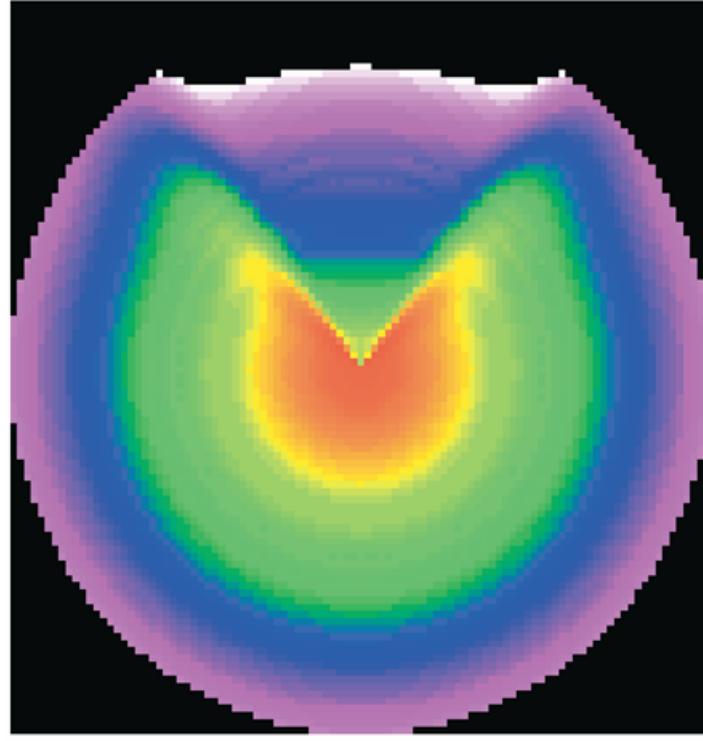


# Type Ia Supernovae: What has Polarimetry Taught Us?

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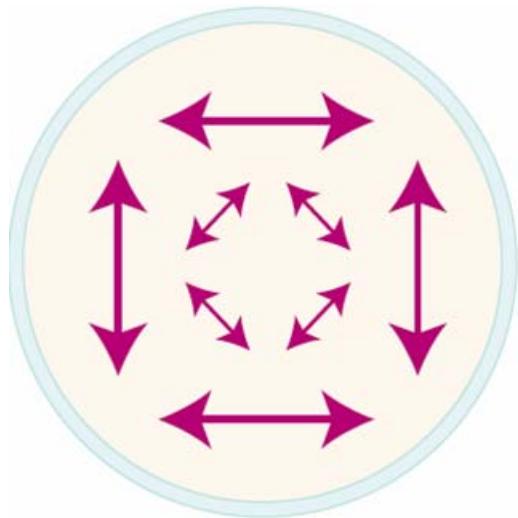


(Image: Kasen et al. 2004)

