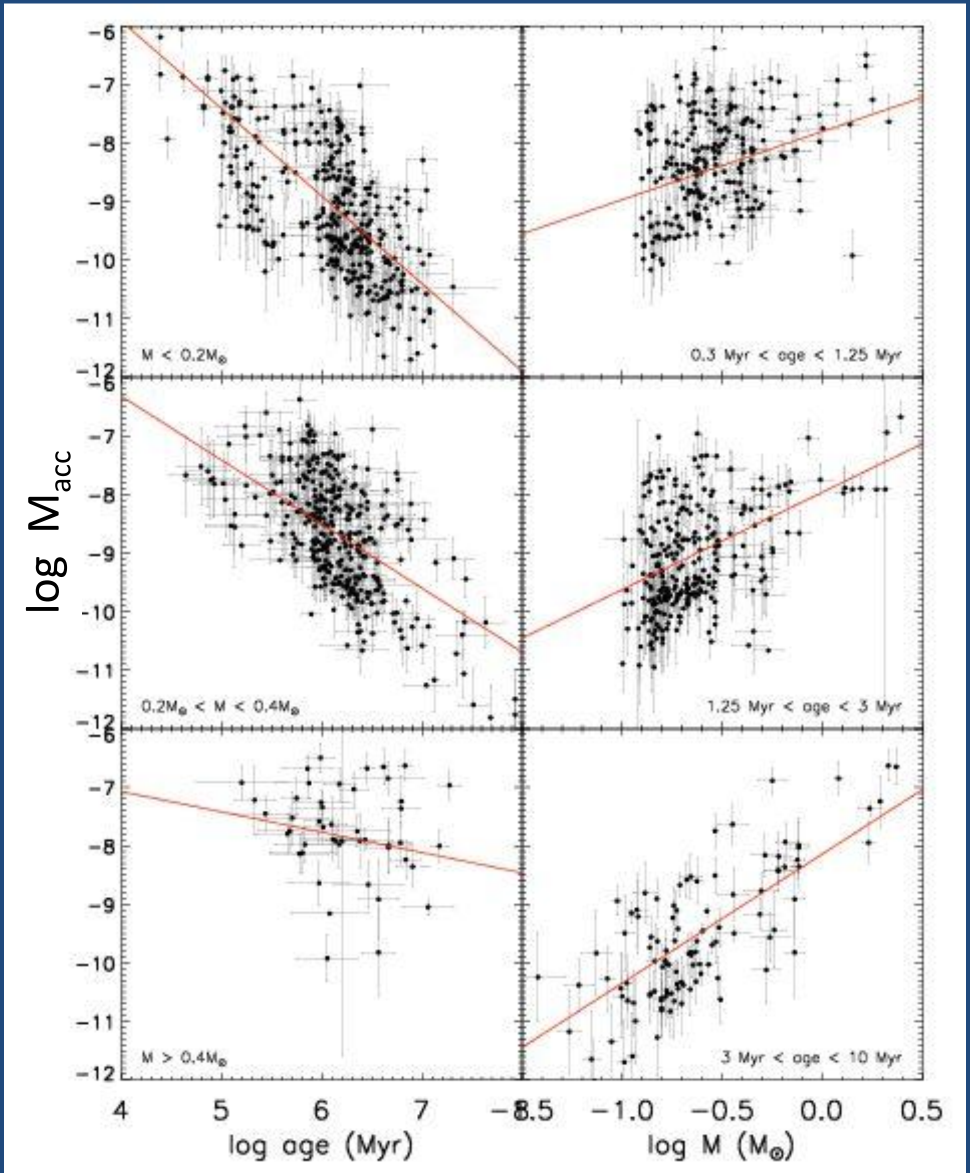


Manara et al., 2011, in prep.

log Age
log M

$$\log \dot{M}_{acc} = -5.12 - 0.46 \log t - 5.78 \log M_* + $$
$$+1.17 \log t \cdot \log M_*$$

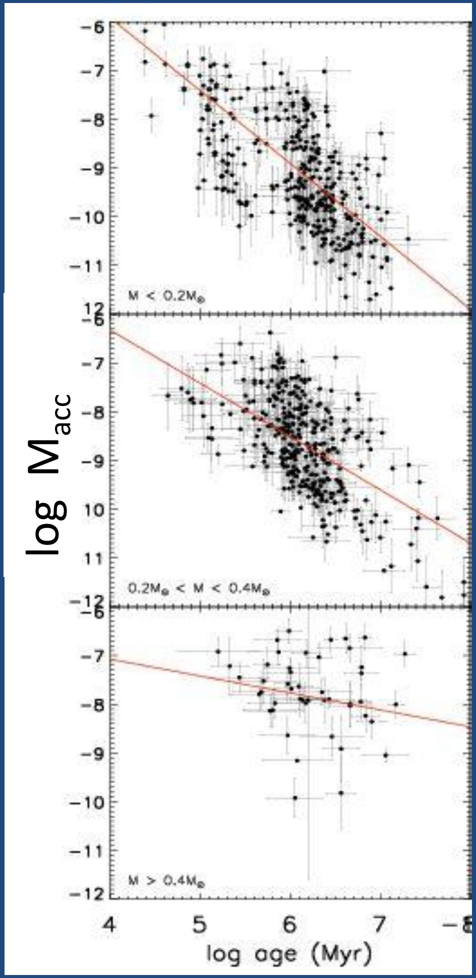
M_{acc} depends on age & M_{star} – new results



Manara et al., 2011, in prep.

