

Variability of massive stars in the Virgo Cluster galaxy NGC 4535 with the Hubble Space Telescope



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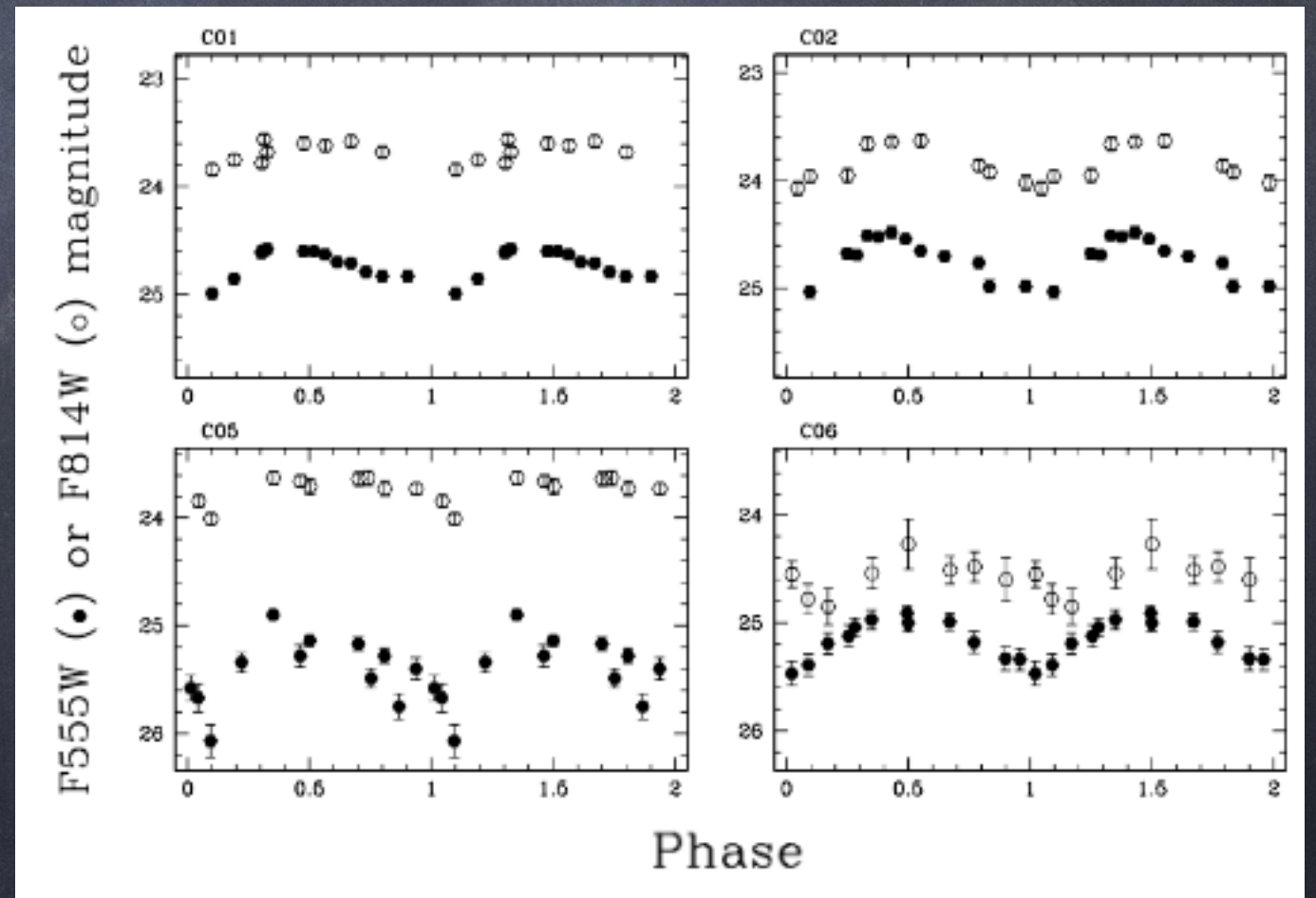


Motivation

- Constraining evolutionary models of massive stars (e.g. rotation, metallicity, binarity)
- Increase observations of massive stars in different environments
- Variability is a powerful tool for identifying massive stars
- Validation of the "Hubble Catalog of Variables" (HCV) for WFPC2

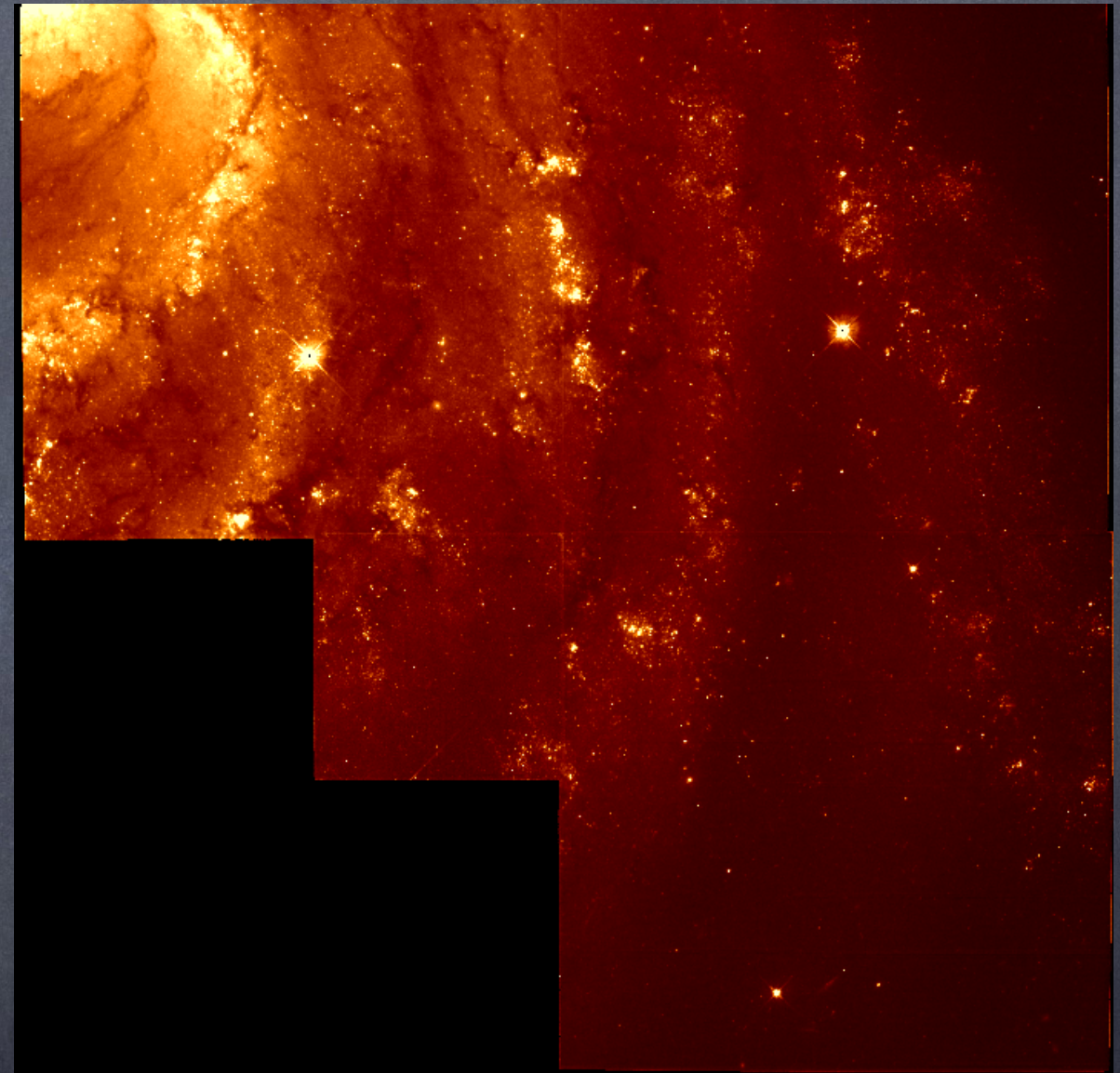
NGC 4535

- HST Key Project galaxy in Virgo Cluster
- Variability search revealed 50 Cepheids (Macri et al. 1999)
- Distance from P-L relation: 16 ± 1.9 Mpc (Macri et al. 1999)
- More variable stars expected