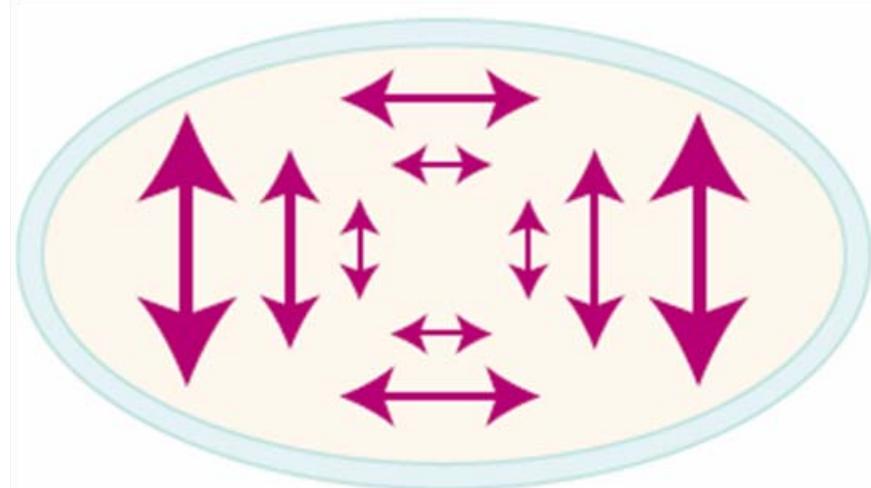
## Douglas Leonard

Department of Astronomy, San Diego State University

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



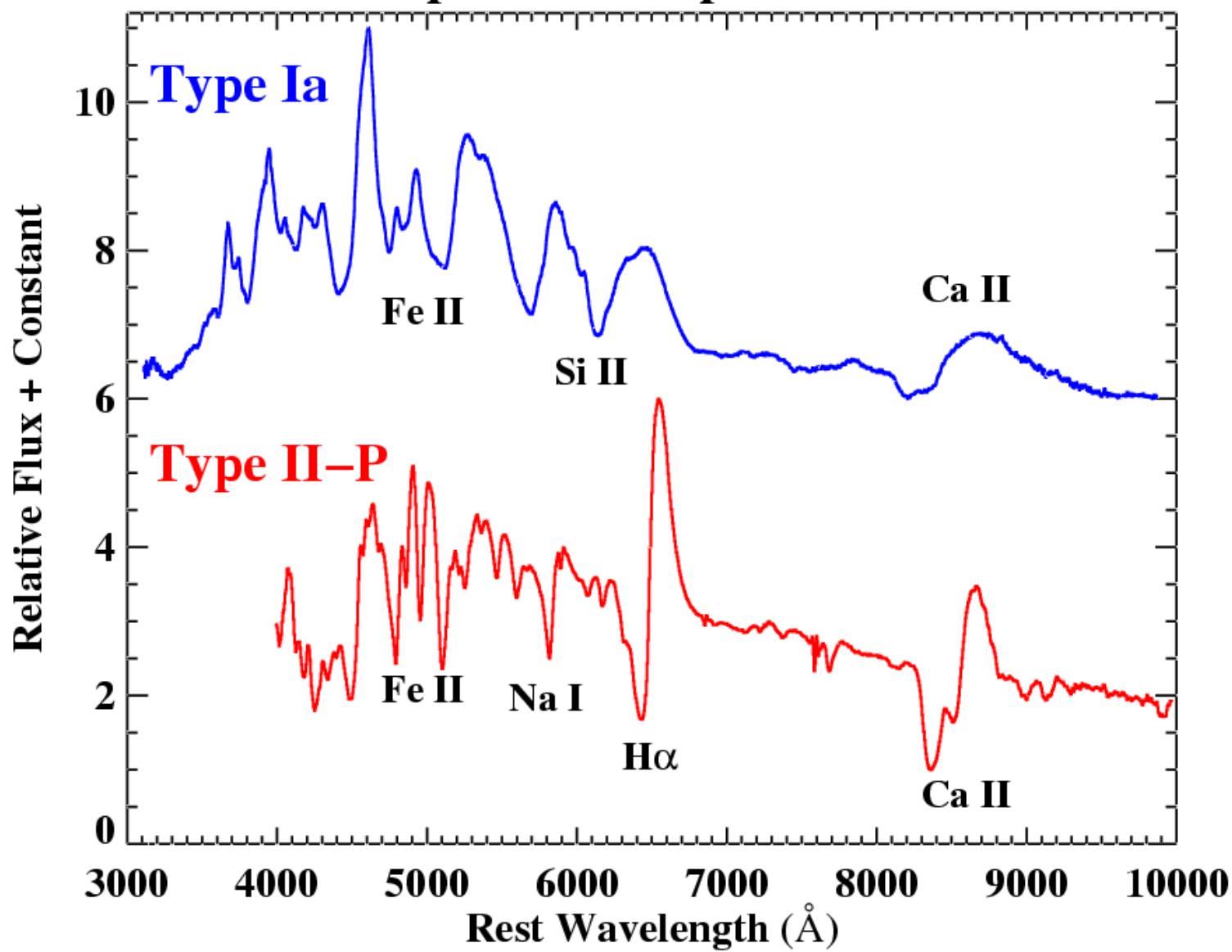
**Aspherical  $P_{\text{net}} > 0\%$**



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

↔ = Direction of electric vector in plane of sky

# Spectra of Supernovae

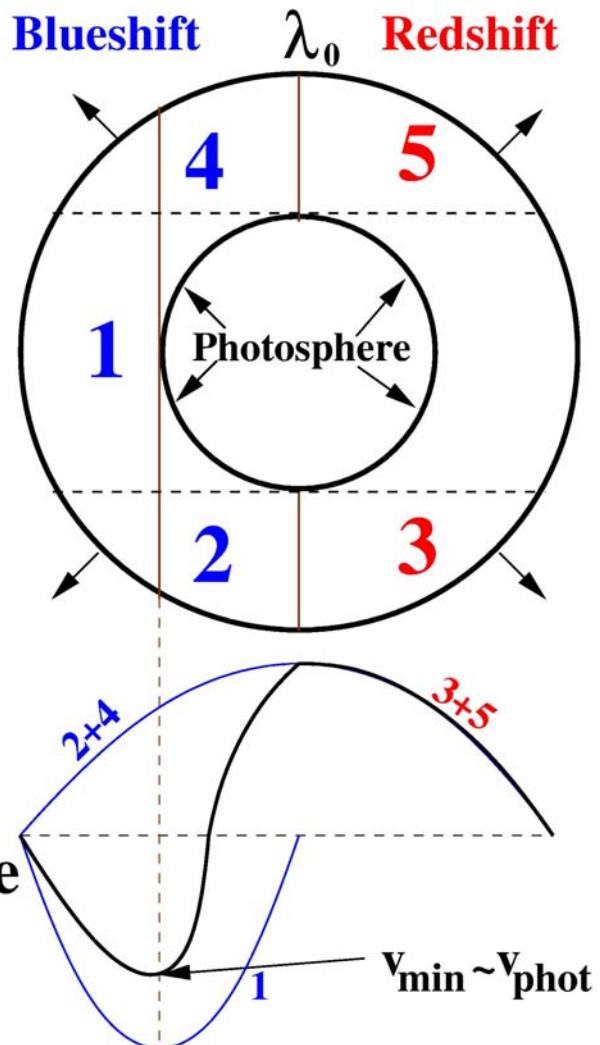


# P-Cygni Line Formation

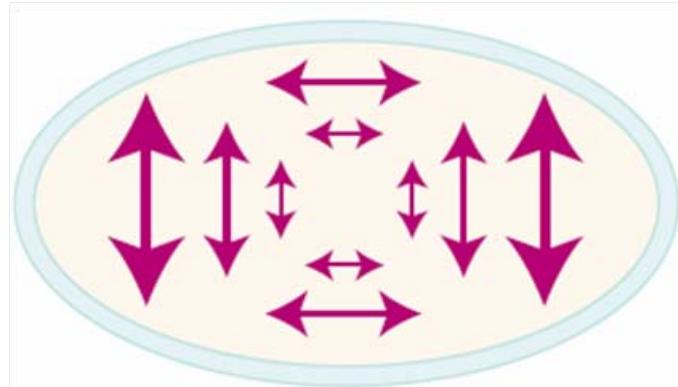
Observer



