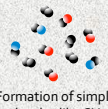
遅い古典新星 V2676 Oph における分子外層の生成

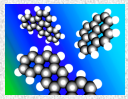
河北秀世 [1]
藤井　貢 [2]
新井　彰 [1]
長島雅佳 [3]
梶川智代 [3]
久保夏紀 [3]

[1]神山天文台・京都産業大学
[2] 藤井-黒崎天文台
[3]京都産業大学・理

Scenario of Dust Formation in Novae

Nova explosion


Formation of simple molecules like CN, CO etc…


Larger molecules like PAHs

Dust formation ("nucleation" around PAHs)

t=0 d | t ~ week – a month?? | t ~ a month? | t ~ 30 – 100 d

(1) Formation of simple molecules in the nova outflow, CN, CO, and etc.
(2) Chemical evolution to form larger-size molecules like PAHs (Poly-cyclic Aromatic Hydrocarbons) in the outflow.
(3) Dust formation by the "nucleation" of ejecta materials around the large molecules as nuclei.

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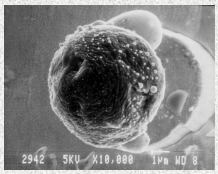
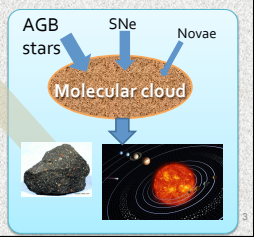
"Presolar" Grains



Secondary electron image of the graphite nova candidate grain KFC1a-551 after SIMS analysis. Image courtesy of S. Amari.
Clayton & Hoyle 1976, Amari et al. 2001; José et al. 2004; José & Hernanz 2007

- Particles surviving the solar system formation and embedded in meteorites.
  → Pristine materials keeping information about pre-solar history.
- Showing isotopic signatures of objects where nucleo-sysnthesis and mass-loss events occurred.
  → Different elemental isotopic ratios from the solar system value (as average of pre-solar material).



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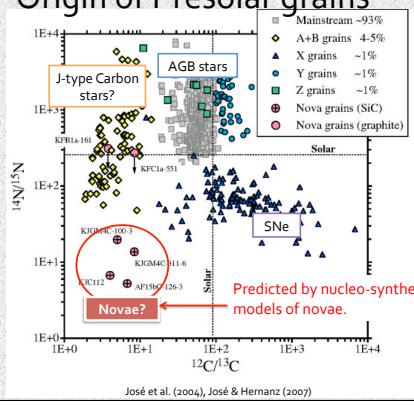
Origin of Presolar grains



José et al. (2004), José & Hernanz (2007)

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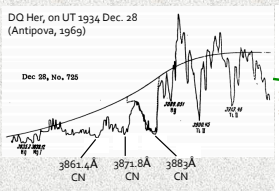
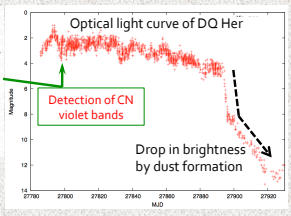
First detection of Molecules in Novae — DQ Her in 1934 —





DQ Her in 1934 : the first nova to be identified as a dust forming nova. The absorption bands of CN were observed just after the brightness maximum (at the first time in novae!).

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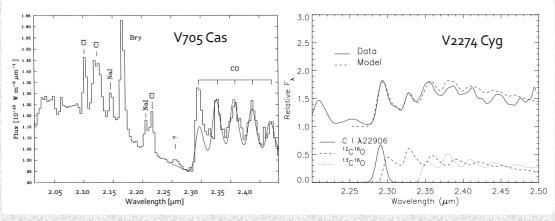
Detection of CO in Novae



Recently, the first overtone vibrational band (Δv=2) of CO was routinely observed in some novae, e.g., V705 Cas (Evans et al. 1996), and V2274 Cyg (Rudy et al. 2003).

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Detected Diatomic Molecules in Novae to Date (until 2013)

Molecule	Nova
CN	DQ Her
CO	FH Ser, NQ Vul, LW Ser, V1668 Cyg, V842 Cen, V705 Cas, V2274 Cyg, V2615 Oph, V496 Sct, V1724 Aql, V2676 Oph

- Only two molecular species (as diatomic molecules)
- CN→1 sample
- CO→11 samples

✓ How rich in chemistry occurred in nova outflow?
✓ Is CN so peculiar product in novae?