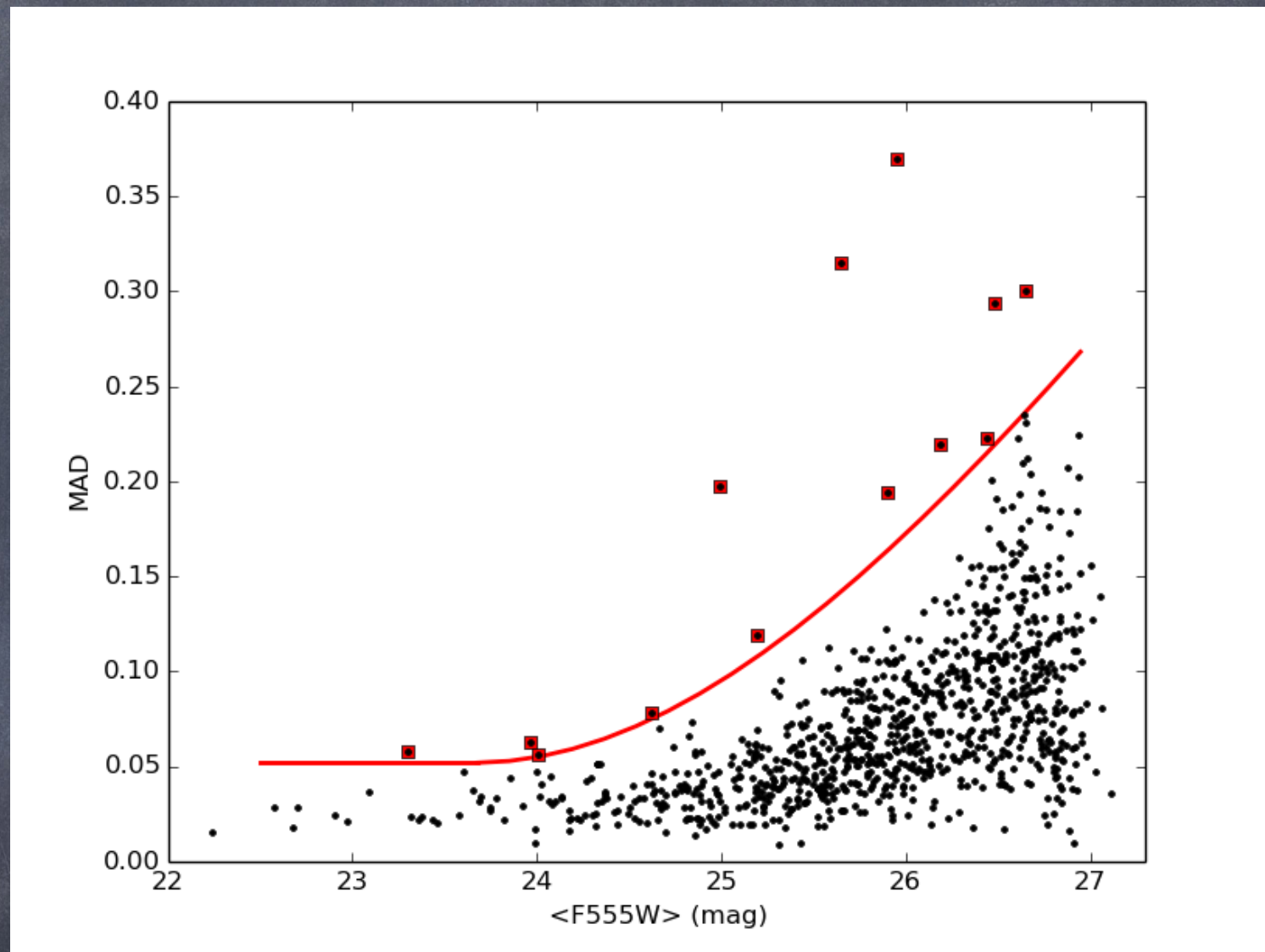
Photometry

- HST/ WFPC2
4 chips (PC, WF2, WF3, WF4)
- F555W: 12 epochs
- F814W: 8 epochs
- May-August 1996
- PSF Photometry: DOLPHOT
(Dolphin 2000)
- Distortion and CTE corrections
were taken into account
- 24353 stars detected in both
filters



Variability Indexes

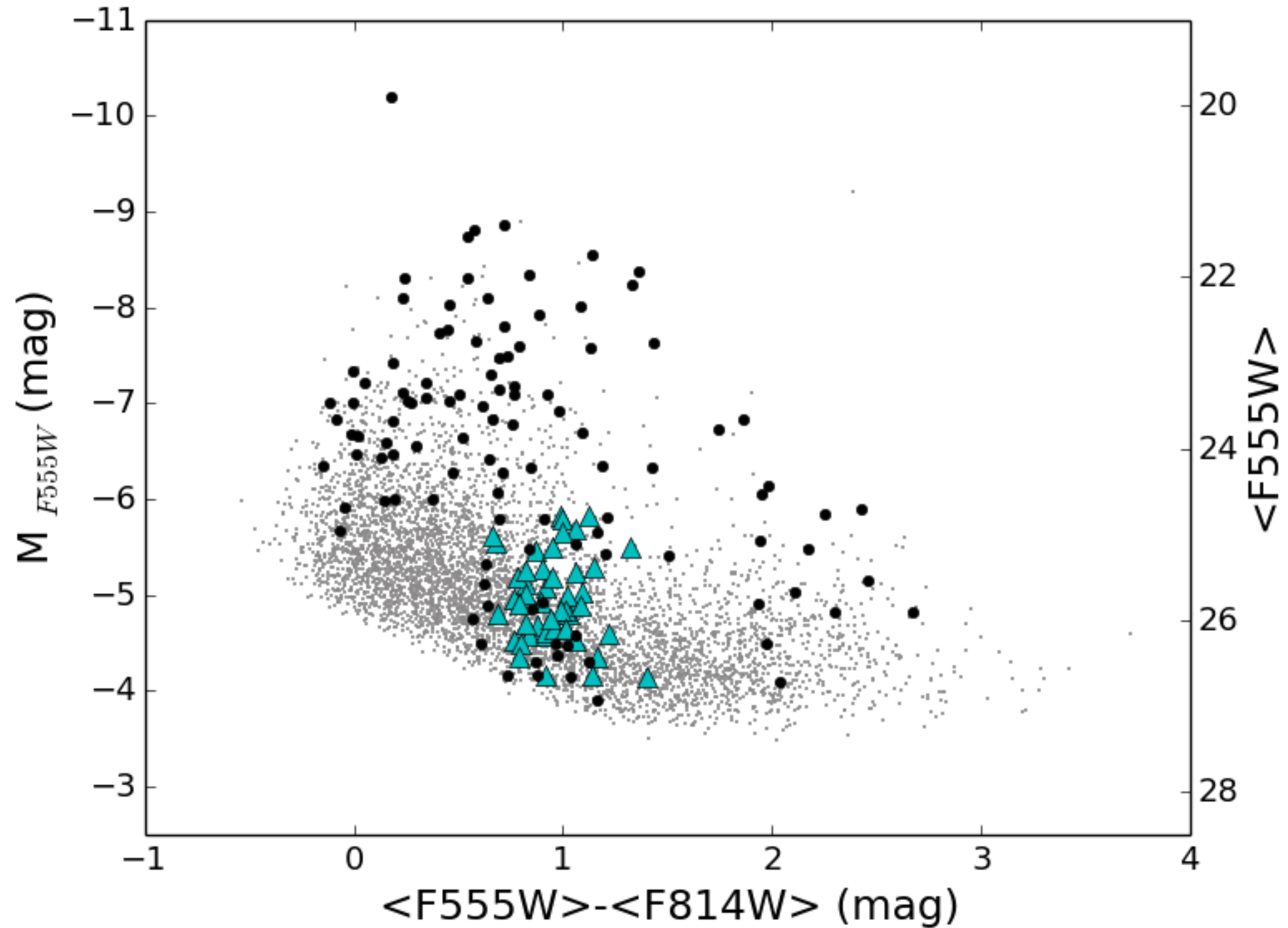
- Mean Absolute Deviation (MAD)
- Interquartile Range (IQR)
- von Neumann ratio ($1/\eta$)
- 3σ cutoff
- **Selection criteria:** Variable in any of the three indexes in either filter



