Acknowledgement

• **Advisor:** Josh Grindlay

• **DASCH team:**
  
  Edward Los, Alison Doane, Bob Simcoe, Jaime Pepper, David Sliski, Silas Laycock, Mathieu Servillat;
  
  Many volunteers: George Champine, Chase Green, Julia Hardy, Ray Kenison, Jim Ostiguy, Steve Siok, Alan Sliski, Bill Toomey, volunteers at AMNH
Acknowledgement

- **Advisor:** Josh Grindlay

- **DASCH team:**
  Edward Los, Alison Doane, Bob Simcoe, Jaime Pepper, David Sliski, Silas Laycock, Mathieu Servillat;
  Many volunteers: George Champine, Chase Green, Julia Hardy, Ray Kenison, Jim Ostiguy, Steve Siok, Alan Sliski, Bill Toomey, volunteers at AMNH

- **Committee members:**
  Dimitar Sasselov, Avi Loeb, Rosanne Di Stefano, Howard Bond; Martin Elvis

- **Many colleagues:**
  Bob Kurucz, Max Moe, Jonathan McDowell, Dave Latham, Jose Fernandez, Sam Quinn, Lars Buchhave, Allyson Bieryla, Scott Kenyon, Andrea Dupree, Anna Frebel, Francesca Civano, Soren Meibom, Warren Brown, Ruth Murray-Clay, Matthew Holman, Branden Allen, Maureen van den Berg, Paul Green, Emilio Falco, Perry Berlind, Nelson Caldwell, Mike Calkins, Jessica Mink, Bill Wyatt, Susan Tokarz; Jerry Orosz, Ronald Gilliland
Acknowledgement

• Advisor: Josh Grindlay

• DASCH team:
  Edward Los, Alison Doane, Bob Simcoe, Jaime Pepper, David Sliski, Silas Laycock, Mathieu Servillat;
  Many volunteers: George Champine, Chase Green, Julia Hardy, Ray Kenison, Jim Ostiguy, Steve Siok, Alan Sliski, Bill Toomey, volunteers at AMNH

• Committee members:
  Dimitar Sasselov, Avi Loeb, Rosanne Di Stefano,
  Howard Bond; Martin Elvis

• Many colleagues:
  Bob Kurucz, Max Moe, Jonathan McDowell, Dave Latham, Jose Fernandez, Sam Quinn, Lars Buchhave, Allyson Bieryla, Scott Kenyon, Andrea Dupree, Anna Frebel, Francesca Civano, Soren Meibom, Warren Brown, Ruth Murray-Clay, Matthew Holman, Branden Allen, Maureen van den Berg, Paul Green, Emilio Falco, Perry Berlind, Nelson Caldwell, Mike Calkins, Jessica Mink, Bill Wyatt, Susan Tokarz; Jerry Orosz, Ronald Gilliland

• All fellow grad students:
  Gongjie Li, Ann Mao, Heng Hao, Roman Shcherbakov, Sasha Tchekhovskoi, Li Zeng, Wen-fai Fong, Joey Nelson, Meng Su and many others

• Faculty members:

• Admin: Peg Herlihy, Donna Adams, Jean Collins, Donna Wyatt, Uma Mirani, Carol Knell; CF/HEA help

• CfA climbing community and many other friends
First question: what are variable stars?

• A star is called variable if its brightness changes over time.

• The variability could be extrinsic, such as eclipse and lensing; or intrinsic, such as pulsation, flares, accretion variability, or explosions.

• The definition depends on the variability amplitude and timescale: all stars are variable if the measurement accuracy is high enough (see e.g. Kepler), or if we could wait long enough.

• My thesis is on ‘long-term’ (timescales from days to 100 years) and ‘extreme’ (amplitude>~0.5 mag) variables with DASCH (Digital Access of a Sky Century@Harvard).
Second question: Why study long-term variables with DASCH?

- They are there, mostly un-explored.

- They provide important information about the physical processes involved, most of which are not clearly understood yet: dust processes, magnetic cycles of stars, accretion, nuclear burning on WDs… Variability is the way stars ‘talk’ to us. We want to decipher ‘the message’ to learn how they work.

