



Hanbury Brown and Twiss Interferometry with Twisted Light

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RESEARCH ARTICLE

OPTICS

Hanbury Brown and Twiss interferometry with twisted light

Omar S. Magaña-Loaiza,^{1,*} Mohammad Mirhosseini,¹ Robert M. Cross,¹
Seyed Mohammad Hashemi Rafsanjani,¹ Robert W. Boyd^{1,2}

The image shows the homepage of the journal Science Advances. At the top, the journal title "ScienceAdvances" is displayed in a large, serif font. To the right of the title is a small thumbnail image of a person's hands working with optical components. Below the title is a horizontal navigation bar with links for "Home", "News", "Journals", "Topics", and "Careers". Underneath this bar is another row of links for "Science", "Science Advances", "Science Immunology", "Science Robotics", "Science Signaling", and "Science Translational Medicine". On the left side of the main content area, there is a sidebar with the text "Exploring twisted light" and "The physics behind random optical wave fields". Below this text is a small copyright notice: "© Dora Trifunovic / Alamy Stock Photo". The main content area features a large, vibrant image of many intertwined, colored optical fibers (red, yellow, green) against a black background, representing the complex interference patterns of twisted light.

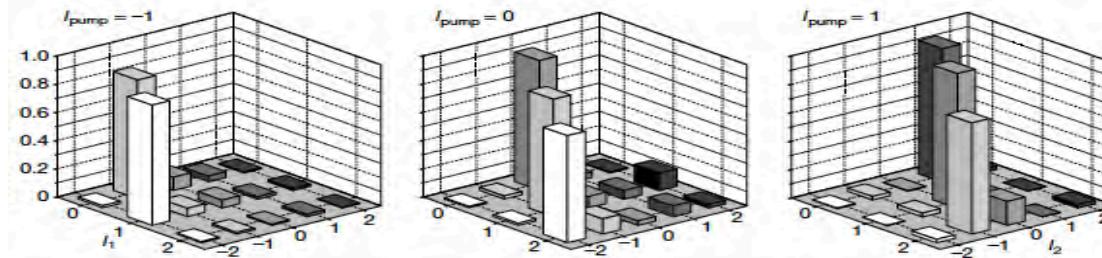
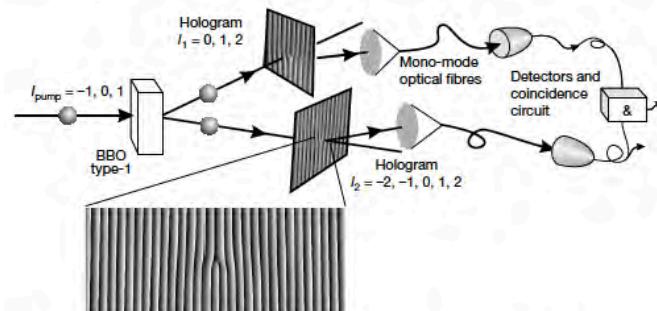
Background

Entanglement of the orbital angular momentum states of photons

Alois Mair*, Alipasha Vaziri, Gregor Weihs & Anton Zeilinger

Institut für Experimentalphysik, Universität Wien, Boltzmanngasse 5, 1090 Wien,
Austria

NATURE | VOL 412 | 19 JULY 2001 | www.nature.com



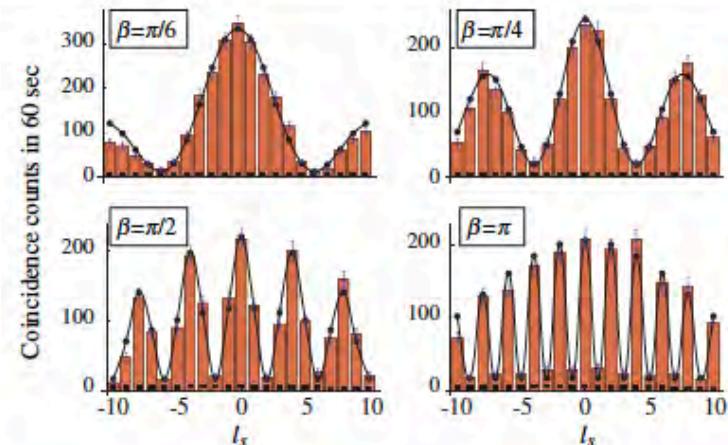
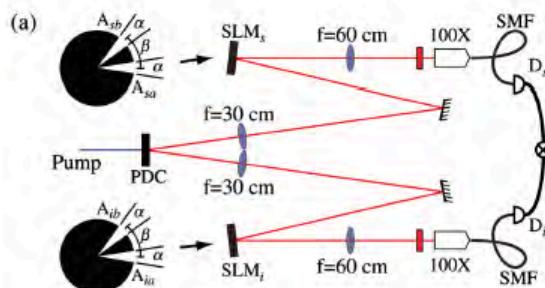
PRL 104, 010501 (2010)

PHYSICAL REVIEW LETTERS

week ending
8 JANUARY 2010

Angular Two-Photon Interference and Angular Two-Qubit States

Anand Kumar Jha,¹ Jonathan Leach,² Barry Jack,² Sonja Franke-Arnold,² Stephen M. Barnett,³ Robert W. Boyd,¹ and Miles J. Padgett²

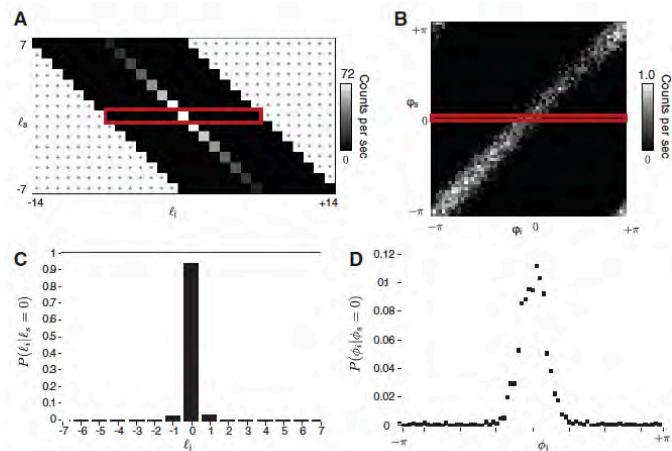
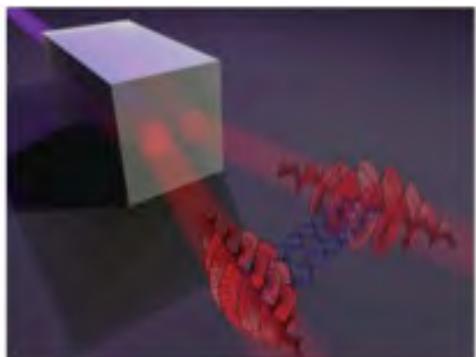


Background

Quantum Correlations in Optical Angle–Orbital Angular Momentum Variables

Jonathan Leach,¹ Barry Jack,¹ Jacqui Romero,¹ Anand K. Jha,² Alison M. Yao,³ Sonja Franke-Arnold,¹ David G. Ireland,¹ Robert W. Boyd,² Stephen M. Barnett,³ Miles J. Padgett^{1*}

6 AUGUST 2010 VOL 329 SCIENCE www.science.org



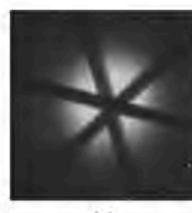
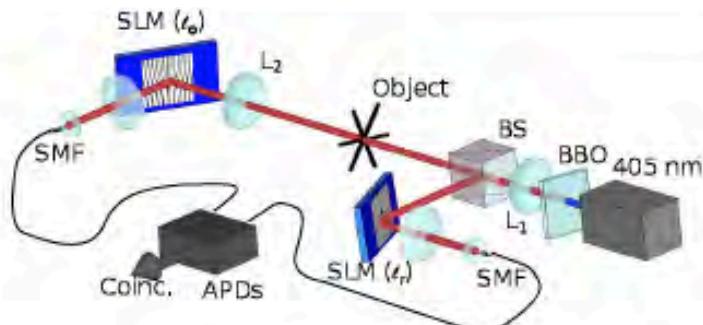
PRL 110, 043601 (2013)