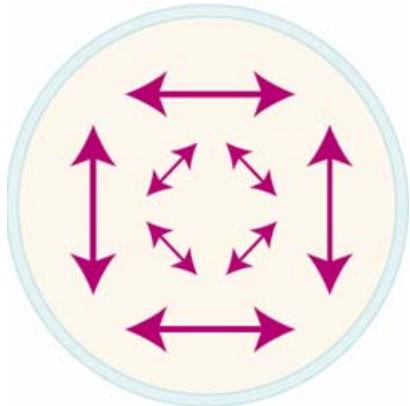
**Resulting  
P-Cygni Profile**



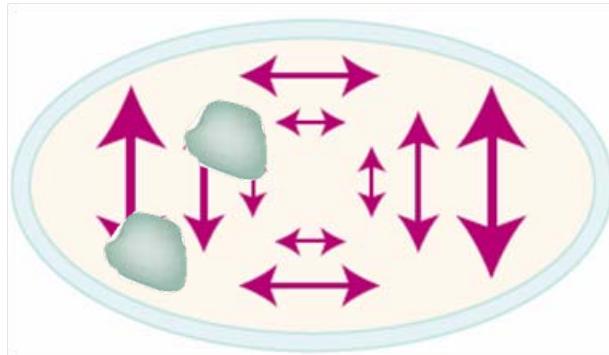
**Aspherical  $P_{\text{net}} > 0\%$**



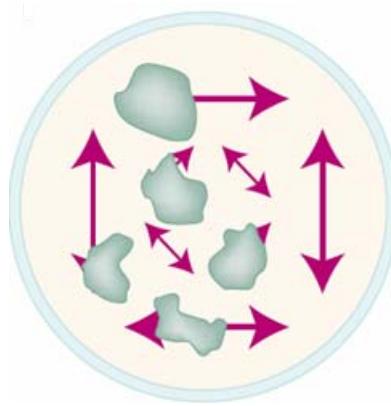
**Spherical  $P_{\text{net}} = 0\%$**



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



**Clumpy Ejecta**



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

↔ = Direction of electric vector in plane of sky

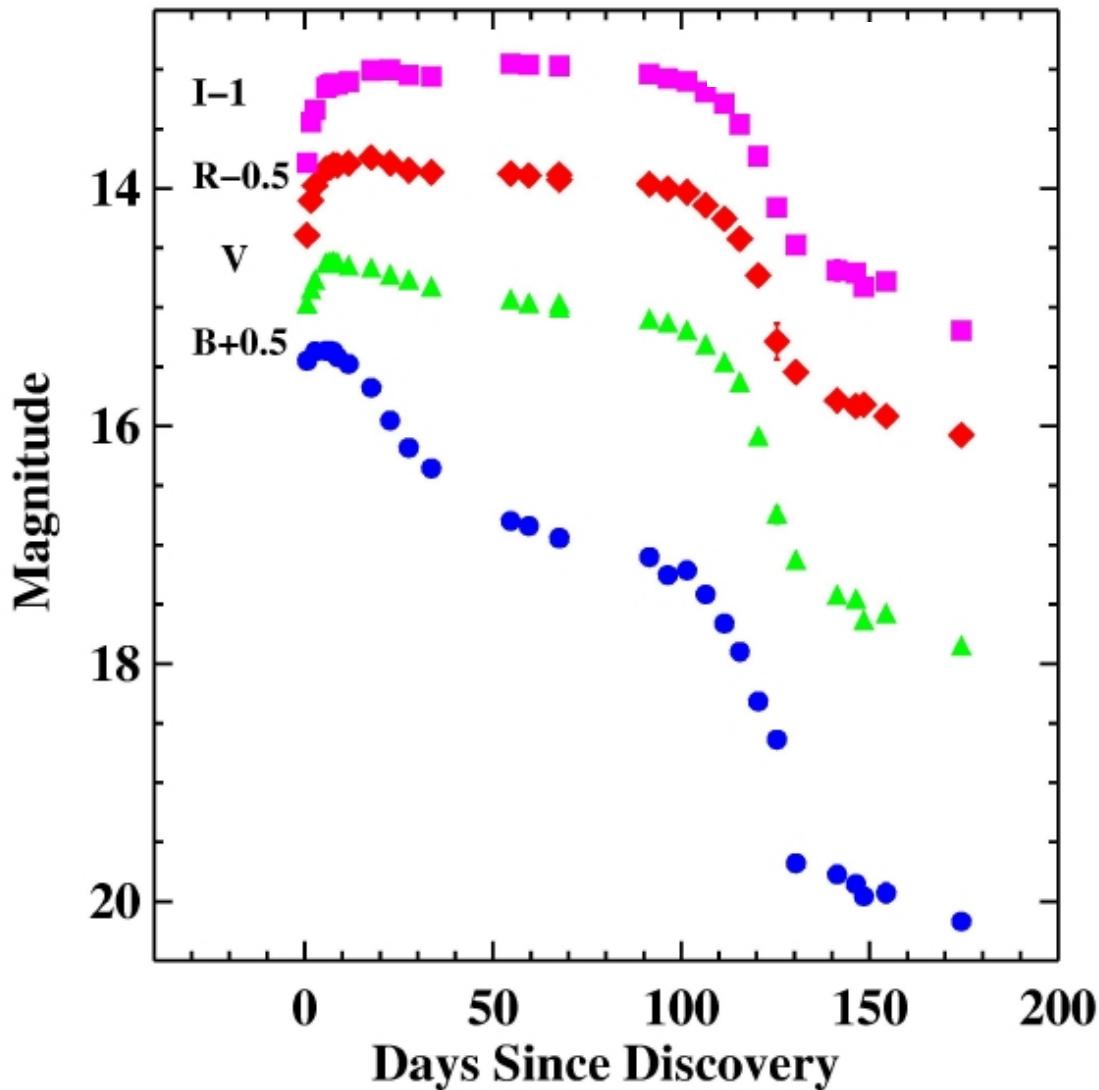
**Global asphericity:** Continuum + line trough polarization (at same PA)