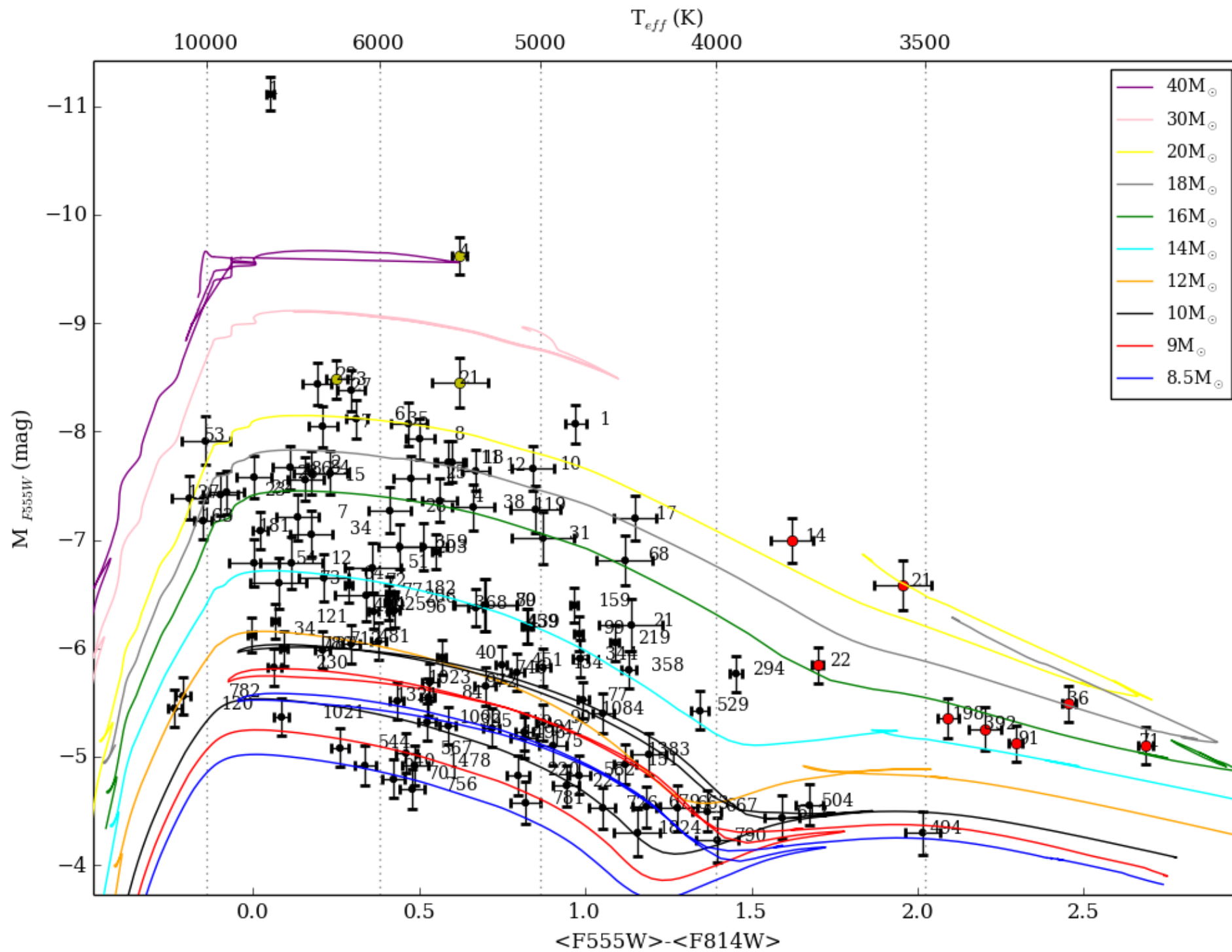
New variable stars in NGC 4535

WFPC2	# Variables
PC	17
WF2	50
WF3	23
WF4	30
Total	120

Color Magnitude Diagram

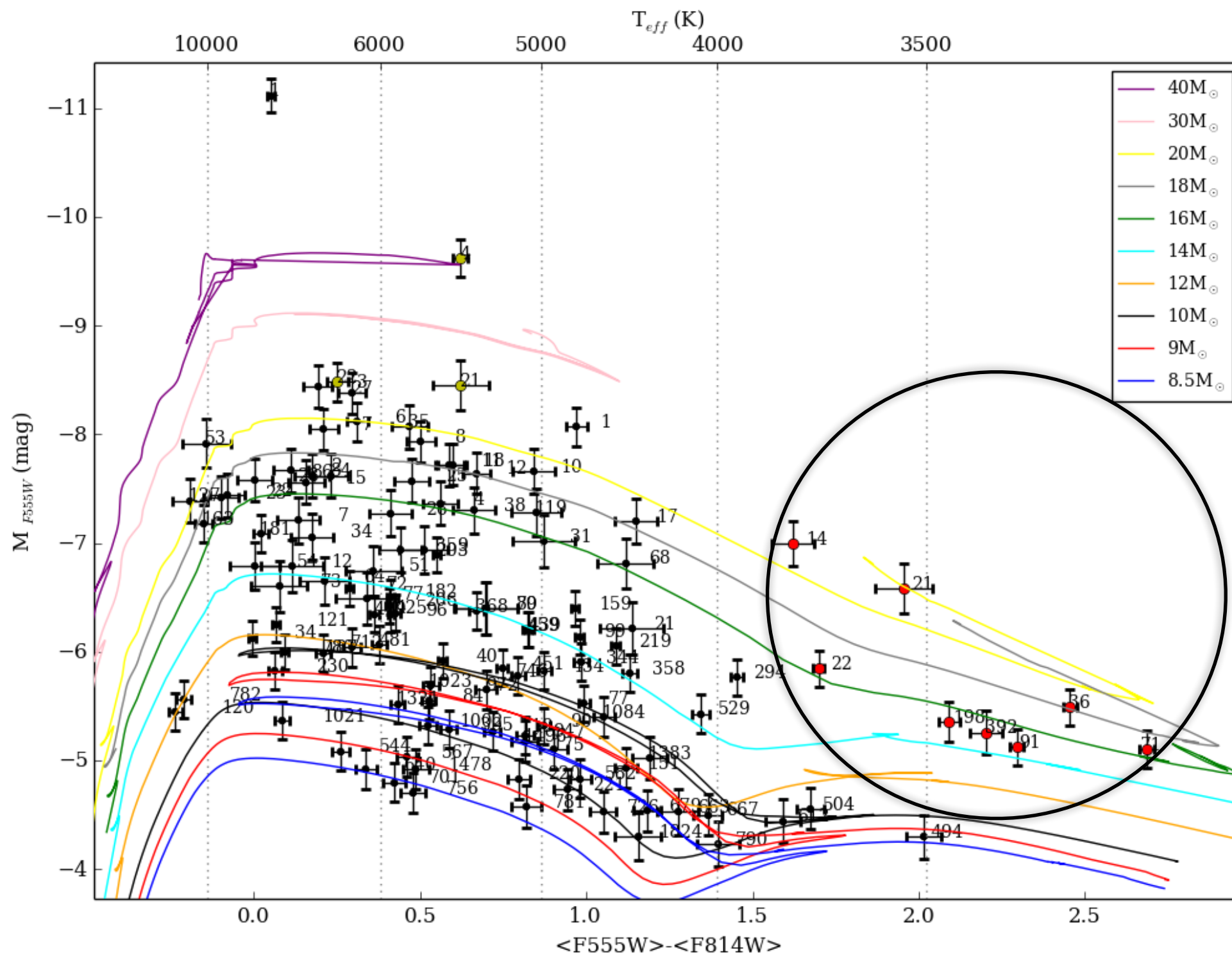


CMD with evolutionary tracks

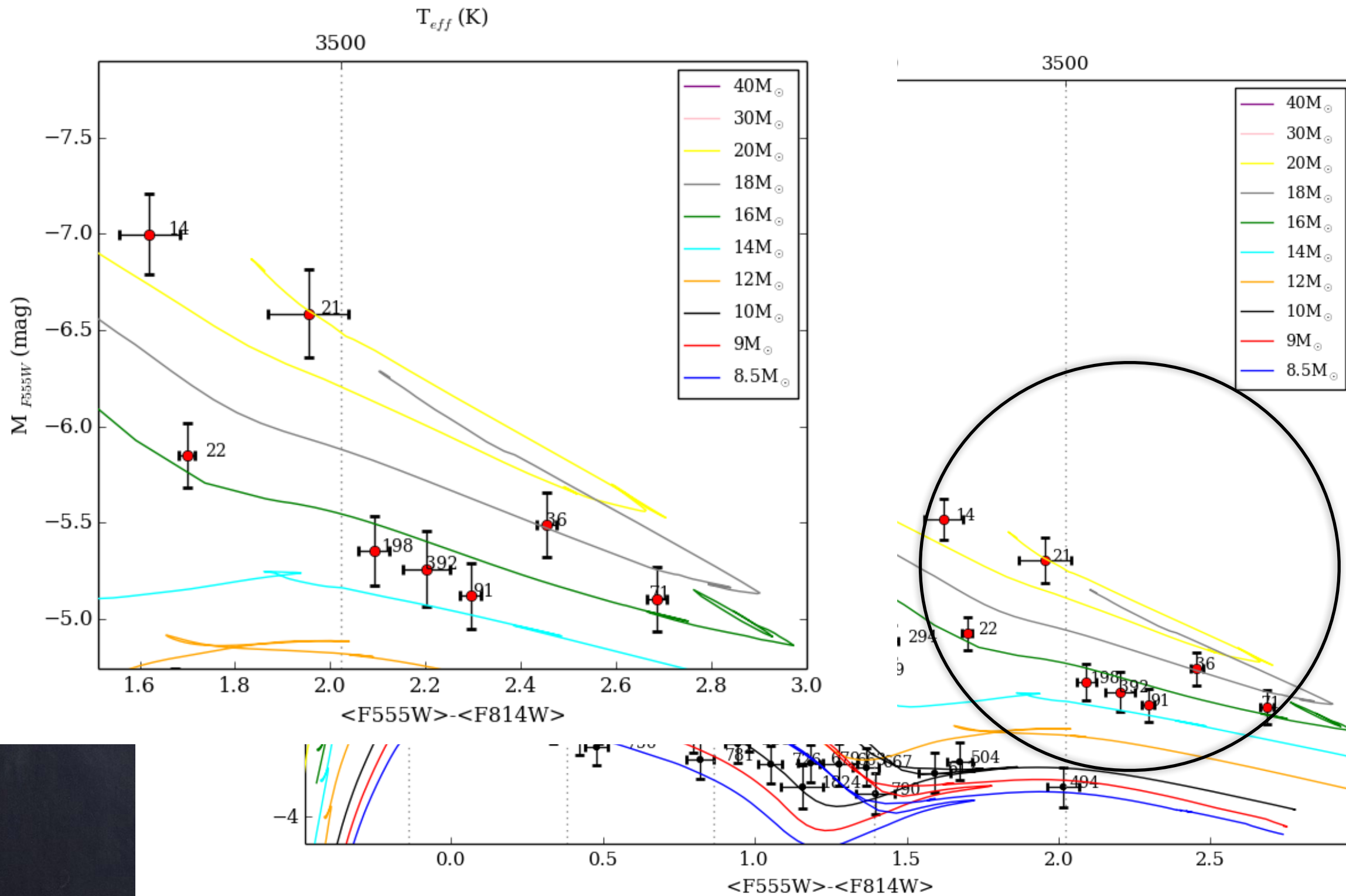


MESA models (Choi et al. 2016)