- And we do not want to wait another 80+ years to study variations over 100 years (while we do do have the data here in the cabinets).
Outline

- What I do: Introduction to DASCH
- How I do it: Photometry and Defect Filtering
  
  (Tang et al. 2012c; Laycock, Tang, et al. 2010)

- What I get - Scientific Results:
  
  - The Kepler Field
    - Planet Host Stars (Tang et al. 2012b)
    - Variable Search and Catalog (Tang et al. 2012d)
  
  - Individual Long-term Variables
    - Peculiar K Giant Variables (Tang et al. 2010; 2012e)
    - KU Cyg: a 5-yr Dust Accretion Event (Tang et al. 2011)
    - A 10-yr Nova-like Outburst (Tang et al. 2012a)
  
  - Two Other Post-Thesis Discoveries

- Summary
Harvard Plate Stacks

Half a million photographic plates from 1885-1992

Including 83 plate series (each typically represents a single telescope) from 22 observatories (MA, CA, South Africa, New Zealand, Peru…)

Bring the plates back to Harvard was not an easy job….

One shipping story that stands out is that of the freighter SS Robin Goodfellow. On July 25, 1944, while carrying a shipment of plates from South Africa, it was torpedoed and sunk by the German submarine U-862 in the South Atlantic. Ironically, the U-862 was transporting valuable cargo to the Japanese, including a shipment of optical glass. But despite these losses, the surviving collection at Harvard is still a quarter of the world’s entire inventory of approximately 2 million plates.

-- Stephen Lieber, Sky & Telescope, Mar 2010
Plate b26816, LMC. Dec 18, 1900, Arequipa, Peru. Used by Henrietta Leavitt on Cepheid stars.

Traditional way

DASCH scanner

Simcoe et al. 2006
DASCH (Digital Access to a Sky Century@Harvard)

PI: Grindlay

Digitize and Measure the Harvard Plates to open the ∼100yr TD Window

- ~500,000 photographic plates between 1880s-1980s covering the whole sky (Grindlay et al. 2009).
- ~500-1000 measurements for each object with B<14 (up to 18 mag in some regions)
- Astrometry: 0.8-3 arcsec
  Photometry: 0.1-0.13 mag (Laycock et al. 2010; Tang et al. 2012c).

- Two advantages of DASCH:
  ✓ Long-term variables
  ✓ Rare bright variables

~22,800 plates scanned (4.5%)
2.3x10⁹ magnitude measurements
(If 1 measurement/sec => 73 years)
DASCH Pipeline

- Lightcurves
- Variable Search

Plates

Clean

Scan

WCS solution

Flag blends, plate defects, pickering wedge, multiple exposures

Photometric calibration

Meta-Data

Logbooks

SKY2000

Tycho-2

Astrometry.net

SCAMP

GSC2.3

KIC

APASS
Outline

- What I do: Introduction to DASCH

- How I do it: Photometry and Defect Filtering
  \((Tang \ et \ al. \ 2012c; \ Laycock, \ Tang, \ et \ al. \ 2010)\)

- What I get - Scientific Results:
  - The Kepler Field
    - Planet Host Stars \((Tang \ et \ al. \ 2012b)\)
    - Variable Search and Catalog \((Tang \ et \ al. \ 2012d)\)
  - Individual Long-term Variables
    - Peculiar K Giant Variables \((Tang \ et \ al. \ 2010; \ 2012e)\)
    - KU Cyg: a 5-yr Dust Accretion Event \((Tang \ et \ al. \ 2011)\)
    - A 10-yr Nova-like Outburst \((Tang \ et \ al. \ 2012a)\)
  - Two Other Post-Thesis Discoveries

- Summary
DASCH Photometry

Tang et al. 2012c;

9 annular bins: to correct vignetting
Thousands of stars in each annular bin
Color-term fitting

To derive the color-responses of the plates, by minimizing rms in the calibration curve

Gaussian fits:
- 168 rh(rb) peak=0.0727,0.272 σ=0.11,0.075
- 89 i peak=0.202, σ=0.088
- 72 bm peak=0.214, σ=0.078
- 46 mc(a,b) peak=0.0841, σ=0.083
- 7 rb peak=0.173, σ=0.1
- 5 dnfr peak=-0.972, σ=0.078

