Type them into questions box!

“Why am I muted?”
Don’t worry. Everyone is muted except the presenter and host. Thank you and enjoy the show.

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Water in the Universe
258th National Meeting, San Diego, CA, 25-29 August 2019
- Water at cosmic distances
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Brett A. McGuire
NRAO Hubble Fellow

Brandon Carroll
Harvard-Smithsonian Center for Astrophysics
**ASTROCHEMISTRY - MY DEFINITION**

**AS • TRO • CHEM • IS • TRY**

/ astrō’keməstrē /

(*n*) the study of molecules in space - where they are, how they got there, and what they are doing

**ASTROCHEMISTRY - A MOLECULAR HISTORY**

- First Stars Born
- First Stars Die
- ‘Heavy’ Element Synthesis
- Stellar Nursery
- New Stars
- Planet Formation
- Chemical Delivery
- Life! (Awww)
- Fiery Cataclysm (Whomp whomp)
- Big Bang H, He
- Alternative Light Pattern 375,000 ym.
- Inflation
- Quantum Fluctuations
FUNDAMENTAL QUESTION OF ASTROCHEMISTRY

How do you make a cat from H and He?
THE SAME, BUT DIFFERENT

THE SAME, BUT DIFFERENT
Chirality

καιραλιτι

χειρ (kheir) - ‘hand’

= out of the plane

= into the plane
Enantiomer

Enantiomers are a pair of molecules that are mirror images of each other and cannot be superimposed on each other. The term 'enantiomer' comes from the Greek words ἐνάντιος (enántios) - 'opposite' and μέρος (méros) - 'part'.

- **Left** (levorotary): L
- **Right** (dextrorotary): D
- **Sinister** (sinister): S
- **Rectus** (rectus): R

The same atoms, bonds, and spectra are present in both enantiomers, but their spatial arrangements are different, leading to different optical properties.

- **Same atoms, bonds**: The molecular structure remains the same,
- **Same melting/boiling/freezing points**: The physical properties are identical,
- **Same spectra**: The spectral properties are identical,
- **Same bones, tendons**: The biological structures are the same,
- **Same shadow**: The shadow cast is the same.
Saying that two enantiomers have the same spectra is not exactly true. What phenomenon detected by spectroscopy should cause small energy shifts in the energy levels of these molecules?

- Parity Violation
- Spectra Deception
- Nuclear Hyperfine Splittings
- Circular Dichroism
- Isomorph Polarity Inversion
Homochirality

All life on Earth uses only a single enantiomer of amino acids, sugars, and other biomolecules
How and when did homochirality arise?
HOMOCHIRALITY

Chiral Mineral Catalysts?

Random Chance?

28 September 1969

Murchison

Australia
Enantiomeric Excesses in Meteoritic Amino Acids

John R. Cronin and Sandra Pizzarello

A few amino acids show excess of $L$ by almost 10%

But why? What is the mechanism?

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ORIGINS OF HOMOCHIRALITY

L-alanine  D-alanine

ORIGINS OF HOMOCHIRALITY

PRL 113, 118103 (2014) PHYSICAL REVIEW LETTERS week ending 12 SEPTEMBER 2014

Chirally Sensitive Electron-Induced Molecular Breakup and the Vester-Ulbricht Hypothesis

J. M. Dritzling and T. J. Guy

38
Selective destruction of one enantiomer via circularly-polarized UV radiation
IN SEARCH OF A CHIRAL MOLECULE

propylene oxide

1,2-propanediol

glyceraldehyde

propylene oxide

1,2-propanediol

glyceraldehyde
I N S E A R C H O F A C H I R A L M O L E C U L E

Brandon Carroll
Kona
Lake Waiau
Sgr B2(N)

Photo Credit: Me!

propylene oxide
propylene oxide

Absorption Signal (K)
Frequency (MHz)

31/10/2018
The center of our galaxy is about how far away?

- 25 Lightyears
- 250 Lightyears
- 2,500 Lightyears
- 25,000 Lightyears
- 250,000 Lightyears

* 1 Lightyear is about 5.88 trillion miles or 9.5 trillion km. (Multiply the number of seconds in one year by the number of miles or kilometers that light travels in one second, and there you have it: one light-year.)
IN SEARCH OF A CHIRAL MOLECULE

Green Bank Telescope

Photo Credit: Me!

Parkes Telescope

ENANTIOMERIC EXCESS?

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?
ENANTIOMERIC EXCESS?

A CHIRAL TAGGING STRATEGY FOR DETERMINING ABSOLUTE CONFIGURATION AND ENANTIOMERIC EXCESS BY MOLECULAR ROTATIONAL SPECTROSCOPY

LUCA EVANGELISTI, WALTER CAMINATI, Dipartimento di Chimica G. Ciaminian, Università di Bologna, Bologna, Italy; DAVID PATTerson, Department of Physics, Harvard University, Cambridge, MA, USA; JAYIX THOMAS, YUNJIE XU, Department of Chemistry, University of Alberta, Edmonton, AB, Canada; CHANNING WEST, BROOKS PATE, Department of Chemistry, The University of Virginia, Charlottesville, VA, USA.

Brooks Pate
UVa Chemistry
CIRCULAR DICHROISM

% Stopped (Exaggerated)

L-thread

R-thread

L-thread

L-thread

ENANTIOMERIC EXCESS?

E-nose

L-CPL

R-CPL

L-CPL

R-CPL
How much weaker is a circular dichroism signal expected to be in rotational vs. vibrational transitions in the infrared?

- About a quarter
- About half
- About a factor of 2
- A few orders of magnitude
- Trick question - rotational circular dichroism is not possible
We’re at the start of a long journey …

… but we’re in the best position we could possibly be.

Thanks Also To:
Ian Finneran, Ryan Loomis, Phil Jewell, Geoff Blake
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