

Asymmetric PNe

what are we learning?

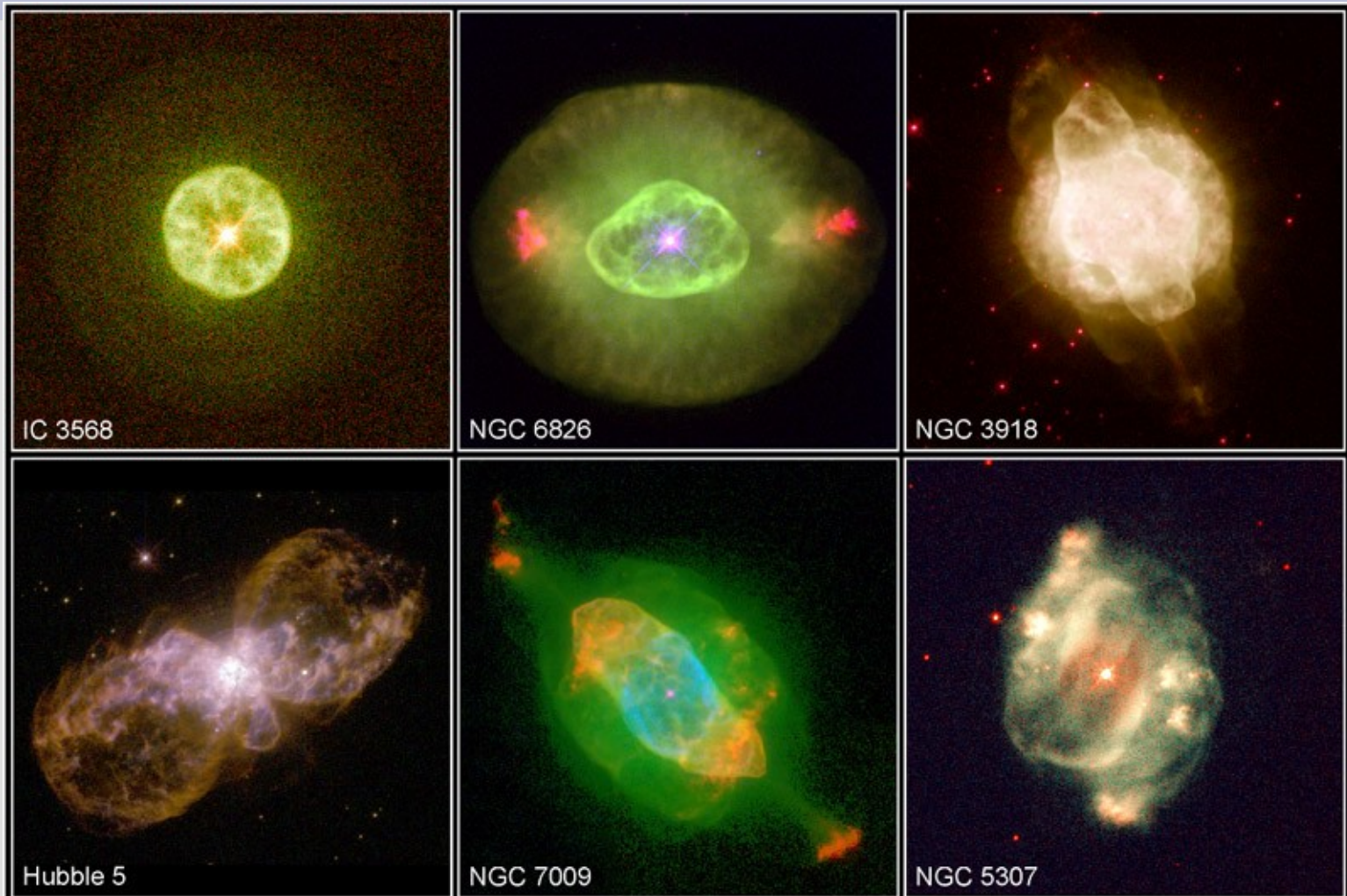


- The problem
- Morphologies
- Advances
- Origin and Evolution
- Binaries
- Future

Thank you!



