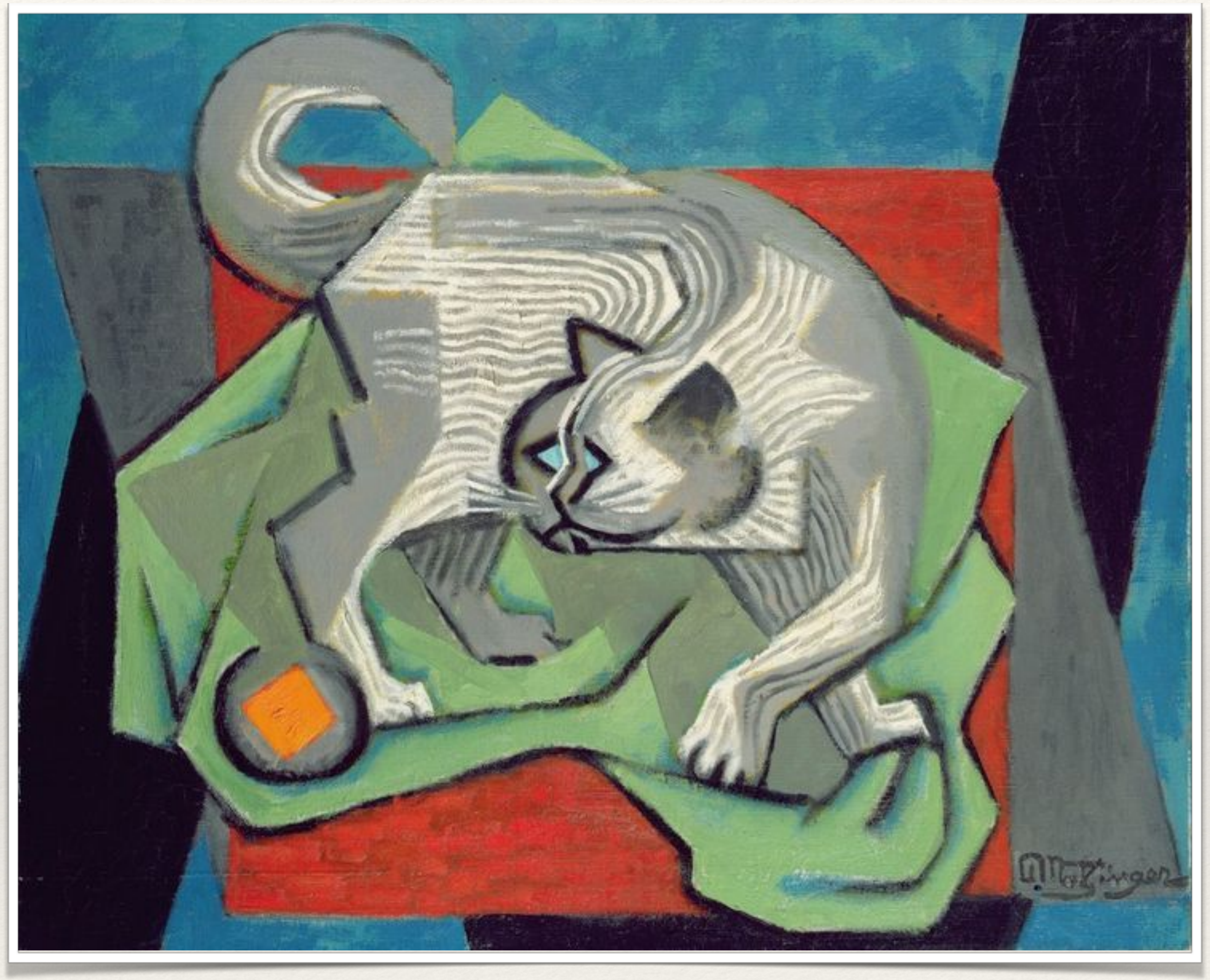
Prof. Steven Flammia

Quantum Mechanics

Lecture 1

Course administration;
Review of Dirac notation and state space;
Operators in quantum mechanics;
Observables, expected values, unitary dynamics.



Administration

- PHYS 3x34, advanced stream 3rd year Quantum Physics.
- Teaching assistant: Alistair Milne, amil1264@uni.sydney.edu.au
- Course website: www.physics.usyd.edu.au/~sflammia/Courses/QM2019/
- 4 Quizzes to be held during Lectures 5, 8, 11, 14.
- 2 Assignments, 1 Exam.
- Marks apportioned: 0.2 Q + 0.2 A + 0.6 E.

Why quantum physics?

- One of the most stunning intellectual achievements in human history.
- It raises deep philosophical and conceptual questions:
  - Determinism, causality, information, locality, *even reality itself*.
- Huge range of scientific and practical applicability:
  - Neutron stars, elementary particles, fission and fusion, magnetism, lasers, transistors, superconductors, chemistry, fiber optics, quantum computers…
- Despite a fearsome reputation, the principles of quantum physics are *simple*.

1927 Solvay conference

29 attendees, 17 Nobel laureates, 18 Nobel prizes.

Dirac notation

Recall that quantum mechanical systems are described by **states**.

Kets = column vectors

Can express any vector in an **orthonormal basis**.

Bras = row vectors

Inner product

States must be **normalized**.

Dirac notation

Example: spin-1/2 system

Finite-dimensional quantum systems

More generally, consider a system with a finite number of orthogonal states.

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Operators

Any complete orthonormal basis forms a **resolution of the identity**.

Example: spin-1/2

Different basis choices allow us to expand states in different bases:

Operators

In general, any linear operator of commensurate dimension can act on a state.
Operators can be thought of as acting from the **left** or from the **right**.

The Hermitian conjugate (complex conjugate + transpose) relates the two actions.
Operator ordering follows the conventions of matrix multiplication.

Operators do not commute!

Eigenstates and eigenvalues

Eigenvalues and eigenstates (or eigenvectors, same thing) are solutions to:

The length of the eigenvector is not specified by this equation, but if it is nonzero, then the length can be chosen to be 1.

A huge fraction of practical quantum calculations involves finding eigenstates and eigenvalues.

Observables and expected values

Observables are operators that are also self-adjoint (or just Hermitian):

They have a complete set of orthonormal eigenvectors and real eigenvalues.

We are often interested in computing **expected values** of operators (usually for observables, but it can be done more generally).

The Born rule and unitary dynamics

The probability of an outcome of a measurement is given by the Born rule.

Example: spin-1/2

Unitary matrices are the inverse of their adjoint:

Unitary dynamics therefore preserves total probability: