The Earth Through Time as an Extrasolar Planet

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GSFC (699) as of May 21!
The Kepler Field of View
Locations of Kepler Planet Candidates

- **Earth-size**
- **Super-Earth size**
  - 1.25 - 2.0 Earth-size
- **Neptune-size**
  - 2.0 - 6.0 Earth-size
- **Giant-planet size**
  - 6.0 - 22 Earth-size
Figure courtesy Andrew Howard
What if a biosphere doesn’t have \( \text{O}_2/\text{O}_3 \)?
FALSE NEGATIVES FOR LIFE:
ANOXIC BIOSIGNATURES

STRATOSPHERE 0.1 Tg

OCS 2.0 Tg

CS₂ 0.07 Tg

H₂S 0.01 Tg

SO₂ 0.35 Tg

CLOUDS AND OH

EXCESS SULFATE
0.25 Tg
(INCLUDING MSA 0.003 Tg)

DMS 0.08 Tg

0.5 Tg yr⁻¹

0.4 Tg yr⁻¹
(5 Tg yr⁻¹)

0

4 - 8 Tg yr⁻¹

40 Tg yr⁻¹

57 - 92 Tg yr⁻¹

Toon et al., 1987
$S_{\text{org}}$ on modern-day Earth
Early Earth around Sun

Early Earth around a low-UV star (AD Leo)

Can SORG gases be used to detect anoxic biospheres?

Yes. But direct signals only for planets that orbit M-dwarfs with low stellar activity.

Indirect signals (from $C_2H_6$) may exist on planets around Sun-type stars.
Can $O_3$ build up on planets without biological $O_2$ production?

The brings us to another question:

If hazes exist on planets, what are the climatic implications? What are the implications for the inner-edge of the habitable zone?
THE INNER EDGE OF THE "HAZY HABITABLE ZONE"
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Solar constant relative to present Earth

Surface temperature (K)

Stratospheric water vapor content

Kasting, et al., 1993
THE INNER EDGE OF THE “HAZY HABITABLE ZONE”

Selsis, et al.
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Selsis, et al.
HD189733b Transmission

$P$, (bar)

 absorption (%)

$W_{\nu}$

$T_{j}$ (K)

$[H_{2}O]/[H_{2}]$

$[CH_{4}]/[H_{2}]$
Questions?