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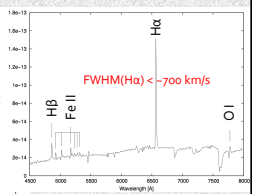
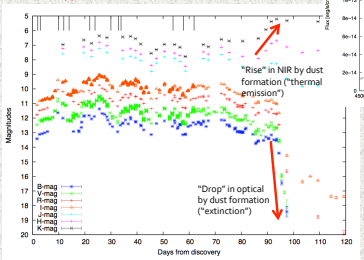
Dust Forming Nova V2676 Oph

Discovered on UT 2012 Mar. 25.8 by H. Nishimura (CBET 3072). Our initial spectroscopic observations (with a low-resolution) revealed narrow emission lines of Hα, Hβ, Fe II, O I with P Cyg profiles (mainly from low-ionized atoms).
→ "Fe II type" nova

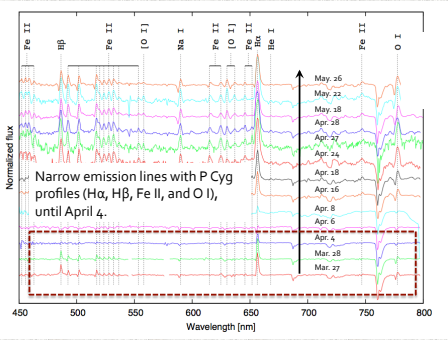




On UT 2012 Mar 27, observed at KAO.
FWHM of Hα emission < ~500 km/s
→ Typical for a "slow" nova, that shows very slow evolutions in both brightness and spectral features and frequently show the dust formation.

Multi-band light curves of V2676 Oph, in optical and near-infrared (taken from AAVSO and SMARTS)

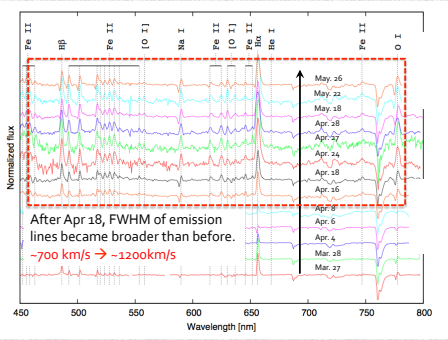
Spectral Evolution in Optical



Narrow emission lines with P Cyg profiles (Hα, Hβ, Fe II, and O I), until April 4.

Normalized spectra (in logarithmic scale) of V2676 Oph from UT 2012 Mar 27 to May 26.

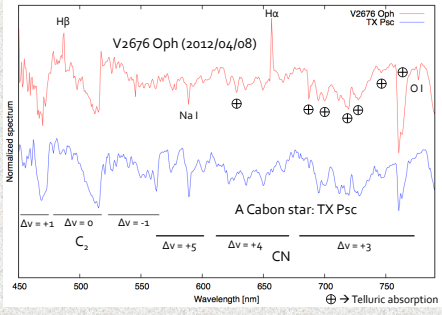
Spectral Evolution in Optical



After Apr 18, FWHM of emission lines became broader than before.
~700 km/s → ~1200km/s

Normalized spectra (in logarithmic scale) of V2676 Oph from UT 2012 Mar 27 to May 26.

The First Detection of both C_2 and CN Molecules in Novae



We detected both C_2 and CN absorption bands on Apr 8. The observed spectrum of V2676 Oph was similar to the spectrum of a typical carbon star (TX Psc).

以上については、以下の論文で今年始めに報告した…。

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THE TRANSIENT MOLECULAR ENVELOPE IN THE OUTFLOW OF THE NOVA V2676 Oph DURING ITS EARLY PHASE

M. Nagashima[1], A. Arai[1,2], T. Kajikawa[1], H. Kawakita[1], E. Kitao[1], T. Arasaki[1], G. Taguchi[1], and Y. Ikeda[1,3]
[1] Kyoto Sangyo University, Koyama Astronomical Observatory, Motoyama, Kamigamo, Kita, Kyoto 603-8555, Japan
[2] Nishi-Harima Astronomical Observatory, Center for Astronomy, University of Hyogo, Sayo-cho, Sayo-gun, Hyogo 679-5313, Japan
[3] Photocoding, 61-112 Iwakura-Kita-Ikedacho, Sakyo-Ku, Kyoto, 606-0004, Japan
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ABSTRACT

Novae are generally considered to be "hot" astronomical objects which show effective temperatures of 10,000 K or higher at their visual maximum. However, theoretical predictions suggest that the outer envelope of the nova outflow can become cool enough to form molecules which would be dissociated at such high temperatures. We detected strong C_2 and CN absorption bands in the optical spectrum of the nova V2676 Oph, a very slow nova with dust formation. This is the first report of the detection of C_2 and the second of CN, in novae during an outburst. Although, based on previous studies, such simple molecules are predicted form in the envelope of the outflow, there are few reports of their detection thus far. The presence of the molecular envelope is considered to be very transient, with a duration of only a few days, in the case of V2676 Oph.

