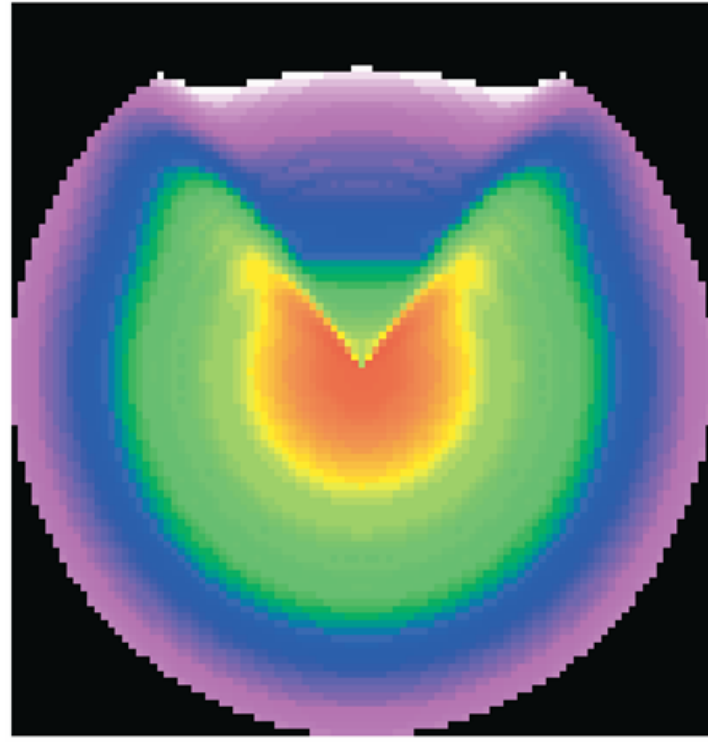


# Type Ia Supernovae: What has Polarimetry Taught Us?

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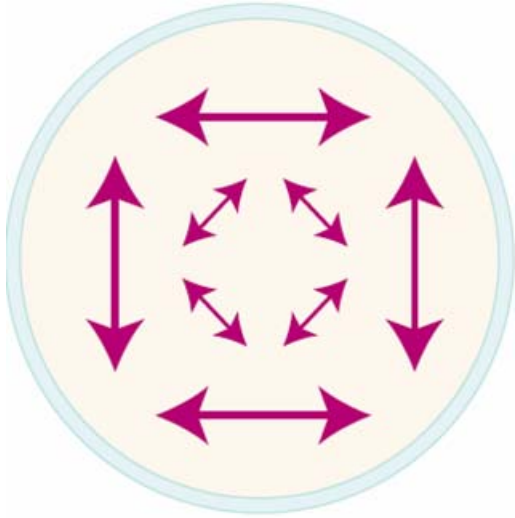


(Image: Kasen et al. 2004)

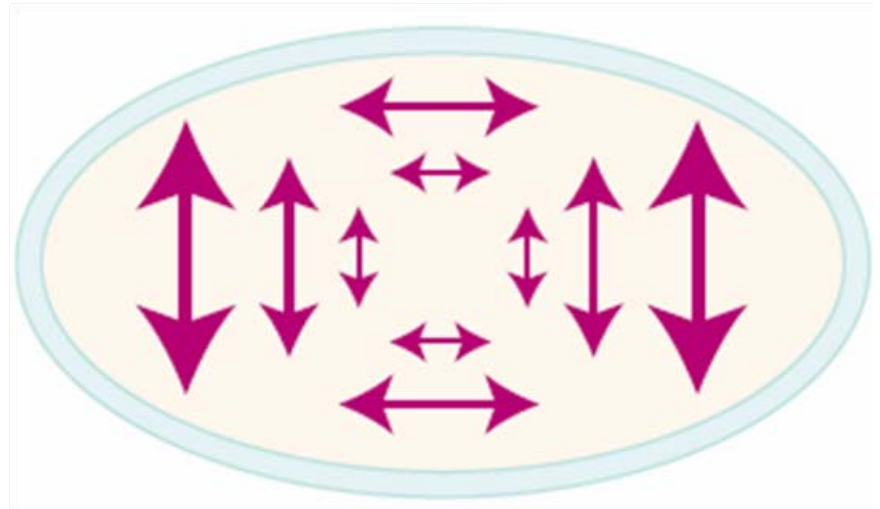
## Douglas Leonard

Department of Astronomy, San Diego State University

**Spherical  $P_{\text{net}} = 0\%$**



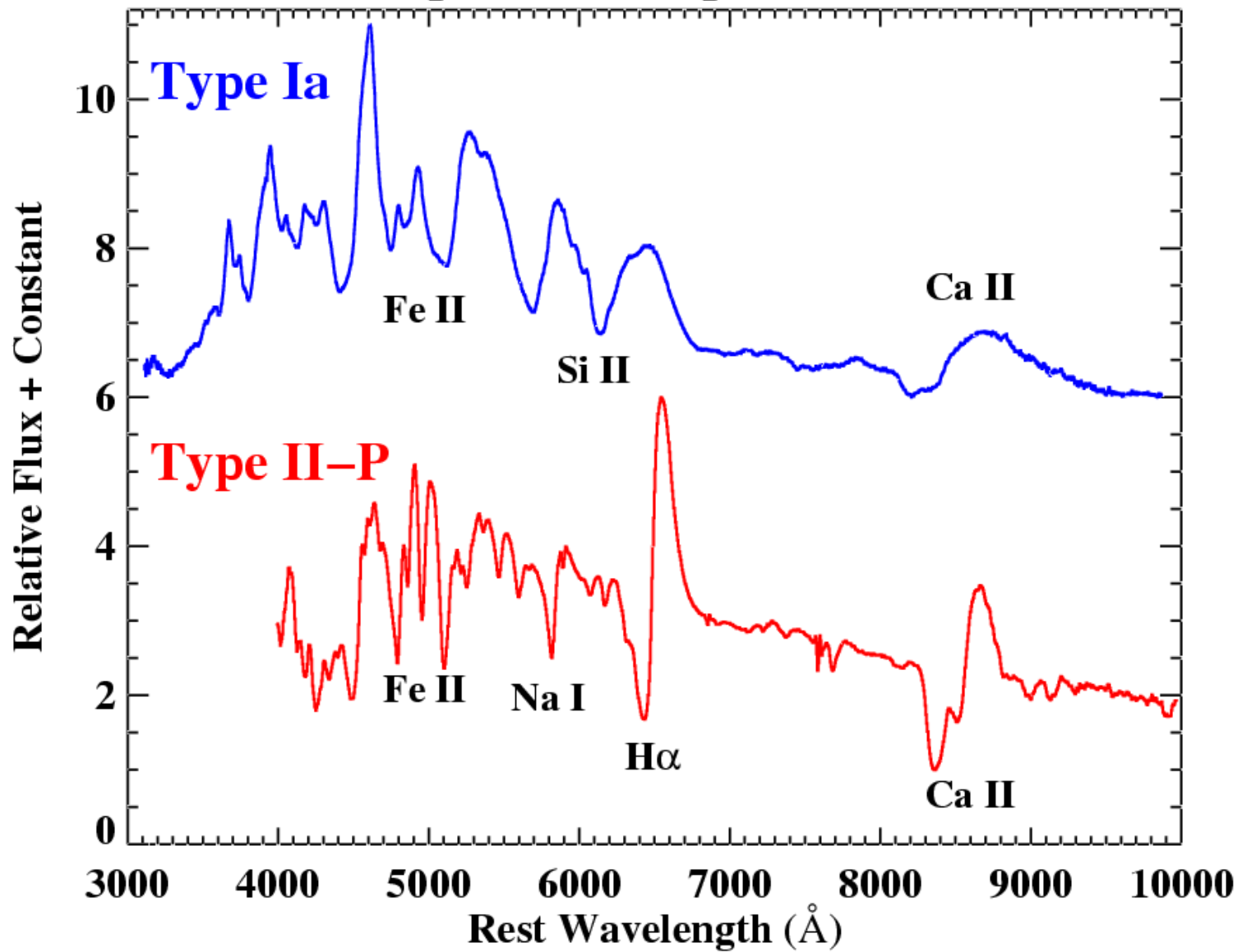
**Aspherical  $P_{\text{net}} > 0\%$**



(Image: Leonard 2007, Science, 315, 193)

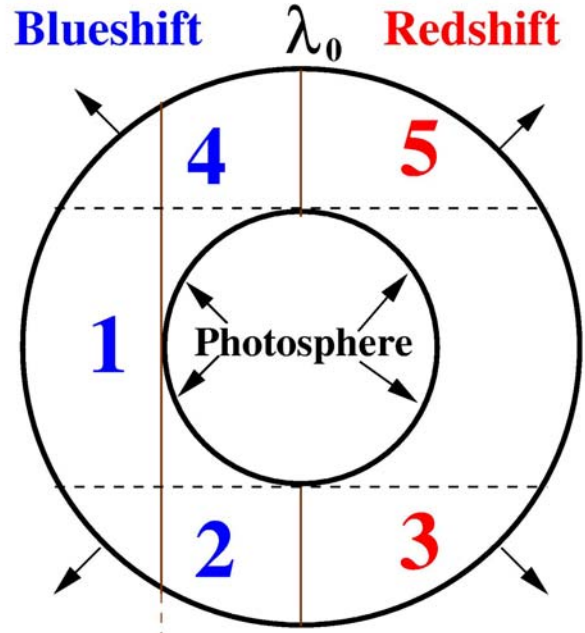
 = Direction of electric vector in plane of sky

# Spectra of Supernovae

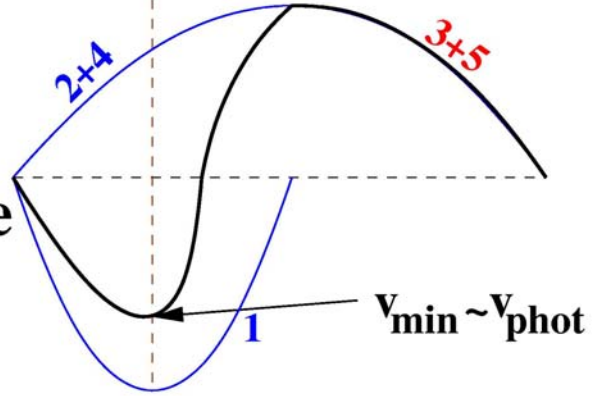


# P-Cygni Line Formation

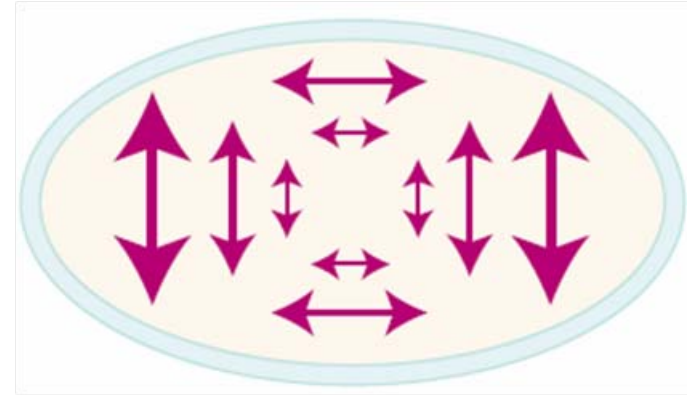
Observer  

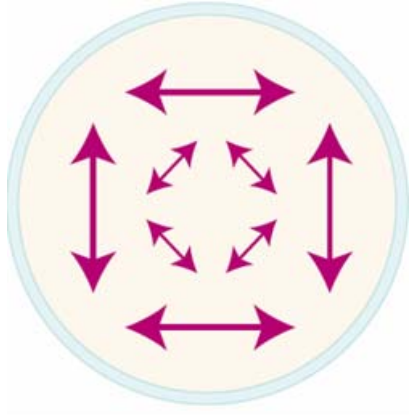
Resulting  
P-Cygni Profile



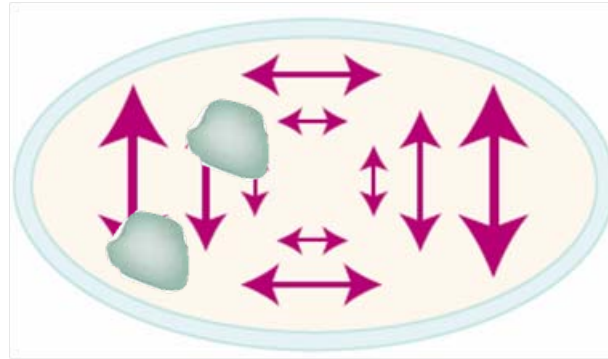
Aspherical  $P_{\text{net}} > 0\%$



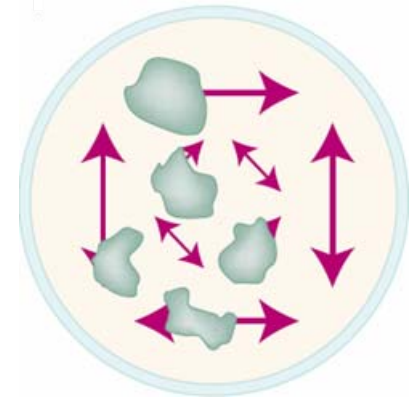
**Spherical  $P_{\text{net}} = 0\%$**



**Aspherical  $P_{\text{net}} > 0\%$**



**Clumpy Ejecta**



(Image: Leonard 2007, Science, 315, 193)

 = Direction of electric vector in plane of sky

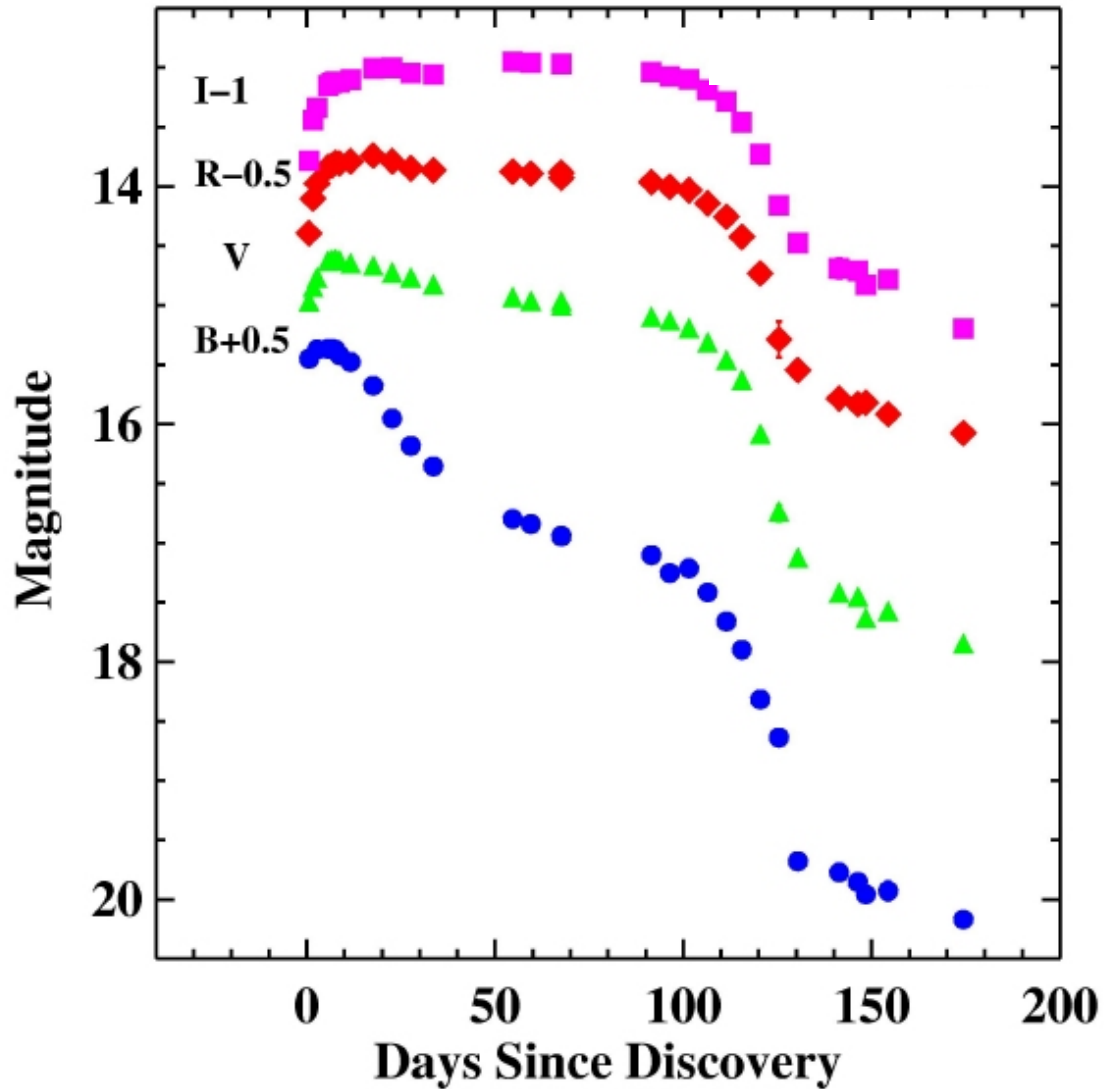
**Global asphericity: Continuum + line trough polarization (at same PA)**

**Clumpy ejecta: No continuum polarization + line trough polarization**

**Global asphericity and clumpy ejecta:**

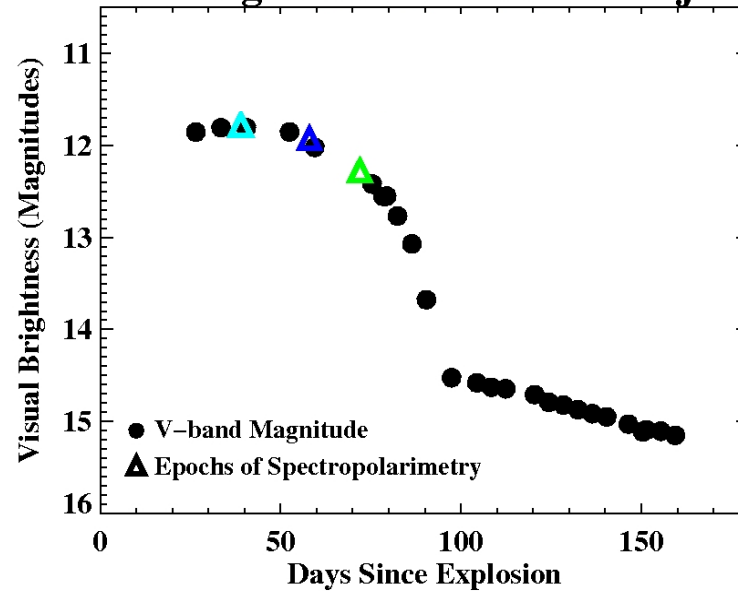
**Continuum + line trough polarization (at different PA)**

# Type II-Plateau Supernova

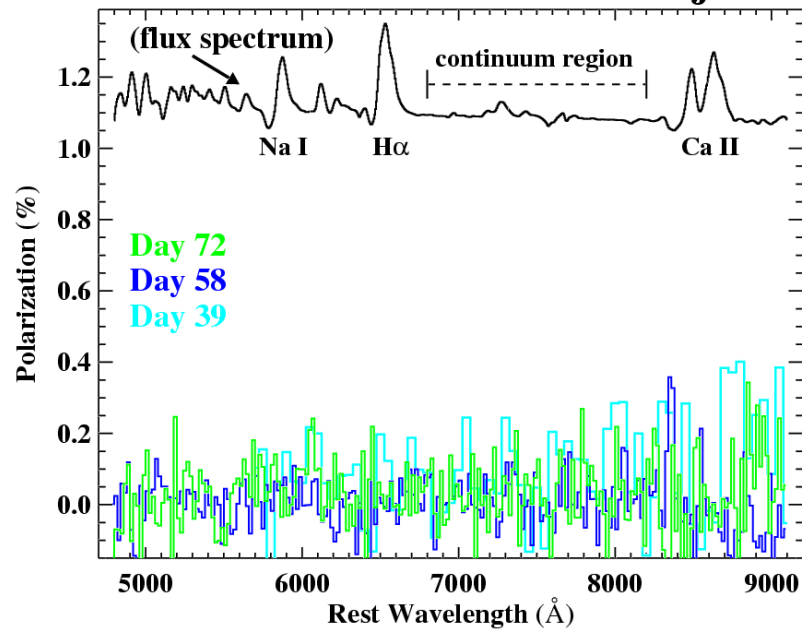


(Leonard et al. 2002)