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

**Global asphericity and clumpy ejecta:**

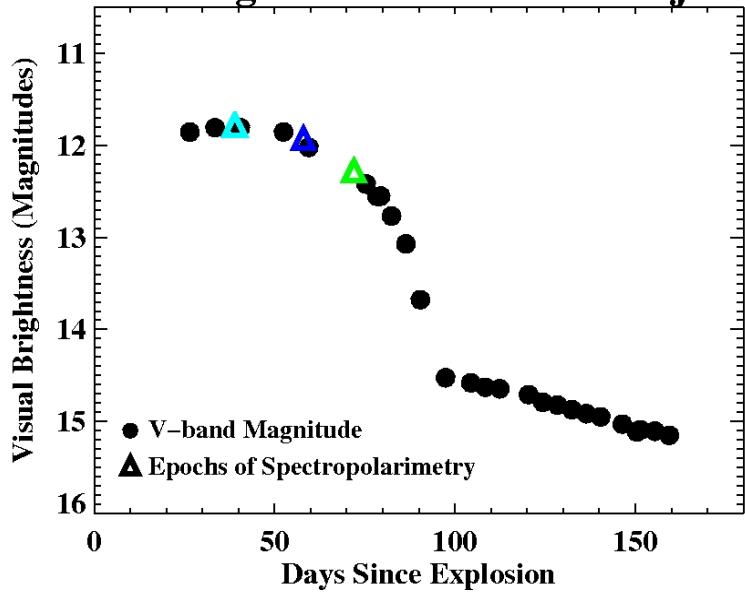
Continuum + line trough polarization (at different PA)

# Type II-Plateau Supernova

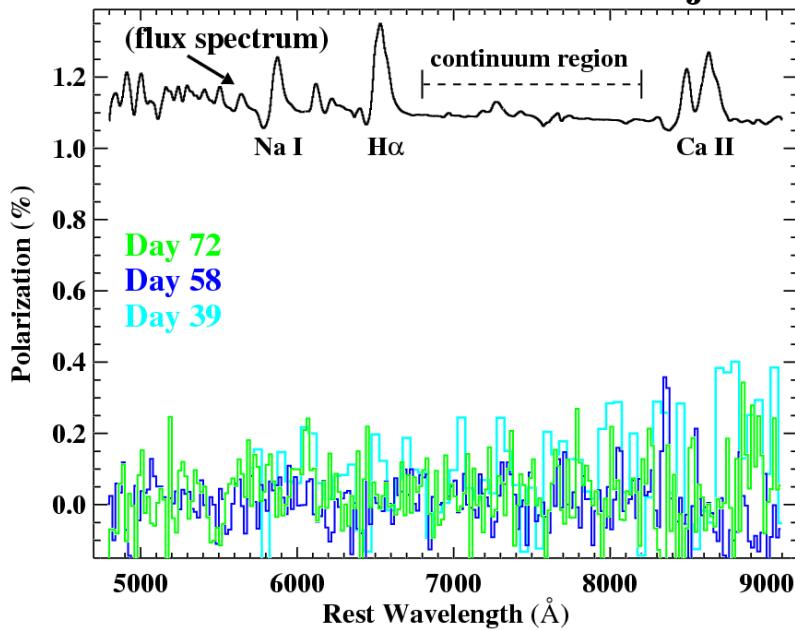


(Leonard et al. 2002)

