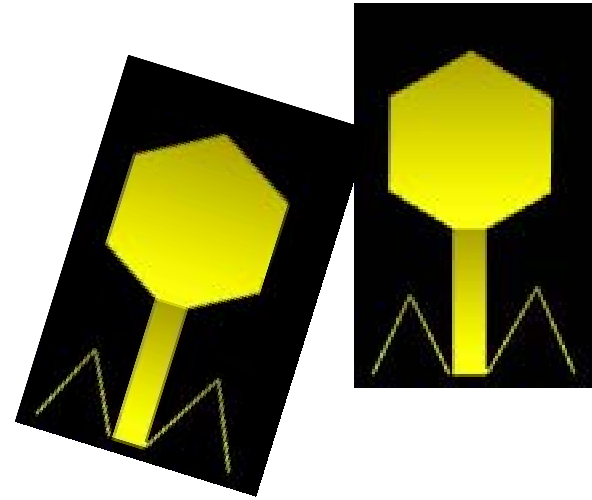
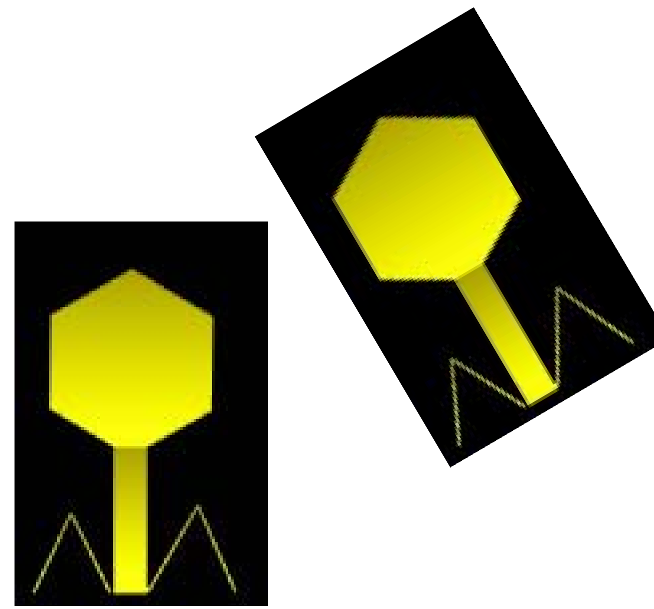


# Viruses in Cold-Seep Sediments

**Christina A. Kellogg, Ph.D.**

**Florida Integrated Science Center**
**St. Petersburg**



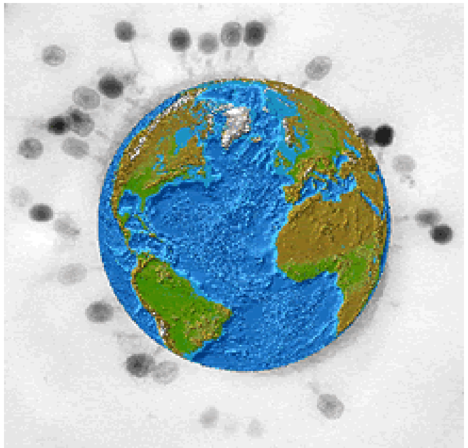
MMS Information Transfer Meeting, January 2009

Photo credit: Ian MacDonald

Image courtesy of TDI-Brooks
CHEMO III cruise

# Viruses are the most abundant biological entities on the planet.

**$10^{31}$ viruses on earth**



www.phage.org/images

**~$10^{7}$ viruses per ml sea water**

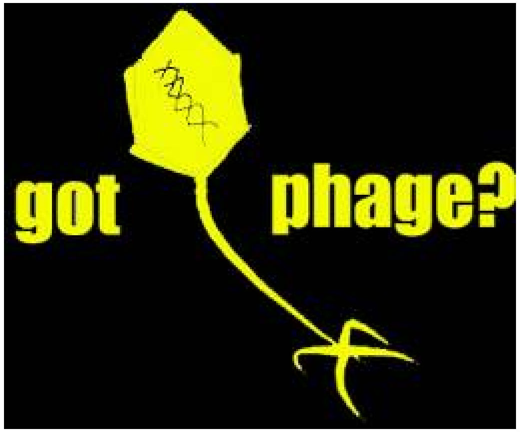
**~$10^{-19}$ great white sharks per ml**