The problem

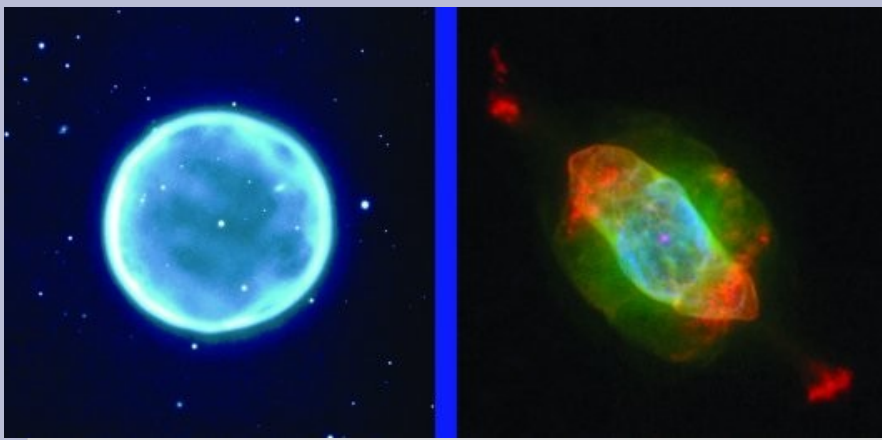


Planetary Nebula Gallery

HST • WFPC2

PRC97-38b • ST ScI OPO • December 17, 1997

H. Bond (ST ScI), B. Balick (University of Washington) and NASA



Questions

- How do the asymmetric morphologies originate?
- How do they evolve?
- How common are they?
- How do we explain deviations from asymmetry?

Data

- Major new data sets
 - PNe: MASH, IPHAS
3000+ Viironen
 - pAGB: Torun catalogue
200+ Garcia-Lario, Garcia-Hernandez, Cerrigone
- Classification schemes
 - PNe, pAGB Balick, Sahai
- Issues
 - lack of automated scheme
 - too many parameters
 - wavelength dependent

Bulge PNe

round	9%;
closed ellipt.	27%;
open elliptt.	30%;
pinched waist	27%;
eq. disk	9%

pAGB

Elliptical	20%
Bipolar	65%
Multipolar	15%

Supporting (web) resources

- Stellar atmosphere models
 - [Rauch](#)
- Nuclear yield models
 - [Karakas](#)
- Binary evolution models
 - [Izzard](#)
- 3D shape/kinematic models **SHAPE**
 - [Steffen](#)

Advances

Imaging

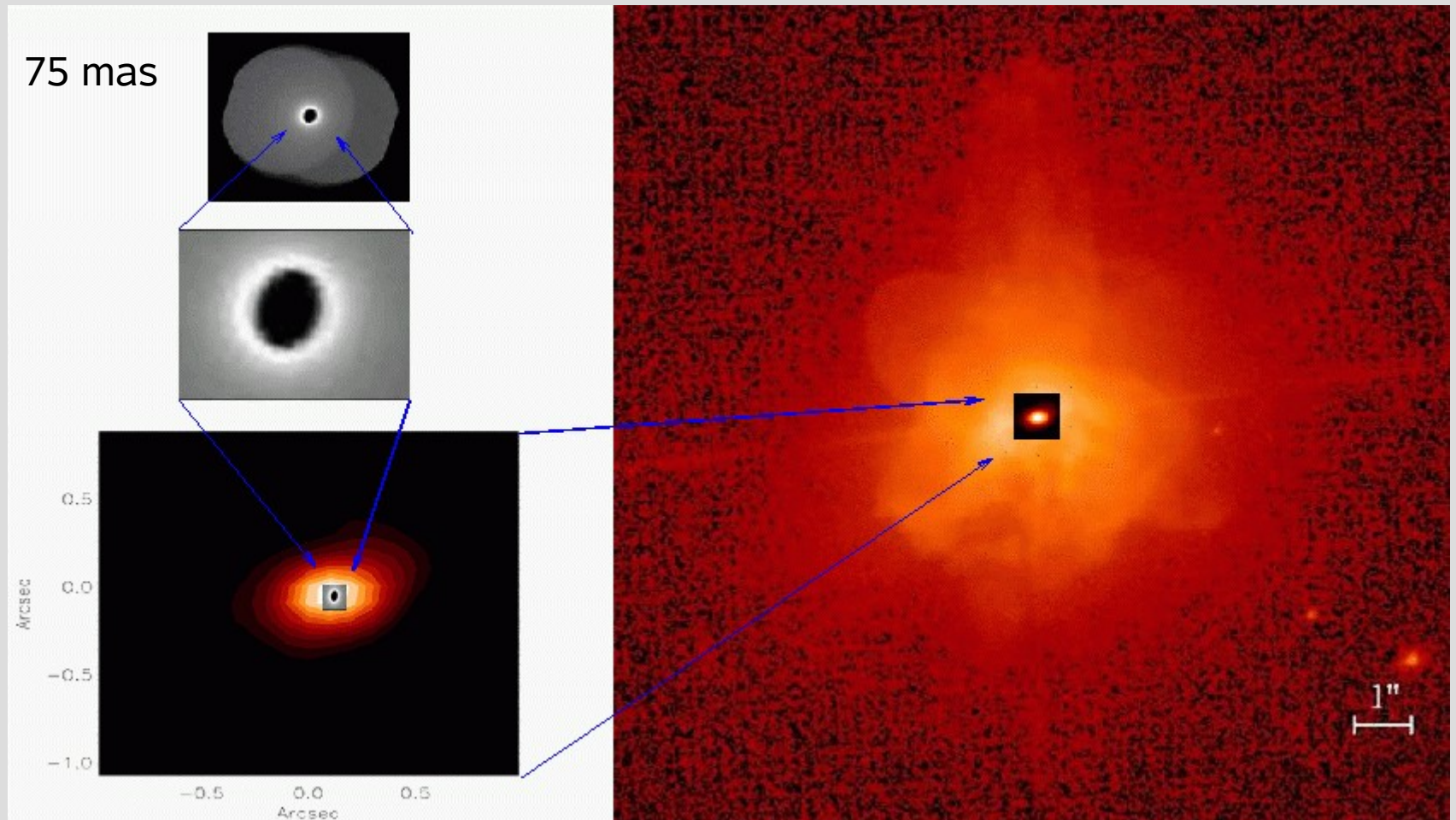
- optical/infrared
 - ACS
 - AO 50mas
 - VLTI 10mas
- Other
 - Spitzer
 - Chandra
 - SMA
 - GALEX