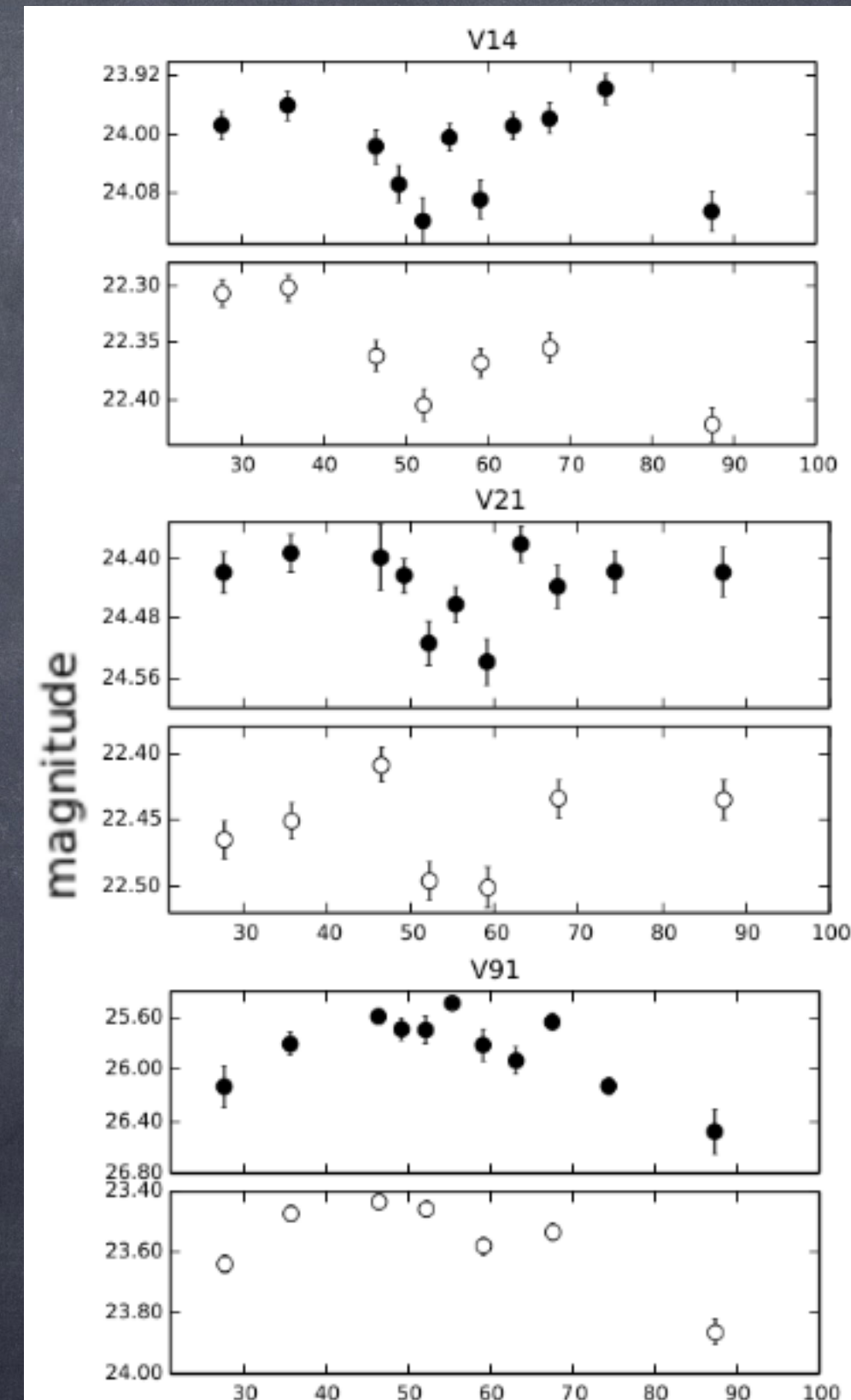
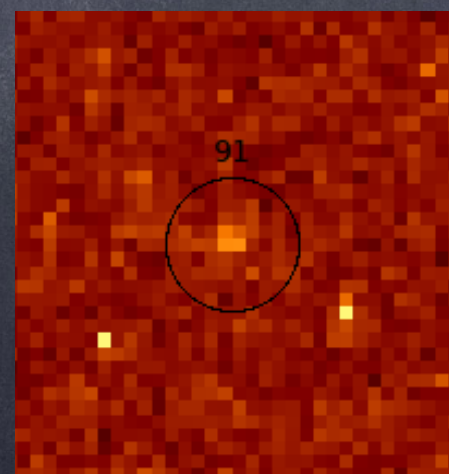
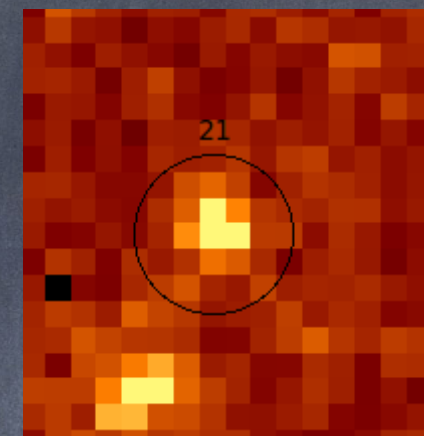
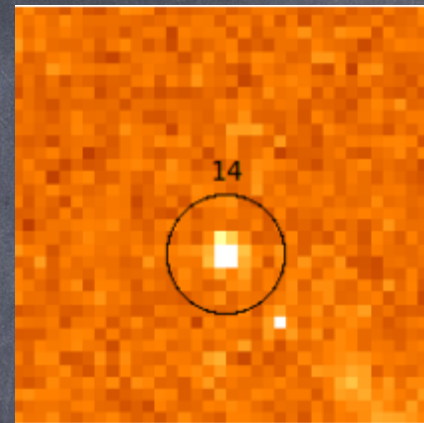
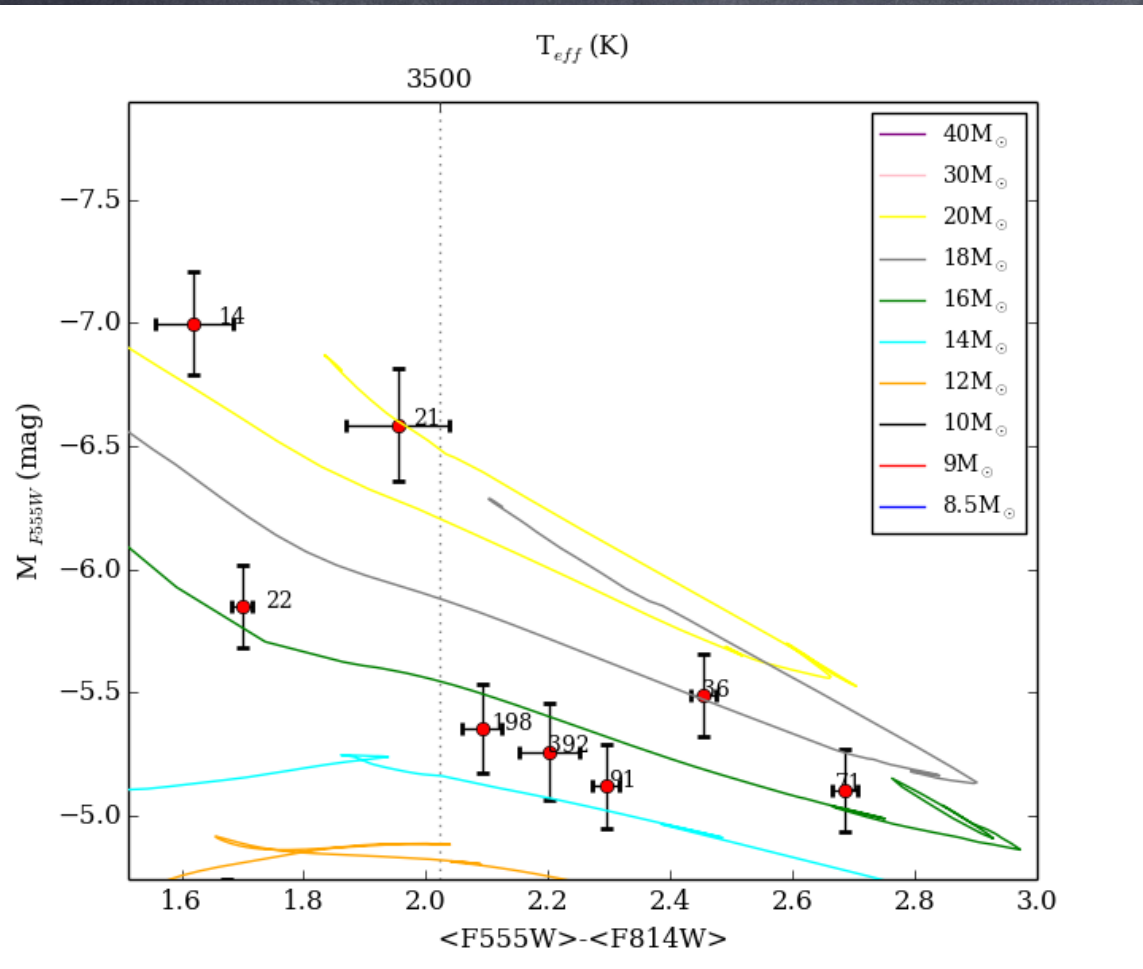
CMD with evolutionary tracks



