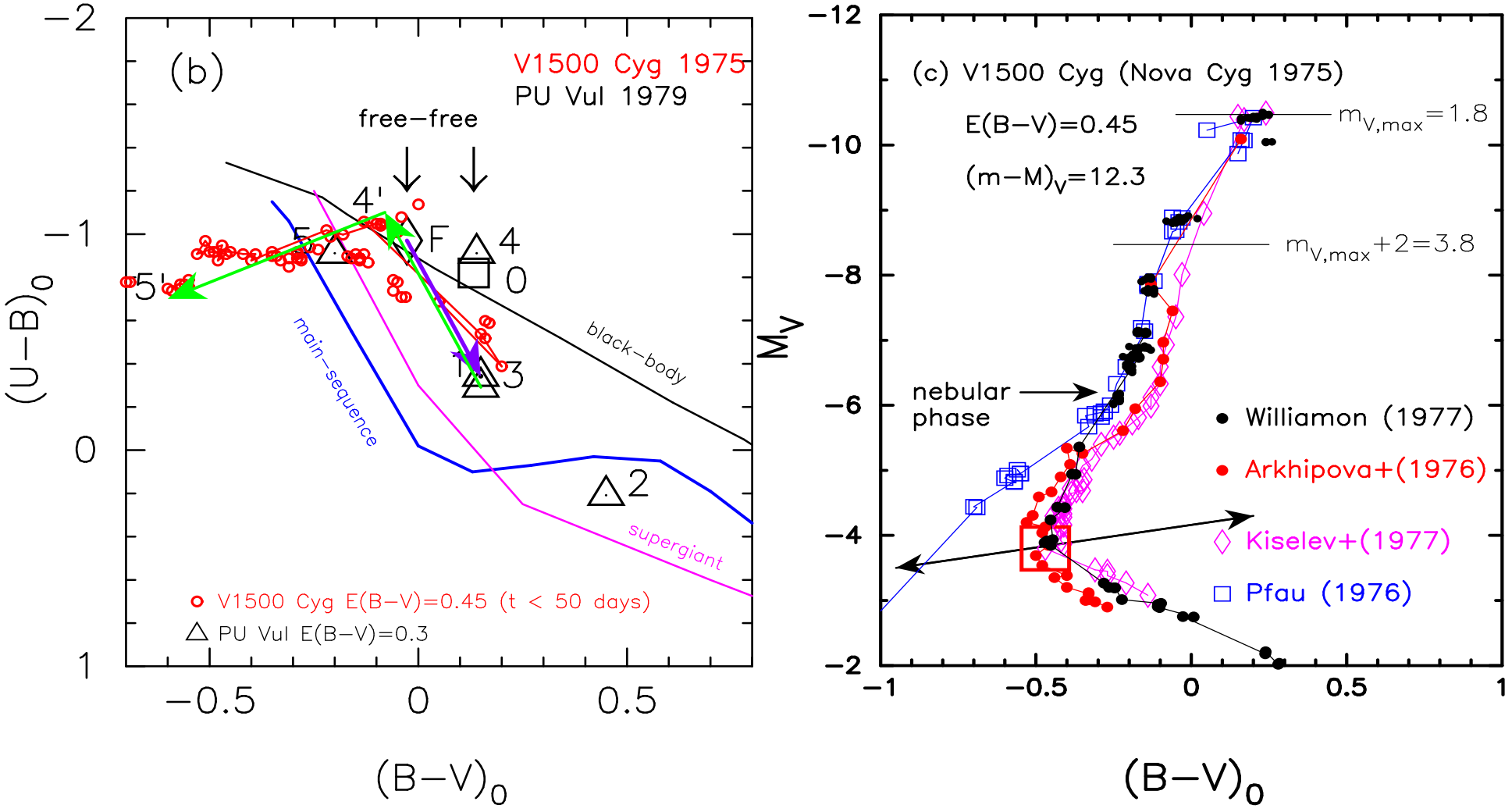
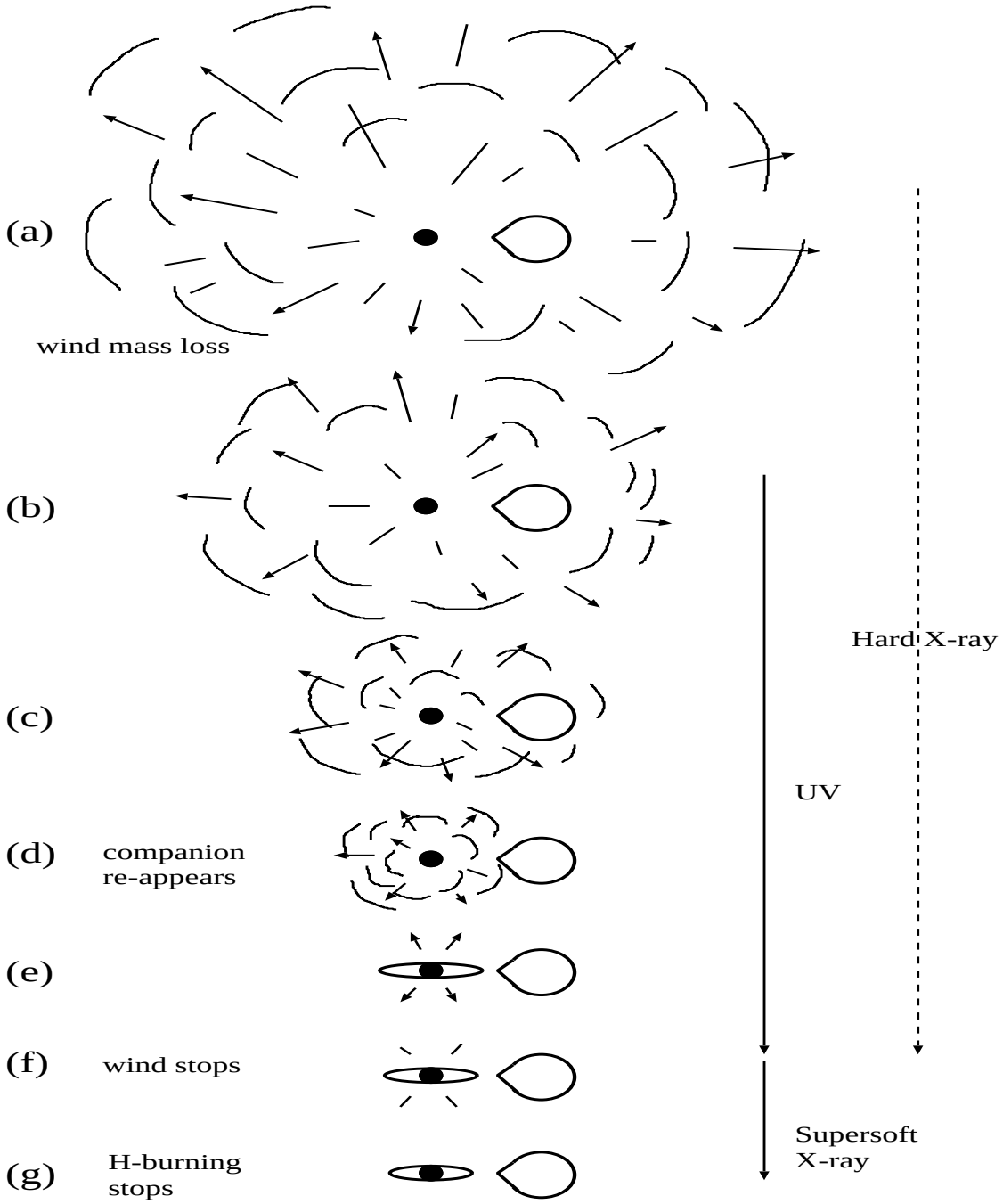
古典新星の普遍的減光則と色等級図

蜂巣 泉 (元東京大学)

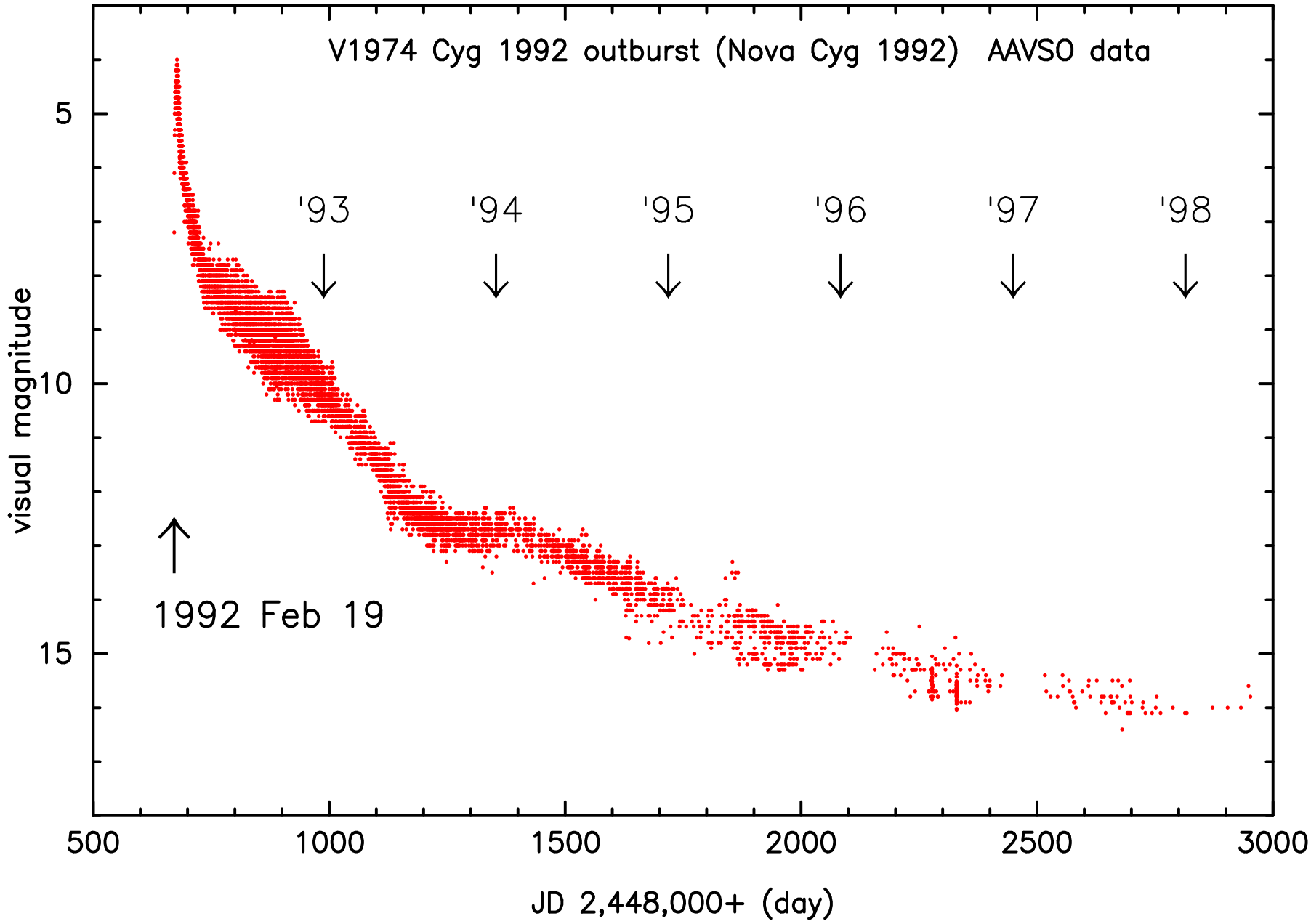
共同研究者： 加藤 万里子 (慶応大学)



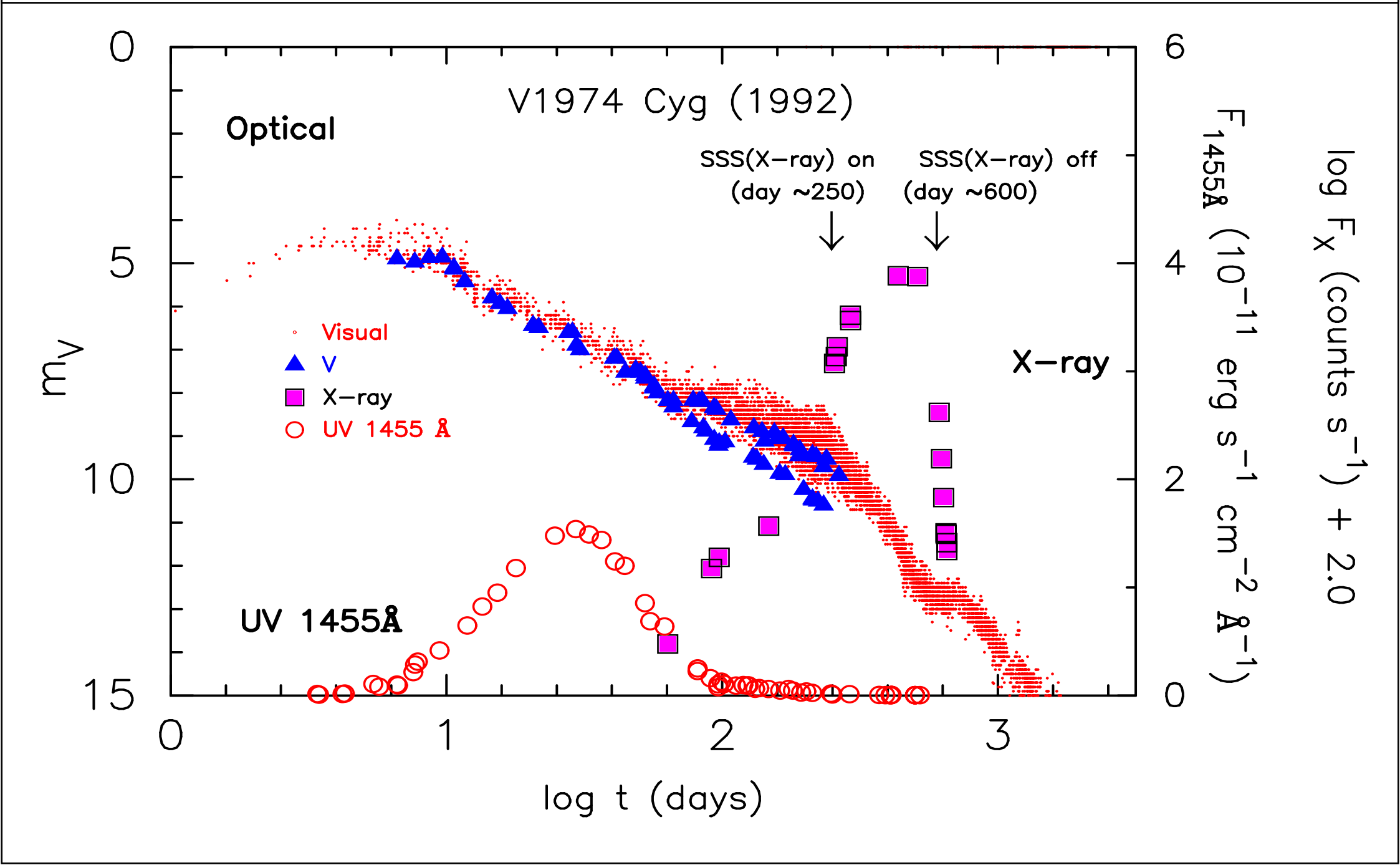
Evolution of Classical Novae



V1974 Cyg の光度曲線

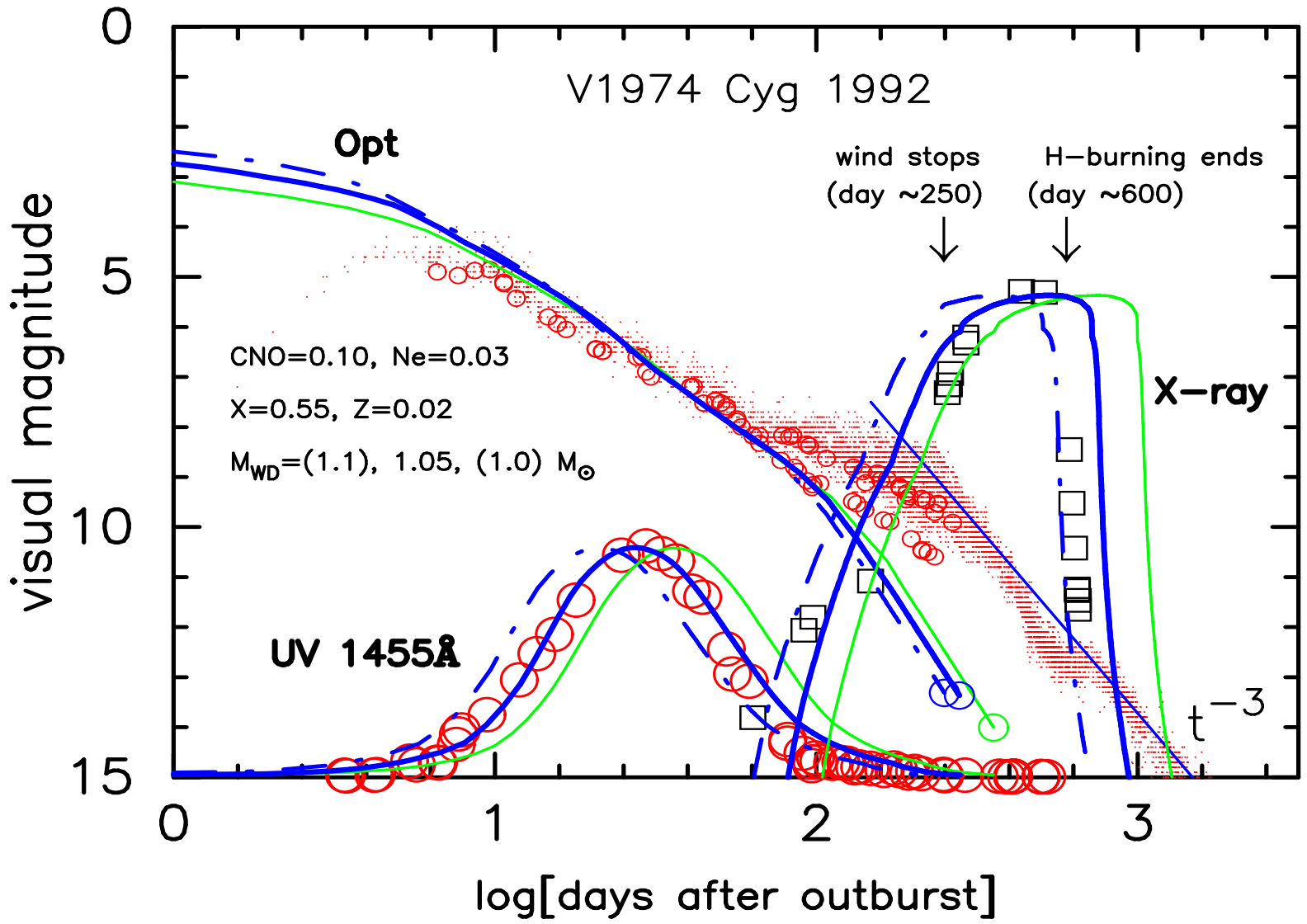


V1974 Cyg の光度曲線 (対数時間)