Slide Credit: Mya Breitbart

# Viruses in Marine Environments

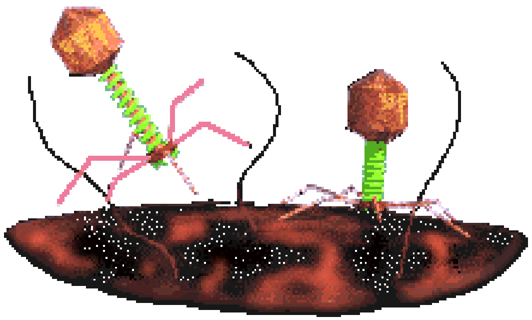
- **10–100 times more in marine sediments than in the water column**

- **Marine viral communities are dominated by bacteriophage (aka phage)**




www.phagehunter.org

# Bacteriophage = species-specific predators of bacteria



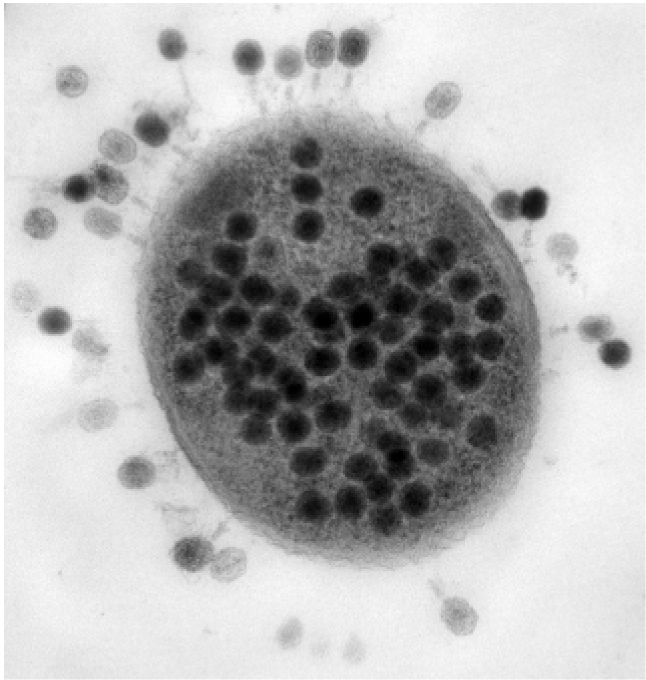
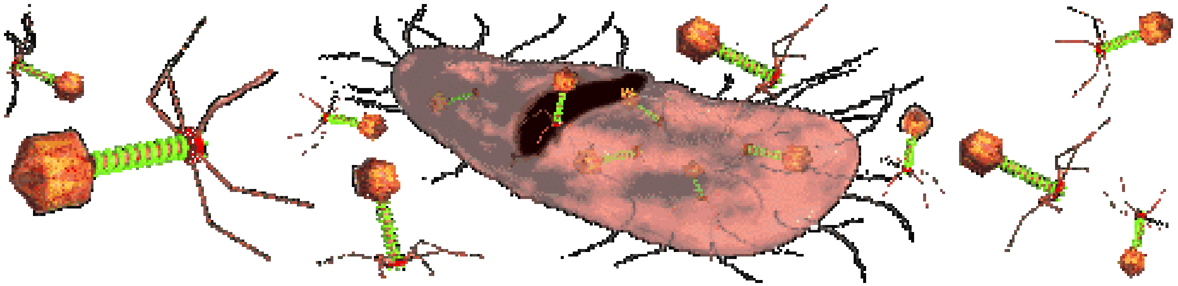


Photo credit: Betty Kutter

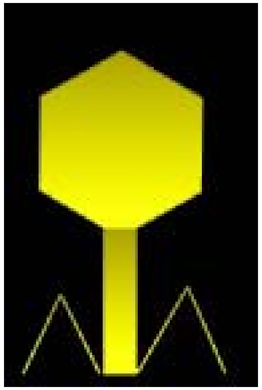


Cartoons from

http://www.cellsalive.com

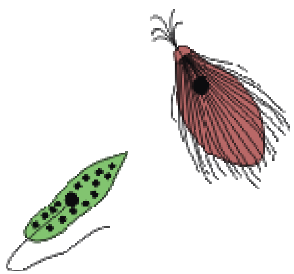
# Who cares?