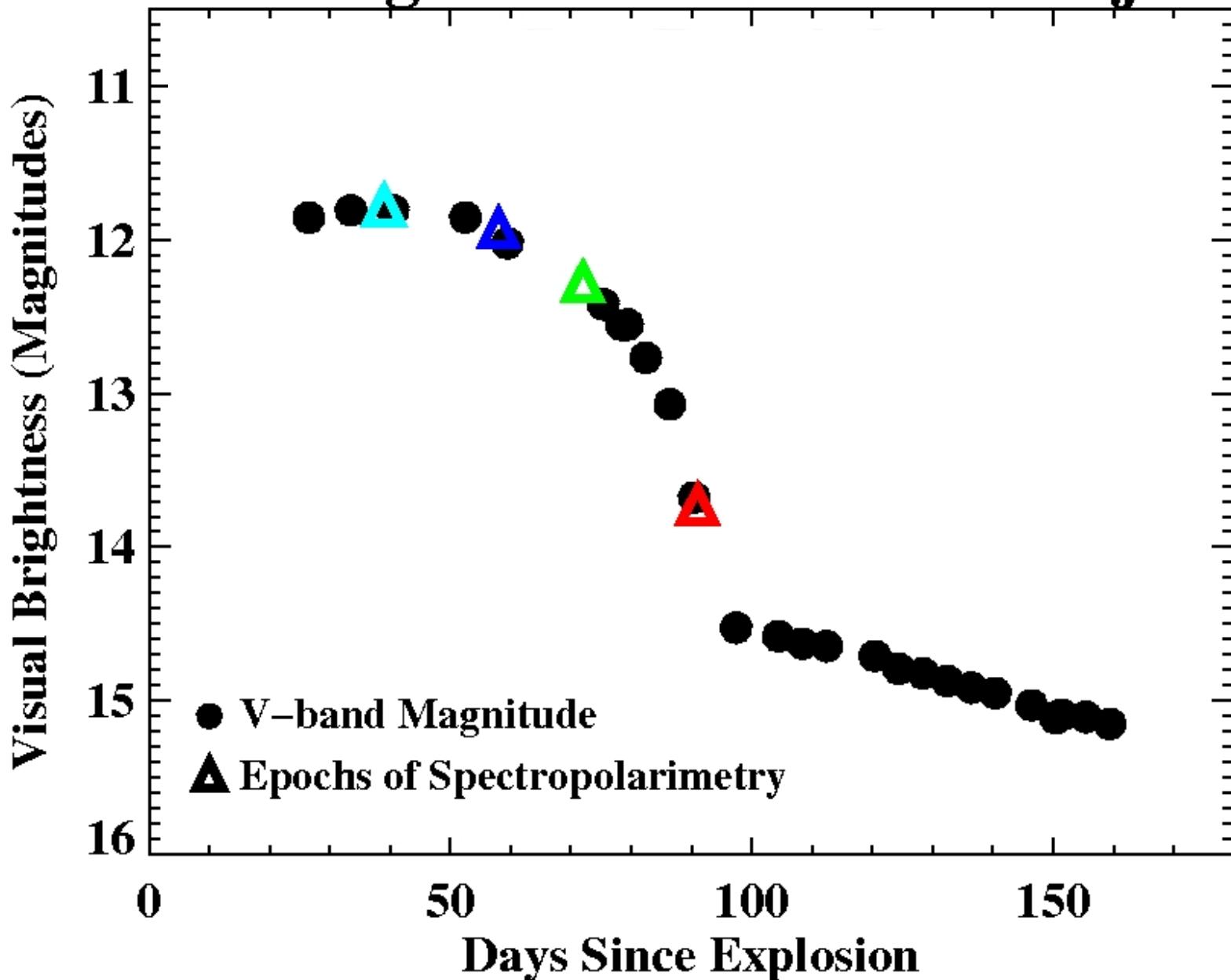
# Light Curve of SN 2004dj



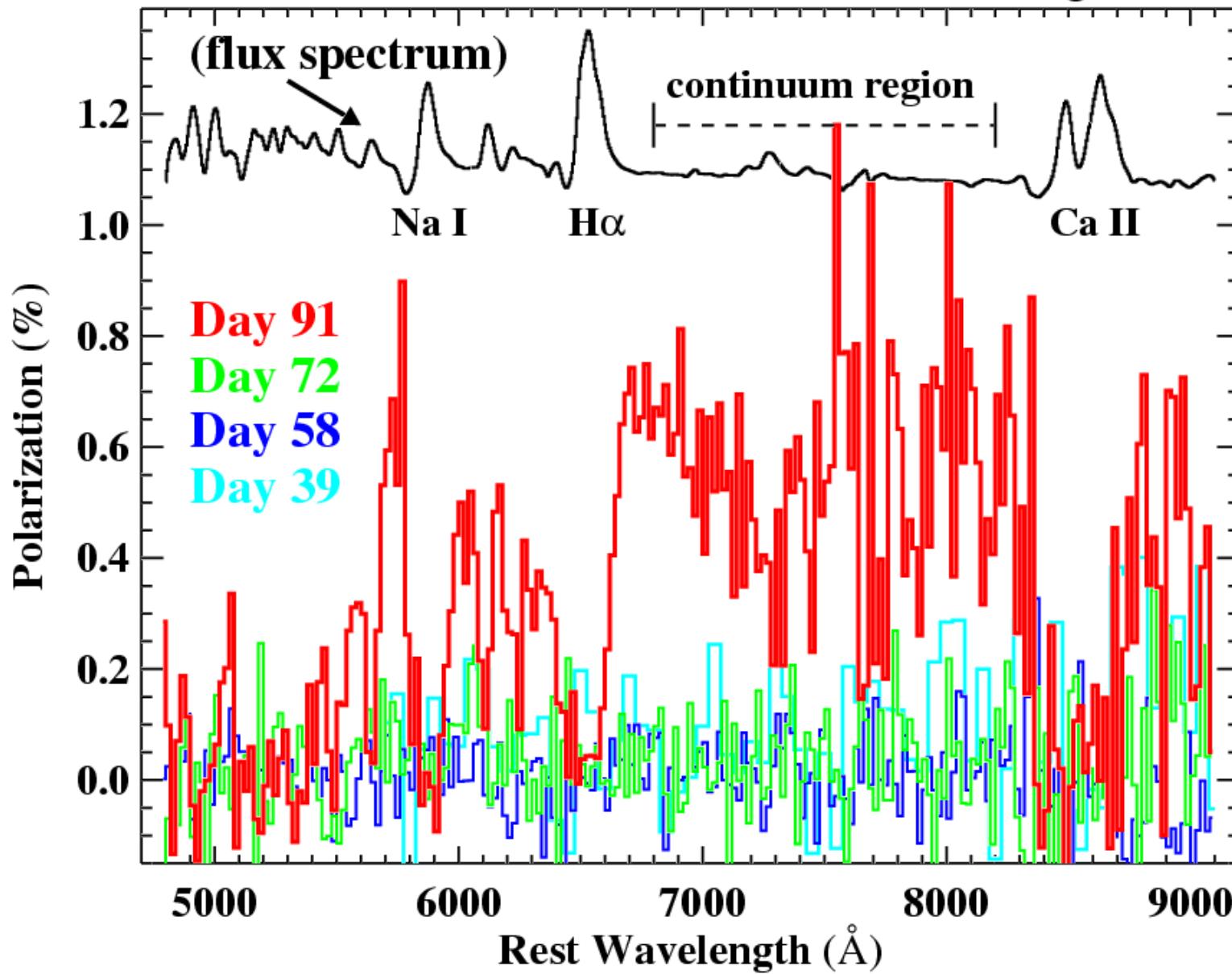
# Polarization of SN 2004dj



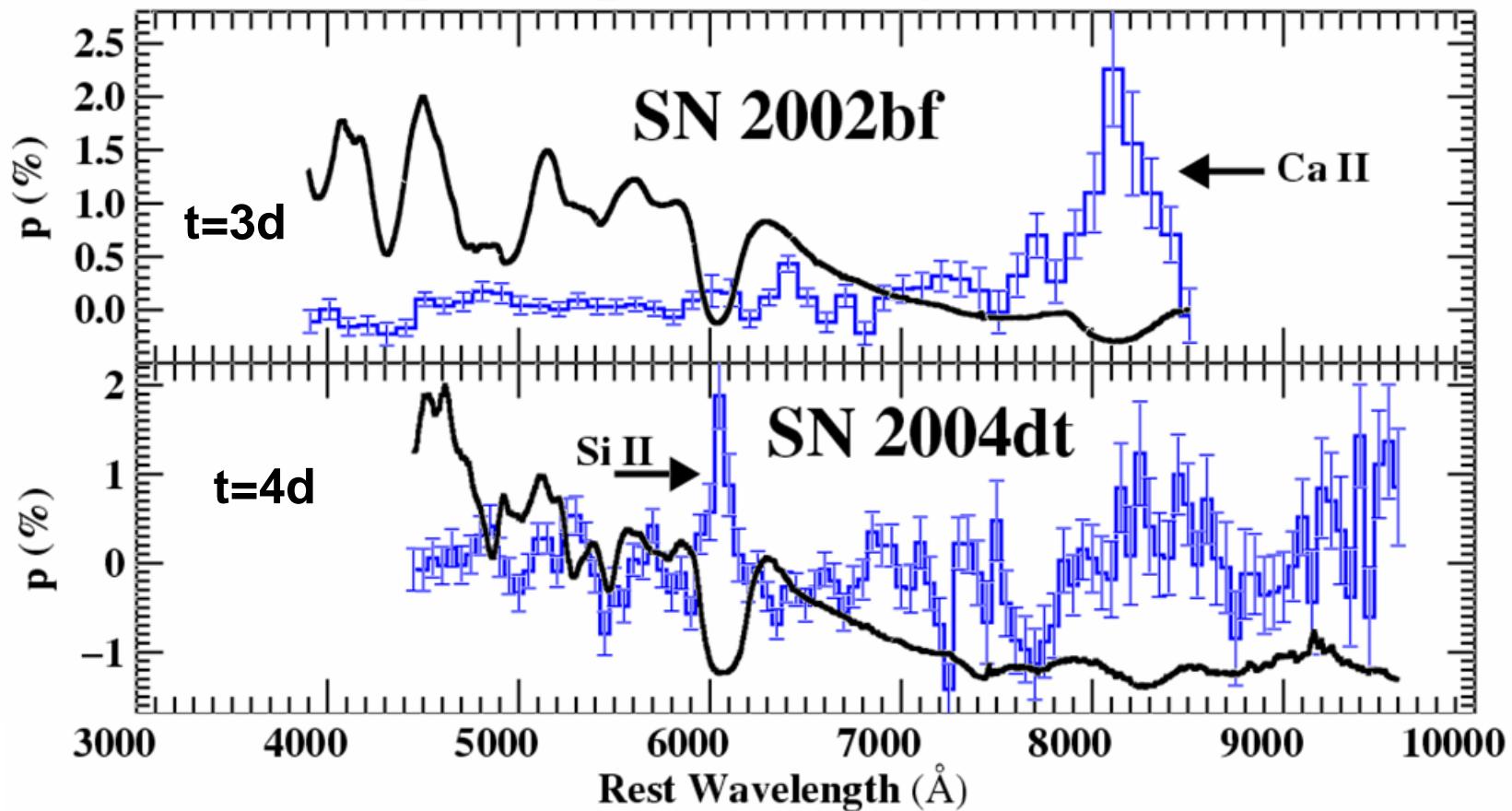
# Light Curve of SN 2004dj



# Polarization of SN 2004dj

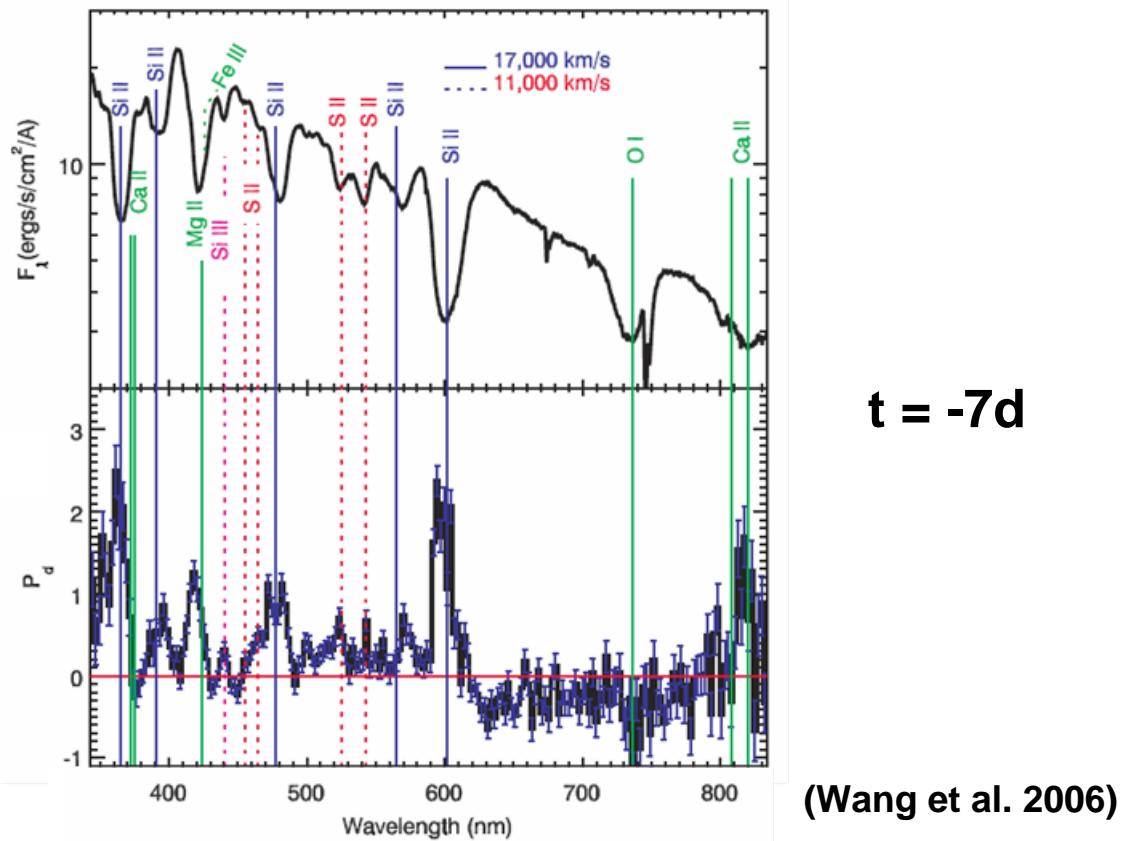


# Spectropolarimetry of SNe Ia



(Leonard et al. 2005)