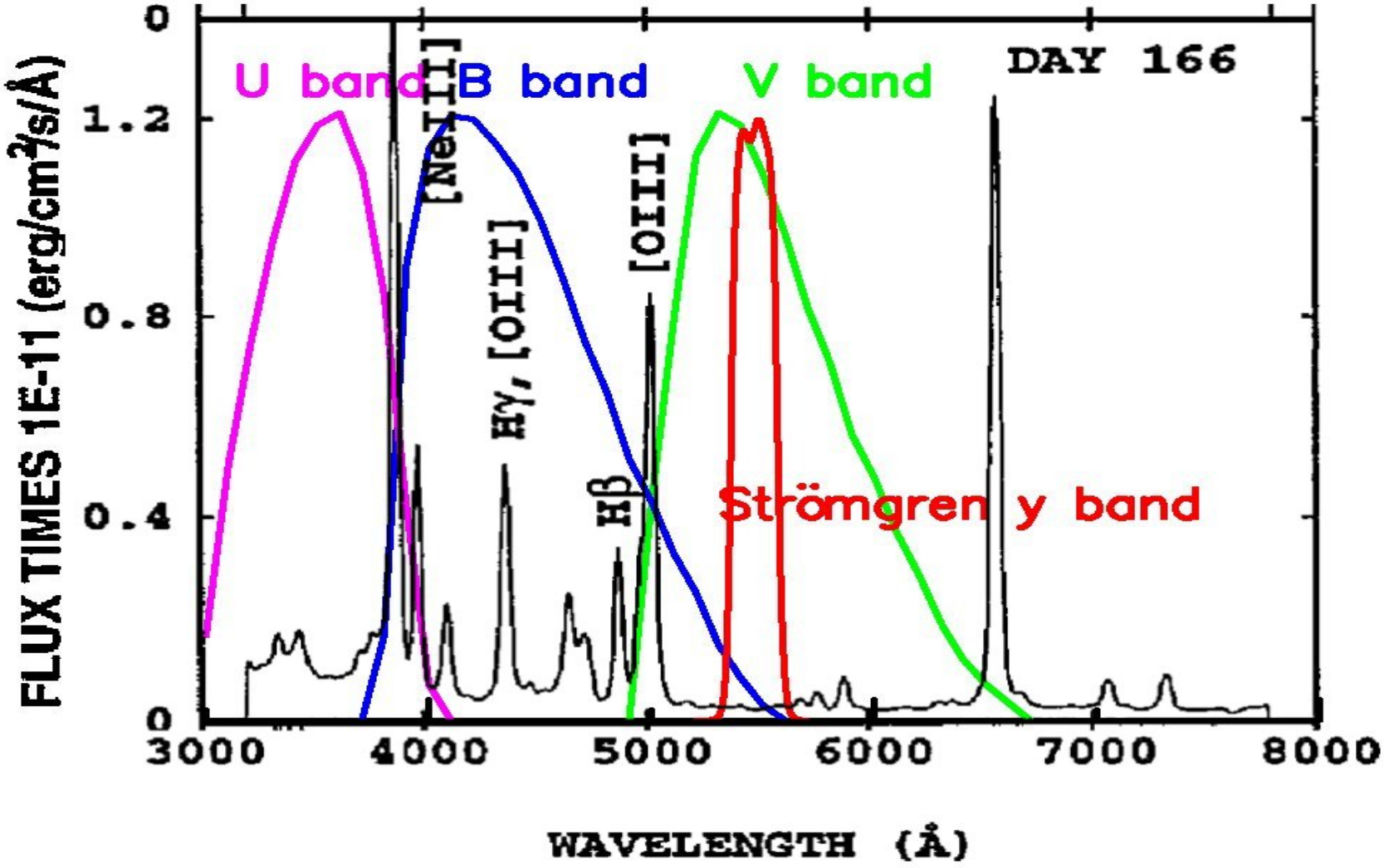
Light Curve Fitting of V1974 Cyg

○ 強い輝線の影響を除けば良く再現できる



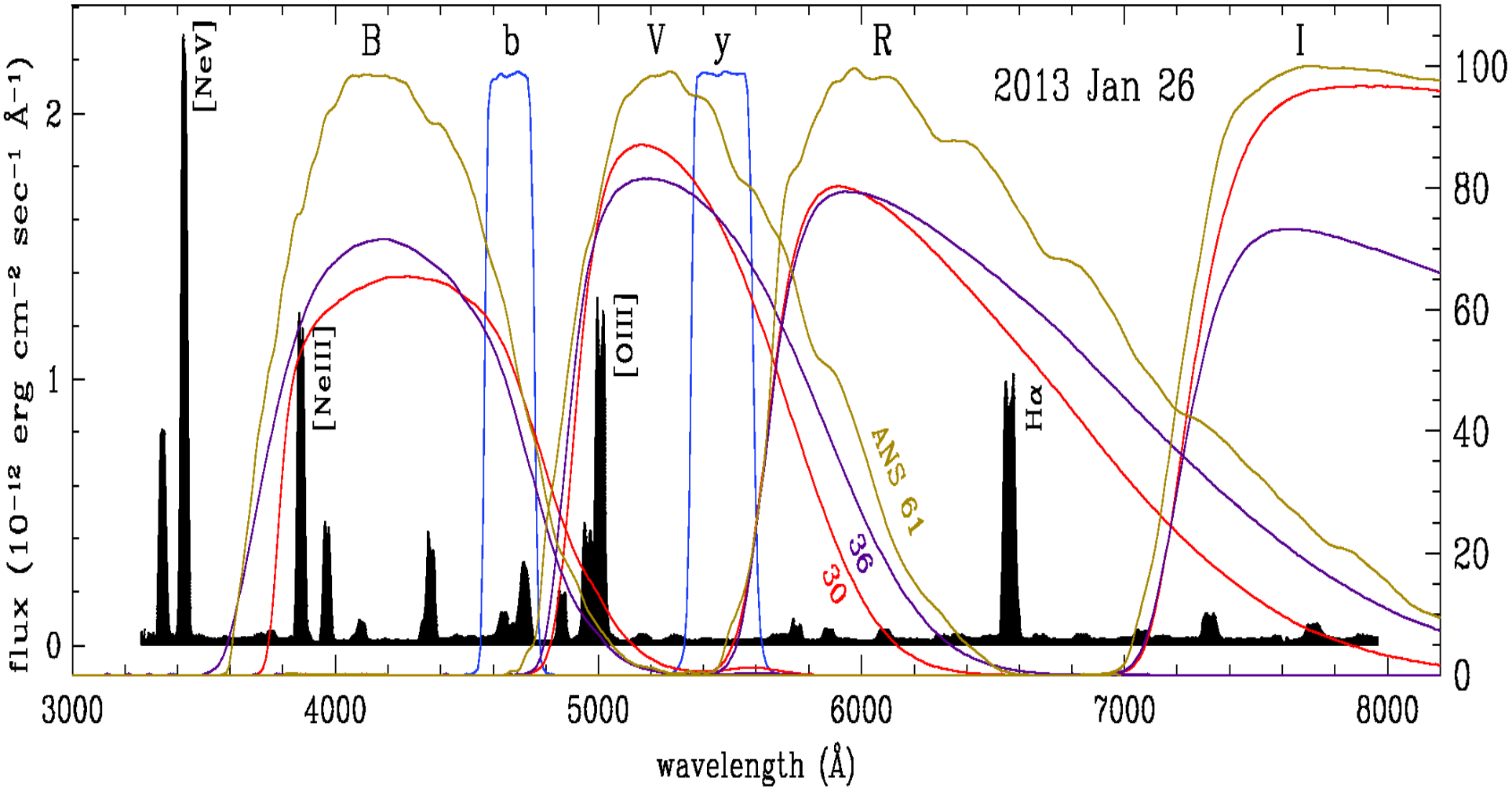
Nebular phase of V1974 Cyg (166 日)

○ 輝線の影響がでる(フィルターエッジに注目)



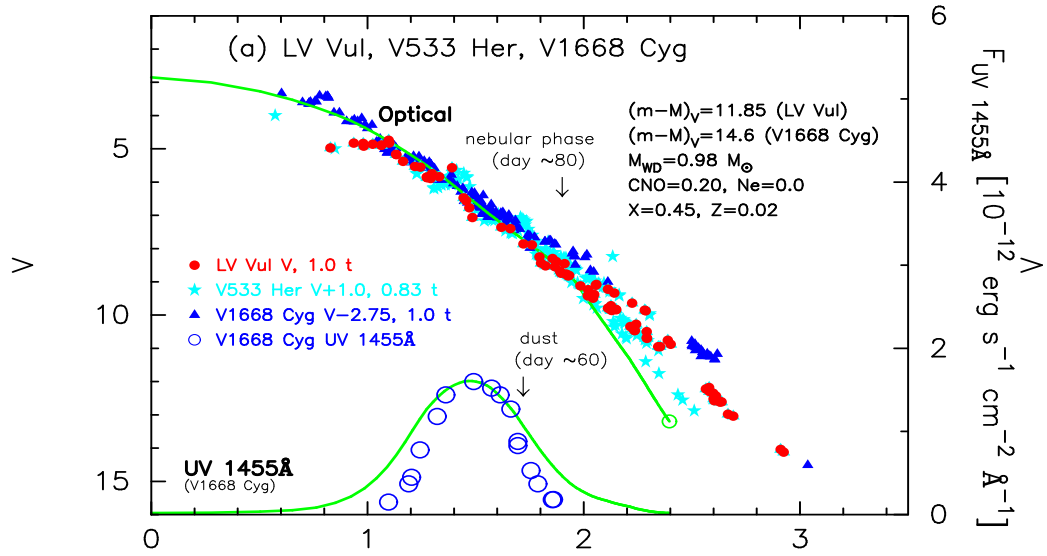
Nebular phase of V959 Mon

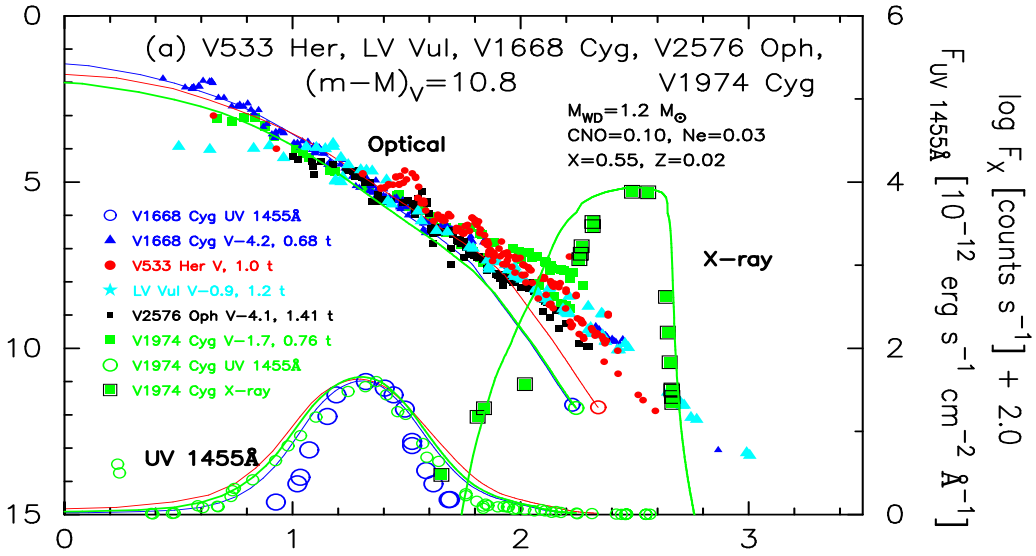
○ 輝線の影響がでる(フィルターエッジに注目)

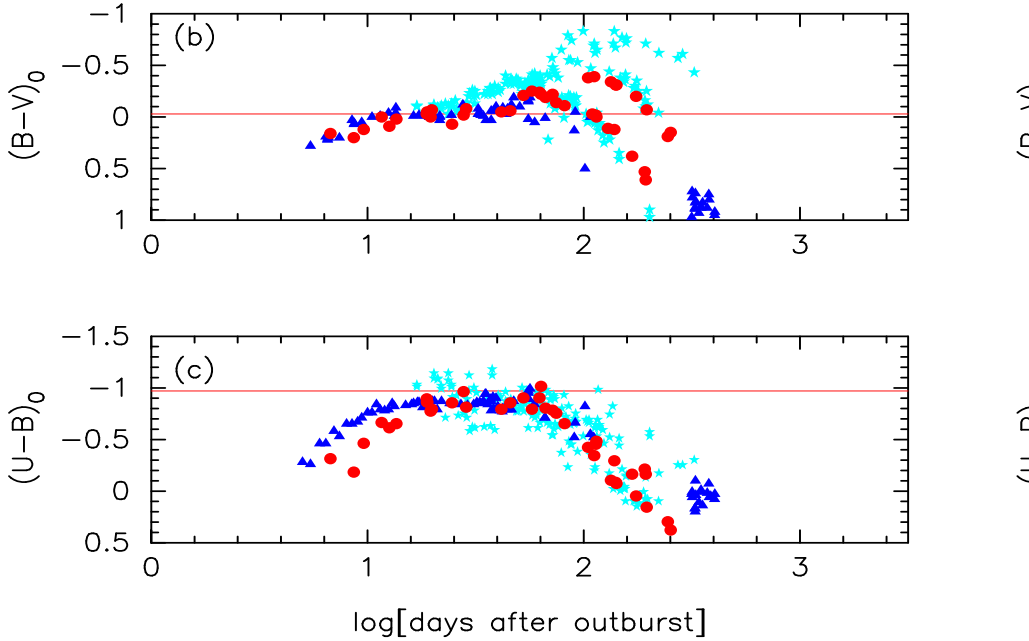


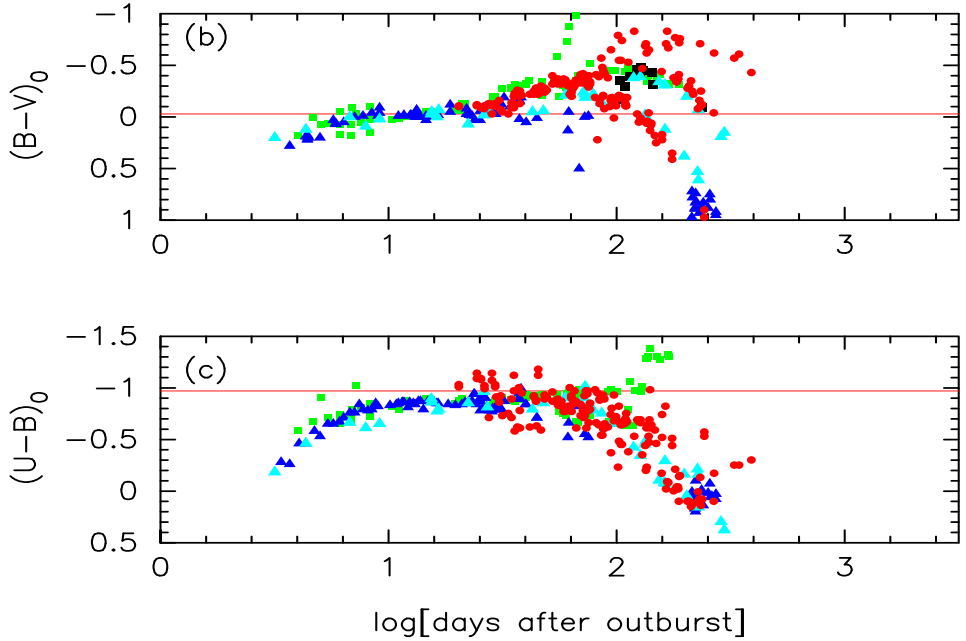
Munari et al. (2013)

古典新星の光度曲線・色変化(1)

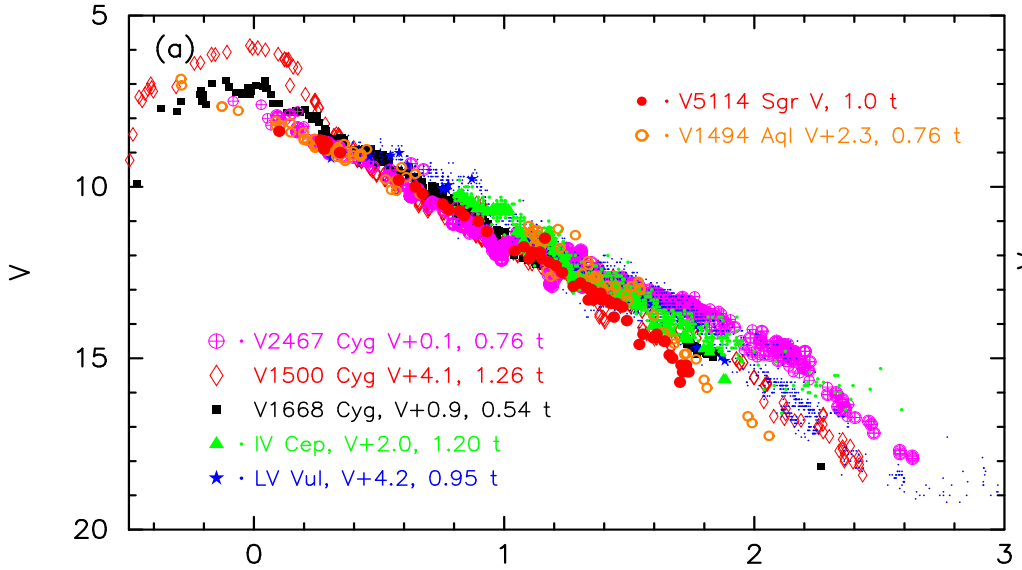


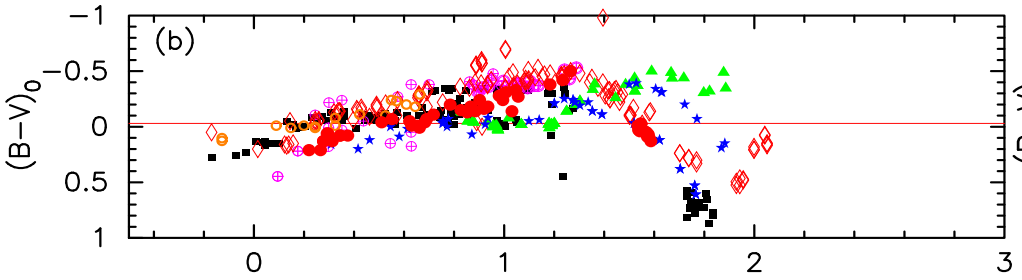


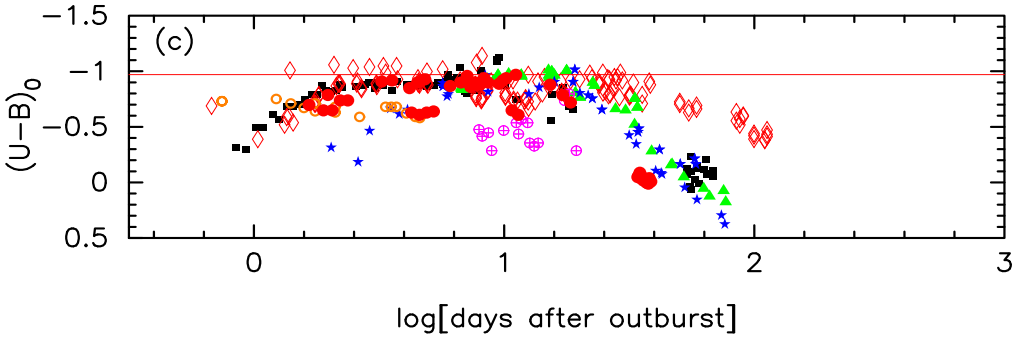


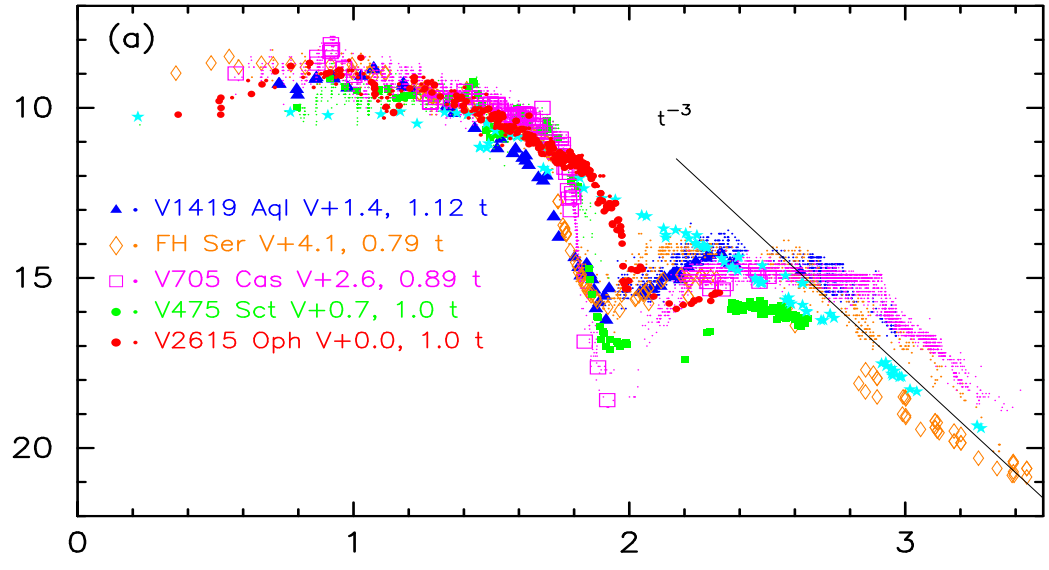


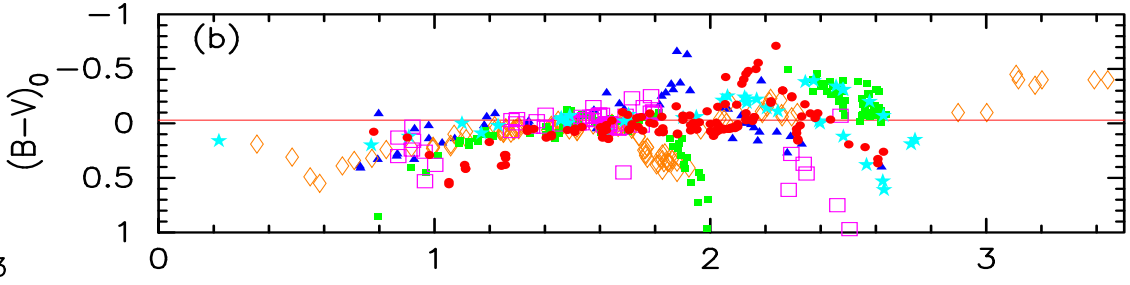
古典新星の光度曲線・色変化(2)