PHYSICAL REVIEW LETTERS

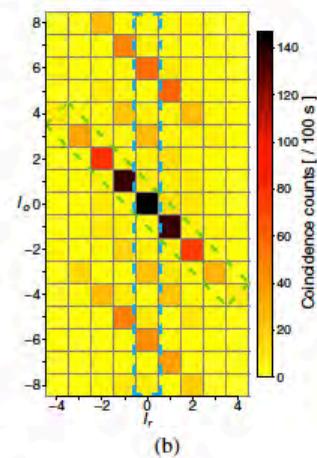
week ending
25 JANUARY 2013

Object Identification Using Correlated Orbital Angular Momentum States

Néstor Uribe-Patarroyo,^{1,*} Andrew Fraine,¹ David S. Simon,^{1,2} Olga Minaeva,³ and Alexander V. Sergienko^{1,4}



(a)

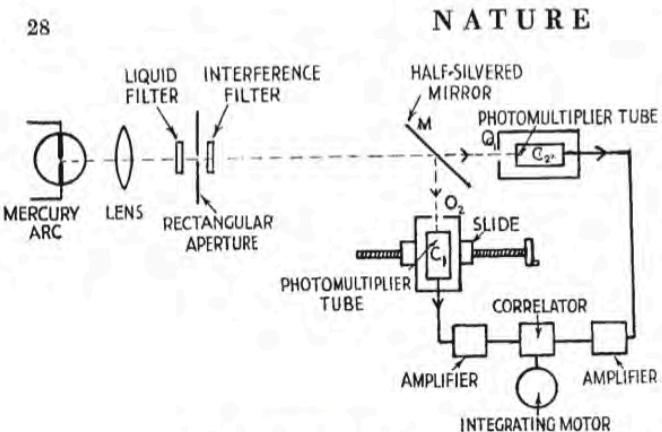


(b)

Chaotic fields of light

Random wave fields

HBT Effect



REVIEW ARTICLES | FOCUS
PUBLISHED ONLINE: 27 FEBRUARY 2013 | DOI: 10.1038/NPHOTON.2013.25

nature
photronics

Disordered photonics

Diederik S. Wiersma

VOLUME 93, NUMBER 9

PHYSICAL REVIEW LETTERS

week ending
27 AUGUST 2004

Ghost Imaging with Thermal Light: Comparing Entanglement and Classical Correlation

A. Gatti, E. Brambilla, M. Bache, and L. A. Lugiato

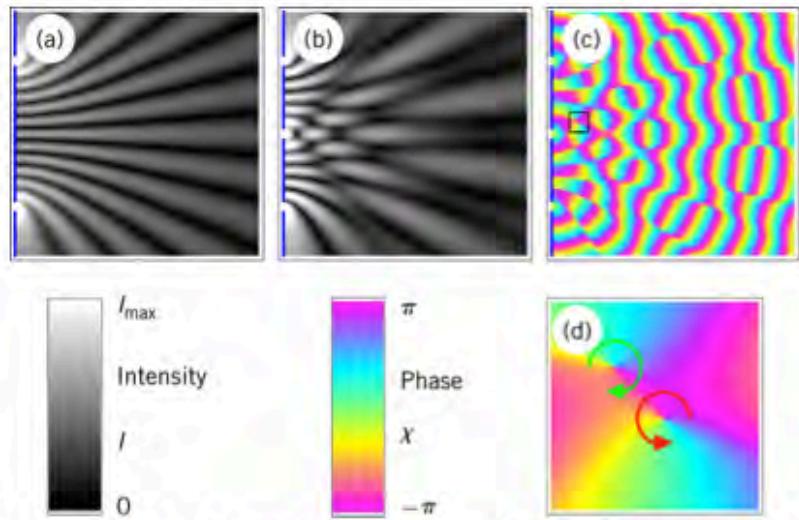
nature
photronics

FOCUS | REVIEW ARTICLES
PUBLISHED ONLINE: 27 FEBRUARY 2013 | DOI: 10.1038/NPHOTON.2013.30

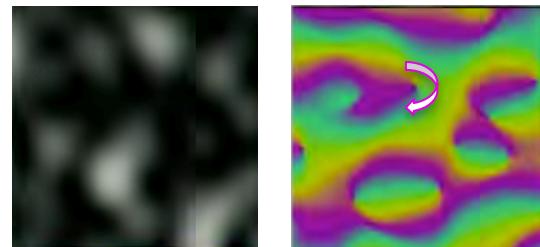
Anderson localization of light

Mordechai Segev^{1,2*}, Yaron Silberberg³ and Demetrios N. Christodoulides⁴

Vortices in wave superposition



Vortices in chaotic light



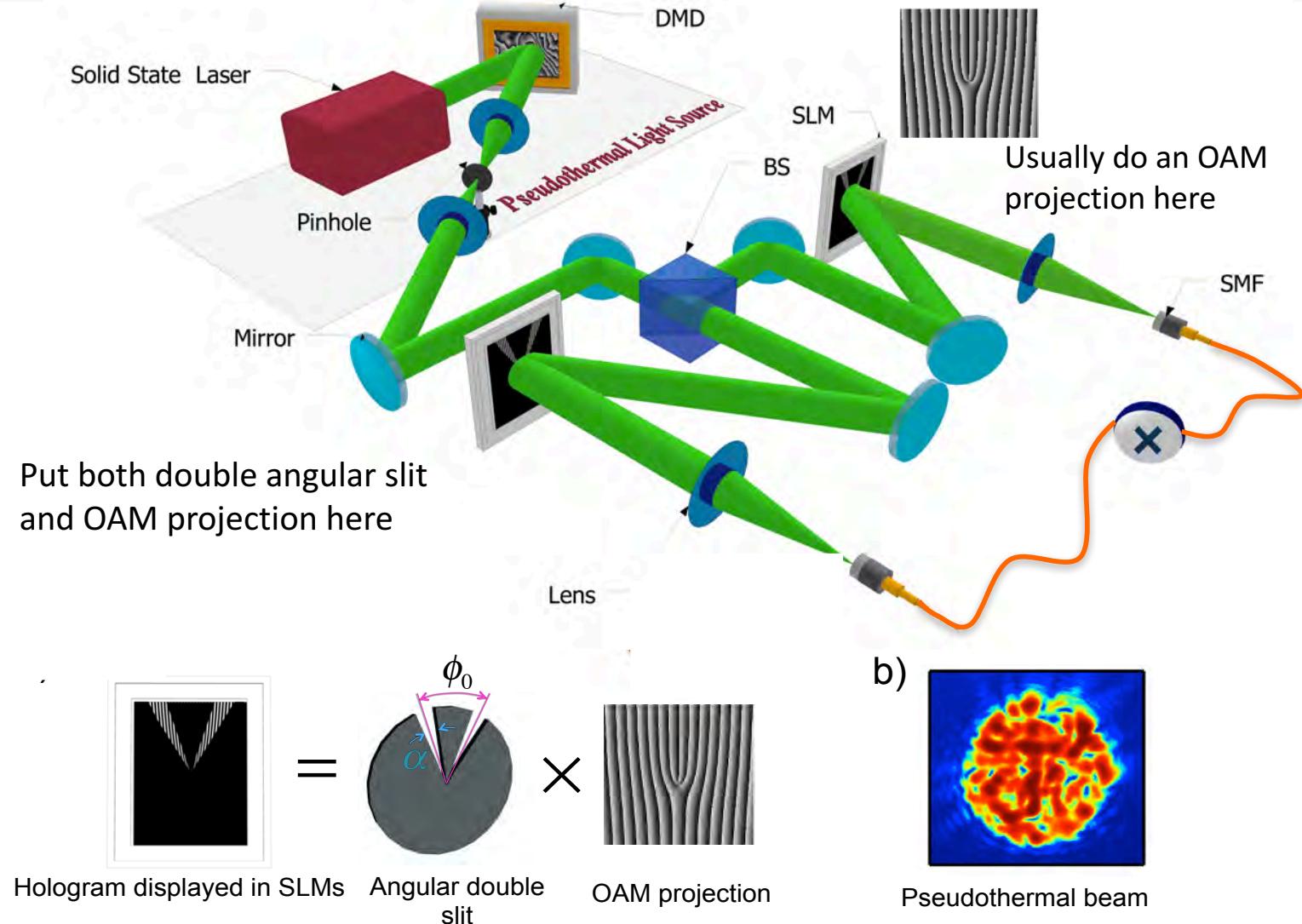
Motivation for this study

We know what Young's interference and HBT correlations look like in real space.