# Pre-Maximum Spectropolarimetry of SN 2004dt

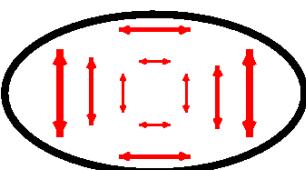
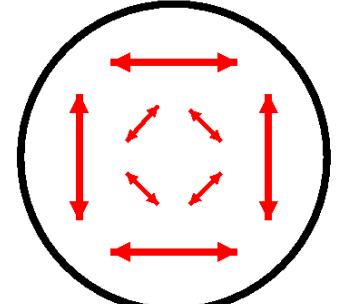


# Spectropolarimetry of Type Ia Supernovae

Supernova	Reference	Notes
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:  $P_{\text{net}} > 0\%$



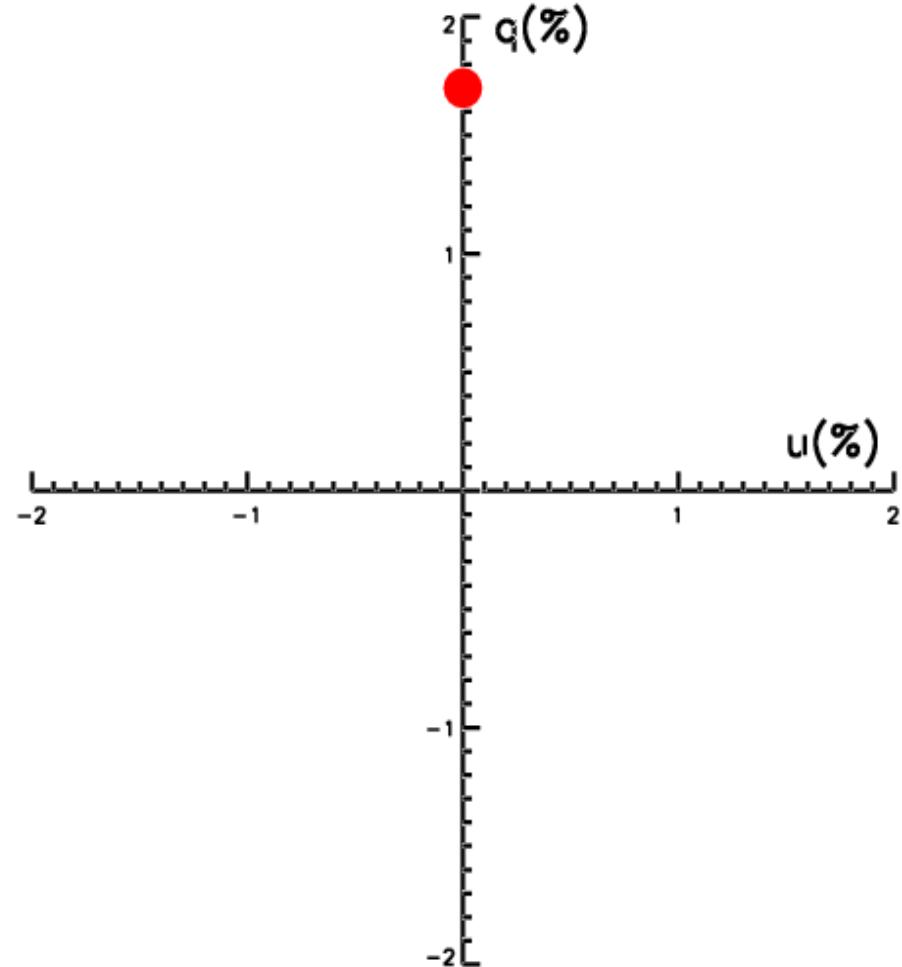
↔ = Direction of electric vector in plane of sky

$$q = \frac{-}{+}$$

Diagram illustrating the definition of the Q parameter. It shows two horizontal double-headed arrows: one above the other. The top arrow is labeled with a minus sign (-) and the bottom arrow with a plus sign (+). Vertical double-headed arrows are shown on either side of the horizontal arrows, indicating the direction of the electric vector in the plane of the sky.