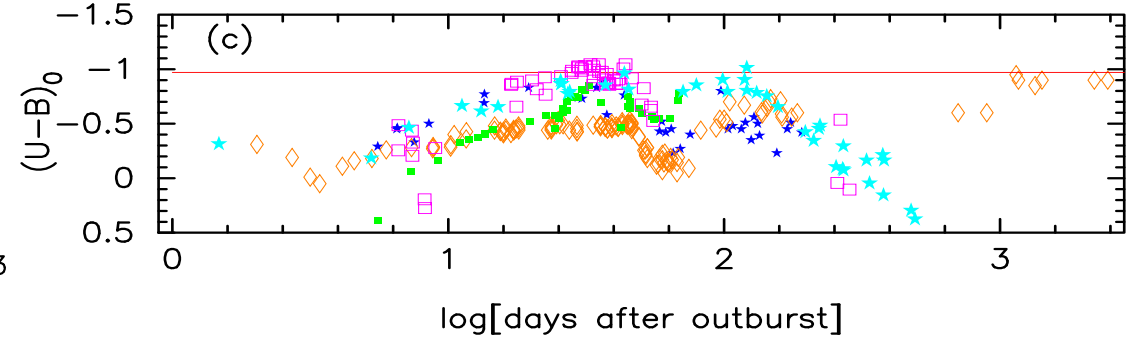






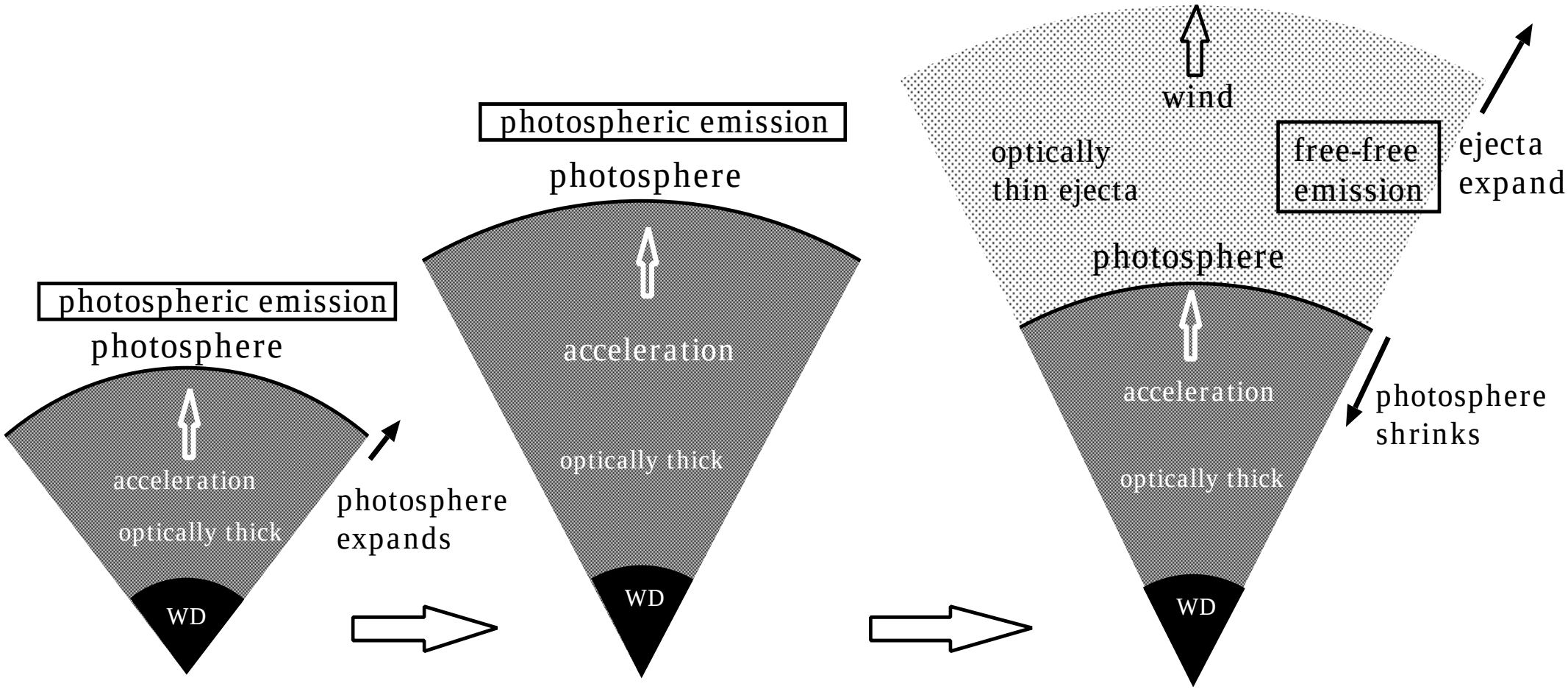






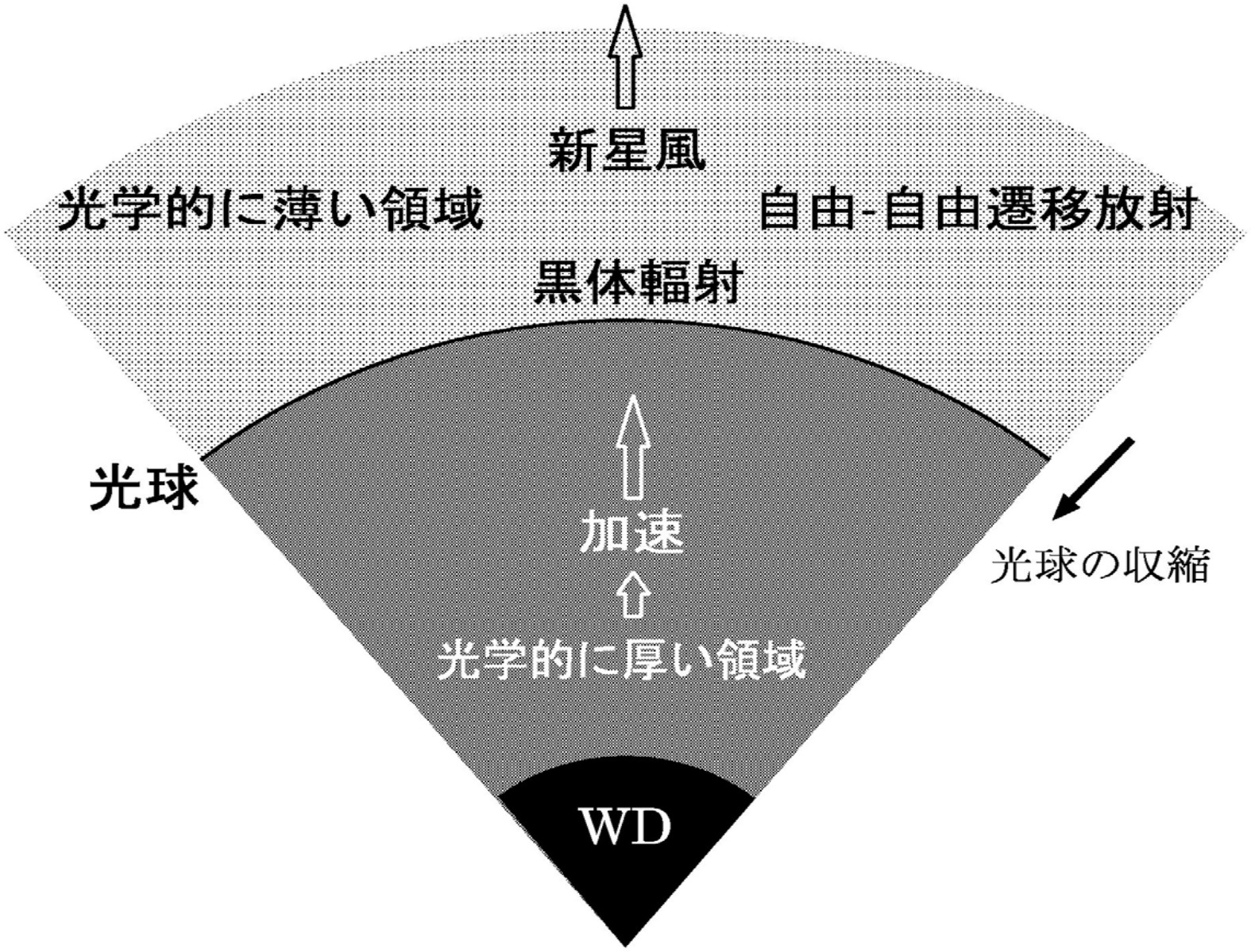
光球面の進化

○ fire-ball stage から free-free emissionへ

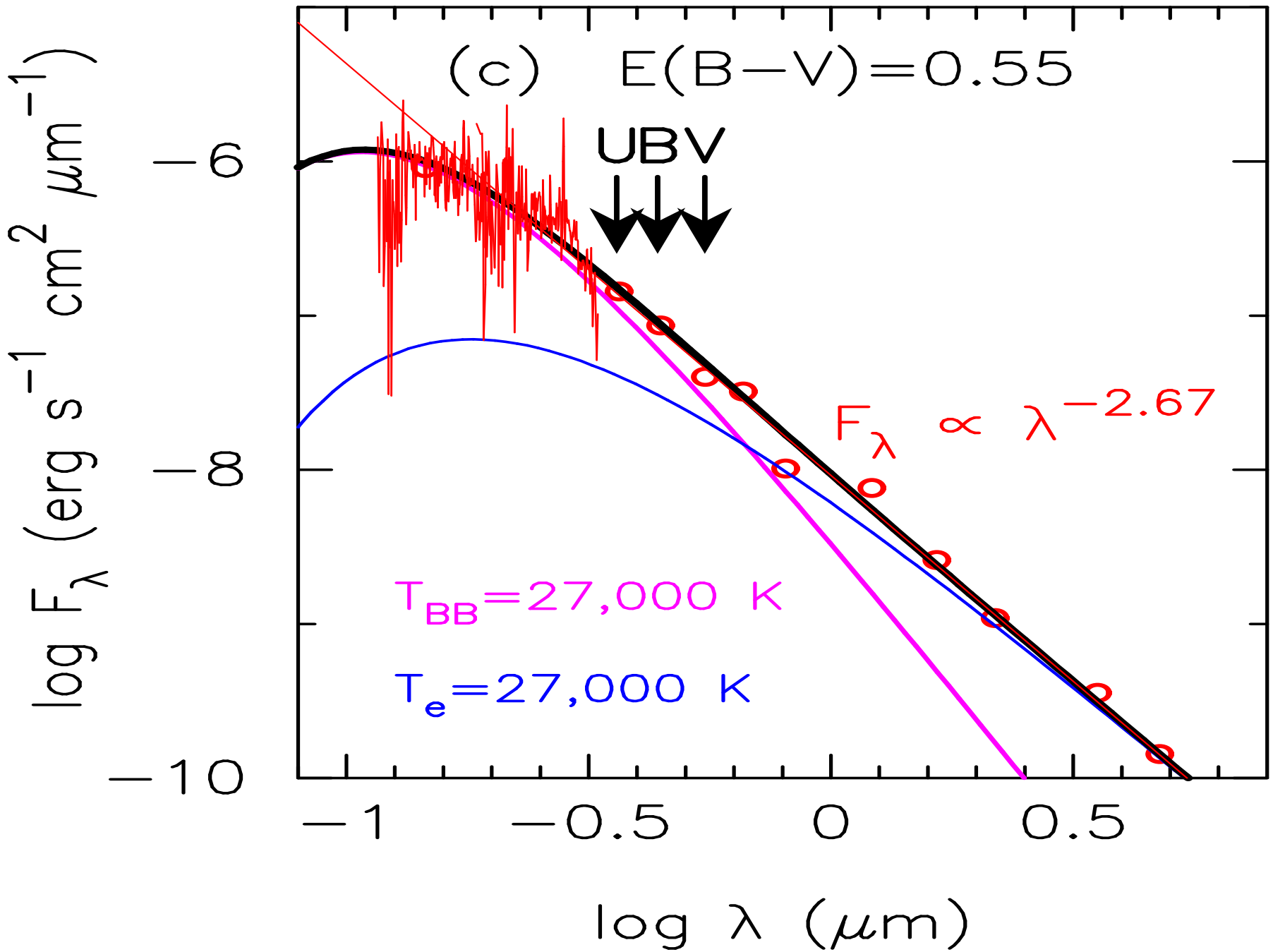


新星の構造

○ WD表面から光球までを「新星風」解として解く

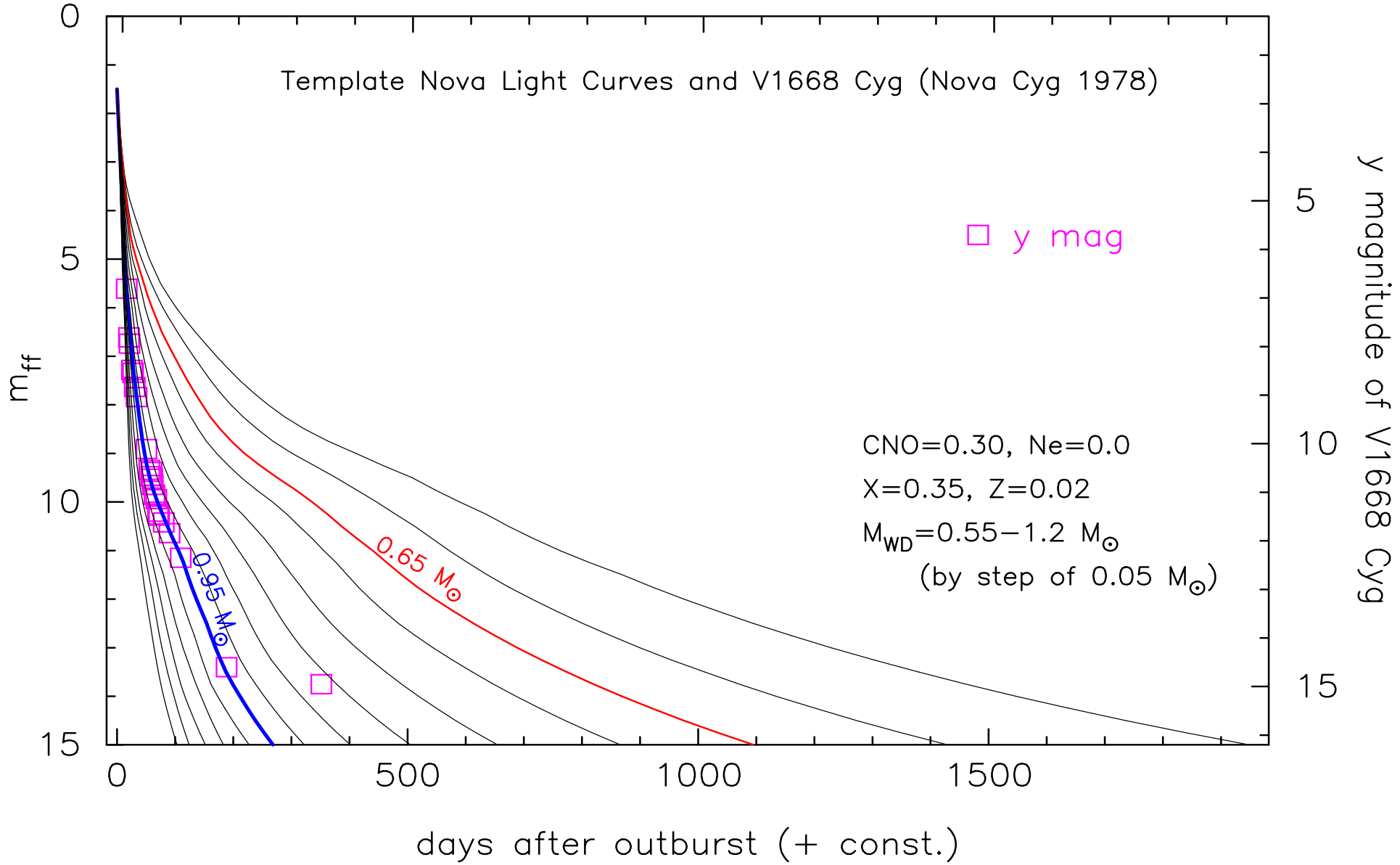


Blackbody + Free-free (PW Vul)