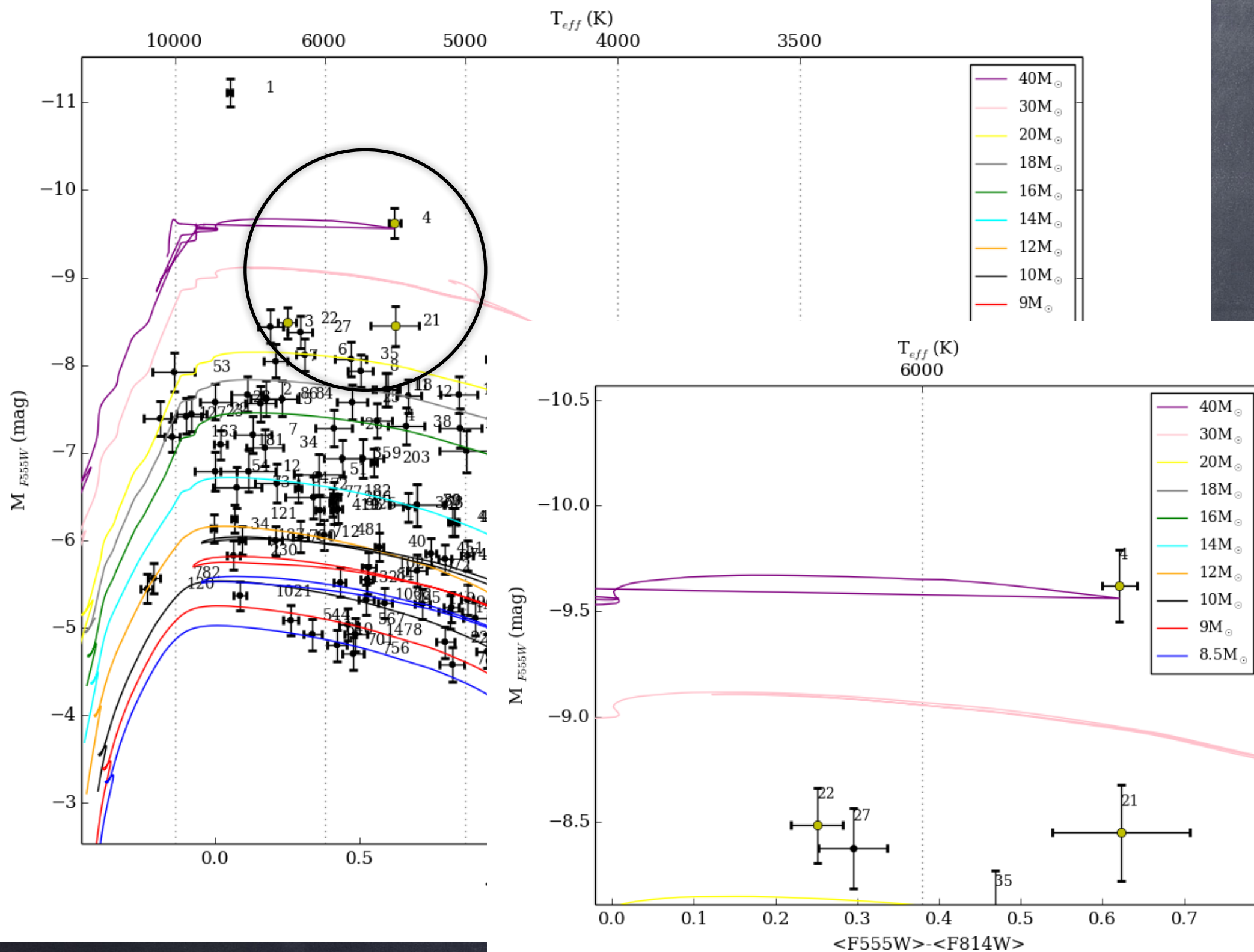
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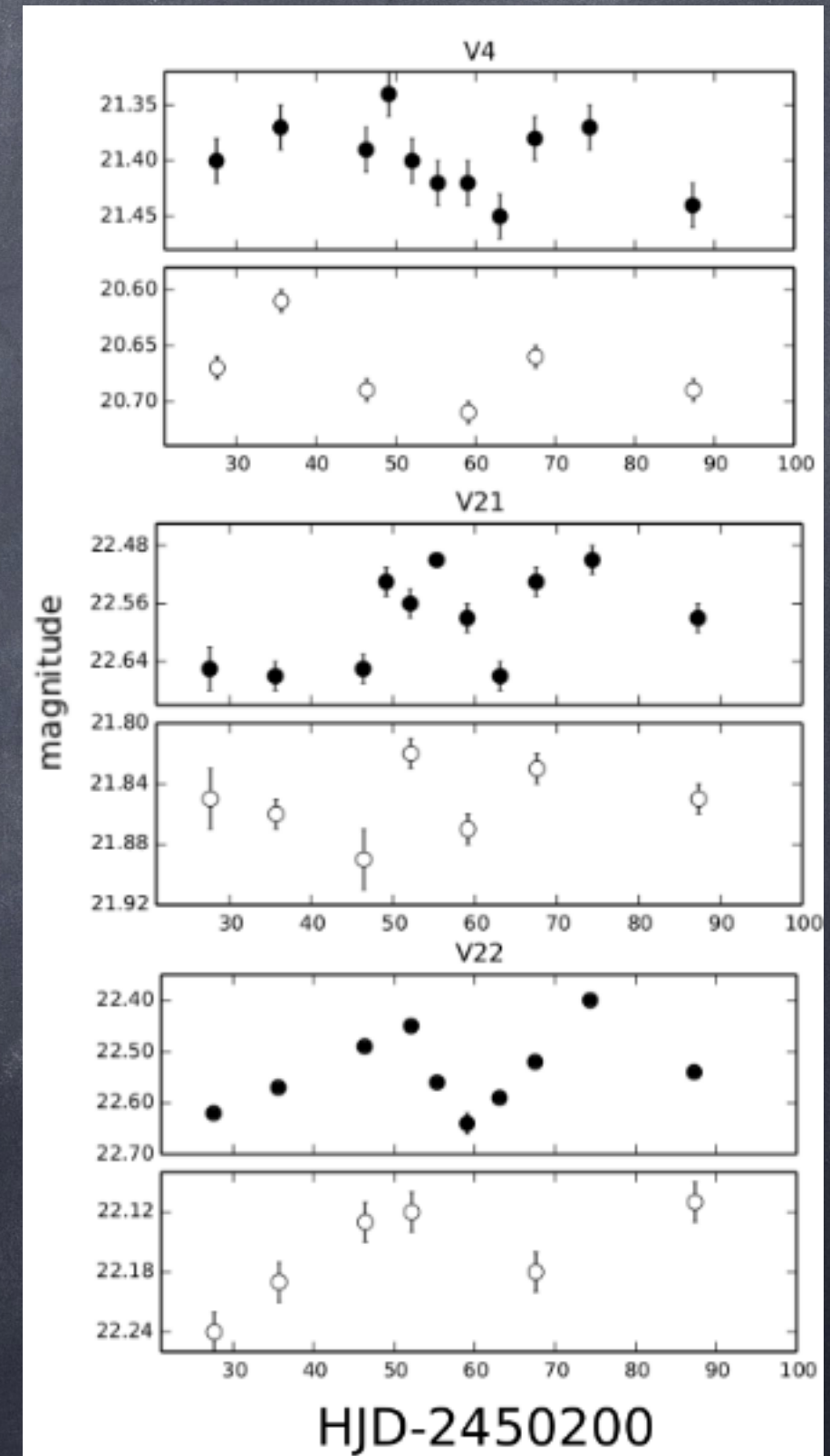
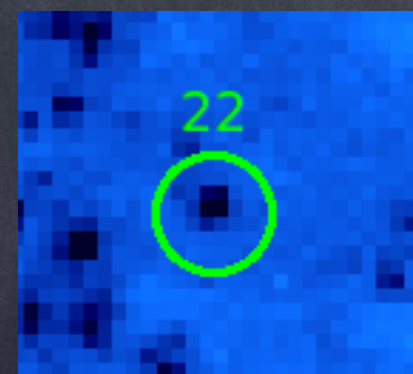