$$u = \frac{-}{+}$$

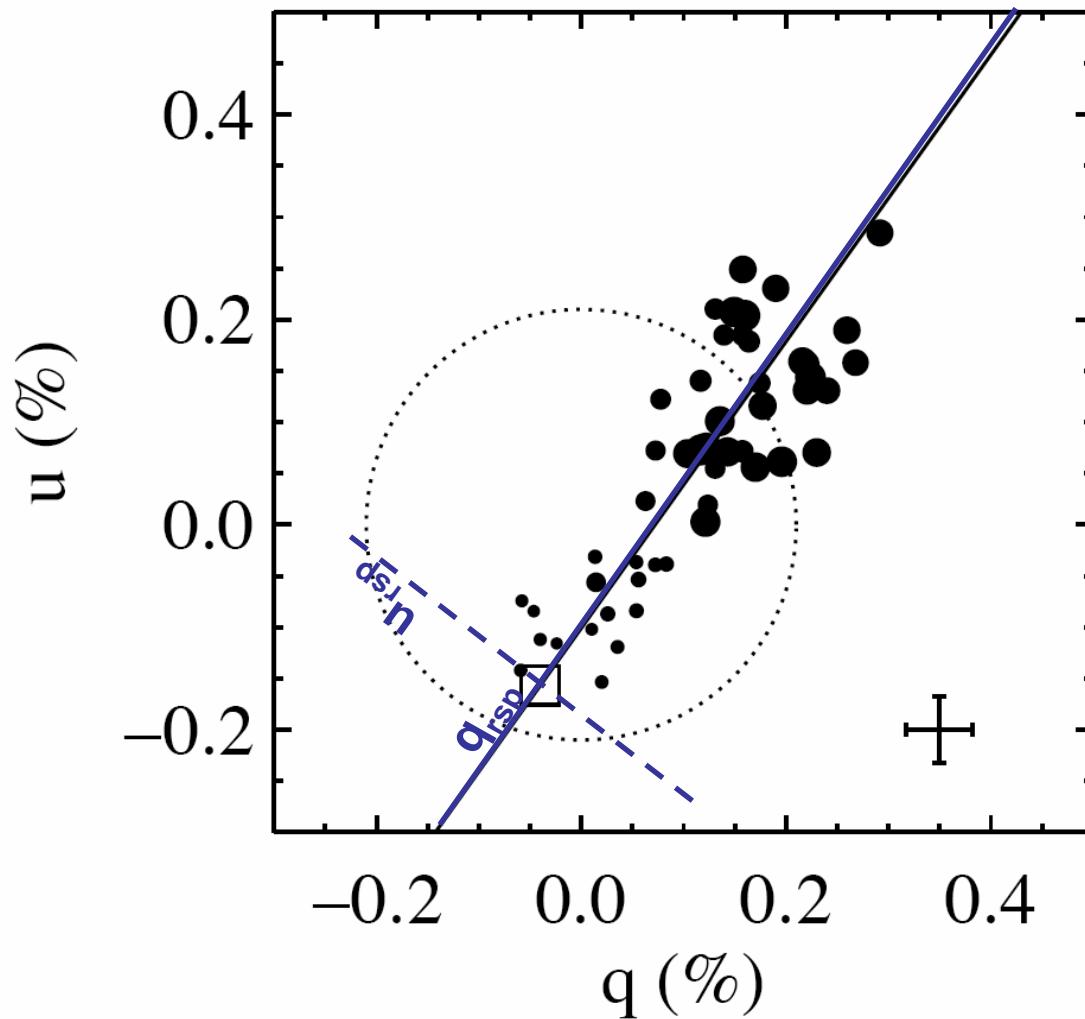
Diagram illustrating the definition of the U parameter. It shows two diagonal double-headed arrows pointing away from each other, labeled with a minus sign (-) above them. Below them, two diagonal double-headed arrows point towards each other, labeled with a plus sign (+) below them. This represents the cross-polarization components.



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

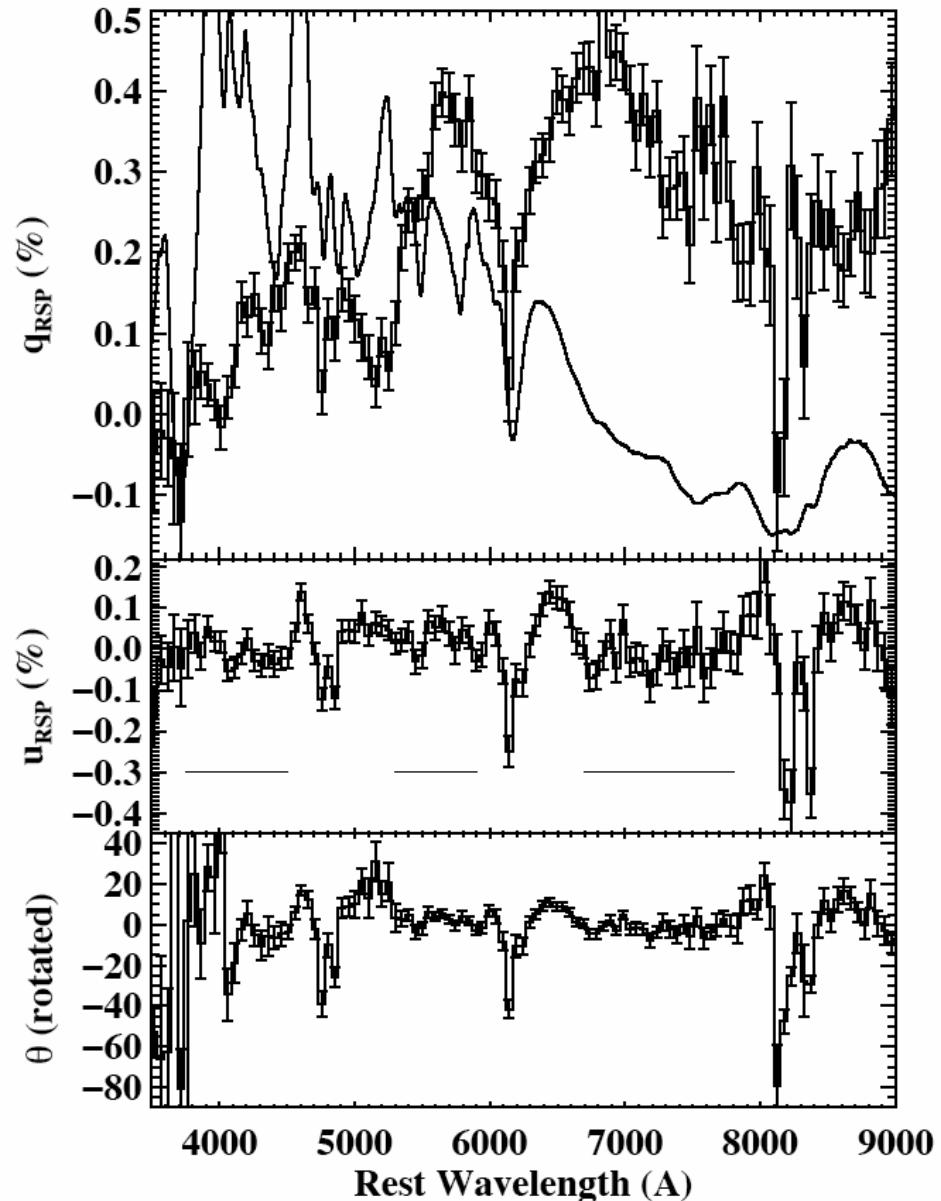
$$\theta = \frac{1}{2} \tan^{-1} \left( \frac{u}{q} \right)$$

# 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

Supernova	Reference	Notes
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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
Various	Wang et al. 2007	Si II line study