Spectroscopy

Goncalves, Riera

- IFU
 - 3d spectra
 - 3d velocity fields
- Sandin, Monteiro
- 3D models
 - MOCASSIN
 - CLOUDY_3D
- Wright

CPD-56



Advances

- Compact disks or flattened shells inside PNe and related objects
 - 50 AU [Chesneau, Deroo](#)
- Angular expansion [Gomez, Lagadec, Yu](#)
 - powerful method, range of wavelengths
- AGB asymmetries [Sanchez Contreras](#)
- Jet-lag [Huggins](#)

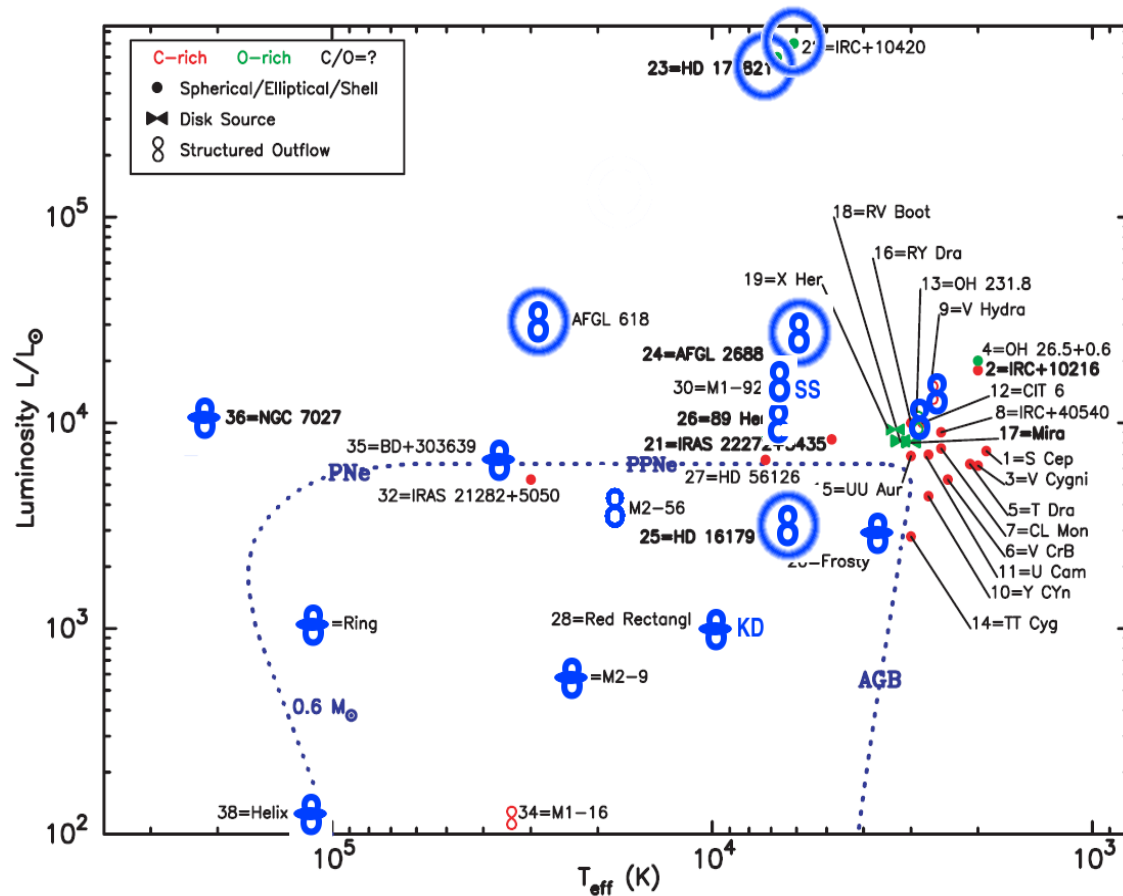
Other news

- Stars de-multiply
- AGB stars create hydrogen
- Magnetic fields look like UFOs
- PNe 'roundify'
- PNe have bad jet-lag
- New names
 - nascent-PPN (??), after-AGB

Structure origin and evolution

- Where theory and observations should meet
 - diagnostics [Icke](#)
- Major advances in measured parameters
 - Morphology, density structures [Matsuura](#)
 - velocity fields [Dobrincic](#)
- Standard model still alive
 - Equatorial enhancements
 - AGB origin?
- Companion-driven jet plausible alternative
 - outflows could compress the equator [Akashi](#)

Evolution



- Development of fast flows inside AGB envelopes

Fong, Alcolea

- What forms earlier?
 - torus, jet have similar dynamical ages
- How common?
 - unbiased survey

AGB asymmetries

- Asymmetric shells around AGB stars do exist
 - Ueta, Castro-Carrizo
- Multiple concentric shells indicate symmetry
 - but: do NOT require uniform density
- Mass loss around the AGB turn-off still a black box
 - anything could happen
- Importance of ISM interaction Wareing

Angular momentum