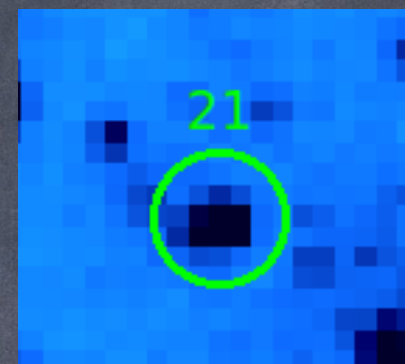
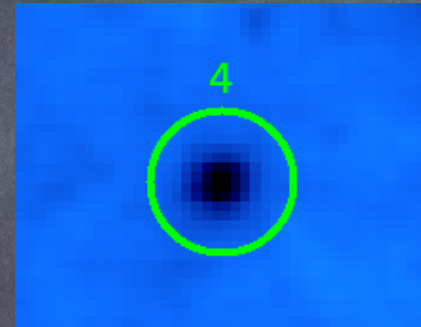
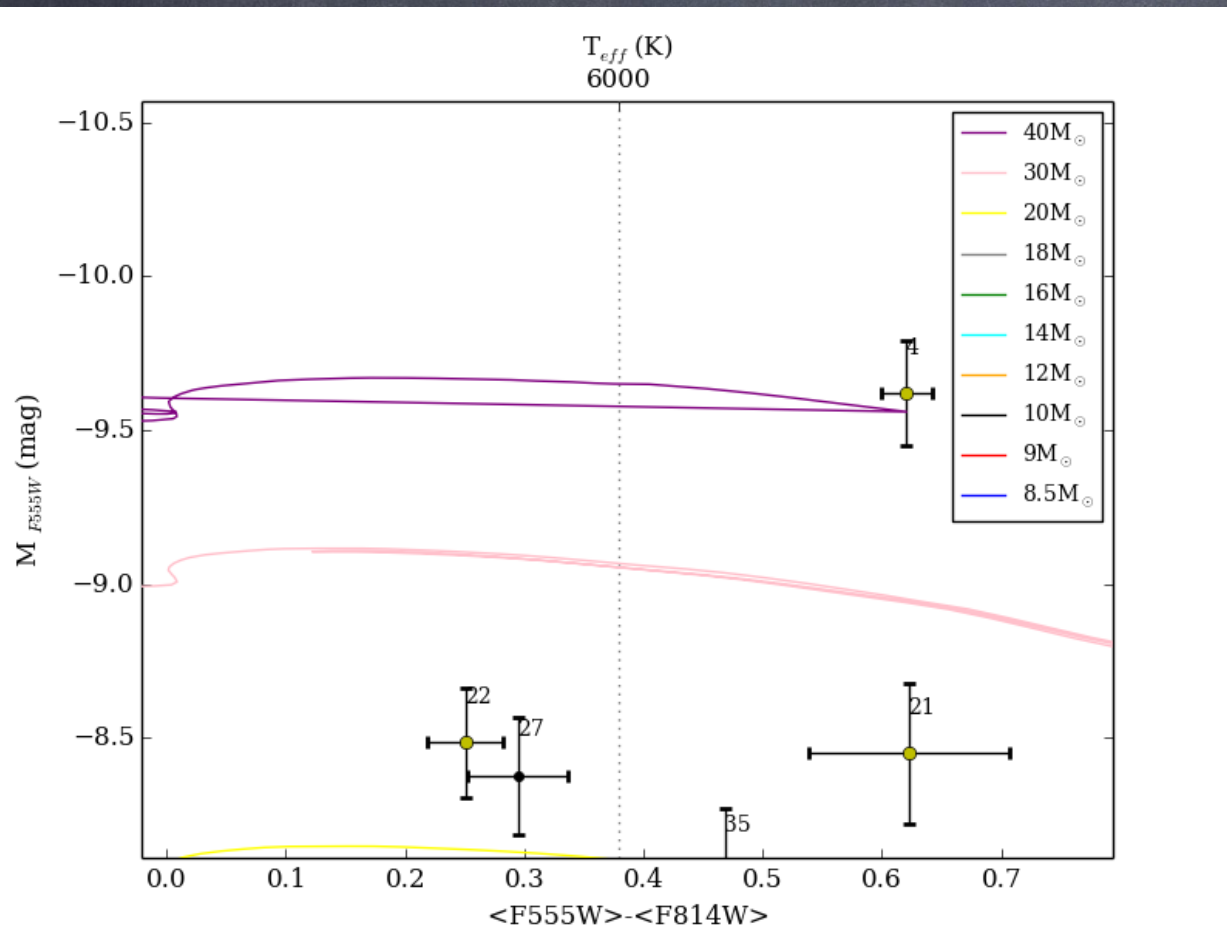
Candidate RSGs