- Major players in global carbon and nutrient cycling
- Control bacterial diversity and succession (“Kill the winner”)
- Horizontal gene transfer

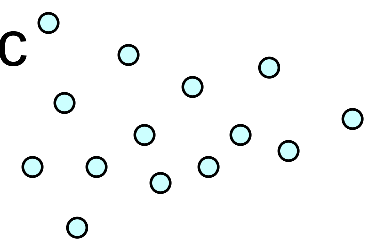


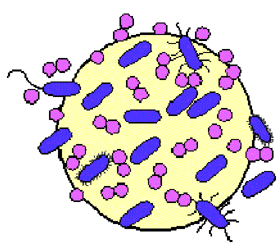
# Affect Food Webs and Biogeochemical Cycles …

Higher Trophic Levels



Dissolved organic matter

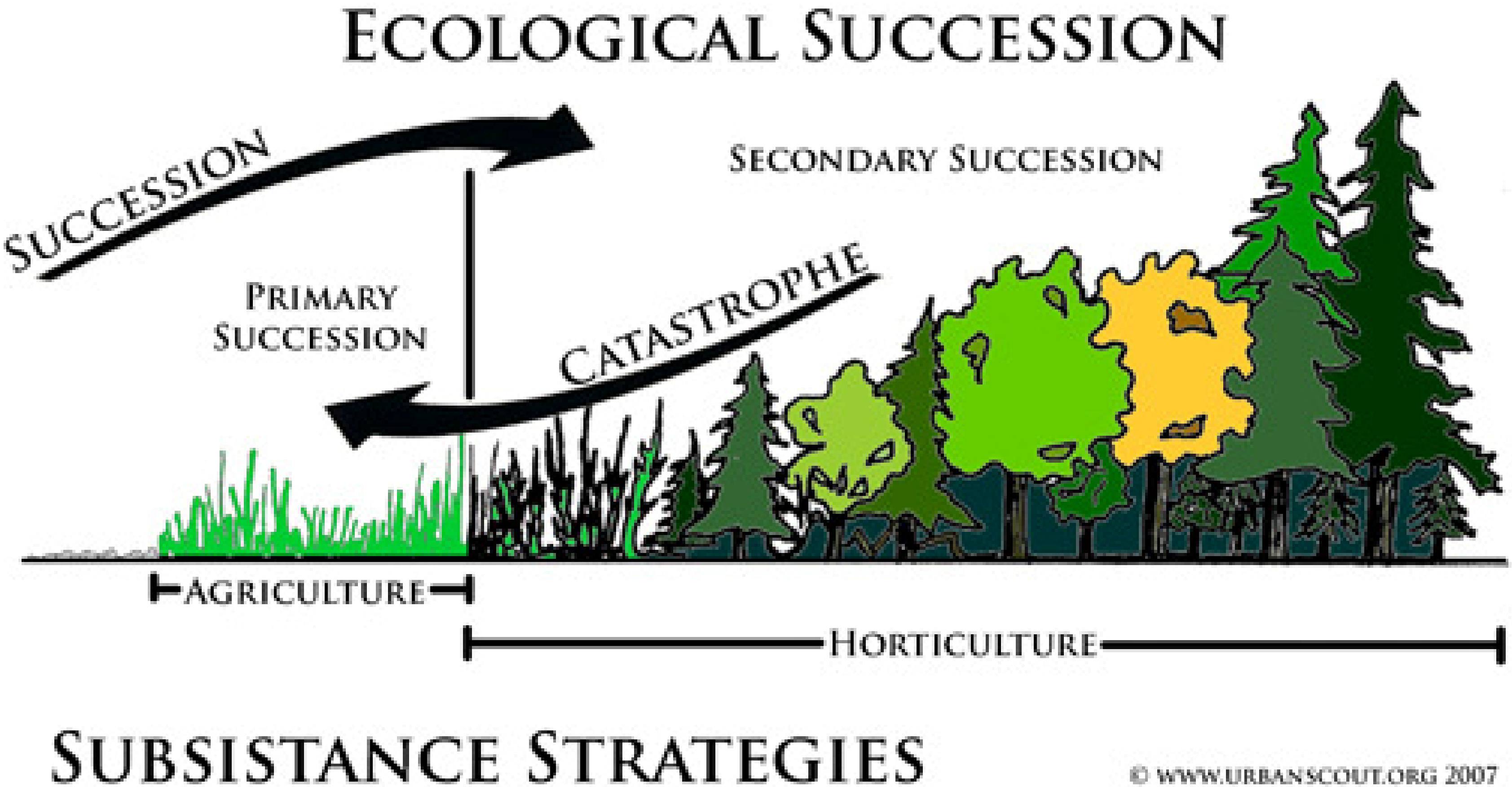




Viral lysis

$H_2S, CH_4$

# Control Bacterial Diversity and Succession …



# Agents of Change! Horizontal Gene Transfer…

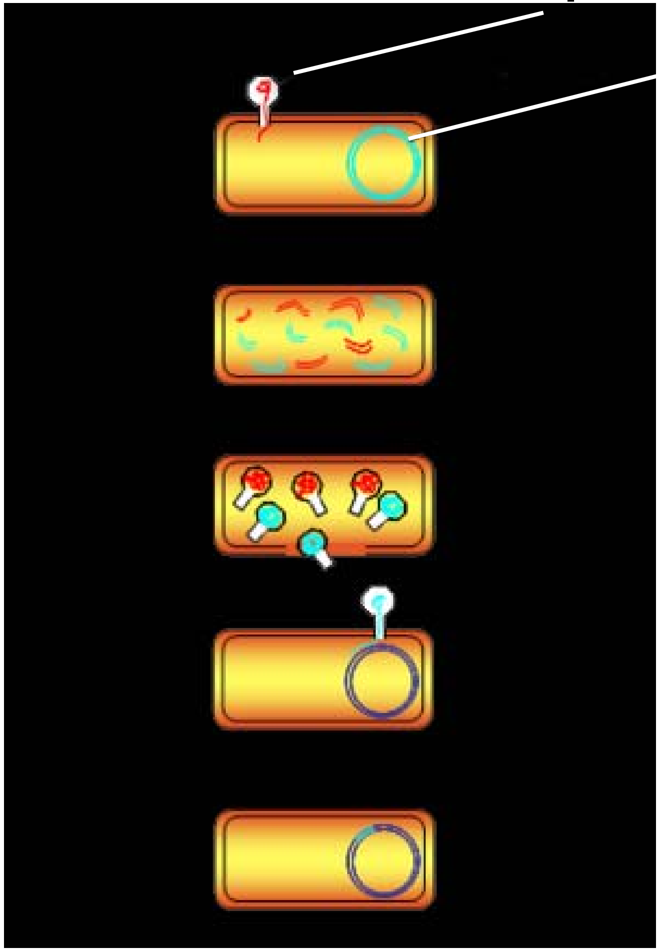
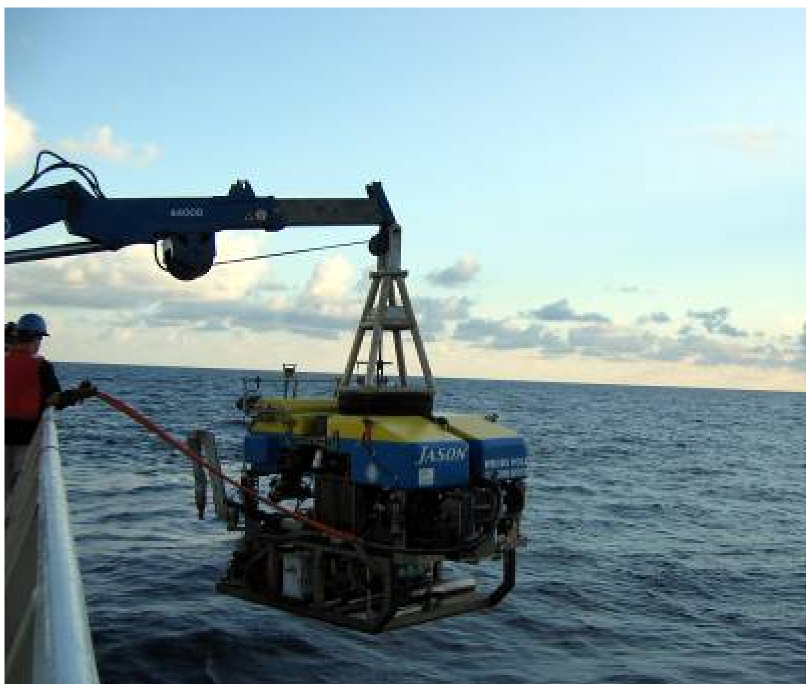


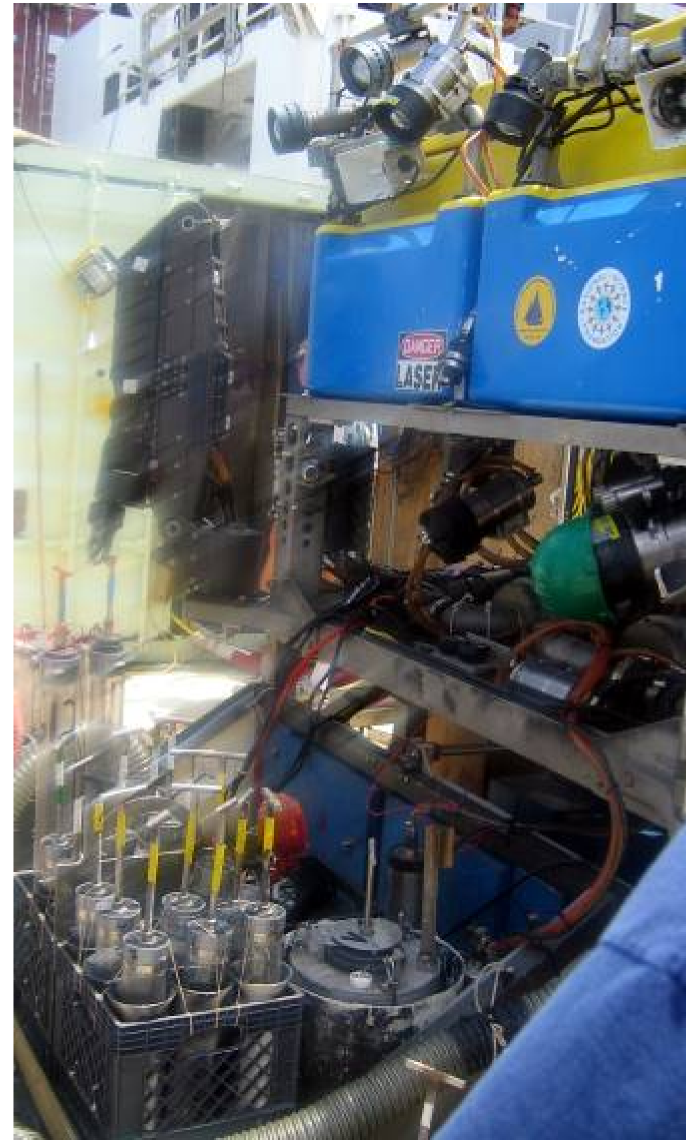

Image:
http://Wiki.biomine.skelleftea.se

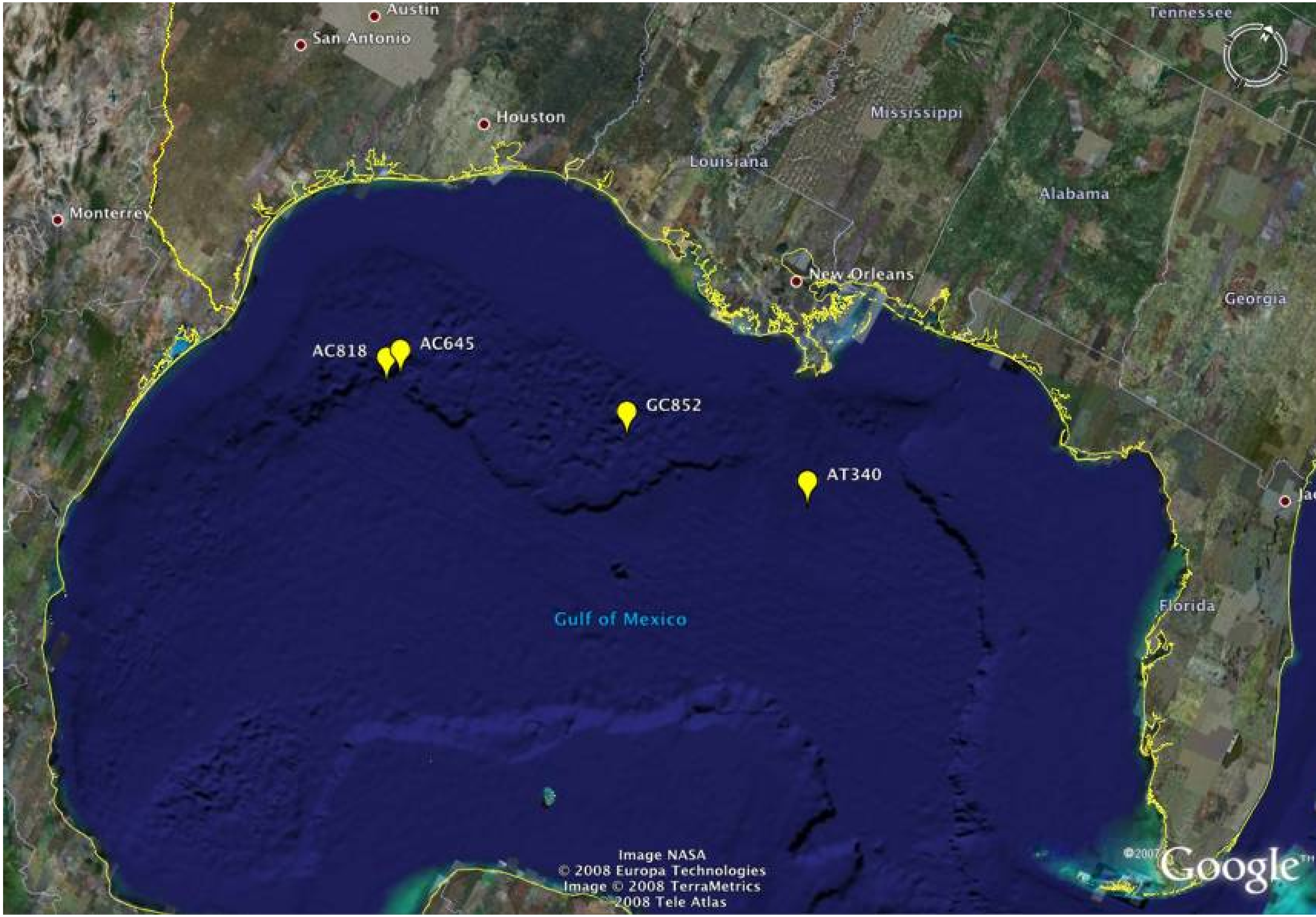
# Viruses in the Deep Sea

- Studies in deep water
  - Wommack et al. 2004
  - Ortmann and Suttle 2005 (hydrothermal plume)
  - Magagnini et al. 2007
  - Parada et al. 2007

- Studies in sediments in waters >1000 m
  - Danovaro and Serresi 2000
  - Danovaro et al. 2002, 2005
  - Middelboe et al. 2006 (cold seep)


JASON


DANGER


Austin
San Antonio
Houston
Monterrey
Louisiana
Mississippi
Alabama
Tennessee
Georgia
New Orleans
AC818
AC645
GC852
AT340
Gulf of Mexico
Florida
Image NASA
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Google

# Site Descriptions

- **Atwater Valley - AT340**
  - **Surface brine flows**
  - **Salinity 38–50 ppt**
  - **Mussels**
  - **White bacterial mats**
  - **Depth ~2,200 m**

Image: Stephanie Lessard-Pilon

# Site Descriptions

- **Green Canyon - GC852**
  - **Shallowest site**
  - **Depth 1,400 m**
  - **Reference sediments**
  - **Salinity 35 ppt**
  - **Coral gardens**
  - **Near carbonate boulders**

Image: Ian MacDonald

# Site Descriptions

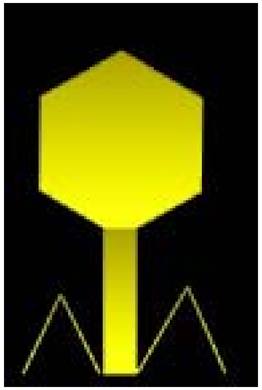
- **Alaminos Canyon - AC645**
  - **Pogonophoran tubeworms**
  - **Depth 2,213 m**
  - **Salinity 36 ppt**

