The ultimate Wide-Field TDA Survey:

**DASCH**
To explore the $\sim 1 \text{wk} - \sim 100 \text{y}$ timescale
and extreme variability
of stellar and non-stellar objects

Josh Grindlay
(and Sumin Tang & DASCH Team)

Wide Field Surveys lunch, July 21, 2011
Overview of DASCH
(see DASCH website for full descriptions…)

• **Goal:** scan the ~550,000 Harvard glass plates which image full sky 1880-1985 and open the ~10-100y TDA window

• **Scanner and software:** scan ~400 plates/day and derive photometric catalogs in overnight Odyssey processing

• **Status:** NSF (2 grants) and now a *Donor* enable start of production runs by Dec. 2011. Finish ~2014?

*DASCH* scanner: scans two standard 8 x 11 plates or one 14 x 17 plate into 10µm pixels in 95sec (Simcoe et al 2006)
DASCH has scanned ~15000 plates
(Now scanning LMC: ~5000 plates, including ~800 A-plates sensitive to B ~18-19)
Brief summary of recent results

- Development and improvement of photometry pipeline and variable search algorithms
- Spectroscopic follow up of DASCH variables using FLWO 1.5m, MMT and Magellan telescopes
- Discovery of a new type of K giant long-term variables
- Discovery of “dust accretion” variable(s)
- Discovery of a new symbiotic nova (only 9 other known)
- Hundreds of other new variable candidates months -decades
**Photometry Calibration**

SExtractor “mag-iso” vs. GSC2.3 mag: Calibration done in 9 annular bins then “corrected” in 50 x 50 “local bins”

Current overall photom. RMS $\sim$0.12-0.15mag. New PSFEx and modified binning and better all-Sky photom. Catalogs (APASS): RMS $\leq 0.1$mag
Discover a nova in Baade's window plates
(only preliminary analysis of limited scans...)

8-magnitude outburst in 1914 (brightened by a factor of 1600)

Before the burst
Early stage of the burst
Late stage of the burst
KU Cyg

*Popper 1964, 1965; Olson 1988; Zola 1992; Olson et al. 1995; Smak & Plavec 1997*

- Algol-type eclipsing binary
  - 3.85 \(M_\odot\) F star + 0.48 \(M_\odot\) K5III
  - Large, thick and dusty accretion disk around the F star: \(\sim 10^{-8}-10^{-5}\) \(M_\odot\)
- Peak accretion rate: \(\sim 10^{-6}\) \(M_\odot\)/yr
- Accretion timescale: a few years
- P=38.439484 days, \(i=86-86.5\) deg
- Extinction of the F star due to the disk: \(\sim 1.3\) mag (*Smak & Plavec 1997*)

- Roche lobe filling
  - 3.85 \(M_\odot\) F star with accretion disk

- Broad secondary eclipse: K5III behind the huge disk
- Broad wing in primary eclipse: disk behind the K5III

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*Smak & Plavec 1997*
DASCH light curve of KU Cyg

5-yr dip around 1900

~0.1 mag variation on year timescales

Folded light curve

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Olson 1988
Zoom in on the 5-yr dip around 1900

Unusual shape of the dip

RY SGR: faster fading, slower recovery
b/c it usually takes shorter time to produce dust, and longer time for the dust to get dispersed
Increased disk extinction of the F star arising from increased m-dot and thus higher disk mass

Slow Fading:
• Increased disk mass => larger optical depth (dust extinction and neutral hydrogen scattering) => star looks fainter
• Timescale: a few years (accretion timescale)
• How much more mass do we need?
  ~ less than double the original disk mass is enough. Given the 1.3 mag extinction in V (0.7 mag blocking + 0.6 mag absorption by disk atmosphere) by the disk in normal state (Smack & Plavec 1997)

Fast brightening and fluctuations:
• Dust evaporates when moves closer to the F star -> brightening
• Some evaporated dust is transported outwards, cools down to condensate (~1500 K), more extinction -> fading
• Energy release on the BL when accreted on the F star -> brightening
Or higher dust to gas ratio?

- Dust ejection from the K5III star in KU Cyg? Similar to dips discovered from K giants probably due to dust ejection (Tang et al. 2010)

- vs. rapid rise in KU Cyg: dust moves in through the disk and is evaporated as it approaches the hot star
An interesting variable with 10 yr flare: a M1III + WD(?) symbiotic nova?

N2211021132, Stdmag = 12.34, B−R = 2.9, rms = 0.34

ASAS

K = 14 km/s, v_rot = 10 km/s
e = 0.02 ± 0.01

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Only 9 other Symbiotic Novae known
Kenyon 1986; Iben 2003; Mikolajewska 2010

- *Thermonuclear novae* in symbiotic systems: an evolved red giant + a hot companion star (mostly WD) accreting from the giant
- *Orbital period >2 yr*, slow & quiet *wind-accreting*; **strong emission lines**. Mostly discovered in outburst and thus pre-outburst observations not available.
- Our star: period 119 days, NO emission lines – no strong wind: Roche lobe filling?