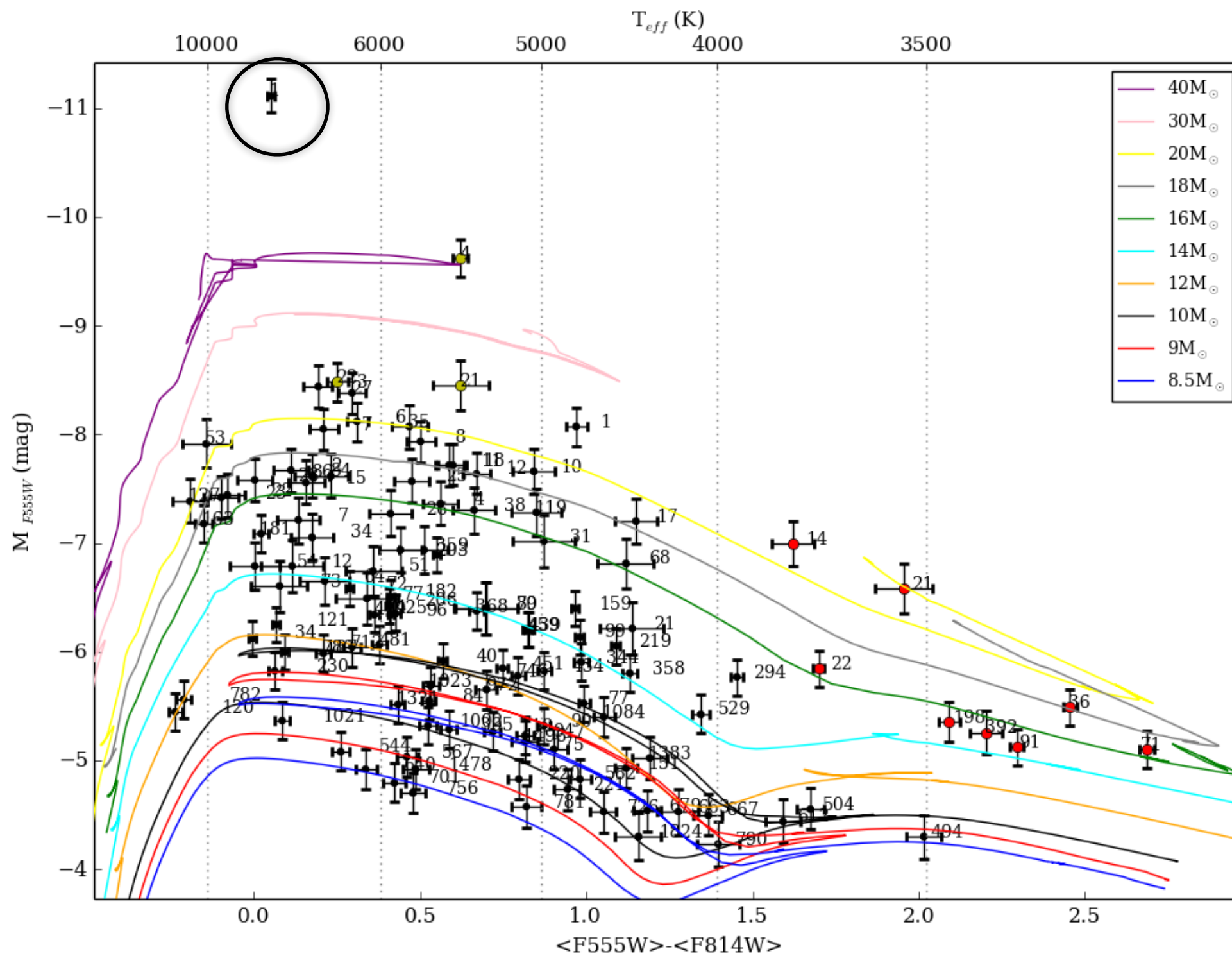
CMD with evolutionary tracks



Candidate YSGs/YHG

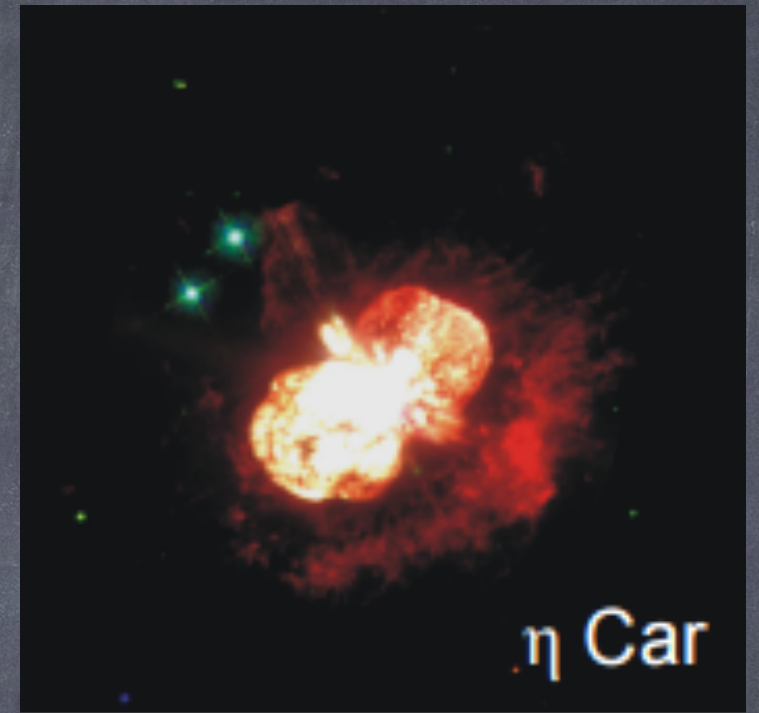


Candidate LBV???



LBVs

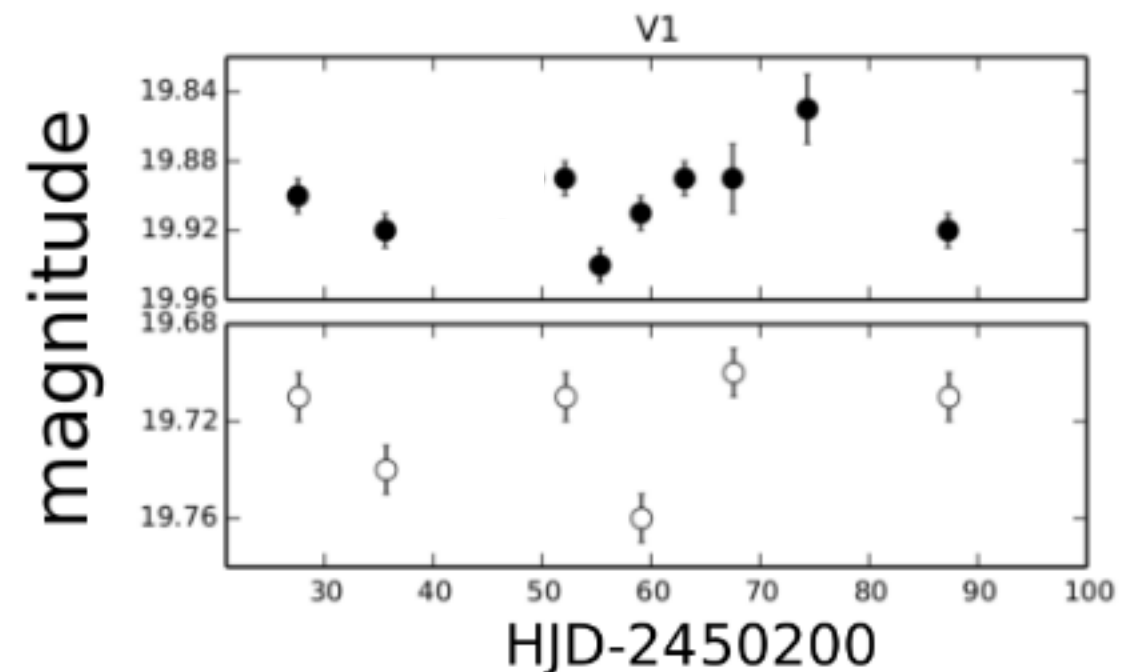
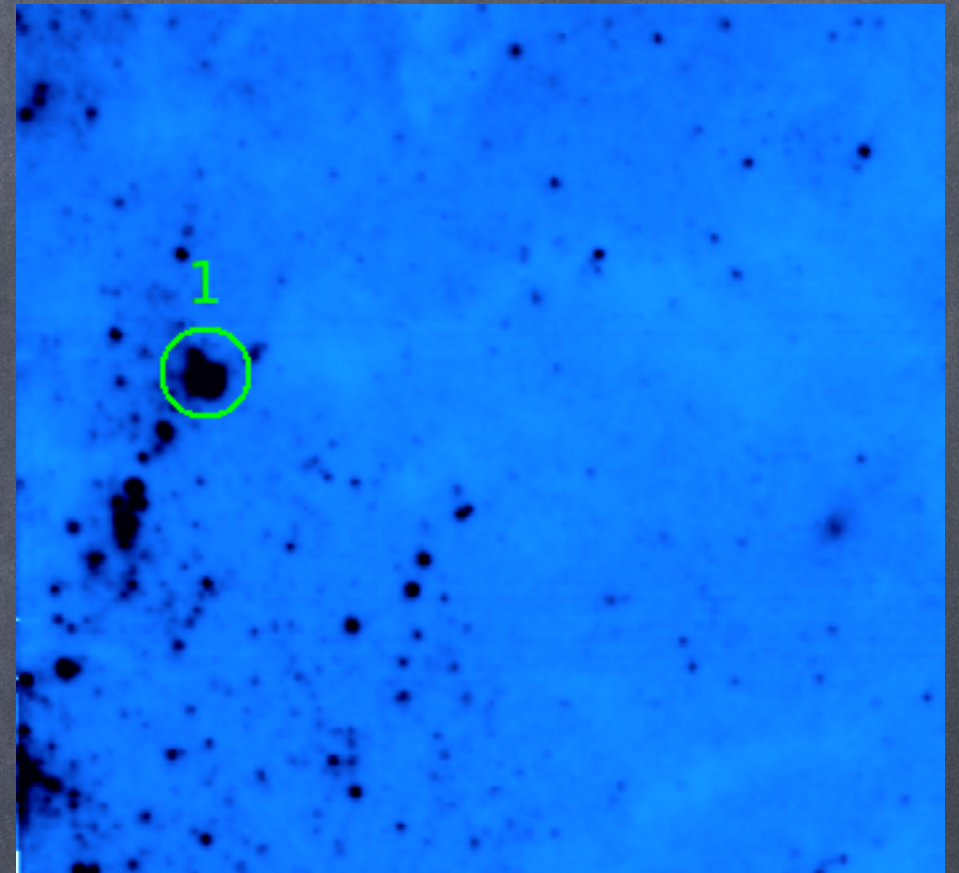
- **Evolved stars:** $M_{\text{bol}} < -9.5$ mag
- **Mass:** 22-120 M_{\odot}
- **Giant eruptions:** >2 mag (η Carinae)
- **Eruptions:** $\sim 1-2$ mag within 10-40 yrs
- **Smaller oscillations:** ~ 0.5 mag
- **Microvariations:** <0.1 mag



HST images of two bipolar LBV nebulae (Weis 1999, 2011)

Candidate LBV

- **Mass:** $> 40 M_{\odot}$
- $M_v \sim -11$ mag
- $T_{\text{eff}} \sim 9000$ K
- $\langle F555W \rangle - \langle F814W \rangle \sim 0.1$ mag
- **Microvariations:** ~ 0.1 mag



Conclusions

- 120 new variable stars in NGC 4535 using archival HST/WFPC2 data
 - 8 candidate RSGs
 - 3 candidate YSGs/ YHG
 - 1 candidate LBV ($M_v \sim -11$ mag)
- Identified massive star candidates at 16 Mpc
- Successful selection of variable stars with variability indexes

Future Projects

- Apply method to other HST Key Project galaxies to search for new variability and massive stars
- Derive new P-L relation with DOLPHOT photometry
- Follow-up spectroscopy and Pan-STARRS photometry for the candidate LBV

THANK YOU!!

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