- Angular momentum is efficiently lost on the AGB
 - GCs: HB stars rotate, pAGB stars do not
 - Thompson et al. 2007
- Angular momentum is stored in circumstellar environment
- Can it be made available at the correct time?
 - radius increase by Mira and OH/IR pulsations

Magnetic fields

- Pure magnetic models are not convincing
Main shaping mechanism is binaries
- Magnetic fields are present
 - evolving toroidal / stretched dipole fields **Sabin**

Questions:

- What is the origin and what is the role of the magnetic field? **Nordhaus, Blackman**
- How do we integrate binary and magnetic models?

Stellar evolution: abundances

- Abundances are the best tracer of
 - mass range
 - evolutionary phase [Karakas](#)
 - binary interaction [Izzard](#)
- Correlation with abundance and morphology
 - initial mass effect ?
 - mass loss effect ?
 - [Stanghelini, Villaver](#)
- S-process elements: almost unexplored
[Sterling](#)

Stellar evolution: VLTP

- Helium flash on cooling track
 - fast repeat of PN evolution
 - ejection of H-poor nebula
- Speed of evolution far too fast (Sak. Obj.)
 - physics of mixing under explosive conditions
- Second nebula bipolar but first PN round
 - core versus envelope rotation ?
- ORL abundances indicate $C/O=0.05$
van Hoof, Kimeswenger, Wesson, Pena

Binaries

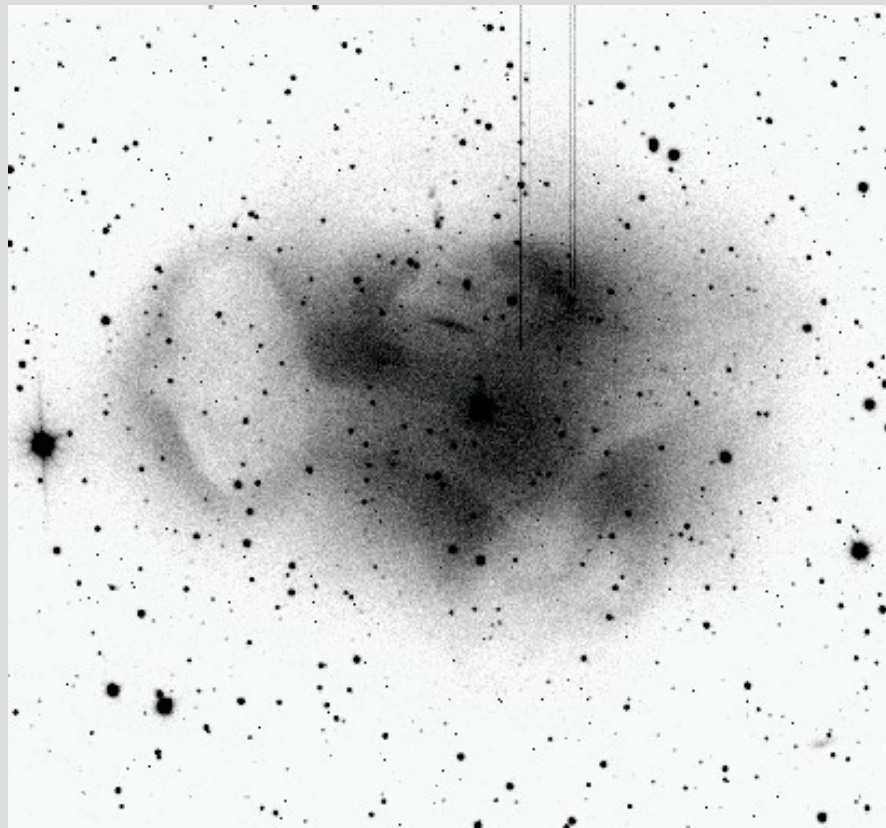
- Improved numbers on binary fractions
 - Frew
- volume limited sample
 - binaries 53 %
 - close binaries 13-31 %
- Periods
 - most 0.2 - 4 days
Tovmassian
 - NGC 2346 16 days