Key words: novae, cataclysmic variables – stars: individual (V2676 Oph) – stars: winds, outflows
Online-only material: color figures

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More Observations Were There?

The 40-cm telescope with a hand-made spectrograph at Fujii-Kurosaki Observatory.
→ Mr. M. Fujii, amateur astronomer, also monitored V2676 Oph!!

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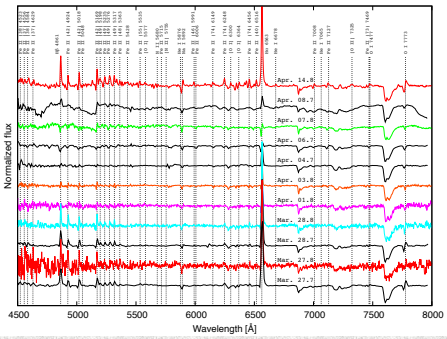
More Observations by Amateur Astronomer (Mr. M. Fujii, Japan)!



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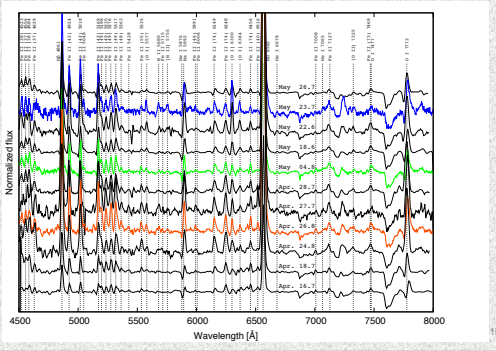
More Observations by Amateur Astronomer (Mr. M. Fujii, Japan)!



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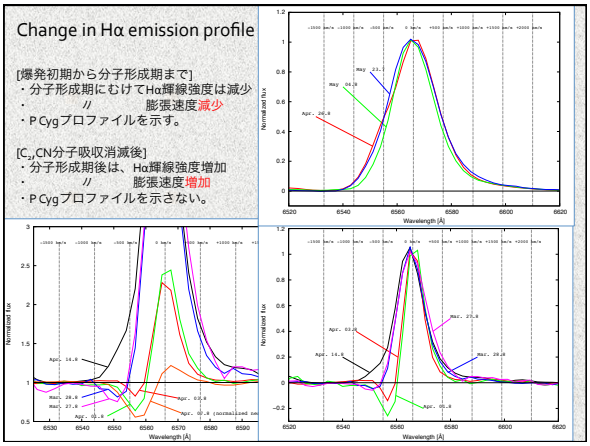
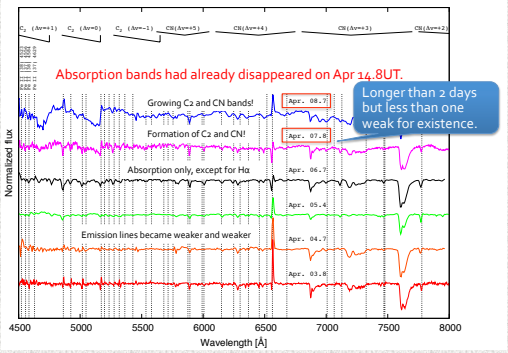
Change in Hα emission profile

[爆発初期から分子形成期まで]
・分子形成期にむけてHα輝線強度は減少
・ 〃 膨張速度減少
・P Cygプロファイルを示す。

[C_2,CN分子吸収消滅後]
・分子形成期後は、Hα輝線強度増加
・ 〃 膨張速度増加
・P Cygプロファイルを示さない。



And one more from "SMARTS"



Day-by-day spectra of V2676 Oph from Apr 3 to Apr 8.

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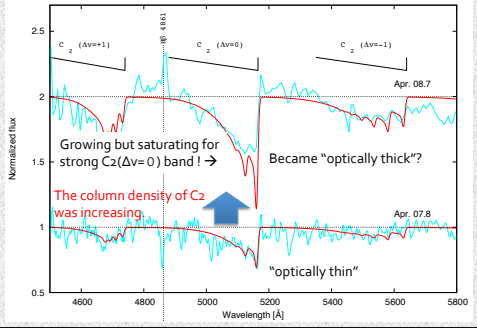
Spectral Evolution of C2 in V2676 Oph from Apr 7.8 to Apr 8.7 UT

Fitting with the model assuming optically thin condition for C2 (T_{ex}=4500K)



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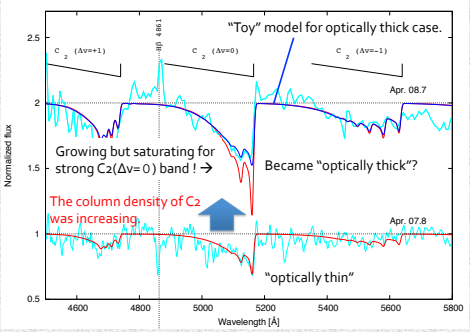
Spectral Evolution of C2 in V2676 Oph from Apr 7.8 to Apr 8.7 UT



Fitting with the model assuming optically thin condition for C2.