- What do they look like in OAM space?
- And could this be useful?

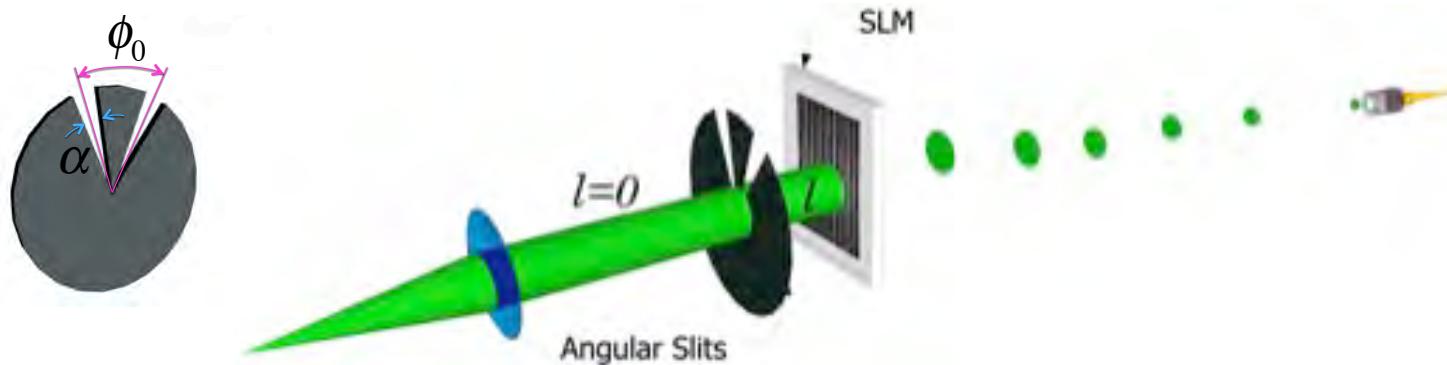
Azimuthal Hanbury Brown and Twiss Interference

Experimental Setup



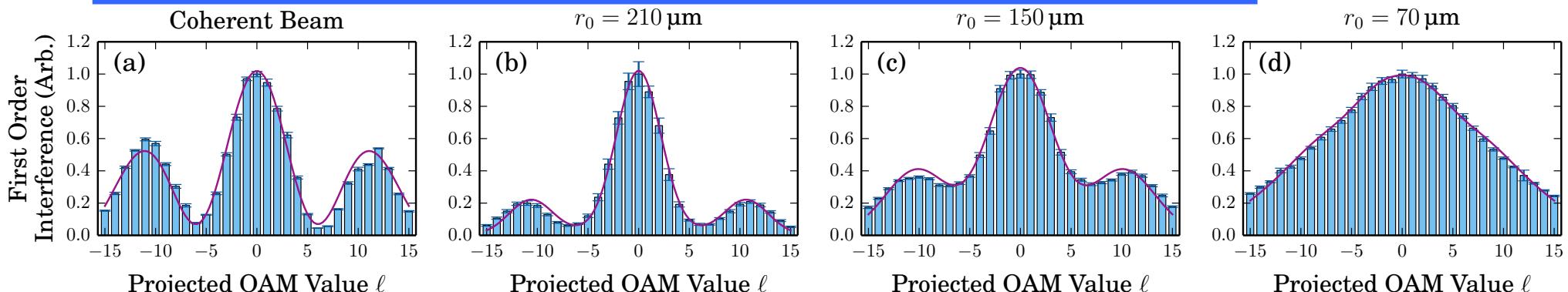
Azimuthal Hanbury Brown and Twiss Interference

First order Interference



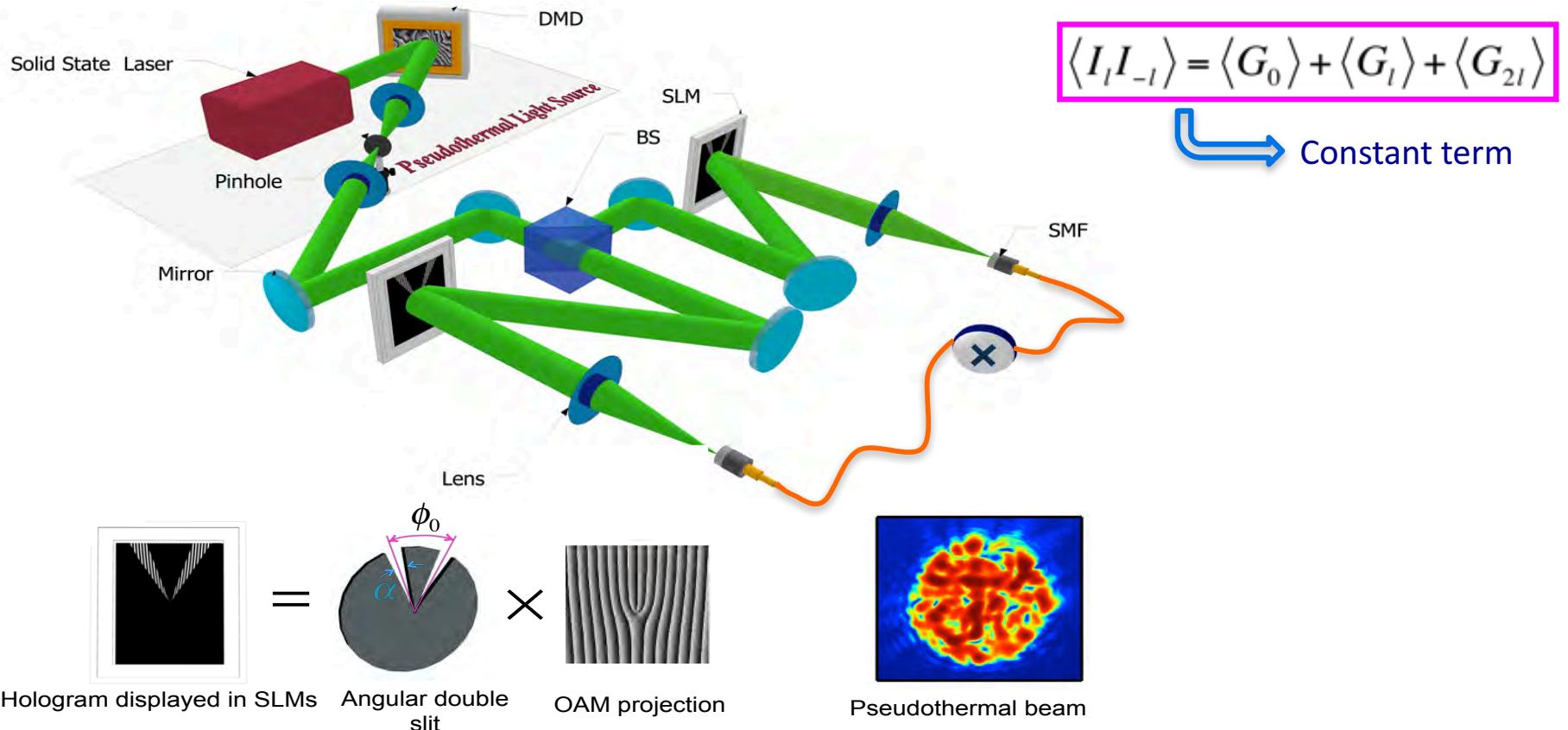
We control the spatial coherence of the illumination through use of the DMD.