Table 1.  **Observed properties of symbiotic novae**

<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>$R_{\text{max}}$ [$R_\odot$]</th>
<th>$T_{\text{red}}$ [yr]</th>
<th>$T_{\text{blue}}$ [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>18 000</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>28 000</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>25 000</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>36 000</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>28 000</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>17 500</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>16 000</td>
<td>60</td>
<td>4</td>
<td>9</td>
</tr>
</tbody>
</table>
Symbiotics WD mass ~1/Period: is this P ~1/3y symbiotic a massive WD and thus SNIa progenitor?

\[ M_2 \sin i = 0.3172 \left( M_1 + M_2 \right)^{2/3} M_\odot \]

If \( i=46.2 \) deg & \( M_{\text{giant}}=2.24 \, M_{\odot} \), \( M_{\text{WD}}=0.98 \, M_{\odot} \)

If \( i=48.9 \) deg & \( M_{\text{giant}}=1.92 \, M_{\odot} \), \( M_{\text{WD}}=0.84 \, M_{\odot} \)

Mikolajewska 2010

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Question: HOW to power the outburst (no wind) and is the M giant Roche lobe filling?

Ellipsoidal Variation? No reasonable solution
(J. Oroscz, private communication)

Not Roche lobe filling?
How to power the outburst in 1940s?
There is no strong wind: no emission line, very symmetric absorption lines

Atmosphere fitting of M stars are extremely hard due to the molecular bands (TiO). Bob Kurucz is trying, but not sure whether he could help constrain the size of the star.

If the M giant rotates synchronous to the orbital period, then $R \sim 24 R_\odot$, far from filling its Roche lobe ($\sim 60-70 R_\odot$)

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This DASCH variable is an *unusual symbiotic nova*

Iben 2003; Townsley et al. 2005

<table>
<thead>
<tr>
<th>Symbiotic Nova</th>
<th>Classic Nova</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outburst amplitude: 1-3 mag</strong></td>
<td>8-10 mag</td>
</tr>
<tr>
<td>Wind accreting</td>
<td>Roche lobe filling</td>
</tr>
<tr>
<td>Accretion rate $\sim 10^{-8}$ solar mass/yr</td>
<td>$10^{-9} - 10^{-11}$ in quiescence</td>
</tr>
<tr>
<td>Slow and quiet burning, without massive optically thick wind, the white dwarf can retain most of the accreted mass</td>
<td>Higher burning rate. Matter expands far and lost soon after the eruption</td>
</tr>
<tr>
<td><strong>Outburst timescale:</strong></td>
<td>weeks</td>
</tr>
<tr>
<td><em>years to decades</em></td>
<td></td>
</tr>
<tr>
<td><strong>Orbital period:</strong></td>
<td>A few hours</td>
</tr>
<tr>
<td>a few years</td>
<td></td>
</tr>
</tbody>
</table>

A missing part of symbiotic family: Its current photometric and spectroscopic profile is not different from a normal red giant binary. It would not be picked out without the capture of its long outburst in 1940s. Must be more (YES…!)
A new way of hunting for Be X-ray High Mass X-ray binaries? (Be + NS)

~100 systems known so far, all from X-ray detections

Figure 1: Upper panel: DASCH light curve of B1e star HD 228256. Lower panel: AAVSO V band light curve of Be X-ray binary X Per binned in 25 day increments, with time of its X-ray burst in 2003 marked by red dashed line (Grundstrom et al. 2007).
More on Be X-ray binaries

• In 42 out of 64 known BeHMXBs within the Milky Way, the compact object emitted X-ray pulsations confirming its identity as a neutron star; the remaining 22 unknown.

• No Be+black hole binaries yet identified and only one system, gamma Cas, is a possible Be+WD system, despite predictions from population synthesis models that 70% of BeXRBs should harbor a WD companion (Raguzova 2001).

• Most Be X-ray binaries were first discovered with X-ray telescopes during outbursts, increasing the susceptibility of the known sample to undetected selection effects.
3 more Be X-ray binary candidates
Further observation needed: X-ray (Swift/XRT), pending;
binary orbit (TRES): ongoing
They are Be systems…(FAST spectra)
Why are DASCH Be variables interesting?

- The luminosity of a typical Be star is subject to variability as a result of mass ejection on a scale < 0.3 mag (Percy et al. 1988; Hubert et al. 2000). Larger variations (~1 mag) seen from transient accretion onto a NS binary companion.

- BeHMXBs might be discovered by optical lightcurves, and may reveal long-dormant BeHMXBs.

- If confirmed (orbital velocity + X-ray), DASCH lightcurves would constrain the galactic BeHMXB population.

- May help uncover Be+BH systems, which must be present but not yet discovered.
DASCH variability “re-discovery” of an AGN

Turned out to be a z=0.382 AGN; probably mislabeled by Craig & Fruscione 1997

Redshifted Hβ

Redshifted OIII

Atmos. abs. bands

EUVE J0502-624

EUVE

ROSAT

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New Long-term K giant variables in the Kepler field: Now studying with Kepler GO data… (RSCVn’s?)
Example Kepler light curves

Short flares!
Summary

• *DASCH* is churning forward. Enormous potential for discovery and opening the ~100y TDA window.

• *New* graduate student being sought to succeed Sumin Tang who finishes in May 2012!

• *Volunteers* are key part of DASCH (scanning ~400 plates today for first time!); more are needed.