$\dot{M}_{acc}$ depends on age & M_{star} – new results

$$\log \dot{M}_{acc} = -5.12 - 0.46 \log t - 5.78 \log M_* + \\ + 1.17 \log t \cdot \log M_*$$



Manara et al., 2011, in prep.

M_{star} ~ 0.13 M_{sun} → $\dot{M}_{acc}$ ~ $t^{-1.5}$

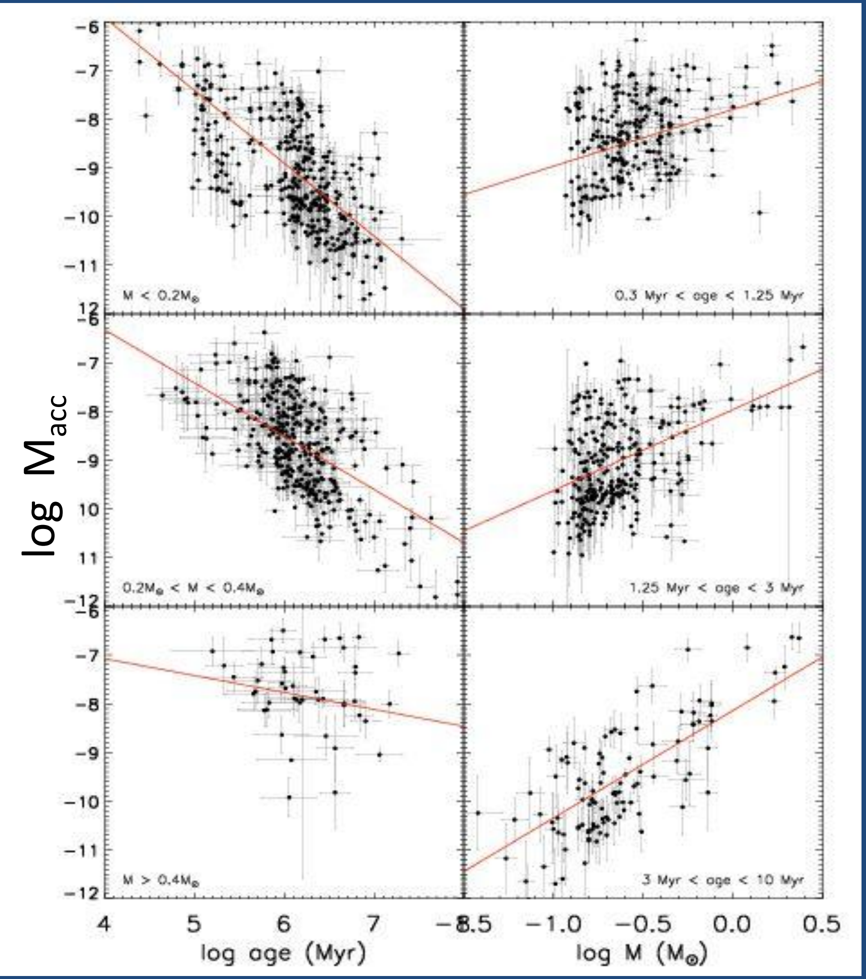
M_{star} ~ 0.3 M_{sun} → $\dot{M}_{acc}$ ~ $t^{-1.07}$

M_{star} ~ 0.5 M_{sun} → $\dot{M}_{acc}$ ~ $t^{-0.8}$

Slower decay for higher mass stars

M_{acc} depends on age & M_{star} – new results

$$\log \dot{M}_{acc} = -5.12 - 0.46 \log t - 5.78 \log M_* + $$
$$+ 1.17 \log t \cdot \log M_*$$



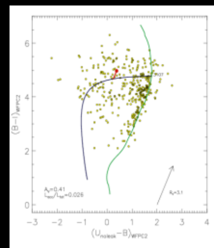
Manara et al., 2011, in prep.