$$\langle I_l \rangle \propto \frac{\alpha^2}{2\pi^2} \text{Sinc}^2\left(\frac{l\alpha}{2}\right) \int r dr E^2(r) \left\{ 2 + e^{-il\phi_0} \langle \Phi^*(r,0) \Phi(r,\phi_0) \rangle + e^{il\phi_0} \langle \Phi^*(r,\phi_0) \Phi(r,0) \rangle \right\}$$



Azimuthal Hanbury Brown and Twiss Interference

Measurement of the azimuthal HBT effect

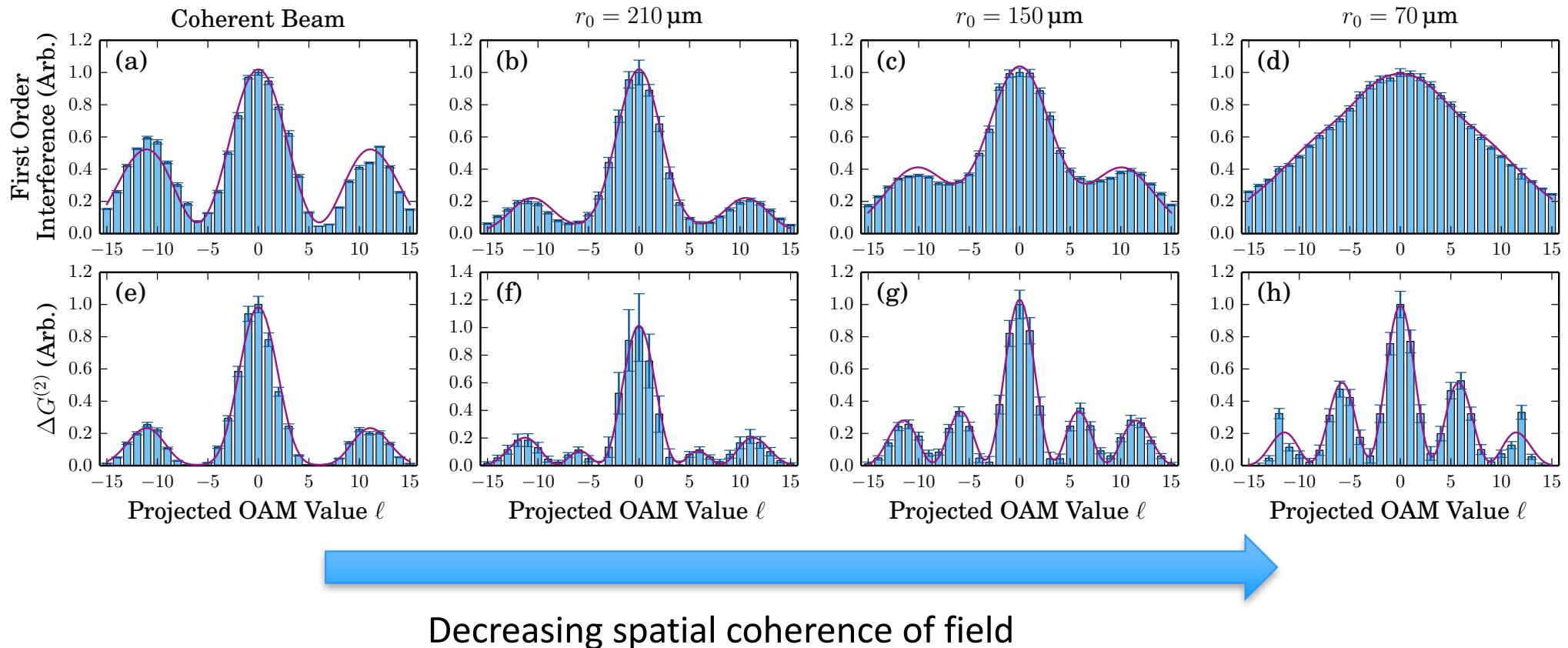


$$\langle G_l \rangle \propto \int r_1 dr_1 r_2 dr_2 \left(e^{-il\phi_0} \left\{ \langle \Phi^*(r_1, 0) \Phi(r_1, \phi_0) \rangle + \langle \Phi^*(r_2, 0) \Phi(r_2, \phi_0) \rangle \right\} + c.c. \right)$$

$$\langle G_{2l} \rangle \propto \int r_1 dr_1 r_2 dr_2 \left(e^{-2il\phi_0} \left\{ \langle \Phi^*(r_1, 0) \Phi(r_1, \phi_0) \Phi^*(r_2, \phi_0) \Phi(r_2, 0) \rangle \right\} + c.c. \right)$$

Azimuthal Hanbury Brown and Twiss Interference

OAM correlations: Experimental results

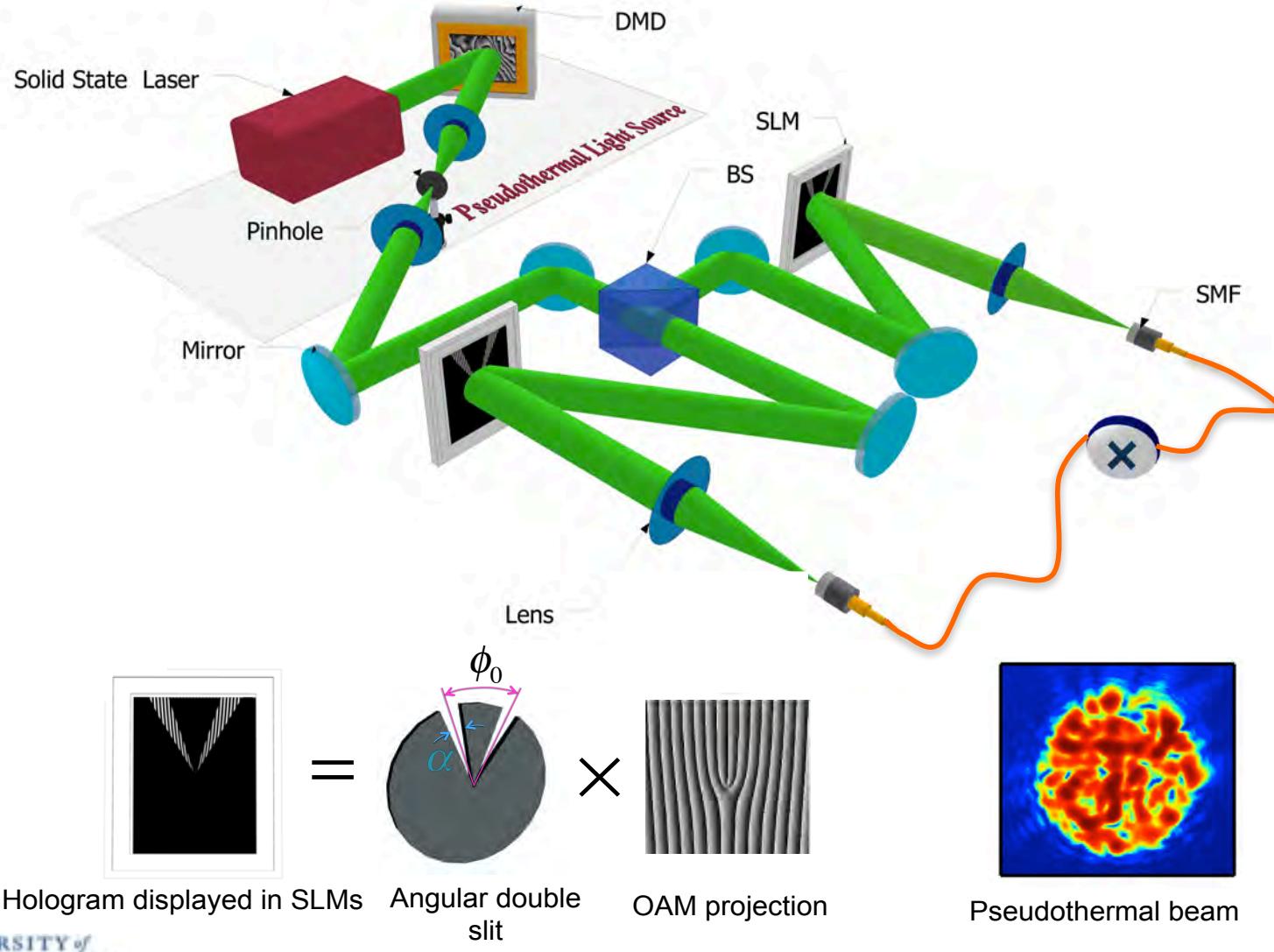


Formation of Second-Order Correlations in OAM!