Error weighted centroid:
- rh 0.23
- i 0.195
- bm 0.207
- mc(a,b) 0.0997
- rb 0.162
- dnfr -0.975
Local calibration using neighbors with similar magnitudes

To correct the inhomogeneity of plates, we divide each plate into 400 local bins

Photometry accuracy:
0.1-0.13 mag

Number of outliers per lc: reduced by one order of magnitude

Tang et al. 2012c
Life is not easy…

A defect image

blended

blended

Marks
To find a real variable is like looking for a needle in a haystack....
Have to get rid of dubious signals
Use SExtractor parameters to filter out the defects

Tang et al. 2012c

80% defects are filtered out
Use SExtractor parameters to filter out the defects

Tang et al. 2012c

80% defects are filtered out
Outline

- What I do: Introduction to DASCH
- How I do it: Photometry and Defect Filtering  
  (Tang et al. 2012c; Laycock, Tang, et al. 2010)
- What I get - Scientific Results:
  - The Kepler Field
    - Planet Host Stars (Tang et al. 2012b)
    - Variable Search and Catalog (Tang et al. 2012d)
  - Individual Long-term Variables
    - Peculiar K Giant Variables (Tang et al. 2010; 2012e)
    - KU Cyg: a 5-yr Dust Accretion Event (Tang et al. 2011)
    - A 10-yr Nova-like Outburst (Tang et al. 2012a)
  - Two Other Post-Thesis Discoveries
- Summary
DASCH Coverage in the Kepler Field
(relatively limited deep coverage compared to other fields)
Kepler planet-candidate host stars


Example light curves:

No variation detected for bright ones with good DASCH coverage.

Good news for the habitability of the plants.
Variations on different timescales are probing different physical processes. Extrapolate does not work, and we cannot predict the 10-100 yr variation by looking at short timescale data, even if the data are extremely accurate. The value of DASCH is not only to discovery (new) variables, but what’s more important, is to study the long-term behavior of stars and to explore the reasons which drive the variation.
Variable Search in the Kepler Fields