Binary PNe

- low mass
- no double shells
- polar jets (Mitchell)
- irregular

NGC 2346: butterfly

DS1
0.4d

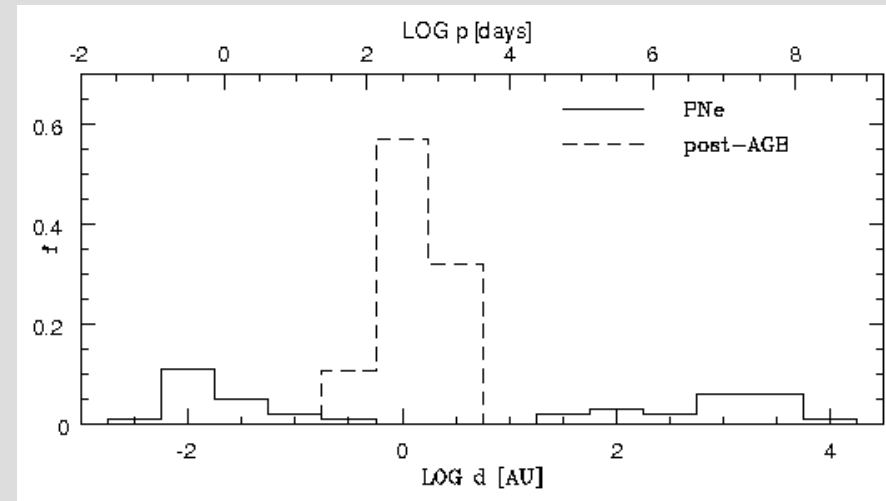


NGC2346
16 days



Binary evolution ?

- 15 % of PNe have close companions
 - periods of hours to days
- 100 % of pAGB stars ? [Hrivnak](#)
 - periods of 1 year
- 10 % of early AGB stars
 - periods of > 10 years



- WDs
 - M3.5 companions [Farihi](#)
 - no super-planets

CE evolution

- 10-15% of stars experience CE
 - consistent with PNe close binaries
- CE evolution leads to fast evolution/ejection
 - Taam, Podsiadlowski
 - Dust? Volk
- AGB stars show extended atmosphere
 - Importance of common atmosphere evolution

CA models

Example: Mira AB Mohamed Shazrene

- Transient torus scenario Frankowski

PN ejection

- Binary mass loss works
- But single stars do it too
 - but binaries do it twice
- How fast is the ejection in binary mass loss?
 - Mass loss rate?
- How do circumbinary disks form?
- How asymmetric can single stars be?

Related objects

- Symbiotics:
 - importance of accretion disks
 - high energy physics
 - mas transfer [Sokolski, Mohamed, Mikolajewska](#)

These effects should occur in 'our' binaries
- eta Car, SN1987A [Smith, Bobrowsky](#)
- Confusion between symbiotic and planetary nebulae
 - [Santander-Garcia, Frew](#)

The Future

- 3D kinematic/density models of PNe
- AGB / early pAGB mass loss
- accretion/excretion disks
- Magnetic fields

- Theory and observation should work together
 - structure development
 - binary evolution models

- Find the binaries

Perspective

- PNe are important tracers for
 - Non-explosive mass ejection
 - Physics of the winds and the CSM
 - Environments of galactic nuclei
- PNe are important for
 - Stellar evolution
 - Galactic evolution
- We live at **the interface of stellar and interstellar/galaxy evolution**

See you at

APN V



Manchester 2010