A. K. Jha, et al., Phys. Rev. Lett. **104**, 010501 (2010)

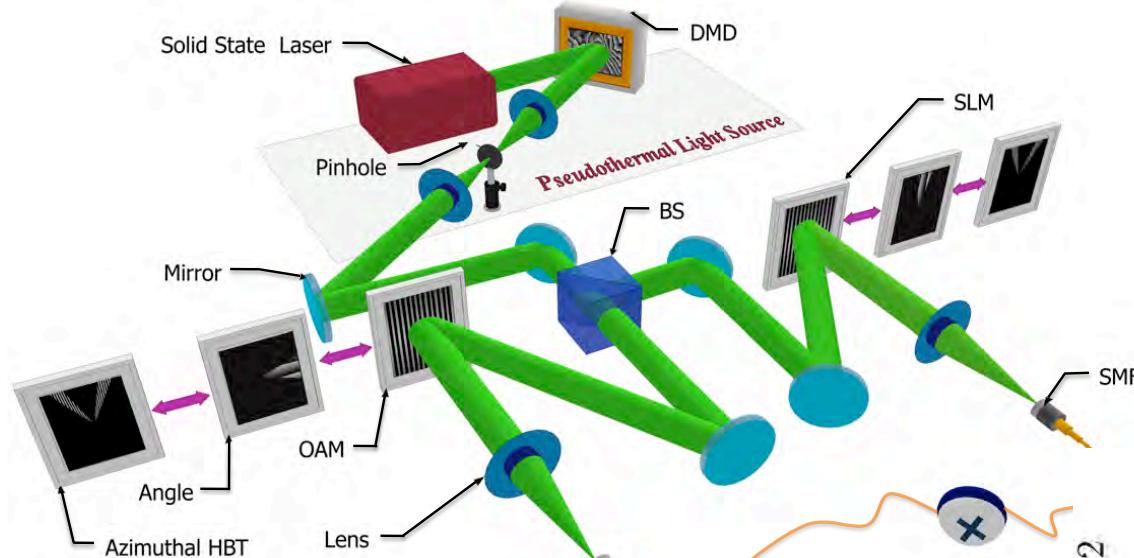
Azimuthal Hanbury Brown and Twiss Interference

Experimental Setup

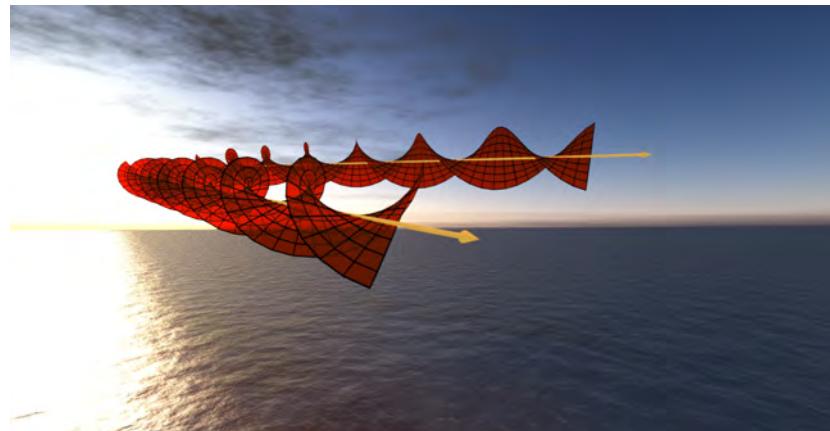


Second-Order Correlations of Pseudothermal light

Correlations in Angular Position and OAM

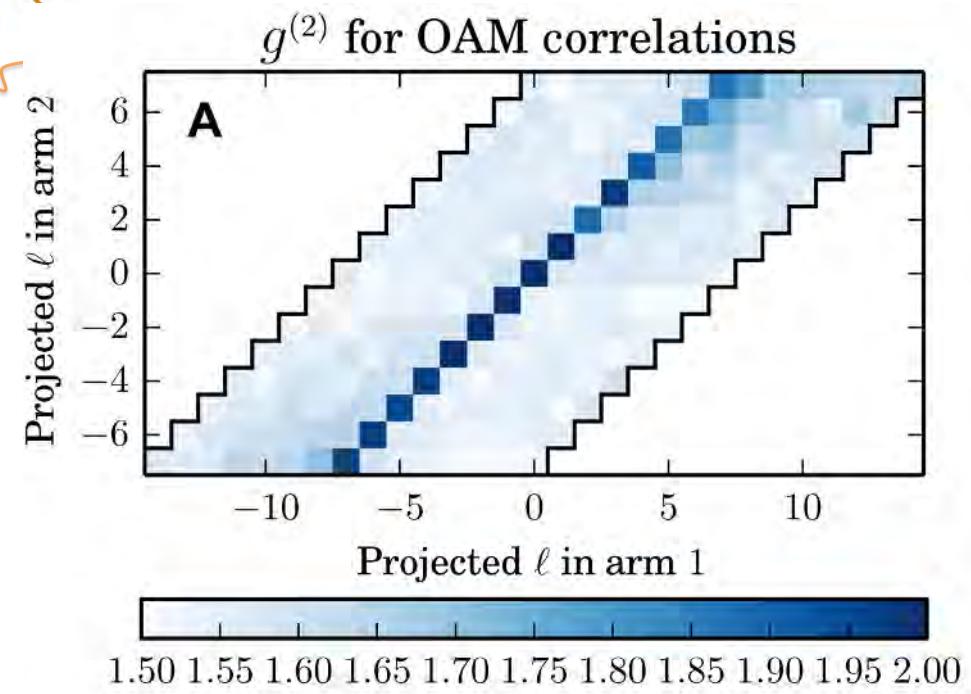


Place forked hologram on each SLM



$$\langle I_{l_1} I_{l_2} \rangle = \langle I_{l_1} \rangle \langle I_{l_2} \rangle (1 + \delta_{l_1 l_2})$$

- Note that (unlike SPDC) OAM correlations sit on top of a background.
- Note also that this expression is non-separable.



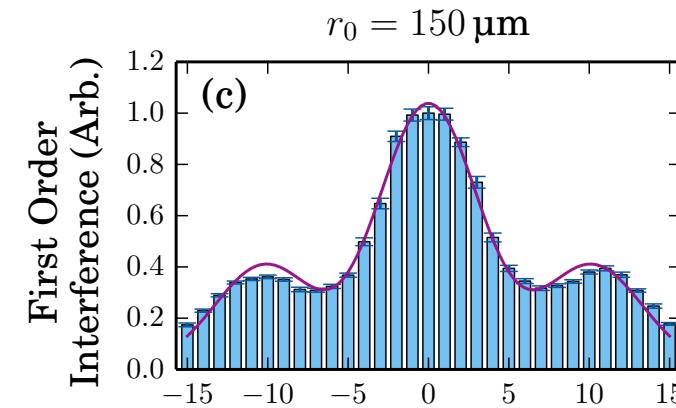
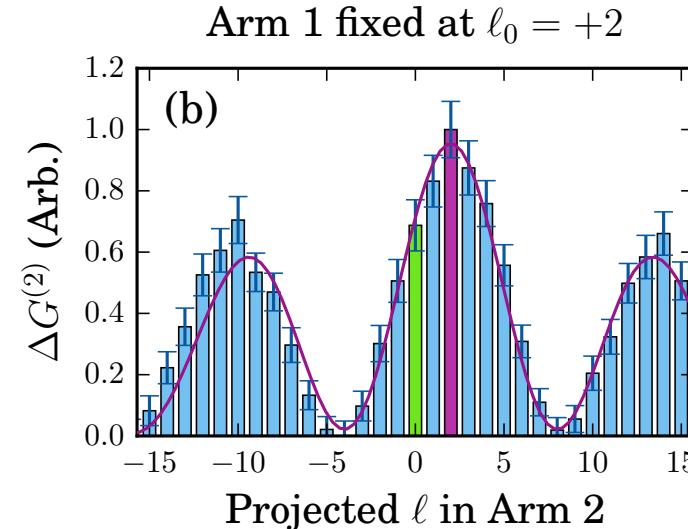
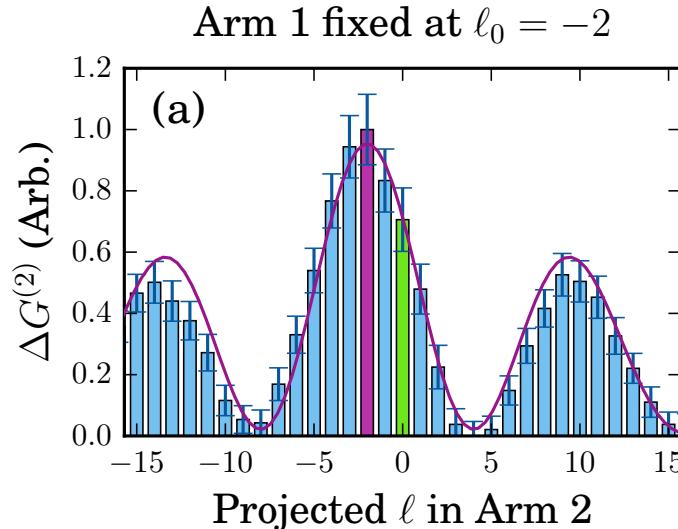
Hanbury Brown and Twiss effect with Twisted Light

Arm 1: Constant Intensity

Arm 2:

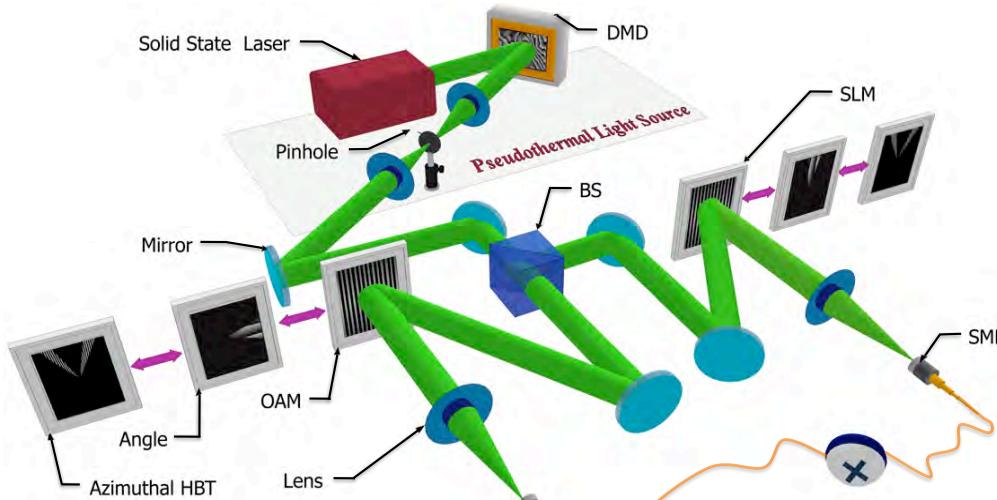
$$\langle G_{l,l_0} \rangle \propto \frac{\alpha^4 \text{Sinc}^4([l-l_0]\alpha/2)}{4\pi^4} \int r_1 dr_1 r_2 dr_2 \left(e^{-i(l-l_0)\phi_0} \left\{ \Phi^*(r_1,0) \Phi(r_1, \phi_0) \Phi^*(r_2, \phi_0) \Phi(r_2, 0) \right\} + c.c. \right)$$

Correlations:



Second-Order Correlations of Pseudothermal light

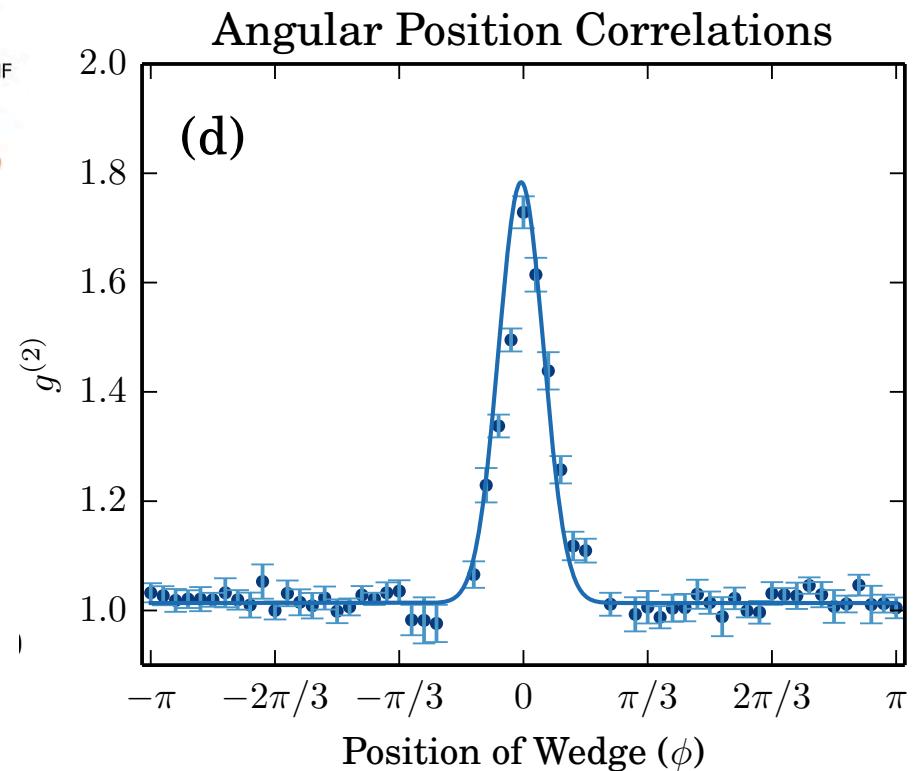
Correlations in Angular Position and OAM



Slit in arm 1 is fixed at 0^0 Slit in arm 2 is rotated

Similar to correlations of entangled photons, except that in our case the correlations sit on top of a constant background

$$\langle I_\phi I_{\phi_0} \rangle = \langle I_\phi \rangle \langle I_{\phi_0} \rangle (1 + f(\phi - \phi_0))$$



POSSIBLE APPLICATIONS

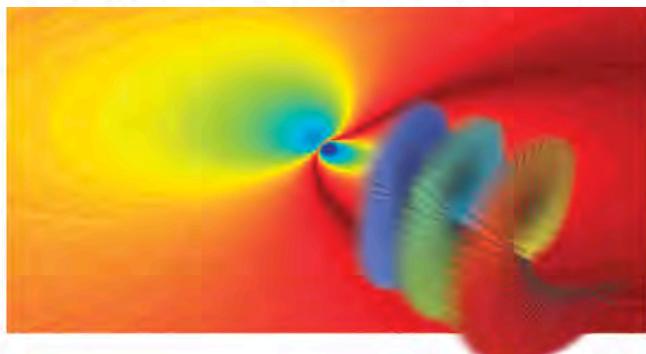
nature
physics

LETTERS

PUBLISHED ONLINE: 13 FEBRUARY 2011 | DOI:10.1038/NPHYS1907

Twisting of light around rotating black holes

Fabrizio Tamburini¹, Bo Thidé^{2*}, Gabriel Molina-Terriza³ and Gabriele Anzolin⁴



PRL 110, 043601 (2013)

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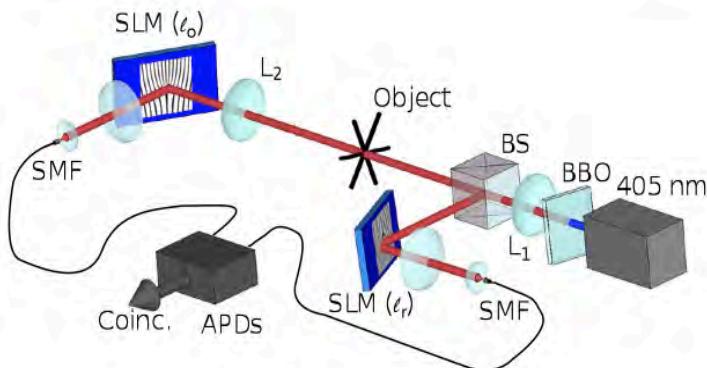
week ending
25 JANUARY 2013

Object Identification Using Correlated Orbital Angular Momentum States

Néstor Uribe-Patarroyo,^{1,*} Andrew Fraine,¹ David S. Simon,^{1,2} Olga Minaeva,³ and Alexander V. Sergienko^{1,4}

¹Department of Electrical and Computer Engineering, Boston University, 8 Saint Marys Street, Boston, Massachusetts 02215, USA

²Department of Physics and Astronomy, Stonehill College, 320 Washington Street, Easton, Massachusetts 02357, USA



PRL 106, 100407 (2011)

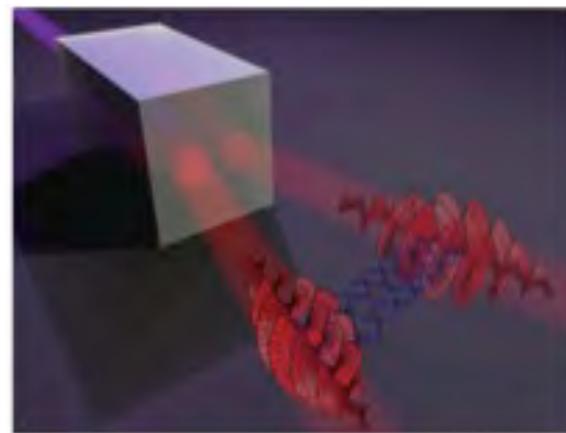
PHYSICAL REVIEW LETTERS

week ending
11 MARCH 2011

Entangled Optical Vortex Links

J. Romero,^{1,2} J. Leach,¹ B. Jack,¹ M. R. Dennis,³ S. Franke-Arnold,¹ S. M. Barnett,² and M. J. Padgett¹

6 AUGUST 2010 VOL 329 SCIENCE www.sciencemag.org



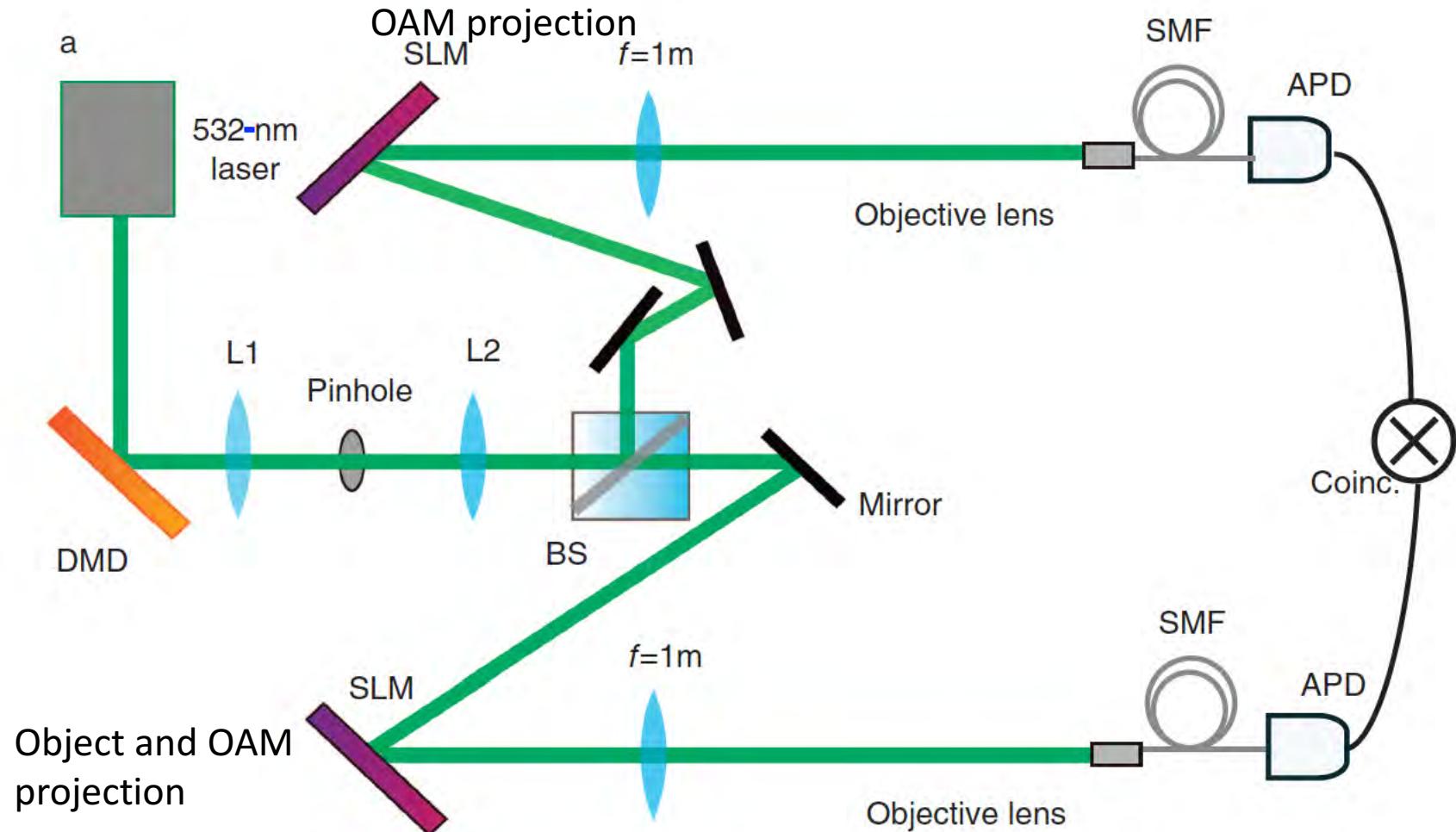
Digital spiral object identification using random light

Zhe Yang^{1,2}, Omar S Magaña-Loaiza², Mohammad Mirhosseini², Yiyu Zhou²,
Boshen Gao², Lu Gao^{2,3}, Seyed Mohammad Hashemi Rafsanjani²,
Guilu Long^{1,4} and Robert W Boyd^{2,5}

- [1] State Key Laboratory of Low-dimensional Quantum Physics and Department of Physics, Tsinghua University, Beijing 100084, China;
- [2] The Institute of Optics, University of Q3 Rochester, Rochester, New York 14627, USA;
- [3] School of Science, China University of Geosciences, Beijing 100083, China;
- [4] Tsinghua National Laboratory for Information Science and Technology, Beijing 100084, China
- [5] Department of Physics, University of Ottawa, Ottawa, Ontario, Canada

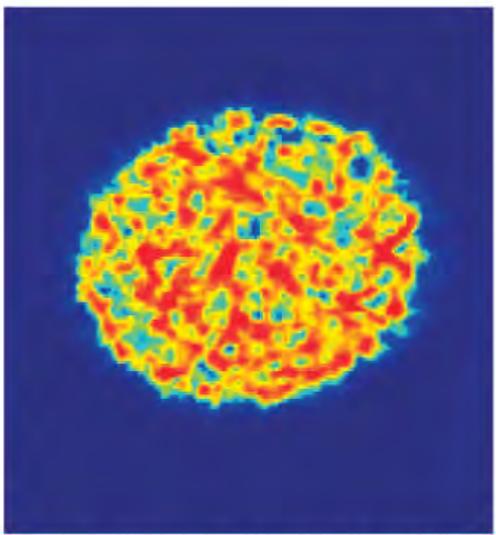
Digital spiral object identification using random light