Compare the light curve statistics locally in each sub-field

Tang et al. 2012d

27977 stars in the Kepler field with ngood>=10

- all DASCH stars
- ASAS variables
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>range_local</td>
<td>difference between the brightest and the faintest points, minus the sum of their errors</td>
</tr>
<tr>
<td>range_local2</td>
<td>similar to range_local, but after removing the brightest and the faintest points.</td>
</tr>
<tr>
<td>lightcurvems1</td>
<td>light curve rms after 4 iterations of 5σ clipping</td>
</tr>
<tr>
<td>lightcurvems2</td>
<td>rms of light curve residuals after de-trending:</td>
</tr>
<tr>
<td>lightcurvems3</td>
<td>de-trended using smooth(x,y,0.4, ‘lowess’)</td>
</tr>
<tr>
<td>lightcurvems4</td>
<td>de-trended using smooth(y,0.8, ‘lowess’)</td>
</tr>
<tr>
<td>lightcurvems5</td>
<td>de-trended using smooth(y,10, ‘golay’))</td>
</tr>
<tr>
<td>lightcurvems6</td>
<td>de-trended using smooth(y,15, ‘loess’)</td>
</tr>
<tr>
<td>Number of outburst and dip points:</td>
<td></td>
</tr>
<tr>
<td>nburst</td>
<td>number of points ≥ 0.8 mag brighter than the median value</td>
</tr>
<tr>
<td>nburst2</td>
<td>number of points ≥ 0.5 mag brighter than the median value</td>
</tr>
<tr>
<td>nburst3</td>
<td>number of points ≥ 0.4 mag brighter than the median value</td>
</tr>
<tr>
<td>nburst4</td>
<td>number of points ≥ 3σ brighter than the median value, where σ is the median value of photometry uncertainty in the light curve</td>
</tr>
<tr>
<td>ndip</td>
<td>number of points ≥ 0.8 mag fainter than the median value</td>
</tr>
<tr>
<td>ndip2</td>
<td>number of points ≥ 0.5 mag fainter than the median value</td>
</tr>
<tr>
<td>ndip3</td>
<td>number of points ≥ 0.4 mag fainter than the median value</td>
</tr>
<tr>
<td>ndip4</td>
<td>number of points ≥ 3σ fainter than the median value</td>
</tr>
<tr>
<td>ndev2</td>
<td>number of points ≥ 2σ brighter or fainter than the median value</td>
</tr>
<tr>
<td>ndev3</td>
<td>number of points ≥ 3σ brighter or fainter than the median value</td>
</tr>
<tr>
<td>Adjacent points in ‘burst’ or ‘dip’:</td>
<td></td>
</tr>
<tr>
<td>adjacentburstdip</td>
<td>a measure of the number of adjacent nburst3/4 and ndip3/4 points</td>
</tr>
<tr>
<td>adjacentburstdip2</td>
<td>a measure of the number of &gt; 5 adjacent nburst3/4 and ndip0/4 points</td>
</tr>
<tr>
<td>adjacentburstdip3</td>
<td>a measure of the number of &gt; 7 adjacent nburst3/4 and ndip8/4 points</td>
</tr>
<tr>
<td>Parameters used to remove dubious variables:</td>
<td></td>
</tr>
<tr>
<td>magvrsacorr</td>
<td>correlation coefficient between light curve magnitude and ra</td>
</tr>
<tr>
<td>magvdeccorr</td>
<td>correlation coefficient between light curve magnitude and dec</td>
</tr>
<tr>
<td>magvlimtingcorr</td>
<td>correlation coefficient between light curve magnitude and plate limiting mag</td>
</tr>
<tr>
<td>Malmquist_factor</td>
<td>clipped median DASCH magnitude of 20 deepest plates</td>
</tr>
<tr>
<td>Malmquist_factorB</td>
<td>clipped median DASCH magnitude of 20 shallower plates using ‘good’ points</td>
</tr>
<tr>
<td>Malmquist_factorC</td>
<td>similar to Malmquist_factor but also includes defects, low altitude, uncertain date and second quality plates</td>
</tr>
</tbody>
</table>
Example 2: a long-term variable

HATnet light curve
Hartman et al. 2004

ASAS light curve
Pigulski et al. 2009

CCD 13: 6σ outliers of lcrms1-to-lcrms5

K5630212, 19:39:10 +40:52:15, CCD13, g=11.3, g-r=0.96, rms=0.23, ASAS ΔV=0.25

K5630997, g=10.89, g-r=0.88, rms=0.17

A long-term variable
1mag dimming over 50yr
Ref star

QPER

LPV

1 month
17 months
Phased, P=30.33
Example 3: adjacent dip points

Example 4: multiple outburst points

Very few good points due to severe crowding

More on it later…
Results: 92 Variable Candidates in the Kepler FOV; 50 of them are ASAS variables

ASAS saturation limit: $V \sim 8.5$ mag (Pojmanski 2002)
All (28/28) rms>0.3 mag, and 92% (34/37) rms>0.25 mag

ASAS variables are found to be variables in DASCH
DASCH light curve examples

**ASAS Mira**

K10003658, 19:13:15.6 +46:58:56, CCD10, g=12.2, g−r=2, rms=1.1, ASAS ∆V=4.5

**Ref star**

K9944140, g=11.84, g−r=0.99, rms=0.19

**ASAS RR Lyr**

K11125706, 19:05:58.8 +48:44:42, CCD9, g=11.9, g−r=0.51, rms=0.26, ASAS ∆V=0.55

**Ref star**

K1112579104, g=11.64, g−r=0.64, rms=0.14

**ASAS EB**

K2708156, 19:21:8.9 +37:56:11, CCD8, g=10.7, g−r=0.11, rms=0.2, ASAS ∆V=0.23

**Ref star**

K2569639, g=10.61, g−r=−0.05, rms=0.1

**An EB not in ASAS cat.**

K9207508, 19:6:22.8 +45:41:54, CCD, g=13.9, g−r=0.27, rms=0.2

**Ref star**

K9207291, g=13.64, g−r=0.3, rms=0.15
The most interesting ones are the ones that do not fit into common categories.

Probably a late-type or post AGB star, with a spectacular 60-yr dust ejection event. Very bright IR source, 0.5-2Jy at 10-50micron (IRAS).