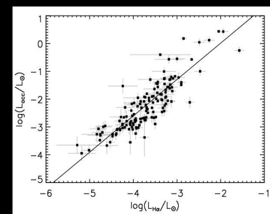
age ~ 1 Myr ⇒ $\dot{M}_{acc} \sim M_*^{1.24}$

age ~ 2 Myr ⇒ $\dot{M}_{acc} \sim M_*^{1.59}$

age ~ 5 Myr ⇒ $\dot{M}_{acc} \sim M_*^{2}$

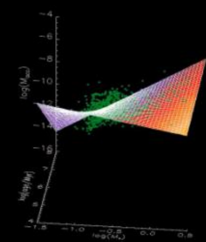
CONCLUSIONS

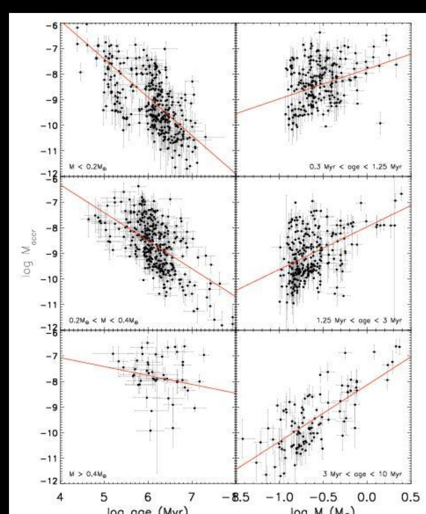




Macc estimate for 730 sources with two methods (2CD and Hα)

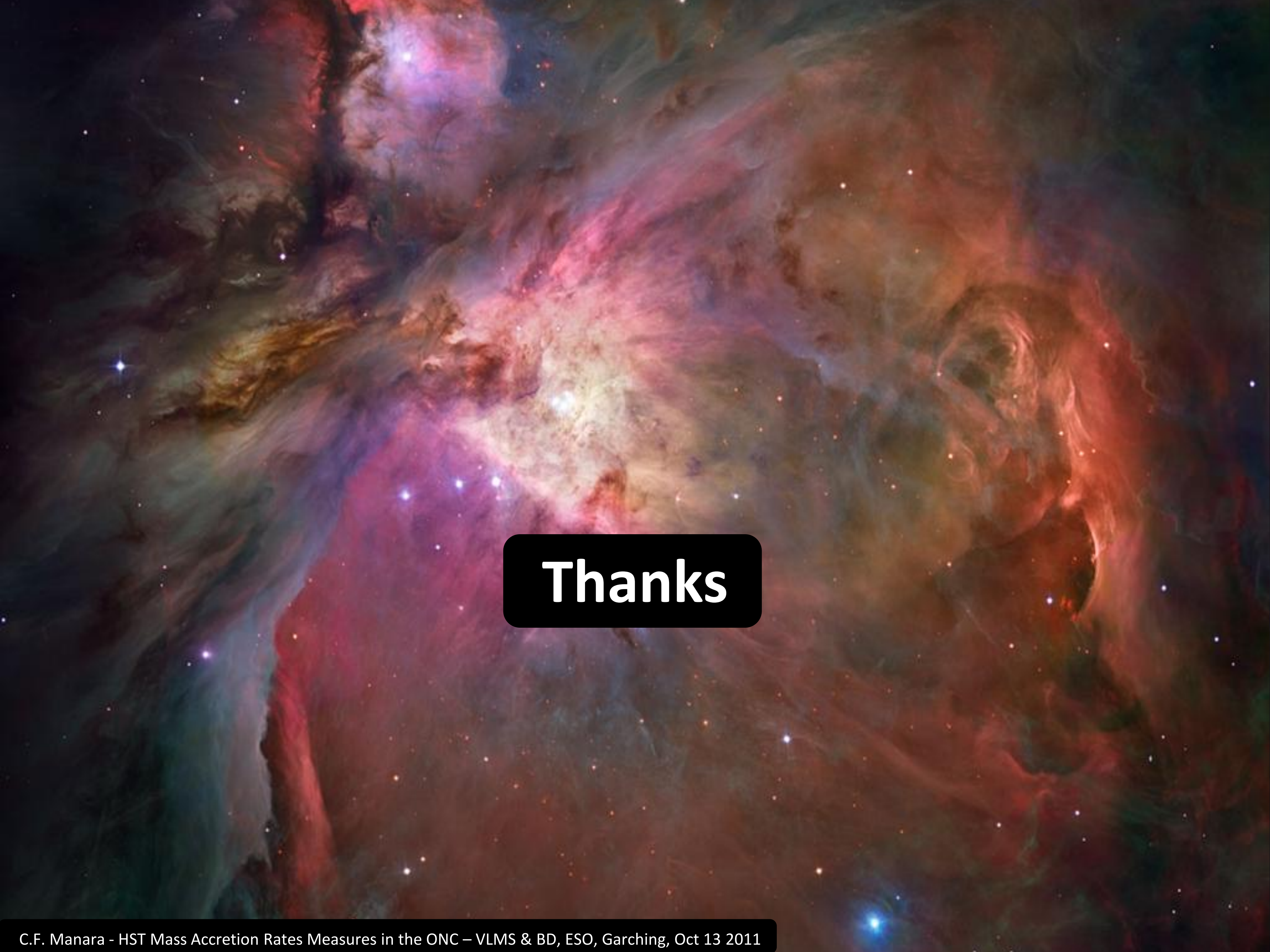
Fit of the the warped plane M_{acc} – age – M_{star}





Different behaviour for different mass and age ranges.

More massive stars evolve more slowly than less massive stars.



Thanks