# Site Descriptions

- **Alaminos Canyon - AC818**
  - **Deepest site, 2,742 m**
  - **Salinity 35 ppt**
  - **Not on a bathymetric high**
  - **Urchin field**
  - **Black (reduced) sediment**

# Abbreviated Methods

- **Push core → surface → cold room**
- **Sample top 2 cm of core**
- **Suspend in water → sonicate → centrifuge**
- **Supernatant stained →slides made**
- **Fluorescent microscopy**
- **Grain size analysis (Coulter counter)**



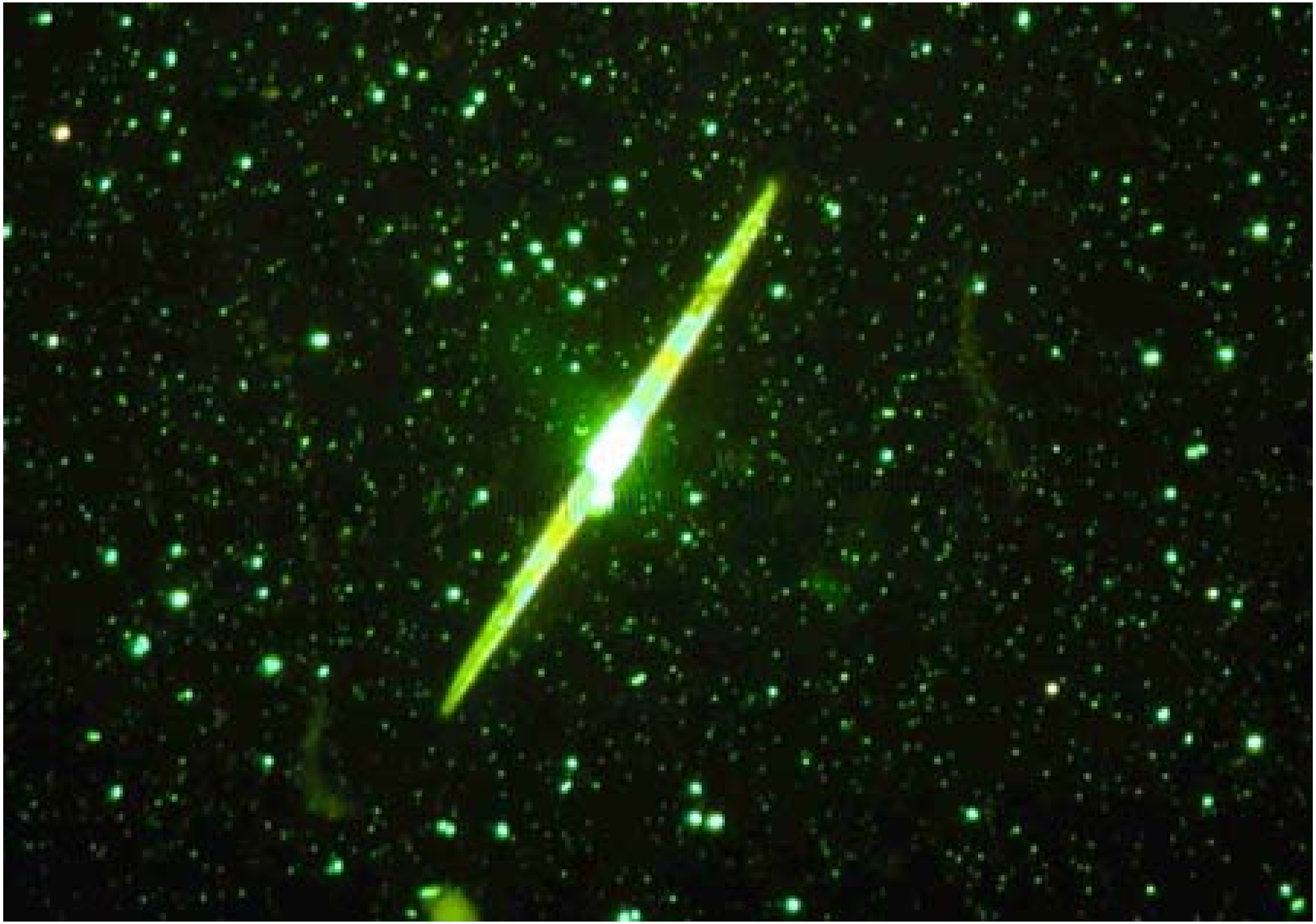


Photo credit: Jed Fuhrman

# Results

- **Comparing to the one published dataset of virus counts from a cold-seep in Japan**
    - **Middelboe et al. 2006**