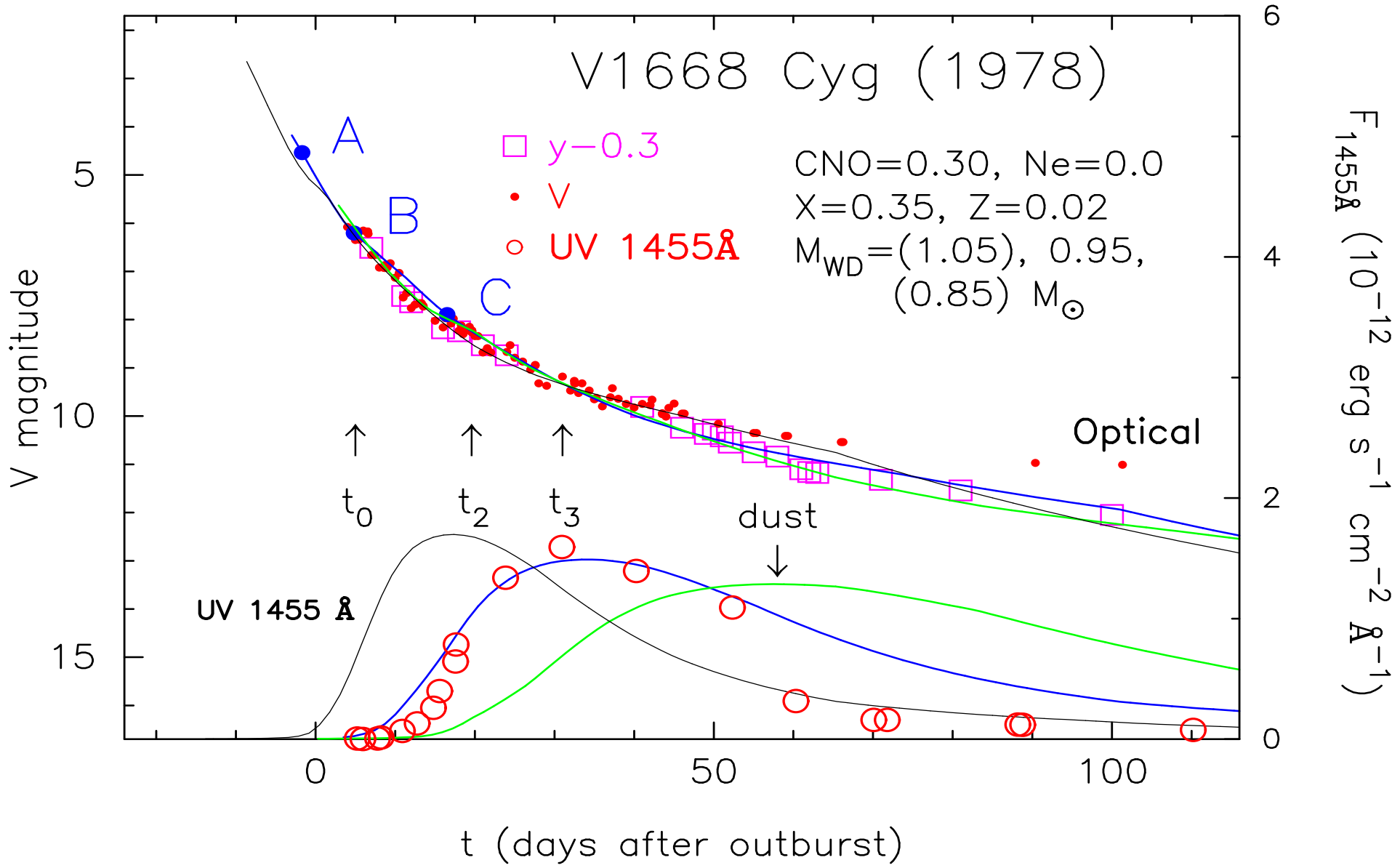
free-free emissionの光度曲線

○ 新星のスピードクラスは白色矮星質量に依存



光度曲線フィッテング

○ UVは黒体輻射近似、可視光はfree-free近似

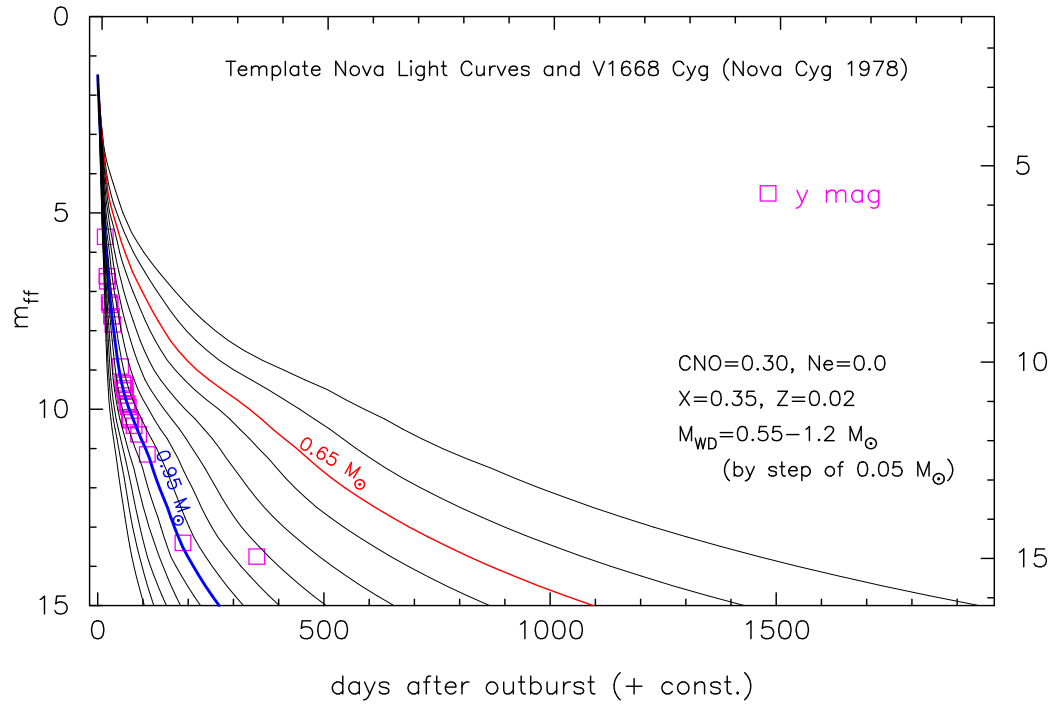


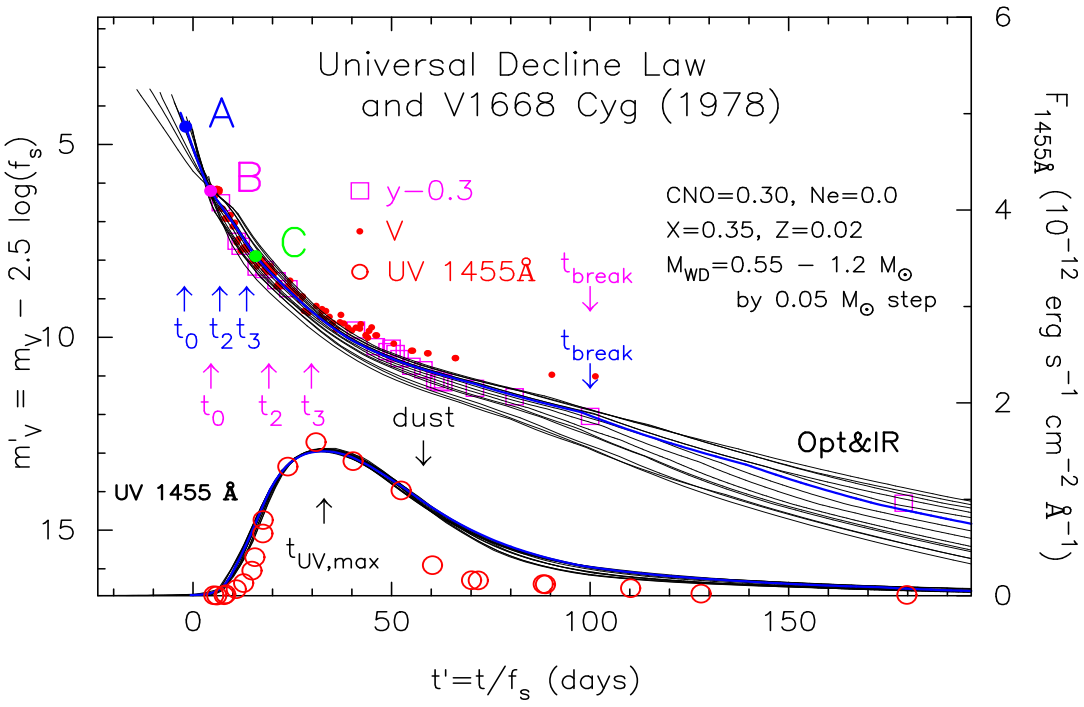
古典新星の普遍的減光則

○ 光度曲線は相似形&同じ明るさ

time-stretching (or squeezing)

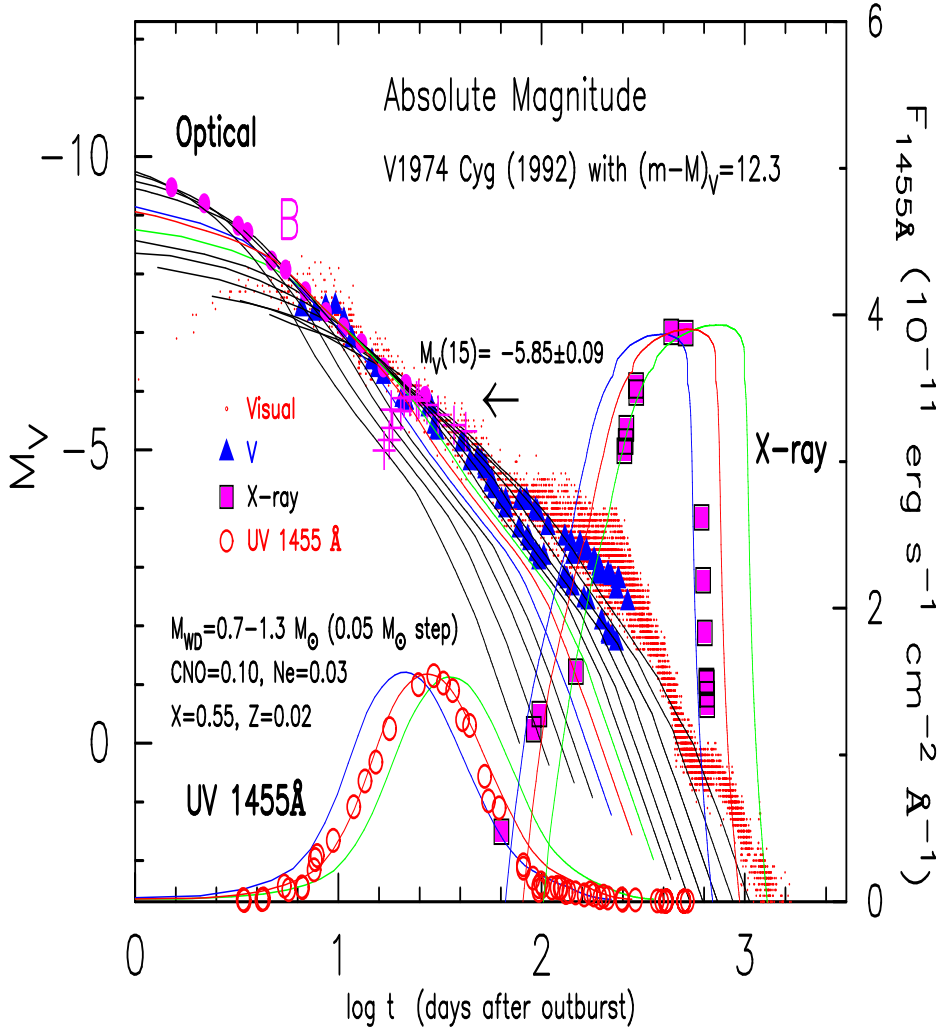
$$m'_V = -2.5 \log \left[\frac{\dot{M}^2_{\rm wind}}{v^2_{\rm ph} R_{\rm ph}} \right]^{\{M_{\rm WD}\}}_{(t/f_{\rm s})} + \text{const.}$$

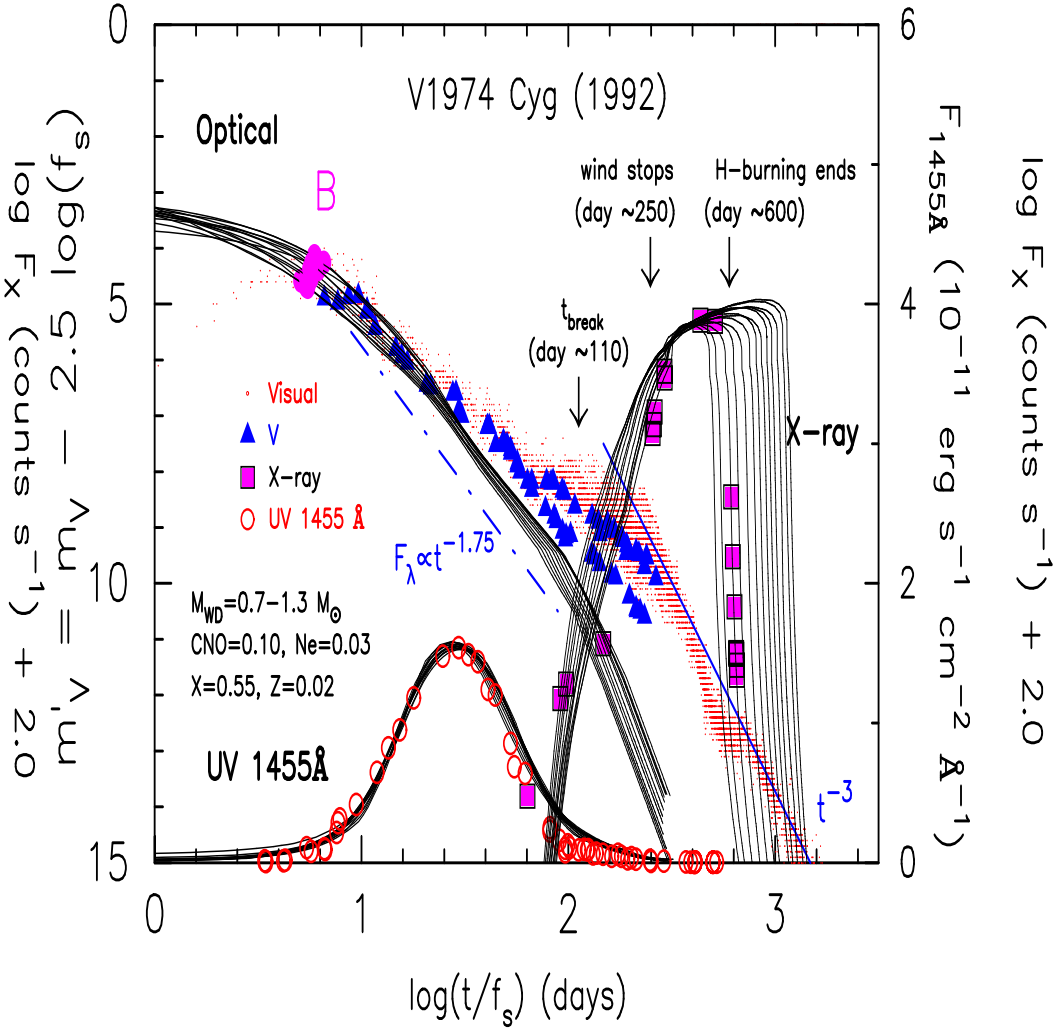




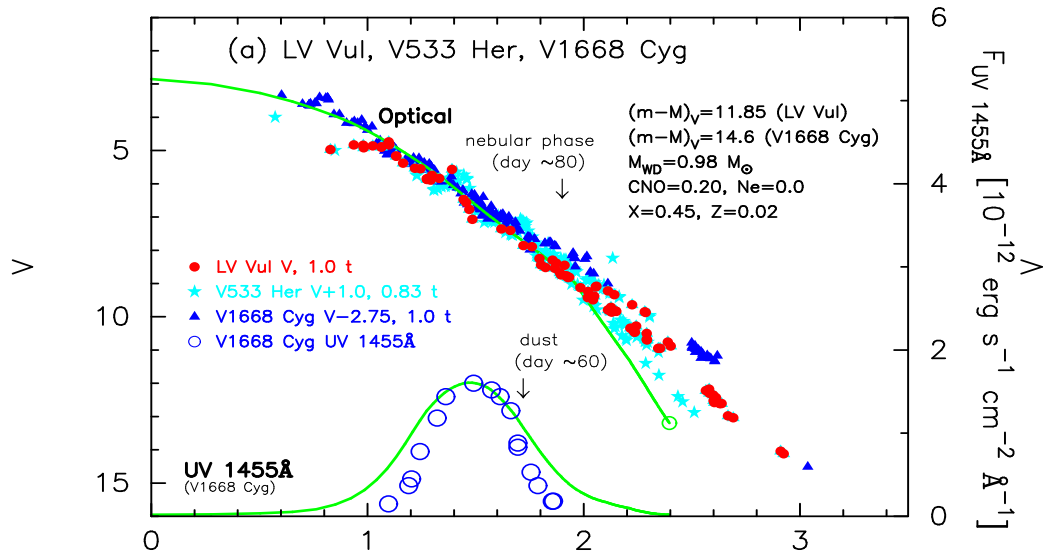
Universal decline law

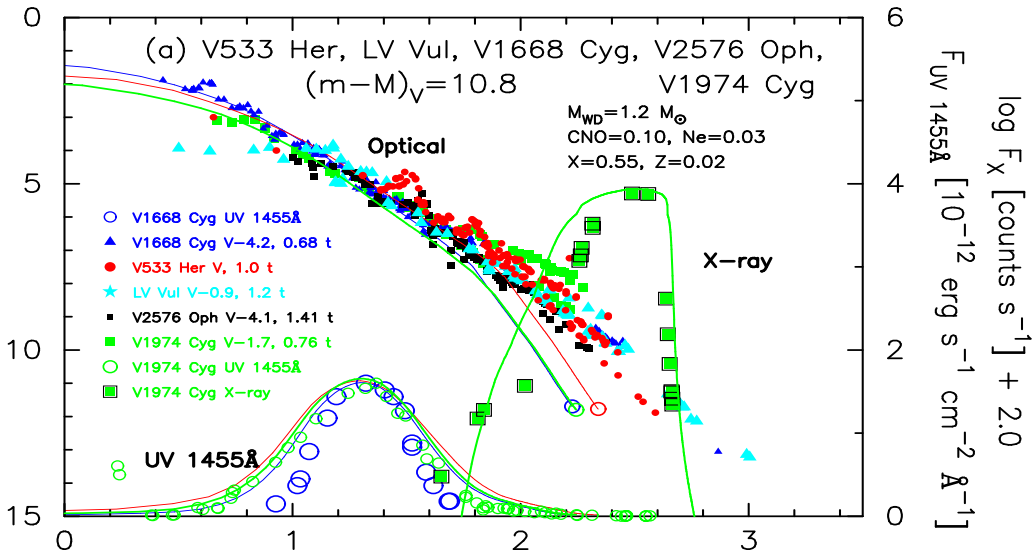
$$M_V = -\left[(m-M)_V\right]_{\mathrm{V1974\ Cyg}} + m'_V + 2.5\log f_s$$