ASAS lc
Phased, P=128.8

FAST spectrum:
a G supergiant

K4645245, g=11.38, g-r=0.34, rms=0.11  Ref star 1

K4737302, g=11.73, g-r=0.24, rms=0.12  Ref star 2
Outline

- What I do: Introduction to DASCH
- How I do it: Photometry and Defect Filtering
  
  (Tang et al. 2012c; Laycock, Tang, et al. 2010)
- What I get - Scientific Results:
  - The Kepler Field
    - Planet Host Stars (Tang et al. 2012b)
    - Variable Search and Catalog (Tang et al. 2012d)
  - Individual Long-term Variables
    - Peculiar K Giant Variables (Tang et al. 2010; 2012e)
    - KU Cyg: a 5-yr Dust Accretion Event (Tang et al. 2011)
    - A 10-yr Nova-like Outburst (Tang et al. 2012a)
  - Two Other Post-Thesis Discoveries
- Summary
Discovery of new type of variable stars: 3 unusual long-term K giant variables; **ALL K2III**

An unknown phase of evolution with dust production?

*Tang et al. 2010, ApJL, 710, L77*
New K giants variables in the Kepler field

Tang et al. 2012c

DASCH light curves

Kepler light curves

1. Strong star spots modulation
2. Strong Ca K&H
3. In binary

Probably a mix of two subgroups:
1. extreme RS CVn binaries with strong magnetic activities induced by binary interaction; variations may be related to ultra strong star spots activity.
2. Single stars; variations may be caused by novel dust formation processes during a certain evolutionary stage.
K giants in Binaries: Extreme RS CVns
Single K giant Stars: unknown dust processes?
Outline

- What I do: Introduction to DASCH
- How I do it: Photometry and Defect Filtering
  (Tang et al. 2012c; Laycock, Tang, et al. 2010)
- What I get - Scientific Results:
  - The Kepler Field
    - Planet Host Stars (Tang et al. 2012b)
    - Variable Search and Catalog (Tang et al. 2012d)
  - Individual Long-term Variables
    - Peculiar K Giant Variables (Tang et al. 2010; 2012e)
    - KU Cyg: a 5-yr Dust Accretion Event (Tang et al. 2011)
    - A 10-yr Nova-like Outburst (Tang et al. 2012a)
  - Two Other Post-Thesis Discoveries
- Summary
KU Cyg: 5-yr dust accretion event


Algol-type eclipsing binary
3.85 $M_{\odot}$ F star + 0.48 $M_{\odot}$ K5III
(Smak & Plavec 1997)

Slow Fading: accretion timescale
Increased mass transfer =>
increased disk mass =>
larger optical depth (dust extinction and neutral hydrogen scattering) => fading

Fast brightening:
Dust evaporates when moves closer to the F star => brightening

Fluctuations:
Dust condensation
Accretion energy release on the boundary layer
What I do: Introduction to DASCH

How I do it: Photometry and Defect Filtering
(\cite{Tang et al. 2012c; Laycock, Tang, et al. 2010})

What I get - Scientific Results:

- The Kepler Field
  - Planet Host Stars (\cite{Tang et al. 2012b})
  - Variable Search and Catalog (\cite{Tang et al. 2012d})

- Individual Long-term Variables
  - Peculiar K Giant Variables (\cite{Tang et al. 2010; 2012e})
  - KU Cyg: a 5-yr Dust Accretion Event (\cite{Tang et al. 2011})
  - A 10-yr Nova-like Outburst (\cite{Tang et al. 2012a})

- Two Other Post-Thesis Discoveries

Summary
A peculiar 10-yr outburst

(a) J0757 light curve

Red: pure giant
Blue: giant + disk + hot spot

(b) TRES RV

(c) SED

NUV excess

DASCH J0757, list of properties:

- Spectral type: M0III
- Orbital Period: 119.18d ± 0.07
- Eccentricity: 0.025 ± 0.01
- \(M_{\text{giant}}\): 1-1.3 \(M_{\odot}\)
- \(M_{\text{WD}}\): ~0.6 \(M_{\odot}\)
- Distance: ~1 kpc
- \(L_{\text{giant}}\): 250 \(L_{\odot}\)
- \(L_{\text{hot, quiescence}}\)
- \(M_{\text{dot}}\): \(\sim 2 \times 10^{-9} M_{\odot}/yr\)
- \(M_{\text{B quiescence}}\): ~2
- \(M_{\text{B outburst}}\): ~1
- RL lobe filling factor: 0.5-0.8

Spectra: normal M0 giant, no emission line

---

**Spectra**

From atmosphere fitting, radial velocity & ellipsoidal variation

**Intensity**

- \(\text{Na D}\)
- \(\text{H\alpha}\)
- \(\text{Ca I}\)
- \(\text{Mg I}\)
- \(\text{Mg II}\)

**Wavelength (Angstrom)**

- ~4000
- ~5000
- ~6000
- ~7000
What powered the outburst?

- **Accretion?**
  
  Light curve of J0757 doesn’t look like the accretion powered systems, such as CH Cyg.

- **Nuclear burning?**
  
  The outburst profile of J0757 more closely resembles that of Z And and CI Cyg, which are believed to have gone through nuclear burning powered outbursts (Mikolajewska 2003, et al. 2002). However, Z And and CI Cyg are hot and luminous during quiescence (H-burning in both quiescence & outburst).
Symbiotic novae?

- **Symbiotic novae**: thermonuclear runaways in symbiotic systems; only 9 symbiotic novae known so far (e.g. Kenyon 1986)
- Orbital period >2 yr, slow & quiet wind-accreting; strong emission lines
- Our object: period 119 days, NO emission lines, NO indication of wind or mass loss

<table>
<thead>
<tr>
<th>Star</th>
<th>Distance [kpc]</th>
<th>Period [yr]</th>
<th>$\dot{M}_{gw}$ [-7]</th>
<th>$L_{pl}$ [$L_\odot$]</th>
<th>$R_{max}$ [$R_\odot$]</th>
<th>$\tau_{obs}^{red}$ [yr]</th>
<th>$\tau_{obs}^{blue}$ [yr]</th>
</tr>
</thead>
<tbody>
<tr>
<td>AG Peg</td>
<td>0.7</td>
<td>2.26</td>
<td>1.6</td>
<td>4000</td>
<td>18</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>V1329 Cyg</td>
<td>3.7</td>
<td>2.60</td>
<td>8</td>
<td>18000</td>
<td>26</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>RT Ser</td>
<td>9.4</td>
<td>12.0</td>
<td>25</td>
<td>28000</td>
<td>100</td>
<td>25</td>
<td>40</td>
</tr>
<tr>
<td>PU Vul</td>
<td>3.2</td>
<td>13.4</td>
<td>2.5</td>
<td>25000</td>
<td>50</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>V1016 Cyg</td>
<td>3.9</td>
<td>&gt; 15</td>
<td>130</td>
<td>36000</td>
<td>6</td>
<td>0</td>
<td>&gt; 40</td>
</tr>
<tr>
<td>HM Sge</td>
<td>2.9</td>
<td>&gt; 15</td>
<td>100</td>
<td>28000</td>
<td>20</td>
<td>4</td>
<td>&gt; 20</td>
</tr>
<tr>
<td>RR Tel</td>
<td>2.6</td>
<td>&gt; 15</td>
<td>50</td>
<td>17500</td>
<td>110</td>
<td>7</td>
<td>&gt; 30</td>
</tr>
<tr>
<td>RX Pup</td>
<td>1.8</td>
<td>200?</td>
<td>40</td>
<td>16000</td>
<td>60</td>
<td>4</td>
<td>9</td>
</tr>
</tbody>
</table>
DASCH J0757 is a rare and new class of symbiotic variables:

A missing part of symbiotic family? Its current photometric and spectroscopic properties is not different from a normal red giant binary. It would not be picked out without the capture of its long outburst in 1940s on DASCH plates.

What sets the nuclear outburst timescale?

- Companion may play an important role (Kato & Hachisu 2011): a closer companion helps drive wind loss => shorter timescales
- With $P=119$ days, J0757 is at the valley between symbiotic novae ($P>2$ yr) and novae in close binaries ($P<1$ day)
- Missing class of possible SN Ia progenitors?