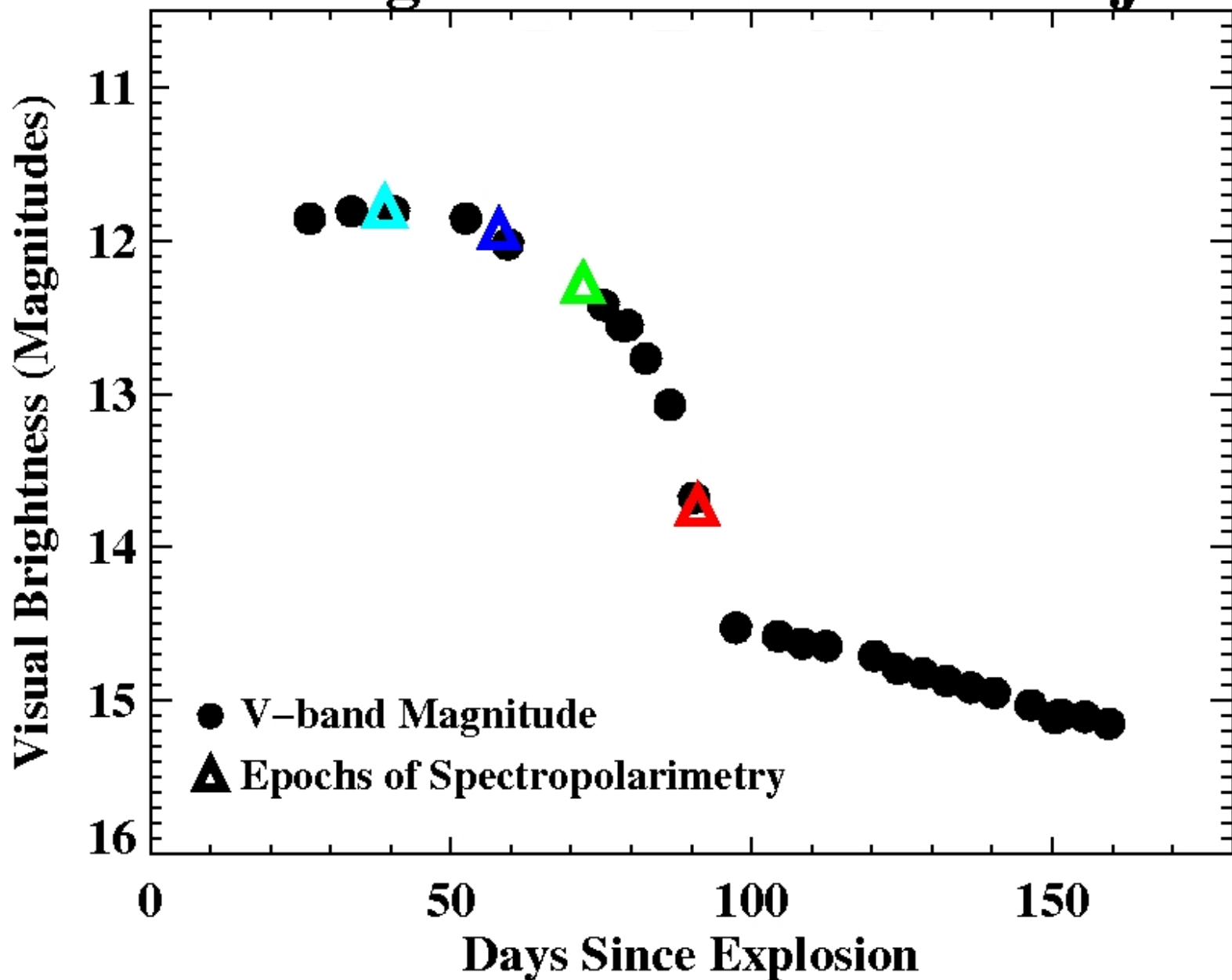
## Light Curve of SN 2004dj



## Polarization of SN 2004dj

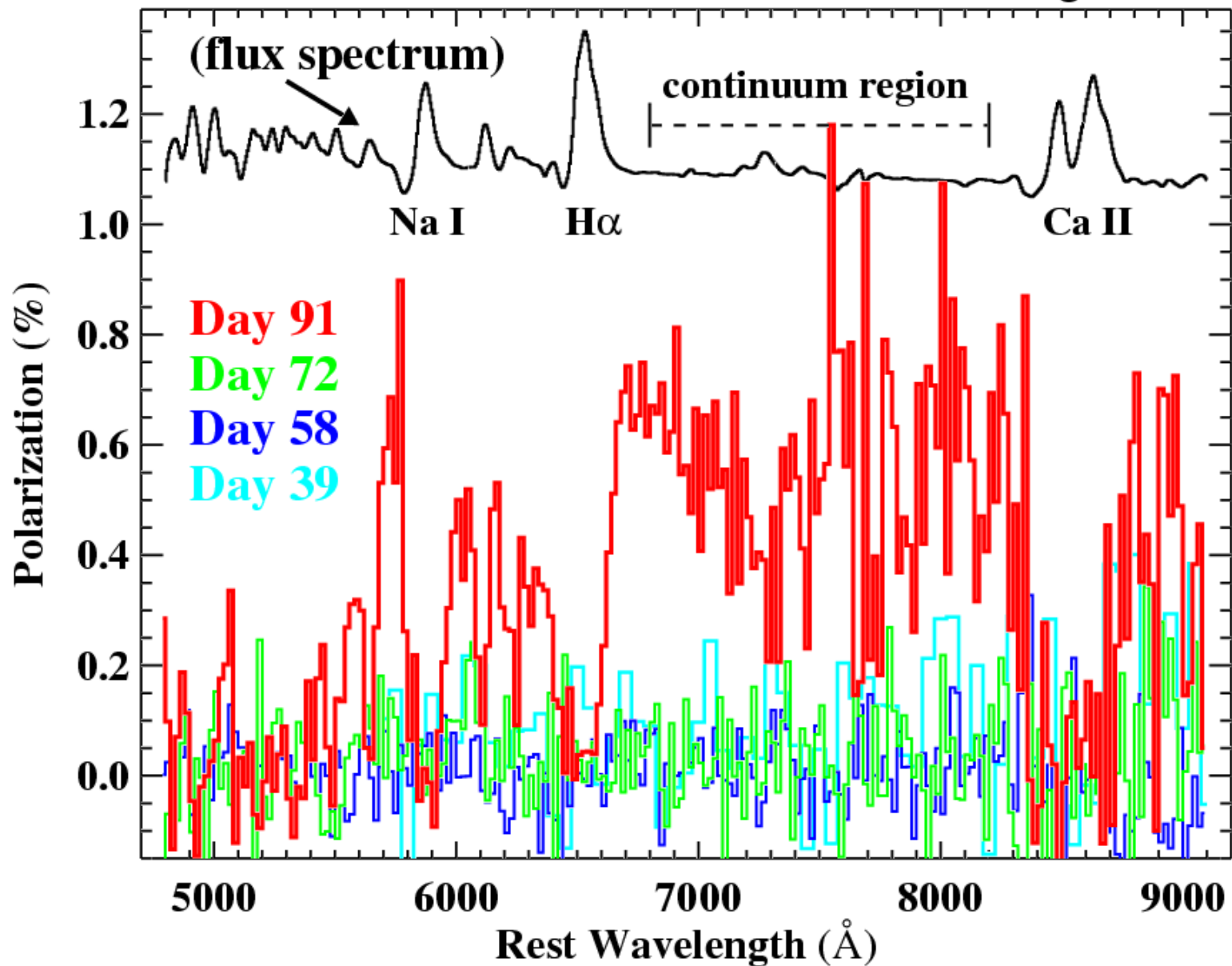


# Light Curve of SN 2004dj

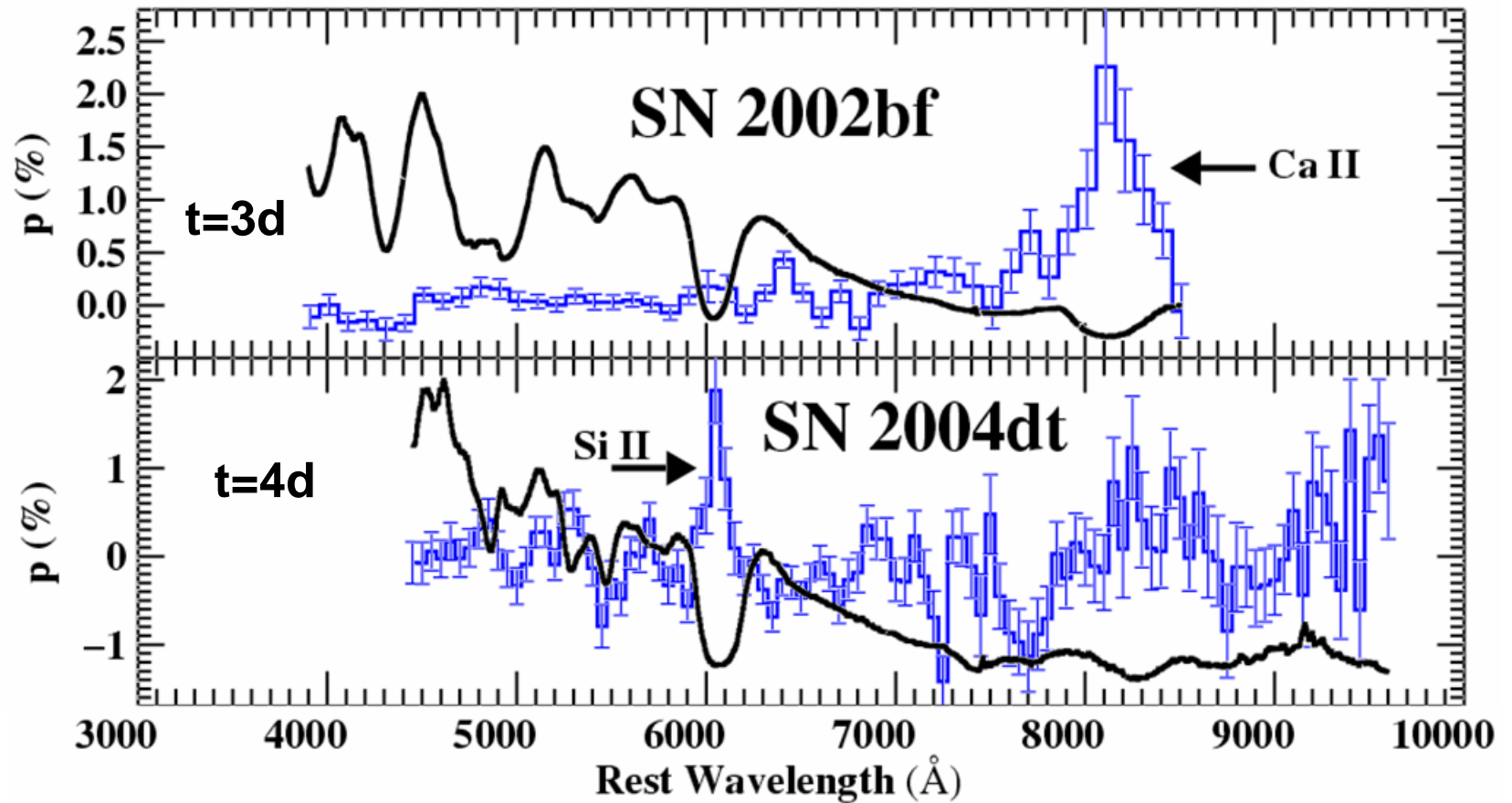




# Polarization of SN 2004dj

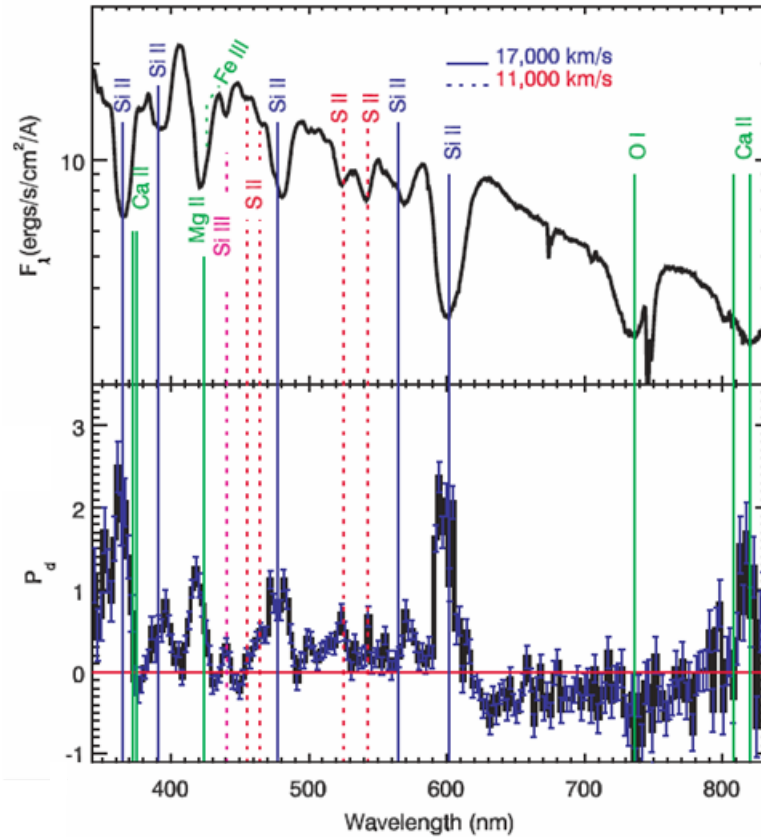


# Spectropolarimetry of SNe Ia



(Leonard et al. 2005)

# Pre-Maximum Spectropolarimetry of SN 2004dt



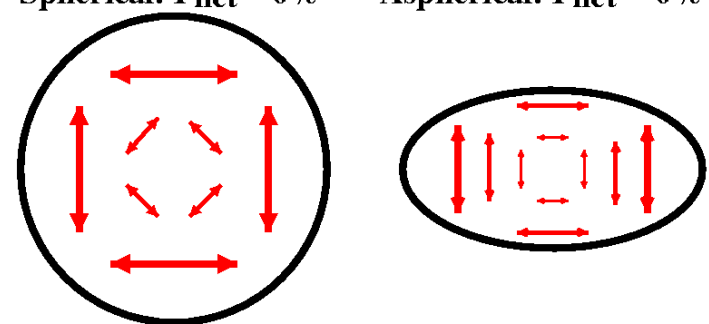
**t = -7d**

**(Wang et al. 2006)**

# Spectropolarimetry of Type Ia Supernovae

<b>Supernova</b>	<b>Reference</b>	<b>Notes</b>
SN 1996X	Wang et al. 1997	Slightly subluminous
SN 1997dt	Leonard et al. 2000, 2004	Normal
SN 1999by	Howell et al. 2001	Subluminous
SN 2001el	Kasen et al. 2003 Wang et al. 2003	Normal
SN 2002bf	Leonard et al. 2005	High velocity lines
SN 2003du	Leonard et al. 2005	Slightly overluminous
SN 2004S	Chornock & Filippenko 2007	Normal
SN 2004dt	Leonard et al. 2005 Wang et al. 2006	High velocity lines
SN 2005hk	Chornock et al. 2007	Peculiar

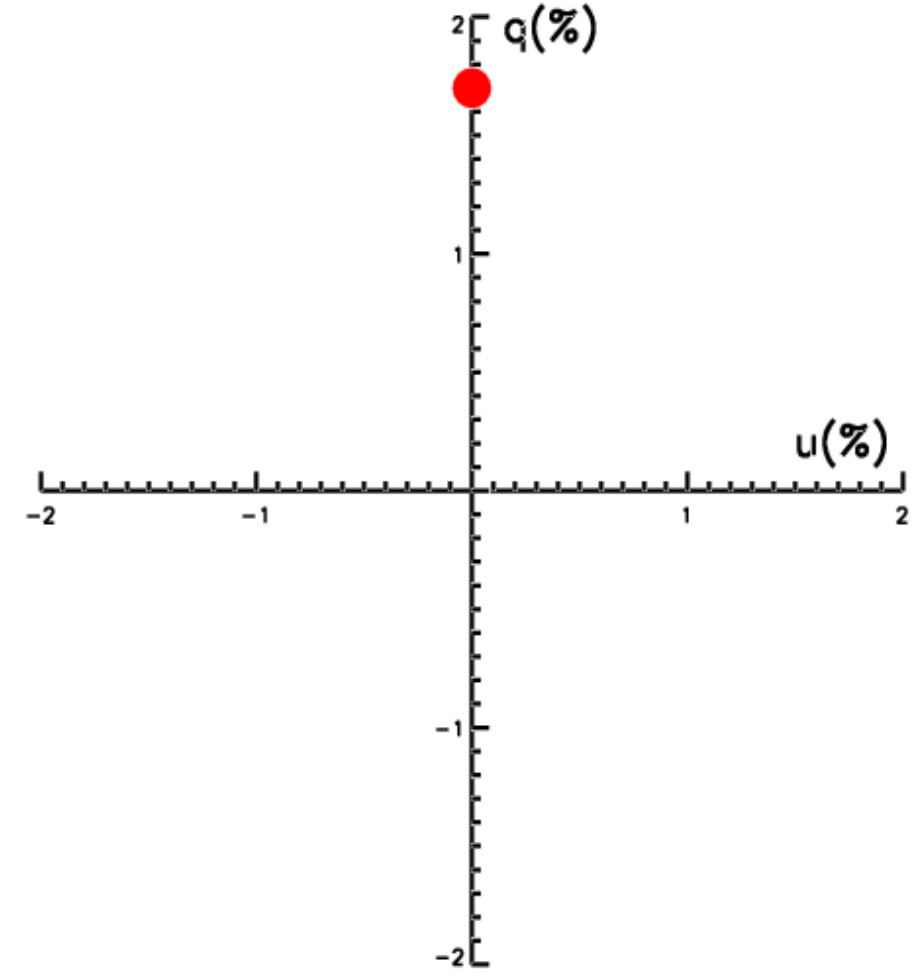
Spherical:  $P_{\text{net}} = 0\%$       Aspherical:  $P_{\text{net}} > 0\%$



$\longleftrightarrow$  = Direction of electric vector in plane of sky

$$q = \frac{\begin{array}{c} \updownarrow - \longleftrightarrow \\ \updownarrow + \longleftrightarrow \end{array}}{\quad}$$

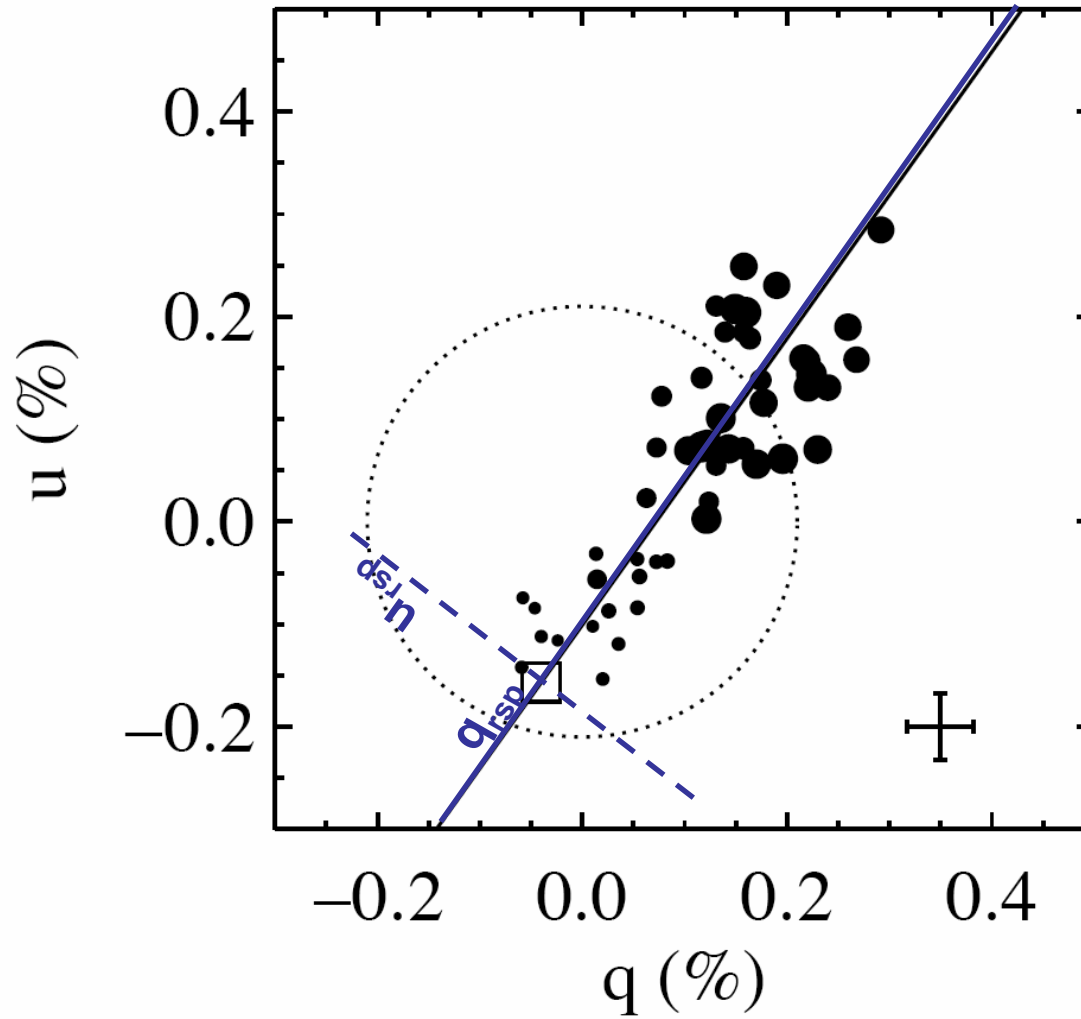
$$u = \frac{\begin{array}{c} \swarrow - \searrow \\ \swarrow + \searrow \end{array}}{\quad}$$



$$p = \sqrt{q^2 + u^2}$$

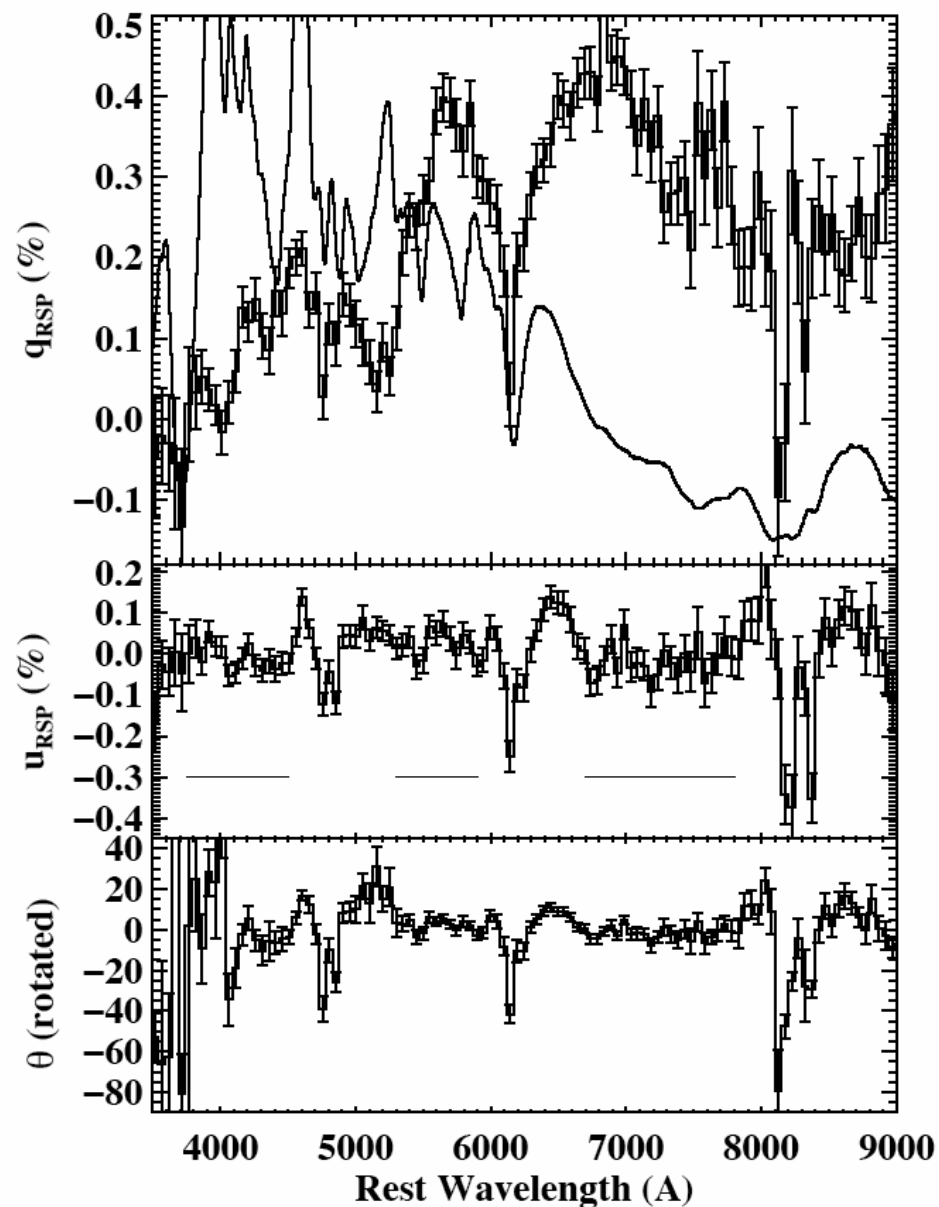
$$\theta = \frac{1}{2} \tan^{-1} \left( \frac{u}{q} \right)$$

# SN 2004S: Data in the q-u Plane



(Chornock & Filippenko 2007)

# SN 2004S: Derived Spectropolarimetry



(Chornock & Filippenko 2007)

# Type Ia Supernovae: What has Polarimetry Taught Us?

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- **Observations:** Low continuum polarization, with a range of line polarization strength.
- **Simplest Interpretation:**
  - **Photospheres:** Minor (~10%), axisymmetric asphericity.
  - **Ejecta:** Geometric distribution of some elements within the ejecta differs from that of the continuum, perhaps due to clumping of newly synthesized elements.



# Spectropolarimetry of Type Ia Supernovae

<b>Supernova</b>	<b>Reference</b>	<b>Notes</b>
SN 1996X	Wang et al. 1997	Slightly subluminous <input type="checkbox"/>
SN 1997dt	Leonard et al. 2000, 2004	Normal <input type="checkbox"/>
SN 1999by	Howell et al. 2001	Subluminous <input type="checkbox"/>
SN 2001el	Kasen et al. 2003 Wang et al. 2003	Normal <input type="checkbox"/>
SN 2002bf	Leonard et al. 2005	High velocity lines <input type="checkbox"/>
SN 2003du	Leonard et al. 2005	Slightly overluminous <input checked="" type="checkbox"/>
SN 2004S	Chornock & Filippenko 2007	Normal <input type="checkbox"/>
SN 2004dt	Leonard et al. 2005 Wang et al. 2006	High velocity lines <input type="checkbox"/> <input type="checkbox"/>
SN 2005hk	Chornock et al. 2007	Peculiar <input type="checkbox"/>
Various	Wang et al. 2007	Si II line study <input type="checkbox"/>