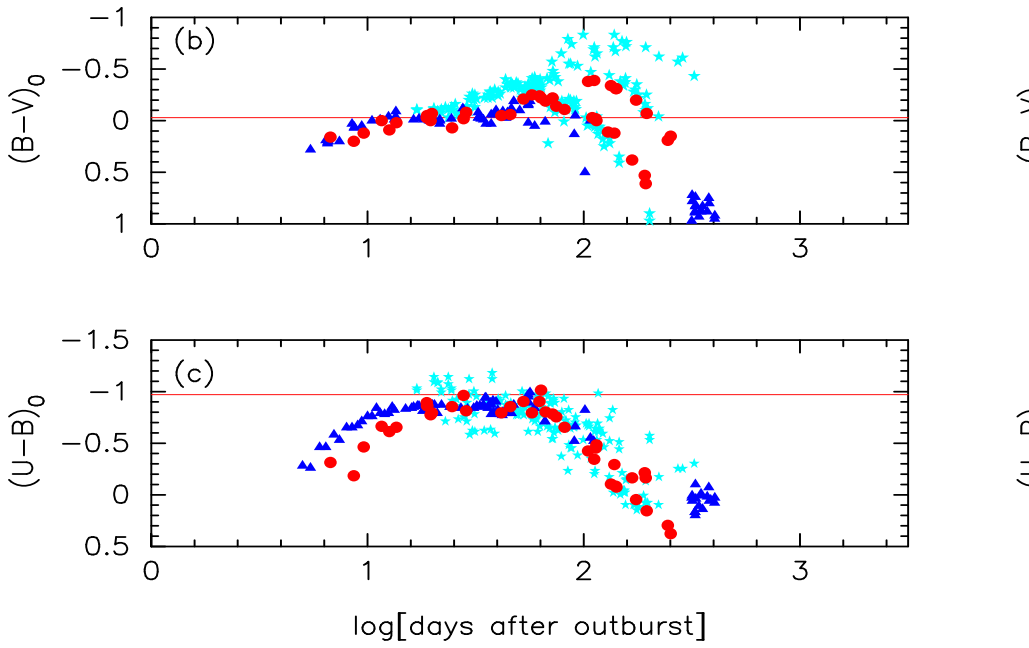


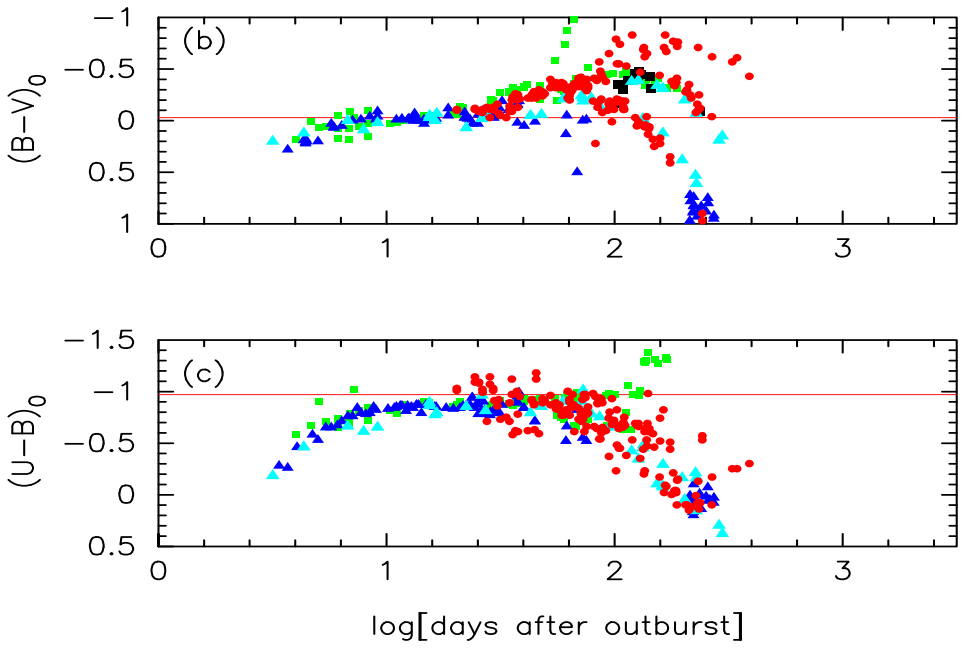


古典新星の光度曲線・色変化



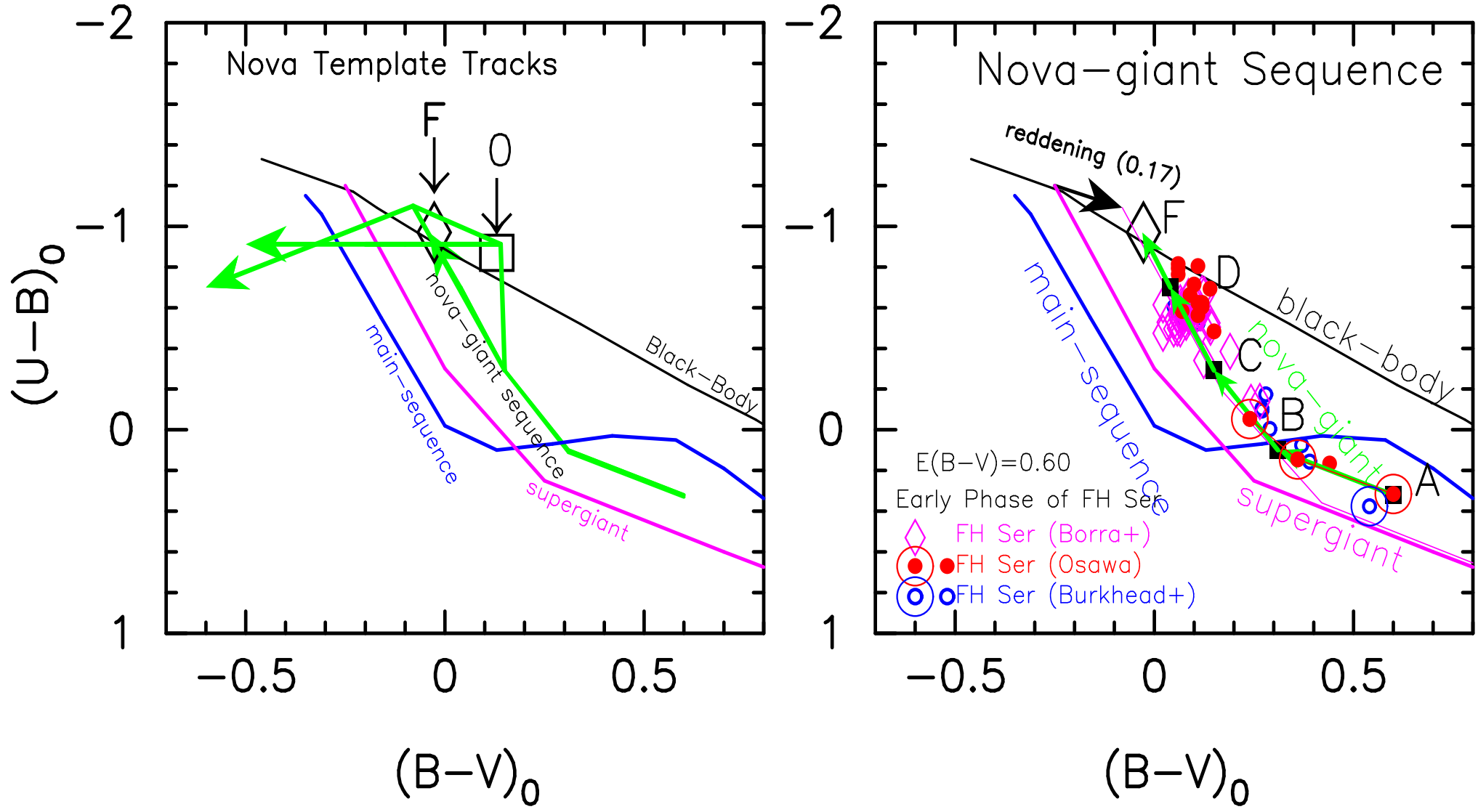






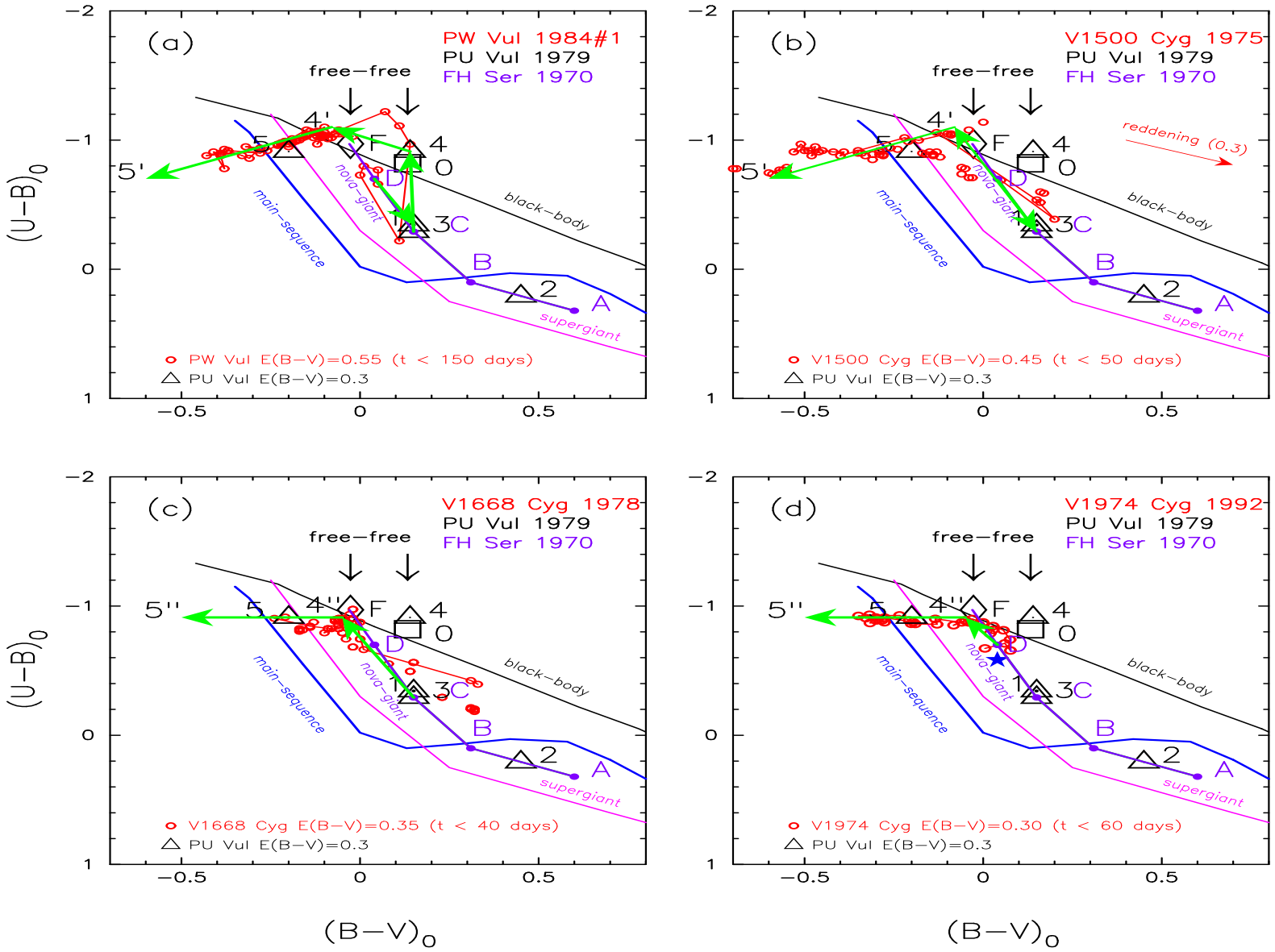
二色図中の一般的な色変化経路

○ general track (nova-giant sequence)

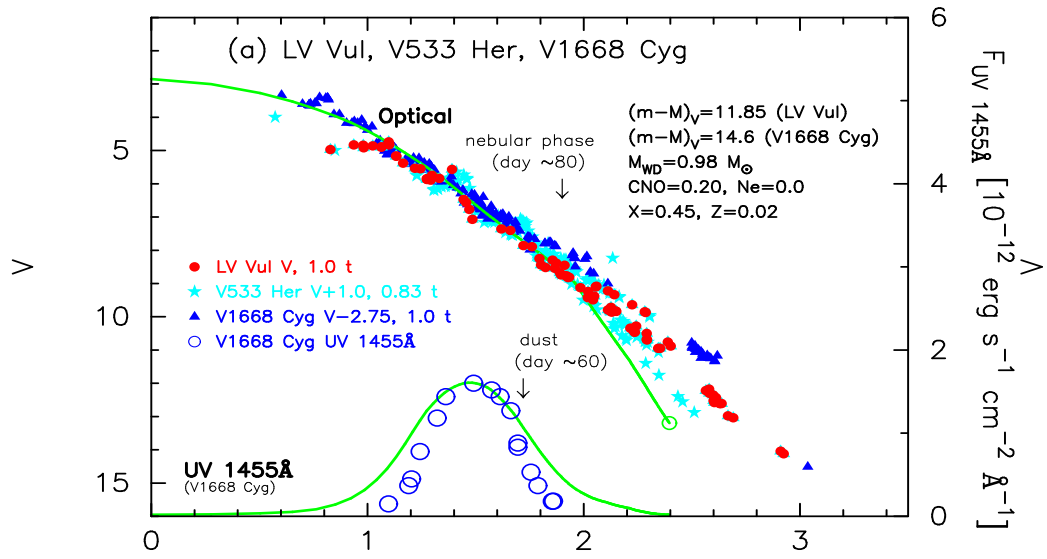


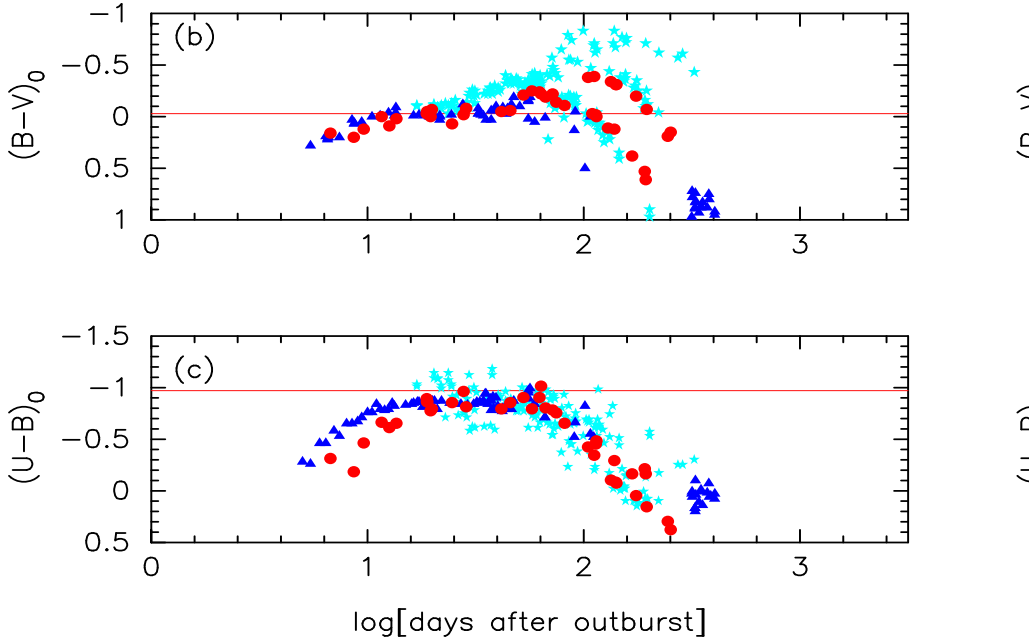
典型的な4例の2色図中の進化

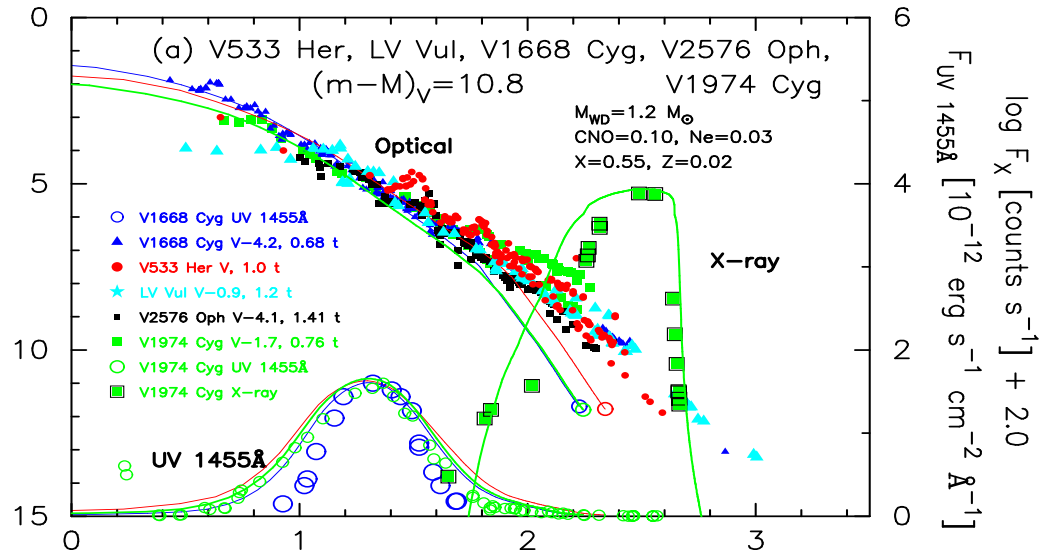
図中の F (thick), 0 (thin) は free-free emission に対応

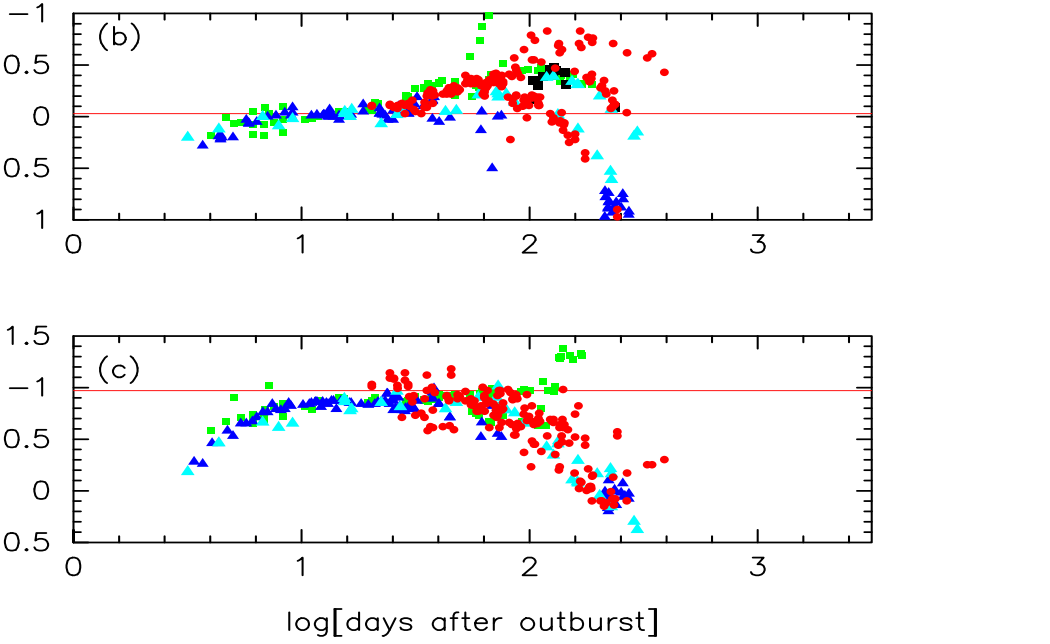


色等級図ではどうか？


(a) LV Vul, V533 Her, V1668 Cyg
Optical
nebular phase
(day ~80)
dust
(day ~60)
(m−M)V=11.85 (LV Vul)
(m−M)V=14.6 (V1668 Cyg)
MWD=0.98 M⊙
CNO=0.20, Ne=0.0
X=0.45, Z=0.02
LV Vul V, 1.0 t
V533 Her V+1.0, 0.83 t
V1668 Cyg V−2.75, 1.0 t
V1668 Cyg UV 1455Å
UV 1455Å
(V1668 Cyg)
V
F UV 1455Å [10−12 erg s−1 cm−2 Å−1]

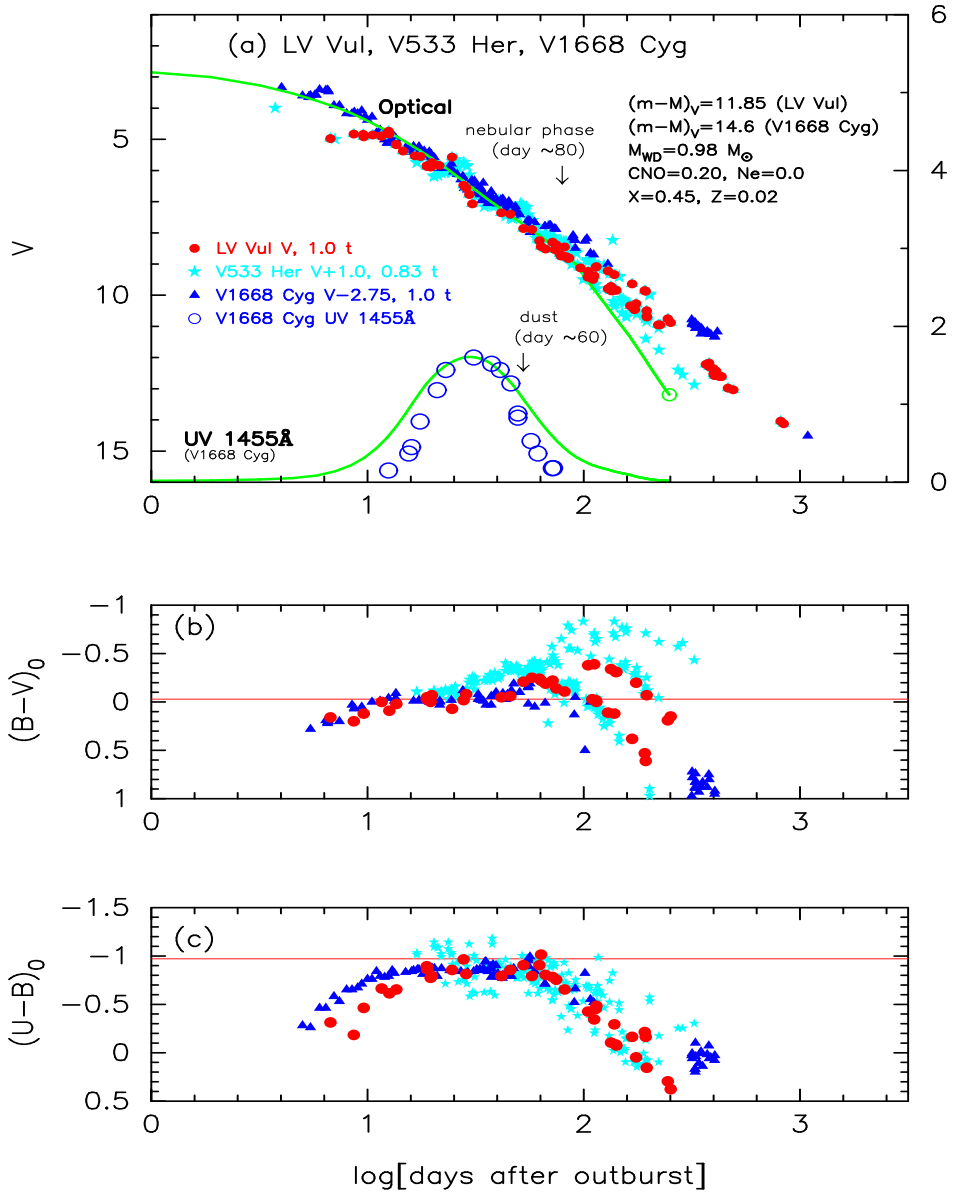

(b)
(B−V)0
(c)
(U−B)0
log[days after outburst]