  - **With the caveat that those samples were fixed and therefore may underestimate the actual virus abundance**

# Reference Sediments

- Similar depths (1,400 vs 1,450 m)

- Similar viral abundances reported
  - Japan 9.90 x $10^8$ viruses/gram
  - GOM 8.20 x $10^8$ and 5.46 x $10^8$

# Microbial Mats

- GOM sites are 1,000 m deeper than Japan sites (2,209 m vs 1,200)
- Prokaryotes
  - Japan 21.80 x $10^7$ cells/gram
  - GOM 37.93 and 35.90 x $10^7$ cells/g
- Viruses
  - Japan 6.80 and 8.80 x $10^8$ viruses/g
  - GOM 129.67 and 130.67 x $10^8$ viruses/g

# Reduced (Black) Sediments

- **Prokaryotes**
  - **Japan 0.50 x $10^7$ cells/g**
  - **GOM 25.93 x $10^7$ cells/g (AT340)**
  - **GOM 2.20 x $10^7$ cells/g (AC818)**

- **Viruses**
  - **Japan 0.05 x $10^8$ viruses/g**
  - **GOM 34.90 x $10^8$ viruses/g (AT340)**
  - **GOM 14.63 x $10^8$ viruses/g (AC818)**

# VPR - Virus/Prokaryote Ratios

- Reference sediments
  - Japan 16.8
  - GOM 6.03, 4.51

Microbial mats

Japan 3.12

GOM 34.30, 36.49

- Reduced (black) sediments
  - Japan 1.00
  - GOM 13.47, 66.36

# Parameter Covariance

| Parameters | Explained variance |
|---|---|
| Prokaryote abundance vs. salinity | $R^2 = 0.7712$ |
| Prokaryote abundance vs. grain size | $R^2 = 0.5845$ |
| Prokaryote abundance vs. viral abundance | $R^2 = 0.5133$ |
| Viral abundance vs. grain size | $R^2 = 0.7106$ |
| Viral abundance vs. percent sand content | $R^2 = 0.7499$ |

# Summary – Enumeration

- Prokaryote counts were an order of magnitude lower in sediments directly in contact with macrofauna (urchins, pogonophorans) compared to all other samples ($10^7$ vs. $10^8$ cells/gram dry weight) and were highest in areas of elevated salinity (brine seeps).

- Viral-like particle (VLP) counts were lowest in the reference sediments and pogonophoran cores ($10^8$ VLP/g dry weight), high in brine seeps ($10^9$ VLP/g dry wt), and highest in the microbial mats ($10^{10}$ VLP/g dry wt).

# Summary – Virus/Prokaryote Ratios

- VPR ranged from <5 in the reference sediment to >30 in the microbial mats and >60 in the urchin field.

- The higher VPR ratios suggest that greater microbial activity in or near chemosynthetic environments results in greater viral production (higher numbers of viruses) and/or that viruses are accumulating in the sediments.

# Summary – Literature Comparison

- Both viral counts and VPR were significantly greater than those reported from deep sediments in the Mediterranean and in most cases were higher than recent data from a cold seep site near Japan

- GOM data is the most accurate baseline for cold seeps and sediments >1,000 m water depth

# THANKS!


- At sea
  - TDI Brooks
  - Charles Fisher
  - R/V Ronald H. Brown
  - ROV Jason
  - Marshall Bowles
  - Kate Segarra
  - Vladimir Samarkin
  - Kim Hunter
- In the lab
  - Molly McLaughlin
  - Zoe Pratte

  - USGS Ecosystems Program, supported by MMS

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**Middelboe, M., R.N. Glud, F. Wenzhöfer, K. Oguri, and H. Kitazato. 2006. Spatial distribution and activity of viruses in the deep-sea sediments of Sagami Bay, Japan. Deep Sea Research Part I–Oceanographic Research Papers 53:1–13.**

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