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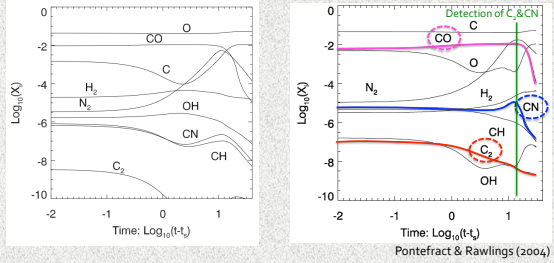
Compared with Molecular Formation Model

In the case of C/O=0.2 (DQ Her-type novae) In the case of C/O=4.8 (carbon-rich type)

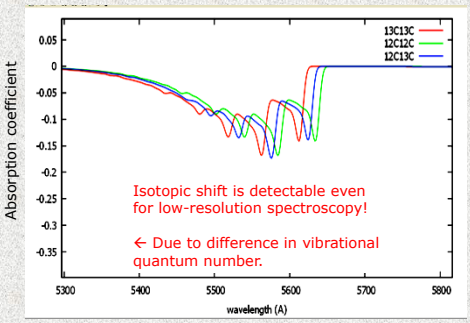


Pontefract & Rawlings (2004)

Our observations may indicate that the envelope was enriched in carbon.

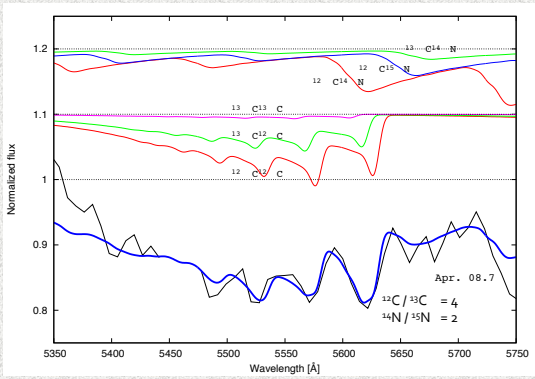
Isotopic shift for C_2

Swan band (Δv=−1) for $^{13}C^{13}C$, $^{12}C^{12}C$ and $^{12}C^{13}C$



Isotopic shift is detectable even for low-resolution spectroscopy!

← Due to difference in vibrational quantum number.



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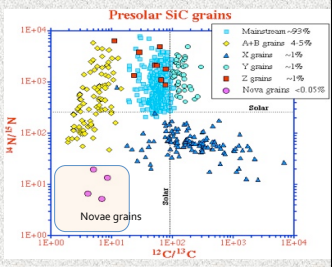
Finally, …

$^{12}C/^{13}C$ = ~4

$^{14}N/^{15}N$ = ~2

We derived both $^{12}C/^{13}C$ and $^{14}N/^{15}N$ ratios successfully. Especially, the nitrogen isotopic ratio was at the first time for novae.

→ Novae might be closely related to the solar system formation.



Nova	$^{12}C/^{13}C$	Molecule	Referenes
NQ Vul	>3	CO	Ferland,Lambert,Netzer (1979)
V842 Cen	2.9±0.9	CO	Wichmann (1990)
V2274 Cyg	1.2±0.3	CO	Rudy (2003)
V705 Cas	>5	CO	Evans (2005)
DQ Her	>1.5	CN	Sneden,Lambert (1975)

To be published in PASJ …
Coming soon!

Formation of C_2 and CN in Nova V2676 Oph around Its Visual Brightness Maximum

Hideyo KAWAKITA
Koyama Astronomical Observatory, Kyoto Sangyo University, Motoyama, Kamigamo, Kita-ku, Kyoto 603-8555, Japan
kawakthd@cc.kyoto-su.ac.jp
Mitsugu FUJII
Fujii-Kurosaki Observatory, 4500 Kurosaki, Tamashima, Kurashiki, Okayama 713-8126
Masayoshi NAGASHIMA
Tomoyo KAJIKAWA
Natsuki KUBO
Kyoto Sangyo University, Motoyama, Kamigamo, Kita-ku, Kyoto 603-8555, Japan
and
Akira ARAI *
Nishi-Harima Astronomical Observatory, Center for Astronomy, University of Hyogo, Sayo, Hyogo 679-5313, Japan

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