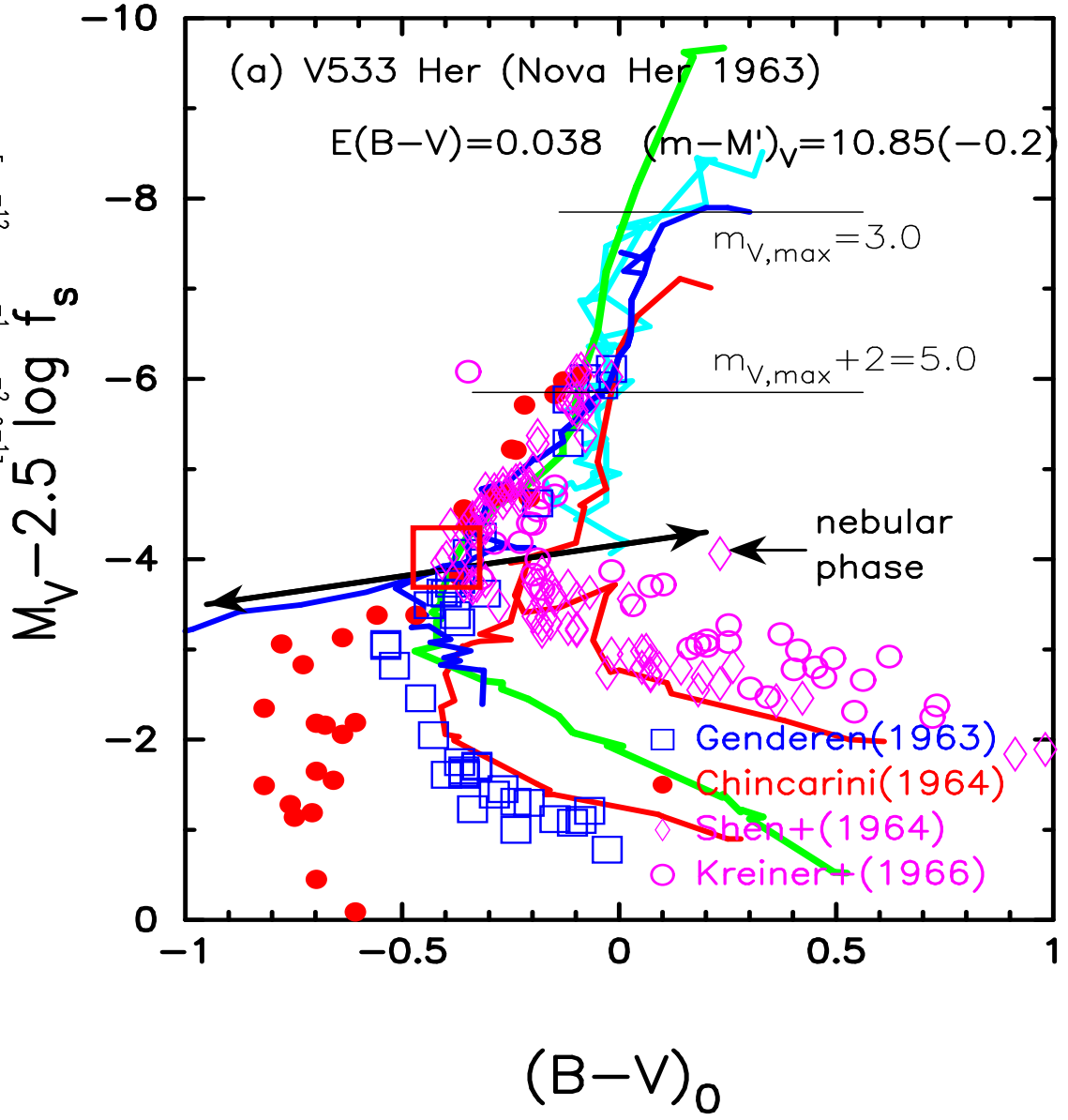

(a) V533 Her, LV Vul, V1668 Cyg, V2576 Oph,
V1974 Cyg
(m−M)V=10.8
MWD=1.2 M⊙
CNO=0.10, Ne=0.03
X=0.55, Z=0.02
Optical
X−ray
V1668 Cyg UV 1455Å
V1668 Cyg V−4.2, 0.68 t
V533 Her V, 1.0 t
LV Vul V−0.9, 1.2 t
V2576 Oph V−4.1, 1.41 t
V1974 Cyg V−1.7, 0.76 t
V1974 Cyg UV 1455Å
V1974 Cyg X−ray
UV 1455Å
F UV 1455Å [10−12 erg s−1 cm−2 Å−1]
log Fx [counts s−1] + 2.0


(b)
(B−V)0
(c)
(U−B)0
log[days after outburst]

色等級図でも使える

$$M_V = -(m - M)_V + m'_V + 2.5 \log f_s$$





絶対等級(距離)と色超過が分かる

○ テンプレートとターゲットのトラックが重なる

→ 縦軸から絶対等級が分かる

(2.5 log fs の補正により)

→ 横軸から色超過 E(B-V) が分かる

○ 絶対等級と色超過から距離が分かる

$$(m - M)_V = 3.1E(B - V) + 5\log(d/10\mathrm{pc})$$

具体例： **V959 Mon 2012**

○ GeV γ 線が受かっている古典新星の１例

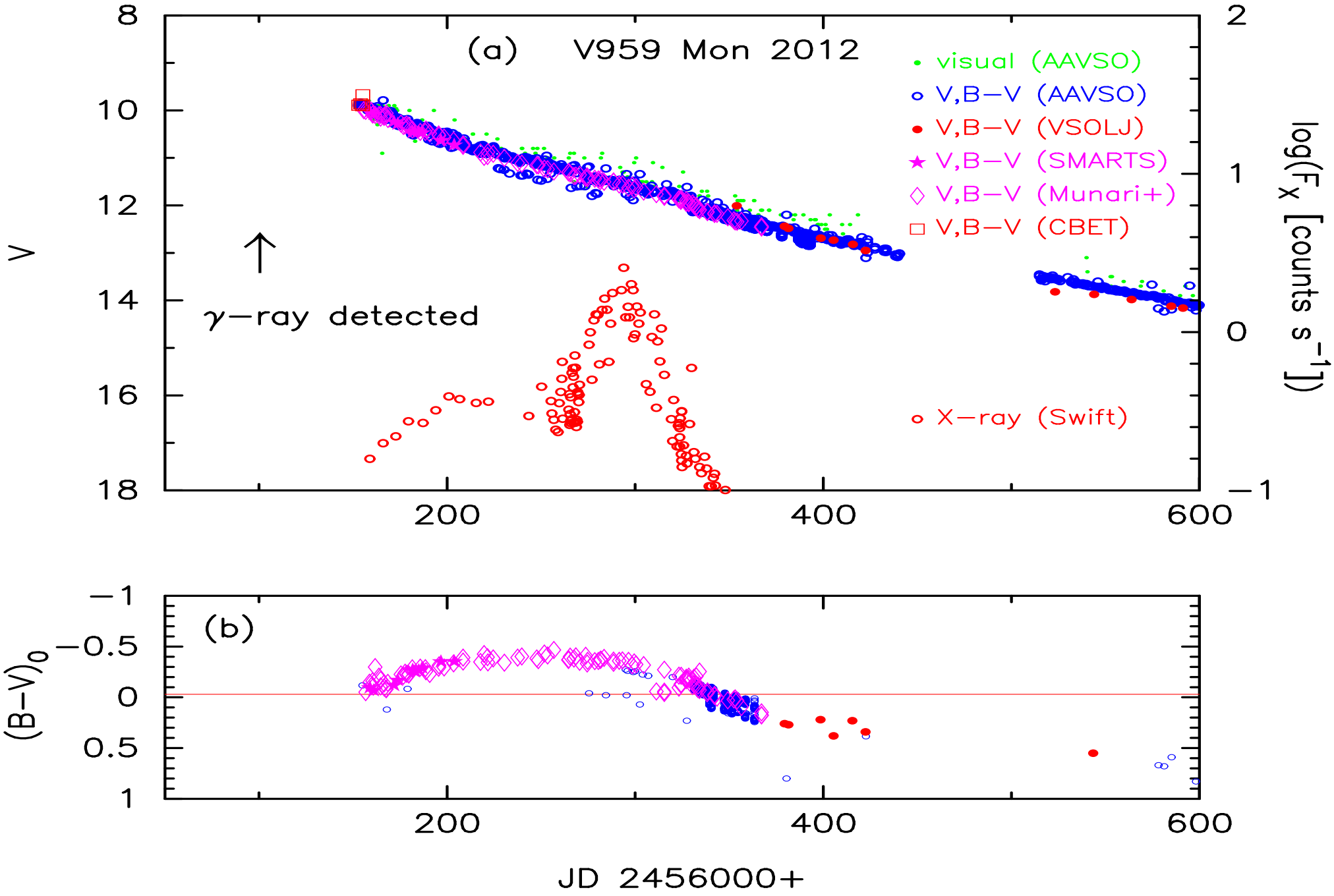
→ 極大を逃している(太陽との合)

