Nova Outflow Geometry

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Outline

• Observations
  – Spatially-unresolved & resolved spectra
  – Imaging (optical/IR & radio)

• Theory
  – Environment vs intrinsic
  – TNR, common envelope, phases of mass-loss, jets
Polar caps & equatorial rings I. HR Del

Hutchings (1972)
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Hutchings (1972)

Solf (1983)
Polar caps & equatorial rings II

HR Del

[OIII]  Hα  [NII]

Polar caps & equatorial rings II

HR Del

[OIII]  Hα  [NII]

Gill & O’Brien (1999)

V705 Cas

Polar caps & equatorial rings III

Polar caps & equatorial rings III


Polar caps & equatorial rings III

FH Ser, RR Pic, V533 Her, DQ Her

WFPC2 bandpass

[NII], Hα, [NII]

[NII]-enhanced equatorial ring


Polar caps & equatorial rings III


Streamers in old nova shells I. DQ Her
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Blueward  Rest wavelength Hα  Redward

Streamers in old nova shells I. DQ Her

Streamers in old nova shells I. DQ Her

Blueward  Rest wavelength Hα  Redward


Also see radial filaments in GK Per

Vaytet et al (2007)
Note there is evidence for collimated accretion disc wind at ~7000 km/s (Selvelli & Friedjung 2003)

Streamers in old nova shells II. HR Del

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Accretion disc shadowing?


Gill (2000)
Shape vs speed class

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Optical imaging of RS Oph

Ribeiro et al (2009)

Model image  
HST image  
Model image (passband corrected)
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Ribeiro et al (2009)

Model image  
HST image  
Model image (passband corrected)

NIR imaging of V445 Pup (He Nova)

Woudt et al (2009)

- Equatorial dusty disc
- Velocity ~ 6,700 km/s
  (blobs ~ 8,500 km/s)
V407 Cyg – flash-ionized CSM?

- Diameter ~ 0.3"
- At 2.7 kpc, ejection speed ~ 60,000 km/s
- But optical lines give $V_{ej} \sim 3200$ km$^{-1}$
- So diameter should be only ~14 mas (if quasi-spherical ejection)
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By Day 25, ejecta diameter (assuming quasi-spherical ejection) should be ~ 0.035” (indicated by scale bar)

Brighter (southern) emission likely to be interaction of ejecta with CSM
Radio imaging of V959 Mon

e-MERLIN imaging: E-W becomes N-S suggests two phases of mass-loss

Healy et al (2016)
Also see Chomiuk et al (2014)
GK Per: A “super nova” remnant

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Optical 1917

Optical 1993

Radio 1997

X-ray 2000

• What drives the asphericity?
  – Is it intrinsic to the thermonuclear runaway – a local TNR?
  – Magnetic field of the white dwarf?
  – Rotation of the white dwarf?
  – Binary interaction (“common envelope”)?
  – Interaction with circumbinary medium (secondary wind, previous mass-loss)?
  – Interaction with interstellar medium?
  – Do the clumps result from RT, KH and thermal instabilities in TNR outburst and/or in cooling shocked shell?
Thermonuclear runaway

- Local TNR e.g. Orio & Shaviv (1993), Glasner et al (2007)
- Casanova et al (2011) in 3D simulations of TNR find that burning front moves around the WD at 100 km/s i.e. half-way round in about a day.
- They also study instabilities & mixing – imprinted in first few minutes and could be linked to clumps seen in images of old nova shells
“Common envelope”

- Expanding ejecta interact with companion – adding energy & angular momentum and helping drive mass-loss in the orbital plane.

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Note: no equatorial ring
Interaction with circumbinary medium

2 & 3-D simulations of V407 Cyg – ejection into RG wind with circumbinary density enhancement
Orlando & Drake (2012)

[also see Pan et al 2015 for V407 Cyg and Walder et al 2008 for RS Oph]
TNR variability & radio light curves

Use 1D TNR output from Hillman et al as input to interacting winds calculation & calculate thermal radio emission (inc free-free absorption)
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Ashworth, Henson, O’Brien
Variable winds & radio light curves

Vary mass-loss rate and velocity & calculate thermal radio emission.

This example is two pulses of mass-loss:
1. 900 km/s wind lasting 3 days ejecting 4e-6 solar masses
2. 100 days later, a 500 km/s wind lasting 3 days ejecting 1.6e-5 solar masses

Obviously an extreme example but can obtain structure in light curves from different types of variability.

Wright, Carter, O’Brien
Multiple ejections?

V723 Cas (very slow nova)

O’Brien, Chochol et al
Multiple ejections?

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[FeVII] disappears, Hell significantly affected
Summary & questions

• Nova mass-loss is not spherical or smooth
• Nova shells are all very clumpy (from TNR instabilities and/or from radiative shock instabilities), presumably helps with dust formation
• Many are elliptical/bipolar with evidence for equatorial rings, and in at least some cases, polar caps/cones
• There is evidence for wind interactions e.g. with old shells at least
• There is evidence for episodic mass-loss
• How does the “common envelope” influence mass-loss?
• Do novae have jets? If so, what collimates them?
• When will someone include magnetic fields?
• Observed diversity arises from the nature of the white dwarf, the binary parameters, nature of companion...and the viewing angle