Kato & Hachisu (2011): all w/ 0.6 Msun WD
Outline

- What I do: Introduction to DASCH
- How I do it: Photometry and Defect Filtering
  (Tang et al. 2012c; Laycock, Tang, et al. 2010)
- What I get - Scientific Results:
  - The Kepler Field
    - Planet Host Stars (Tang et al. 2012b)
    - Variable Search and Catalog (Tang et al. 2012d)
  - Individual Long-term Variables
    - Peculiar K Giant Variables (Tang et al. 2010; 2012e)
    - KU Cyg: a 5-yr Dust Accretion Event (Tang et al. 2011)
    - A 10-yr Nova-like Outburst (Tang et al. 2012a)
  - Two Other Post-Thesis Discoveries
- Summary
1st example: G8 dwarf binary with variations over decades

TRES spectra: \( \text{Teff} = 5250 \pm 125 \), \( \text{log(g)} = 4.50 \pm 0.25 \), \( \text{Vrot} = 16 \pm 2 \), \( \text{[m/H]} = 0.00 \pm 0.25 \)

ROSAT source, 0.1 cts/s => \( L(0.1-2.4 \text{ keV}) = 4 \times 10^{30} \text{ erg/s} \) (Sun: \( L_x \sim 10^{27}-10^{28} \text{ erg/s} \))

Also a bright GALEX source, 10 times brighter than a normal G8V

14yr cycle?
What is the companion & what powered the outbursts

If the weak CaH&K component from the companion, then mass ratio: 1:0.67
G8V, M1 = 0.8-0.9 Msun, M2 = 0.5-0.6 Msun (most likely a WD)
⇒ a=2-2.1 Rsun; RL1=0.8-0.9 Rsun
⇒ The G dwarf is approximately Roche-lobe filling

14-yr-cycle-like outbursts: As the G dwarf has very strong magnetic activity, it is natural to explain it as ‘solar cycle’ driven accretion on to a companion WD.
2nd example: ε Aurigae-like (8 AU disk)?
Eclipsed by a foreground cloud? 4yr x 10km/s = 8 AU

No significant 2MASS (JHK) & AKARI/IRC(9micron) flux excess

Neighbor: B=13.1
It is entering another eclipse now, 69 yrs after 1943, with ~4-4.5 mag dimming in optical (uBVgriz) and NIR (JHK) bands => solid body blocking, not dust extinction
Nov 11, 2009, before eclipse

Mar 16, 2012, in eclipse

April 21, 2012, in eclipse

Na D

Halpha
What causes the eclipses?

- Two eclipses: 1943-1946; 2012-?
- Coverage from 1890-1950 & 1970-1990: period = 69/N, N>1 is ruled out => P=69yr
- Similar change in optical and NIR bands => solid body blocking, not dust extinction
- What causes 3yr solid body blockings in a P=69yr binary?
  - A companion with a huge disk
- Where is the disk come from?
  - It is a M0III star, not a huge-mass-loss late AGB star; no mechanism to provide mass loss to form a disk for its companion
  - It is a M0III star, not a young object, its companion is unlikely to have a protoplanetary disk
Summary

• Development of DASCH photometry and variable search
  ➢ Photometry achieved 0.1-0.13 mag: photometric calibration, color-term fitting, defect filtering and local calibrations using neighbor stars with similar magnitudes (Tang et al. 2012c; Laycock, Tang, et al. 2010, AJ)
  ➢ Variable Search and Catalog: effectively found most large amplitude variables (RMS>0.25 mag) (Tang et al. 2012d)

• Study long-term variables using DASCH data, archive data & spectroscopic follow-up observations
  ➢ Peculiar K Giant Variables with ~1 mag variations over decades: provide new insights into dust formation processes or extreme magnetic activities on stars (Tang et al. 2010, ApJL; 2012e)
  ➢ A 10-yr Nova-like outburst in a peculiar symbiotic system, may be powered by nuclear burning without significant mass loss and thus the WD could grow. (Tang et al. 2012a, ApJ, in press)

• Ongoing work: hundreds of variables; a few dozen of them do not belong to any common class - stay tuned