→ 距離が良く決まっていない

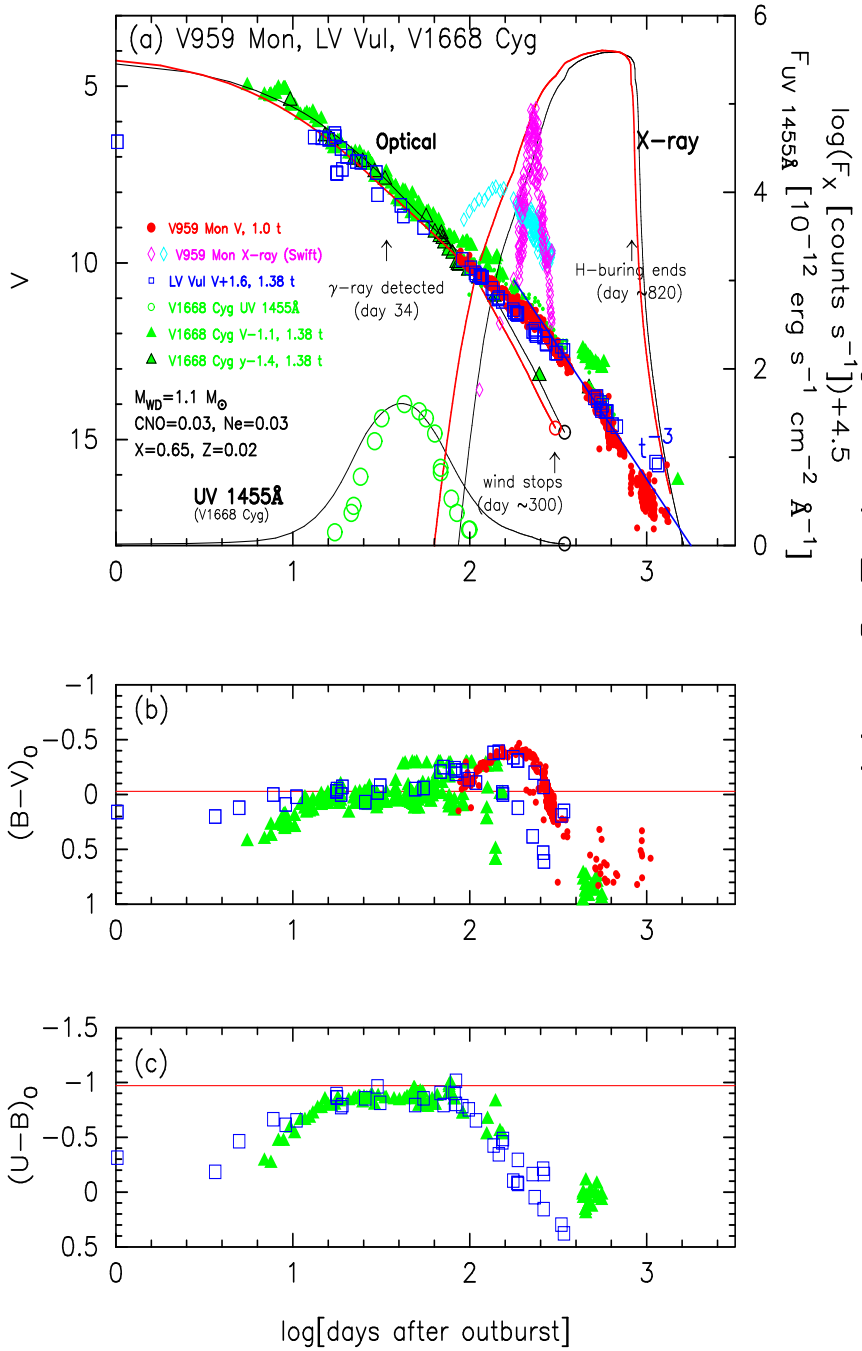
○ GeV γ 線が受かっている古典新星の特徴は何？

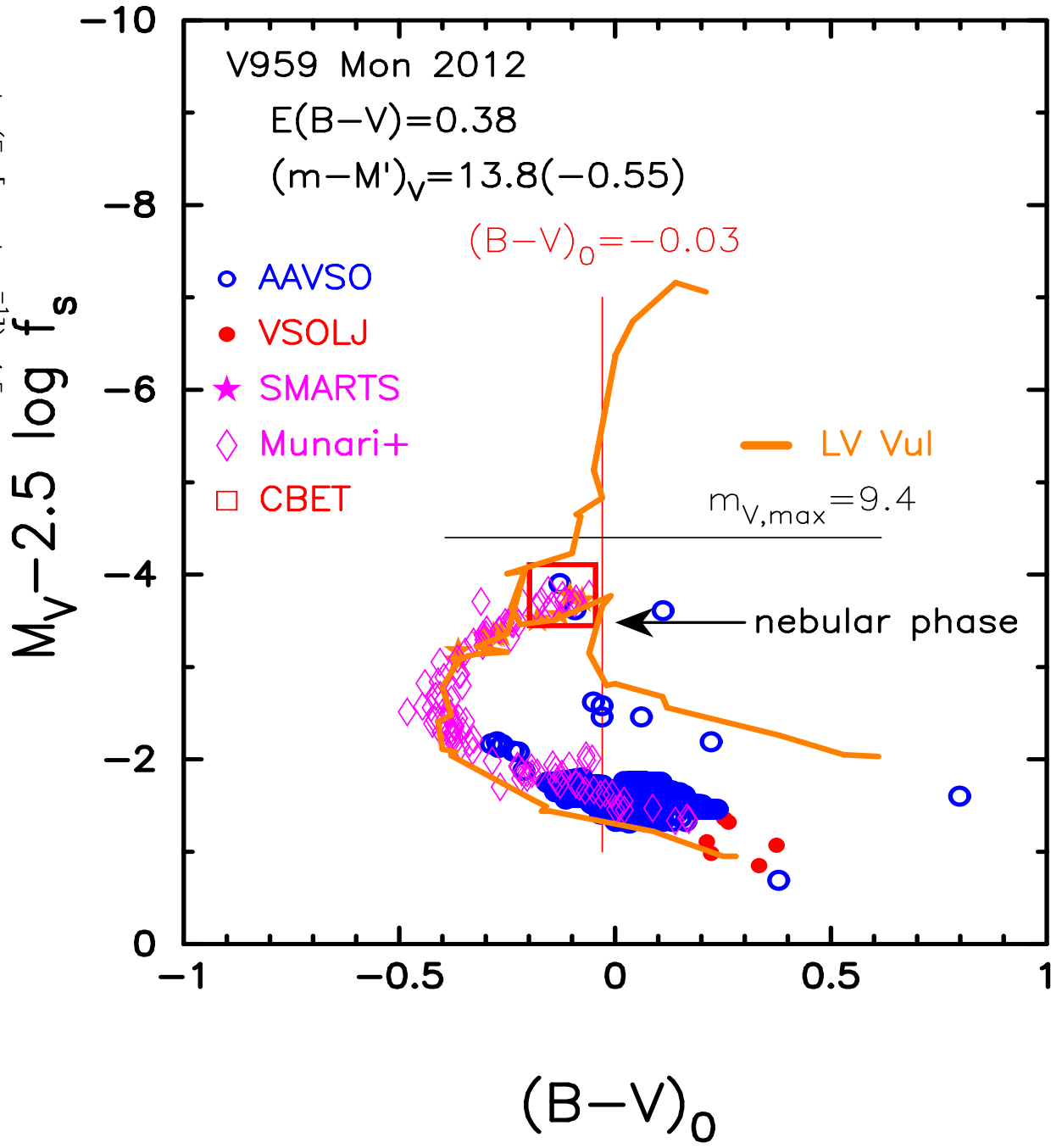
→ 単に距離が近いだけ？

Light Curve of V959 Mon 2012

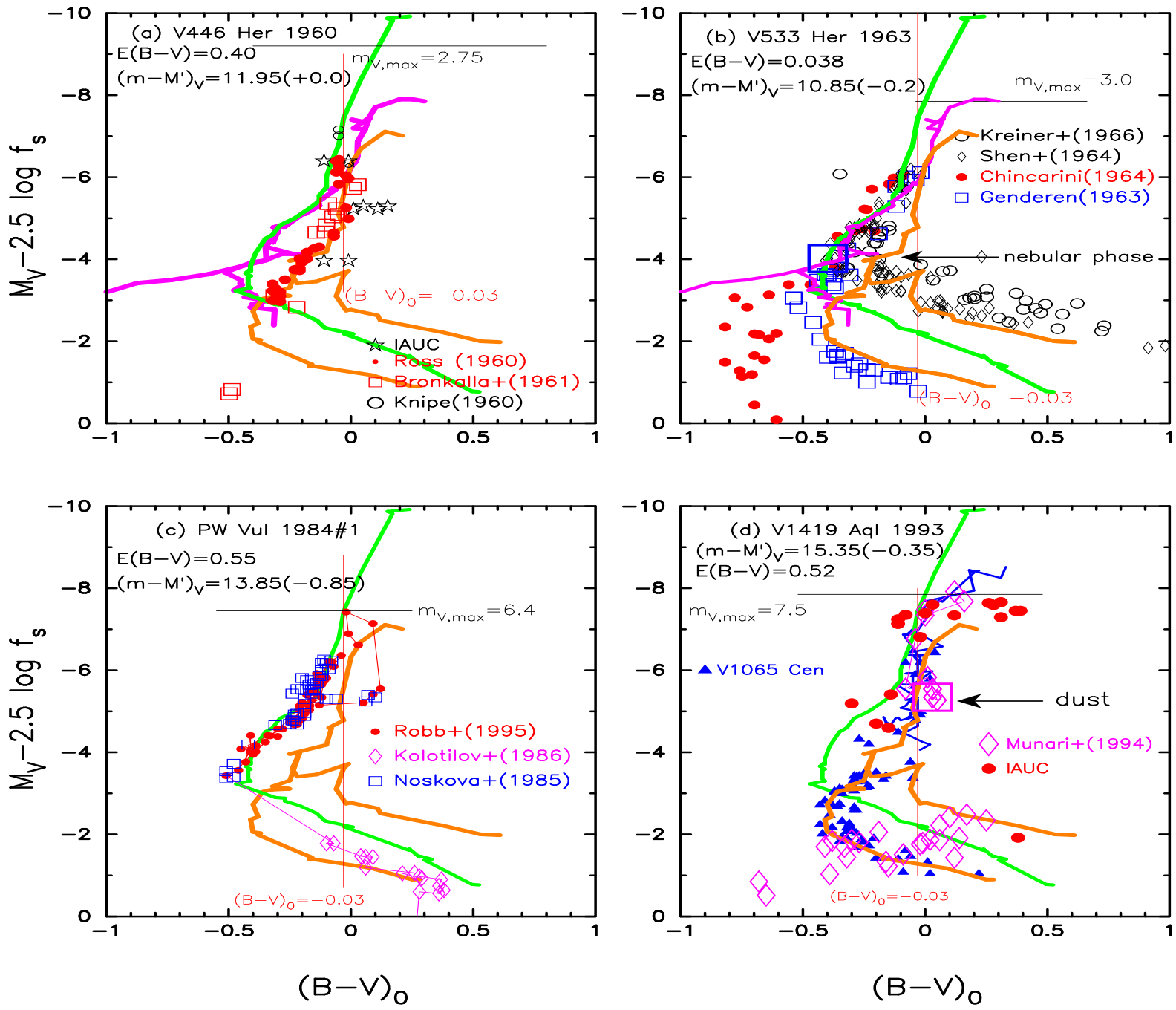


Light Curve of V959 Mon 2012

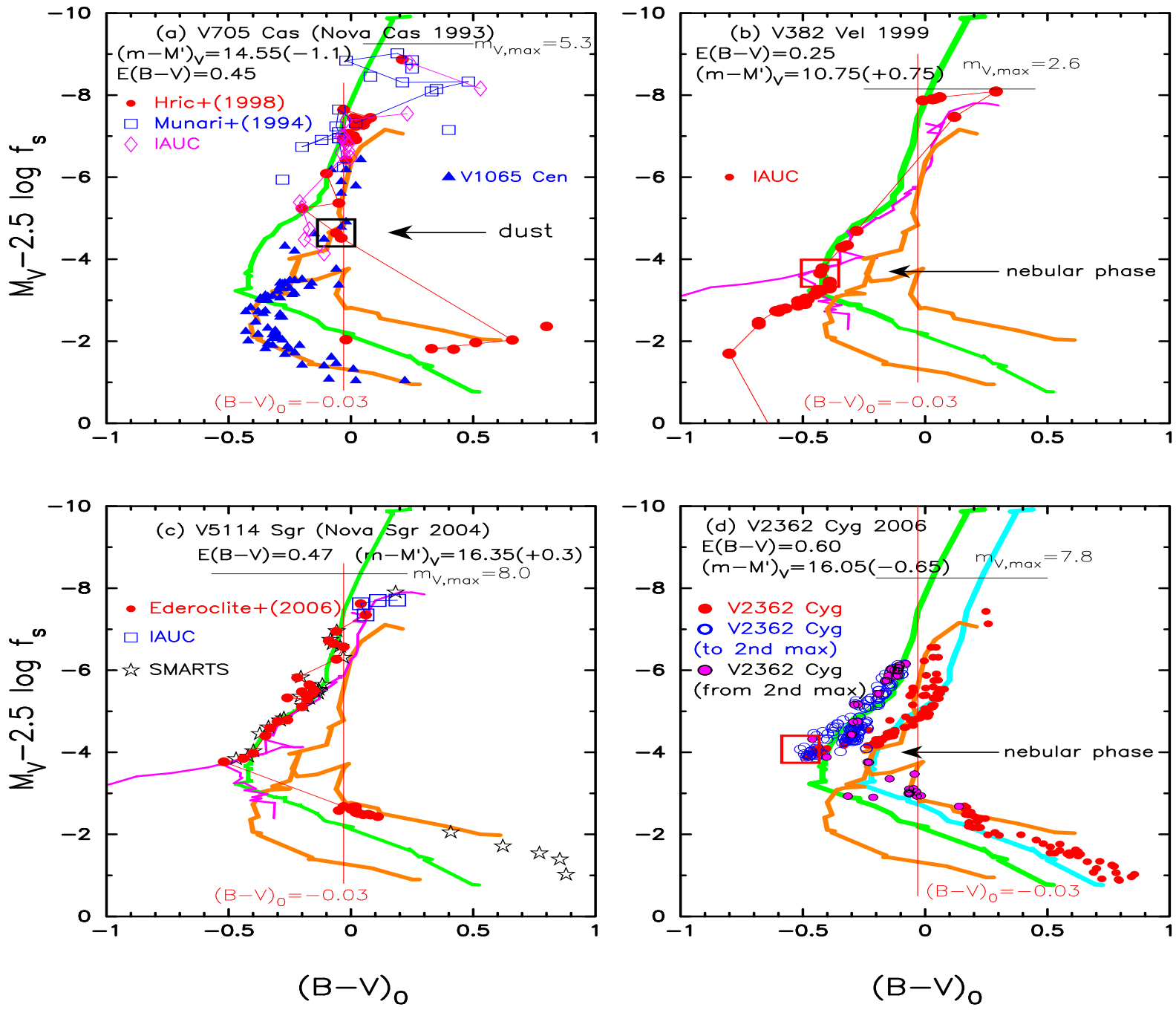




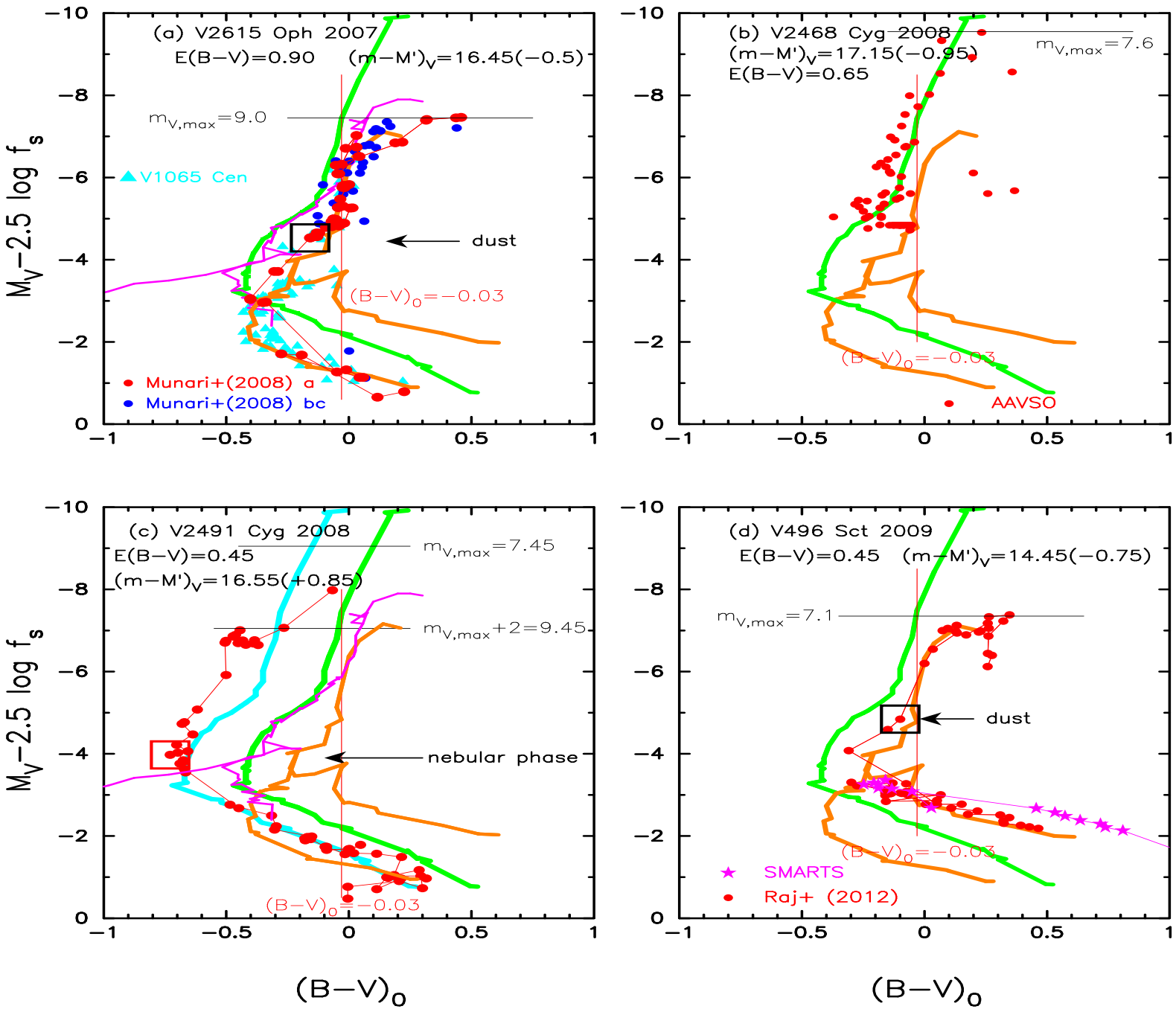
V446 Her, V533 Her, PW Vul, V1419 Aql



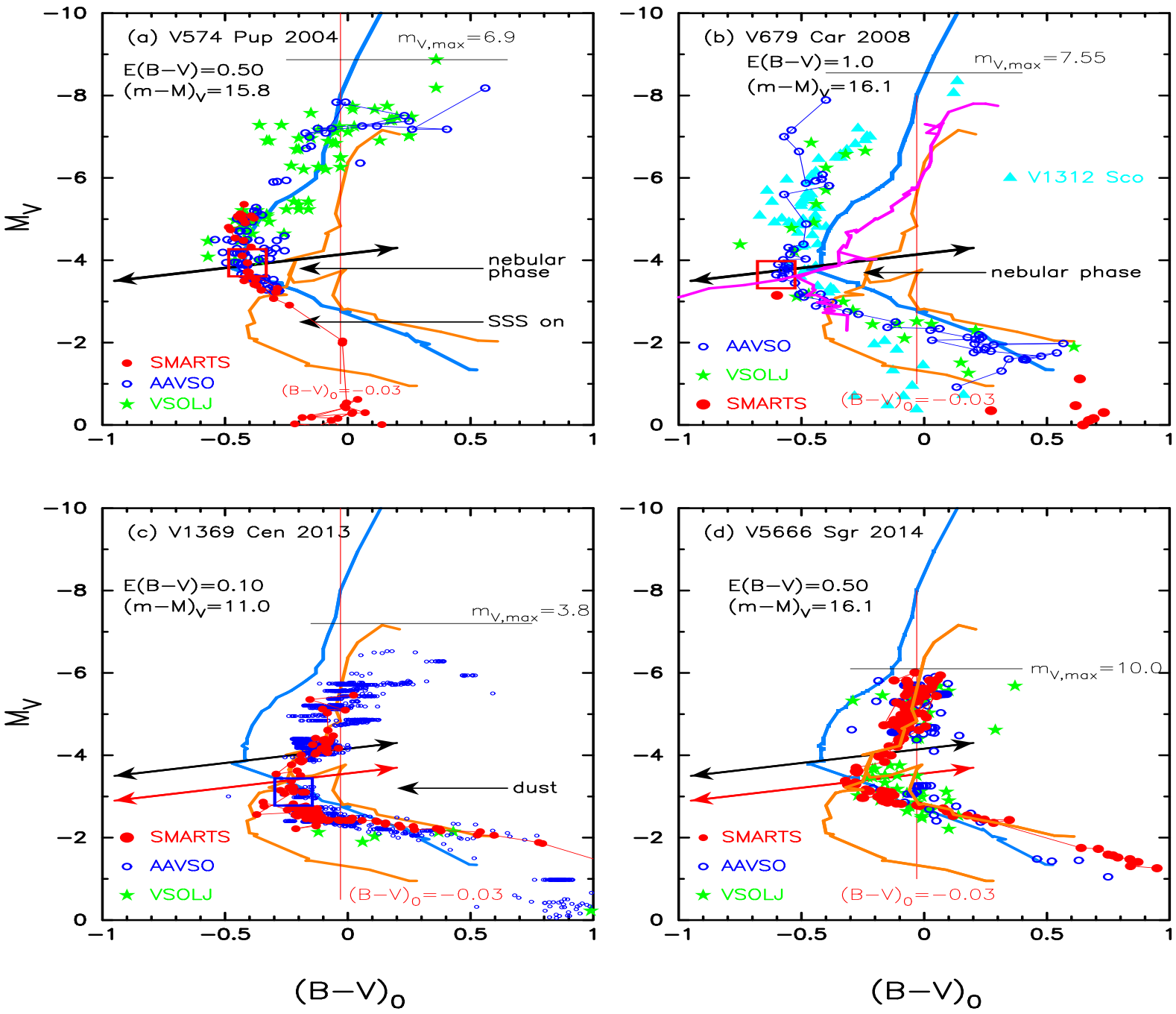
V705 Cas, V382 Vel, V5114 Sgr, V2362 Cyg



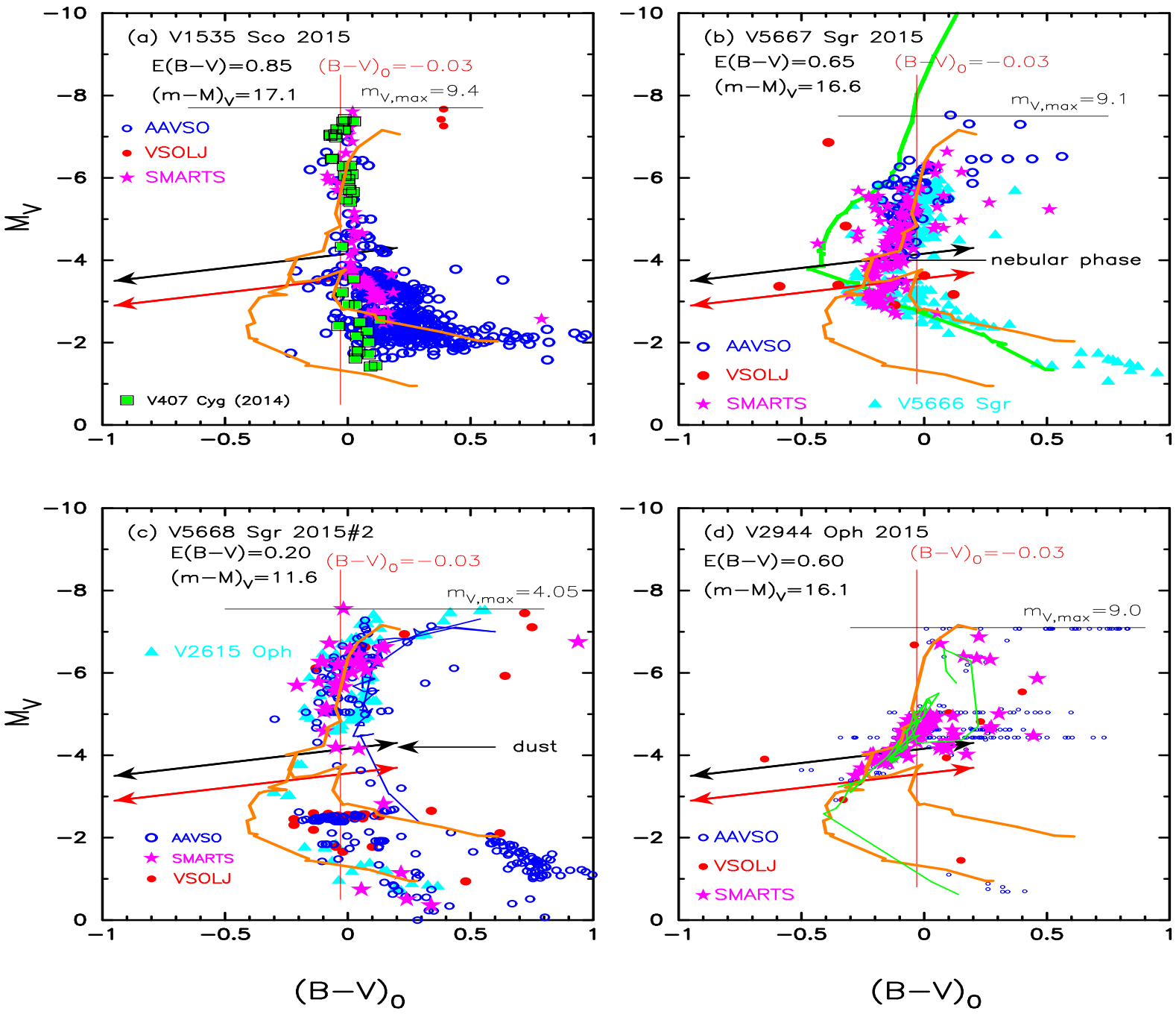
V2615 Oph, V2468 Cyg, V2491 Cyg, V496 Sct