Experimental Setup

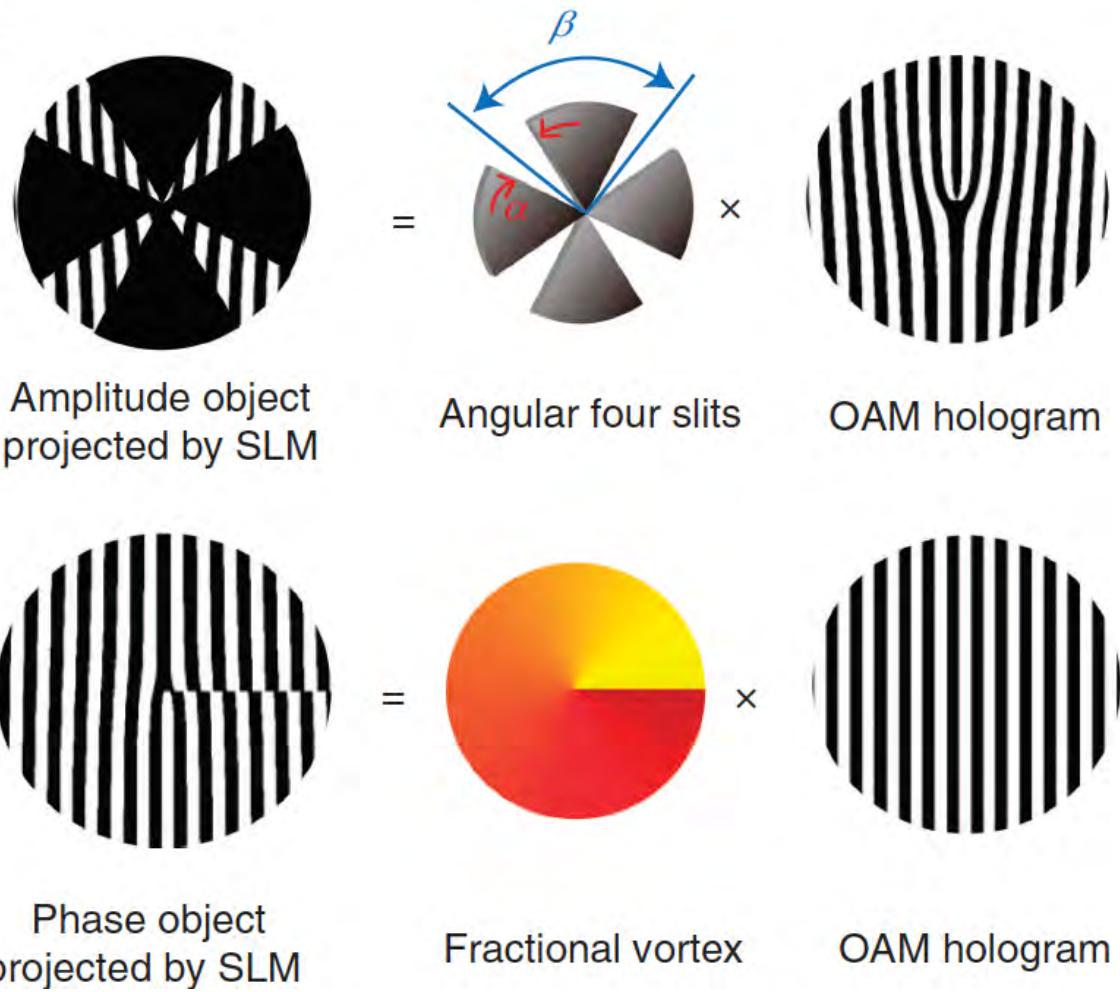


Digital spiral object identification using random light

Some examples

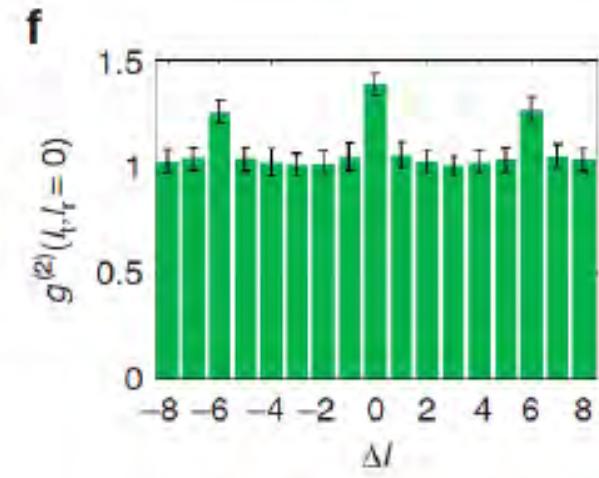
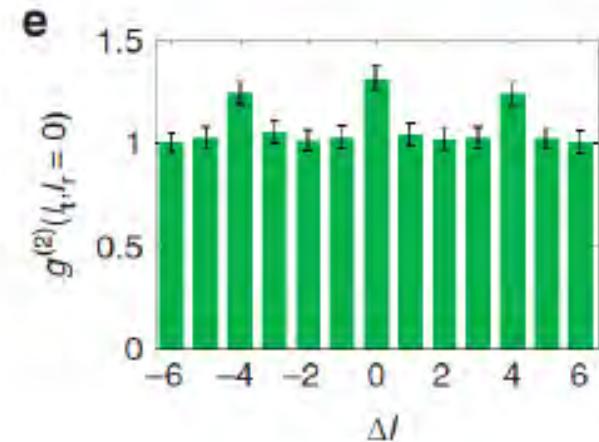
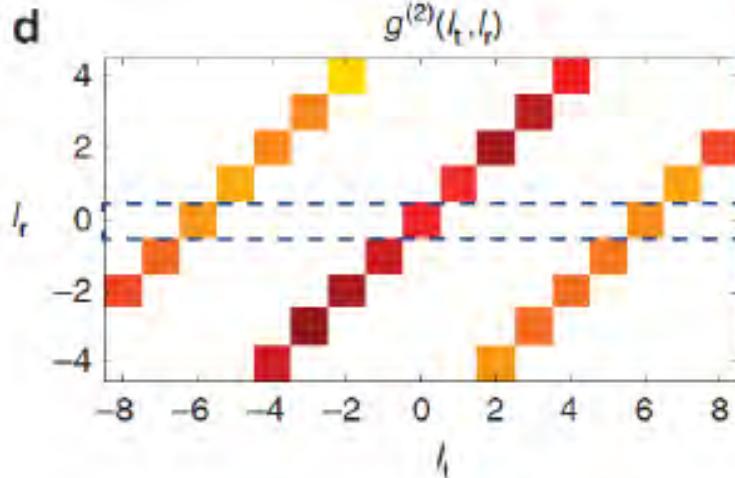
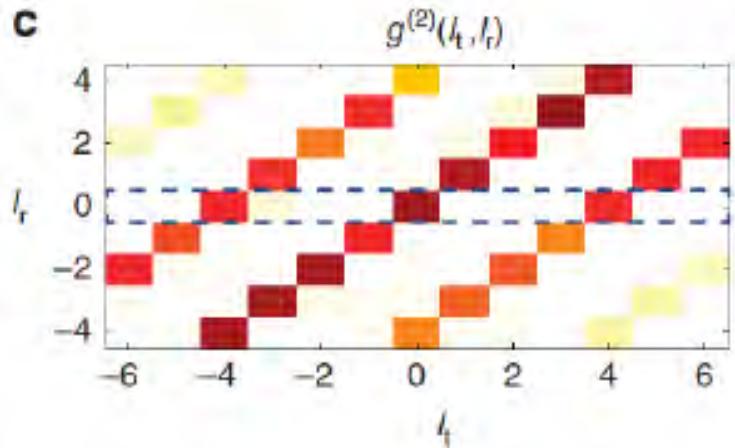
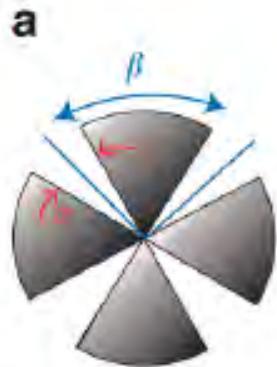


Pseudothermal light



Digital spiral object identification using random light

Symmetry of object shows up in OAM correlations



- Could this method be applied to more complicated objects?

An Application





The end