V574 Pup, V679 Car, V1369 Cen, V5666 Sgr

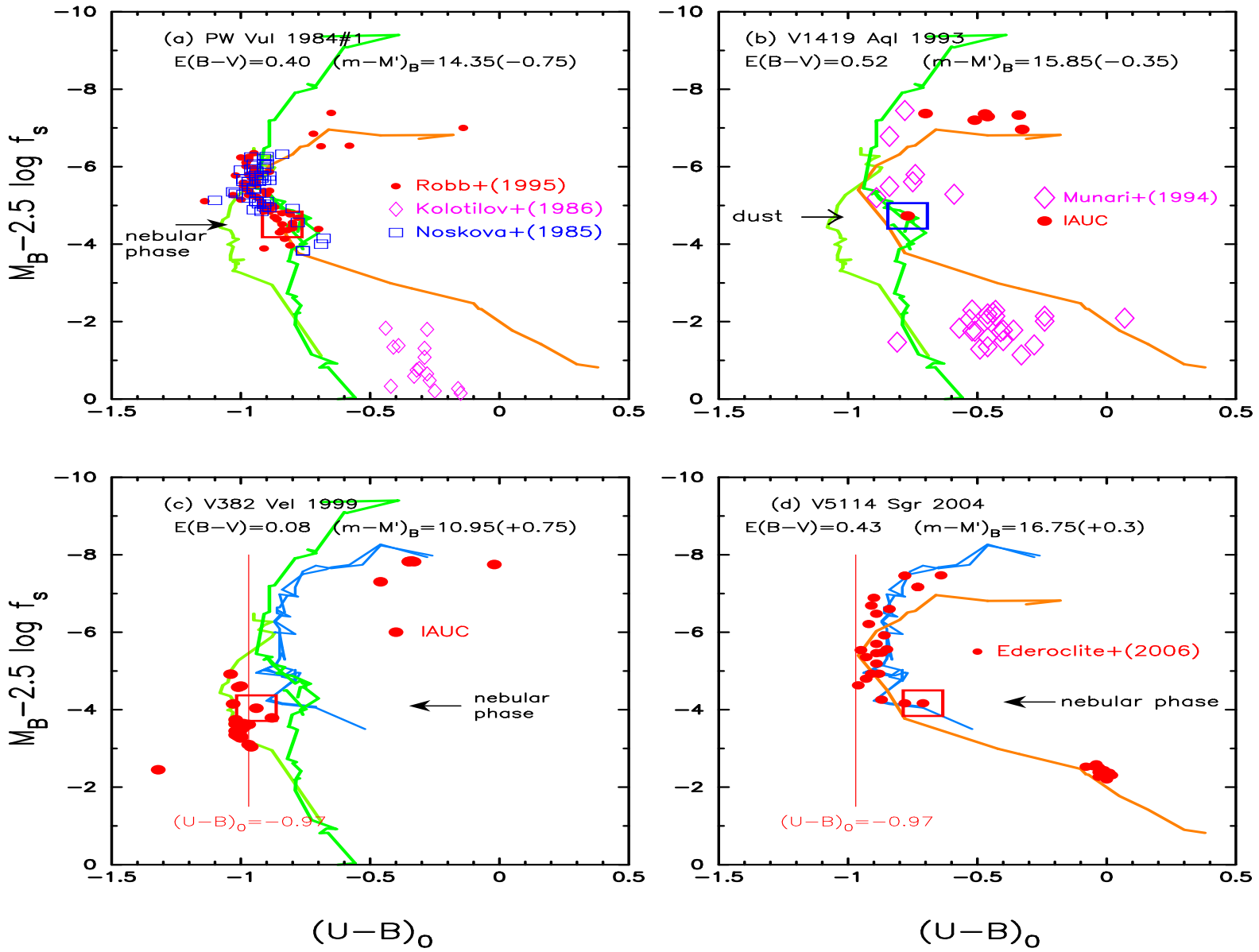


V1535 Sco, V5667 Sgr, V5668 Sgr, V2944 Oph

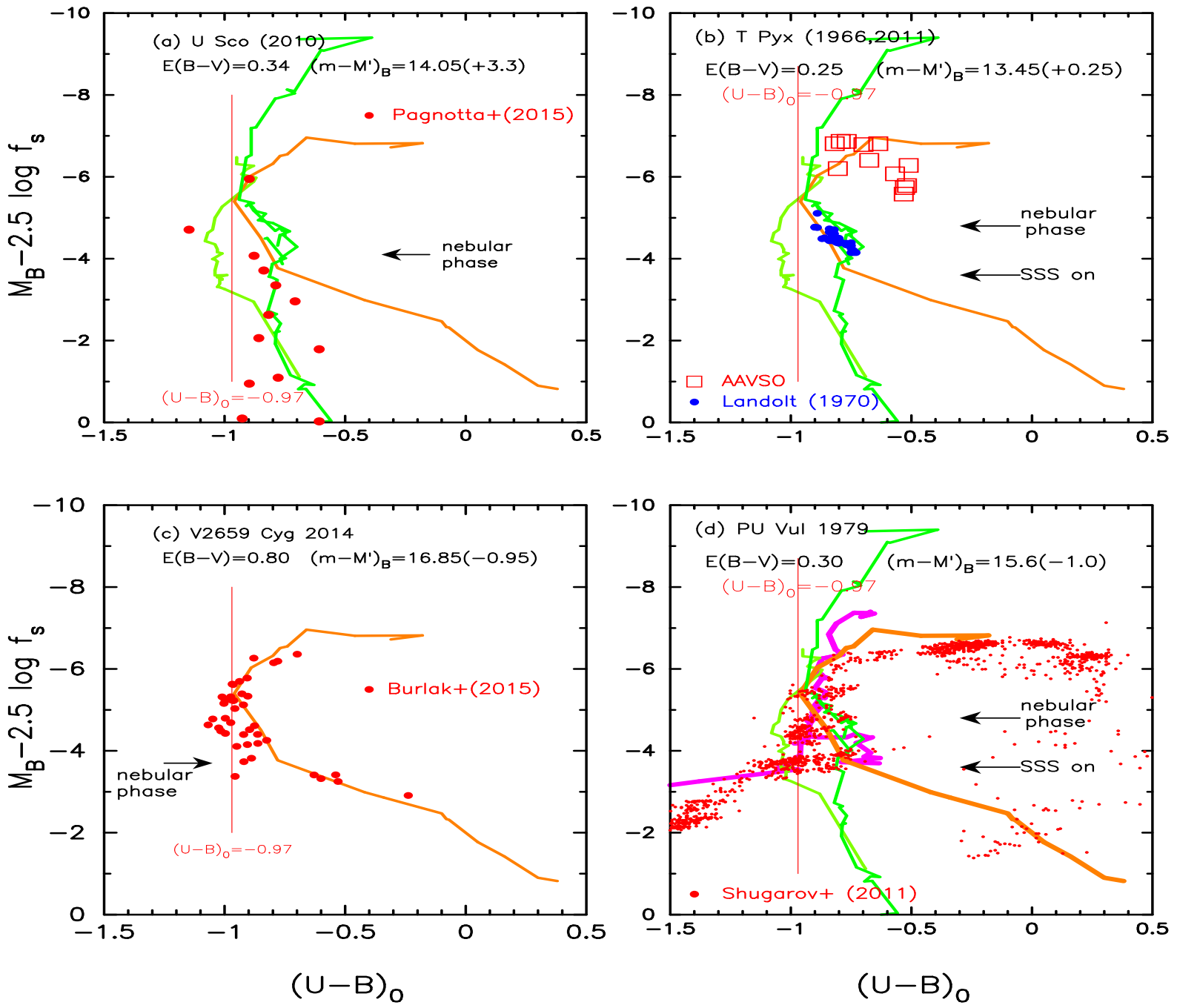


PW Vul, V1419 Aql, V382 Vel, V5114 Sgr

○ U-B color vs. B magnitude

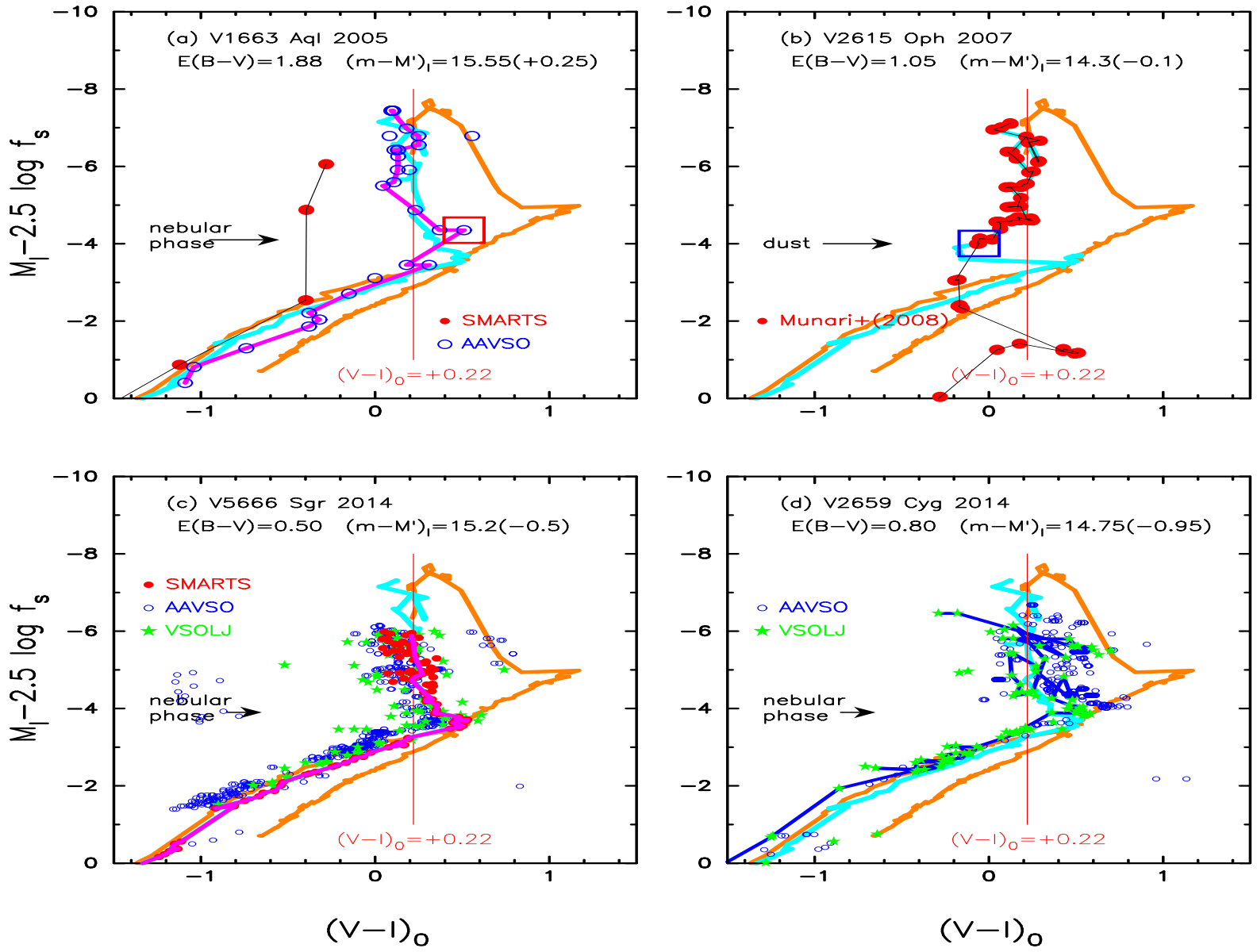


U Sco, T Pyx, V2659 Cyg, PU Vul

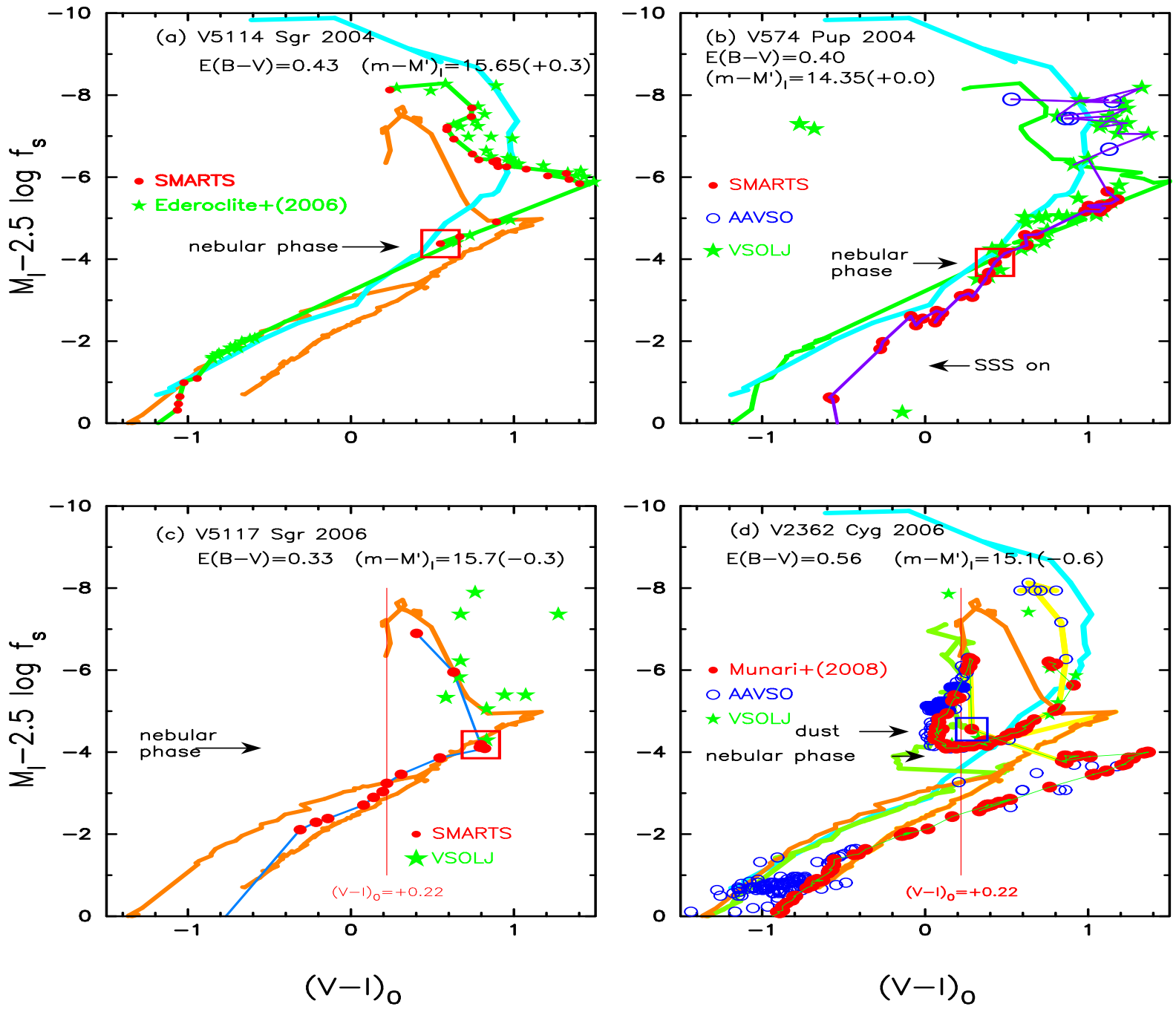


V1663 Aql, V2615 Oph, V5666 Sgr, V2659 Cyg

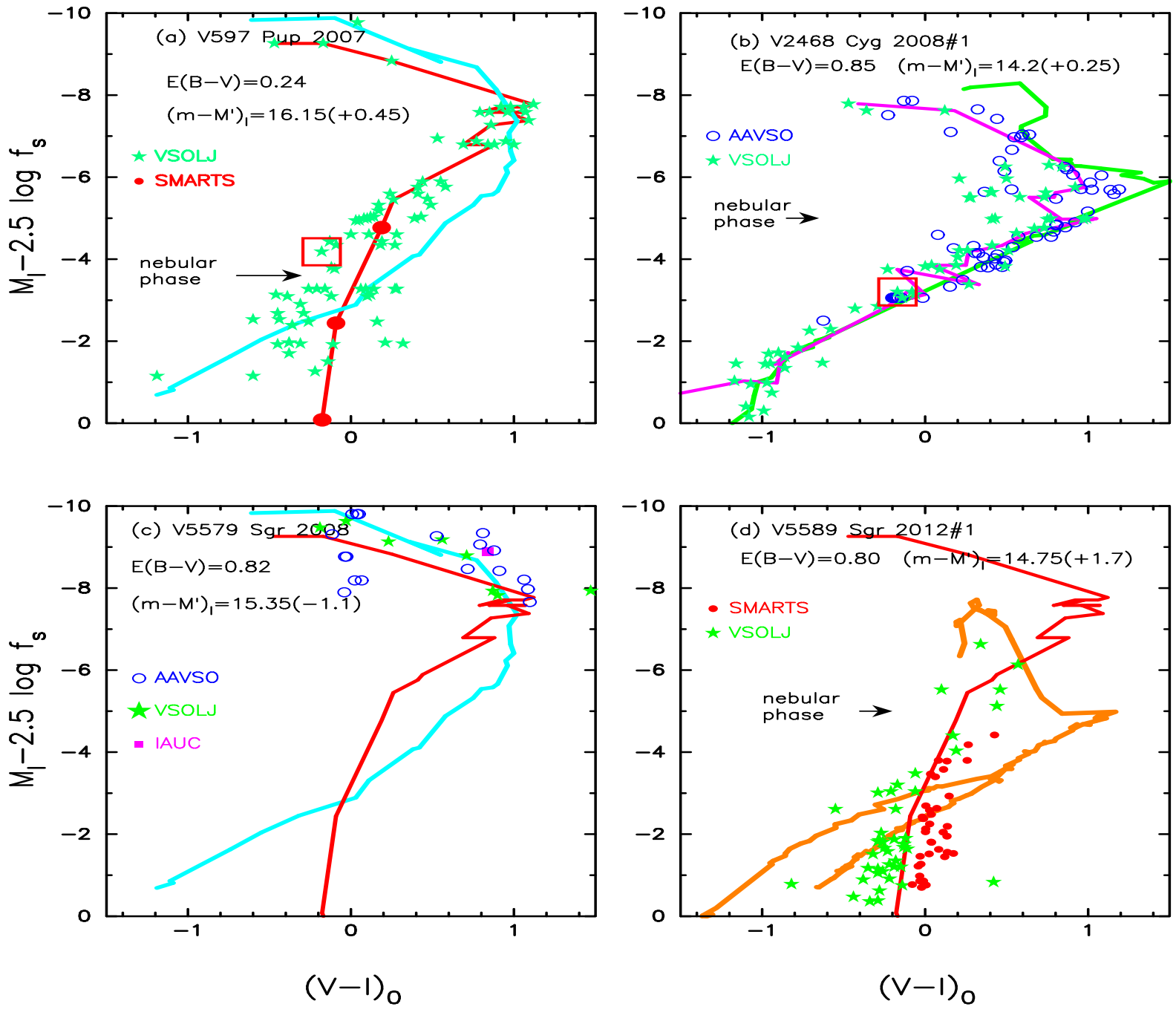
○ V-I color vs. I magnitude



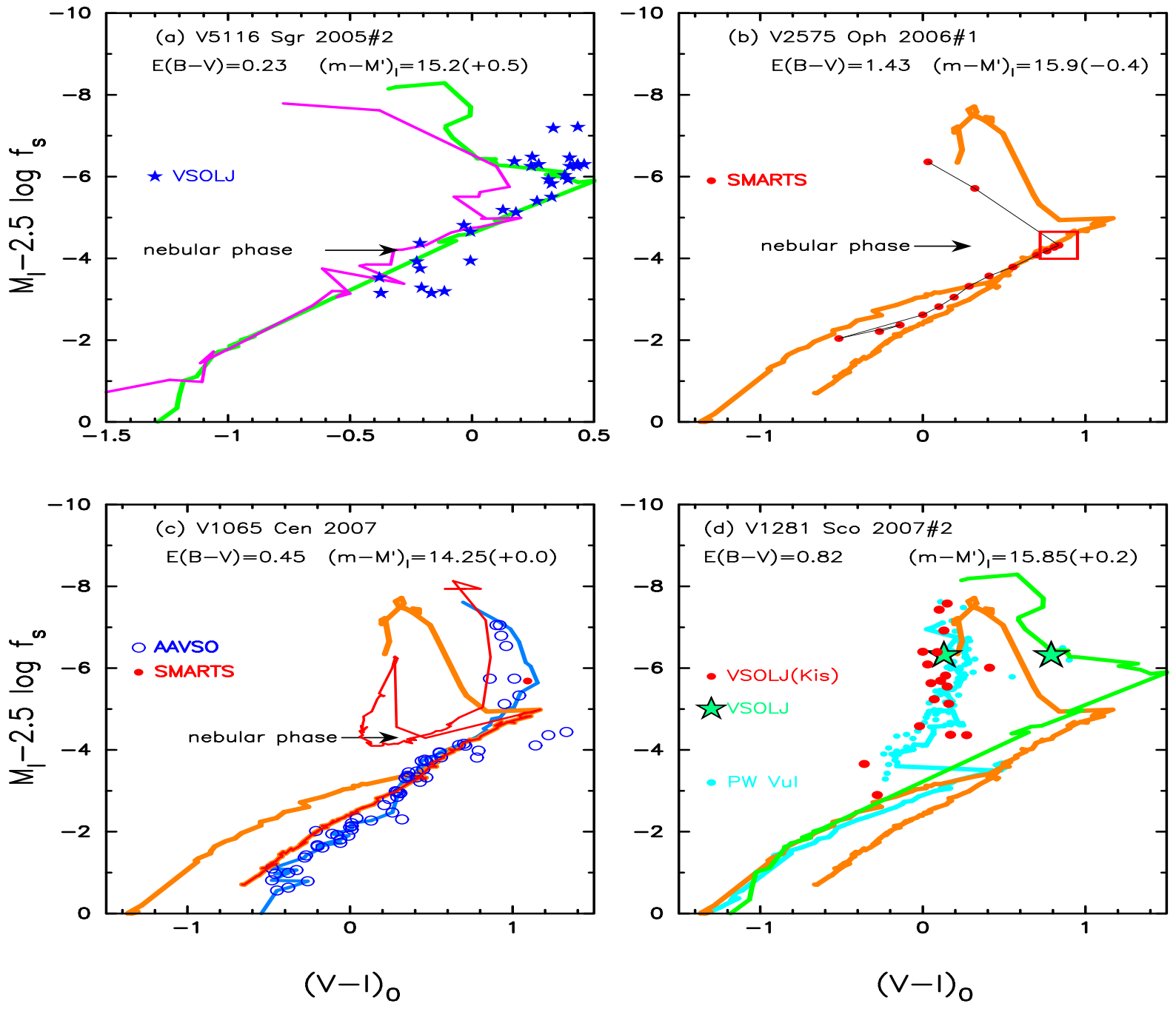
V5114 Sgr, V574 Pup, V5117 Sgr, V2362 Cyg



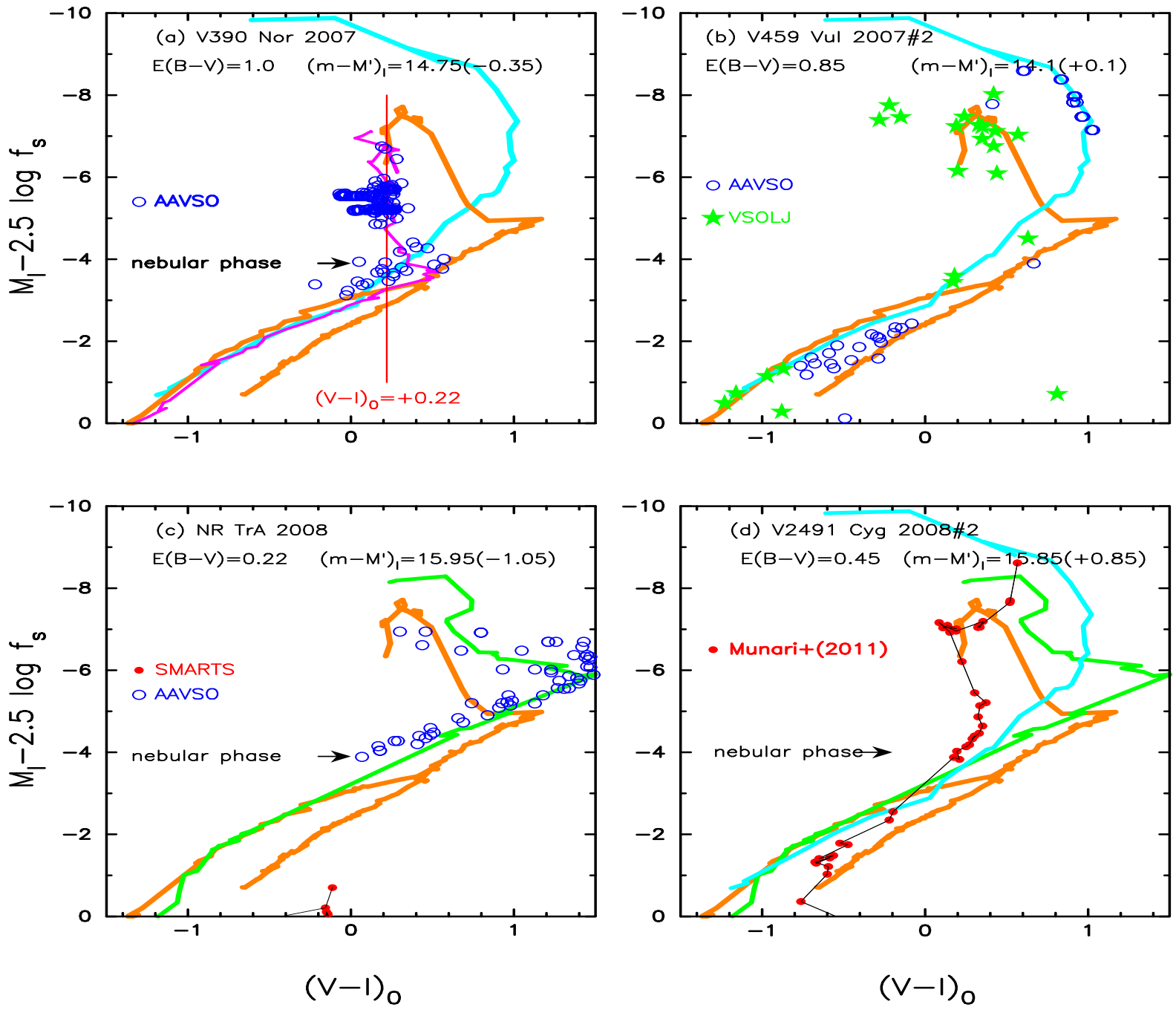
V597 Pup, V2468 Cyg, V5579 Sgr, V5589 Sgr



V5116 Sgr, V2575 Oph, V1065 Cen, V1281 Sco



V390 Nor, V459 Vul, NR TrA, V2491 Cyg



古典新星の色等級図のまとめ

１.可視光および近赤外線の光度曲線

→ **free-free emission** モデル近似で再現できる

→ **universal decline law** の存在

→ **stretching factor (fs)** で絶対等級の決定

２.２色図中の一般的な進化経路とのフィット

→ **E(B-V)**の決定

３.色等級図中の進化経路のフィット

→ 横軸で**E(B-V)**、縦軸で絶対等級、距離決定

４．　１と２と３の組合せで精度向上**(70**個の新星**)**

時間スケールと白色矮星質量